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Hazard Assessment of LNG Loading-Unloading Process in Cirebon Port

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Abstract

Cirebon Port has spacious work and water area that provides opportunities to be developed in industrial sectors, particularly the petrochemical industries such as ethylene and Liquefied Natural Gas (LNG). In atmospheric condition, they are classified as volatile gas. Either in processing or transporting, they are stored in closed system. However, they still have a probability to be released to the environment and may lead to a fire or explosion. This probability is increased in the existence of coal stockpile in the port area which can evoke a fire. Therefore, a safety study is needed to identify the risk of the loading-unloading activities. The problem was solved by following steps. First, the data such as physical properties, layout area, and geographical condition around the port were collected. Then, the hazardous nodes were identified qualitatively, and then the quantitative analysis was done using As Low As Reasonably Practicable (ALARP) analysis. From the safety study, a suitable handling and safety system is provided to ensure safety viability in the ethylene and LNG loading-unloading process at the Cirebon port.

Keywords: *ethylene; hazard assessment; LNG; loading-unloading process; Quantitative Risk Assessment (QRA)*

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INTRODUCTION

Cirebon port is located in the northern coastline of West Java, Indonesia, approximately 250 km to the east from Jakarta, the capital city of Indonesia. This port has 51 hectares of working area and more than 8000 hectares of seawater area, with the ground plan shown at Figure 1. With such a large area, this port is likely to be able to accommodate the loading-unloading process, including loading-unloading activities of petrochemical industry raw materials such as Liquified Natural Gas (LNG).

This port is projected to have a chemical loading-unloading terminal area. Nonetheless, the projected area is close to a coal stockpile which has the potential to evoke fire. Moreover, LNG is classified as a hazardous material since it is highly flammable. Consequently, it is necessary to do a safety study regarding of LNG loading-unloading process to ensure that the process can be carried out safely. The study was also conducted to recommend an appropriate handling and safeguard system.

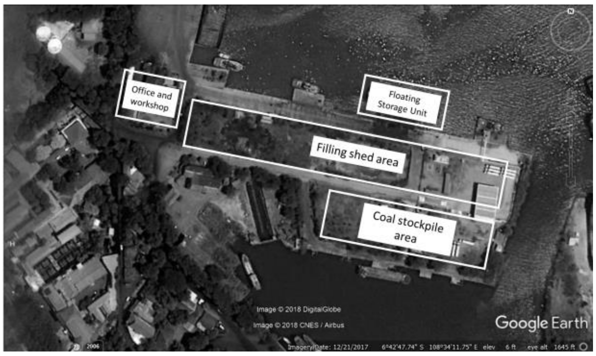

Figure 1. Cirebon Port Map (Source: maps.google.com with additional details)

RESEARCH METHOD

The safety assessment of loading-unloading process in Cirebon port was carried out with the following considerations and assumptions:

a. Wind speed and direction data at the study area are 6.94 m/s headed northwest. The average ambient temperature is 28.5°C and the average relative humidity is 75%. The data are provided by Meteorological, Climatological, and Geophysical Agency (BMKG, 2018).
b. The port area is assumed as an unsheltered single storage. The weather condition is partly cloudy, and the stability class is D.
c. The loading-unloading process LNG is done without using a temporary storage tank on the ground, so the loading/unloading process from the floating storage in the ship to the filling shed is using pipes, then transported to the truck tank.
d. The cylindrical LNG tank on truck has a capacity of 25,000 L and 2 m in diameter. The maximum amount of LNG in the tank is 80% of the tank volume. The leak occurs at the bottom of the tank.

The safety assessment of LNG loading-unloading process in Cirebon port was conducted with the following steps (ABS, 2016; Crowl and Louvar, 2011; Holden, 2014)

Identification of Hazardous Nodes

The nodes are identified based on potential hazards that may be the initiating events. The reference used in this step is CCPS (*Center for Chemical Process Safety*), published by AIChE (*American Institute of Chemical Engineers*) (CCPS, 2010).

Qualitative Risk Assessment

Nodes obtained from the previous step were screened so that the most possible hazardous nodes are selected. The selection of the most hazardous nodes was done based on the operating condition and the types of fluid. Furthermore, the chosen nodes then evaluated quantitatively to identify the possible accident scenarios.

Quantitative Risk Assessment (QRA)

The Quantitative Risk Assessment (QRA) was performed to determine the impact of each hazardous nodes. The QRA method in this study refers to API 521:

a. Determine the accidents frequency (f) of the nodes using fault tree and event tree analysis. In this study, the calculation of f is referring to OREDA (Offshore Reliability Database) (2015) and UK HSE Body (2012).
b. Determine the consequence of every hazard using dispersion analysis software; the software used in this study is ALOHA 5.4.4. From each dispersion model, the number of accidents (N) can be estimated. The N value states the possibility of an accident that may lead to fatality.
c. The f and N data obtained from previous steps are then analyzed in F-N Diagram (Frequency to the Consequences Diagram) (Crowl and Louvar, 2011) so that the tolerability of a hazard can be known. The categories in an F-N Diagram are acceptable, As Low as Reasonably Practicable (ALARP), and unacceptable. Therefore, it can be stated that the F-N Diagram can provide conclusions related to whether a node chosen in the beginning of the study is safe or not. From this diagram, recommendations can also be selected to reduce the impact of accidents belonging to ALARP and unacceptable categories.

Determination of Recommendations

Specific recommendations are selected to reduce the risk of accidents that belonging to ALARP or unacceptable categories so that every hazardous node becomes safe.

RESULTS AND DISCUSSION

Identification of Hazardous Nodes and Qualitative Risk Assessment

The possible hazardous nodes that may be the initiating events are presented in Table 1.

Table 1. Nodes list

Nodes	Description
Node 1	Storage tank
Node 2	Unloading arm
Node 3	Filling shed
Node 4	Compressor
Node 5	Genset
Node 6	Electricity substation
Node 7	Water storage tank
Node 8	Pump House PMK

The nodes are then evaluated qualitatively to obtain the list of nodes that may lead to an accident with the most harmful impact. Nodes 1-4 were chosen as the most hazardous nodes because:

1. The equipment in nodes 1-4 operate at extreme condition and contain volatile compound. If the LNG vapor is released into the air and there is a source of fire, a fire or even an explosion can occur.

2. The nodes 5-8 were not selected since it is still possible to prevent accidents from the start.

After the nodes screening, Hazard Identification (HAZID) is conducted. Table 2 shows the result of the identification of hazard.

After identifying the hazardous nodes, QRA can be conducted. Table 3 summarizes the selected hazard events with the assumption of the event.

Table 3. Potential hazard events in loading-unloading area of Cirebon port.

Events	Description
A	1” hole at the transfer pipe
B	Fracture of the transfer pipe
C	1” hole at the filling shed pipe
D	1” hole at the LNG tanker
E	1” hole at the boil-off pipe

Quantitative Risk Assessment (QRA)

Calculation of *f* (frequency) value

The frequency of accident event is calculated using event tree analysis. The analysis is done by compiling an event tree based on some common hazardous events that may occur and their impact. The events frequencies and the failure probabilities of safety function were obtained from OREDA Handbook (2015), UK HSE (2012), and Ronza *et al.* (2003). Figure 2 shows the example of event tree of the event A from the Table 3.

Calculation of *N* (consequence) number or number of fatality

The number of fatality is obtained from the multiplication of the affected area by the hazard and the population density in Cirebon port (assumed to be evenly distributed). The affected area is collected from the ALOHA software that simulated the impact of events.

Table 4 summarized the value of *f* and *N* obtained from the analysis and the zone at F-N Diagram which is shown in Figure 3.

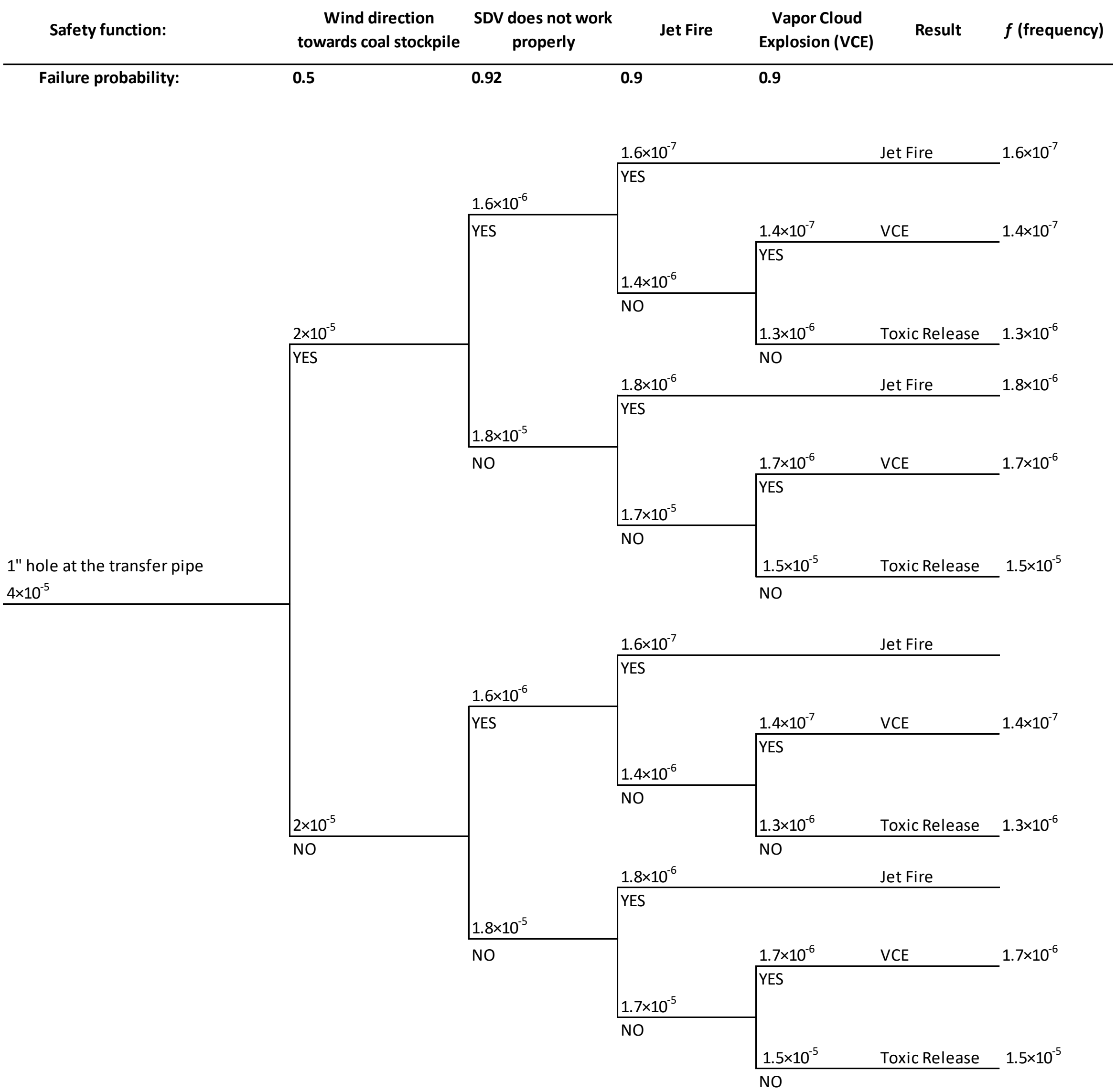

Figure 2. Event tree analysis of 1” hole at the transfer pipe.

Table 2. Hazard Identification of LNG loading-unloading process at the Cirebon port

Events	Hazard	Consequence	Mitigation
	Leakage on pipes as it flows LNG from ship to Filling Station		
A	- Improper pipes material selection - Vibration - Excessive movement on the loading arm	Leakage of LNG resulting in brittle fracture on deck, fire / explosion hazard on surrounding equipment	- Ensure ESD system is functionally operate - Install a gas detector - Perform inspection of equipment before bunkering and regularly checked - Select more suitable material for handling
	Excessive movement in the loading arm		
B	- Failure of control system on loading arm - Human error - Maintenance error	Leakage of LNG on pumps, pipes, hoses during LNG transfer	- Ensure ESD system is functionally operate - Perform regular inspection of the loading arm
	Leakage of LNG in the filling shed pipe		
C	- Damage to the gasket - Improper pipes material selection	Leakage of LNG resulting in fire / explosion hazard on surrounding equipment	- Perform regular inspection of the equipment - Select more suitable material for handling - Install a gas detector
	Leakage of LNG occurs at the bottom of the truck tank at the filling shed location		
D	- Improper pipes material selection - Corrosion	Leakage of LNG resulting in fire / explosion hazard on surrounding equipment	- Perform regular inspection of the equipment - Select more suitable material for handling - Install a gas detector
	LNG leakage occurs on the boil-off gas pipes at the discharge flow of the compressor		
E	- Improper pipes material selection - Vibration	Leakage of LNG resulting in fire / explosion hazard on surrounding equipment	- Perform regular inspection of the equipment - Select more suitable material for handling - Install a gas detector

Table 4. The analysis result of the safety level from an accident.

Events		Impact	*f* (impact / year)	*N*	Zone
A	1	VCE	6,03x10^{-9}	85,56	Acceptable
	2	*Jet fire*	6,70x10^{-9}	2,12	ALARP
	3	*Toxic release*	5,43x10^{-8}	24,95	Acceptable
B	4	VCE	5,85x10^{-10}	4.078,63	ALARP
	5	*Jet fire*	6,50x10^{-10}	228,93	Acceptable
	6	*Toxic release*	5,27x10^{-9}	1.380,45	ALARP
C	7	VCE	4,50x10^{-7}	85,56	ALARP
	8	*Jet fire*	5,00x10^{-7}	2,12	Acceptable
	9	*Toxic release*	4,05x10^{-6}	24,95	ALARP
D	10	VCE	3,60x10^{-6}	4,42	ALARP
	11	*Jet fire*	4,00x10^{-6}	9,83	ALARP
	12	*Toxic release*	3,24x10^{-5}	8,24	ALARP
E	13	VCE	6,03x10^{-9}	3,16	Acceptable
	14	*Jet fire*	6,70x10^{-9}	12,56	Acceptable
	15	*Toxic release*	5,43x10^{-8}	25,29	ALARP

Mitigation recommendation

The mitigation recommendation was suggested to ensure that each types of accidents become acceptable. Three mitigation recommendation scenarios have been selected, namely the addition of a gas detector, the addition of a green belt in the port area, and the addition of a gas detector and green belt simultaneously. Each scenario is re-analyzed using event tree analysis so that the *f* value decreased. Figure

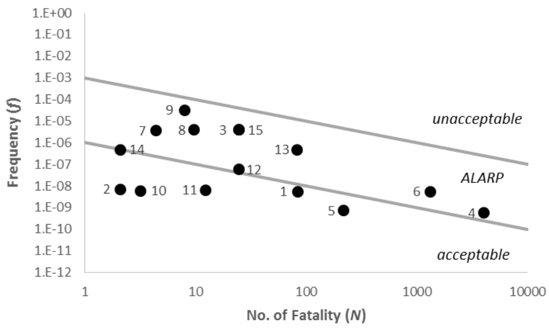

Figure 3. The analysis of F-N diagram before mitigation.

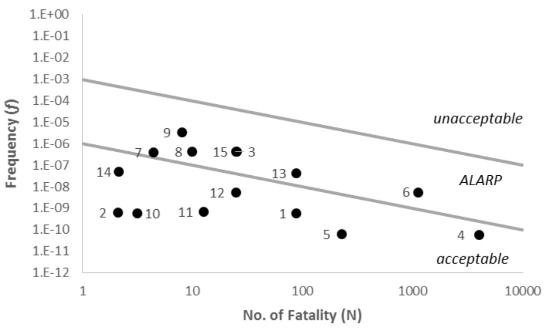

Figure 4. F-N Diagram analysis after the addition of gas detector

4 to Figure 6 show the F-N Diagram after mitigation. From the diagrams, we can conclude that the best mitigation scenario is when a gas detector and a green

belt are installed simultaneously, indicated by all accidents are in the acceptable.

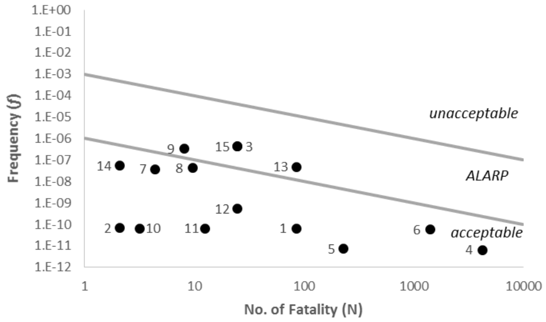

Figure 5. F-N Diagram analysis after the addition of green belt

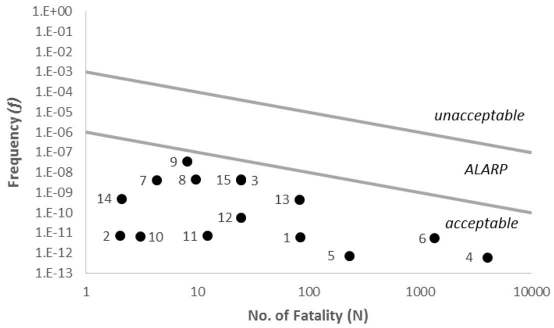

Figure 6. F-N Diagram analysis after the addition of gas detector and *green belt*

CONCLUSION

Based on this safety analysis of LNG loading-unloading process on Cirebon port, it can be concluded that all accident occurrences are not in the unacceptable category. Nevertheless, there are 9 events in the ALARP category that need to be given a mitigation recommendation to ensure that all events are in the acceptable category. Three mitigation recommendation scenarios, in the form of installation of gas detector, green belt, and both, have been given and re-analyzed. All events are in acceptable category if Cirebon port area is equipped with gas detector and green belt.

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