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Analysis of Work Accident Potential Using the Hazard Analysis and Operability Study (HAZOP) Method in Bulk Cargo Loading and Unloading Processes

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Abstract

The bulk cargo loading and unloading process is an important part of sea and port transportation. Bulk cargo such as fertilizers, kernels, and wheat has a high risk that can endanger workers and the environment, so identification and analysis of potential hazards is needed at every stage of operation to maintain the safety and smooth loading and unloading process. This research aims to identify potential hazards that occur, provide an assessment of the risk level, and provide solutions for actions or improvements to potential risks that can occur during the process of loading and unloading bulk cargo fertilizer at Makassar Port. This research can contribute to encouraging increased compliance of Makassar Port employees to the implementation of K3 management, which not only protects personal safety, but also supports performance improvement and this research also enriches the author's knowledge through empirical experience, addition of scientific references, and the application of concepts that have been obtained during lectures. Analysis of potential occupational safety risks in the loading and unloading of bulk fertilizer cargo activities using the Hazard and Operability Study (HAZOP) method. To analyze it, it requires a literature study, data collection in the form of observations, interviews, and questionnaires, then identifying/formulating problems with the level of hazard/risk of work accidents, then classifying the risk matrix and providing solutions for corrective actions from the potential risk of occupational accident hazards. The analysis of the highest risk level was obtained in loading and unloading operations at the port and in the warehouse area which then became a reference for designing appropriate corrective action solutions so that the level of occupational safety risks at the Port of Makassar could be reduced, thereby creating a safer, more efficient, and productive work environment for all parties involved in bulk fertilizer cargo loading and unloading activities. The results are how much potential danger is obtained, an assessment of likelihood, consequence, and severity to determine the level of low, medium, high, and extreme risk and provide the best solution in taking more targeted preventive measures.

Keywords: Hazard Potential; HAZOP; Loading and Unloading; Occupational Safety; Risk

1. INTRODUCTION

Indonesia, as a country with a larger/dominant water area than its land area, has been a maritime country since ancient times. The maritime industry in Indonesia focuses more on shipping, particularly the port sector. According to Government Regulation of the Republic of Indonesia Number 69 of 2001 [1], ports are generally located at the border between the sea and the mainland or located on rivers or lakes. According to Fair, a port consists of three parts, namely: (1) waters or docks that provide shelter; (2) waterfront facilities such as moorings, piers, warehouses, or facilities for serving passengers, cargo, fuel, and supplies for ships; (3) floating equipment such as rescue boats and lifting equipment in the water [2].

The process of loading and unloading bulk cargo is an important part of the transportation and logistics industry, especially in the port and maritime transport sectors. This activity carries a high risk of causing workplace accidents that can endanger worker safety and damage the environment [3]. The Hazard Analysis and Operability Study (HAZOP) method is one of the commonly used approaches to identify potential hazards and operational problems in a system or process [4].

Some of the challenges faced in determining the potential for workplace accidents in bulk cargo loading and unloading activities include the use of tools and the complexity of the process (the bulk cargo loading and unloading process involves many stages that require coordination between various parties [5]). Occupational health and safety (OHS) aspects are not yet a priority for companies in Indonesia, especially private companies.

This is because private companies minimize labor and expenses by maximizing profits and employers are less concerned about the importance of OHS aspects [6].

Occupational safety and health aim to prevent or reduce accidents and find out their causes and effects, as well as to secure ships, work equipment, and cargo [7]. Limited resources (not all companies have sufficient resources to conduct adequate training or to analyze risks thoroughly), working environment conditions (environmental factors, such as bad weather, dust, or material spills, can increase the risk of accidents and make analysis more difficult) [8]. This topic is highly relevant to current industry conditions, particularly in the port and bulk cargo transportation sectors. These industries continue to grow with the increase in international trade volumes, which in turn increases the volume of loading and unloading activities at ports.

This study aims to determine the potential and sources of hazards that may occur in the loading and unloading process using the HAZOP method, provide an assessment and determine the level of Occupational Safety and Health risks in the loading and unloading process using the HAZOP method, and find solutions to prevent or minimize the occurrence of work accidents.

2. METHODS

This research was initiated through a literature review of relevant articles and journals, followed by a field survey conducted at PT Pelindo (Persero) Sub-Holding Pelindo Multi Terminal Branch Makassar (SPMT), or Makassar Port, to observe company conditions, understand the loading and unloading process, interview workers, and collect supporting data through questionnaires. Based on the findings from the field survey and literature study, the main problems were identified and formulated into specific research questions, which then guided the determination of the research objectives and scope. The data collection stage consisted of primary data, including observations of working conditions, distribution of accident questionnaires, interviews with workers, and brainstorming sessions related to likelihood and consequences, as well as secondary data such as company profiles, loading and unloading procedures, and records of potential hazards in the warehouse area.

The collected data were then analyzed using the Hazard and Operability Study (HAZOP) method, which involved identifying the sequence of operational processes, recognizing hazards in the research area, completing the HAZOP worksheet, classifying hazards according to their sources and frequency, describing operational deviations, identifying their causes and consequences, determining temporary control actions, assessing risks based on likelihood and consequence criteria, ranking hazards using a risk matrix, and formulating improvement recommendations for risks classified as medium to extreme. In this study, likelihood (L) refers to the probability of an accident occurring when workers are exposed to hazards, while consequence (C) or severity (S) refers to the level of impact or harm caused by the deviation, including consideration of lost workdays. The likelihood values range from 1 to 5 based on qualitative descriptions that were then reviewed against quantitative information from company records, while consequence values were determined based on the severity of impact arising from each identified risk.

The final risk level was obtained by combining likelihood and consequence values through the risk assessment matrix, with the criteria for likelihood, consequence, and the risk matrix presented in Tables 1, 2, and 3 [9], while the formula for determining the risk level is shown in Equation 1.

Table 1. Likelihood

Level	Criteria	Description
1	Rare	Almost never occurs
2	Unlikely	Has not happened yet but could appear or happen at some point
3	Possible	May have occured or emerged
4	Likely	May occur easil, may appear in most situations occur
5	Almost certain	Frequently occurs, appears in the most common circumstances

Table 2. Severity/Consequences

Level	Criteria	Description Of Severity
1	Insignificant	The incident did not cause any loss or human injury
2	Minor	The incident resulted in minor injuries, minor losses, and did not have a significant impact on business continuity
3	Moderate	The incident causes moderate injury, does not result in permanent disability, but moderate losses

Level	Criteria	Description Of Severity
4	Major	The incident resulted in serious injuries, permanent disability, and significant losses
5	Catastrophic	The incident resulted in death, severe losses, and business interuption

Table 3. Risk Matrix

Risk Matrix	Consequence				
Likelihood	Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Catastrophic (5)
Almost Certain (5)	5	10	15	20	25
Likely (4)	4	8	12	16	20
Possible (3)	3	6	9	12	15
Unlikely (2)	2	4	6	8	10
Rare (1)	1	2	3	4	5

The risk level is obtained by multiplying the likelihood value and the impact or consequence value to obtain a severity value that is used as a reference for determining the risk level.

$$\text{Risk/Severity} = L \times C \quad (1)$$

Explanation:
L : Likelihood (Level of Possibility)
C : Severity/Consequences
: Low
: Medium
: High
: Extreme (Extreme/Very High)

Based on these results, improvement recommendations were formulated, focusing on efforts to minimize workplace accidents and operational disruptions. The final stage involved drawing conclusions and formulating suggestions in line with the problem formulation, objectives, and analysis results, in order to provide constructive input for the company in improving workplace safety.

3. RESULTS AND DISCUSSION

3.1. Karakteristik Responden

The presentation of characteristic data aims to provide an initial description of the respondents' condition, so that further analysis can be carried out in a more targeted manner and in accordance with the research context.

a. Age

This characteristic shows the age range of workers involved in the process of loading and unloading fertilizer bulk cargo at Makassar Port. The age criteria of the respondents can be seen in Table 4.

Table 4. Respondent Age Criteria

Age Range (Years)	Frequency	Presentase (%)
22-40	17	65
41-53	9	35

b. Education

This characteristic shows the last education of workers involved in the process of loading and unloading fertilizer bulk cargo at Makassar Port. The respondent's last educational criteria can be seen in Table 5.

Table 5. Respondent's Last Education Criteria

Final Education	Frequency	Presentase (%)
SD	1	4
SMP	2	8
SMA	4	15
SMK	4	15
SLTA	2	8
DIPLOMA 3 (D3)	1	4
SRATA 1 (S1)	12	46

c. Long Time Working

This characteristic shows the length of work of workers involved in the process of loading and unloading bulk fertilizer cargo at Makassar Port. The criteria for the respondent's length of employment can be seen in Table 6.

Table 6. Respondent's Length of Employment Criteria

Length of Service (Years)	Frequency	Presentase (%)
1-11	20	77
12-21	6	23

d. Jobs

This characteristic shows the type of work of workers involved in the process of loading and unloading fertilizer bulk cargo at Makassar Port. The respondents' employment criteria can be seen in Table 7.

Table 7. Respondent Employment Criteria

Jobs	Frequency	Presentase (%)
Loading and Unloading Workers	6	23
Operations Department	1	4
Komersil	1	4
Operational/Foreman	1	4
Driver Truk	1	4
Officer HSSE	2	8
Cleaning Service	2	8
Mechanical	1	4
Equipment Officer	4	15
Operations Officer	1	4
PnC (Ship Talker)	2	8
Terminal Planner	2	8
Dispatcher	1	4
Administration & General	1	4

3.2. Hazard Identification

Hazard identification was carried out in the bulk fertilizer loading and unloading area. Hazard identification using the HAZOP method focused on the risk of deviations occurring from worker activities in the bulk fertilizer loading and unloading process, environmental factors, and work equipment by looking at unsafe actions (potentially caused by one's own actions) and unsafe conditions (potentially caused by the work environment). Risk and potential hazard identification was obtained by conducting observations and questionnaires in the unloading process area. Nine potential hazards were identified in bulk fertilizer cargo loading and unloading, consisting of four potential hazards of unsafe actions (such as operator negligence in planning and monitoring the berthing position of ships, which could cause potential delays in ship berthing, increased ship queues, and potential operational cost losses) further negligence of drivers in driving, which causes potential accidents between trucks colliding or crashing due to sudden stops, injuries to drivers and officers, damage to portal facilities, then the lack of caution of technicians, foremen, or equipment operators in checking heavy equipment and infrequent equipment maintenance, which causes potential collisions with equipment, tripping, being hit by equipment, and injuries during equipment component inspections, as well as the lack of caution among workers during inspections and the opening of hatches and the lack of PPE used, causing potential injuries from falling into hatches or being pinched, injuries or broken limbs, and respiratory

problems), 3 potential hazards of unsafe conditions (such as vehicle and cargo density causing potential vehicle accidents, bruises to drivers, truck overload, followed by excessively hot weather and the lengthy process of unloading fertilizer, which causes potential truck engine overheating, blocked evacuation routes and increased air pollution, as well as excessive truck capacity, scattered and fallen materials on the road and in the sea, which cause potential truck skidding or cause other vehicles to skid on the road, injuries to workers who are hit by trucks that are still in the fertilizer unloading area), 2 potential hazards of both unsafe actions and conditions (such as falling and scattered materials making the road slippery and the use of heavy equipment causing potential skidding, injuries from being hit by materials and heavy equipment, respiratory disorders, chemical gas poisoning and slippery floors, untidy piles of cargo, heavy equipment operation that does not comply with SOPs, stuffy rooms and poor ventilation, fertilizer dust and flammable materials that cause potential slipping, minor to serious injuries such as broken bones or head injuries and even death, respiratory problems, skin and eye irritation, burns, entrapment, fainting and dehydration. Hazard identification can be seen in Table 4.

Table 8. Hazard Identification

No	Process	Source Of Hazard	Deviation	Cause	Consequences
1	Planning and Control	Unsafe Action	Operator error positioning ship berthing	Operator negligence in planning and monitoring ship berthing position	Delay in berthing, ship queues increase, potential cost losses operational
2	Open Activity /In Out Gate	Unsafe Condition	Density vehicles and cargo loaded	Number of trucks queueing and goods that loaded beyond the truck's capacity	Vehicle accident, injuries bruises on the driver, overload
3	Scan QR For Trucks	Unsafe Action	Truck stopped for QR scanning	Driver negligence in driving	Truck-on-truck accident because the truck stopped suddenly, the driver suffered bruises to the driver and officer, damage to portal
4	Truck Waiting	Unsafe Condition	Truck that waiting too long time in the buffer area	Extremely hot weather and long unloading process fertilizer	Truck engine overheating, evacuation route blocked and increased air pollution
5	Preparation and Inspector of Equipment Unload	Unsafe Action	Damaged equipment and old equipment	Lack of caution technicians, foreman/equipment operators when checking heavy equipment and rare equipment maintanance	Colliding with equipment, tripping, being hit by equipment, and injured during component inspection tool
6	Inspection of the opening ship's hatch	Unsafe Action	Opened hatch and workers around it	Lack of caution laborers when examination and opening hatch and lack of PPE used	Injury from falling into injuries or broken limbs, respiratory distress
7	Fertilizer bulk unloading operation	Unsafe Action and Condition	Falling materials and scattered causing slippery roads and use of heavy equipment	Workers are not wearing PPE that adequate and lack attention during the unloading process fertilizer	Slipping injury from being stuck by heavy materials and equipment, distruption respiratory
8	Transportation to warehouse	Unsafe Condition	Overload trucks, falling materials	Truck capacity excessive, material that scattered and falling on the road and at sea	Truck skidding/other vehicles skidding on the road, injury workers hit by trucks still in the fertilizer unloading area
9	Packaging in warehouse or stacking area	Unsafe Condition dan Unsafe Action	Unloading and cargo packaging	Slippery floor, piles cargo that is not neatly packed, operation of equipment heavy loads that are not appropiate SOP, stuffy room and poor ventilation, fertilizer dust and also flammable	Slipping, minor injuries to serious injuries such as broken bones or head injuries or even death, respiratory distress, skin irritaion and eyes, burns, pinched, fainting and dehydration

3.3. Risk Assesment

Risk assessment is a method used to determine the magnitude of a risk by considering the severity and likelihood of occurrence [10]. After obtaining the above analysis results, they are then compiled in a HAZOP worksheet to clearly identify the loading and unloading process, sources of danger, deviations, causes, consequences, actions to be taken, likelihood, consequence, and severity values, as well as the level of risk, So that the most extreme level among the 9 activity procedures was obtained. The results of the HAZOP worksheet identification can be seen in Table 5.

Tabel 9. Hasil Identifikasi Worksheet HAZOP

No	Process	Source Of Hazard	Deviation	Cause	Consequence	Action	L	C	S	Risk Level
1	Fertilizer bulk unloading operation	Unsafe Action and Condition	Falling materials and scattered causing slippery roads and use of heavy equipment	Workers are not wearing PPE that adequate and lack attention during the unloading process fertilizer	Slipping injury from being stuck by heavy materials and equipment, chemical gas poisoning	Workers use complete PPE, conduct safety briefings and safety controls, and every operational officer enforces the rules HSSE	4	4	16	Extreme
2	Packaging in warehouse or stacking area	Unsafe Condition dan Unsafe Action	Unloading and packaging of cargo	Slippery floors, untidy cargo piles, heavy equipment operation not in accordance with SOP, stuffy rooms and poor ventilation, fertilizer dust and flammable materials	Slips, minor to serious injuries such as broken bones or head injuries, even death, respiratory problems, skin and eye irritation, burns, being crushed, fainting, and dehydration	Conducting occupational safety and health (OSH) training for all workers, providing complete personal protective equipment (PPE), ensuring proper room conditions and ventilation inside the warehouse, and conducting routine inspections of equipment and work environment conditions	4	5	20	Extreme

Based on the results above, the most extreme level was the operation of loading and unloading fertilizer bulk and packaging in the warehouse/stacking area where the likelihood and consequences are high so that the severity is also high, this is because both activities have serious consequences such as death. The source of the hazard comes from unsafe action and unsafe conditions, where unsafe action is the fault of the worker himself such as not wearing adequate PPE and lack of caution due to fatigue, as well as lack of training obtained.

3.4. Recommendations for Improving the Results of HAZOP Analysis on Bulk Fertilizer Cargo Loading and Unloading

Based on the HAZOP analysis, improvement measures are required to mitigate hazards classified within the moderate to extreme risk levels, comprising two moderate risks, three high risks, and two extreme risks. These recommendations are intended to provide effective and practical control measures for major hazards, thereby reducing workplace accidents, enhancing worker protection, and ensuring the continuity of loading and unloading operations. The proposed improvements include: (1) the development of a standardized worker health-check SOP, covering pre-employment, periodic, and special medical examinations for high-risk or older workers; (2) strengthening occupational health and safety (OHS) aspects through regular training, improved HSSE quality and capacity, and monthly internal OHS evaluations; (3) controlling dust and chemical gas exposure by installing active ventilation systems, dust collectors, gas detectors, and enforcing the use of appropriate PPE and restricted zones; (4) preventing collisions with heavy equipment through operator training, motion sensors, automatic alarms, one-way traffic arrangements, and clear safe-zone markings; (5) reducing slip hazards by requiring anti-slip safety shoes, improving housekeeping, repairing drainage systems, adding warning signs, and ensuring adequate lighting; (6) preventing heat stress by providing shaded rest areas, drinking water, emergency shelters, work rotation schemes, and medical monitoring; (7) minimizing the risk

of falling materials by limiting fertilizer stack height to 8–10 layers, applying stable cross-stacking methods, using pallets, and enforcing the use of helmets and safety shoes; and (8) preventing fire hazards by installing automatic temperature and humidity monitoring systems with early warning alarms, providing dry chemical fire extinguishers, and storing fertilizer in dedicated, well-ventilated, and fire-resistant areas.

4. CONCLUSION

Based on the analysis of potential workplace accidents in the bulk cargo loading and unloading process using the Hazard Analysis and Operability Study (HAZOP) method, several conclusions can be drawn. First, a number of potential hazards were identified, including slipping, being struck by objects, being caught between equipment, and exposure to hazardous gases, which may arise from worker negligence, environmental factors, or a combination of both. In total, nine hazard sources were identified, consisting of four hazards related to unsafe actions, three hazards related to unsafe conditions, and two hazards resulting from both unsafe actions and unsafe conditions. Second, the assessment of likelihood, consequence, and severity for each activity in the bulk fertilizer loading and unloading process was used to determine the level of risk, resulting in two extreme risks, three high risks, two medium risks, and two low risks. Third, the proposed corrective actions include strengthening occupational health and safety (OHS) training and standard operating procedures, installing active ventilation systems, dust collectors, and gas detectors in unloading and packaging areas, ensuring the use of appropriate personal protective equipment, particularly masks, establishing restricted zones, using tarpaulins during sea transport and on truck loads, equipping heavy equipment with motion sensors, requiring anti-slip safety shoes, providing shaded rest areas, emergency tents, and accessible drinking water, implementing work rotation systems, and installing automatic temperature and humidity monitoring systems integrated with early warning alarms, along with the provision of dry chemical fire extinguishers in warehouse areas.

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