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Analysis of Occupational Health and Safety Hazard Risk Using Hazard and Operability and Fault Tree Analysis Methods

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Abstract

This study aims to identify the potential for occupational health and safety hazards using the Hazard and Operability (HAZOP) method and to provide recommendations for resolving the root causes of work accidents using Fault Tree Analysis (FTA). This study was conducted at PT. X, engaged in the plantation and processing of latex, is called Crumb Rubber. Based on data from 2022 to 2023, there are eight potential work accidents caused by several factors, such as the work environment, machines, and humans. The company has implemented an occupational health and safety program to support the safety of the company workforce. Even so, work accidents in the company still occur due to workers not being aware of the importance of occupational health and safety; this can be seen in workers who ignore their safety by not using complete personal protective equipment provided by the company. This still causes the potential for work accidents to occur. The study results show that the Hazard and Operability analysis revealed four different sources of danger that need attention: Low risk, such as split palms and slipping; Medium risk, including incidents such as sprained hands. High risk, including the potential for feet being stabbed by hooks, injured or cut hands, blistered and itchy hands, forklift accidents, and exposure to chemicals. Extreme risk is the potential for eye irritation. Based on the root causes of work accidents that have been observed using the Hazard and Operability method, recommendations were obtained using the Fault Tree Analysis method in the form of improving work attitudes, including creating a work health and safety training schedule, developing worksheets, and implementing attractive poster displays (visual displays). Recommendations for improving work environment conditions are recommended, especially managing puddles and chemical spills and optimizing machine maintenance.

Keywords: *Safety, Health, Work, Hazard, Operability, Hazop.*

1. Introduction

The existence of industry has become an essential part of human evolution. One of the factors that significantly influences it is human resources, especially workers. All of these advances require a higher level of occupational safety and health. Therefore, occupational health and safety is increasingly important in the industrial world. Occupational health means maintaining the safety and health of workers when they do their work, especially in heavy work such as construction. However, work accidents often occur in the industrial world or work [1]. A work accident involves an individual or group in an unexpected event [2].

According to statistical analysis, 85% of workplace accidents are caused by unsafe acts carried out by individuals, while only 15% are caused by hazardous environmental conditions. This data underlines the importance of cultivating a culture of safety and awareness among all employees to reduce risks and improve well-being in the workplace [3]. There are many reasons why accidents can occur in the workplace, namely due to hazardous conditions related to human factors, machines, the work environment, and production processes. Understanding and addressing these causes is essential for effective risk management and mitigation [4] [5]. The Occupational Safety and Health Program was created to help employers and workers work together to keep everyone safe and healthy so that no one gets hurt or sick. By fostering a comprehensive understanding of potential hazards and implementing proactive measures, the program aims to reduce the risk of work-related incidents significantly. Furthermore, the Occupational Health and Safety Program is strategically designed to safeguard workers' well-being and reduce the financial burden on the company associated with workplace accidents and occupational diseases [6].

The company has provided personal protective equipment (PPE) for all employees to carry out their work. The company has also implemented an occupational health and safety program to support the safety of the company workforce. Even so, work accidents in the

company still occur due to workers not being aware of the importance of occupational health and safety, and this can be seen in workers who ignore their safety by not using complete personal protective equipment provided by the company.

Based on company data from the accident category from 2022 to 2023, 8 potential work accidents are caused by factors such as the work environment, machines, and humans. The potential for work accidents includes four workers in the raw material receiving section who suffered leg injuries due to being hit by a hook and hand injuries due to being hit by a rubber cutting knife, causing them to lose more than 2 weeks of work. This data is only part of the work accident data recorded by the occupational health and safety management system.

HAZOP investigates various causal factors that can cause accidents in the workplace. By identifying potential deviations and their associated negative consequences, HAZOP is a way to find problems and provide valuable ideas to ensure they don't cause significant issues [7][8]. According to Juniani, the main reason for conducting a HAZOP study is to observe how something works, such as a machine or a process [9]. To keep people safe in the workplace and prevent accidents from happening, it is essential to have a good plan. This plan should include finding out what hazards are around, figuring out how serious they are, creating a plan to stay safe, and checking regularly to make sure everything is still secure. Organizations can effectively improve their processes by implementing HAZOP and confidently reduce potential risks. Types of HAZOP include Process HAZOP, Human HAZOP, Procedure HAZOP, and Software HAZOP [10] [11] [12] [13]. In addition to using the HAZOP method, a method that serves as an invaluable resource to achieve occupational safety and health is the Fault Tree Analysis (FTA) method. This innovative method was initially used to assess the safety of the Minuteman intercontinental missile launch system. FTA provides a systematic approach to evaluating product reliability by explaining the complex cause-and-effect relationships between events [14]. FTA uses a top-down approach, starting with an overview of an event, specifically, the general failure that occurred before investigating the specific underlying causes. This methodology is represented visually through a fault tree, which depicts the state of system components (elementary events) and explains the complex relationships between these elementary events and the overarching primary event. FTA uses tree diagrams to elegantly illustrate the relationship between desired outcomes and underlying causes, and to analyze the various potential sources of failure [15] [16].

This study aims to identify the possibility of occupational safety and health hazards using the Hazard and Operability (HAZOP) method and propose solutions to work accidents using the Fault Tree Analysis (FTA) method. The ultimate goal of this study is to foster an atmosphere that supports peak productivity and well-being in the workplace [17].

3. Research Method

This research was conducted in stages, from primary data (interviews and observations) to secondary data (books, internet, and journals). After data collection, researchers processed the data using the Hazard and Operability (HAZOP) and Fault Tree Analysis (FTA) methods until the recommendation stage. The stages of data processing using Hazard and Operability (HAZOP) are as follows [18] [19]:

a. Determining the Likelihood value
   The likelihood value can be assessed elegantly using the Possibility Criteria Table.
a. Determining the Consequences/Saverity Value
   To ensure the Consequence/Severity value, one can refer to a comprehensive Consequence/Severity table.
b. Risk Assessment
   Risk assessment is carried out through a quantitative approach, where the risk value is obtained by multiplying the probability of an event occurring by the potential consequences that may arise. The formula used for assessing the likelihood and consequences of risk is:

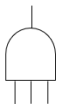
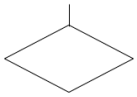
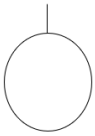
$$R = L \times C \quad \text{.......} (1)$$

Note: R = risk value result (risk matrix)
L = Likelihood value
C = Consequences value

The Fault Tree Analysis method uses a tree diagram to describe the source of accidents in the workplace with a fault tree model, which provides a clear and structured picture of potential sources of failure. The following are the steps for processing data using the Fault Tree Analysis method:

a. Interpreting accidents
b. In essence, the rampant work accidents in an organization are often caused by the actions of the employees themselves, especially those who are less vigilant in carrying out their duties.
c. Developing a fault tree
   First, we will define precisely the nature of the accident and then create a fault diagram that will allow us to identify the root causes of the incident.
d. Symbols: The Fault Tree Analysis (FTA) method uses symbols to describe the relationship between events that cause system failure. In its application, the FTA technique used qualitatively has 2 (two) basic notation types: events and logic gates. In the event symbol, it is used to indicate the nature of each event in the system. These event symbols will make it easier to identify the events that occur. Meanwhile, logic gates indicate the relationship between events in the system. Each event in the system can, individually or together, cause other events to appear [20]. The fault tree analysis description symbols can be seen in Table 1.

Table 1. Symbol Description Fault Tree Analysis

	Symbols	Information
Logic gates		Top event: The peak event that must be explained in more detail/incident that occurred
		Or-Gate: Indicates that one event was enough to cause the accident
		And Gate: This indicates that an output event will occur only when all input events occur simultaneously.
Input event		The Undeveloped Event : Represents an event that has not been investigated because of insufficient information or because its implications are considered negligible.
		The bacic Event: Introduces fundamental equipment failure that does not require further investigation into the underlying cause

4. Result and Discussion

Table 2 shows data in the form of types and number of potential work accidents in the company during 2 years (2022-2023).

Table 2. Number of Work Accidents

Year	Number of Accidents	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2022	14	1	2	0	1	2	0	1	3	0	1	2	1
2023	12	0	1	4	0	2	1	2	0	0	0	1	1

Furthermore, the types of data on potential work accident findings collected from 6 production stations for more details can be seen in Table 3.

Table 3. Data on Potential Work Accident Findings

Raw material receiving station		
Process	**Description of hazard findings**	**Risk**
Sorting rubber latex and separating the rubber blocks from other piles of latex	Hook tool	Feet stabbed with a hook
Cutting/splitting the sap to separate it from the waste inside.	rubber cutting knife	Injured/cut hand.
Dryer station		
Process	**Description of hazard findings**	**Risk**
Operating the trolley	Trolley crank	Sprained hand
Waste treatment station		
Process	**Description of hazard findings**	**Risk**
Splashed with wastewater while checking the waste PH	Wastewater	Eye irritation
Splashed with wastewater while checking the waste PH	Wastewater	Hand wounds blister and itch

Packing Station		
Process	**Description of hazard findings**	**Risk**
Packaging the sap that has just come out of the cooking tool	Hot rubber block	Hands and body blistered from burns when trying to pack the sap.
Mistakes in operating forklifts and trucks	Forklift	The tool crashed into the surrounding area; the worker was hit
Slab cutter station/raw material cutting machine		
Process	**Description of hazard findings**	**Risk**
Hit by a slab cutter knife	Slab Cutter Knife	Split palm
Stasiun *cleaning*		
Process	**Description of hazard findings**	**Risk**
Pallet Washing	Chemical water	Exposed to chemicals
Pallet Washing	Chemical water	Worker slipped

Once the identification process is complete, move on to the risk assessment phase, which is done through qualitative analysis. Risk quantification is achieved by multiplying the likelihood and consequence values, which gives a clear risk value. This risk level can be visualized with the results of the description in the risk matrix table.

Table 4. Risk Assessment of Raw Material Receiving Station

Process	Description of hazard findings	Risk	L	C	S	Risk Level
Sorting rubber latex and separating the rubber blocks from other piles of latex	Hook tool	Feet stabbed with a hook	4	2	8	High
Cutting/splitting the sap to separate it from the waste inside.	rubber cutting knife	Injured/cut hand.	4	2	8	High

Based on Table 4, the risk assessment results at the raw material receiving station, such as stabbed by a hook and hit by a rubber cutting knife, have the same score of 8 with a High-risk level category. After identifying the risk assessment, the next step is to create a fault tree to show all the reasons, such as mistakes that people might make or things that could be damaged, which could cause an accident. By looking at this picture, the company can find weak points and fix them, which helps maintain the safety of everyone in the workplace. Fault tree analysis of being stabbed by a hook and being hit by a rubber cutting knife can be seen in Figure 1 and Figure 2:

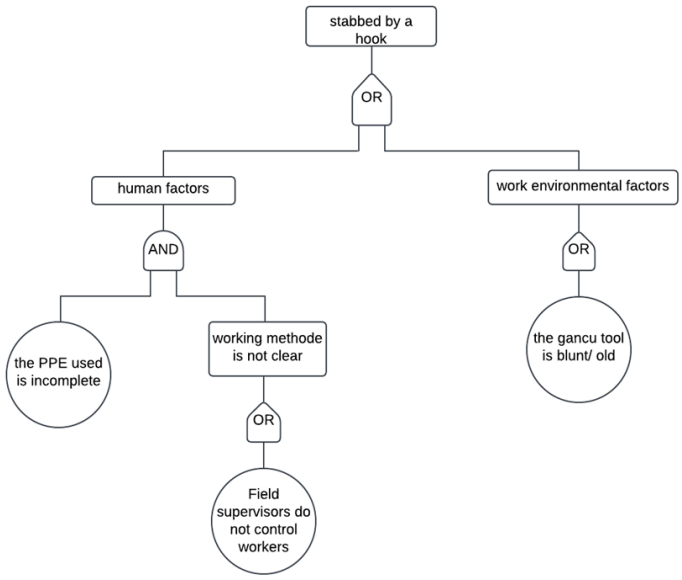


Fig 1. Fault Tree Analysis Tercucuk Gancu

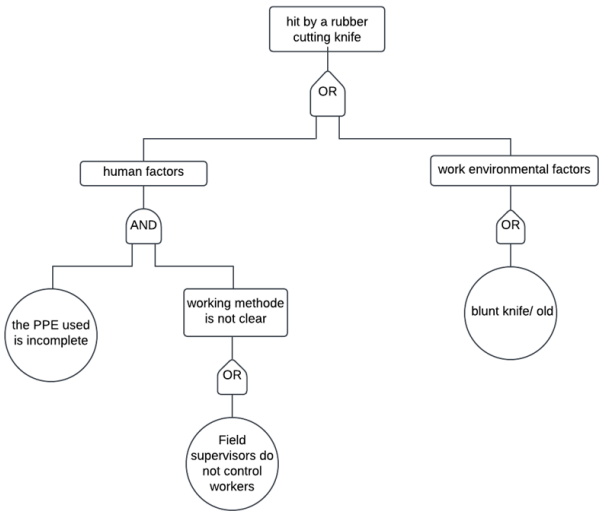


Fig 2. Fault Tree Analysis Hit by a rubber cutting knife

Table 5. Risk Assessment of Drying Station/Dryer

Process	Description of hazard findings	Risk	L	C	S	Risk Level
Operating the trolley	Trolley crank	Sprained hand	1	3	3	Currently

Based on Table 5, the results of the risk assessment at the drying station/ Drayer such as being hit by a trolley crank show a score of 3 with a Medium risk level category. After identifying the risk assessment, the next step is to create a fault tree to show all the reasons, such as mistakes that people might make or things that could be damaged, that could cause an accident. By looking at this picture, the company can find weak points and fix them, which helps maintain the safety of everyone in the workplace. The fault tree analysis of being hit by a trolley crank can be seen in Figure 3:

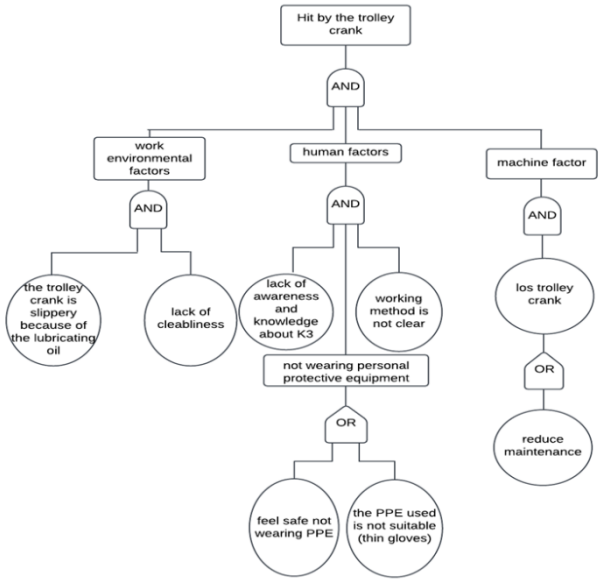


Fig 3. Fault Tree Analysis Affected by Trolley Crank

Table 6. Risk Assessment of Waste Treatment Station

Process	Description of hazard findings	Risk	L	C	S	Risk Level
Splashed with wastewater while checking waste PH	Wastewater	Eye irritation	4	4	16	Extreme
Splashed with wastewater while checking waste PH	Wastewater	Hand wounds blister and itch	4	3	12	High

Based on Table 6, the risk assessment results at the waste treatment station include exposure to factory waste, causing eye irritation and blistered and itchy hand wounds. Eye irritation shows a score of 16 in the Extreme risk level category, and blistered hand wounds show a score of 12 in the High category. After identifying the risk assessment, the next step is to create a fault tree to show all the reasons, such as mistakes that people might make or things that could be damaged, which can cause accidents. By looking at this picture, the company can find weak points and fix them, which helps maintain the safety of everyone in the workplace. Fault tree analysis exposed to factory waste can be seen in Figure 4:

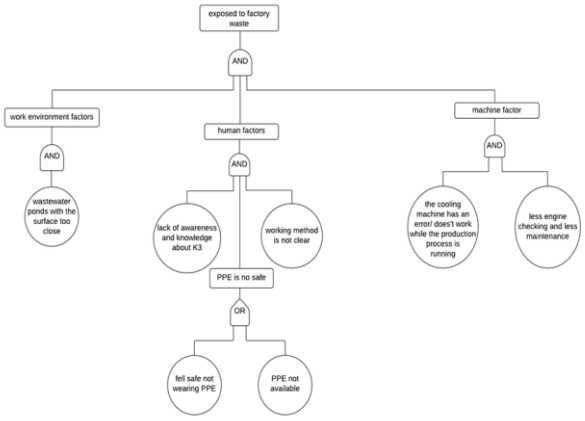


Fig 4. Fault Tree Analysis Affected by Factory Waste

Table 7. Packaging Station Risk Assessment

Process	Description of hazard findings	Risk	L	C	S	Risk Level
Packing the sap that has just come out of the cooking tool.	Hot rubber block	Hands and body blistered from burns when trying to pack the sap	1	3	3	Currently
Forklift operating error	Forklift	The forklift hit so that the forklift driver was hit	4	2	8	High

Based on Table 7, it can be seen that the risk assessment results at the packaging station, such as being exposed to hot sap, show a score of 3 in the medium category. Meanwhile, the error in forklift operating scores 8 in the High-risk level category. After identifying the risk assessment, the next step is to create a fault tree to show all the reasons, such as mistakes that people might make or things that could be damaged, which could cause an accident. By looking at this image, the company can find weak points and fix them, which helps maintain the safety of everyone in the workplace. Fault tree analysis of being exposed to hot sap and errors in operating the forklift can be seen in Figures 5 and 6: The Fault Tree Analysis of being exposed to Hot Sap to be packaged can be observed in Figure 5.

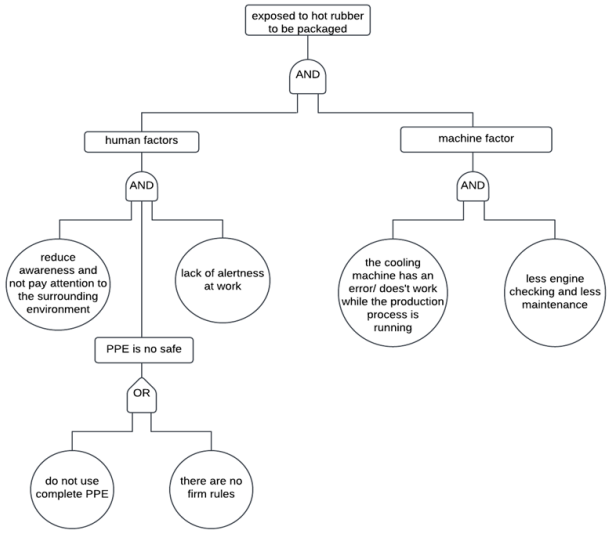


Fig 5. Fault Tree Analysis of hot sap to be packed

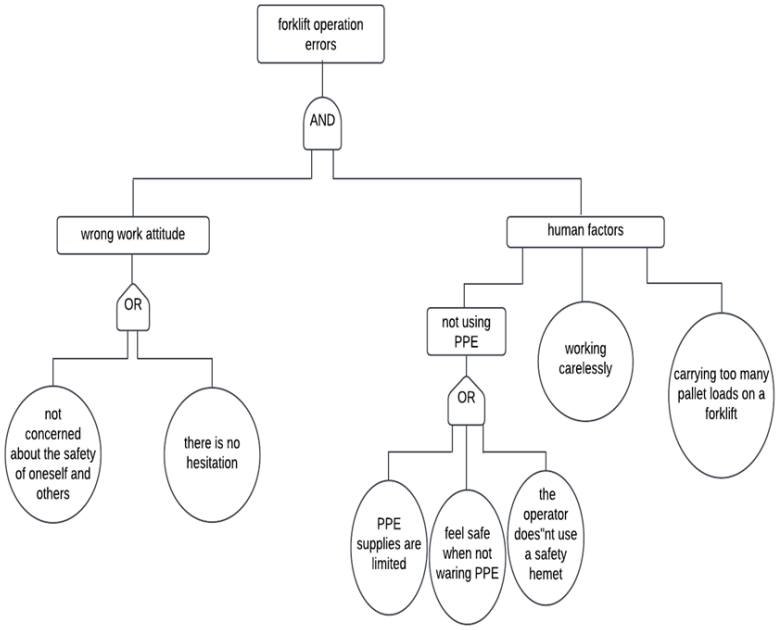


Fig 6. Fault Tree Analysis of Operational Errors of Forklip Tools

Table 8. Risk Assessment of Slab Cutter Station/Raw Material Cutting Machine

Process	Description of hazard findings	Risk	L	C	S	Risk Level
Hit by a slab cutter knife	Slab cutter knife	Split palm	2	2	4	Low

Based on Table 8, it can be seen that the results of the risk assessment at the slab cutter station/raw material cutting machine such as being hit by a slab cutter blade, show a score of 4 with a Low-risk level category. After identifying the risk assessment, the next step is to create a fault tree to show all the reasons, such as mistakes that people might make or things that could be damaged, which could cause an accident. By looking at this image, the company can find weak points and fix them, which helps maintain the safety of everyone in the workplace. Fault tree analysis of being hit by a slab cutter blade can be seen in Figure 7:

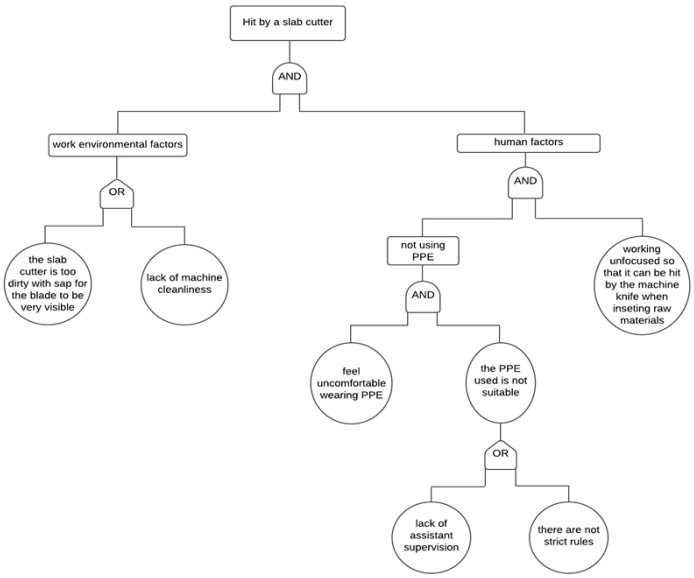


Fig 7. Fault Tree Analysis Hit by Slab Cutter Blade

Table 9. Cleaning Station Risk Assessment

Process	Description of hazard findings	Risk	L	C	S	Risk Level
Fallet washing	Chemical water	Workers exposed to chemicals	1	4	4	High
Fallet washing	Chemical water	Worker slipped	1	1	1	Low

Based on Table 9, the risk assessment results at the cleaning station can be seen, such as the chemical water that causes workers to be exposed to chemicals and slip. Exposure to chemicals shows a score of 4 with a High-risk level category and slips a 1 with a Low category. After identifying the risk assessment, the next step is to create a fault tree to show all the reasons, such as mistakes that people might make or things that could be damaged, which can cause accidents. By looking at this picture, companies can find weak points and fix them, which helps maintain the safety of everyone in the workplace. Fault tree analysis of being exposed to chemicals can be seen in Figure 8:

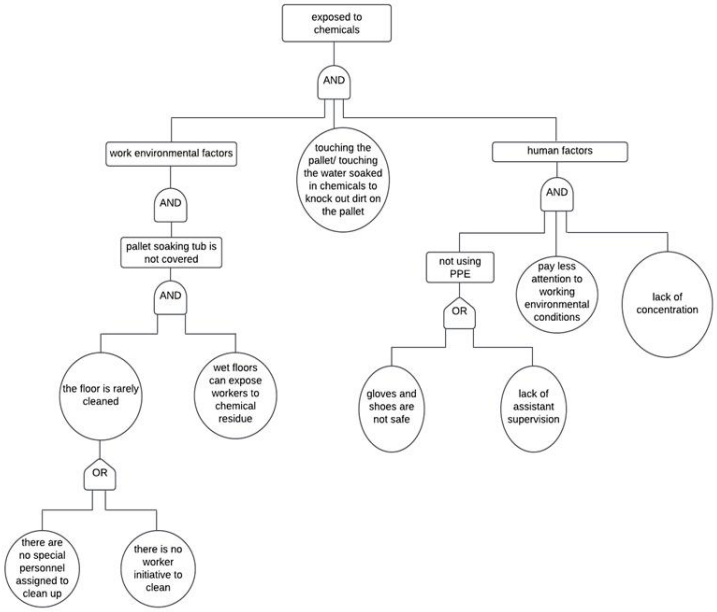


Fig 8. Fault Tree Analysis of Chemical Exposure

Next, identify risk categories, such as low, medium, high, or critical, which relate to factors such as the type of work, the tools used, and the working conditions. Categorizing risks makes it easier to set priorities for handling so that work improvement steps can be adjusted to the risk level of each worker. The hazard risks in the production area can be seen in Table 10.

Table 10. Worker Risk Categorization

Risk Classification	Worker Risk
Low	Split palm
	Worker slipped
Currently	Sprained hand
	Legs stabbed by hook
	Hands injured/cut
High	Hands blistered and itchy
	The forklift hit, so the driver hit
	Exposed to chemicals
Extreme	Eye irritation

Recommendations for resolving the root causes of work accidents using Fault Tree Analysis include improving work attitudes, which include establishing a comprehensive occupational health and safety training schedule, developing detailed worksheets, and implementing attractive poster displays (visual displays). Recommendations for improving work environment conditions, especially addressing the management of puddles and chemical spills and optimizing machine maintenance. Recommendations for root causes can be seen in Table 11.

Table 11. Recommendations

No	Potential	Improvement suggestions
1.	Got a Gancu	• Increase supervision by increasing the number of supervisors on active duty to monitor worker activities and use work tools. • Replace the hook tool with new, safer equipment • Create a worksheet • Create a poster (visual display)
2.	Hit by trolley crank.	• Improve cleanliness in the work area • Ensure that the trolley crank is permanently lubricated with lubricant oil • Perform regular maintenance on the trolley • Create a worksheet • Create a poster (visual display) • Ensure that workers always use Personal Protective Equipment (PPE)
3.	Exposed to factory waste	• Conduct a thorough inspection of the machine system • Consider old equipment with new models • Create a worksheet • Create a poster (visual display) • Deepen the waste pond
4.	Hit by a rubber cutting knife	• Increase the role of field supervisors • Need to replace or rejuvenate old work tools • Create worksheets • Create posters (visual displays) • Ensure workers always use Personal Protective Equipment (PPE)
5.	Hit by hot sap	• Create SOPs using appropriate PPE. • Create SOPs to accurately determine the cooling duration required for rubber. • Create worksheets • Create posters (visual displays)
6.	Forklift operating errors	• Conduct regular training on understanding the importance of using Personal Protective Equipment (PPE) • Create worksheets • Create posters (visual displays) • Ensure that forklifts are only used to carry loads within their capacity.
7.	Exposed to chemicals	• Ensure that there are special officers who clean hazardous chemicals • Provide special training • Create worksheets • Create posters (visual displays) • Ensure that workers always use Personal Protective Equipment (PPE) • Increase worker concentration and alertness
8.	Hit by a slab cutter knife	• Ensure the knife is clean and free from dirt and sap • Overall machine cleanliness must be maintained by carrying out regular maintenance and cleaning • Create a worksheet • Create a poster (visual display) • Ensure workers always use Personal Protective Equipment (PPE) • Increase worker concentration and alertness

5. Conclusion

Based on the results of data analysis obtained from the research conducted, the identification of the possibility of occupational safety and health hazards using the Hazard and Operability method, four different sources of hazards need attention, including:

a. Low Risk
   Low-risk incidents include split palms with a risk matrix value of 4 and slipping experienced by workers with a risk matrix value of 1.
b. Medium Risk
   Medium-level risk is a sprained hand with a risk matrix value of 3.
c. High Risk
   High risks faced include the potential for feet to be pierced by hooks (risk matrix 8), injured or cut hands (risk matrix 8), and discomfort due to blisters and itching (risk matrix 12). In addition, there is a risk of forklift accidents (risk matrix 8) and exposure to hazardous chemicals for workers (risk matrix 4).
d. Extreme Risk
   The risk that falls into the extreme group is the potential for severe eye irritation due to exposure to chemical splashes, with a risk matrix value of 16.

Recommendations for resolving the root causes of work accidents using Fault Tree Analysis include improving work attitudes, which include establishing a comprehensive occupational health and safety training schedule, developing detailed worksheets, and implementing attractive poster displays (visual displays). Recommendations for improving work environment conditions are recommended, especially managing puddles and chemical spills and optimizing machine maintenance.

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