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Identification of Occupational Accidents at PTPN IV Air Batu, Kisaran Using Job Safety Analysis and Hazard and Operability Methods

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Abstract

Workplace accidents remain a critical concern in the palm oil processing industry, which is characterized by complex operations and high-risk activities, particularly in key operational areas such as sterilizers, clarification units, boilers, screw presses, and sand trap tanks. This study aims to identify potential hazards and assess the level of occupational accident risk at PT Perkebunan Nusantara IV Unit Air Batu using a combined approach of Job Safety Analysis (JSA) and Hazard and Operability Study (HAZOP). Data were collected through field observations, questionnaires, and accident reports recorded between 2023 and 2024. The findings indicate that the primary causes of workplace accidents stem from technical equipment failures, unsafe working environments, and non-compliance with standard operating procedures. The highest risk levels were identified at the boiler and sterilizer stations, with risk scores reaching 20–25, categorized as extreme hazard zones. Dominant hazards include exposure to high-temperature steam and hot oil, pressure leakage, musculoskeletal injuries from manual handling, and gas exposure in confined spaces. Recommended corrective actions involve strengthening engineering controls through the installation of interlock systems and automated sensors, developing risk-based standard operating procedures, enforcing appropriate personal protective equipment (PPE) usage, and implementing regular safety training and evaluation. The integration of JSA and HAZOP methods proved effective in providing a comprehensive risk mapping framework and can serve as a strategic reference for enhancing occupational health and safety (OHS) management systems in the palm oil industry.

1. INTRODUCTION

Occupational safety and health (OSH) remains a fundamental aspect in industrial operations, particularly within the palm oil processing sector which involves complex processes, heavy machinery, high-temperature operations, and chemical exposure. Inadequate implementation of OSH measures can lead not only to workplace injuries but also to operational downtime and increased production costs. According to BPJS Ketenagakerjaan (2022), Indonesia recorded over 234,000 occupational accident cases, with the agricultural and plantation sector being one of the highest contributors.

PT Perkebunan Nusantara IV Unit Air Batu, one of Indonesia's major palm oil mills, has reported recurring workplace accidents within its primary processing stations, namely sterilizer, clarification, boiler, screw press, and sand trap tank. Preliminary observations identified 23 incidents during 2023–2024, ranging from slips, thermal burns, to musculoskeletal injuries. These accidents were attributed to equipment failure, unsafe working environments, and deviation from standard operating procedures. Furthermore, the use of conventional hazard identification approaches has proven inadequate, often lacking systematic structure and preventive focus.

Address this gap, a hybrid analytical method combining Job Safety Analysis (JSA) and Hazard and Operability Study (HAZOP) is adopted in this study. JSA allows for structured breakdown of job tasks to

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identify specific hazards, while HAZOP provides a deviation-based analysis to evaluate operability risks under abnormal conditions.

This study aims to: (1) identify the root causes of occupational accidents in key processing units; (2) assess risk levels using JSA and HAZOP; and (3) propose hazard control measures tailored to the operational context of PT Perkebunan Nusantara IV Air Batu. The findings are expected to contribute to the development of a proactive and data-driven OSH strategy, supporting the broader goal of injury prevention and operational sustainability in the palm oil industry (Setiyoso et al., 2019).

According to Law No. 3 of 1992 on Social Security for Workers, an occupational accident is defined as an accident that occurs in relation to work, starting from the time a worker departs from home to the workplace and until returning home through the usual or reasonable route. Furthermore, based on the Regulation of the Minister of Manpower of the Republic of Indonesia No. 03/MEN/1998 concerning the procedures for reporting and investigating accidents, an occupational accident is defined as an incident that may cause harm to human life and property (Pratama, 2019).

1.1 The definition of Occupational Safety and Health (OSH)

According to the International Labour Organization (ILO) is the promotion and maintenance of the highest degree of physical, mental, and social well-being of all workers in all occupations. It aims to prevent health disorders caused by work, protect workers from risks arising from factors that may affect their health, place and maintain workers in an occupational environment adapted to their physiological and psychological capacities, and ensure a proper match between the job and the worker, as well as between each individual and their tasks (Basuki, M. Y, 2020).

A hazard is a source with the potential to cause harm, such as injury, illness, property damage, environmental damage, or a combination of these. Hazard is a characteristic that is inherent in a material, condition, system, or equipment. Understanding the concept of hazard is essential, as a misunderstanding of this concept may result in ineffective hazard control measures. Hazards are also closely related to the presence of energy, and for an accident to occur, there must be contact with energy or a harmful substance (Umiyati, 2021).

1.2 Job Safety Analysis (JSA)

Job Safety Analysis (JSA), also known as Job Hazard Analysis, is one of the risk assessment and hazard identification systems that emphasizes the identification of hazards present in each step of a job or task performed by workers. It is a method used to examine and detect hazards that may have been previously overlooked during the design of the workplace, work facilities or equipment, machinery used, and work processes (Ilmansyah et al., 2020).

Job Safety Analysis (JSA) is an effort to analyze tasks and procedures within an industry. JSA is defined as a method for studying a job to identify hazards and potential incidents associated with each step, and to develop solutions that can eliminate or control such hazards and incidents. Once hazards have been identified, control actions can be implemented in the form of physical modifications or improvements to work procedures to reduce occupational risks. In its implementation, the JSA process requires training, supervision, and written job descriptions to facilitate employees' understanding of safe work procedures (Syahra, S, 2022).

An organization possesses various resources as 'inputs' that are transformed into 'outputs' in the form of goods or services. These resources include capital or financial assets, technology to support the production process, methods or strategies used in operations, human resources, and others. Among these resources, human resources (HR) are considered the most important element (Irmayani et al., 2020).

The steps in conducting a Job Safety Analysis (JSA) are as follows: (Angkasa et al., 2021):

1) Job Selection
2) Job Breakdown and Hazard Identification in the Plantation Area
3) Job Breakdown and Hazard Identification in the Mill Area
4) Hazard Control

1.3 Hazard and Operability Study (HAZOP)

Hazard and Operability Study, commonly abbreviated as HAZOP, is a risk assessment process used to support safety decision-making for new or modified systems in order to identify potential hazard issues. HAZOP is utilized with the objective of examining processes or activities within a system to evaluate whether performance deviations could lead to incidents or disasters (Nur, 2020).

The stages carried out in the Hazard and Operability (HAZOP) method are as follows (Peng et al., 2021):

a. Classifying the identified potential hazards, including their sources and frequency of occurrence.

b. Describing the deviations that occur during the operational process.

c. Identifying the causes of these deviations.

d. Describing the possible consequences resulting from the deviations.

e. Determining temporary or immediate actions that can be taken.

f. Assessing the risks by defining the criteria for Likelihood and Consequences (Severity)

In the process of assessing the level of risk severity using a risk matrix table, the values of likelihood and consequences obtained are processed through the risk matrix to determine the level of risk severity. Each color in the matrix indicates a different score or risk level. The risk matrix can be seen in Table 1 as follows:

Table 1. *Risk Matrix* Table

SCALE		*LIKELIHOOD*				
		1	2	3	4	5
SEVERITY	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5

Source: (Peng et al., 2021)

Description:

= Exreme

= High

= Medium

= Low

The steps involved in the Hazard and Operability (HAZOP) method are as follows (Hicham, 2024):

a) Classify the identified potential hazards, including their sources and the frequency of occurrence.
b) Describe the deviations that occur during the operational process.
c) Identify the causes of the deviations.
d) Describe the consequences that may result from these deviations.
e) Determine the temporary actions or immediate measures that can be taken.
f) Assess the risk by defining the criteria for *Likelihood* and *Consequences* (Severity.

2. METHOD

2.1 Data Collection Techniques

The data collection techniques used in this study are as follows:

a. Primary data refers to information that is directly observed, recorded, and obtained from the original source. This includes unprocessed data such as direct observations of activities at each work station relevant to the research topic.

b. Secondary data refers to information obtained from existing sources, including scientific books, articles, and data provided by the research site itself, such as company history, organizational structure, and historical workplace accident records. The data incorporated into this research includes the results of observations and qualitative analyses.

c. The basis for determining the Likelihood (L) and Severity (S) scales in this study was obtained through questionnaire surveys distributed across the five processing stations under investigation. The responses from workers and supervisors were then aggregated and analyzed to assign the appropriate risk scores.

d. The risk assessment was conducted collaboratively by the OHS team of PTPN IV and the researchers through focus group discussions (FGD), involving operators, technicians, and supervisors.

e. The scope of this study was limited to five critical stations, namely sterilizer, clarification, boiler, screw press, and sand trap tank. The JSA analysis was focused on five types of work that had recorded occupational accidents at these stations. Data were collected through field observations, questionnaires, and incident reports from 2023–2024 (covering one operational period). The questionnaires were distributed to five workers representing the five critical stations, namely sterilizer, clarification, boiler, screw press, and sand trap tank.

2.1 Method of Analysis

The method used in this research is a combination of Job Safety Analysis (JSA) and Hazard and Operability (HAZOP), which includes the following stages:

a. Job Selection
Jobs with a poor safety record are given priority and must be analyzed first. This step ensures that high-risk tasks receive focused attention in hazard identification.

b. (Job Breakdown)
The selected job is broken down into detailed steps, from the beginning to the end of the task. Each step is described clearly to facilitate the identification of potential hazards associated with each activity.

c. (Hazard Control)

In the final phase of the accident analysis, hazard control measures are proposed by identifying alternative solutions to develop effective safety procedures for the work environment.

d. Hazard Classification and Deviation Analysis
Identified potential hazards are classified based on their sources. Deviations that occur during operations are described, along with their causes and potential consequences. Temporary actions or interim measures are also determined to address these issues.

e. risk asessment
Risk is assessed by defining the criteria for Likelihood (frequency) and Consequence (severity). The risk score is calculated using the following formula:
Risk Score = Likelihood Value x Severity Value..(1)
Description:
Likelihood Value= Frequency or probability of the hazard occurring
Severity Value = Level of impact or consequence if the hazard occurs.

3. RESULT DAN DISCUSSION

3.1 Hazard Zone Level Determination Recapitulation

The recapitulation of hazard zone level determination can be seen in Table 2 as follows:

Table 2. The recapitulation of hazard zone level

No	Process	Hazard Identification	Likelihood Level	Severity Level	Risk Level (L×S)	Risk Category
1	Sterilizer	Fire due to spilled hot oil	2	4	8	(High)
		Burned by steam around separator	3	3	9	(High)
		Muscle injury from pushing heavy trolley	3	2	6	(Medium)
2	Clarrification	Fire caused by spilled hot oil	2	4	8	(High)
		Burn injury due to hot steam around the separator	3	3	9	(High)
		Steam leakage during high pressure	3	4	12	High
		Fire caused by spilled hot oil	2	4	8	(High)
		Burn injury due to hot sludge	3	3	9	(High)

		Exposed to chemicals while cleaning the tank	3	2	6	(Medium)
		Slipping due to slippery floor and scattered fibers	3	3	9	(High)
3	*Boiler*	Explosion due to overpressure	2	3	6	(Medium)
		Burned by residual heat during inspection	3	2	6	(Medium)
		Exposed to hot dust during manual removal	2	5	10	High

Source: Data Processing

Tabel 2 The recapitulation of hazard zone level

No	**Process**	**Hazard Identification**	**Likelihood Level**	**Severity Level**	**Risk Level (L×S)**	**Risk Category**
4	*Screw Press*	Caught or pulled into machinery	3	3	9	(High)
		Exposed to hot oil splashes	3	3	9	(High)
		Injury from moving parts	3	3	9	(High)
		Burned by machinery that hasn't cooled down	3	2	6	(Medium)
5	*Sand Trap Tank*	Slipping due to hot sludge spill	3	5	15	Extreme
		Oxygen deficiency, H_2S gas exposure	2	3	6	(Medium)
		Muscle injury, slipping	3	3	9	(High)
		Slipping in confined space without PPE	3	3	9	(High)

Source: Data Processing

3.2 Recapitulation of Hazard and Operability Study (HAZOP) Matrix Results

Based on the results of the calculations using the Hazard and Operability Study (HAZOP) matrix at each workstation, a summary was compiled in the form of a matrix table, highlighting the highest risk levels identified. The summary can be seen in Table 3 as follows:

Table 3. Summary Matrix of Hazard and Operability Study (HAZOP) Calculation Results

DESCRIPTION	*SEVERITY*	SCALE	*LIKELIHOOD*				
				Exposed to hot dust	Steam leakage, crushed	Fire	Slipping
			1	2	3	4	5
Boiler (Exposed to hot dust during manual removal)		5	5	**10**	15	20	25
Sterilizer (Steam leakage during high pressure)		4	4	8	**12**	16	20
Screw Press (Caught or pulled into machine), Sand Trap Tank (Hot sludge spill causing slip)		3	3	6	**9**	12	**15**
Clarification (Fire caused by spilled hot oil)		2	2	4	6	**8**	10
		1	1	2	3	4	5

Source: Data Processing

Based on the analysis results, we can see on the Table 1. Risk Scoring Definitions as follows:

Table 4. Risk Scoring Definitions

Scale	Likelihood (Frequency)	Data Source	Severity (Consequence)	Data Source
1	Very rare (<1x/5 years)	Incident records	First aid only (no LTI)	Incident records
2	Rare (1x/2–5 years)	Expert estimation	LTI (>1 day lost time)	Observation
3	Occasional (1x/year)	Incident records	Serious injury / hospitalization	Incident records
4	Frequent (≥3x/year)	Field observation	Single fatality / major asset impact	Expert estimation
5	Very frequent (≥1x/month)	Mixed (historical + observation)	Multiple fatalities / severe asset or environmental damage	Historical + expert

Source: Data Processing

Proportion of data sources: 40% incident history, 40% field observation, 20% expert judgment (safety team). Risk assessments were conducted by three assessors: a station supervisor, a senior operator (>10 years of experience), a certified ohs staff member. All assessors had received internal OHS training. Cross-audit reliability on 10 priority hazards yielded an 85% agreement level, indicating good consistency.

A total of 23 workplace incidents were recorded during 2023–2024. Monthly distribution shows incident peaks in February–March (rainy season, slippery floors) and October–November (machine overhauls). The stations with the highest incident frequency were Boiler and Sterilizer. A heatmap analysis confirmed recurring risks in high-pressure zones and areas with hot steam exposure.

Findings are consistent with studies in palm oil mills in South Sumatra (Sari et al., 2022), Kalimantan (Rahman et al., 2021), and Malaysia (Tan & Lee, 2019), which also identified Boiler and Sterilizer stations as high-risk due to heat and pressure exposure. A unique finding at Air Batu is that the Sand Trap Tank showed extreme risk (slip and H_2S exposure), a hazard not frequently reported in other mills.

Top-3 Risks per Station and Control Options:

a. Sterilizer: Steam leakage at high pressure
   Elimination: redesign sterilizer doors with double-locking mechanism
   Substitution: automatic pressure sensors
   Engineering: interlock systems
   Barrier: high capital cost
   KPI: ≥50% reduction in burn injuries
b. Boiler: Hot dust exposure
   Elimination: automated ash removal system
   Engineering: local exhaust ventilation + filters
   Administrative: SOP on hot surface inspection
   Barrier: production downtime during retrofit
   KPI: PPE compliance increased to 90%
c. Sand Trap Tank: Slip and H_2S gas exposure
   Elimination: redesign of tank access and walkways
   Substitution: portable gas detectors
   Engineering: mechanical ventilation
   Barrier: limited budget allocation
   KPI: zero asphyxiation cases annually

Respondents consisted of 20 workers: 10 operators, 5 technicians, 3 supervisors, and 2 OHS staff. Work experience ranged from 2–20 years. All participants provided informed consent with full confidentiality of personal data. This study was limited to a single mill (Air Batu), hence results may not be fully generalizable to other mills. The graph of workplace accident incidents during one period, detailed on a monthly basis, can be seen in the following figure:

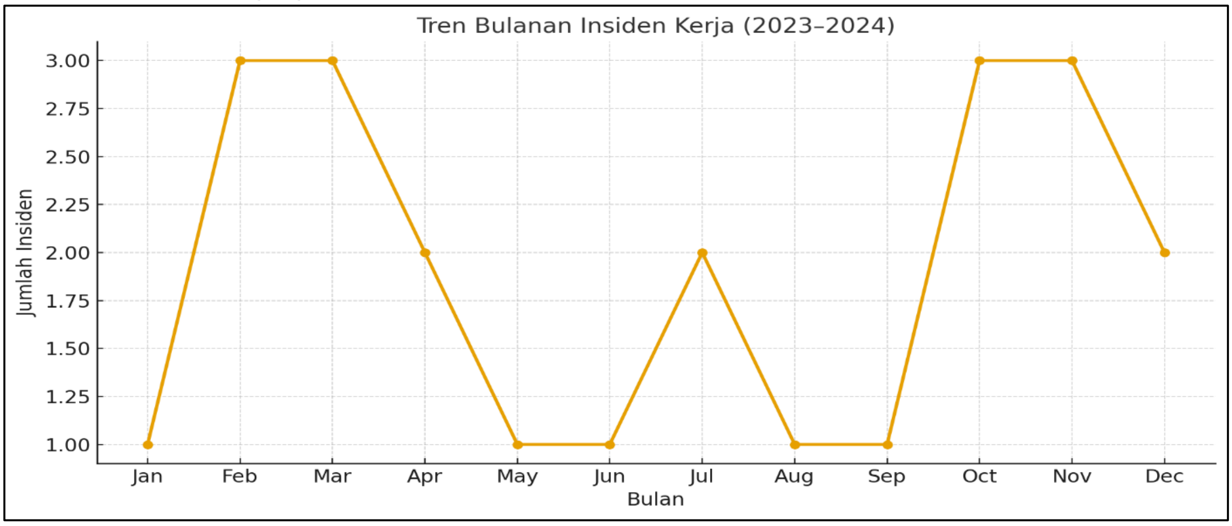

Figure 1. Monthly trend of workplace incidents (2023–2024) showing seasonal peaks in February–March and October–November.

The figure illustrates the monthly distribution of workplace accidents, with notable peaks in February–March and October–November. These increases are associated with the rainy season, which causes slippery floors, and scheduled machinery overhauls that elevate operational hazards. Heatmap of incident distribution across processing stations can be seen in the following figure:

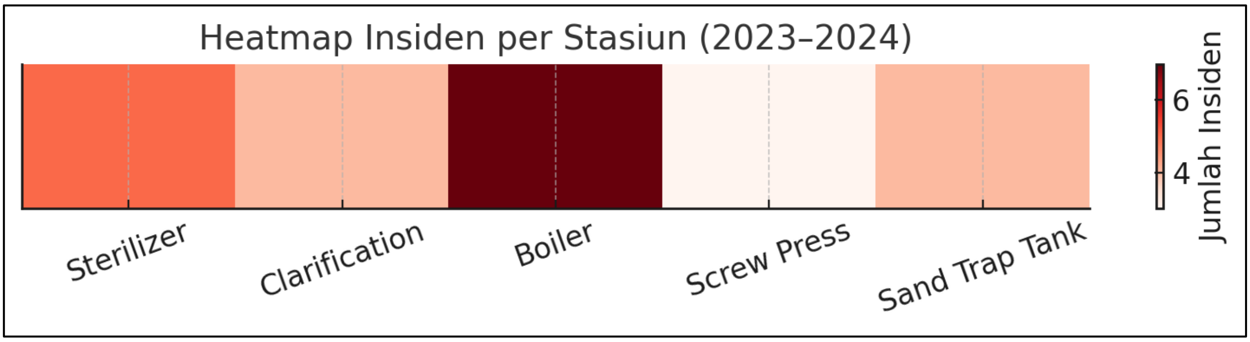

Figure 2. Heatmap of incident distribution across processing stations (Boiler highest risk, followed by Sterilizer and Sand Trap Tank).

The heatmap shows the concentration of incidents across key stations. The Boiler recorded the highest frequency of accidents, followed by the Sterilizer and Sand Trap Tank, primarily due to exposure to hot steam, dust, and hazardous gases. This highlights the critical need for targeted risk control measures in these areas.

The identified risks in PTPN IV Air Batu palm oil mill predominantly arise from a combination of technical failures, unsafe environmental conditions, and unsafe work behaviors. For instance, fire hazards at the sterilizer are triggered by spilled hot oil coming into contact with ignition sources, while steam leakage in the boiler is primarily caused by uncontrolled pressure buildup due to inadequate maintenance. These risks have severe implications, including production downtime, equipment damage, and serious injuries such as burns,musculoskeletal disorders, or even fatalities (Hong, 2022). In this context, risk control strategies can be effective if implemented through a layered approach based on the hierarchy of controls (Winkler et al., 2022). Engineering measures such as installing interlock systems and automatic sensors serve as the primary barrier. Administrative measures, including the establishment of risk-based Standard Operating Procedures (SOPs), scheduled inspections, and internal safety audits, further enhance control (Sravanthi et al., 2025; Azzahra & Tualeka, 2024). Finally, behavioral measures, such as regular safety training, enforcement of proper use of personal protective equipment (PPE), and building a strong safety culture, (Goesman et al., 2024; Joseph, 2021; Unnikrishnan et al., 2015) ensure long-term sustainability of accident prevention programs in PTPN IV Air Batu .

The results indicate that the highest risk levels were identified at the boiler and sterilizer stations.These stations involve operations with high-pressure steam, hot oil, and confined spaces, which inherently carry greater accident potential compared to other units. The high risk in the boiler is mainly attributed to uncontrolled pressure and exposure to hot dust, while in the sterilizer the hazards are related to steam leakage and burns from contact with hot oil (Kamarden et al., 2014; Shawal et al., 2018). In contrast, stations such as clarification and screw press present medium to high risks, but the consequences are relatively less severe. This explains why risk scores are disproportionately higher in certain stations.

The findings are consistent with earlier studies in palm oil mills and other high-temperature process industries. For example, Ilmansyah et al. (2020) highlighted that thermal burns and steam-related injuries are dominant hazards in processing units. Similarly, Angkasa and Samanhudi (2021) found that boilers represent a critical hazard zone due to explosion and fire potential. These similarities reinforce the validity of the results. However, compared to Nur (2020), who found chemical exposure as a dominant risk in processing industries, the current study observed that mechanical and thermal hazards are more prominent.

The findings align with the ILO (International Labour Organization) definition of Occupational Safety and Health (OSH), which emphasizes the prevention of hazards through adapting work environments to workers' capacities. According to the Joint ILO/WHO Committee on Occupational Health, OSH should aim at "promoting and maintaining the highest degree of physical, mental and social well-being of workers in all occupations" (Mensah & Mahama, 2021). This definition encompasses not merely the absence of disease or infirmity, but also the physical and mental elements affecting health that are directly related to safety and hygiene at work (Amaya, 2025). In Indonesia, these results are particularly relevant to the implementation of Permenaker No. 5/2018 on Occupational Safety and Health in the Work Environment, which mandates risk-based hazard control (Suti, et al, 2021). The implication is that PTPN IV Air Batu must strengthen its compliance with both national regulations and international standards such as ISO 45001:2018, which requires systematic risk assessment and continuous improvement in OHS management.

This study has several limitations. First, the assessment of Likelihood (L) and Severity (S) was based primarily on questionnaire surveys and focus group discussions, which may introduce subjectivity despite validation efforts. Second, the research was confined to one palm oil mill unit (PTPN IV Air Batu), limiting the generalizability of results to other mills with different technological levels, safety cultures, or management practices. Therefore, while the findings provide strong insights into high-risk stations, caution must be exercised before extrapolating to other industrial contexts.

From a practical standpoint, several technical and strategic measures are recommended for PTPN IV Air Batu. Technically, the company should install interlock systems in boilers and sterilizers, improve ventilation in confined spaces, and strengthen preventive maintenance for pressure vessels. Strategically, management should embed JSA and HAZOP results into regular safety audits, intensify worker training on PPE use and emergency response, and cultivate a proactive safety culture through leadership commitment. These actions not only reduce accident potential but also support operational continuity and compliance with national OHS regulations.

4. CONCLUSION

Based on the analysis of the five main workstations at PKS PTPN IV Unit Air Batu, occupational accidents are caused by a combination of technical, environmental, and human factors. Unstable equipment conditions, such as uncontrolled steam pressure and unguarded machinery, along with unsafe working environments, including slippery floors and poor ventilation, significantly increase the risk of accidents. Furthermore, unsafe work behaviors, such as failure to use personal protective equipment (PPE) and the absence of lockout/tagout (LOTO) systems, contribute to serious incidents such as burns, muscle injuries, and even asphyxiation. 2.

Risk assessments using the Job Safety Analysis (JSA) and Hazard and Operability Study (HAZOP) methods indicate that most work activities fall into the medium-risk category; however, some activities are classified as high to extreme risk, such as opening the sterilizer door while pressure is still high. To address these issues, control measures are recommended, including the installation of automatic interlock systems, the development of stricter work procedures, training on PPE use, and regular evaluation and monitoring of safety systems. This comprehensive approach is expected to minimize the potential for workplace accidents and enhance overall operational safety. .

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