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Waste Area Risk Mitigation PT. XYZ Using the HIRARC Method and Bow Tie Analysis

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ABSTRACT

Objective: *At PT. XYZ often experiences several work accidents which result in large losses due to weak existing risk management. Frequent work accidents include employees being crushed by rotting buildings, as well as problems arising from inadequate waste disposal and waste burning which causes smoke to enter the production area and become a big problem for production activities.* ***Method:*** *The method used in this research is HIRARC which is used to determine the highest risk and also Bow Tie Analysis which is used as an appropriate risk mitigation tool.* ***Results:*** *The results of this research show that one of the appropriate mitigation methods is to always wear complete personal protective equipment when working and carry out strict supervision and control of K3.* ***Novelty:*** *One of the long-term recommendations that can be applied to company risk mitigation is the creation of official K3 rules that can be updated regularly.*

INTRODUCTION

In this era of increasing industrial advancement and development, companies are bound to have a control system responsible for preventing the occurrence of hazardous risks in the system and work area [1]. Controlling or managing a hazard risk is very important for the safety of all human resources within that environment.

PT. XYZ is one of the companies that produces textile goods in the form of yarn rolls. This company has been established for quite some time in Mojokerto, East Java, and also has a very large production land capacity. Risk management is a useful tool in the decision-making process to reduce the risks associated with a specific object that could lead to losses [2]. Risk management at PT. XYZ focuses on the dense production system, while in production systems and areas considered less dense, risk management can be said to be very weak, and work accidents frequently occur in the waste area, which has a weak risk management system. At PT. XYZ, several work accidents frequently occur, resulting in significant losses due to the weakness of the existing risk management. The highest percentage of work accidents is 35%, which includes employes being struck by dilapidated buildings and major fires caused by sparks from burning solid waste near the material warehouse. Environmental pollution also contributes to a risk percentage of 20%, resulting from improperly treated waste disposal, and 25% of health risks and impaired employe focus due to smoke from burning waste entering the production area.

The problem of high risks that arise can be a major disruption to the company. This research helps to analyze and also assists in improving the company's weak risk control system. The methods used in this study are HIRARC and Bow Tie Analysis.

Research Objectives: (1). To formulate appropriate and effective mitigation strategies for the highest and most dominant risks that may occur within the scope of the waste area. (2). To determine long-term recommendations that can be provided to minimize the occurrence of workplace accidents that may happen in the future.

HIRARC is a method used to detect hazards in work activities before performing a certain activity. HIRARC is the process of identifying potential hazards that may occur during routine or non-routine activities within an organization and conducting a risk assessment of those hazards [3]. The HIRARC method has the advantage of being able to identify all risk variables of hazards in every work area and provide a clear risk assessment [4]. The HIRARC method can also provide risk control in accordance with the principles of OHS regulations, which can create safe and comfortable conditions, thus minimizing the occurrence of work accidents that can happen at any time [5].

Bowtie analysis is an analytical tool that uses a bowtie-shaped diagram to illustrate the relationships between hazard scenarios, threats, controls, and impacts. Bowtie analysis is used as a tool to prevent, control, and reduce adverse events by establishing logical connections between the causes and consequences of such events [6].

Research on risk has been conducted extensively before, and one of them is Nur's risk research. In his study titled "Analysis of Occupational Health and Safety (OHS) Risk Levels Using the HIRARC Method at PT. XYZ" in 2021, the aim was to determine the severity of the risks present in the company and how to minimize existing risks to optimize the company's risk management system. The results revealed numerous high-risk opportunities that require appropriate and optimal risk management.

RESEARCH METHOD

A. Research Time and Place

This research was conducted in one of the waste disposal areas of PT. XYZ, which was considered a high-risk area. This area was the main focus of the research, which applied an analysis method and environmental condition improvement, with the research lasting approximately 1-4 months.

B. Data Collection

This research used qualitative research, where qualitative data consisted of information related to problems in the field obtained from interviews with relevant parties. This information was then used for risk analysis with descriptive evaluation. In this study, the required data is primary data, which includes a preliminary questionnaire and a main questionnaire. Directly asking questions to the staff working in the high-risk area regarding appropriate mitigation in risk analysis using the Bow Tie Analysis method.

C. Research Flow

The research flow begins with the problem identification process and culminates in conclusions and suggestions. The following is a flowchart that can be seen in Figure 1.

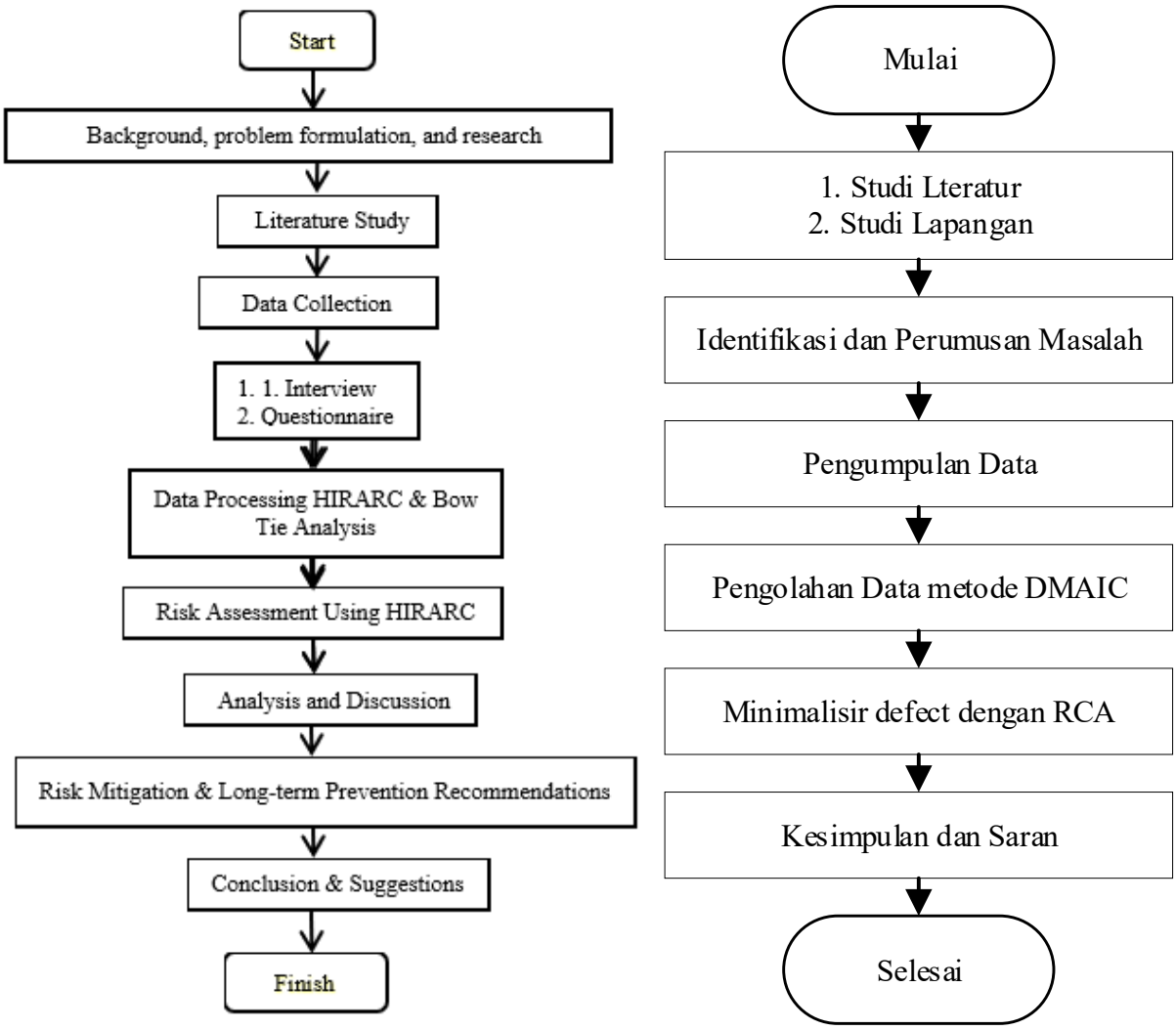

Figure 1. Research Flowchart.

The steps in this research are as follows: first, formulating the background based on the problem to be studied and the objectives to be achieved from this research. Next, conducting a literature review by examining several journal articles and books related to the problem to be solved. Data collection was done by conducting interviews to determine the risks that arise and cause workplace accidents, then distributing a questionnaire to be filled out by several employes directly involved with the waste area. The questionnaire variables contained existing risks that cause workplace accidents in the waste area. Next, the data is processed using the HIRARC method to obtain risk values from lowest to highest. HIRARC analysis is performed using the formula:

$$R = L \times C \qquad (1)$$

Explanation:

R = Risk.

L = Likelihood Value (Probability Value).

C = Consequences/severity Value.

The purpose of analyzing and discussing the risk values after calculation is to group the risk values according to the values obtained using HIRARC. The highest selected risk, which is the highest source of danger, will then have a risk mitigation plan created to

minimize the recurrence of workplace accidents caused by that highest risk source. The severity of a risk can be calculated, and the results refer to the likelihood level table, which has levels 1-5 with the following meanings: level 1 means the frequency is very rare, level 2 means rare, level 3 means possible, level 4 means frequent, and level 5 means it occurs at all times. Furthermore, it also refers to the severity level table, which also has 5 levels: 1 with no injury, 2 with minor injury, 3 with moderate injury, 4 with serious injury, and 5 with fatal consequences and potential for death. Next is to provide long-term recommendations, and then conclusions and suggestions can be drawn from this research.

RESULTS AND DISCUSSION

A. Level of Risk Frequency and Impact

The level of risk frequency (Likelihood) is the degree to which the occurrence of a risk is likely or the frequency of a risk event [7]. The determination of this level value is based on the occurrence of an event, which is highly subjective and more based on reason and experience. The risk frequency level value scale can be seen in Table 1 below.

Table 1. Likelihood Level.

Likelihood (l)	Description	Level
Almost Certain (AC)	Can occur at any time	5
Likely (L)	Frequent	4
Possible (P)	Can occur occasionally	3
Unlikely (U)	Rare	2
Rare (R)	Almost never occurs, very rare	1

Source: [8].

Risk impact (Severity) is a direct consequence that arises and occurs due to an event error [9], while the risk impact level is the severity of the consequences that arise after the risk occurs [10]. The risk impact level value scale can be seen in Table 2 below.

Table 2. Severity Level.

Description	Explanation
1 Insignification	No injury occurs, minor financial loss
2 Minor	Minor injury, minor financial loss
3 Moderate	Moderate injury requires medical treatment, resulting in moderate financial loss
4 Major	Severe injury ≥ 1 person, major loss, and disrupts production
5 Catastrophic	Fatality ≥ 1 person, very large loss and very wide impact, resulting in the cessation of all activities

Source: [11].

The identified risk assessments will be analyzed. The purpose of risk analysis is to determine the magnitude of the risk by looking at how likely it is to occur and the severity of the potential consequences [12]. This risk assessment uses the formula:

$$R = L \times C \quad (2)$$

Explanation:
R = Risk
L = Likelihood Value (Probability Value)
C = Consequences/severity Value.

The matrix scale shows the severity levels presented in the form of a color table that represents the severity and level of each color. The matrix scale can be seen in Tables 3 and 4 below.

Table 3. Matrix Scale.

***Likelihood*/ kemungkinan**	***Consequence*/Konsekuensi**				
	1 ***Insignificant*** / sangat kecil	2 ***Minor*** / kecil	3 ***Moderate*** / sedang	4 ***Major*** / besar	5 ***Catasthropic*** / sangat besar
5 ***Almost certain*** / hampir terjadi	**5 H**	**10 H**	**15 E**	**20 E**	**25 E**
4 ***Likely*** / sangat mungkin terjadi	**4 M**	**8 H**	**12 H**	**16 E**	**20 E**
3 ***Posible*** / mungkin	**3 L**	**6 M**	**9 H**	**12 E**	**15 E**
2 ***Unlikely*** / hampir mungklin	**2 L**	**4 L**	**6 M**	**8 H**	**10 E**
1 ***Rare*** / jarang terjadi	**1 L**	**2 L**	**3 M**	**4 H**	**5 H**

Source: [15].

A risk assessment matrix works by presenting various risks in a color-coded chart, with high risks marked in red, medium risks in orange or yellow, and low risks in green. Risk matrices come in various shapes and sizes, but each matrix has two axes: one axis that measures the likelihood of a risk occurring, and another axis that measures its severity. In other words, the impact of risk on operations [13].

Table 4. Matrix Level Scale.

Risk Level	Action
E Extreme	Unacceptable, immediate corrective action must be taken. Management involvement is required for control in accordance with the hierarchy of controls.
H High	Reduction to an acceptable level is required, involving training by management, and scheduling corrective actions as soon as possible to reduce the risk level.

M Medium	Work may be carried out, with handling by the relevant management. Controls must be implemented in accordance with the hierarchy of risk control.
L Low	No additional controls are required; monitoring is necessary to ensure existing controls are maintained and implemented.

Source: [15].

The risk matrix is analyzed based on the matrix level, which is grouped into four levels: (1). Low (Low Risk), indicated by the color green, (2). Medium (Medium Risk), indicated by the color purple, (3). High (High Risk), indicated by the color yellow, (4). Extreme, marked by the color red [14].

B. Risk Calculation using HIRARC

The HIRARC method has the advantage of being able to identify all hazard risk variables in each work area and can provide a clear risk assessment. The HIRARC method can also provide risk control in accordance with the principles of OHS regulations, which can create safe and comfortable conditions, thus minimizing the occurrence of work accidents that can happen at any time. The existing risks have been observed and identified based on grouping one risk subject followed by other variables, as shown in Table 5 below.

Table 5. Hazard risks in the waste area of PT. XYZ.

No.	Source of Hazard	Variable
1.	No information board	Employees do not know whether the area is dangerous or not
2.	No safety fence around the pond	Employees fall into the pond
3.	No cover on the waste pond	Waste odor spreads into the production area The emergence of many flies and other insects that carry diseases
4.	Poorly treated wastewater	Environmental pollution
5.	Gas waste is only discharged through an air hose	Environmental pollution
6.	Gas waste is discharged through a hose and left directly on the ground and burned	Causes fire The temperature of the waste environment becomes hot
7.	Hot temperature due to burning	Employees feel uncomfortable with the hot temperature caused by gas waste burning
8.	Solid waste is not properly treated	Solid waste in the form of scattered garbage causes the emergence of flies and diseases Pungent odors due to accumulated solid waste greatly disturb the work of production employees

		High environmental pollution of soil and air occurs due to accumulated solid waste that is not properly treated
9.	Poorly maintained waste control room	Work accidents occur, namely being crushed by buildings due to building damage Hot, dirty, and dusty area conditions cause employees to become dehydrated and short of breath Lack of maintenance of waste treatment facilities and infrastructure causes frequent work accidents for employees in the waste area
10.	No PPE for employees	Work accidents occur very frequently

Risk assessment aims to identify the value of occupational accident risk. This risk level determination is based on the likelihood of occurrence and the severity of the potential impact. The following is the risk assessment result using the HIRARC method, obtained by multiplying the likelihood (L) and severity (C) values, as shown in Table 6 below.

Table 6. Risk Assessment using HIRARC.

No	Source of Hazard	Variable	Risk assessment			
			L	C	Risk value	Risk level
1.	No information board	Employees do not know whether the area is dangerous or not	3	1	3	3 L
2.	No safety fence around the waste pond	Employees fall into the pond	5	5	25	**25 E**
3.	No cover on the waste pond	Waste odor spreads into the production area	2	1	2	**2 L**
		The emergence of many flies and other insects that carry diseases	2	1	2	**2 L**
4.	Poorly treated wastewater	Environmental pollution	2	1	2	**2 L**
5.	Gas waste is only discharged through an air hose	Environmental pollution	2	1	2	**2 L**

6.	Gas waste is discharged through a hose and left directly on the ground and burned	Causes fire	5	5	25	**25 E**
		The temperature of the waste area environment becomes high	3	2	6	**6 M**
7.	Hot temperature due to burning	Employees feel uncomfortable with the hot temperature caused by gas waste burning	4	2	8	**8 H**
8.	Solid waste is not properly treated	Solid waste in the form of scattered garbage causes the emergence of flies and diseases	4	2	8	**8 H**
		Pungent odors due to accumulated solid waste greatly disrupt the work of production employees	3	1	3	**6 M**
		High environmental pollution of soil and air occurs due to accumulated waste that is not properly treated	4	1	4	**4 L**
9.	Poorly maintained waste control room	Work accidents occur, namely being crushed by buildings due to building damage	5	5	25	**25 E**
		Hot, dirty, and dusty area conditions cause employees to become dehydrated and short of breath	3	3	9	**9 H**
		Lack of maintenance of waste treatment facilities and infrastructure causes frequent work accidents for employees in the waste area	5	5	25	**25 E**
10.	No PPE for employees	Work accidents frequently occur	5	5	25	**25 E**

Based on Table 6 above, the method for determining the risk value (risk assessment) is by using a risk assessment matrix, which involves multiplying the likelihood level value by the severity level value. After obtaining the results of the hazard identification for each waste area at PT. XYZ, the next step in the HIRARC method is risk assessment. This assessment is used to determine the level of risk from the identified hazards. The risk levels in this assessment are based on comparing the likelihood of a risk occurring with the severity of the risk's impact. The results of the risk assessment for this waste area risk are categorized by risk level, namely: low risk (L) in green, medium risk (M) in purple, high risk (H) in yellow, and extreme risk (E) in red. And the results obtained are that out of the 16 risk variables, there are 5 extreme risk variables, 3 high-risk variables, 2 medium-risk variables, and 6 low-risk variables.

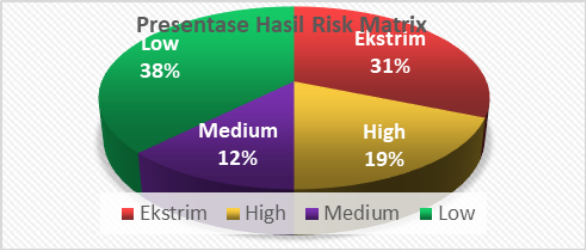

Figure 2. Pie chart of risk assessment results.

Based on Figure 2 above, there is a risk variable in the waste area that is at very high risk of causing a workplace accident. The percentage values for extreme risk are 31%, high risk is 19%, medium risk is 12%, and low risk is 38%. The presentation of the risk assessment percentages uses a pie chart, which can be seen in Figure 2 above. Here is an example calculation for LCL in January.

C. Risk Mitigation using Bow Tie Analysis

The risk mitigation measures developed are based on the calculation results from the HIRARC method, where mitigation is constructed by analyzing selected risks with a sufficiently high risk value to determine appropriate and optimal mitigation measures to prevent the risks from occurring again in the future.

In this analysis using the bow tie method, the focus is on several variables with the highest risk of occurrence. Three variables with extreme risk levels were identified: employes falling into the pool, fires caused by burning gas waste, and workplace accidents due to an unmaintained waste area. Below is a bow tie analysis diagram of the selected extreme risks, which can be seen in figures 3, 4, and 5 below.

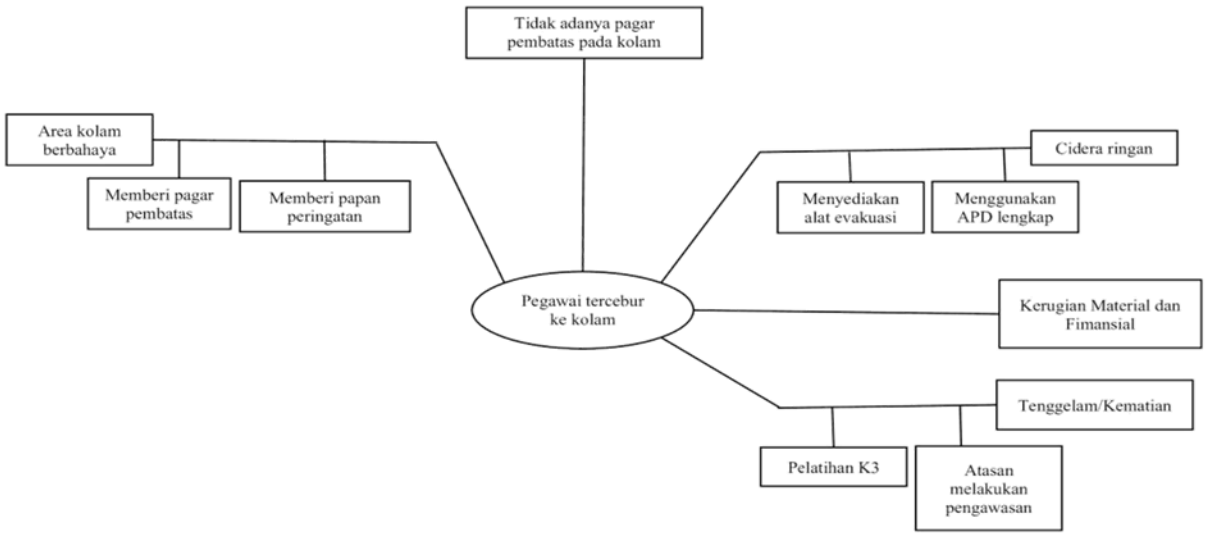

Figure 3. Bow Tie Analysis Diagram: Employee Falls into Pool.

After conducting a risk analysis on Figure 3, the causes, effects, and controls of the risk of an employee falling into the pool can be identified as follows: Causes and Controls: (a). Dangerous pool area: install a fence and also post warning signs for the dangerous area. Impact and control: (a). Minor injury: use full PPE, provide evacuation equipment. (b). Material and financial losses. (c). Drowning/Death: The supervisor oversees, provides training, and educates employees on the importance of OHS.

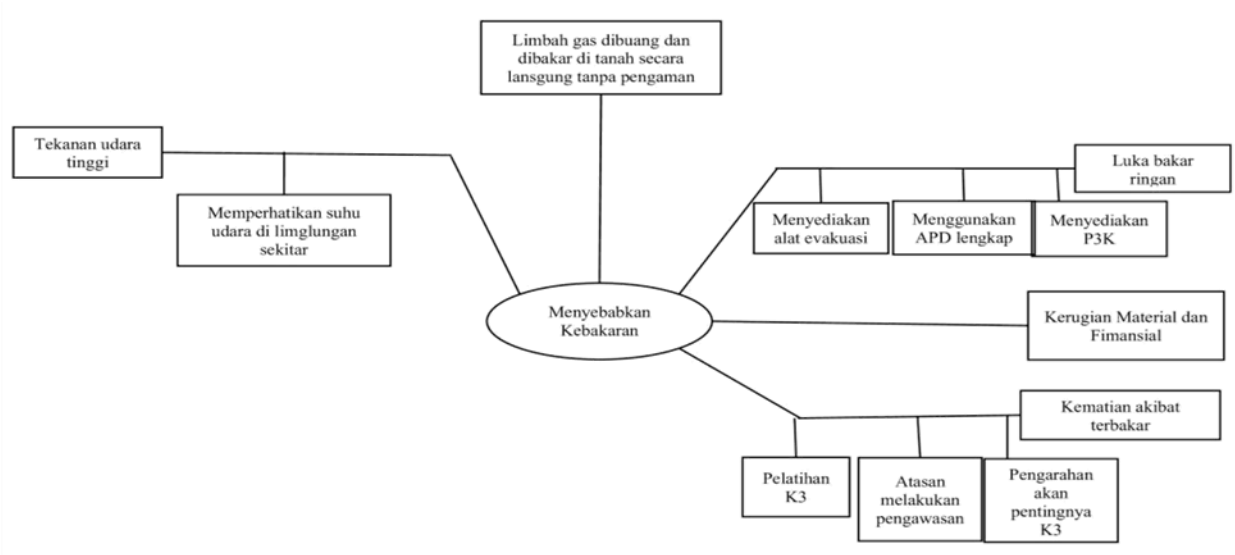

Figure 4. Bow Tie Analysis Diagram of Fire Caused by Burning Gas Waste.

After conducting a risk analysis on Figure 4, the causes, effects, and controls of fire risk caused by burning gas waste can be identified as follows: Causes and controls: (a). High air pressure: paying attention to the ambient air temperature. Its impact and control: (a). Minor burns: use full PPE, provide first aid, and provide evacuation equipment. (b). Material and financial losses. (c). Death: The supervisor oversees, and also provides training and education to employees on the importance of OHS.

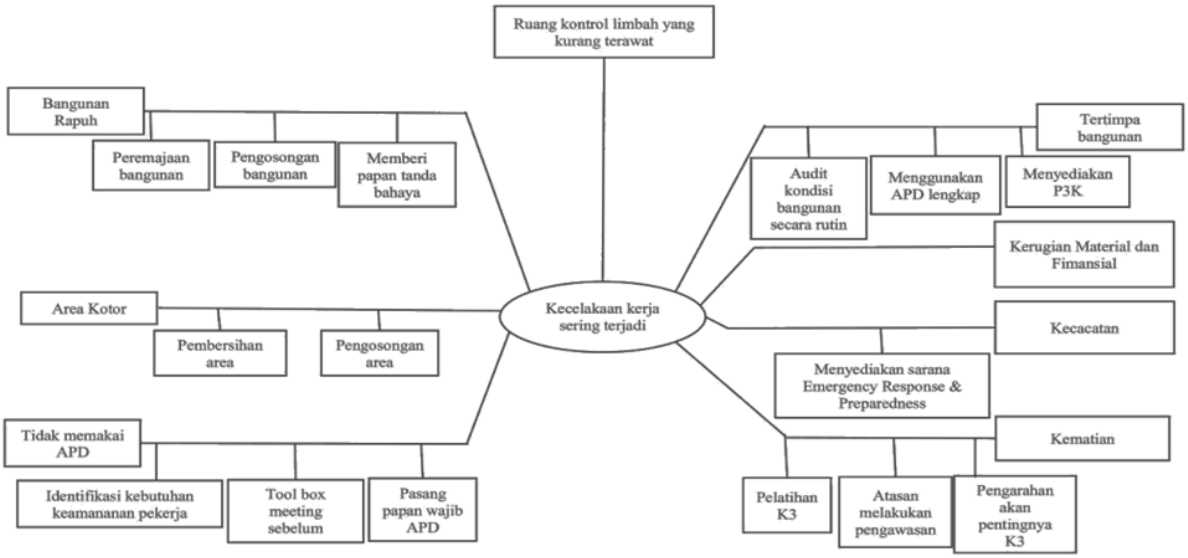

Figure 5. Bow Tie Analysis Diagram of a workplace accident caused by an unmaintained waste control room.

After conducting a risk analysis on Figure 5, the causes, effects, and controls of the workplace accident caused by the unmaintained waste control room can be identified as follows: Causes and controls: (a). Dilapidated buildings: building renovation, building evacuation, installing danger signs. (b). Dirty areas: cleaning the area and also evacuating the area. (c). Not using complete PPE: identifying all safety needs of employes, posting safety information boards in areas where PPE is required, and holding toolbox meetings before work. Impact and control: (a). Being hit by a dilapidated building: wearing complete PPE, regularly auditing building conditions, and providing first aid. (b). Material and financial losses. (c). Physical disability: wearing full PPE and providing ERP (Emergency Response & Preparedness) facilities. (d). Death: The supervisor monitors, trains, and educates employes on the importance of OHS. The following are long-term prevention recommendations that can be implemented for mitigating the company's risks: (a). Formally creating and periodically updating OHS regulations, considering environmental conditions on a periodic basis as well. (b). Conducting regular OHS socialization every month. (c). Regular workplace inspections as an effort to maintain workplace safety conditions. (d). Providing first aid and safety equipment in corners of the workplace with a high likelihood of accidents.

CONCLUSION

Fundamental Finding : Based on the discussion results, the risk mitigation found in this study is the mitigation of the highest occupational accident risk caused by the unmaintained waste control room, specifically: Causes and controls: (a). Dilapidated building: building renovation, building evacuation, installation of danger signs. (b). Dirty area: cleaning the area and also clearing the area. (c). Not using complete PPE: identifying all safety needs of employes, posting safety information boards in areas where PPE is

required, and holding toolbox meetings before work. **Implication :** Impact and control: (a). Being hit by a dilapidated building: wearing complete PPE, conducting regular building condition audits, and providing first aid. (b). Material and financial losses. (c). Physical disability: wearing complete PPE and providing ERP (Emergency Response & Preparedness) facilities. (d). Death: The supervisor monitors, trains, and educates employes on the importance of OHS. **Limitation :** Material and financial losses. **Future Research :** The following are long-term prevention recommendations that can be implemented for this company's risk mitigation: (a). Formal and periodically updated development of OHS rules, also considering environmental conditions periodically. (b). Conducting regular monthly OHS socialization. (c). Regular workplace inspections as an effort to maintain workplace safety conditions. (d). Providing first aid kits and safety equipment in corners where there is a high risk of workplace accidents.

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