

ANALYSIS OF OCCUPATIONAL SAFETY AND HEALTH (OSH) RISKS IN THE TRANSPORTATION PROCESS OF HAZARDOUS AND TOXIC WASTE (B3) USING THE HAZOP METHOD AND RISK MATRIX

Andrea Felic Lim¹, Kevin Jerrykent², Uni Pratama Pebrina Br Tarigan^{3*}

^{1,2,3}PUI Product Design, Universitas Prima Indonesia

E-mail: andrefelic722@gmail.com¹, kevin.jerrykent@gmail.com², unipratama@gmail.com^{3*}

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Abstract

Occupational safety and health (OSH) is an important aspect of industrial activities, particularly in the transportation of hazardous and toxic waste (B3), which poses high potential risks to workers, the environment, and the surrounding community. PT.XYZ, as a hazardous waste transportation service company, faces various potential hazards at each stage of its operational process, including vehicle preparation, loading, transportation to the destination, unloading, as well as administration and housekeeping activities. This study aims to identify potential hazards, analyze the level of occupational safety and health risks, and formulate risk control recommendations in the hazardous waste transportation process at PT.XYZ. The research method used in this study is descriptive-analytical research with qualitative and quantitative approaches. Hazard identification was carried out using the Hazard and Operability Study (HAZOP) method based on field observations, interviews, and documentation studies. Risk level assessment was conducted using the Risk Matrix method by applying likelihood and severity parameters to classify risks into low, medium, high, and extreme categories. The results show that there are 20 potential hazards identified across all stages of the hazardous waste transportation process. The risk level recapitulation indicates that high and medium risk categories each account for 45%, extreme risk accounts for 10%, and no risks fall into the low category. Extreme risks were found during the transportation stage to the destination, particularly those related to driver fatigue and uncontrolled vehicle speed. Based on these findings, risk control recommendations were formulated using a risk control hierarchy approach, including administrative controls, engineering controls, and the use of personal protective equipment. The implementation of these recommendations is expected to reduce OSH risk levels and improve occupational safety and health performance in the hazardous waste transportation process at PT.XYZ.

Keywords: occupational safety and health, hazardous waste, hazop, risk matrix, waste transportation

INTRODUCTION

Occupational Safety and Health (OSH) is one of the important aspects in every industrial activity, especially those related to the management and transportation of hazardous and toxic waste (B3). The transportation of B3 waste carries a high level of risk because it involves materials that can cause serious impacts on worker safety, public health, and the environment if not properly managed. A common phenomenon occurring in many companies is the lack of systematic management, as well as suboptimal layout arrangements and work procedures, which can trigger potential workplace accidents and environmental pollution. The process of transporting hazardous and toxic waste has significant potential hazards, both for workers and the surrounding community. The risks that may occur include waste spills, exposure to hazardous chemical substances, traffic accidents, fires, and even explosions. If these risks are not properly controlled, they can lead to major losses such as environmental damage, health impacts, and financial losses for the company. Therefore, the implementation of Occupational Safety and Health (OSH) principles in the transportation process of B3 waste is very important. Based on data from BPJS Ketenagakerjaan, workplace accident cases in Indonesia have shown an increasing trend over the past three years. In 2022, there were 298,000 cases, which increased to 370,747 cases in 2023, and rose again to 462,241 cases in 2024. Meanwhile, in 2025, up to April alone, 47,300 cases had already been recorded. These data indicate that the implementation of OSH remains a major challenge in Indonesia, particularly in the transportation and logistics sector, which contributes a significant percentage of national workplace accidents.

Table Number of Workplace Accident Cases in Indonesia (2022–2025)

Year	Number of Cases	Description
2022	298,000	Full-year data
2023	370,747	Full-year data
2024	462,241	Full-year data
2025 (Jan–Apr)	47,300	Data up to April

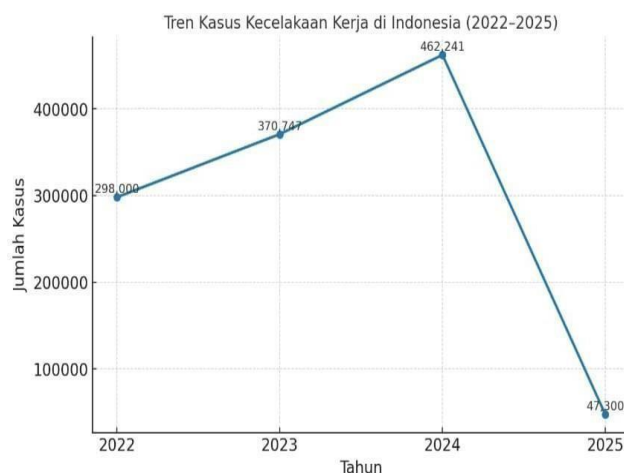


Figure Trend of Workplace Accident Cases in Indonesia (2022–2025)

These data indicate that the risk of workplace accidents remains high, highlighting the need for a more effective risk management system. PT.XYZ is a company engaged in the transportation of hazardous and toxic waste (B3). As a company handling hazardous materials, PT.XYZ is required to implement strict Occupational Safety and Health (OSH) procedures to ensure that transportation activities are carried out safely, in compliance with regulations, and with minimized risks. However, in practice, several issues often arise, such as inadequate risk identification at each stage of the transportation process, incomplete documentation of work procedures, and limitations in implementing risk control measures according to established standards. These conditions can increase the likelihood of workplace accidents, asset damage, and negative environmental impacts. Therefore, a systematic and comprehensive analysis is required to identify potential hazards and improve the effectiveness of risk management in the hazardous waste transportation process.

This study applies the Hazard and Operability Study (HAZOP) method and the Risk Matrix to analyze potential hazards in the hazardous waste transportation process at PT.XYZ. HAZOP is used to systematically identify hazards, operational deviations, possible causes, and their consequences at each stage of the process, including fleet preparation, waste loading, transportation, and waste delivery. The identified risks are then evaluated using a Risk Matrix, which assesses the level of risk based on likelihood and severity to determine the priority of risk control actions. Through the integration of HAZOP and Risk Matrix, this study aims to provide a comprehensive understanding of potential hazards and to formulate appropriate mitigation strategies, such as improving standard operating procedures, providing additional training, ensuring the use of personal protective equipment, and conducting regular fleet inspections in order to enhance workplace safety and comply with applicable regulations.

LITERATURE REVIEW

Occupational Safety and Health (OSH)

Occupational Safety and Health (OSH) is a systematic effort aimed at protecting workers from the risks of workplace accidents and occupational diseases while ensuring a safe and healthy working environment. The implementation of OSH not only focuses on protecting workers but also safeguards company assets, maintains operational continuity, and prevents environmental damage. In Indonesia, the implementation of OSH is regulated under Law of the Republic of Indonesia No. 1 of 1970 concerning Work Safety, which requires companies to provide safe working systems for employees.

Occupational Safety and Health Management System (OSHMS)

The Occupational Safety and Health Management System (OSHMS) is part of an organizational management system used to control occupational safety and health risks in a structured and continuous manner. OSHMS includes policies, planning, implementation, evaluation, and continuous improvement in safety management. Through the implementation of OSHMS, companies can identify potential hazards at an early stage and establish appropriate control measures.

Hazardous and Toxic Waste (B3 Waste)

Hazardous and Toxic Waste (B3 waste) refers to waste generated from activities that contain hazardous and toxic substances that may pollute the environment and endanger human health and other living organisms. B3 waste has characteristics such as flammable, toxic, corrosive, reactive, and infectious. Therefore, the management of B3 waste must be conducted in accordance with applicable regulations to prevent negative impacts on the environment and human health.

Transportation of Hazardous Waste

The transportation of hazardous waste is the activity of moving B3 waste from the source of generation to treatment or final disposal facilities using transportation equipment that meets technical and safety requirements. This process is one of the critical stages in hazardous waste management because it involves high potential risks and therefore requires strict supervision and the implementation of proper safety procedures.

Concept of Hazard and Risk

A hazard is any condition, source, or action that has the potential to cause injury, damage, or health disturbances. Meanwhile, risk is the combination of the likelihood of a hazardous event occurring and the severity of its consequences. Understanding the concepts of hazard and risk is essential in OSH implementation because it forms the basis for identifying and controlling risks in the workplace.

Occupational Safety and Health Risk Management

Occupational safety and health risk management is a systematic process aimed at identifying, analyzing, evaluating, and controlling risks that may cause workplace accidents or occupational diseases. Through risk management, companies can determine acceptable levels of risk and prioritize control measures based on the likelihood and impact of the risks.

Hazard and Operability Study (HAZOP)

Hazard and Operability Study (HAZOP) is a risk analysis method used to identify potential hazards and operational deviations from the normal conditions of a process. This method is conducted systematically using guide words to identify possible deviations at each stage of the process. HAZOP is widely applied in high-risk industries because it provides a detailed analysis of potential hazards and their causes.

Risk Matrix

A Risk Matrix is a risk assessment tool used to determine the level of risk based on the combination of the likelihood of occurrence and the severity of its impact. Through a Risk Matrix, risks can be classified into categories such as low, medium, high, and extreme, which helps organizations determine the priority of risk control measures.

OSH Risk Control Policy

OSH risk control policies represent the commitment of company management to create a safe and healthy working environment. Risk control can be implemented through several approaches, including engineering controls, administrative controls, and the use of personal protective equipment (PPE). The proper implementation of risk control policies is essential to prevent workplace accidents and minimize environmental impacts.

METHOD

This study employs a descriptive analytical research design with both qualitative and quantitative approaches to analyze occupational safety and health (OSH) risks in the transportation process of hazardous and toxic waste (B3) at PT.XYZ. The qualitative approach is used to identify potential hazards, analyze the causes of risks, and describe the working conditions at each stage of the hazardous waste transportation process. Hazard identification is conducted through field observations, interviews with relevant personnel, and the completion of HAZOP worksheets. Meanwhile, the quantitative approach is applied to assess the level of risk by assigning numerical values to each identified hazard based on likelihood and severity parameters using a Risk Matrix. Through this method, risks can be categorized into low, medium, high, and extreme levels. The research was conducted at PT.XYZ, located on Jl. Kapten M. Jamil Lubis No. 1, Bandar Selamat, Medan Tembung, which operates in hazardous waste transportation services. The object of this research is the entire transportation process of B3 waste, including preparation, loading, transportation, and unloading stages, as well as the workers, equipment, vehicles, procedures, and work environment involved in these activities. The study focuses on identifying potential hazards and analyzing OSH risk levels using the HAZOP method and Risk Matrix. In this research framework, independent variables include factors causing OSH risks such as equipment and vehicle conditions, worker competence and compliance with SOPs, work environment conditions, and the OSH management system. The dependent variable is the level of OSH risk in hazardous waste transportation. The research process begins with hazard identification using HAZOP, followed by risk evaluation using the Risk Matrix to determine risk levels and priorities, which ultimately lead to recommendations and risk control strategies to improve occupational safety in hazardous waste transportation activities.

RESULTS AND DISCUSSION

Data Collection

PT.XYZ is a company engaged in hazardous and toxic waste (B3) transportation services. The company acts as a third-party service provider that transports B3 waste from various waste-generating industries to Temporary Storage Facilities (TPS) for hazardous waste or to licensed hazardous waste treatment facilities in accordance with applicable regulations in Indonesia.

As a hazardous waste transportation service provider, PT.XYZ has a significant responsibility to ensure occupational safety and health (OSH) throughout the entire transportation process. This is because hazardous waste has dangerous characteristics such as flammable, toxic, corrosive, and reactive properties, which may pose negative impacts on workers, the environment, and the surrounding community if not properly managed and transported.

The process of transporting hazardous waste at PT.XYZ involves several operational activities that carry relatively high OSH risks. These risks arise not only from the hazardous characteristics of the waste itself but also from material handling activities, the use of work equipment, and the operation of waste transportation vehicles on public roads. Therefore, each stage of the hazardous waste transportation process needs to be analyzed systematically to identify potential hazards and occupational safety and health risks that may occur.

In general, the hazardous waste transportation process at PT.XYZ consists of several stages as follows:

1. Preparation and Inspection of Hazardous Waste Transportation Vehicles

This stage is the initial step before transportation activities begin. It involves inspecting the condition of hazardous waste transportation vehicles, including vehicle feasibility, tire conditions, braking systems, vehicle lights, and safety equipment such as fire extinguishers (APAR), spill kits, and personal protective equipment (PPE). This inspection aims to ensure that vehicles and supporting equipment are in proper operational condition in order to minimize the potential for workplace accidents and waste spills during the transportation process.

2. Loading Process of Hazardous Waste into Vehicles

The loading stage involves transferring hazardous waste from the waste generator location into the transportation vehicle. Hazardous waste is generally packaged in drums, jerry cans, or other containers according to the characteristics of the waste. At this stage, potential hazards include container leakage, waste spills, and injuries resulting from improper handling or incorrect load securing. Therefore, the

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loading process must be carried out in accordance with established work procedures and supported by the proper use of personal protective equipment.

3. Transportation Process to the Destination

The transportation stage involves carrying hazardous waste using vehicles to temporary storage facilities or waste treatment facilities. During this stage, OSH risks may increase because vehicles operate on public roads and interact with traffic conditions and external environmental factors such as weather and road conditions. Potential hazards that may occur include traffic accidents, driver fatigue, and load shifting that may cause leakage or spills of hazardous waste.

4. Unloading Process of Hazardous Waste

The unloading stage involves removing hazardous waste from the vehicle at the destination location. This activity has potential hazards such as waste falling during unloading, exposure of workers to hazardous substances, and slipping hazards due to unsafe unloading areas. Therefore, the unloading process must be conducted under proper supervision, supported by appropriate handling equipment, and carried out in accordance with strict occupational safety procedures.

5. Administration and Documentation (Hazardous Waste Manifest)

The administration and documentation stage involves recording and reporting hazardous waste transportation through a hazardous waste manifest. The manifest serves as legal documentation and a monitoring tool for tracking the movement of hazardous waste from the generator to the treatment facility. Errors in filling out the manifest may lead to administrative and legal risks for the company. Therefore, accuracy and verification of data are essential aspects of this stage.

Each stage of the hazardous waste transportation process has different potential hazards and OSH risks. Therefore, an analytical method is required to identify potential hazards in detail and assess the level of risk involved. In this study, the Hazard and Operability Study (HAZOP) method and the Risk Matrix are used as approaches to analyze occupational safety and health risks in the hazardous waste transportation process at PT.XYZ in a systematic and structured manner.

Data Processing

Based on field observations, interviews with relevant personnel, and documentation studies, potential hazards were identified at each stage of the hazardous and toxic waste (B3) transportation process at PT.XYZ. Hazard identification was conducted using the Hazard and Operability Study (HAZOP) method, which aims to identify potential deviations from normal operating conditions that may lead to hazards and risks.

The identification process considered existing conditions in each work activity, followed by analysis of possible deviations, causes, and consequences. Each identified hazard was then assessed by determining the Likelihood (L) and Severity (S) values. The resulting risk values were classified into risk levels using a Risk Matrix.

Table Hazard Identification and Risk Assessment

Preparation and Vehicle Inspection Stage

No	Existing Condition	Potential Hazard	L	S	Risk Value	Risk Level
1	Fire extinguishers are not inspected regularly	Fire extinguishers fail during a fire incident	2	5	10	High
2	Vehicle tires are worn	Vehicle skidding or tire burst	3	4	12	High
3	Incomplete spill kit	Suboptimal response to waste spills	3	3	9	Medium
4	Vehicle lights and safety signs are incomplete	Vehicle less visible to other road users	3	4	12	High

Based on Table 4.1, most hazards during the vehicle preparation and inspection stage are related to vehicle feasibility and safety equipment readiness. High risk levels are found in the condition where fire extinguishers are not routinely inspected and when vehicle tires are worn. These conditions can increase accident severity if an incident occurs during hazardous waste transportation.

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Table Hazard Identification and Risk Assessment

Hazardous Waste Loading Process

No	Existing Condition	Potential Hazard	L	S	Risk Value	Risk Level
5	Waste drums not inspected before loading	Leakage and hazardous waste spills	4	4	16	High
6	Load securing is not strong enough	Drums shift or fall during transport	4	4	16	High
7	Workers do not wear complete PPE	Exposure to hazardous waste and work injuries	4	3	12	High
8	Manual lifting without equipment	Muscle injury and worker fatigue	4	2	8	Medium

Based on Table 4.2, most hazards in the loading process fall into the high-risk category. These risks are mainly caused by failure to inspect waste drums before loading and insufficient load securing. Such conditions may lead to leakage or hazardous waste spills, which can harm workers and contaminate the environment.

Table 4.3 Hazard Identification and Risk Assessment

Transportation Process to Destination

No	Existing Condition	Potential Hazard	L	S	Risk Value	Risk Level
9	Excessive driver working hours	Fatigue and microsleep	4	5	20	Extreme
10	Uncontrolled vehicle speed	Traffic accidents	4	5	20	Extreme
11	Route passes through densely populated areas	Wider accident impact	3	4	12	High
12	Extreme weather conditions	Vehicle skidding or overturning	3	4	12	High
13	Emergency communication is not optimal	Delayed accident response	2	4	8	Medium

Based on Table 4.3, the transportation stage shows the highest risk level in the hazardous waste transportation process. Extreme risks are associated with driver fatigue and uncontrolled vehicle speed.

Table 4.4 Hazard Identification and Risk Assessment

Hazardous Waste Unloading Process

No	Existing Condition	Potential Hazard	L	S	Risk Value	Risk Level
14	Slippery unloading area	Workers slip	3	3	9	Medium
15	Manual drum unloading	Drums fall and leak	3	4	12	High
16	Lack of supervision	Work procedure errors	3	3	9	Medium

Based on Table 4.4, hazards during the unloading stage mostly fall into medium to high risk categories.

Table 4.5 Hazard Identification and Risk Assessment

Administration and Housekeeping Stage

No	Existing Condition	Potential Hazard	L	S	Risk Value	Risk Level
17	Manifest not verified	Administrative and legal violations	3	3	9	Medium
18	Unclear waste labels	Incorrect waste handling	2	4	8	Medium
19	PPE not suitable for waste type	Exposure to hazardous substances	4	3	12	High
20	Vehicle not cleaned after operation	Cross contamination	3	2	6	Medium

Table 4.6 Recapitulation of Risk Levels

Risk Level	Number of Hazards	Percentage (%)
Extreme	2	10
High	9	45
Medium	9	45
Low	0	0
Total	20	100

Based on Table 4.6, high and medium risk levels dominate the hazardous waste transportation process at PT.XYZ, each accounting for 45%. Meanwhile, extreme risks represent 10% of the identified hazards, and no hazards were classified as low risk. The dominance of high and medium risks indicates that most hazardous waste transportation activities still involve significant potential hazards and require appropriate risk control measures. Although extreme risks represent a smaller percentage, they have very high severity and must remain the top priority in occupational safety and health risk management.

Risk Level Distribution Analysis

Risks categorized as extreme were entirely found in the transportation stage to the destination location, namely hazards related to driver fatigue and uncontrolled vehicle speed. This condition indicates that the travel stage is the most critical stage because it involves direct interaction with public traffic and external environmental factors that are difficult to predict. Risks categorized as high were mostly found in the loading and transportation stages, which are related to potential waste leakage, insufficient load securing, and non-compliance in the use of personal protective equipment (PPE). Risks categorized as medium are generally related to administrative aspects, housekeeping, and suboptimal work area conditions. This distribution of risk levels shows that occupational safety and health (OSH) risks in the hazardous waste transportation process are not influenced by a single factor but are the result of the interaction between human factors, vehicles, work methods, and the operational environment.

Implications of Risk Recapitulation Results

Based on the recapitulation and analysis of risk levels, it can be concluded that the working environment in the hazardous waste transportation process at PT.XYZ is in a risk-prone condition, particularly in the high and extreme risk categories. The level of OSH risk is highly influenced by the severity of impact and the likelihood of workplace accidents occurring. The higher the severity and likelihood of accidents, the higher the resulting risk level. Therefore, planned and sustainable risk control strategies are required to reduce risk levels, especially for risks categorized as extreme and high. The results of this recapitulation are then used as the basis for developing risk control strategies using the HAZOP method, which will be discussed in the following subsection.

OSH Risk Control Strategy Using the HAZOP Method

Risk control efforts are the next stage after hazard identification and risk level assessment. Risk control aims to reduce occupational safety and health (OSH) risk levels from high or extreme categories to lower and more acceptable levels. Risk control is carried out using the hierarchy of risk control approach, which includes elimination, substitution, engineering, administrative controls, and the use of personal protective equipment (PPE). In this study, the development of risk control strategies is based on the Hazard and Operability Study (HAZOP) method. The HAZOP method is used to analyze the relationship between deviations, causes, and consequences of each hazard source so that relevant and targeted control actions can be formulated.

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Table OSH Risk Control Design Based on the HAZOP Method in the Hazardous Waste Transportation Process

A. Vehicle and Work Equipment Factors

No	Deviation	Cause	Impact	Control Recommendation
1	Vehicle not roadworthy	Irregular inspection	Accidents and hazardous waste spills	Establish vehicle inspection schedule (Administrative)
2	Fire extinguisher not ready for use	Service life and lack of maintenance	Uncontrolled fire	Inspection and replacement of fire extinguishers (Administrative & Substitution)
3	Incomplete spill kit	Limited procurement	Suboptimal spill handling	Provision of spill kits according to standards (PPE)

B. Loading and Unloading Process Factors

No	Deviation	Cause	Impact	Control Recommendation
4	Drum leaks during transfer	Unfit packaging	Waste exposure and environmental contamination	Packaging inspection and use of overpack (Engineering)
5	Load securing not strong enough	Non-standard tying techniques	Drums fall during transportation	Standardization of load securing methods (Administrative)
6	Manual lifting without tools	Limited facilities	Worker muscle injuries	Provision of lifting equipment (Engineering)
7	Slippery unloading area	Poor housekeeping	Workers slipping	Implementation of area cleanliness SOP (Administrative)

C. Transportation Process Factors

No	Deviation	Cause	Impact	Control Recommendation
8	Driver fatigue	Excessive working hours	Traffic accidents	Work-hour management and rest periods (Administrative)
9	Excessive vehicle speed	Lack of supervision	Fatal accidents	Installation of GPS and speed limiter (Engineering)
10	Route not according to procedure	Limited supervision	Increased accident risk	Route determination and monitoring (Administrative)
11	Emergency communication not optimal	Limited communication system	Delayed accident response	Provision of emergency communication systems (Engineering)

D. Administrative Factors and Worker Behavior

No	Deviation	Cause	Impact	Control Recommendation
12	Errors in manifest completion	Lack of verification	Legal violations	Two-stage manifest verification (Administrative)
13	PPE not used according to standards	Lack of supervision	Hazardous waste exposure	Enforcement of PPE discipline (Administrative & PPE)
14	Low OSH awareness	Lack of training	Repeated workplace accidents	OSH training and socialization (Administrative)

Based on Table 4.7, OSH risk control strategies in the hazardous waste transportation process focus on the main hazard sources identified in the previous subsection. Risk control in vehicle and work equipment factors is mostly directed toward administrative and substitution approaches because the main issues originate from insufficient routine inspection and maintenance.

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In the loading and unloading process factors, risk control is primarily directed toward engineering and administrative approaches. This is due to the high risk of waste leakage and workplace injuries caused by suboptimal work methods and facilities. The provision of work aids and standardization of work procedures are expected to reduce the likelihood of workplace accidents. Risk control in the transportation process focuses on extreme risk categories, such as driver fatigue and vehicle speed. Therefore, control measures are directed toward implementing fatigue management systems, speed monitoring, and route monitoring during transportation. Meanwhile, in administrative factors and worker behavior, risk control focuses on improving discipline, providing OSH training, and strengthening the administrative system for hazardous waste transportation. Overall, the proposed risk control strategies have been developed based on the hierarchy of risk control and the HAZOP method, which are expected to reduce OSH risk levels in the hazardous waste transportation process at PT.XYZ.

Discussion of OSH Risk Analysis Results

In the Hazardous Waste Transportation Process, based on the results of hazard identification, risk assessment, and the formulation of risk control strategies using the HAZOP method and risk matrix, it can be identified that the transportation process of Hazardous and Toxic Waste (B3) at PT.XYZ has significant Occupational Safety and Health (OSH) risk potential. These risks are distributed across all stages of the work process, starting from vehicle preparation to administrative and housekeeping activities.

Risk Level Analysis Based on Process Stages

The analysis results show that the transportation stage to the destination location is the stage with the highest risk level compared to other stages. This is indicated by the discovery of risks categorized as extreme, which are related to driver fatigue and uncontrolled vehicle speed. Risks at this stage have a high level of severity because traffic accidents involving hazardous waste have the potential to cause widespread impacts on workers, surrounding communities, and the environment. The hazardous waste loading stage also shows a dominance of risks categorized as high. These risks are mainly caused by the potential leakage of waste due to improper packaging conditions, insufficient load securing, and workers' non-compliance in using personal protective equipment (PPE). This condition indicates that the waste transfer process is a critical stage that requires the implementation of safe work procedures and strict supervision. Meanwhile, the vehicle preparation, unloading, and administration and housekeeping stages are generally dominated by risks categorized as medium to high. Although the risks at these stages are not always fatal, they can trigger an increase in risk levels in subsequent stages if they are not properly managed.

Risk Level Distribution Analysis

Based on the recapitulation of risk levels, it is known that risks categorized as high and medium are the most dominant, each accounting for 45%. This condition indicates that most hazardous waste transportation activities are still at a risk level that requires further control measures. Although the percentage of extreme risks is relatively small, at 10%, these risks must remain a top priority because they have a very high level of severity. The dominance of high and medium risk categories indicates that the existing OSH control system has not yet fully reduced the risk level to an acceptable level. This emphasizes the need for the implementation of more structured and sustainable risk control strategies.

Hazard Source Analysis Based on the HAZOP Method

Based on the results of the HAZOP analysis, hazard sources in the hazardous waste transportation process can be classified into four main factors, namely vehicle and work equipment factors, work method and procedure factors, operational environmental factors, and human factors. Vehicle and work equipment factors become one of the dominant sources of hazards, particularly those related to vehicle feasibility, readiness of safety equipment, and waste packaging conditions. Work method and procedure factors also contribute significantly to risks, especially in loading and unloading processes that are still largely performed manually. Human factors, particularly those related to driver fatigue and compliance with OSH procedures, have a major influence on the occurrence of extreme risks. Meanwhile, operational environmental factors such as road conditions, weather, and traffic density also increase the potential risk during the transportation stage. These results indicate that OSH risks in the hazardous waste transportation process are not only caused by worker errors (human error), but are also influenced by the readiness of the work system, supporting facilities, and the operational environment.

Implications of Risk Control

The risk control strategies developed based on the HAZOP method and the hierarchy of risk control approach show that most risks can be controlled through a combination of administrative approaches, engineering controls, and the use of PPE. Administrative control plays an important role in strengthening the OSH management system, such as the preparation of SOPs, regulation of driver working hours, and operational supervision. Engineering approaches are required to reduce the likelihood of accidents, especially for risks categorized as extreme, through the implementation of technologies such as GPS, speed limiters, and ergonomic work equipment. Meanwhile, the use of PPE serves as the final layer of protection to minimize impacts if risks cannot be completely eliminated. With the implementation of appropriate risk control strategies, it is expected that the OSH risk level in the hazardous waste transportation process can be reduced from high and extreme categories to lower and more acceptable categories.

Discussion Synthesis

Overall, the analysis results show that the hazardous waste transportation process at PT.XYZ has a relatively high OSH risk level and requires serious attention from management. The highest risks were found in the transportation and loading stages, which are influenced by human factors, vehicle conditions, and the operational environment. Therefore, risk control must be implemented comprehensively and in an integrated manner in order to create a hazardous waste transportation system that is safe, healthy, and sustainable.

CONCLUSION

Based on the review of the analytical stages that have been carried out, it can be concluded that this study has appropriately applied the risk matrix method in assessing Occupational Safety and Health (OSH) risks. The use of the risk matrix is demonstrated through the determination of likelihood (L) and severity (S) values for each potential hazard identified using the Hazard and Operability Study (HAZOP) method. The obtained likelihood and severity values were then mapped into the risk matrix to determine the risk level, namely low, medium, high, and extreme risks. The implementation of the risk matrix has been applied consistently across all stages of the hazardous waste transportation process, as shown in the hazard identification tables, risk level recapitulation, and risk level distribution analysis. Thus, it can be stated that the HAZOP method was used as a method for identifying and analyzing hazard sources, while the risk matrix was used as a method for assessing the level of risk. The combination of these two methods has been applied systematically and complementarily, so that the OSH risk analysis in the hazardous waste transportation process at PT.XYZ has been conducted comprehensively, in a structured manner, and in accordance with scientific principles.

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