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EVALUATION OF HAZARDOUS WASTE MANAGEMENT OF THE MANUFACTURING INDUSTRY IN PT. X

Kancitra Pharmawati [1], Prayudha Rohan P [1*]

[1] Department of Environmental Engineering, Faculty of Civil Engineering and Planning, Institut Teknologi Nasional, Bandung, Indonesia, 40124

*Corresponding Email: prayudharohanp@gmail.com
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Abstract

PT. X is the largest viscose fibre manufacturing company in Indonesia. Production at PT X generates hazardous and toxic waste, potentially harming human health and the environment. The hazardous waste generated is oil, electronic waste, used batteries, tubular lamps, asbestos and rock wool, and hazardous packaging with the most significant quantity of WWTP (Wastewater Treatment Plant) sludge and cellulose alkali. Exposure to high concentrations of cellulose alkali can cause acute poisoning and even death. This study aims to evaluate the management of hazardous waste by considering the Minister of Environment and Forestry Regulation No. 6 of 2021, the Minister of Environment and Forestry Regulation No. 14 of 2013 on symbols and labels of hazardous and toxic waste, and Government Regulation No. 22 of 2021 on the implementation of environmental protection and management, then the level of conformity is assessed using the Likert method. There are several aspects of hazardous and toxic waste management, namely aspects of reduction, packaging, collection, symbol and labelling, and temporary storage. The results of the suitability of hazardous waste management from the aspects of reduction are 100%, packaging is 88%, collection is 100%, giving symbols and labels is 71%, and storage is 96%; from the average overall result, a value of 91% is obtained and categorised as 'very good'.

Keywords: *alkali cellulose, hazardous waste, likert method, viscose*

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1. Introduction

The manufacturing industry involves a wide range of activities, such as designing, manufacturing, and distributing goods. Its focus is on processing raw materials into semi-finished or finished products. The industry is instrumental in transforming raw

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materials into ready-to-use products, but it also faces significant risks to occupational safety during the process (Irfan and Susilowati 2021). Indonesia's manufacturing sector plays a significant role in the country's economy. In addition to supplying a lot of labour, the sector contributes to the gross domestic product. The manufacturing industry contributes significantly to Indonesia's economic growth by absorbing a lot of labour and playing a role in national exports. In 2020, the sector accounted for around 20 per cent of Indonesia's total gross domestic product, demonstrating the vital role manufacturing plays in the country's economic structure. The manufacturing industry significantly affects the environment, especially regarding hazardous waste management. If not managed properly, hazardous waste generated from the production process can harm the environment and human health. Industrial hazardous waste management in Indonesia still faces many challenges, including a lack of understanding of sustainable and integrated management. This implies that the manufacturing industry needs to improve its hazardous waste management practices to minimize its negative impacts (Nursabrina et al., 2021).

PT X is a manufacturing company that produces viscose fibre and is one of Indonesia's largest viscose fibre producers. The production of PT X produces hazardous waste, namely alkaline cellulose from the production process in the viscose department, used oil, electronic waste, used batteries, used tubular lamps, wastewater treatment plant sludge, asbestos, and hazardous used packaging, namely sodium hydroxide (NaOH), carbon disulfide (CS_2), softener agent, sulfuric acid (H_2SO_4), and sodium hypochlorite and contaminated goods. Industries generate hazardous wastes, and these wastes have significant effects on the environment and human health. These hazardous wastes can contaminate soil, water, and air and pose substantial health risks to residents living around industrial sites (A. Nursabrina et al., 2021). Managed hazardous waste can contain harmful substances that can cause respiratory problems, skin irritation, and cancer (Putri, 2023).

Hazardous waste management system evaluation is essential in ensuring that the waste is managed safely and by applicable regulations. This evaluation aims to compare the current condition of waste management with the ideal conditions set by government regulations, the Minister of Environment and Forestry Regulation No. 6 of 2021 with the Minister of Environment and Forestry Regulation No. 14 of 2013 concerning symbols and labels of hazardous and toxic waste and Government Regulation No. 22 of 2021 concerning the implementation of environmental protection and management and the results of the evaluation can provide recommendations for improving hazardous waste management(Pramestie & Wilujeng, 2023).

2. Method

This research compares existing conditions with government regulations and then assesses the level of conformity (scoring) using the Likert Scale method. The evaluation of hazardous waste reduction, hazardous waste packaging, and waste storage in hazardous waste temporary storage areas is compared with the Minister of Environment and Forestry Regulation No.6 of 2021. The evaluation of hazardous waste collection was compared with Government Regulation No.22 of 2021. The hazardous waste symbol and labelling evaluation was compared with the Minister of Environment and Forestry Regulation No.14 of 2013. Methods The feasibility of hazardous waste management was

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assessed using a Likert scale. This evaluation uses a scale of three, where the Likert Scale measures the opinions, attitudes, and perceptions of a person or group of people about the object of research (Sugiyono, 2017). The Likert scale in Table 1 will be used to score the comparison results. Existing conditions are assessed according to the suitability of the applicable regulations; existing conditions with a score of 2 are categorised as 'suitable', existing conditions with a score of 1 are categorised as 'less suitable', and existing conditions with a score of 0 is categorised as 'not suitable'. The description of the Likert Scale scoring used is presented in Table 1.

Table 1 Weighting of Likert Scale Scoring

Suitability	Score
Suitable	2
Less Suitable	1
Not Suitable	0

Source : Sugiyono, 2017

The level of conformity will be calculated by the formula presented in equation (1) by comparing the implementation of hazardous waste management with the relevant regulations, using the following formula:

$$\%\text{Conformity} = \frac{\text{PT X suitability assessment score}}{\text{Maximum score of suitability}} \qquad \text{(equation 1)}$$

The category of the results of the percentage of conformity is shown in Table 2

Table 2 Categories of Achievement of Hazardous Waste Management

Conformity Value (%)	Category of Achievement
0-20	Very Poor
21-40	Poor
41-60	Fair
61-80	Good
81-100	Very Good

Source : Sugiyono, 2017

3. Result and Discussion

3.1 Hazardous Waste Identification

The first step is to find the characteristics of the waste generated by PT X by looking at the type of waste generated and ensuring that the waste is by applicable regulations. The codes and characteristics of the waste can be found in Appendix IX of Government Regulation No. 22 of 2021 concerning the Implementation of Environmental Protection and Management. Hazardous waste generated by PT X consists of solid and liquid waste, which are the types and characteristics of hazardous waste from PT. X can be seen in Table 3.

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Table 3. Hazardous Waste Identification

No	Waste Category	Waste Source	Waste Code	Hazard Category	Characteristics Hazardous Waste
1	Used oil lubricating oil engine	Machinery Production	B105-d	2	Flammable and toxic
2	Used Battery and batteries	Production Machines, operational vehicles, offices,	A102-d	1	Corrosive and toxic
3	Electronic waste	Office, production room, warehouse chemicals	B107-d	2	Toxic
4	WWTP Sludge	Production Process	B441	2	Flammable solids ignite
5	Rockwool & Asbestos	Production space (civil activities such as waste turnover building roof)	B102-d	2	Toxic
6	Majun cloth and similar/ contaminated materials	Production space warehouse chemicals	B110-d	2	Toxic
7	Tubular lamps	Electronics Office	B107-d	2	Toxic
8	Packaging hazardous used	Production room, chemical warehouse, office, bathroom	B104-d	2	Toxic
9	Cellulose alkali	Production Process	A305-5	1	Solids Easy Ignite

Source: Analysis Results, 2025

PT X generates nine types of hazardous waste from its production process. The hazardous waste designation falls into two categories. Category one includes acute hazardous wastes directly affecting people and the environment. Category one (1) includes hazardous wastes with acute properties, meaning they directly impact people and the environment. Category one hazardous wastes include toxic, corrosive, and reactive materials. Examples are medical wastes from healthcare facilities, which often

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contain infectious materials, hazardous chemicals, and sharps. (Rahim et al. 2023). Category two (2) is a type of waste with a delayed effect. Its negative impact on human health and the environment is not immediately apparent but may appear after a certain period. These wastes can usually cause long-term damage if not appropriately managed. This waste category includes hazardous chemicals that can accumulate in the human body or the environment, such as heavy metals and toxic organic compounds (Pramestie & Wilujeng, 2023).

3.2 Hazardous Waste Generation

Hazardous waste generation refers to the amount and type of waste generated from various industrial, health, and household activities that contain hazardous materials (Hasibuan, Mubarok, and Firmansyah 2023). Hazardous waste at PT X is recorded on the balance sheet and logbook. The hazardous waste balance sheet is a tool used to measure, record, and analyse the amount and type of hazardous waste generated by operations or industries (Nurhayati & Purnomo, 2023). The logbook serves as an official record that records all activities related to hazardous waste management, including the type of waste, volume, collection date, and management method (Munzir, Kristiawanto, and Ismed 2024). Total waste generation in the hazardous waste period, July 2023 - June 2024, can be seen in Figure 1.

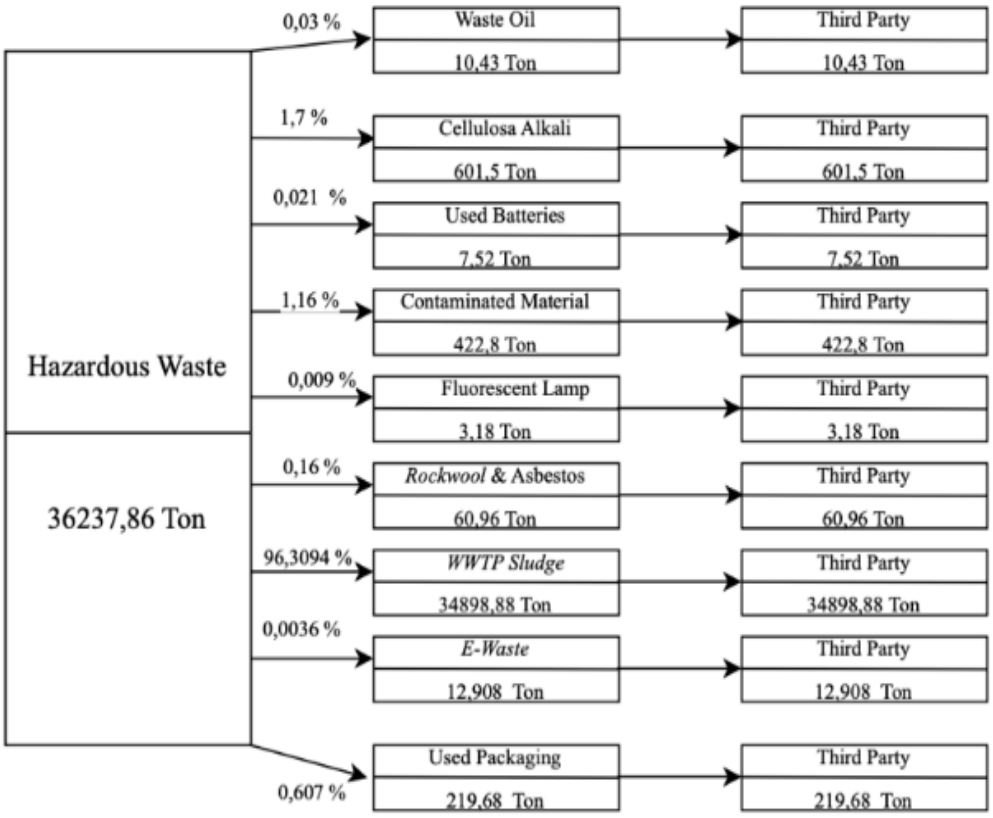

Figure 1: Waste Balance of PT X Period July 2023-June 2024
Source: Analysis Results, 2025

From Figure 1, it can be seen that PT X produces cellulose alkali hazardous waste and WWTP sludge, whose quantity is the dominant waste compared to other hazardous

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wastes; this is because the hazardous waste is the result of the main raw material in the production process that does not stop producing. As for the explanation of the highest quantity of hazardous waste :

1. Cellulose Alkali hazardous waste comes from the viscose fibre production process, which involves using cellulose feedstock extracted from natural sources such as wood or agricultural waste. This process usually involves several stages, including delignification, where lignin is removed from the raw material to obtain pure cellulose. In this context, alkalis such as sodium hydroxide (NaOH) facilitate this process (Mufid et al. 2018). These wastes are often solids, such as unused cellulose fibre remnants, residues from the delignification process, and chemical residues used during production. Solid waste can be flakes, powders or fibre containing alkali and cellulose (Kusniawati, Sari, and Putri 2023). According to Government Regulation 22 of 2021, the cellulose alkali waste code is A305-5 and is a flammable solid. The viscose fibre production process involves chemicals, mainly sodium hydroxide (NaOH) and carbon disulfide (CS_2), which are hazardous materials. The viscose fibre production process consists of chemicals, primarily sodium hydroxide (NaOH) and carbon disulfide (CS_2), which are hazardous materials. Sodium hydroxide is a strong alkali that can react with water and generate heat. At the same time, carbon disulfide is an organic compound that can potentially increase fires due to its flammability (Hendriana and Mardyanto 2023). High concentrations of CS_2 can cause acute poisoning, with symptoms such as headache, dizziness, nausea, vomiting, and even death(Iriana, 2018).

2. WWTP sludge comes from wastewater treatment, where solid particles are deposited from chemical and biological reactions. This process produces sludge, which is a mixture of organic and inorganic materials and the remains of chemicals that do not decompose (Rahmaulina et al., 2022). According to government Regulation No. 22 Year 2021, the code of this WWTP sludge waste is B441, and it is flammable solids. The sludge waste is flammable because various chemicals are used in the viscose fibre production process, including alkalis and organic compounds that have the potential to increase the possibility of fire. The sludge waste generated from this process may contain residues of flammable chemicals, such as carbon disulphide and other organic compounds (Salsabilla et al., 2023).

3.3 Hazardous Waste Reduction Evaluation

PT X has taken steps to reduce hazardous waste, as stated in the Minister of Environment and Forestry Regulation No. 6 of 2021, by replacing raw materials, process modifications or environmentally friendly technology. PT X, in addition to using materials for dissolving pulp using chemicals such as NaOH and others PT X also uses materials dissolving pulp that are environmentally friendly, namely N-methylmorpholine-N-oxide (NMMO) in the production process; this solvent is used to dissolve pulp directly without any chemical changes. Therefore, viscose production is much simpler. NMMO is biodegradable, meaning it can be broken down by microorganisms naturally. This is important to prevent the build-up of harmful chemicals in the environment. NMMO has the unique ability to dissolve cellulose, the main ingredient in textile fibres. Hence, it enables sustainable and environmentally friendly

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production of Lyocell fibres from natural resources such as wood pulp (Chen, 2015).

PT X has also tried to reduce hazardous waste by using WWTP sludge as boiler raw material. Textile industry sludge contains organic components that can be burned and have a significant calorific value. The sludge generated from the WWTP can be utilised as a feedstock for briquettes, demonstrating the potential energy generated from the sludge. The study also indicated that the proximate analysis of the sludge showed that the calorific value of the sludge is quite competitive compared to coal, making it a viable alternative for energy generation (Rahmaulina et al., 2022). As part of the global effort to reduce the impact of burning fossil fuels, using sludge can reduce greenhouse gas emissions compared to coal. The utilisation of sludge as a fuel requires proper drying and processing. The optimum drying time for sludge can vary, requiring investment in infrastructure and technology (Rahmaulina et al., 2022). However, this is no longer used because it no longer has a permit to process WWTP sludge. The sludge hazardous waste utilisation permit validates that PT X is not only based on processing alone but also fulfils government permit regulations and pays attention to environmental safety. Its testing is carried out with the TCLP test (toxicity), calorie test, and trial burning test (ash, mercury, emissions) (Minister of Environment and Forestry Regulation No. 18, 2020). Based on the parameters set by the government, the hazardous waste reduction aspect received a score of 2 out of 2 maximum scores for suitability, so it has a score of 100%, which means that the hazardous waste reduction aspect is carried out 'very good'.

3.4 Hazardous Waste Packaging Evaluation

Government Regulation No. 22 Year 2021 on the Implementation of Environmental Protection and Management emphasises the importance of packaging due to the hazardous and toxic nature of the waste. Thus, there is a need for packaging that can effectively prevent waste leakage and safeguard the environment. Hazardous waste packaging is selected based on the characteristics of the hazardous waste to be contained. Hazardous waste packaging is designated according to its properties, such as using 200L sealed metal drums for liquid hazardous waste with toxic and flammable properties, 2-tonne jumbo bags for solid hazardous waste with toxic properties, and IBC tanks for liquid waste.

The hazardous waste packaging is well done and close to regulatory compliance, but plastic and metal drums are still combined, as seen in Figure 2d. Combining these two types of drums can complicate the recycling process. Metal and plastic drums have different recycling processes, and mixing the two can result in contamination, reducing the recycling value of both materials (Quds & Slamet, 2022). Figure 2a and Figure 2b jumbo bags for storing sludge, contaminated materials, asbestos, and hazardous packaging are still visible hazardous waste overcapacity exceeding the jumbo bag packaging can cause leakage or spillage of hazardous waste. Hazardous waste contains hazardous and toxic materials and can contaminate the surrounding soil and water sources (Setiyono, 2018).

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A B C

D

Figure 2: Jumbo Bag Hazardous Waste Packaging (Sludge) (A), Used Solid Waste Packaging (B), Jumbo Bag Refrigator Hazardous Waste Packaging (C), Used Oil Hazardous Waste Packaging (Metal and Plastic Drums) (D)

Source : Analysis Results, 2025

Based on the parameters set by the regulation, the packaging aspect received a score of 7 out of a maximum suitability score of 8, with a value of 88%, which can be interpreted as indicating that the packaging aspect of hazardous waste is carried out 'very good'.

3.5 Hazardous Waste Collection Evaluation

Based on Government Regulation No. 22 of 2021, hazardous waste collection collects hazardous waste from its source before being handed over to the party that utilises or stockpiles it. Hazardous waste collection at PT X is carried out daily to the hazardous waste temporary storage area. The collection process uses a forklift as a transport tool. The transport route is not fixed and depends on the location of the waste source; if no waste is generated, then there is no transport to the temporary storage of hazardous waste. PT. X has two temporary hazardous waste storage areas that accommodate different types of hazardous waste from each department or other building. Therefore, hazardous waste will be collected with different flows according to the kind of hazardous waste stored in the existing hazardous temporary storage sites, one or two. The path to the temporary storage of hazardous waste passes through an uphill-downhill road with a width of 6 metres. Sludge waste from the WWTP is put into jumbo bags; some are transported directly by trucks. All transportation to the hazardous waste temporary storage area uses a forklift. The hazardous waste collection process is determined based on the source of the waste generated. The waste collected at the designated collection location is then transported to the dangerous waste temporary storage area using a forklift. The blue-coloured groove goes to the temporary storage of

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existing hazardous waste one, while the red-coloured groove goes to the temporary storage of existing hazardous waste two. The following is a hazardous waste collection layout shown in Figure 3.

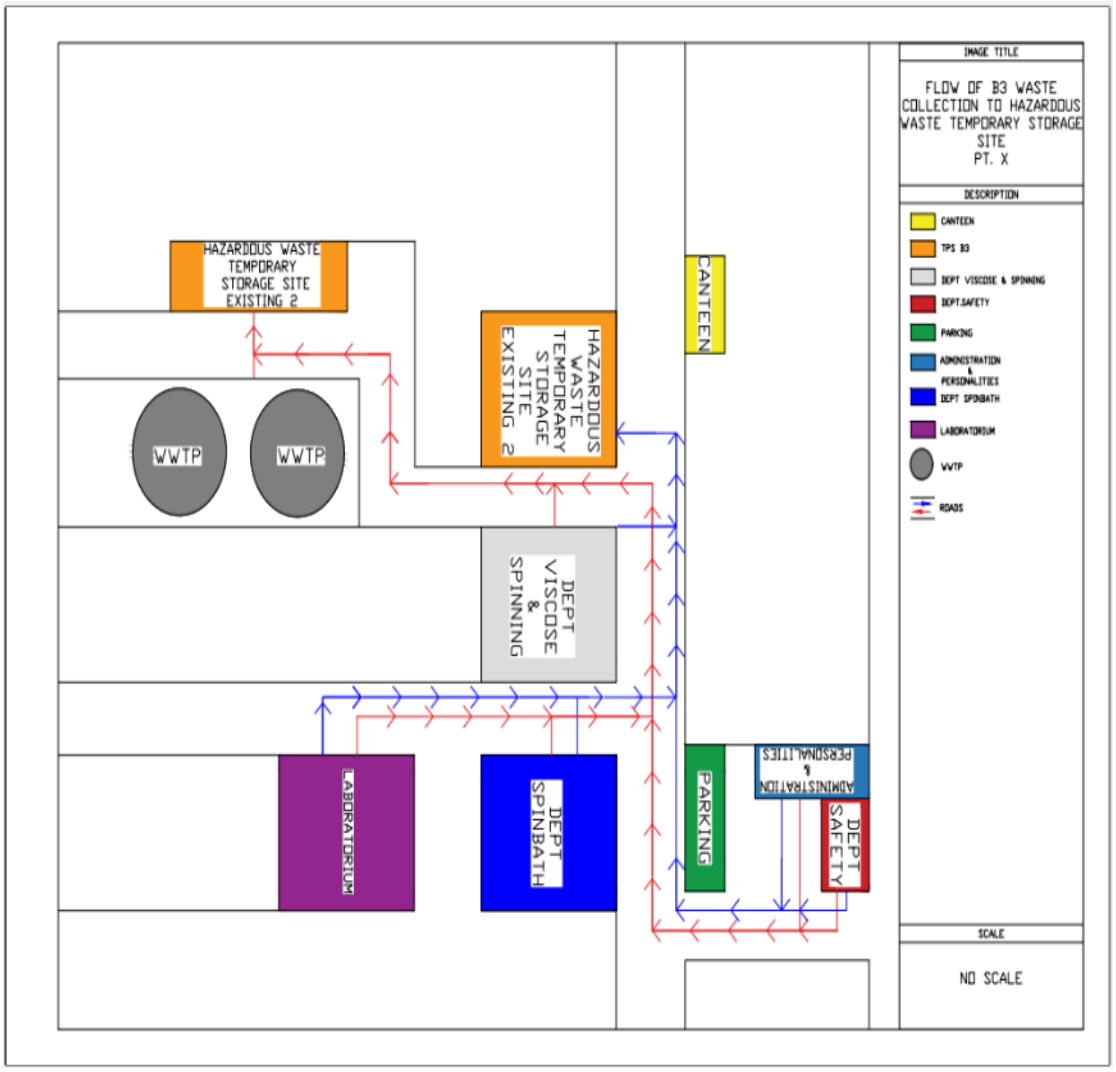

Figure 3. Flow of hazardous waste collection to temporary storage at PT. X
Source: Analysis Results, 2025

Based on the parameters set by the regulation, the collection aspect received a score of 6 out of 6 maximum scores for suitability, resulting in a score of 100%, which can be interpreted to mean that the hazardous waste collection aspect is carried out 'very good'.

3.6 Hazardous Waste Symbols and Labels Evaluation

In hazardous waste management, providing symbols and labels is very important. Symbols and labels on hazardous waste packaging provide quick and clear visual information about the waste's hazardous nature. This symbol helps identify the type of waste and the potential hazards posed. Appropriate symbols can reduce the risk of accidents and unwanted exposure to workers and the public (Wardhani & Lisnawati, 2023).

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The following is the installation of symbols and labels in the temporary storage of hazardous waste at PT X. Some hazardous waste containers at PT X have been equipped with hazardous waste symbols and labels that are by the characteristics of the hazardous waste stored, and some hazardous waste containers have not been equipped with symbols and directions for hazardous waste lids as seen in Figure 4A and for hazardous waste symbols as seen in Figure 4B on the walls of the hazardous inner waste temporary storage area have not been installed.

A B

Figure 4: Symbol and Label Labeling on Hazardous Waste Packaging (A), No Hazardous Waste Symbol on the Wall and No 'EMPTY' Label on the Packaging (B)

Source: Analysis Results, 2025

Based on the parameters set by the regulation, the symbol and label aspect has a score value of 10 out of 14 maximum conformity scores, resulting in a score of 71%, which can be interpreted as indicating that the symbol and label aspect of hazardous waste is done 'good'.

3.7 Hazardous Waste Storage Evaluation

Before being transferred to the central collection point at the hazardous waste temporary storage site, hazardous waste is collected at temporary storage sites in each department. According to the Minister of Environment and Forestry Regulation No. 6 of 2021, a good and correct temporary storage place considers many things, such as the location and completeness of storage, the layout of packaging storage in buildings and the storage time of hazardous waste. The temporary storage of hazardous waste at PT X stores liquid and solid phase hazardous waste. The first area of the existing hazardous waste temporary storage area in PT. X is 5.4 m^2 x 24.6 m^2, while the second location of in PT. X is 6 m^2 x 10 m^2. The following is the layout of the temporary storage of hazardous waste in Figure 5 and Figure 6.

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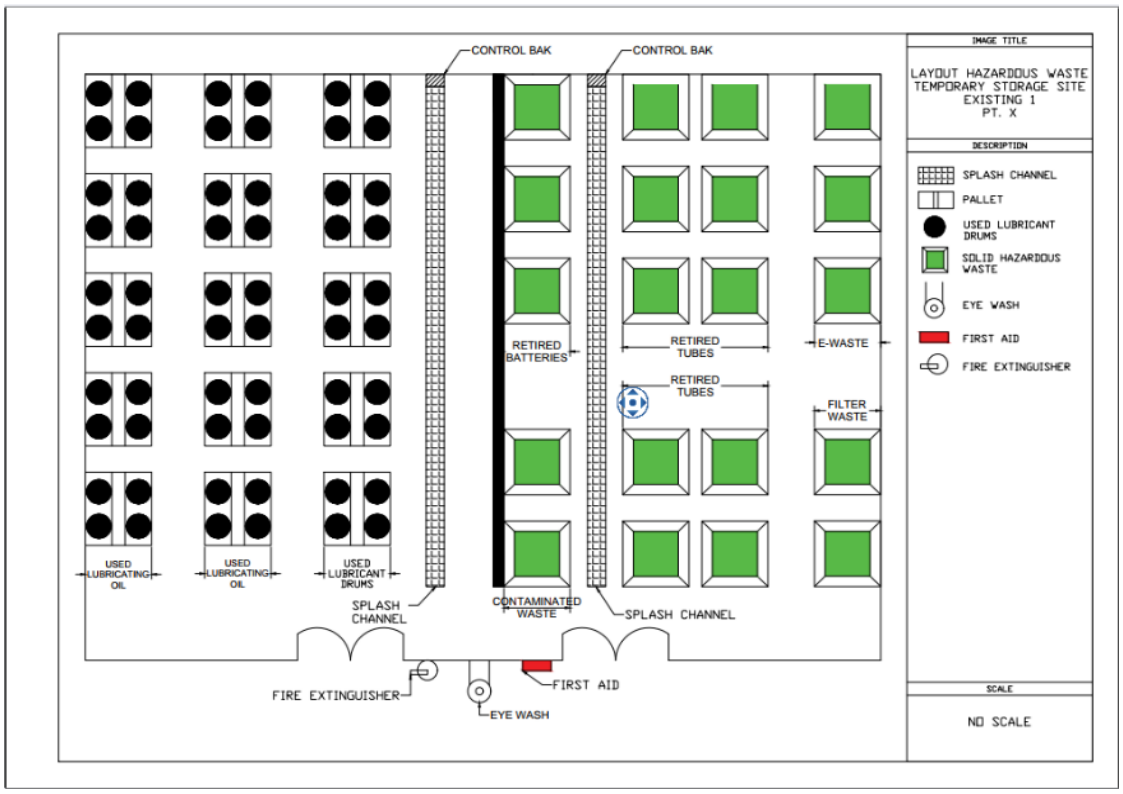

Figure 5: Layout of the First Hazardous Waste Temporary Storage Site at PT. X
Source: Analysis Results, 2025

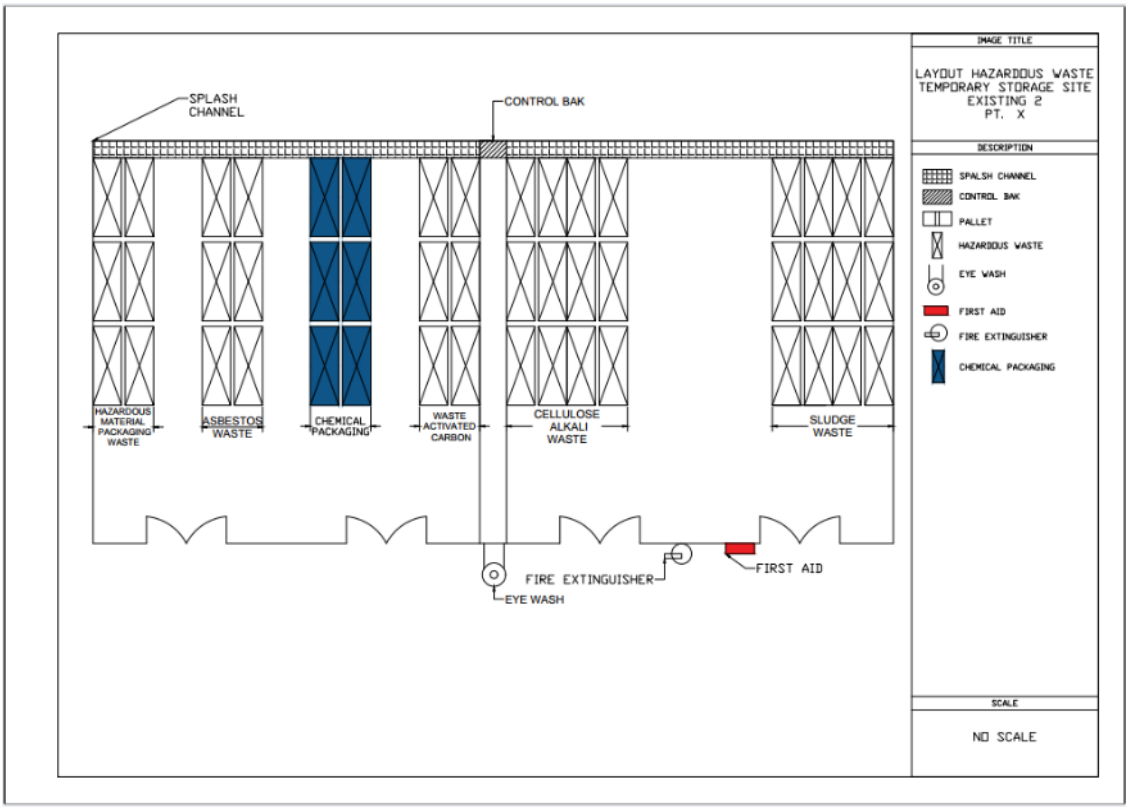

Figure 6: Layout of the Second Hazardous Waste Temporary Storage Site at PT. X
Source: Analysis Results, 2025

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The first hazardous waste site: Used oil, used catalysts, used tubes, usedbatteries,electronic waste and used tabular lamps, used filters .Second hazardous waste site: Sludge, alkaline cellulose, activated carbon, chemical packaging, asbestos.

There are hazardous waste symbols that have not been installed entirely on the walls and the door of the temporary storage of hazardous waste at PT X, and the logbook still does not include the source and characteristics of hazardous waste in the temporary storage of hazardous waste. The incompleteness of logbooks and hazardous waste symbols can result in a lack of information regarding the type and amount of hazardous waste generated, and it can increase the risk of exposure for workers who handle such waste. Improper management of hazardous waste can pose serious health risks to humans, including the potential occurrence of diseases due to exposure to hazardous materials (Nursabrina et al., 2021). condition of the temporary storage area can be seen in Figure 7.

A B

Figure 7: Symbols at Hazardous Waste Temporary Storage Site, (A) Water Sprinkler (B)
Source: Analysis Results, 2025

From the parameters regulated by the regulation with the corresponding results score 46 out of 48 maximum suitability scores, it has a value of 96%, which can be interpreted as indicating that the temporary storage aspect is carried out ‘very good’.

3.8 Recapitulation of Evaluation of Hazardous Waste Management at PT. X.

In hazardous waste management, PT X conducts reduction, collection packaging, use of symbols and labels, and storage in temporary storage. This hazardous waste evaluation is carried out by comparing regulations regarding hazardous waste, the Minister of Environment and Forestry Regulation No. 6 of 2021 concerning hazardous waste management in the form of reduction and storage, and the Minister of Environment and Forestry Regulation 14 of 2013 concerning symbols and hazardous waste. The following recapitulation results of hazardous waste management at PT. X can be seen in Table 4 with an overall result of 91% which is still categorised as ‘very good’ for hazardous waste management at PT X .

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Table 4. Recapitulation of Evaluation of Hazardous Waste Management at PT. X

No	Hazardous Management Aspect	Confirmity (%)	Category of confirmity
1	Reduction	100	Very Good
2	Packaging	88	Very Good
3	Symbol and Labels	71	Good
4	Collection	100	Very Good
5	Temporary Storage	96	Very Good
Total		455	
Average		91 %	

Source: Analysis Results, 2025

4. Conclusion

Based on field observations, hazardous waste generation at PT X consists of several types of used oil, used batteries, cellulose alkali, contaminated materials, used tubular lamps, rockwool & asbestos, electronic waste, used chemical bottles and WWTP sludge. Characteristics of hazardous waste at PT X are flammable liquids and toxic, reactive, and flammable solids. In the production process, the evaluation of hazardous waste reduction by replacing solvents, namely NaOH to N-methylmorpholine-N-oxide (NMMO), shows that this NMMO is biodegradable. Evaluation of hazardous waste packaging should be improved by adjusting the packaging capacity and not combining different types of packaging. The assessment of hazardous waste collection is already running well, and no hazardous waste has been collected for more than one day in each department. The placement of hazardous waste symbols and labels must be evaluated, such as installing hazardous waste symbols and labels by the regulations. Completing symbols in temporary storage areas must improve the evaluation of hazardous waste storage. The recapitulation of the results of the evaluation of hazardous waste management with the Likert method assessment gets an average score of 91% and is categorised as 'very good'.

REFERENCES

Chen JH, Guan Y, Wang K, Xu F, Sun RC. 2015. "Mengatur Efek Hemiselulosa Pada Preparasi Dan Sifat Serat Lyocell Komposit. Selulosa 22(3):1505–1516."

Dinar Pramestie, Innez Shessariefta, and Susi Agustina Wilujeng. 2023a. "Evaluasi Pengelolaan Limbah Bahan Berbahaya Dan Beracun (B3) Di PT XYZ." *Jurnal Teknik Its* 12 (2). https://doi.org/10.12962/j23373539.v12i2.120730.

Hasibuan, Ardian Azmi, Danang Andrian Mubarok, and Amrie Firmansyah. 2023. "TIinjauan Penerapan Pengelolaan Limbah B3 Pada Sektor Kesehatan Di Indonesia Berdasarkan GRI 300." *Journal of Law Administration and Social Science* 3 (2): 220–33. https://doi.org/10.54957/jolas.v3i2.545.

Hendriana, Tasya Afrida, and Mas Agus Mardyanto. 2023. "Kajian Risiko Lingkungan Pada Pengelolaan Bahan Berbahaya Dan Beracun (B3) Dan Limbah B3 Industri Kimia Di PT XYZ Dengan Metode Failure Mode and Effect Analysis (FMEA)." *Jurnal Teknik Its* 12 (3). https://doi.org/10.12962/j23373539.v12i3.121683.

Irfan, Muhammad, and Indri H Susilowati. 2021. "Analisa Manajemen Risiko K3 Dalam

Manuscript received 20 Feb 2025; revised 15 May 2025; accepted 16 May 2024

Industri Manufaktur Di Indonesia: Literature Review." *Prepotif Jurnal Kesehatan Masyarakat* 5 (1): 335–43. https://doi.org/10.31004/prepotif.v5i1.1635.

Iriana, D., Sedjati, S., & Yulianto, B. 2018. "Kemampuan Adsorbsi Kitosan Dari Cangkang Udang Terhadap Logam Timbal. Journal of Marine Research, 7(4), 303–309."

Kusniawati, Euis, Dian Kurnia Sari, and Mareska Karenina Putri. 2023. "PEMANFAATAN SEKAM PADI SEBAGAI KARBON AKTIF UNTUK MENURUNKAN KADAR PH, TURBIDITY, TSS, DAN TDS." *Journal of Innovation Research and Knowledge* 2 (10): 4183–98. https://doi.org/10.53625/jirk.v2i10.5405.

Mufid, Mufid, Agung Ari Wibowo, Ade Sonya Suryandari, An Nisaa' Fithriasari, and Pravianti Anindita Nastiti. 2018. "Sintesis Asam Oksalat Dari Limbah Serbuk Kayu Jati (Tectona Grandis L.F.) Dengan Proses Hidrolisis Alkali." *Jurnal Teknik Kimia Dan Lingkungan* 2 (1): 17–22. https://doi.org/10.33795/jtkl.v2i1.57.

Munzir, Marinov, Kristiawanto Kristiawanto, and Mohamad Ismed. 2024. "Pertanggungjawaban Pidana Dalam Tindak Pidana Lingkungan Hidup Pengelolaan Limbah Bahan Berbahaya Dan Beracun (B3)." *Armada Jurnal Penelitian Multidisiplin* 2 (3): 214–24. https://doi.org/10.55681/armada.v2i3.1248.

Nurhayati, Radityazty Dahayu, and Yayok Suryo Purnomo. 2023. "Rencana Pengelolaan Limbah B3 Pada Industri Makanan Laut." *Envirous* 4 (1): 66–72. https://doi.org/10.33005/envirous.v4i1.178.

Nursabrina, Aisya, Tri Joko, and Onny Septiani. 2021. "Kondisi Pengelolaan Limbah B3 Industri Di Indonesia Dan Potensi Dampaknya: Studi Literatur." *Jurnal Riset Kesehatan Poltekkes Depkes Bandung* 13 (1): 80–90. https://doi.org/10.34011/juriskesbdg.v13i1.1841.

Putri, Amara Cindradewi Anton. 2023. "Persepsi Masyarakat Desa Lakardowo Terhadap Pencemaran Limbah B3 PT. PRIA Pada Pertanian, SDA, Dan Kesehatan" 3 (1). https://doi.org/10.58954/epj.v4i1.111.

Quds, Sulthan Muchammad, and Agus Slamet. 2022. "Evaluasi Proses Pengeringan Lumpur Pada Unit Sludge Drying Bed Dengan Media Filter Cloth Di IPAL Komunal Telaga Abadi Kabupaten Gresik." *Jurnal Teknik Its* 11 (2). https://doi.org/10.12962/j23373539.v11i2.88712.

Rahim, Fitri Kurnia, Bibit Nasrokhatun Diniah, Faisal Maulana Akbar, Muhammad Ikhsan Al'Faridz, and Muhamad Rifqi Sucipto. 2023. "Gambaran Pengelolaan Dan Timbulan Limbah Medis Bahan Berbahaya Dan Beracun (B3) Pada Fasilitas Dan Pelayanan Kesehatan Di Wilayah Jawa Barat Tahun 2022." *Journal of Public Health Innovation* 3 (02): 198–204. https://doi.org/10.34305/jphi.v3i02.648.

RAHMAULINA, DINI, ETIH HARTATI, and DYAH MARGANINGRUM. 2022. "Studi Pendahuluan Pemanfaatan Sludge IPAL Industri Tekstil Sebagai Bahan Baku Briket." *Jurnal Teknologi Lingkungan* 23 (1): 035–043. https://doi.org/10.29122/jtl.v23i1.4639.

Salsabilla, Yoan, Heny Dewajani, and Achmad Chumaidi. 2023. "Analisis Sistem Pengelolaan Limbah Bahan Berbahaya Dan Beracun (B3) Pada Perusahaan Pestisida." *Distilat Jurnal Teknologi Separasi* 9 (4): 548–57. https://doi.org/10.33795/distilat.v9i4.4177.

Setiyono, Setiyono. 2018. "POTENSI LIMBAH BAHAN BERBAHAYA DAN BERACUN (B3) DI WILAYAH DKI JAKARTA Dan STRATEGI PENGELOLAANNYA." *Jurnal Air Indonesia* 1 (3). https://doi.org/10.29122/jai.v1i3.2358.

Wardhani, Eka, and Novi Lisnawati. 2023. "Evaluasi Pengelolaan Limbah Bahan Berbahaya

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Dan Beracun Di TPS Industri Persenjataan." *Jurnal Serambi Engineering* 8 (3). https://doi.org/10.32672/jse.v8i3.6117.

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