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Regional Case Study

Design of Temporary Storage for Hazardous Waste at Politeknik Perkapalan Negeri Surabaya

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Abstract

Politeknik Perkapalan Negeri Surabaya has workshops or laboratories that generate hazardous waste from practical learning activities. Currently, hazardous waste is not stored in accordance with regulations, it will pose a danger to the environment and human health. Therefore, this research requires a design for hazardous waste storage that complies with the Minister of Environment and Forestry Regulation number 6 of 2021. The design of fire extinguisher requirements is based on the Regulation of the Minister of Manpower and Transmigration of the Republic of Indonesia No. Per.04/Men/1980 and the design of lighting based on SNI 03-6575-2001. This research discusses the design of hazardous waste storage, including the characteristics of hazardous waste, the design of packaging and the supporting facilities. The characteristics of hazardous waste at the Politeknik Perkapalan Negeri Surabaya consist of flammable waste, toxic waste, and infectious waste. While, the packaging for hazardous waste is equipped with symbols and labels according to their characteristics and volume. The design of the hazardous waste storage building at the Politeknik Perkapalan Negeri Surabaya has dimensions of 11 m x 7 m, equipped with 12 lights and light fire extinguishers, taking into account the location, facilities, and emergency response.

Keywords: Hazardous waste; hazardous waste characteristics; hazardous waste packaging; hazardous waste storage

1. Introduction

Politeknik Perkapalan Negeri Surabaya (PPNS) is one of the higher education institutions specializing in shipbuilding and other applied science fields with the total number of students, lecturers, and employees in 2024 was 5200. Based on the number of academic community and their academic activities, PPNS have potential to generate hazardous waste, especially from laboratories and workshops field. PPNS generates a significant amount of hazardous waste from various sources, including workshops, laboratories, polyclinics, and office buildings. PPNS has 10 laboratories and 7 workshops as learning facilities for practical courses. These activities produce hazardous waste continuously during the learning activity in the laboratory and workshop. The types of waste produced include epoxy resin, used

paint, lamps, batteries, oil, syringes, and other materials classified as hazardous due to their flammable, toxic, reactive, corrosive, or infectious properties (Wardhani & Rosmeiliyana, 2020). In addition, PPNS has 3 service facilities and 1 clinic that have to produce hazardous waste as mentioned medical waste. Unfortunately, an initial assessment revealed that some of this waste is stored improperly, raising environmental and health concerns (Yunus et al., 2019). Research shows that technical institutions with frequent hands-on activities are prone to producing hazardous waste due to the materials commonly used in engineering, medical, and industrial processes (Fikri et al., 2015). Despite existing hazardous waste management applied, hazardous waste handling at PPNS faces several challenges. A preliminary assessment indicates that hazardous waste is often stored in inappropriate conditions, posing environmental and health risks.

Furthermore, PPNS has ranked by UI Green Metric in 2024. UI Green Metric is a global ranking system initiated by Universitas Indonesia (UI) to assess universities worldwide according to the sustainability efforts (Suwartha and Sari, 2013). PPNS had scored 3655, this number still 36% of the highest score in the UI Green Metric. This score consists of 6 criteria including Setting and Infrastructure/SI (395), Energy and Climate Change/EC (950), Waste/WS (375), Water/WR (210), Transportation/TR (1050), and Education and Research/ED (675). This indicates that the scores for the waste (WS) and water (WR)criteria are the lowest among all criteria. One of the key sub-criteria under waste is hazardous waste management, highlighting the need for immediate improvements in this area. One attempt to improve hazardous waste management under the waste (WS) criteria is that PPNS requires the design of hazardous waste storage buildings. Hazardous waste management is carried out from the beginning when the waste is generated until it is disposed of or destroyed (Wardhani & Rosmeiliyana, 2020). Proper hazardous waste management will reduce the pollution produced (Fikri et al, 2015). However, there is limited empirical research focusing on the specific challenges faced by polytechnic institutions in managing hazardous waste. This research gap underscores the need for a systematic approach to hazardous waste storage that aligns with technical standards and institutional requirements.

To address these issues, PPNS needs to establish a dedicated hazardous waste storage facility that meets technical standards and institutional requirements. Effective hazardous waste management is essential to reduce environmental pollution and minimize potential risks (Saputra et al., 2021). Based on Government Regulation of the Republic of Indonesia Number 22 of 2021), hazardous waste is the residue of an activity or process containing hazardous materials with characteristics such as flammable, explosive, reactive, infectious, corrosive, and toxic. Hazardous waste must be managed due to its potential to pollute the environment, both in terms of its nature and quantity. Waste management attempt for hazardous waste, according to Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Management of Hazardous Waste, consist of waste reduction, waste storage, waste collection, waste transportation, waste utilization, waste management, and hazardous waste disposal. In addition, according to the Government of the Republic of Indonesia Regulation No. 22 of 2021, producers of hazardous waste must temporarily store hazardous waste until it is handed over to by a third party.
Hazardous waste management that had been carried out by university shown comprehensive effort. The Laboratory of Chemical Department and Laboratory Pharmaceutical classified hazardous waste consist of corrosive, toxic, flammable, and easily oxidized. The classification determined the management system included reduction, storage, packaging, collection, utilization, processing, and transportation (Wirodimurtia et al., 2022). In addition, hazardous waste management program conducted in chemistry schools that produced numerous product that classified as hazardous waste by a system consist of classification and reduction (Lara et al, 2017). Hence, waste must be managed and controlled in accordance with the required procedures and quality standards established by applicable laws and regulations (Taufan & Purwanto, 2018).

Temporary storage of hazardous waste must be equipped with facilities that meet technical standards, including integrity of labels and symbols, waste transport routes, occupational safety and health systems, and emergency response in storage site for hazardous waste (Government of the Republic of Indonesia Regulation No. 22 2021). In existing conditions, PPNS does not yet have a hazardous waste management that accordance with the regulation. In addition, hazardous waste packaging was still not in appropriate with the provisions of hazardous waste management standard (this can be seen in Figure

1). Currently, PPNS lacks a dedicated hazardous waste storage facility that complies with the regulation. Hazardous waste in PPNS was put in each source such as laboratory, workshop then handed over to a third party. Based on those condition, PPNS have to design of hazardous waste temporary storage based on regulation. Furthermore, it can be UIGM score increasing and reduce negative impact to environment. Therefore, this research aims to design PPNS hazardous waste temporary storage building according to the technical standards, type and capacity of the hazardous waste generated. In another hand, based on Bhardawaj, 2019 and Fikri et al., 2015, the if this is not managed properly, it will be serious consequences .In the end, hopefully this research will give contribution to managed hazardous waste by design for temporary storage of hazardous waste to prevent the generated hazardous waste from causing the risk of environmental pollution and harm to the safety and health especially in college sector.

2. Methodology

The research methodology includes data measurement and analysis. Data measurement consists of hazardous waste characteristic in PPNS. In addition, data was analysed to design hazardous waste packaging, and hazardous waste storage facility. It was designed with use Autocad and Regulation of the Minister of Environment and Forestry number 6 of 2021 as guideline.

2.1. Hazardous Waste Characteristic Measurement

The measurement of hazardous waste was carried out on the PPNS for one month. The measurement of hazardous waste characteristic did in the all area at PPNS which it produce hazardous waste. The area was welding workshop, construction workshop, sheet metal and tool workshop, combustion engine workshop, chemistry laboratory, waste and microbiology laboratory physics, laboratory basic electricity and instrument laboratory, automation and robotics laboratory, basic electricity and instrument laboratory, building electricity K workshop, robotics room, clinic, Non-Metal Workshop, material testing laboratory, CNC laboratory, boiler laboratory, fluid laboratory, pneumatic laboratory, PJP and UPT Building, Security Post and Garden. This is done by measuring the hazardous waste inventory. The measurement of hazardous waste includes measuring the amount of hazardous waste generated (kg/day) and the volume of hazardous waste (m^3/day), a list of hazard categories, sources, characteristics and the amount of hazardous waste generated per unit time (Kanagamani et al., 2020).

2.2. Design of Hazardous Waste Packaging

Hazardous waste packaging in PPNS consist of drum and jumbo bag. According to the Regulation of the Minister of Environment and Forestry number 6 of 2021, Article 68 paragraph 2, the requirements for hazardous waste packaging consist of: Using packaging made of metal or plastic materials that can contain hazardous waste according to the characteristics of hazardous waste; Able to contain hazardous waste to remain within the packaging; Having a strong closure to prevent spills during storage; Transfer, and/or transportation; and being in a condition that is leak-proof, rust-free, and undamaged.

In addition to the packaging and/or container requirements as referred to in Article 69 and Article 70 (Regulation of the Minister of Environment and Forestry number 6 of 2021), hazardous waste stored in buildings must meet the provisions. The provisions referred to are that hazardous waste is packaged according to its type, characteristics, and/or compatibility and considering the potential for volume expansion of hazardous waste, gas formation, or pressure increase.

2.3. Hazardous Waste Storage Facility Design

Based on Ministry of Environment and Forestry Regulation No. 6 of 2021, Article 56 (a), 60 (2), and 67. In addition, the specifications for the lamps used are LED 25 Watt with 1800 lumens, so the required number of lamps can be calculated as following equation (1) (SNI 03-6575-2001):

$$N = \frac{E \; x \; L \; x \; W}{\emptyset \; x \; LLF \; x \; Cu \; x \; n} \quad (1)$$

Where N is number of lamps; E indicates illumination intensity (lux); L is building length (meter); while W building width (meter); ∅ is lamp value (lumen); while LLF is light loss factor (70%); Cu is utility coefficient (50%); then n is number of lamp point. The requirement for lighting is determined based on several factors such as the need for lighting levels based on room activity, the area to be illuminated, the lumen of the lamp according to the power of the lamp used, utilization and maintenance factors. The number of lamps needs that have been obtained is placed according to the layout of the room to be illuminated. Fire Extinguisher (APAR) must be added in hazardous waste storage facility design. Providing the number of indoor APARs is also regulated in the Republic of Indonesia Minister of Manpower and Transmigration Regulation No. Per.04/Men/1980 can use the following formula equation:

$$\text{APAR Requirement} = \frac{Building\ Area}{Protection\ Area\ 1\ APAR} \quad (2)$$

2.4. Placement of Compatibility Rules

Placement of compatibility rules namely grouping hazardous waste according to the characteristics of hazardous waste. Analysis of hazardous waste properties under hazardous waste management regulations (Minister of Environment and Forestry Regulation number 6 of 2021). The use of barrels referred to in Article 70 (1) (a) to store hazardous waste must meet the several requirements such as stacked by package type; the distance between the packing pile and the roof is at least 1 meter; and use block system storage. The block system arranges with the following conditions: each block consists of 2 (two) x 3 (three); and the width of the aisles between the blocks is at least 60 centimeters or adjusted according to the needs of people passing by and the operation of transport vehicles (forklifts).

2.5. Design the Hazardous Waste Storage Building

Design the hazardous waste storage building using Autocad software. The Autocad to practical application of AutoCAD in engineering, architecture, and design. Furthermore, this research use it for design of temporary storage for hazardous waste (Elliot and Kaebisch, 2024).

3. Result and Analysis

3.1. Characteristics of Hazardous Waste

The identification of hazardous waste characteristics generated at PPNS was conducted based on the monthly generation of hazardous waste in 2023 at several locations such as workshops, laboratories, clinics, and office buildings. The characteristics of hazardous waste, based on Appendix X of Government Regulation No. 22 of 2021 concerning the Implementation of Environmental Protection and Management, include flammable liquids, flammable solids, reactive materials, explosive materials, toxic materials, corrosive liquids, infectious materials, and environmentally hazardous materials. The identification of hazardous waste characteristics includes the source of waste, type of waste, and waste code. Furthermore, determining the characteristics of the waste allows for the determination of appropriate containers, compatibility of hazardous waste, and the shelf life of hazardous waste, thus obtaining a temporary hazardous waste storage design that meets the needs of the hazardous waste generated at PPNS.

The identification of hazardous waste characteristic conducted by discovery hazardous waste monthly generation (kg or liter) from each source such as workshops, laboratories, clinics, and office buildings. The source of hazardous waste also determines its category based on Government Regulation No. 22 of 2021 divided into specific and non-specific category. Furthermore, the characteristics and of hazardous waste generated are determined based on Appendix X of Government Regulation No. 22 of 2021 consist of flammable, toxic, and infectious. Flammable and toxic characteristic predominantly created by workshop and laboratories, while the infectious characteristic produced by clinics. Each characteristic of the hazardous waste has a different code, so it will facilitate tracking of the hazardous

waste types, hazardous waste management, and ensuring the utilization of hazardous waste according to regulations. In addition to the characteristics, hazardous waste management determined by the amount for packaging needs and shelf life. Several of the largest amounts of hazardous waste from workshop activities generate lubricating oil and metal, liquid hazardous waste from chemical lab activities, spray paint cans from material testing laboratory, then iron from CNC lab activities. The potential for enormous amounts of hazardous waste is due to those activities carried out in daily with the need for the usage of the materials in massive quantities as shown detail in table 1. in the supplementary file.

3.2. Packaging of Hazardous Waste at PPNS

The hazardous waste that has been identified in terms of its characteristics can then have its type of packaging determined. The packaging criteria, including materials and dimensions, must be adjusted based on the characteristics and the amount of hazardous waste generated. Additionally, the compatibility factors of each characteristic of hazardous waste also determine the division of packaging according to the Regulation of the Minister of Environment and Forestry number 6 of 2021. Based on the characteristics of hazardous waste at PPNS, which are toxic, flammable, and infectious, it is divided into 6 blocks with the types of packaging as shown detail in table 2. in the supplementary file.

Figure 1 shows the existing condition of hazardous waste packaging at PPNS, in the form of steel drum and plastic drum that stored improperly. Thus, the hazardous waste packaging at PPNS is planned with a design in containers comes in two types: steel and plastic, in drum and jumbo bag form. Steel containers have capacities of 5 liter, 100 liter, and 200 liter. Plastic containers have capacities of 25 liter and 100 liter. The design of hazardous waste packaging is based on the quantity and characteristics of the waste. The type of steel drum packaging is generally used for metal waste and oil from workshop activities, while plastic drum packaging is used for liquid waste from laboratory activities, packaging of hazardous waste and medical activities. Based on Ministry of Environment and Forestry Regulation No. 6 of 2021, the containers must be made of metal or plastic materials capable of holding hazardous waste according to the characteristics of the waste, as stipulated in Article 68, paragraph 2. The materials used for hazardous waste packaging are HDPE plastic and steel. These materials are resistant to leakage, corrosion, and strong, as recommended in the regulations (Article 52). Furthermore, in accordance with the Ministry of Environment and Forestry Regulation No. 6 of 2021, Appendix VII. Article 70, paragraph 2, mandates that hazardous waste containers must have symbols and labels.

As shown as figure 2, several hazardous waste packaging consists of steel drum, plastic drum and jumbo bags with various capacities. The packaging is completed with symbol and label. The label contains information about the source of waste, type, code, quantity and date of hazardous waste packaging in order to facilitate the storage and transportation of hazardous waste. The hazardous waste symbol is to indicate the characteristics of hazardous waste and simply to recognize basic information about the waste to minimize the risk of environmental pollution and health exposure. Meanwhile, the different colours of each drum indicate the different of the storage block based on its characteristics and type of the packaging (markers in the design, details on Figure 4).

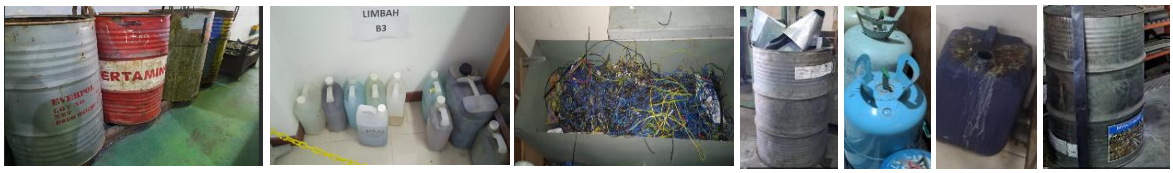
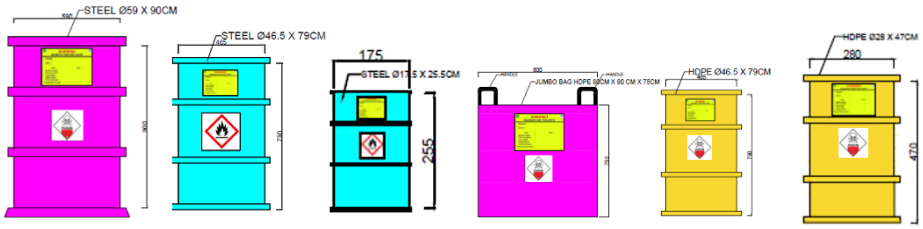


Figure 1. Hazardous waste packaging in existing condition of PPNS



(A) (B) (C) (D) (E) (F)

Figure 2. Hazardous waste packaging; a. steel drum packaging 200 liter; b. steel drum packaging 100 liter; c. steel drum packaging 5; d. jumbo bag packaging; e. plastic drum packaging 100 liter; f. plastic drum packaging 25 liter.

The design of hazardous waste containers is adjusted to the characteristics of the waste. This will impact the potential hazards to the surrounding environment. Furthermore, it will lead to environmental pollution, impacting human health (Exposto, 2021). Additionally, hazardous waste should not be disposed of directly into the environment. Hazardous waste must be stored using containers appropriate to its characteristics to prevent environmental harm (Xi et al., 2022).

3.3. The Storage Period for Hazardous Waste at PPNS

According to the data on hazardous waste generation calculated every 1 months, the planned storage period for hazardous waste is shortest for 90 days (3 months) and longest for 365 days (1 year). Additionally, the shelf life of hazardous waste is also influenced by the category of hazardous waste based on the Regulation of the Minister of Environment and Forestry number 6 of 2021. The hazardous waste stored for a period of 90 days is classified as waste with a volume of more than 50 kg per day including metal plates and iron shavings. Furthermore, hazardous waste stored for 180 days is classified as category 1 with a volume of less than 50 kg including refrigerant cylinders, oil, liquid hazardous waste, gloves, resin-coated wooden, batteries, grinding residues, cigarettes, used HCL bottles, leftover medicine bottles, syringes, needles. Meanwhile, the rest of hazardous waste categorizes as category 2 with a storage period 365 days, the detail data can be examined in Table 2 and Table 4 (supplementary file). The shelf-life requirements affect the need for packaging to be used. The planned packaging requirements for hazardous waste based on storage time is also detailed in table 3 in the supplementary file.

Table 3 shows that the packaging needed for cleaning cloth and batteries is the highest among all types of hazardous waste for 25 liter packaging at PPNS. The generation of cleaning cloth waste can be reduced by efficient the usage of cleaning cloth. Batteries are one type of hazardous electronic waste that can be addressed with the 3R principle (Reuse, Recycle, and Recovery) (Roy et al., 2022) supported by community participation (Safari et al., 2018). In addition, the highest packaging is also produced from the metal sheets and iron grams for steel drum 200 liter. Those hazardous waste generated from student practical activities in welding process learning. The planning of hazardous waste packaging will be successfully implemented if supported by the participation of the entire PPNS community in classifying hazardous waste according to its nature (Lara et al., 2017). This metal is an inorganic waste that is toxic and can pollute the environment if not managed properly (Zhang et al., 2022).

Waste storage at the hazardous waste storage site depends on the characteristic of hazardous waste. Each hazardous waste has different characteristics and shelf life. This affects the volume of hazardous waste storage site needed (Sengupta, 2018). It is in line with the findings of Inglezakis and Konstantinos (2015) that household-scale hazardous waste management with sorting based on characteristics is very effective in its management.

3.4. Pallet Requirements

Pallets are needed as a base for plastic or steel drum packaging. The maximum number of drum stacks will be 3 stacks, both metal and plastic, in accordance with the Ministry of Environment and Forestry Regulation No. 6 of 2021. Pallet requirements are adjusted to the dimensions and number of packages used. Therefore, pallet requirements can be calculated as follows, using pallet dimensions of 110 cm x 110 cm. The requirement for pallets as a base for hazardous waste packaging at the hazardous waste storage site at PPNS is 16 units, detailed in table 4 in the supplementary file. The details are 3 pallets for steel drum and jumbo bag in toxic block, 2 pallets for steel drum in flammable block, 1 pallet for plastic drum in toxic block, 4 pallets for plastic drum in flammable block, 5 pallets for plastic drum in toxic block, 1 pallet for plastic drum in infectious block. The most pallet needs in flammable and toxic blocks for plastic drum. Besides, the need for pallets for toxic blocks is also concerned with the presence of 200 liter steel drum packaging and jumbo bags. Hazardous waste packaging required includes various dimensions (59 x 90), (17.5 x 25.5), (46.5 x 79), (80 x 80 x 75), and (28 x 47). The packaging of hazardous waste determines the need for pallets and affect the dimensions of the storage area as well.

3.5. Storage Blocks

The determination of separation blocks for hazardous waste storage is based on the compatibility of the characteristics of each hazardous waste. The identified hazardous waste characteristics are flammable, toxic, and infectious. Hazardous waste in solid and liquid form with toxic, flammable, and infectious characteristics are not compatible according to Ministry of Environment and Forestry Regulation No. 6 of 2021, Appendix VI. Storing hazardous waste according to its characteristics will facilitate the subsequent processing (El-Saadony, 2023). The storage block division consists of:

a. Block 1: Toxic for solid waste with metal packaging, such as metal plates and iron scraps, copper pipes, refrigerant tubes, and iron.
b. Block 2: Flammable for liquid waste with metal packaging, such as lubricating oil, oil, and used oil.
c. Block 3: Toxic for liquid waste with plastic packaging, such as liquid hazardous waste
d. Block 4: Flammable for solid waste with plastic packaging, such as cables, electronic component legs, epoxy resin, gloves, majun cloth, and used resin wood.
e. Block 5: Toxic for solid waste with plastic packaging, such as pilox cans, batteries, grinding residue, markers, lamps, cigarettes, used HCL bottles, and leftover medicine bottles.
f. Block 6: Infectious for medical waste with plastic packaging, such as syringes and needles.

Based on these regulations, storage at the hazardous waste storage site is separated between each characteristic, in solid or liquid form, by fire-resistant wall partitions. The determination of the block dimension depends on the need of pallets and packaging in each block that has been intent on the amount and storage period of the hazardous waste. The block area defined 3.5 m x 2 m for blocks 1 and 4; 3 m x 2 m for blocks 2 and 5; 2,1 m x 2 m for blocks 3 and 6, it can be detailed in Figure 4.

3.6. The Hazardous Waste Storage at PPNS

The storage location for hazardous waste at PPNS is planned at the coordinates of latitude (-7.2826954) and longitude (112.7956782) that can be seen in Figure 3. This location is safe from floods and disasters in accordance with the Regulation of the Minister of Environment and Forestry number 6 of 2021. The storage of hazardous waste is adjusted according to its characteristics, generation, type of packaging, and packaging needs of hazardous waste.

The hazardous waste storage site layout can be determined after identifying the hazardous waste, type of packaging, and storage period. The hazardous waste storage site is planned with a building area of 7 m x 11 m. The building area is divided into several blocks according to the division of hazardous waste characteristics, consist of 6 blocks for hazardous waste storage according to the order from block 1 to 6, and 1 block/room for administrative or operator needs at the hazardous waste storage site. Each block is

separated by a 0.15-meter thick, 4-meter-high fire-resistant partition. Along the blocks, access for operational needs or human and vehicle traffic is designed. In addition to these regulations, based on Government Regulation No. 22 of 2021, this hazardous waste storage site building must also be equipped with supporting facilities such as collection tanks and drainage, fire extinguishers, lighting, and ventilation. The design of the hazardous waste storage site has been adjusted to the requirements of hazardous waste storage site in Ministry of Environment and Forestry Regulation No. 6 of 2021, articles 56, 60, and 67. However, it is not yet automatic in hazardous waste storage. This will affect the efficiency of hazardous waste management (Xu and Yang, 2022).

Figure 3. Planned coordinates for the storage site location of hazardous waste

3.6.1. Collection Tank

Based on Government Regulation No. 22 of 2021, the hazardous waste storage site facility must be equipped with a spill collection tank and drainage. The collection tank specifications, based on Ministry of Environment and Forestry Regulation No. 6 of 2021, are 110% of the largest hazardous waste packaging. The volume of the largest hazardous waste packaging is 0.2 m3, so the spill collection tank requirement is 0.22 m3. From this result, a collection tank with a minimum volume of 0.2 m3 is designed, resulting in dimensions of 200 cm x 150 cm x 200 cm. The collection tank functions as the final collection point for spilled hazardous liquid if it spills onto the floor. Therefore, the building floor is also designed to slope towards the final spill collection tank with a 1% slope. Spills are channelled to the collection tank through a 60 cm wide channel/ditch along the waste storage block, placed underground with a cover to avoid safety risks (Wisdayana et al., 2022). In addition, other supporting facilities are drainage to channel rainwater runoff to prevent flooding around the hazardous waste storage site.

3.6.2. Fire Extinguishers

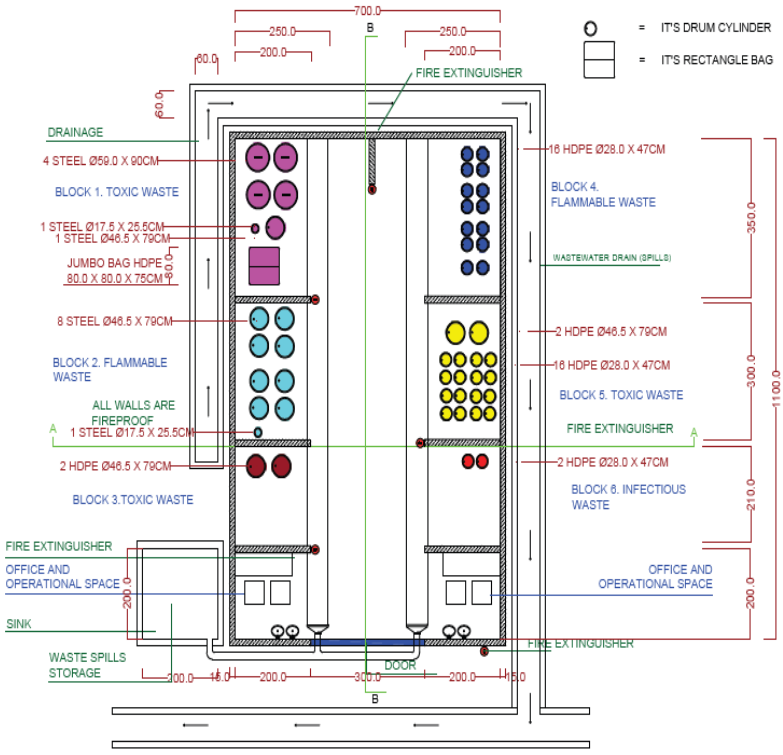
The provision of fire extinguishers (APAR) at the hazardous waste storage site is a mandatory requirement due to the storage of flammable hazardous waste, which has the potential to cause fires. The potential fire type is class B, so the fire extinguishers used are dry powder type. Based on Ministry of Manpower and Transmigration Regulation No. Per.04/Men/1980, the number of fire extinguishers in the room (formula equation 2) is 5 units. The requirement for 5 dry powder fire extinguishers in a 77 m2 building area. However, considering safety factors, the planned fire extinguisher provision is divided into 4 fire extinguishers placed inside the room and 1 outside. The placement of fire extinguishers inside the room is placed near the exit access near the flammable hazardous waste storage block. The placement of fire extinguishers outside the room is placed near the entrance. Each placement is on the wall, 90 cm from the floor, without any obstruction. According to El-Saadony et al. (2023), hazardous waste storage site must be equipped with safety equipment because all components in the hazardous waste storage site have the potential to be harmful to the environment.

3.6.3. Lighting

The hazardous waste storage site must have sufficient lighting with anti-spark criteria. This requirement can be calculated based on SNI 03-6575-2001 regarding building types. The hazardous waste storage site building can be categorized as a warehouse, so it must have a minimum illumination level of 100 lux. Based on the calculation (formula equation 1), the number of lamps required is 12 units. The calculation result for a 11 m x 7 m room area with a minimum illumination level of 100 lux requires 12 LED lamps of 25 watts with 1800 lumens. The lamps are placed in the centre of the room to maximize illumination and minimize the potential for sparks directly on the stored hazardous waste packaging.

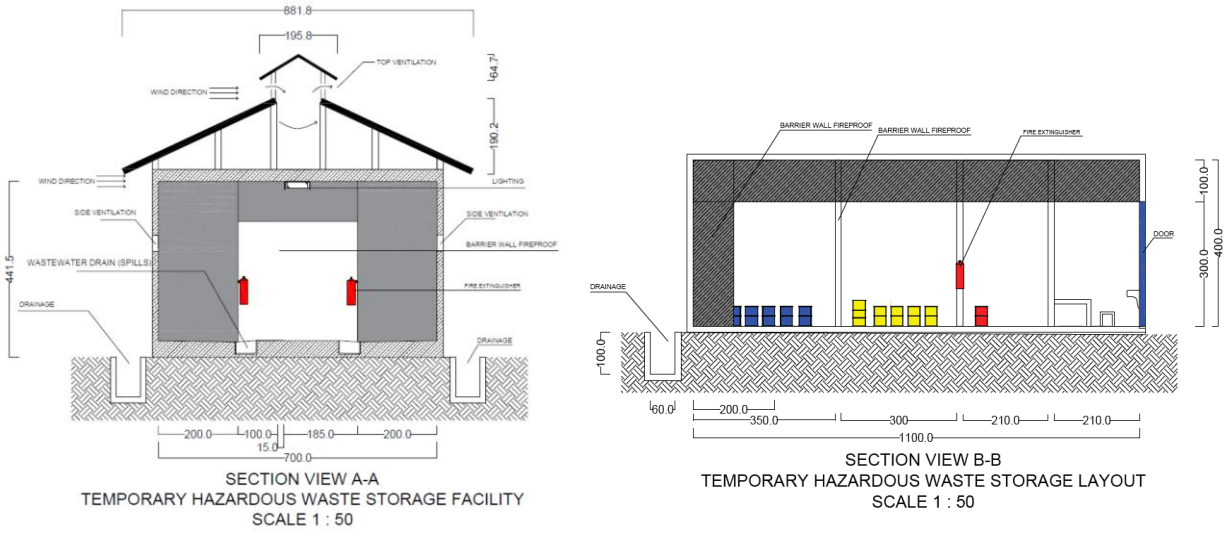
3.6.4. Ventilation

Ventilation is important to prevent potential explosions or fire risks from storing hazardous waste with flammable or explosive characteristics. The ventilation requirements for the hazardous waste storage site, based on SNI 03-6572-2001, are classified as class 7 buildings and are included in the storage/warehouse building type. Class 7 buildings must meet ventilation requirements of at least 10% of the room area to be used for air circulation. The hazardous waste storage site room area is 77 m^2. Therefore, the required ventilation area is 10% of 77 m^2, or 7.7 m^2. Based on this, the hazardous waste storage site building is designed with wider and higher roof ventilation, side and front building ventilation, and wide opening doors of 60 cm. Based on the layout description and supporting facilities, the design plan for the hazardous waste temporary storage can be depicted using AutoCAD software in Figure 4 for the 2-dimensional layout and Figure 5 for the 3-dimensional.



TEMPORARY HAZARDOUS WASTE STORAGE LAYOUT
SCALE 1 : 100

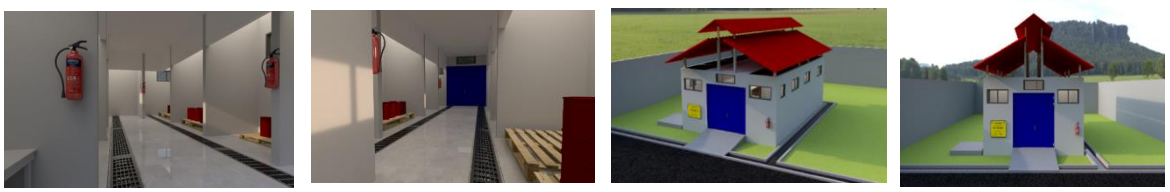
(A)



(B) (C)

Figure 4. Layout of the hazardous waste storage; (A) Block division and hazardous waste storage facility layout; (B) Cross-section A-A of the hazardous waste storage design; (C) Cross-section B-B of the hazardous waste storage design

As detailed in (Figure 4) hazardous waste storage designed with dimensions of 77 m² divided into several blocks. Block 1 for toxic characteristic covering an area of 7 m² with steel drum packaging with a capacity of 200 liters, 100 liters and jumbo bags. Block 2 for flammable characteristic covering an area of 6 m² with steel drum packaging with a capacity of 100 liters 5 liters. Block 3 for toxic characteristic covering an area of 4.1 m² with plastic drum packaging with a capacity of 100 liters. Block 4 for flammable characteristic covering an area of 7 m² with plastic drum packaging with a capacity of 25 liters. Block 5 for flammable characteristic covering an area of 6 m² with plastic drum packaging with a capacity of 100 liters and 25 liters. Block 6 for flammable characteristic covering an area of 4.1 m² with plastic drum packaging with a capacity of 25 liters. Each block is separated by a 0.15-meter thick, 4-meter-high fire-resistant partition (based on the maximum height of 3 stacks of the largest 200-liter drum packaging). While the hazardous waste is also completed for 2 operator rooms with an area of 4 m². In addition, it is equipped with a 3-wide for operational needs or vehicle traffic. Furthermore, the hazardous waste storage is also supported with wastewater drain with dimensions of 200 cm x 150 cm x 200 cm, drainage with dimensions 100 cm x 60 cm, adequate ventilation, sufficient lighting and 5 fire extinguishers. The building is designed with fire-resistant walls, fire-resistant roofs, and waterproof floors.



(A) (B) (C) (D)

Figure 5. Hazardous waste storage design; (a) hazardous waste storage rear block design; (b) hazardous waste storage front block design; (c) hazardous waste storage side view design; (d) hazardous waste storage front view design.

As presented in Figure 5. in the 3-dimensional model of the hazardous wate storage plan according to the design calculations. The hazardous waste storage is complete with the building location coordinates, security system of fire extinguishers, adequate ventilation from the top and sides of the building, sufficient lighting to cover the entire block. Moreover, hazardous waste storage divided into several blocks according to its characteristics, equipped with pallets for the base of the safety stored waste packaging, the fire extinguisher, and wastewater drain for collecting spills. The overall design has met the storage capacity needs and applicable regulatory standards.

4. Conclusions

This research concludes that the planned land area for the hazardous waste storage site building is 77 m^2 (long: 11 am and length: 7 m) at the coordinates of latitude (-7.2826954) and longitude (112.7956782). Hazardous waste at PPNS has toxic, flammable, and infectious characteristics. Based on the characteristics, the hazardous waste generated by PPNS is processed into a type of container in the form of steel drums, plastic, and jumbo bags with a capacity of 5 liters, 25 liters, 100 liters, and 200 liters. Furthermore, the packaging and the storage life of hazardous waste determine the dimension of the storage block based on each of the characteristics of hazardous. The block area is divided into several dimensions 7 m^2, 6 m^2, 4 m^2 depends on the capacity. Each block is separated by a 0.15-meter thick, 4-meter-high fire-resistant partition. The hazardous waste storage is also divided into operator rooms and access road for operational needs or vehicle traffic with designed a width of 3 m. The hazardous waste storage design equipped with supporting facilities such as ventilation (7.7 m^2), fire extinguishers (5 units), lamps (12 units), a collection tank (200 cm x 150 cm x 200 cm) with a block system (6 blocks). Further research can be developed on hazardous waste processing to reduce the waste generated at PPNS. Furthermore, subsequent research can also be developed on hazardous waste management based on the Internet of Things (IoT). This will significantly affect the capacity of the hazardous waste storage site to remain usable for a longer time and be more efficient.

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