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Identification of Types and Characteristics of Hazardous Waste at Campus X

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Keywords

B3 Waste; Waste Generation; Hazardous Characteristics; Campus Environment; Waste Management

Abstract

Hazardous and toxic waste (B3 waste) management in higher education environments is important to prevent environmental pollution and health risks caused by improper waste handling. Campus operational activities, laboratories, offices, and facility maintenance activities have the potential to generate various types of hazardous waste that require proper management according to environmental regulations. This study aimed to identify the types, characteristics, sources, and generation of B3 waste produced at Campus X. The research used a descriptive observational method through direct field observations, waste generation measurements for seven consecutive days, documentation, and short interviews during the observation process. The results showed that hazardous waste generated at Campus X originated from laboratory activities, office activities, campus operational activities, and equipment maintenance. The identified waste types included electronic waste, used batteries, expired chemicals, infectious waste, fluorescent lamps, and used hazardous waste packaging. The total hazardous waste generation during the observation period reached 57.53 kg with an average generation of 8.22 kg/day. Most of the waste characteristics were classified as toxic, corrosive, infectious, flammable, and environmentally hazardous. The study also found that hazardous waste segregation and temporary storage practices at Campus X were still not fully implemented according to technical standards. Therefore, improvements in waste segregation systems, provision of temporary storage facilities, and strengthening of hazardous waste management practices are necessary to support environmentally sustainable campus management.

INTRODUCTION

According to Law Number 32 of 2009 concerning Environmental Protection and Management, waste is defined as the residue of activities or business processes that may cause environmental pollution if not properly managed. One type of waste requiring special attention is hazardous waste, as it contains substances that may pose risks to human health and cause damage to environmental ecosystems (Kabul et al., 2024). Improper handling of hazardous waste may result in soil contamination, water pollution, air quality degradation, and long-term ecological impacts (Sihite, 2021). Hazardous waste in higher education institutions is primarily generated through laboratory activities, equipment maintenance, administrative operations, and healthcare services (Dinayah & Novembrianto, 2023). Various types of waste such as used chemicals, electronic waste, used batteries, infectious waste, and expired laboratory materials are commonly produced from these activities (Rafidah & Yunus, 2023). Although the quantity generated in educational institutions is generally smaller than in industrial sectors, improper management still has the potential to create environmental and health risks within the campus area and surrounding communities (Aisha et al., 2021).

The measurement of hazardous waste generation is an important aspect of environmental management because it provides basic information regarding the quantity, characteristics, and sources of waste produced (Wilujeng et al., 2021). In addition to environmental impacts, improper management of hazardous and toxic waste may also create occupational health risks for campus communities (Exposto & Sujaya, 2021). Laboratory personnel, cleaning service workers, students, and maintenance staff are among

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the groups that are directly exposed to hazardous substances generated from campus activities (Aulia & Suhardono, 2024). Exposure to chemical residues, infectious materials, heavy metals from electronic waste, and corrosive substances may result in respiratory disorders, skin irritation, poisoning, and other long-term health effects when waste-handling procedures insufficiently enforced (Gunasekara et al., 2026). Therefore, adequate waste-segregation systems, safety equipment, and temporary storage facilities are essential for minimizing potential risks within the campus environment (Ferrucci, 2024).

Higher education institutions currently play an important role in supporting environmentally sustainable development through the implementation of the green campus concept (Sadaqat et al., 2025). This concept encourages universities to extend their focus beyond academic activities by strengthening environmental responsibility in daily operations, including waste-management systems. Proper hazardous waste management reflects institutional commitment toward environmental protection and sustainable resource management (Rico et al., 2023). Several universities in Indonesia have started implementing integrated waste management systems; however, the implementation level varies significantly depending on institutional policies, facilities, financial support, and environmental awareness among campus communities (Rico et al., 2021). The growing use of electronic devices, laboratory chemicals, and educational support equipment has also contributed to increased hazardous-waste generation within educational institutions (Asmat-Campos et al., 2025). Electronic waste such as damaged computers, laboratory instruments, batteries, and fluorescent lamps contains hazardous substances including lead, mercury, and cadmium which may contaminate soil and groundwater if disposed of improperly.

Similarly, chemical waste generated through laboratory activities may react with the surrounding environment and produce harmful effects when mixed with general waste. These conditions underscore the need for continuous monitoring and evaluation of hazardous-waste management within university environments (Dahalan & Mulia, 2025).

Several previous studies have identified key challenges in hazardous-waste management within educational institutions, including limited temporary storage facilities, inadequate waste-classification practices, insufficient knowledge among waste handlers, and insufficient monitoring systems (Arumdani et al., 2021). In some cases, hazardous waste remains mixed with domestic waste because of unclear operational procedures and limited awareness of environmental risks (Ruliana et al., 2016). These findings highlight the continued need to strengthen hazardous-waste management systems in educational institutions to support safer and more environmentally responsible campus operations (Siregar et al., 2026). Through the identification of waste types, characteristics, and generation rates, educational institutions can obtain baseline data required for planning sustainable waste management strategies. This information is necessary to assess storage capacity needs, develop waste segregation systems, transportation requirements, and formulate partnership arrangements with licensed third-party waste-treatment providers (Hasiany et al., 2023). Furthermore, comprehensive waste data may assist universities in evaluating their environmental performance and improving institutional compliance with environmental regulations. Through waste generation data, institutions can determine appropriate storage capacity, waste segregation systems, transportation planning, and suitable treatment methods in accordance with environmental regulations.

In addition, accurate identification and quantification of hazardous waste contribute to environmental protection by reducing the risks associated with uncontrolled disposal and environmental contamination (Wichard et al., 2025).

Regulation of the Minister of Environment and Forestry No. 6 of 2021 and Government Regulation No. 22 of 2021 require all hazardous-waste-generating institutions to manage such waste appropriately through reduction, storage, labeling, documentation, transportation, and final treatment (Irawan et al., 2019). However, several studies have shown that hazardous waste management practices in educational institutions are still not fully implemented according to technical standards. Limitations in temporary storage facilities, lack of waste segregation practices, and insufficient monitoring systems are among the common problems found in many campuses in Indonesia (Ari et al., 2024). Based on preliminary observations conducted at Campus X, several issues related to hazardous waste management were identified. Hazardous waste generated from laboratories and campus operational activities was still stored separately in each unit without a standardized temporary storage facility for hazardous waste. In addition, waste recording activities had not been conducted consistently, and several waste types were still mixed with general waste. These conditions indicate that the current hazardous waste management system at Campus X still requires evaluation and improvement to comply with applicable environmental regulations (Nurulasyrof & all, 2023).

Earlier studies on hazardous-waste management in educational institutions have generally focused on laboratory waste-management systems and waste-treatment methods (Matin et al., 2021). However, research specifically identifying the types, characteristics, and generation of hazardous waste from various campus activity sources in an integrated manner remain limited. Therefore, this study aims to provide a comprehensive analysis of hazardous-waste generation at Campus X, including the identification of waste sources, characteristics, and quantities, as a basis for improving campus environmental-management systems. This study seeks to promote sustainable environmental-management practices in higher education institutions and contribute to the achievement of Sustainable Development Goal 12, which concerns responsible consumption and production. Its findings may also serve as a basis for campus policy development on hazardous-waste management and environmental protection (Deanova et al., 2022).

RESEARCH METHOD

This study employed a descriptive observational design to identify the types, characteristics, and generation rates of hazardous and toxic waste at Campus X. Data were collected through waste-generation measurements, direct field observations, documentation, and brief interviews with personnel involved in campus operations and laboratory activities. The observations focused on waste sources, characteristics, temporary-storage conditions, segregation practices, and daily waste generation across several campus activity units. Waste generation measurements were conducted using gravimetric methods through direct weighing of hazardous waste generated during the observation period. In addition, short interviews were conducted to obtain supporting information regarding existing waste handling practices and operational conditions in the field. Documentation activities were also carried out to support the observation results and provide visual evidence related to hazardous waste management conditions at Campus X. To obtain consistent and representative data regarding hazardous waste generation at Campus X, several sampling and measurement procedures were applied during the observation process. These

Table 1
Embankment Sampling Techniques

Components	Descriptions
Sampling Period	It is carried out for 1 week (7 consecutive days) with normal campus activity conditions.
Sampling Frequency	Weighing was carried out once every day for 7 days so that there were 7 data generated.
Sampling Method	Using the waste generation sampling method with gravimetric techniques (direct weighing).
Sampling Procedure	-Collect waste from each source -Segregate based on hazardous and hazardous materials characteristics -Weigh the total daily waste weight -Record the results on the waste generation form
Weekly Generation Formula	$T_h = \frac{\sum W_i}{7}$ (1) Th: Average daily generation (kg/day) Wi: Weight of waste on day -(i)
Respondent Selection Technique	Purposive sampling, with the following criteria: officers are directly involved, understand the waste management process

Source: Processed Primary Data, 2026

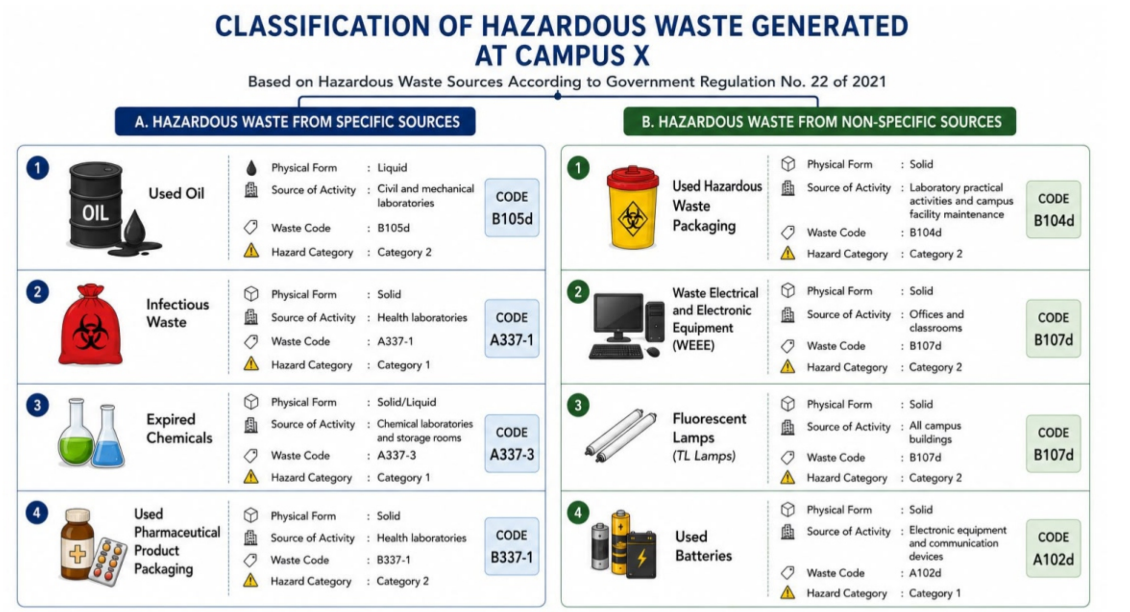
procedures were arranged to ensure that waste identification, weighing activities, and data recording could be carried out systematically throughout the sampling period. The components and stages used in the waste generation sampling process are presented in Table 1.

RESULT AND DISCUSSION

Identification of Types, Sources, and Characteristics of Hazardous Waste

Field observations showed that hazardous waste generated at Campus X mainly originated from laboratory activities, campus operational activities, equipment maintenance, and cleaning activities. During the observation process, several waste types were found stored separately in each activity unit, although some units had not yet implemented consistent waste segregation practices based on waste characteristics. Temporary storage conditions also varied between units depending on the availability of storage containers and operational activities conducted in each location. Short interviews conducted during the observation process indicated that several campus personnel were still facing limitations in hazardous waste handling practices, closely linked to temporary storage facilities and waste segregation systems. One laboratory staff member stated that hazardous waste generated from laboratory activities was generally stored temporarily in each laboratory room before being collected for further handling. Similar conditions were also observed in several campus operational units where electronic waste and used batteries were accumulated in storage areas due to the absence of a centralized hazardous waste temporary storage facility. Based on the observation and identification results, various types of hazardous and toxic waste were found from different campus activity sources. The identified waste was then classified according to its characteristics, source categories, physical forms, and hazard classifications based on Regulation of the Minister of Environment and Forestry No. 6 of 2021 on Procedures and Requirements for the Management of Hazardous and Toxic Waste. The detailed identification results are presented in Figure 1.

Based on the identification results presented in Figure 1, it is known that there are eleven types of hazardous waste generated from various activities on



Source: Processed Primary Data (2026)

Figure 1

Results of Identification of Types and Characteristics of Hazardous Waste

campus, particularly those related to laboratory activities, offices, and facility maintenance. These types of waste include used oil, used hazardous packaging, used electronics (e-waste), used batteries, infectious waste, expired chemicals, fluorescent lamps, used pharmaceutical product packaging, contaminated fabrics, and expired pharmaceutical products. The waste generated generally exhibits hazardous characteristics, notably flammability, toxicity, corrosiveness, and infectiousness. Based on Government Regulation No. 22 of 2021, the waste produced consists of hazardous waste from specific sources, general specific sources, and non-specific sources. Meanwhile, the waste produced varies in form, including liquid and solid.

The identification results indicate that electronic waste and used batteries were the predominant types of hazardous waste generated at Campus X. This condition is related to the increasing use of electronic equipment to support academic and administrative activities within the campus environment. Electronic waste generally contains hazardous substances such as lead, mercury, and cadmium that may pollute soil and groundwater if disposed of improperly. In addition, damaged electronic equipment is often accumulated for extended periods before being transported for further treatment, thereby increasing the potential risk of environmental contamination. Expired chemicals and infectious waste generated from laboratory activities also require special attention due to their hazardous characteristics. Chemical waste may react with other substances and potentially cause environmental pollution when mixed with general waste. Meanwhile, infectious waste generated from health laboratory activities may contain biological contaminants that can threaten public health if not handled using proper safety procedures. These conditions underscore the importance of segregating waste according to its characteristics to minimize environmental and health risks on campus.

Based on observations, several activity units had attempted to separate hazardous waste according to waste type; however, the implementation was still inconsistent due to limited storage facilities and the absence of centralized temporary hazardous waste storage areas. Similar findings were also reported in previous studies conducted in educational institutions, where hazardous waste management practices were often constrained by limited facilities, lack of monitoring systems, and insufficient operational support (Susi et al., 2021). Therefore, enhancing waste management systems and enhancing environmental awareness among campus communities are essential to promoting sustainable campus operations. The generation of hazardous waste from operational activities further underscores the need for ecologically responsible management systems within higher education institutions. Beyond their educational role, universities can promote sustainable environmental practices through green-campus programs. Effective hazardous-waste management can protect the environment, mitigate pollution risks, and support Sustainable Development Goal 12 on responsible consumption and production.

Hazardous Waste Generation

Hazardous waste generation at Campus X was quantified the measurements described in the Research Method section. The measurement results showed that the total hazardous waste generated during the seven-day observation period was 52.63 kg, resulting in an average daily generation of 7.52 kg/day. A summary of the types and quantities of hazardous waste generated is presented in Table 2.

Based on Table 2, it can be seen that the types of hazardous waste generated in the Campus X campus environment are quite diverse, including infectious waste, used pharmaceutical product packaging, electronic waste, TL lamps, batteries, expired chemicals, contaminated cloth, used batteries, and used B3 packaging. This variety of waste types shows that the waste sources come from various activities such as health services, laboratory activities, and maintenance of campus facilities.

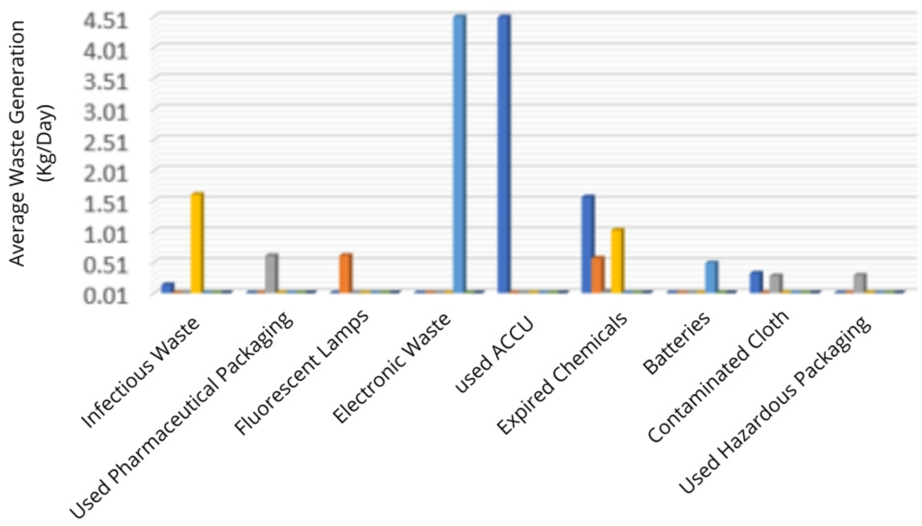
The total generation of hazardous and toxic waste during the 7 days of observation was 52.63 kg, with an average generation of 7.52 kg/day. The amount of waste generated exhibited significant daily fluctuations The highest generation occurred on the 5th day at 30.5 kg, which was dominated by electronic waste, thus indicating the activity of disposing or replacing large amounts of electronic equipment on that day. In addition, battery waste contributed substantially on the first day, reaching 15 kg, indicating intensive battery replacement activities.

Expired chemical waste also contributed to the generation of hazardous and toxic waste on several observation days in varying amounts, although not as large as electronic waste and batteries. Meanwhile, other types of waste such as

Table 2
Recapitulation of Types and Amounts of Hazardous and Toxic Waste Piles at Campus X

Types	Generation (KG)							Average day/KG
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	
Infectious waste	0.143	0	0	1.613	0	0	0	0.25
Used pharmaceutical product packaging	0	0	0.616	0	0	0	0	0.09
TL lamps	0	0.62	0	0	0	0	0	0.09
Used electronics	0	0	0	0	30	0	0	4.29
Used batteris	15	0	0	0	0	0	0	2.14
Expired chemicals	1.575	0.576	0.032	1.032	0	0	0	0.46
Used batteris	0	0	0	0	0.5	0	0	0.07
Used rags	0.331	0	0.289	0	0	0	0	0.09
Used B3 packaging	0	0	0.3	0	0	0	0	0.04
Number of types of waste day	17.049	1.196	1.237	2.645	30.5	0	0	7.52
Total				52.63				

Source: Processed Primary Data, 2026



Source: Processed Primary Data (2026)

Figure 2

Hazardous Waste Generation Graph/Day

infectious waste, pharmaceuticals, fluorescent lamps, used batteries, and contaminated fabrics and packaging had relatively small amounts and did not occur every day, indicating that this waste was generated incidentally according to specific needs or activities. These fluctuations indicate that hazardous-waste generation was highly dependent on the daily operational activities carried out across the campus during the observation period. The significant increase in waste generation on the fifth observation day was mainly associated with the disposal and replacement of electronic equipment from several campus units. Electronic waste generally accumulates over a certain period before being collected simultaneously, resulting in higher waste quantities on particular days. Similar conditions were also observed for used batteries, where replacement activities were not conducted routinely every day but occurred periodically depending on equipment conditions.

Compared with other types of hazardous waste, infectious waste and expired pharmaceutical products showed relatively smaller quantities during the observation period. However, despite their lower generation amounts, these waste types still require careful handling because they pose greater risk to both human health and the environment. Infectious waste, for example, may contain microorganisms capable of causing disease transmission if disposed of improperly. Therefore, proper packaging, labeling, and temporary storage procedures remain essential even for waste generated in smaller quantities. The results of this study generally show similarities with previous research conducted in educational institutions, where hazardous waste generation is commonly dominated by laboratory waste, electronic waste, and maintenance-related waste. Research conducted by Susi et al. (2021) also reported that educational institutions produce various hazardous waste types originating from academic, laboratory, and operational activities. However, differences in waste quantities may occur depending on campus size, laboratory intensity, operational activities, and the availability of waste management facilities.

In addition, the absence of a centralized hazardous waste temporary storage facility at Campus X may potentially affect the effectiveness of waste handling practices. During observations, several hazardous waste types were still types were still stored separately in each operational unit due to limited storage infrastructure. This condition may increase the risk of improper waste handling, inappropriate waste mixing, and environmental contamination if not properly managed. Therefore, the provision of standardized temporary storage facilities is considered necessary to support safer hazardous waste management practices on campus. From an environmental management perspective, hazardous waste generation data are important as a basis for planning future waste management systems. Information regarding waste quantity, characteristics, and generation patterns may assist institutions in determining transportation schedules, storage capacity requirements, waste reduction strategies, and cooperation mechanisms with licensed third-party waste treatment services. Continuous monitoring of hazardous waste generation is also necessary to evaluate the effectiveness of implemented management systems and support environmentally sustainable campus development.

Overall, the pattern of hazardous waste generation by type exhibits fluctuating characteristics and is strongly influenced by specific activities taking place on campus, such as laboratory activities, health services, and equipment maintenance and replacement. Several types of hazardous waste did not appear during the sampling period, namely used oil waste from the mechanical laboratory and pharmaceutical product waste from the health laboratory. Although not identified during the observation, based on literature studies, it is known that laboratory activities on campus still have the potential to generate such waste. Without appropriate management, this condition may lead to improper waste handling, inadequate waste segregation, and increased environmental exposure to hazardous substances.

Therefore, for the purposes of planning the capacity of the hazardous waste disposal site, a generation estimation approach was used based on literature. The generation of hazardous waste was assumed to be 0.7 kg/day, originating from pharmaceutical products and used oil (Susi et al., 2021; Alfina et al., 2023). Thus, the total generation of hazardous waste over 7 days increased from 52.63 kg to 57.53 kg, with an average generation of 8.22 kg/day.

CONCLUSION

The identification results show that the hazardous waste generated at Campus X originates from various activities, including office, domestic, laboratory, equipment and machine maintenance, photocopying, campus cleaning, and laboratory equipment. The types of hazardous waste generated consist of specific sources such as used oil; non-specific sources such as used hazardous waste packaging, used electronics, fluorescent lamps, batteries, and contaminated cloth; and general specific sources such as infectious waste, expired chemicals, expired pharmaceutical products, and used pharmaceutical product packaging. The characteristics of the hazardous waste generated include toxic, corrosive, infectious, flammable solids, flammable liquids, and hazardous to the environment. Based on the results of measurements during 7 days of observation, the generation of hazardous waste at Campus X was 57.33 kg with an average daily generation of 8.22 kg/day. These findings highlight the need to strengthen the hazardous-waste management system at Campus X by establishing standardized temporary storage facilities, implementing consistent waste-segregation practices, conducting routine monitoring, and promoting environmental awareness among the campus community. In addition, cooperation with licensed hazardous waste management companies is important to ensure that hazardous waste generated from campus activities can be managed safely and in accordance with applicable environmental regulations.

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