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Regional Case Study

Hazardous Solid Waste Management in Universitas Diponegoro: Planning Towards Environmental Sustainability

Sri Sumiyati[1], Bimastyaji Surya Ramadan[1], Mochamad Arief Budihardjo[1], Aufa Rahma Al-Hafidz[1], Haekal Awliya Muhammad Salman[1*], Rizal Adi Wirawan[1]

[1] Departemen Teknik Lingkungan, Fakultas Teknik, Universitas Diponegoro, Jl. Prof. Soedarto, SH, Kampus Undip Tembalang, Semarang, Indonesia 50275
*Corresponding author, e-mail: haekal.awliya@gmail.com

Abstract

Universitas Diponegoro has a role in contributing to considerable numbers of hazardous solid waste from academic activities as it is the largest university in Central Java Province, Indonesia. Therefore, improper hazardous solid waste will cause potential disease for humans and pollute the environment. For this reason, proper hazardous solid waste management is urgently needed. This research aims to design hazardous solid waste management for Universitas Diponegoro as a pilot testing study. The research used questionnaires, surveys, in-depth interviews, and observations to construct an appropriate hazardous waste management system. The result showed that hazardous solid waste in Universitas Diponegoro came from 5 sources: education, office, laboratory, supporting facilities, and Pleburan Campus. The estimation of hazardous solid waste produced by the Universitas Diponegoro in 2021 is as much as 100.4 kg/day. The hazardous waste characteristics are toxic, corrosive, flammable, and infectious. In the hazardous management planning that was developed, the design of the waste transportation and storage system at the waste station in the Tembalang and Pleburan campuses has a total investment and operation cost of Rp 6,259,841,999 for 10 years of operation. This design is hoped to enhance the campus's achievement in sustainability efforts.

Keywords: Environmental sustainability; hazardous solid waste; Universitas Diponegoro; waste management system

1. Introduction

Campus sustainability is a primary concern of many universities around the world. Management of the universities is opening their eyes to commit to environmental sustainability through several policies and operations (Alshuwaikhat and Abubakar, 2008). Some universities are also participating in a voluntary metrics such as UI Greenmetric (Suwartha and Sari, 2013), the Academic Ranking of World Universities, the Times Higher Education World University Ranking (Liu et al., 2019), Environmental and Social Responsibility Index (Puertas and Marti, 2019), and many more as part of their effort to participate in the sustainable development goals. Therefore, the primary concern in all metrics is how the universities include eco-friendly systems in their daily activities.

Universitas Diponegoro (UNDIP) is one of the largest public universities in Central Java. In 2021 the number of students, lecturers, and employees at Universitas Diponegoro was 59,867 (Sumiyati et al.,

2021). The previously reported study mentioned that UNDIP produced around 4,574.1 kg/day of waste from academic activities and supporting facilities. Most of the waste consists of organic waste, which accounted for more than 50%, followed by paper, plastics, cardboard, metal, and other waste. All wastes are still mixed. There is a center solid waste processing facility in Tembalang Campus to separate all waste before being sent to landfill (Budihardjo et al., 2021a).

UNDIP has received the UI GreenMetric 2020 award with a national 2nd rank, While, at the international level, Undip is ranked 39th out of 912 universities from 84 countries. As waste management becomes one of the critical points of sustainability assessment, there is a need to maintain the achievement through a better waste management system. However, as far as this research conducted, the hazardous waste management effort on the UNDIP campus is still low, and only adequately managed the campus hospital hazardous waste. At the same time, laboratory activities have many possibilities to generate much hazardous waste (Budihardjo et al., 2021b). Managing hazardous waste is essential for achieving campus sustainability. Thus, better management practice is needed. For instance, in the Universidad Autonoma de Nuevo Leon, some policies engage the staffs and students to do the hazardous waste management program at the university. They also proposed a new hazardous waste classification, primarily for chemical laboratories (Ramírez Lara et al., 2017). METU campus, Turkey, has a Hazardous Waste Commission on their campus, which is responsible for managing the generation of hazardous waste. This commission is also part of laboratory safety to ensure that any hazardous waste can be managed safely (Bahçelioğlu et al., 2020). Scientific evidence has proven that initiatives on integrated solid waste management on campus will help the management pursue continual improvement, promote regulatory compliance, and promote environmental awareness within the community (Alshuwaikhat and Abubakar, 2008; Parvez et al., 2019; Ugwu et al., 2020). However, there is a lack of information on how to design a good and better hazardous waste management system partially. Therefore, there is a need for the campus to make a sustainable plan to manage their waste, thus leading appropriate waste management in the city since the campus acts as a small city that needs an adequate waste management infrastructure system.

The government has regulated hazardous waste management through Government Regulation no. 101 of 2014 concerning Management of Hazardous and Toxic Materials. Based on Government Regulation No. 101 of 2014 in Chapter II, Article 3 paragraph 1 states that "Everyone who produces hazardous waste is obliged to manage it." Hazardous waste management activities are a series of activities that include reducing, storing, and landfilling hazardous waste (Kepmen LH No. 18 of 2009). This study describes the hazardous solid waste generation and composition at Universitas Diponegoro, thus, designing a sustainable waste management system by optimizing transportation, storage, and disposal of hazardous waste at Universitas Diponegoro. The investment and operational costs were also calculated for a better sustainable waste management system.

2. Methods

Universitas Diponegoro has 5 campuses where Tembalang Campus is the main and the largest campus, which has also become the center of academic activity of Universitas Diponegoro. Pleburan Campus, located in the center of Semarang City, is the former campus, and now, only postgraduate studies take place (Budihardjo et al., 2021b). Pleburan campus is separated around 9 km away from the Tembalang Campus. The other 3 campuses are located outside Semarang City (Batang City, Pekalongan City, and Rembang City). This study focuses on the hazardous solid waste produced by all activities in Pleburan and Tembalang Campus, Universitas Diponegoro. Hazardous solid waste in campus activities mainly comes from offices and laboratories such as lamps, cartridges, used batteries, electronic equipment, and laboratory tools and materials. There are 5 clusters of facilities determined as the potential source of hazardous waste in Universitas Diponegoro, including education, office, laboratory, supporting facilities, and Pleburan Campus. This research consists of two stages: data collection and processing, which will be explained further in the following sub-section.

2.1. Data Collection

The amount of waste generated and the existing waste management system are identified. The waste generation was determined by sampling waste in the 5 sources. Each source was calculated using the SNI 19-3964-1994 method concerning the Collection and Measurement of Samples of Generation and Composition of Municipal Waste. Since all waste is directly collected at a facility called Undip's integrated solid waste processing facility (Undip ISWPF), the sampling was carried out at the ISWPF with the sample sources presented in Table 1.

Table 1. Number of samples per sector collected in Undip ISWPF

No	Facilities Cluster	Sources
1.	Education	Faculty of Medical
		Faculty of Science and Mathematics
		faculty of Economics and Business
		Faculty of Agriculture and Livestock and Agriculture
2.	Office	MWA WP
		ICT PKM
3.	Supporting facilities	Diponegoro National Hospital
		Campus Mosque
		Diponegoro gas station
4.	Pleburan	Faculty of Law (postgraduate)
		Faculty of Economics and Business (postgraduate)

While the number of laboratory sources is defined using cluster sampling, which is taken by specific criteria according to the cluster. Each laboratory activity has different activities depending on the materials used in the laboratory. Laboratory materials are divided into unique materials and available materials as described in the general provisions of the Regulation of the Minister for Empowerment of State Apparatus and Bureaucratic Reform Number 03 of 2010. The number of laboratories at Universitas Diponegoro, the number of samples required, and the locations of the laboratories to be sampled are listed in Table 2.

Table 2. Type and number of laboratory samples of hazardous waste

No	Facilities Cluster	Total	Sample
1.	Physics/Chemistry (Special)	36	6
2.	Biology	36	6
3.	Medical/Clinic	5	2
4.	Physics/Chemistry (General)	4	2

2.2. Data Processing and Analysis Techniques

Data processing and analysis have three stages. Starting with design preparation by evaluating the data from the available documents with the required criteria. The criteria required to refer to 5 aspects of waste management operational, technical, legal and regulatory, institutional, financial, and community participation aspects (Kemen PU, 2013). The last stage is to provide recommendations so that the sustainable waste management system can continue to run. Recommendations are given based on the data obtained, evaluation of data analysis, and the design note performed. The recommendations will be helpful for the authority of waste management to create a proper strategy to reduce waste that goes to IWPFs and landfill sites.

3. Result and Discussion

This study used a scenario of hazardous solid waste segregation at the Tembalang and Pleburan campuses because the planning area is in the two separated areas, requiring two hazardous solid waste management system plans. This research will analyze the advantages and disadvantages of each waste management system to get the most effective design.

3.1 Analysis of the Existing Condition of Waste Generation

Calculation of the projection of hazardous waste generation in the next 10 years requires data on the average generation unit. Table 3 presents the projected hazardous waste generation in each source. Laboratory activity has the highest hazardous waste generation compared to other sources.

Table 3. Projected total hazardous waste generation on 2021-2030

Year	Weight (kg/person/day)					Volume (Liter/person/day)				
	Education	Pleburan Campus	Office	Facilities	Laboratory	Education	Pleburan Campus	Office	Facilities	Laboratory
2021	0.0001	0.0006	0.0006	0.0022	1.1110	0.0017	0.0027	0.0309	0.0617	31.5107
2022	0.0001	0.0007	0.0007	0.0023	1.1334	0.0018	0.0028	0.0315	0.0629	32.1341
2023	0.0001	0.0007	0.0007	0.0023	1.1549	0.0018	0.0028	0.0321	0.0641	32.7447
2024	0.0001	0.0007	0.0007	0.0024	1.1760	0.0018	0.0029	0.0327	0.0652	33.3427
2025	0.0001	0.0007	0.0007	0.0024	1.1967	0.0019	0.0029	0.0333	0.0664	33.9285
2026	0.0001	0.0007	0.0007	0.0024	1.2169	0.0019	0.0030	0.0338	0.0675	34.5023
2027	0.0001	0.0007	0.0007	0.0025	1.2368	0.0019	0.0030	0.0344	0.0686	35.0644
2028	0.0001	0.0007	0.0007	0.0025	1.2562	0.0020	0.0031	0.0349	0.0697	35.6151
2029	0.0001	0.0007	0.0007	0.0026	1.2752	0.0020	0.0031	0.0354	0.0707	36.1547
2030	0.0001	0.0008	0.0008	0.0026	1.2938	0.0020	0.0032	0.0360	0.0718	36.6834

Based on Table 3, hazardous waste generation at Universitas Diponegoro is projected to increase every year. The increasing number of campus residents will gradually increase the number of hazardous wastes generated on the campus. In 2030, hazardous waste will be generated as much as 1.29 kg/person/day or 36.79 l/person/day.

3.2 Sustainable Hazardous Solid Waste Management in Diponegoro Campus

The sustainable hazardous solid waste management system is designed by arranging waste from storage to processing to a ^{third} parties includes sorting the waste according to the hazardous category by campus residents with garbage collection in each sector; transport of waste using a 3-wheeled motor box to the waste station located at the Tembalang campus and the pleburan campus; waste sortation according to its respective characteristics and accommodated in a container with a regulated distance; and hazardous waste final processing by ^{third} parties.

3.2.1 Storage and Sorting

Universitas Diponegoro hazardous solid waste storage is carried out with a sorting system at the source. Garbage containers are designated only for hazardous solid waste such as expired drugs, a bleach for clothes, batteries, and fluorescent lights. Hazardous solid waste containers are planned for all sectors at Universitas Diponegoro. This container is used to accommodate hazardous waste in all facilities for 1 week. The results of the total housing requirements for all units from this calculation can be seen in Table 4. It can be seen from table 4 that the total need for 50 liter containers at Universitas Diponegoro is 64, while for transport containers with a volume size of 240 liters, it requires 17. The laboratory container is combined with education. Specifically for RSND and ICT at this location, there is no need to use container planning because they already have a waste station at the existing location. Figure 1 shows the waste station at RSND and ICT.

Table 4. The total requirement for 50-liter containers and 240 liter carts

Facilities Cluster	Unit	Generation (l/day)	Container 50 liter	Container 240 liter
Education	FH FISIP	23.87	0	1
	FIB	9.99	1	1
	SV	15.95	5	1
	FT 1	9.68	1	1
	FT 2	15.71	8	1
	FEB	7.58	1	1
	F.PSI	3.65	1	1
	FSM	11.50	6	1
	FPIK	9.77	8	1
	FPP	7.75	4	1
	FK FKM	18.31	9	1
Office	WP	1.39	0	1
	ICT & UPT	16.35	0	0
Supporting facilities	RSND	51.71	0	0
	UNDIP Apartment	69.26	10	1
	UNDIP Gas Station	2.60	0	1
	Mosque	34.46	5	1
Pleburan	FH PLE	7.54	1	1
	FEB PLE	9.22	1	1
Total		326.28	62	17

Figure 1. Transfer station of hazardous waste in RSND and UPT

3.2.2. Transport and Collection

A collection vehicle is a tool used to collect hazardous waste from the source to the waste station which can be box cars and motorbikes. The advantage of using a box car is that the transported hazardous waste can reach a large volume capacity, but the drawback is that it cannot reach all areas at Universitas Diponegoro which have narrow roads so that it cannot be accessed by a box car. The advantage of using a box motorbike is that it can reach all access roads in the service area, but the carrying capacity of a box motorbike is not as big as that of a box car. Considering the above advantages

and disadvantages, in this design concept, a hazardous solid waste transportation fleet was selected using a motor box, because the main factor in hazardous solid waste services is the service to all service areas.

The capacity of the box is chosen with the volume on the market for the motor box factory, which is 2381.4 liters. Based on the calculation of the average volume of hazardous solid waste at the Universitas Diponegoro, the need for a fleet is 2 motor boxes. The following table show the result of the planned ritation calculation for the transportation of hazardous solid waste.

Table 5. Hazardous solid waste transport time

Transport Routes	**Distance (km)**	**Reach time (minute)**	**Loading time (minute)**	**Total time (minute)**
WT - Mosque	1.28	0	5	8.84
Mosque - ICT	0.31	1	5	5.93
ICT - FT1	0.46	5	5	6.38
FT1 – FH	0.17	1	5	5.51
FH – SV	0.29	8	5	5.87
SV-FIB	0.25	1	5	5.75
FIB - SAMWA & WP	0.51	1	5	6.53
SAMWA & WP - FEB	0.21	6	5	5.63
FEB - Hospital	0.16	8	5	5.48
Hospital - FK & FKM	0.22	4	5	5.66
FK FKM - FSM	0.33	9	5	5.99
FSM - FPIK	0.1	0	5	5.3
FPIK-FT2	0.11	0	5	5.33
FT2 – FPP	0.16	0	5	5.48
FPP – UNDIP Apartment	1.2	10	5	8.6
UNDIP Apartment – Gas Station	1.38	0	5	9.14
Gas Station - WT	1.1	5	5	8.3
Total Transport For Tembalang Campus	**5.76**			**109.72**
FH – WT	0.697	2.091	5	7.091
FEB, Post-Graduate & BNI- WT	0.522	1.566	5	6.566
Total Transport For Pleburan Campus	**2.48**			**13.657**

From the Table 5, it can be seen that the collection time for the transportation of hazardous solid waste for the Tembalang area takes a total of 110 minutes while for the Pleburan area it takes 13 minutes.

3.4 Waste Station

Hazardous solid waste transported from each unit must be provided with a storage area. In this proposed design, hazardous solid waste storage is carried out from Undip ISWPF. The determination of the size of the container or storage container is known from the volume of hazardous solid waste, population number, and frequency of collection. A collection building should support collection activities that meet several requirements as stated in Bapedal Decree No. 1 of 1995. At the waste station, a container of 2 m^3 is provided to accommodate temporary hazardous solid waste collection with a total of 1655.21 l/day in the Tembalang area. At the same time, for Pleburan, it is 16.75 l/day, then the generation is multiplied by the frequency of the amount of waste entering. From several activities, waste

with toxic characteristics will be accommodated for up to 30 days, while others will be accommodated for 90 days. The volume of waste that enters the Universitas Diponegoro waste station is shown in Table 6.

From the data shown in Table 6, it can be seen that there are 2 types of containers, namely 1,100 liters and 10,000 liters. The number of containers needed for the Tembalang waste station is 17 containers for 1,100 liters and 4 containers for 10,000 liter. For the Pleburan waste station, 50 liters, 4 containers, and 6 containers are needed for 240 liters. The calculation of the number and size of solid waste containers adjusts the volume of hazardous solid waste with a storage frequency of 30 days for toxic characteristics and 90 days for corrosive, flammable, and infectious characteristics, with a total of 63,870.619 liters for the Tembalang waste station and 1,507,853 liters for the Pleburan waste station before submitting it to the collector per Government Regulation no. 101 of 2014 concerning Hazardous Waste Management.

Table 6. Tembalang & Pleburan waste station storage needs

Sector	**Generation (liter)**			
	Corrosive (90 days)	**Toxic (90 days)**	**Flammable (90 days)**	**Infectious (90 days)**
Education	695.972	1,994.986	2,912.476	2,444.727
Office	407.540	304.562	90.253	185.317
Supporting facilities	303.665	4,745.091	2,822.861	1,063.509
Laboratory	952.225	37,659.672	2,835.649	4,345.260
Total	63,763.765			
Percentage	3.70%	3.70%	3.70%	3.70%
Container	1,100 liter	10,000 liter	1,100 liter	1,100 liter
	2	4	8	7
Pleburan	84.778	83.504	895.930	443.641
Total	1,507.853			
Percentage	5.62%	5.54%	59.42%	29.42%
Container	50 liter	50 liter	240 liter	240 liter
	2	2	4	2

The vacant land area in the UNDIP ISWPF is very suitable for building a waste station because the conditions are green and free from flooding. Then, the Pleburan area was chosen for the Faculty of Law area. The condition of the dense Pleburan area so that it lacks land, making this place suitable for building a waste station because there is still vacant land and a gathering point for all waste in the Pleburan area. After knowing the number of containers needed at the waste station and location, it can be seen the land requirements for the Universitas Diponegoro hazardous solid waste area. The required area consists of a waste storage area according to its characteristics and other needs areas, such as loading and unloading areas with a total land requirement of the size of Tembalang waste station is 14.45 m x 19.45 m, while the size of the Pleburan waste station is 4.24 m x 7.58 m. this is the design of the Tembalang and Pleburan waste stations.

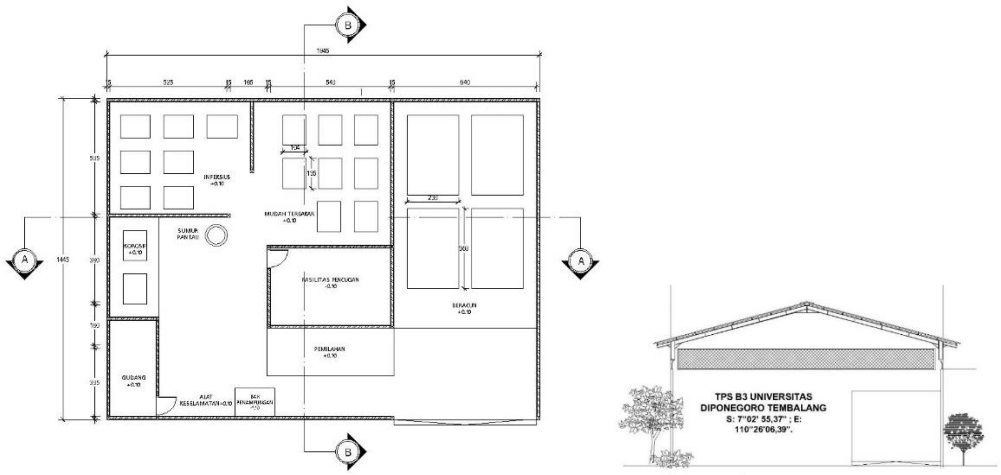

Figure 2. Waste station Tembalang Campus design

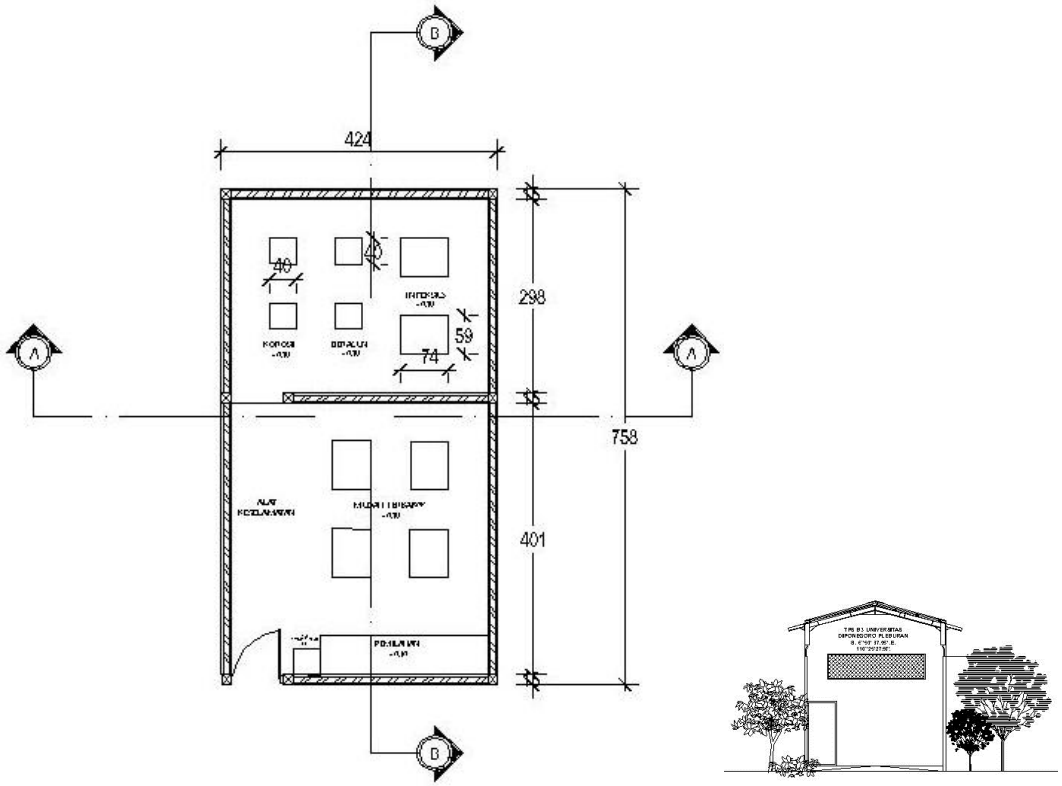

Figure 3. Waste station Pleburan Campus design

In this waste station building, ventilation design is also carried out based on SNI 03-6572-2001 concerning Procedures for Designing Ventilation and Air Conditioning Systems in Buildings. The ventilation area is adjusted to the building class for the waste station, namely class 7 for storage buildings or warehouses, which is by the following ventilation area calculations.

Table 6. Details of the length and width of the waste station ventilation

Waste Station Tembalang			
Waste room	**Room area m³**	**Ventilation Requirements**	
		Length	**Width**
Corrosive	7.7	0.8	1
Toxic	65.2	6.5	1
Flammable	37.7	3.8	1
Infectious	26.25	2.6	1
Waste Station Pleburan			
Waste room	**Room area m³**	**Ventilation Requirements**	
		Length	**Width**
Corrosive, Toxic & Infectious	7.7	0.8	1
Flammable	65.2	6.5	1

3.4 Economic Analysis

The financing of hazardous solid waste management includes supporting investment costs of unit storage facilities, collection facilities, waste station equipment, and waste station building costs. With a total investment cost of IDR 2,500,568,400, there are supporting investment costs consisting of waste station collection equipment, fuel costs, maintenance costs per unit, maintenance costs, waste station equipment, employee salaries, and costs for processing hazardous waste third parties. Table 7 shows the investment costs for hazardous waste management at the Universitas Diponegoro unit.

Table 7. Total supporting investment costs from 2021 to 2030

Year	**Supporting Investment**	**Employee Salary**	**Waste Treatment Costs**	**Total Fixed Cost**
2021	Rp 14,528,833	Rp 202,321,800	Rp 109,126,839	Rp 325,977,472
2022	Rp 14,910,070	Rp 207,630,724	Rp 113,585,217	Rp 336,126,011
2023	Rp 15,301,310	Rp 213,078,954	Rp 118,037,953	Rp 346,418,217
2024	Rp 15,702,816	Rp 216,806,415	Rp 122,524,360	Rp 355,033,592
2025	Rp 16,114,858	Rp 222,495,416	Rp 127,051,424	Rp 365,661,698
2026	Rp 16,537,712	Rp 228,333,695	Rp 131,620,477	Rp 376,491,885
2027	Rp 16,971,662	Rp 234,325,172	Rp 136,219,720	Rp 387,516,554
2028	Rp 17,416,998	Rp 240,473,864	Rp 140,845,037	Rp 398,735,900
2029	Rp 17,874,020	Rp 246,783,898	Rp 145,509,253	Rp 410,167,172
2030	Rp 18,343,035	Rp 253,259,508	Rp 150,204,571	Rp 421,807,113
Total	**Rp 163,701,315**	**Rp 2,265,509,447**	**Rp 1,294,724,850**	**Rp 3,759,273,599**

from the Table 7, the supporting costs from 2021 to 2030 are IDR 3,759,273,599, that the total investment cost for hazardous solid waste management in UNDIP is Rp 6,259,841,999

4. Conclusions

The average number of hazardous wastes produced in the UNDIP is 1.29 kg/person/day, or 36.79 l/person/day, 326.28 kg/day. This number of wastes is essential for considering the design of a hazardous waste management system. Looking for the characteristic of the generated hazardous waste, the waste management system that can be applied at Universitas Diponegoro Tembalang and Pleburan campuses includes sorting and storing, transportation and collection, and temporary storage at the waste station with a building size of 14.45 m x 19.45 m. In contrast, the size of the Pleburan waste station is 4.24 m x 7.58 m. with a total investment cost of Rp 6,259,841,999 for 10 years of operation. Future studies should include the acceptance rate of the academic society to segregate hazardous waste. The participation rate should also be measured to ensure the potential development of hazardous waste management facilities in the studied area.

References

Alshuwaikhat, H.M., Abubakar, I., 2008. An integrated approach to achieving campus sustainability: assessment of the current campus environmental management practices. Journal of Cleaner Production 16, 1777–1785.

Badan Standarisasi Nasional. 1994. SNI 19-3964-1994, Tentang Metode Pengambilan dan Pengukuran contoh Timbulan dan Komposisi Sampah Perkotaan. Jakarta : Balitbang, DPU

Badan Standarisasi Nasional. 2002. SNI 03-6572-2001 Tata Cara Perancangan Sistem Ventilasi dan Pengkondisian Udara pada Bangunan Gedung. Badan Standarisasi Nasional : Jakarta

Badan Standarisasi Nasional. 2002. SNI 19-2454-2002 Tata Cara teknik Operasional Pengelolaan Sampah Perkotaan. Badan Standarisasi Nasional : Jakarta

Bahçelioğlu, E., Buğdaycı, E.S., Doğan, N.B., Şimşek, N., Kaya, S.Ö., Alp, E., 2020. Integrated solid waste management strategy of a large campus: A comprehensive study on METU campus, Turkey. Journal of Cleaner Production 265, 121715.

Budihardjo, M.A., Humaira, N.G., Putri, S.A., Ramadan, B.S., Syafrudin, S., Yohana, E., 2021a. Sustainable solid waste management strategies for higher education institutions: diponegoro university, indonesia case study. Sustainability 13, 13242.

Budihardjo, M.A., Ramadan, B.S., Putri, S.A., Wahyuningrum, I.F.S., Muhammad, F.I., 2021b. Towards sustainability in higher-education institutions: analysis of contributing factors and appropriate strategies. Sustainability 13, 6562.

Kepala Bapedal. 1995. Keputusan No. 1: Tata Cara dan Persyaratan Teknis Penyimpanan dan Pengumpulan Limbah Bahan Berbahaya dan Beracun. Badan Pengendalian Dampak Lingkungan Republik Indonesia

Kepala Bapedal. 1995. Keputusan No. 2: Dokumen Limbah Bahan Berbahaya dan Beracun. Badan Pengendalian Dampak Lingkungan Republik Indonesia.

Kementerian Pendayagunaan Aparatur Negara dan Reformasi Birokrasi 2010 Peraturan Menteri Pendayagunaan Aparatur Negara dan Reformasi Birokrasi Nomor 03 tahun Petunjuk Teknis Jabatan Fungsional Pranata Laboratorium Pendidikan Dan Angka Kreditnya. Jakarta

Liu, Z., Moshi, G.J., Awuor, C.M., 2019. Sustainability and indicators of newly formed world-class universities (NFWCUs) between 2010 and 2018: empirical analysis from the rankings of ARWU, QSWUR and THEWUR. Sustainability 11, 2745.

Parvez, N., Agrawal, A., Kumar, A., 2019. Solid waste management on a campus in a developing country: a study of the indian institute of technology roorkee. Recycling 4, 28.

Peraturan Pemerintah Nomor 101 Tahun 2014 tentang Pengelolaan Limbah Bahan Berbahaya dan Beracun.

Peraturan Pemerintah Nomor 22 Tahun 2021 tentang Penyelenggaraan Perlindungan Dan Pengelolaan Lingkungan Hidup

Peraturan Pemerintah Nomor 27 Tahun 2020 tentang Tentang Pengelolaan Sampah Spesifik

Puertas, R., Marti, L., 2019. Sustainability in Universities: DEA-GreenMetric. Sustainability 11, 3766.

Ramírez Lara, E., De la Rosa, J.R., Ramírez Castillo, A.I., Cerino-Córdova, F. de J., López Chuken, U.J., Fernández Delgadillo, S.S., Rivas-García, P., 2017. A comprehensive hazardous waste management program in a Chemistry School at a Mexican university. Journal of Cleaner Production 142, 1486–1491.

Sumiyati, S., Budihardjo, M., Ramadan, B., Al-Hafidz, A., Salman, H., Wirawan, R., Fadhilah, H., 2021. Improving recycling behaviour through waste bank implementation in diponegoro university. E3S Web Conf. 317, 01092.

Suwartha, N., Sari, R.F., 2013. Evaluating UI GreenMetric as a tool to support green universities development: assessment of the year 2011 ranking. Journal of Cleaner Production 61, 46–53.

Ugwu, C.O., Ozoegwu, C.G., Ozor, P.A., 2020. Solid waste quantification and characterization in university of Nigeria, Nsukka campus, and recommendations for sustainable management. Heliyon 6, e04255.

Wardana, Y.N., Syafrudin. Rezagama A. 2015. Sistem pengelolaan sampah B3 rumah tangga di kecamatan semarang barat, kota semarang. semarang : universitas diponegoro