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Evaluation of Waste Management in XYZ University Area in Yogyakarta

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ABSTRACT

The increasing volume of waste is driven by several factors, including population growth, urbanization, and changes in lifestyle. This rise in waste generation has outpaced the capacity of available landfill space, leading to the improper accumulation of unmanaged waste. This study aims to evaluate the current waste management practices, analyze the waste generation and composition, and propose an effective waste management scenario. A quantitative descriptive analysis approach was employed, utilizing waste generation and composition data measured in accordance with the Indonesian National Standard (SNI) 19-3964-1994. The proposed waste management scenario is aligned with the guidelines outlined in Sleman Regency Regulation No. 4 of 2015. The operational techniques for managing waste include stages such as storage, collection, transportation, and treatment, which are outsourced to a third party. The findings of this study indicate that the waste at eight sampling points averaged 359,250 kg/day and 4,058 m³/day. The waste composition is predominantly organic (2.48%), paper and cardboard (12.4%), and other types of waste (11.07%). The proposed processing methods focus on utilizing technologies for organic waste and residue treatment, such as Masaro technology.

1. Introduction

All human activities generate waste, with the quantity of waste produced being directly linked to population growth and lifestyle changes. Solid waste encompasses various forms, including materials discarded from industrial, commercial, mining, agricultural, and everyday activities, such as those on a university campus (Babatunde et al., 2013). The rising volume of waste generation has not been matched by the availability of landfill space, leading to poorly managed waste disposal sites. According to Law No. 18 of 2008, waste is defined as solid waste originating from human activities, whether from processes or natural occurrences.

As reported by the World Bank in 2019, global municipal solid waste production exceeded 3.5 million tons per day, with projections suggesting this could rise to approximately 6.1 million tons per day by 2025. The National Waste Management Information System (SIPSN) recorded that waste generation in the Special Region of Yogyakarta, specifically Sleman Regency, was around 738.71 tons per day in 2022 (SIPSN, 2022). In the campus setting, waste generation averages 129,356 kg/day, with a corresponding volume of 1,903,983 liters/day (Hariz, 2020). XYZ University, with an academic population of 28,737 individuals, has the potential to produce significant waste. However, detailed data on the quantity of waste generated, its composition, and the absence of processing facilities on XYZ University are currently lacking.

This study aims to address these gaps by assessing waste generation and composition using 12 waste categories defined by the Waste Wise Cities Tool, including kitchen/canteen waste, garden/park waste, paper and cardboard, plastic film, rigid plastic, metal, glass, textiles and shoes, wood, special waste, composite products, and other waste types (UN Habitat, 2021). The objectives of this study are to evaluate existing waste management practices, analyze the quantity and composition of waste produced, and propose an effective waste management scenario encompassing the entire process from source separation to final disposal.

2. Methods

2.1 Site location

This study employs a quantitative descriptive analysis approach, utilizing waste generation and composition data collected and measured in accordance with the Indonesian National Standard (SNI) 19-3964-1994, which outlines the methods for sampling and measuring urban waste generation. Data collection was conducted over an eight-day period at XYZ University, located in the Special Region of Yogyakarta Province. Sampling was carried out at eight specific study locations within the university (Buildings A, B, C, D, E, F, G, and H).

2.2 Research tools and materials

The equipment used in this study adheres to the guidelines set by SNI 19-3964-1994. This includes 40-liter plastic bags for waste collection, along with shovels and gloves for handling the samples. For volume measurement, a measuring tub with dimensions of 1.0 m x 0.5 m x 1.0 m was utilized, equipped with a height scale for accurate assessment. Additionally, a digital scale was employed to precisely measure the weight and composition of the collected waste.

2.3 Research procedure

The waste measurement and collection process begin by selecting specific locations for waste collection and measurement. Filled plastic bags containing waste are then gathered. Following this, the waste is emptied from the plastic bags into a 500-liter measuring tank. The tank is shaken by lifting it 20 cm off the ground three times to ensure even distribution. The volume (Vb) and weight (Bs), of the waste are then measured. To assess waste composition, the waste is sorted into 12 categories according to the Waste Wise City Tool (WACT).

Table 1. Waste Composition Criteria

No.	Waste Composition	Sample
1.	Kitchen/canteen waste	Bread, coffee grounds, tea grounds, leftover cooked or raw cooking ingredients, fruits, vegetables, meat, fish, egg shells.
2.	Garden waste	Leftover cut leaves, tree branches, grass, weeds
3.	Paper and cardboard	Brochures, magazines, serial boxes, cards, books, wrapping paper, paper bags/fast food wrappers, envelopes, tickets, cardboard, printed paper.
4.	Plastic film	Biscuit wrappers, tape, plastic bags, plastic garbage bags, plastic film packaging, and thin plastic wrapping.
5.	Solid plastic	All bottles, jars, plastic wrap for utensils, bank cards/credit cards, fast food boxes, buttons, CD discs, lamps, pens, cosmetic/glue/paint supplies.
6.	Metal	Soda packaging, aluminum foil sheets, shoe polish cans, canned food packaging, aerosol packaging (deodorant, perfume, hair spray), keys, iron shelves, nails, clips, tools, radiators, padlocks, pots and pans.
7.	Glass	All made of glass such as medicine bottles, glass bottles, etc. Mixture of broken glass.
8.	Textiles and shoes	Clothing, blankets, carpets, rags, bed linen, towels, shoes, curtains, spools of wool, fine furniture, and household upholstery.
9.	Wood (processed)	All made of processed wood
10.	Specific waste	Electrical and electronic equipment, batteries, accumulators, B3 waste, face masks and gloves are free.
11.	Composite products	Products made of different materials such as scissors, knives, razors, umbrellas. Composite packaging such as aluminum foil-coated cartons and beverage containers (tetrapack packaging)
12.	Others	Pads/diapers, rubber, light bulbs, and materials.

2.4 Data analysis procedure

This study employs a quantitative descriptive analysis approach, utilizing data on waste generation and composition that has been systematically collected and measured. The new paradigm in waste management emphasizes comprehensive strategies for effective reduction and handling, addressing the entire process from the source to final disposal. The calculations used to analyze waste generation and composition in the XYZ University area are as follows:

- - Average waste volume

$$= \frac{\left[\frac{V_{s1}}{u} + \frac{V_{s2}}{u} + \cdots + \frac{V_{sn}}{u}\right]}{n} \text{ liter/person/day} \text{ ....(1)}$$

- Average waste weight

$$= \frac{[\frac{B_{S1}}{u} + \frac{B_{S2}}{u} + \cdots + \frac{B_{Sn}}{u}]}{BBS} \text{ kg/person/day} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

- % waste weight per component

$$= \frac{[\frac{B_{S1}}{u} + \frac{B_{S2}}{u} + \cdots + \frac{B_{Sn}}{u}]}{BBS} \times 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

- - Bulk density

$$= \frac{weight}{volume} \text{ kg/m}^3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

3. Results and Dicussion

This research was conducted in the XYZ University Area in 8 buildings or study points including buildings A, B, C, D, E, F, G, and H. The waste produced is directly proportional to the number of students and campus activities. The Campus Area has 7 Faculties, 27,347 students, and 1,390 academic members, making it a significant source of waste.

3.1 Existing Waste Management

Operational waste management techniques encompass storage, collection, transportation, and processing. Waste management at XYZ University follows several key stages (Figure 1). First, storage: Not all buildings have waste storage systems that separate waste based on its characteristics, such as organic waste, recyclable materials, and residues. Currently, only Buildings A and B have implemented sorting at the storage stage. The average capacity of existing waste bins is 42 liters. Second, waste collection: Daily waste collection at the Temporary Storage (TPS) for each building is carried out by routine cleaning staff, including the collection of garden waste, which is separated into blue bins. Third, transportation: Waste transportation is managed by two entities. The private sector is responsible for processing organic and inorganic waste generated on campus, while waste from areas outside the campus, such as garden and road waste, is managed by the Campus Facilities Manager. Finally, waste management: The processing of waste is outsourced to a third party. To optimize campus waste management, it is essential to analyze the generation and composition of the existing waste to identify effective processing options.

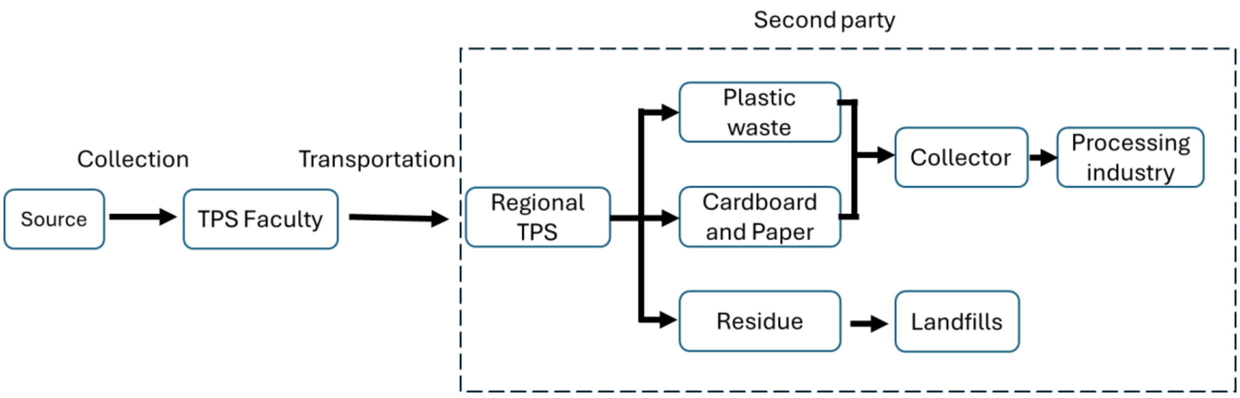


Figure 1. Existing Waste Management Flowchart

3.2 Waste Generation and Characteristics

Lecture buildings and the rectorate are significant sources of non-residential waste, generating waste comparable to that of households. A total of 28,737 individuals across 8 sampling locations were accounted for in this study. Sampling was conducted to measure the waste's weight, volume, specific gravity, and composition for each building.

3.2.1. Weight and Volume of Waste

The weight of waste generated during the study exhibited fluctuations (Table 2), influenced by variations in lecture activities and the number of academicians. Table 2 highlights the daily variations in waste weight across the buildings, with notable peaks on sampling days 2, 5, and 8. The highest recorded waste generation occurred on day 8, reaching 458.584 kg/day. Building D was identified as the largest waste producer, contributing 74.536 kg/day, attributable to its high academic population, whereas Building G produced the least waste at 15.146 kg/day due to its relatively smaller academic population. On average, XYZ University generated 359.250 kg/day of waste, amounting to approximately 112.4 tons annually. This waste generation rate at XYZ University is lower than that of the University of Lampung, which is approximately 770 kg/day (Yuliandari *et al.*, 2019), but higher than that of UIN Walisongo, which stands at 129.356 kg/day (Hariz, 2020).

Table 2. Weight of Waste from Sampling Results

Building	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Average
	Weight (kg)								(kg)
A	37.925	96.773	47.509	36.045	32.331	17.305	40.694	89.717	49.787
B	66.582	92.289	56.518	71.248	46.286	36.420	63.896	96.485	66.216
C	31.238	35.565	36.478	28.537	43.749	25.787	33.425	36.632	33.926
D	72.028	84.117	64.274	57.380	95.779	61.880	74.189	86.641	74.536
E	44.750	65.005	55.090	61.415	87.240	60.145	46.988	68.255	61.111
F	22.427	32.109	26.564	15.965	24.005	13.394	23.773	33.715	23.994
G	14.768	15.397	11.600	19.935	14.426	12.462	15.949	16.629	15.146
H	36.548	29.057	34.421	37.946	47.940	21.475	38.375	30.510	34.534
Total	326.266	450.312	332,454	328.471	391.756	248.868	337.289	458.584	359.250

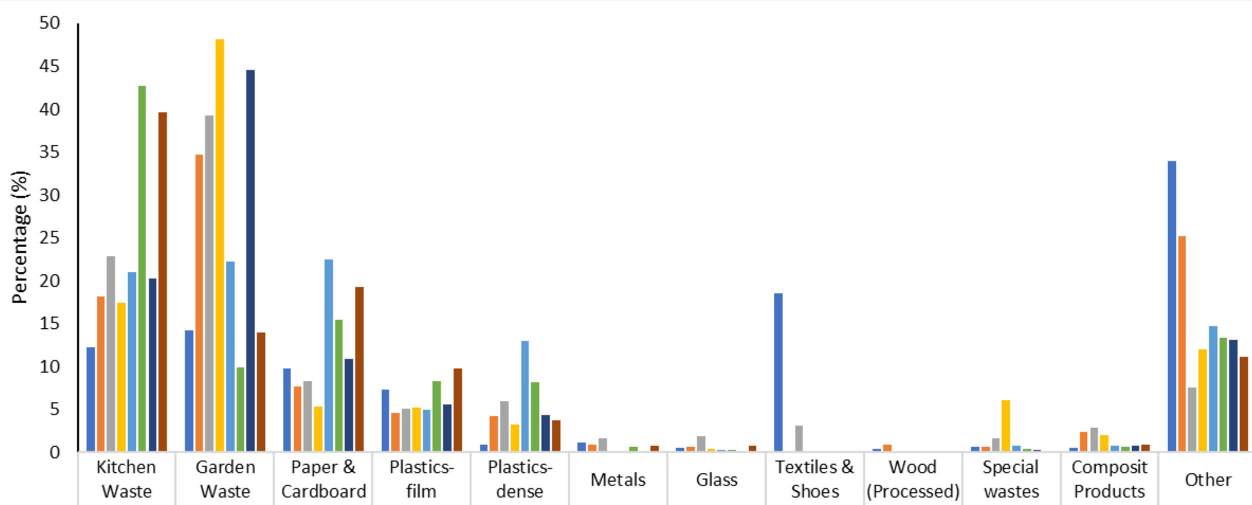
Table 3. Waste Volume

Building	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Average
	Volume (L)								(L)
A: FTSP	325.0	640.8	480.6	440.5	400.5	222.0	480.6	560.7	443.8
B: FPSB/FK	900.5	1235.5	1215.5	1045.5	675.5	505.5	985.5	1225.5	973.6
C: FTI	385.0	480.0	490.0	420.0	500.0	395.0	460.0	515.0	455.6
D: FMIPA	717.5	892.5	722.5	872.5	882.5	607.5	757.5	942.5	799.4

Building	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Average (L)
	Volume (L)								
E: FH	440.0	680.0	920.0	675.0	575.0	235.0	425.0	365.0	539.4
F: FIAI	290.0	415.0	420.0	345.0	395.0	250.0	235.0	425.0	346.9
G: D3 FBE	229.8	199.8	194.8	384.8	189.8	214.8	239.8	214.8	233.5
H: Rektorat	235.5	160.9	314.0	345.7	353.5	235.5	162.9	323.8	266.5
Total	3523.3	4704.5	4757.4	4529.0	3971.8	2665.3	3746.3	4572.3	4058.8

3.2.2. Waste Composition

Figure 2 reveals that the average waste generated within the XYZ University environment is comprised of organic waste, paper, cardboard, and various other materials. Organic waste constitutes the largest proportion, with garden waste accounting for 28.18% and food waste for 24.3%. The second major category is paper and cardboard waste, which makes up 12.4%, primarily from food packaging and campus activities. However, this percentage has been declining due to the university's transition to digital media for disseminating lecture information. Paper and cardboard waste are frequently sold to informal recycling channels. The remaining 11.07% of waste consists of miscellaneous items, including synthetic cork, materials, sanitary napkins/diapers, and tissues that are often mixed with wet waste.



	Kitchen Waste	Garden Waste	Paper & Cardboard	Plastics-film	Plastics-dense	Metals	Glass	Textiles & Shoes	Wood (Processed)	Special wastes	Composit Products	Other
A	12.29	14.23	9.81	7.25	0.89	1.08	0.48	18.55	0.37	0.64	0.51	33.9
B	18.14	34.74	7.72	4.61	4.25	0.85	0.6	0.15	0.83	0.67	2.31	25.13
C	22.82	39.21	8.29	5.09	5.93	1.57	1.91	3.14		1.59	2.88	7.57
D	17.43	48.15	5.29	5.26	3.25	0.14	0.35	0.13		6.05	1.94	12.01
E	21.01	22.17	22.42	4.93	12.92	0.01	0.23	0.01		0.81	0.78	14.71
F	42.74	9.88	15.47	8.35	8.19	0.67	0.28	0.02	0.01	0.45	0.62	13.32
G	20.31	44.62	10.94	5.62	4.35	0.01	0.01	0.02	0.01	0.25	0.82	13.04
H	39.62	14.01	19.22	9.72	3.72	0.77	0.81	0.01	0.01	0.19	0.83	11.09

Figure 2. Percentage of Waste Composition

3.3 Waste Management Evaluation

1. Container

Improvement needs for container activities are as follows:

a. Implementing separate waste containers to facilitate the sorting of three distinct waste types: organic waste, recyclable waste, and residual waste (Figure 3). The initial sorting process significantly impacts the quality of raw materials destined for reprocessing and streamlines subsequent waste management procedures.

b. Conducting comprehensive socialization on waste sorting at the source within the XYZ University area. This education should be integrated and centralized, targeting the entire academic community, particularly during orientation activities for new students.
c. Replacing waste containers with color-coded bins that prioritize both functionality and aesthetics.

2. Collection

The collection improvementt needs are as follows:

a. Ensure that the waste that has been sorted remains sorted until final processing.
b. Maximize the utilization of existing TPS facilities.

3. Transportation

The waste transportation plan utilizes pick-up trucks designed to handle the collection of organic, inorganic, and residual waste. It is essential that waste remains separated into the three categories—organic waste, recyclable waste, and residual waste—throughout the transportation process. The required number of waste transport vehicles is determined using a method analogous to that employed for calculating the capacity of waste containers.

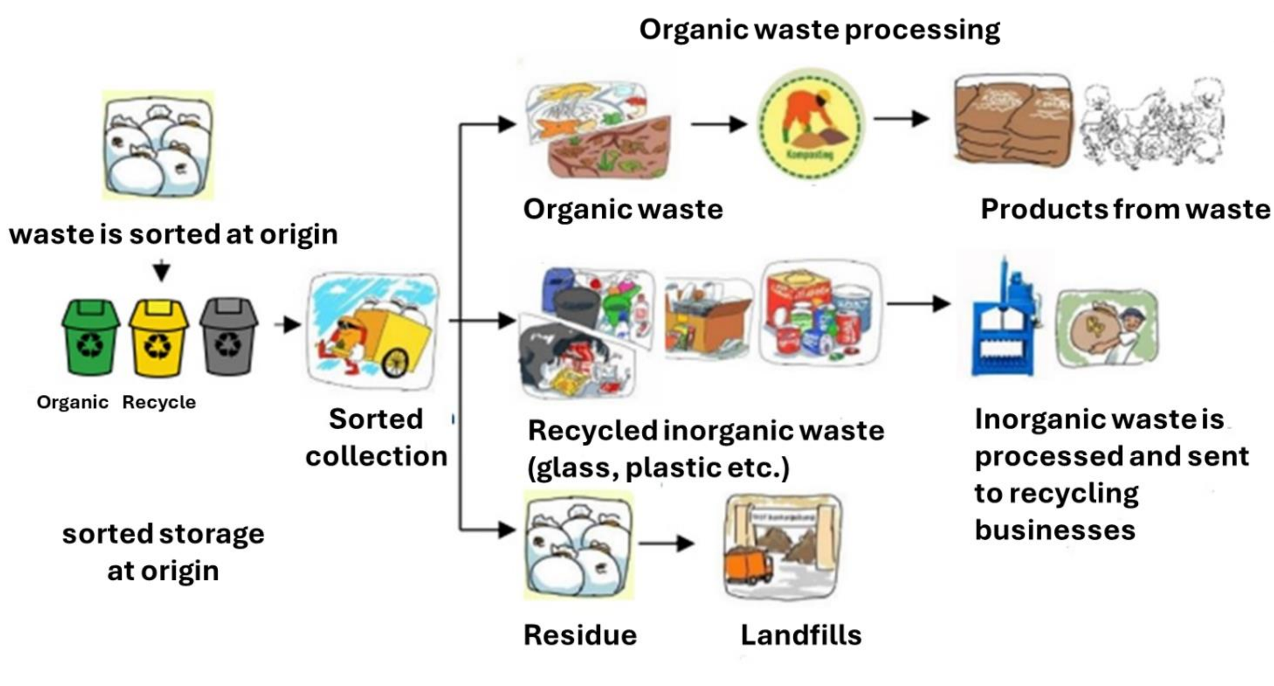


Figure 3. Waste Management Evaluation

3.3 Technology Option

Masaro technology was introduced to enhance the processing of organic waste, which is categorized into fast-decomposing and slow-decomposing materials. Fast-decomposing waste is processed into POCI/KOCI, while slow-decomposing waste is converted into Masaro compost. According to sampling results, garden waste falls into the slow-decomposing category, whereas food waste is classified as fast-decomposing (Abidin *et al.*, 2021).

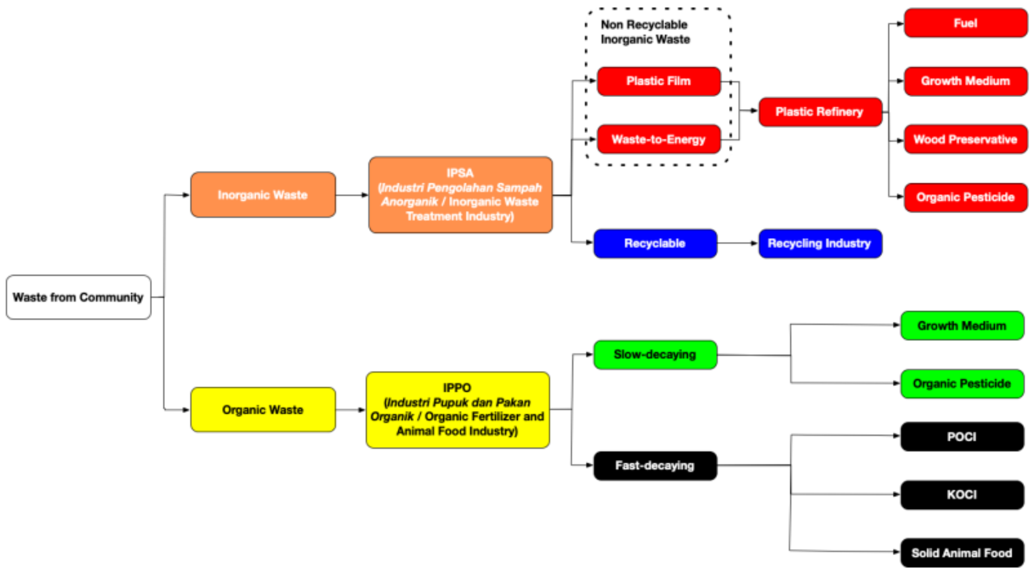


Figure 4. Masaro Technology Flow Diagram

Masaro technology addresses the challenge of non-biodegradable, non-recyclable waste with low economic value through the use of a plastic refinery unit. This unit includes an incinerator, pyrolysis chamber, and wet scrubber (Abidin *et al.*, 2021). The plastic refinery produces several byproducts, including fuel, growth media, wood preservatives, and organic pesticides. Plastic film waste is incinerated to produce fuel with a quality comparable to diesel. Other non-recyclable waste is combusted to generate hot gas and ash residue. The hot gas serves as a pyrolysis energy source, while the ash is repurposed as a planting medium. Condensation water, used for cooling the hot gas, is then utilized as a wood preservative and natural pesticide (Abidin *et al.*, 2021). This technology primarily focuses on processing organic waste and residues with low economic value. Additionally, waste management options such as pyrolysis (Czajczyńska *et al.*, 2017) and biogas production using biodigesters (Cortez *et al.*, 2022) are also considered.

4. Conclusions

The current waste management system at the XYZ University Integrated Campus Area involves storage, collection, transportation, and processing, which are outsourced to the private sector. Buildings A and B have implemented waste sorting at the source into three categories, while other buildings have not yet adopted this practice. The average daily waste generation on campus is approximately 359.25 kg/day and 4.05 liters/day across 8 sampling points, with an average waste generation per person of 0.031 kg/person/day and 0.287 liters/person/day. The waste composition is predominantly organic (52.48%), followed by inorganic waste (30.72%), and residual waste (16.8%). Based on the waste generation and composition, a waste management plan can be developed by implementing three-way sorting at the storage stage. During collection and transportation, waste types should remain separated. Additionally, various waste processing technologies, such as Masaro, pyrolysis, biogas production, composting, and hydrothermal treatment, can be employed.

5. Reference

Abidin, A. Z., Bramantyo, H., Baroroh, M. K., & Egiyawati, C. (2021). Circular Economy on Organic Waste Management with MASARO Technology. *IOP Conference Series: Materials Science and Engineering*, 1143(1), 012051. https://doi.org/10.1088/1757-899x/1143/1/012051

Abidin, A. Z., Yemensia, E. V, Wijaya, K. W., & Rahardjo, A. P. (2021). Circular Economy on Non-Biodegradable Waste Management with MASARO Technology. *IOP Conference Series: Materials Science and Engineering*, 1143(1), 012052. https://doi.org/10.1088/1757-899x/1143/1/012052

Babatunde B, Vincent-Akpu I, Woke G, Aharanwa U, & Green A. (2013). Comparative analysis of municipal solid waste (MSW) composition in three local government areas in Rivers State, Nigeria. *African Journal of Environmental Science and Technology*, 7(9), 874–881. https://doi.org/10.5897/AJEST12.112

Cortez, S. C., Cherri, A. C., Jugend, D., Jesus, G. M. K., & Bezerra, B. S. (2022). How Can Biodigesters Help Drive the Circular Economy? An Analysis Based on the SWOT Matrix and Case Studies. *Sustainability*, 14(13). https://doi.org/10.3390/su14137972

Czajczyńska, D., Nannou, T., Anguilano, L., Krzyzyńska, R., Ghazal, H., Spencer, N., & Jouhara, H. (2017). Potentials of pyrolysis processes in the waste management sector. *Energy Procedia*, 123, 387–394. https://doi.org/10.1016/j.egypro.2017.07.275

Hariz, A. R. (2020). Studi Timbulan dan Komposisi Sampah dalam Perencanaan Pengelolaan Sampah di Kampus 2 UIN Walinsongo. *Neo Teknika*, 6, 29–33. https://doi.org/10.37760/neoteknika.v6i2.1626

Peraturan Daerah Sleman No. 4. (2015). Pengelolaan Sampah Rumah Tangga dan Sampah Sejenis Sampah Rumah Tangga.

SIPSN. (2022). Timbulan Sampah DIY 2022. https://sipsn.menlhk.go.id/sipsn/public/data/timbulan

SNI 19-3964-1994. (1994). Metode Pengembilan dan Pengukuran Contoh Timbulan dan Komposisi Sampah Perkotaan.

UN Habitat. (2021). WASTE WISE CITIES TOOL. https://unhabitat.org/wwc-tool

UU No. 18 Tahun 2008. (2008) tentang Pengelolaan Sampah.

World Bank. (2019, September 23). Pengelolaan Limbah Padat. https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management

Yuliandari, P., Suroso, E., & Anungputri, S. (2019). Studi Timbulan Dan Komposisi Sampah Di Kampus Universitas Lampung. *Journal of Tropical Upland Resources.* 1(1). https://doi.org/10.23960/jtur.vol1no1.2019.15