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ARTICLE

Solid Waste Analysis across USTP System: Basis for a Sustainable Management Framework

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ABSTRACT

Solid waste management remains a critical concern for academic institutions striving for sustainability. This study assesses waste generation and composition across the seven campuses of the University of Science and Technology of Southern Philippines (USTP) to inform a system-wide solid waste management framework. A seven-day waste analysis and characterization study (WACS) was conducted in USTP CDO (Cagayan de Oro Campus), Claveria, Panaon, Oroquieta, Villanueva, Jasaan, and Alubijid to determine waste types, percentage composition, weight, volume, and per capita

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generation. Results show notable variation among campuses. USTP CDO generated 13 waste types, with residuals comprising 41%. Claveria recorded 14 types, with recyclable plastics (53%) dominating. Oroquieta and Panaon each had 12 types, with biodegradable waste at 53% and 52%, respectively. Villanueva (11 types) and Jasaan (16 types) were led by recyclable plastics at 29% and 27%, while Alubijid (6 types) had the highest share of residuals (51%). Differences in waste weight, volume, and density reflect variations in campus size and activity levels. Per capita estimates indicate that USTP CDO had the highest waste generation (0.90 kg/person/day; 1.2 L/person/day), followed by Claveria, while other campuses showed moderate to lower rates. The findings highlight the need for tailored waste management strategies across campuses. The study recommends implementing a comprehensive recycling program, strengthening waste segregation, and adopting appropriate technologies to reduce waste generation and improve overall system efficiency.

Keywords: Solid Waste Management; Solid Waste Segregation and Characterization; Solid Waste Management Policy And Framework; WACS

1. Introduction

Waste is an unused or unavoidable product of human activity. Waste management has become one of the major problems, especially in developing countries, because of the rapid increase in population [1]. An extraordinary increase in solid waste generation was traced to fast urbanization, extensive industrial development, and significant economic growth in the Association of Southeast Asian Nations (ASEAN) region since 2000 [2]. According to Ansar et al. [3], the problem of solid waste generation and poor waste management is further compounded by rapid urbanization and population growth, leading to the generation of enormous quantities of solid waste that are often discarded by open dumping. As solid waste generation increases, the environmental risk caused by waste materials, including human health risks and ecological degradation, equally escalates [4].

Solid Waste Management (SWM) is a cross-cutting issue that impacts various areas of sustainable development. The SWM strategies and approaches affect the ecological, economic, and societal sustainability domains of each country [5]. In the Philippines, Republic Act (RA) 9003, otherwise known as the Ecological Solid Waste Management Act of 2000, was enacted to provide efficient and organized administration of waste management activities. Notwithstanding this law, there is the practice of open, unrestrained dumps, a poor solid waste management practice in local governments that have the primary responsibility for waste management [6]. Moreover, the act gives prime importance to the roles of Local Government Units (LGUs) in managing their respective solid wastes, which was inscribed in Section 20 of the Act. Provided, further, that nothing in this section prohibits a local government unit from implementing re-use, recycling, and composting activities designed to exceed the goal [7]. In line with the act's objectives, according to a news report, the Local Government Unit of Cagayan de Oro implemented, last March 1, 2024, the City Ordinance No. 13378-2018 or the "No Segregation, No Collection" Policy of waste. This policy mandates that households separate their garbage into decomposable and non-biodegradable components. University communities can be regarded as "mini cities" with extensive territorial coverage, and diverse human activities, these having different degrees of effect on the environment [3]. According to the study of Voukkali et al., Romianingsih and Nacua and Lacang [8–10], the higher education institutions play an important role in shaping positive behaviour in society and activities related to environmental management.

Despite existing national policies and growing awareness of sustainable waste practices, there remains a significant gap in institution-specific, data-driven SWM planning within multi-campus universities. In particular, there is a lack of comprehensive studies that analyze and compare solid waste streams across different campuses within a unified university system. For the University of Science and Technology of Southern Philippines (USTP), no existing study has systematically established baseline data on waste composition, generation rates, volume, and per capita waste generation across its campuses. This absence of empirical data limits the development of an integrated and sustainable SWM framework tailored to the specific conditions and needs of each campus. Addressing this gap is crucial, as effective SWM planning requires accurate and localized data to inform policy formulation and implementation. Without such data, institutional efforts may remain fragmented, reactive, and misaligned with national sustainability goals.

In response, this study aims to generate comprehensive baseline information on solid waste streams across USTP campuses. Specifically, it seeks to: (a) determine the types of waste per campus; (b) analyze the percentage composition of waste; (c) measure the weight and volume of waste generated; and (d) estimate per capita waste generation per day. The findings of this study will serve as the basis for developing a sustainable and unified Solid Waste Management framework for the USTP System, thereby strengthening institutional capacity to address current and future waste management challenges.

2. Materials and Methods

2.1. Study Approach

This study utilized a descriptive–comparative design to examine solid waste generation across seven campuses of the USTP System. The descriptive component focused on identifying the types, composition, and quantities of waste generated, while the comparative component evaluated differences in waste generation patterns among campuses. This approach enabled both detailed characterization and cross-campus analysis of waste streams.

2.2. Study Sites and Institutional Context

The study was conducted across the seven campuses of the USTP, a state university established through Republic Act No. 10919. The university system originated from the integration of the Mindanao University of Science and Technology (MUST) in Cagayan de Oro and the Misamis Oriental State College of Agriculture and Technology (MOSCAT) in Claveria. The rest of the campuses were established after the integration of these two (2) major campuses.

The campuses included in the study (**Figure 1**) were:

- **USTP Cagayan de Oro (CDO)**—An urban campus with diverse academic and administrative activities
- **USTP Claveria**—A large agricultural-based campus.
- **USTP Oroquieta and USTP Panaon**—Satellite campuses located in Misamis Occidental.
- **USTP Alubijid, USTP Jasaan, and USTP Villanueva**—Campuses situated in Misamis Oriental with varying land uses (industrial, marine, and technological focus).

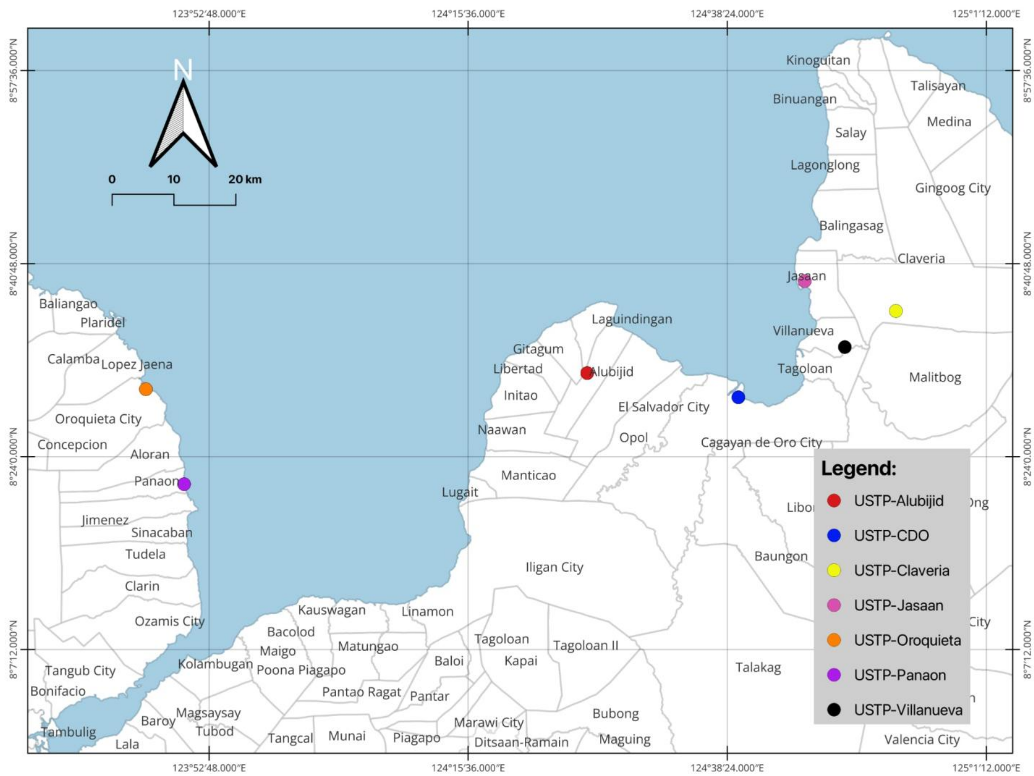

Figure 1. Map of the campuses of the USTP system.

These campuses differ in land area, population density, and academic specialization, making them suitable for comparative analysis of waste generation. The total student population across the system exceeds 20,000, contributing to significant and diverse waste streams typical of "mini-city" environments.

Figure 1 shows the map of the campuses of the USTP system. Both USTP CDO and Claveria are major campuses situated in Northern Mindanao, strategically positioned to serve, train and develop students from various regions of Mindanao. The university has a 7.3-ha Cagayan de Oro campus located at latitude 8.4855° N and longitude 124.6565° E. Its Claveria campus has 101.37 ha of rich agricultural land and is located at the latitude of 8.3641° N and longitude 124.5319° E. USTP Oroquieta, with a land area of 9.0 ha and USTP Panaon, with a land area of 4.2 ha, are located in the province of Misamis Occidental. The campus promotes a learning environment grounded in community engagement, research participation, and experiential learning, including programs that align with Panaon's rich coastal and marine environment. Meanwhile, USTP Alubijid, USTP Jasaan and USTP Villanueva are located in Misamis Oriental. USTP Alubijid is located in Barangay Lourdes, Alubijid Misamis Oriental, with a latitude of about 8.57° N and a longitude of about 124.47° E. It has a total area of 292 ha. This expansive area sets the stage for future developments like the AGILA Science and Technology Park, envisioned as a university-led science, technology, and innovation hub. Meanwhile, USTP Jasaan is a satellite campus situated in Jasaan, Misamis Oriental. It has a land area of 1.6 ha and serves as a regional center for technology and engineering education, with particular emphasis on marine and industrial technology. USTP Villanueva, on the other hand, is another major campus of the University of Science and Technology of Southern Philippines (USTP) established by Republic Act No. 11307 in 2019. It has a land area of about 5 ha situated in Poblacion 1, Villanueva, Misamis Oriental, Philippines, a growing industrial and innovation hub near the PHIVIDEC Industrial Estate in northern Mindanao.

2.3. Waste Sampling and Collection Procedure

Solid waste collection was conducted daily for one week on each campus. Collection activities were scheduled between 8:00 AM and 10:00 AM and carried out with the assistance of campus ground maintenance personnel. This was conducted during weekdays and weekends for a consecutive seven (7)-day period.

Unsegregated waste was collected from various buildings (e.g., classrooms, offices, and common areas) and transported to a designated open space within each campus. These areas served as temporary sorting stations where waste was prepared for characterization and measurement. The method is uniform all throughout the campuses.

2.4. Waste Segregation and Classification

Collected waste materials were manually sorted into predefined categories based on standard waste classification systems:

- Biodegradable waste;
- Non-plastic recyclables (e.g., paper, metals, glass);
- Plastic recyclables;
- Residual recyclables;
- Residual waste for disposal;
- Special waste (e.g., hazardous or electronic waste).

This classification allowed for a more detailed understanding of waste composition and potential recovery or disposal pathways.

2.5. Measurement of Waste Volume and Weight (Pre-Drying)

Waste volume was estimated using a standard container method. A pail with known dimensions (height and diameter) was used to approximate volume capacity. Waste materials were placed loosely inside the container without compaction to reflect their actual physical state.

Weight measurements were obtained using a calibrated 100-kg digital weighing scale, ensuring accuracy and consistency across all campuses. Initial measurements were taken immediately after collection to capture the fresh (wet) weight and volume of the waste.

2.6. Moisture Reduction through Sun Drying

To minimize the effect of moisture content on waste measurements, the segregated waste samples were subjected to sun drying. The drying process was conducted for approximately five hours per day over a one-week period.

This step was essential to reduce variability in weight caused by water content, particularly in biodegradable materials, and to allow for more reliable comparison across waste categories and campuses.

2.7. Measurement of Waste Volume and Weight (Post-Drying)

After the drying period, all waste categories were re-measured using the same procedures and instruments. The final (dry) weight and volume were recorded and used for analysis.

These post-drying measurements provided a more accurate representation of the actual waste mass and density, which are critical parameters in waste management planning and infrastructure design.

2.8. Data Analysis

The collected data were analyzed to determine:

- Waste type and composition (%).
- Waste generation (weight & volume) per campus.
- Waste generation rate (kg/day and kg/capita/day).
- Comparative differences among campuses.

Descriptive statistics and comparative analysis were used to identify trends and variations in waste generation across the USTP System.

3. Results and Discussion

3.1. Types and Percentage Composition of Waste Generated per Campus

The data presented in **Figure 2** was gathered over a 7-day sampling period, providing an overview of the composition of solid waste generated across the USTP system.

Waste Composition by Campus

The percentage composition of solid waste generated across the seven USTP campuses reveals significant variability in waste profiles, reflecting differences in campus activities, land use, and consumption patterns.

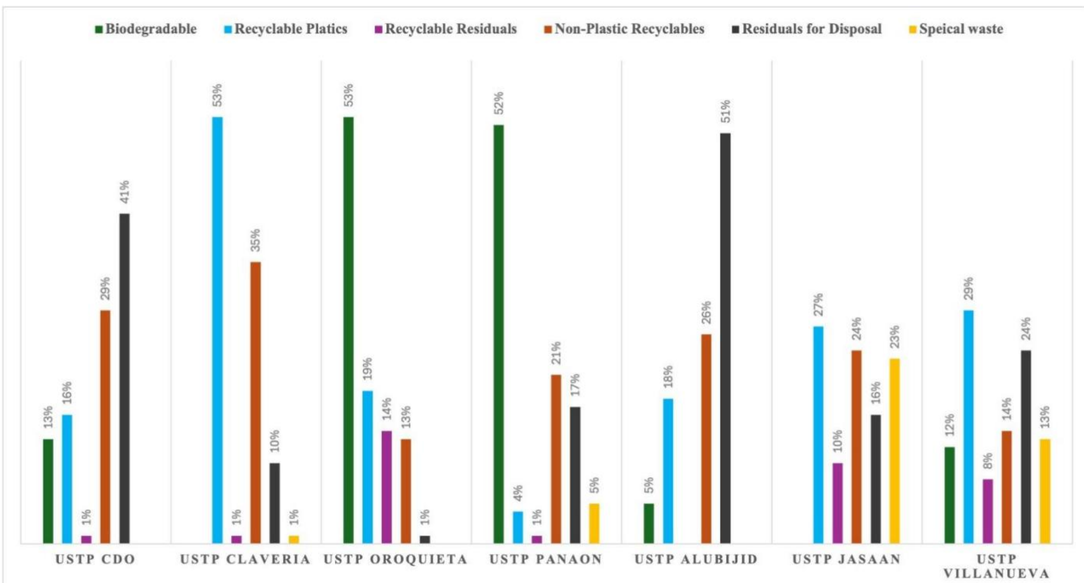

Figure 2. Solid waste composition across USTP campuses.

3.1.1. Discussion of USTP CDO

The waste composition analysis at USTP Cagayan de Oro (CDO) shows a predominance of residual waste (41%), indicating that a large portion of generated waste is either non-recoverable or not properly segregated at source. This reflects inefficiencies in segregation practices and limited diversion strategies within the campus. Similar trends have been observed in university-based waste studies, where poor segregation compliance leads to higher residual fractions and reduced material recovery efficiency[11]. Global assessments further emphasize that inadequate source segregation increases landfill-bound waste and constrains recycling and composting opportunities[12,13]. Meanwhile, the combined share of non-plastic recyclables (29%) and recyclable plastics (16%) suggests moderate to high recovery potential, consistent with findings that over 65% of institutional waste can be recyclable when properly managed[13]. Studies in Asian universities also report recyclable fractions ranging from 30–50%, indicating strong diversion opportunities when Materials Recovery Facility (MRF) systems and recycling programs are optimized[14]. The presence of recyclable plastics further reflects global trends of increasing plastic waste generation in institutional settings due to higher consumption of packaged goods[15].

In contrast, the biodegradable fraction (13%) is relatively low compared to typical municipal solid waste in developing countries, where organics often exceed 40–50%[10]. This may indicate under-segregation of organic waste or greater reliance on packaged and processed materials within the campus. The minimal proportion of recyclable residuals (1%) suggests limited secondary recoverable materials; however, the overall waste profile still highlights strong opportunities for diversion. The high residual fraction, alongside significant recyclable components, underscores the need to improve source segregation, strengthen recycling systems, and expand composting initiatives. Consistent with solid waste management literature, institutions with high recyclable fractions can substantially reduce landfill dependence through targeted waste minimization and circular economy strategies, including stricter segregation enforcement, reduction of single-use materials, and optimization of recovery systems[13,15,16].

3.1.2. Discussion of USTP Claveria

The waste composition analysis for USTP Claveria indicates a predominantly recyclable waste stream, with recyclable plastics (53%) and non-plastic recyclables (35%) comprising about 88% of total waste, reflecting strong potential for material recovery and circular resource use. The dominance of plastics aligns with national and global trends driven by widespread use of single-use packaging and convenience products[13,15]. Meanwhile, the relatively low residual fraction (10%) suggests more effective segregation practices compared to other contexts, where residual waste is significantly higher, such as 68.42% in agricultural communities and 35–38% in institutional settings[17,18]. The minimal presence of special waste (1%) and recyclable residuals (1%) indicates low generation of hazardous and low-recovery materials, although proper handling remains essential due to associated environmental and health risks[19]. However, the absence of biodegradable waste data, particularly agricultural residues, due to methodological limitations likely overestimates recyclable fractions, as organics can exceed 50% when fully accounted for[20].

The substantial share of non-plastic recyclables and diverse plastic types (e.g., Polyethylene Terephthalate (PET), High-Density Polyethylene (HDPE), Low-Density Polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS) highlights strong opportunities for recovery through improved Materials Recovery Facility (MRF) operations and enhanced segregation systems, consistent with findings in university settings where paper and packaging waste dominate[14,16]. The presence of recyclable residuals such as textiles and rubber also suggests potential for reuse and upcycling within circular economy approaches[10,15]. Despite this, the high proportion of plastic waste underscores the need for targeted reduction strategies linked to convenience-driven consumption behaviors[13]. Overall, while USTP Claveria demonstrates strong diversion potential, a more comprehensive assessment that includes biodegradable waste, alongside strengthened segregation and improved data capture in future WACS activities, is essential for more accurate and sustainable waste management planning.

3.1.3. Discussion of USTP Oroquieta and USTP Panaon

USTP Oroquieta and USTP Panaon both exhibit waste streams dominated by biodegradable materials, reflecting conditions typical of campuses with agricultural, coastal, or community-based activities where organic residues are prevalent. Biodegradable wastes such as food scraps and vegetable peels decompose naturally through microbial processes and commonly dominate institutional waste due to daily food service operations[8]. Their diversion through composting or anaerobic digestion is widely recommended to reduce landfill disposal while generating useful by-products like compost or biogas[21]. At USTP Oroquieta, biodegradable waste accounts for 53%, followed by recyclable plastics (19%), recyclable residuals (14%), and non-plastic recyclables (13%), with only 1% residuals. This aligns with studies showing organic fractions exceeding 40–50% in institutions with active food services[12,21]. The low residual fraction further indicates high diversion potential, while the presence of recyclables suggests opportunities for improved recovery systems [12,13].

Similarly, USTP Panaon shows a biodegradable fraction of 52%, consistent with institutional waste profiles where organics typically comprise 30–60% of total waste [22]. Non-plastic recyclables (21%) and recyclable plastics, particularly PET bottles, represent significant recoverable materials that can be diverted through effective segregation and behavioral interventions [22,23]. Recyclable residuals such as textiles and leather also offer opportunities for reuse and specialized recycling [24,25]. However, the higher residual fraction (17%) compared to Oroquieta suggests possible segregation inefficiencies, while the presence of special waste (5%) highlights the need for strict hazardous waste management [26]. Overall, both campuses demonstrate strong diversion potential, but effective outcomes depend on consistent segregation, adequate infrastructure, and institutional compliance.

3.1.4. Discussion of USTP Alubijid

USTP Alubijid recorded the highest proportion of residual waste for disposal (51%) among all campuses, indicating significant gaps in waste segregation and recovery efficiency, with much of the waste either non-recoverable or improperly sorted. Despite the presence of non-plastic recyclables (20–26%) and recyclable plastics (18%), suggesting moderate recovery potential, the very low biodegradable fraction (5%) implies under-segregation or minimal capture of organic waste. The waste stream during the seven-day WACS was largely composed of soiled paper (51%) from food and beverage consumption, such as napkins and tissues, which become non-recyclable when contaminated, further intensified by the use of single-use paper products in campus settings [27,28]. Additional recyclable materials, including cartons and plastics like PET and HDPE, reflect typical institutional consumption patterns tied to packaging and bottled goods [29,30]. Although the campus generates relatively low total waste due to its small and recently established population, the high residual fraction highlights a disposal-oriented system influenced by reliance on single-use materials, underscoring the need for improved source segregation, reduction strategies, and strengthened recycling and composting systems to support more sustainable waste management.

3.1.5. Discussion of USTP Jasaan

USTP Jasaan exhibits a relatively balanced waste composition, with recyclable plastics (27%), non-plastic recyclables (24%), and a notably high proportion of special waste (23%), likely linked to laboratory and technical activities, while the very low biodegradable fraction (1%) suggests limited organic waste generation or poor segregation. The dominance of paper-based materials among non-plastic recyclables aligns with studies showing their prevalence in institutional waste streams [31] and their significant contribution to municipal waste in the Philippines [32]. Residual waste (16%) is mainly composed of sanitary composites and soiled paper such as diapers, napkins, and tissues which are non-recyclable and require landfill disposal [33]. At the same time, the presence of diverse recyclables, including plastics (PET, LDPE, PP, PS), glass, and metals, indicates strong recovery potential, although increasing reliance on single-use plastics remains a concern due to environmental impacts [34,35]. Recyclable residuals like textiles offer opportunities for reuse, while the significant share of special waste, such as batteries and chemical containers, highlights the need for strict hazardous waste management. Overall, the campus waste profile underscores the importance of strengthening segregation, recycling systems, hazardous waste control, and waste minimization strategies for sustainable solid waste management.

3.1.6. Discussion of USTP Villanueva

USTP Villanueva exhibits a mixed waste profile, with recyclable plastics (29%) as the dominant component, followed by residuals for disposal (24%) and non-plastic recyclables (14%), while the presence of special waste (13%) and biodegradable waste (12%) reflects diverse sources influenced by nearby industrial activities, laboratory operations, and food services. Biodegradable waste, largely from canteen and food consumption activities, poses risks such as odor, pests, and methane emissions if unmanaged, but also offers opportunities for composting and biofertilizer production to reduce landfill dependence [36–38]. The prominence of recyclable plastics, particularly PET bottles, highlights high consumption of packaged beverages and strong recovery potential if properly segregated, while non-plastic recyclables like paper, glass, and metals further support recycling opportunities, with materials such as glass being fully recyclable without quality loss. However, the relatively high residual fraction mainly soiled paper and sanitary waste, indicates persistent segregation challenges, and the presence of hazardous special waste underscores the need for strict management protocols. Overall, the campus demonstrates moderate diversion potential, but improving segregation, enhancing recycling and composting systems, and strengthening hazardous waste control are essential for more sustainable waste management, consistent with the need for campus-specific strategies across varying waste profiles within the USTP system.

3.2. Weight and Volume of Waste Generated per Campus

Table 1 showed the Average Weight & Volume of solid waste collected in a 7-day period, Waste Analysis and Characterization Study (WACS). The WACS study conducted across the seven campuses of the University of Science and Technology of Southern Philippines (USTP) demonstrates distinct variations in average daily solid waste generation and waste characteristics, underscoring the influence of campus activity levels and waste composition on overall waste profiles. The CDO campus produced the highest quantity of solid waste (93.03 kg/day; 1,258.09 L/day), which is consistent with findings that waste generation rates in educational institutions are directly associated with population density, campus size, and the presence of commercial and food service outlets [39].

Panaon campus also showed high waste weight but exhibited the lowest volume-to-weight ratio (0.0087 m^3/kg), indicating denser waste, likely attributable to a larger fraction of damp organic materials such as food waste which research shows tends to elevate waste density due to its moisture content. Smaller campuses such as Alubijid (1.11 kg/day) and Jasaan (6.33 kg/day) recorded significantly lower waste generation, reflecting their smaller populations and limited campus operations, which is in line with recent campus waste studies that link lower waste outputs to smaller institutional scales. The volume-to-weight ratios further highlight compositional differences: Villanueva exhibited the highest ratio at 0.0471 m^3/kg, suggesting a predominance of low-density materials such as plastics, packaging, and paper. This observation is supported by recent waste characterization research indicating that campuses with higher shares of plastics and packaging generate waste streams with elevated volume relative to weight [40].

Table 1. Average Weight & Volume of Waste Collected per Campus in 7 days.

USTP Campus	Ave. Weight of Solid Waste Collected (kg)	Ave. Volume of Waste Collected (L)	Volume (m^3) to Weight (kg) Ratio
CDO	93.03	1,258.09	0.0135
Claveria	38.53	629.31	0.0163
Oroquieta	29	606.9	0.0209
Panaon	59.1	514.4	0.0087
Alubijid	1.11	20.52	0.0185
Jasaan	6.33	99.67	0.0157
Villanueva	7.38	347.72	0.0471

Intermediate waste generation and moderate volume-to-weight ratios in Claveria and Oroquieta suggest mixed waste streams with both organic and inorganic fractions, consistent with integrated waste assessments in tertiary institutions that emphasize the influence of student behavior and institutional services on waste composition [41]. Understanding both the mass and density of waste is imperative for infrastructure planning, such as selecting appropriate containers, scheduling collections, and designing Materials Recovery Facilities (MRFs), as highlighted in recent solid waste management frameworks [37]. Collectively, these results validate the necessity of tailored, data-driven waste management strategies across campuses of differing sizes and functions, aligning with contemporary solid waste management research advocating for context-specific interventions to optimize diversion, recycling, and treatment outcomes [39].

3.3. Generated Waste per Capita per Day per Campus

Table 2 below shows the waste generation per capita per day in terms of weight and volume generation. It is calculated according to the formula in kilograms and in liters:

$$\text{Waste Generation per Capita per Day(kg/capita/day)} = \frac{\text{Total Waste Generated (kg)}}{\text{Population Size} \times \text{Number of Days}}$$

$$\text{Waste Generation per Capita per Day (liters/capita/day)} = \frac{\text{Total Waste Volume (liters)}}{\text{Population Size} \times \text{Number of Days}}$$

Table 2. Waste Generation per capita per day in kg and L.

USTP Campus	Expansion Factor	Adjusted Waste Generation (kg)	Per Capita Waste Generation in Weight (kg)	Per Capita Waste Generation in Volume (L)
CDO	0.85	79.48	0.90	1.2
Claveria	0.87	48.32	0.75	1.1
Oroquieta	0.88	16.53	0.6	0.9
Panaon	0.83	11.58	0.7	0.85
Alubijid	0.78	6.92	0.5	0.7
Jasaan	0.84	8.92	0.65	0.8
Villanueva	0.82	15.62	0.7	0.9

Table 2 presents the adjusted waste generation and per capita waste generation (kg/day and L/day) across the seven campuses of the University of Science and Technology of Southern Philippines (USTP), incorporating expansion factors (0.78–0.88) to estimate total daily waste beyond the 7-day sampling period. The use of expansion factors is consistent with standard waste assessment methodologies, which recommend adjusting measured data to better represent actual generation rates in institutional settings [28,42]. Among the campuses, CDO recorded the highest per capita waste generation at 0.90 kg/person/day (1.2 L/person/day), followed by Claveria at 0.75 kg/person/day (1.1 L/person/day). These values are relatively high compared with global averages for municipal solid waste generation in low- and middle-income countries, which range from 0.5 to 0.8 kg/person/day according to the World Bank Report *What a Waste 2.0* [38]. The elevated per capita rate in CDO may be attributed to higher campus population density, increased academic and laboratory activities, and the presence of commercial food establishment factors that have been shown to increase waste generation in higher education institutions. Larger campuses typically demonstrate higher per capita values due to diversified consumption patterns and greater on-site services.

Moderate per capita generation was observed in Panaon (0.70 kg/day), Villanueva (0.70 kg/day), and Jasaan (0.65 kg/day), while Oroquieta (0.60 kg/day) and Alubijid (0.50 kg/day) exhibited comparatively lower rates. These figures fall within the lower range of institutional waste generation benchmarks reported in recent Asian campus waste studies [43]. Lower per capita generation may reflect smaller student populations, fewer commercial establishments, and potentially more efficient resource use. However, per capita waste values must also be interpreted alongside waste composition data, as institutions dominated by food waste may show higher weight-based values due to moisture content, whereas campuses with greater proportions of plastics and paper may exhibit higher volume-based indicators. The per capita waste generation in volume (0.7–1.2 L/person/day) generally follows the same trend as weight, reinforcing the relationship between institutional scale and waste output. Recent literature emphasizes that per capita indicators are critical metrics for planning waste storage capacity, collection frequency, and diversion targets in both universities and communities [44]. Moreover, benchmarking per capita generation enables institutions to evaluate the effectiveness of waste reduction initiatives over time and align strategies with sustainable campus frameworks.

Overall, the results suggest that USTP campuses with higher per capita waste generation, particularly CDO and Claveria, should prioritize waste minimization programs, source segregation reinforcement, and composting initiatives. Meanwhile, campuses with lower per capita values may focus on preventive measures to maintain low generation rates. These findings support contemporary solid waste management principles that advocate for data-driven, site-specific planning to enhance resource efficiency and sustainability in higher education institutions.

4. Conclusion

Across all USTP campuses, waste profiles and generation rates vary according to campus size, population, activities, and consumption patterns. Larger campuses like CDO and Claveria produce higher overall and per capita waste, dominated by organic and food-related materials or plastics and recyclables, while smaller campuses generate less waste with lower per capita outputs. Variations in composition and volume-to-weight ratios highlight differences in density and material types, underscoring the need for tailored, data-driven strategies. Overall, these findings emphasize the importance of campus-specific interventions, including source segregation, recycling, composting, appropriate collection systems, and monitoring per capita generation, to improve sustainability, optimize waste diversion, and support effective solid waste management across the university system.

Recommendations

It is recommended that the USTP system implement campus-specific waste management strategies focusing on enhanced source segregation, recycling of plastics, paper, metals, and glass, and composting of organic waste. Larger campuses should prioritize frequent collection, adequate storage, and targeted reduction programs, while smaller campuses can focus on efficient segregation, recycling, and awareness campaigns. All campuses should apply clear policies for hazardous and special wastes, use per capita and composition data to guide planning, and monitor compliance to improve diversion, sustainability, and overall campus waste management.

Author Contributions

All authors contributed equally to the conception, design, data collection, analysis, and writing of this study. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

The data used in this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

AI Use Statement

The authors declare that no artificial intelligence (AI) tools were used in the preparation of this manuscript.

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