Scientific Research Publishing

Open Journal of Applied Sciences, 2026, 16(3), 905-926
https://www.scirp.org/journal/ojapps
ISSN Online: 2165-3925
ISSN Print: 2165-3917

Solid Waste Generation and Management Practices at the University of Education, Winneba

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How to cite this paper: Gesuli-Saliba, K.A., Kabutey, F.T., Annan, S.T., Nyieku, F.E., Agbosu, W.K., Lumorh, P.D.-D. and Nkansah, F.K. (2026) Solid Waste Generation and Management Practices at the University of Education, Winneba. *Open Journal of Applied Sciences*, **16**, 905-926.
https://doi.org/10.4236/ojapps.2026.163054

Received: February 16, 2026
Accepted: March 20, 2026
Published: March 23, 2026

Abstract

Solid waste generation and management have become major environmental concerns in developing countries, particularly in institutional settings where rapid population growth and urban development exceed the capacity of existing waste management systems. This study examined the composition, energy recovery potential, and management practices of the solid waste generated at the South Campus of the University of Education, Winneba (UEW), Ghana, to provide empirical data to inform circular-economy-oriented waste management strategies. A mixed-methods approach was adopted, integrating quantitative waste characterisation and focus group discussions. Nineteen (19) waste bins were selected through stratified proportionate sampling from a total of sixty-two (62) across five student halls of residence, whereas ten (10) participants were randomly selected for the focus group discussion. Waste samples were collected daily for sixty (60) days, spanning both the dry and wet seasons. The waste was manually sorted, weighed, and analysed for moisture content, volatile matter, ash content, fixed carbon content, and calorific value. The results revealed that organic waste constituted the predominant fraction (60.65%) of the total waste stream, followed by plastics (28.93%), paper (5.12%), metal (3.64%), glass (1.66%), and textiles and e-waste (<1%). The average calorific value of the organic fraction was 14.20 MJ/kg, with mean moisture and ash content values of 39.27% and 7.53%, respectively. These findings indicate that the waste stream has viable potential for energy recovery through biological conversion processes, such as anaerobic digestion and composting. The study recommends that the UEW implement structured segregation, composting, and small-scale waste-to-energy initiatives to promote sustainable resource utilisation and align institutional waste management practices with Ghana's circular economy transition.

Keywords

Solid Waste Characterisation, Calorific Value, Proximate Analysis, Circular Economy, Waste-to-Energy

1. Introduction

The accelerated growth of global solid waste generation and management has become a critical sustainability concern with profound implications for environmental quality, public health, and institutional resilience [1]. This challenge is particularly acute in developing economies, where rapid urban expansion, shifting consumption patterns, and limited technological capacity have outpaced the development of effective waste management infrastructure and governance systems [2].

Shabani and Jerie [3] argued that the persistent imbalance between escalating waste volumes and inadequate management responses continues to produce severe environmental externalities, strain municipal budgets, and undermine efforts toward sustainable urban development. In sub-Saharan Africa, particularly Ghana, waste management is dominated by traditional linear disposal pathways, primarily open dumping, rudimentary landfilling, and occasional burning [4]. These practices contribute massively to soil and water contamination, air quality deterioration, and greenhouse gas emissions, while simultaneously limiting opportunities for resource recovery from high-value waste fractions, such as organics and plastics [5].

Structural challenges, including inadequate source segregation, limited logistical and financial capacity, and low public awareness, further constrain the adoption of modern and sustainable waste management systems [6].

Institutions of higher learning constitute dynamic microcosms of urban environments that generate diverse and substantial quantities of waste from academic facilities, residential halls, commercial activities, and campus-wide social engagements [7]. Their controlled environments and predictable waste streams offer a strategic opportunity to develop, test, and institutionalise sustainable waste management models that can be scaled to broader municipal perspectives. Despite this potential, many Ghanaian universities, including the University of Education, Winneba (UEW), continue to operate within a linear framework that neglects the economic and environmental benefits of material recovery, recycling, and energy generation [8].

Zhang and his colleagues [9] are of the view that the circular economy (CE) paradigm presents a transformative alternative to these linear systems by promoting closed-loop material flows, optimized resource use and the reconceptualization of waste as a valuable resource rather than a liability. The institutional adoption of CE principles enhances operational efficiency and reduces environmental footprints, aligning with national and global policy priorities, such as the Sustainable Development Goals [10]. However, the operationalisation of circular economy models requires reliable, context-specific data on waste composition, quantity, and seasonal variability, which are limited across Ghanaian tertiary institutions.

Previous research established that universities characterized by intensive academic operations, high residential occupancy and diverse commercial engagements generate substantial quantities of solid waste [11] [12], however, at the University of Education, Winneba (UEW) South Campus, detailed empirical evidence on the generation, composition and resource recovery potential of these waste streams remains limited. This knowledge gap constrains strategic planning, delays the adoption of sustainable waste management pathways, and hinders the university's ability to leverage its waste stream for resource and energy recovery [13] [14]. By transitioning to a circular economy model, the UEW (South Campus) can improve waste management practices and serve as a model for other institutions and communities to emulate.

Unlike earlier studies that primarily employed perception-based tools such as questionnaires and interviews to evaluate waste management practices in higher education institutions, this study introduces a proximate analysis-based approach to directly quantify the energy recovery potential of solid waste generated at the UEW.

Accordingly, this current study aimed to establish the empirical foundation necessary for sustainable and circular solid waste management at the UEW South Campus, specifically to characterise the composition of solid waste generated across the halls of residence and evaluate the energy recovery potential embedded in the organic waste fraction, thereby informing CE-aligned interventions.

2. Materials and Methods

2.1. Description of Study Area

The University of Education, Winneba, is located in the Central Region of Ghana. It was established in 1992 and now serves as Ghana's leading teacher-education institution [15]. It operates three main campuses in Winneba: North, South, and Central. The university houses approximately 72,0840 students and 2,3190 staff, of which approximately 1,983 are full-time [16].

The focus of the current study is the South Campus, which is situated along the Accra-Cape Coast highway at approximately 5˚20 N latitude and 0˚37 W longitude, covering about 0.65 km^2. It hosts key academic and residential units, including the Faculty of Science Education, Foreign Languages, and Aggrey and Ghartey halls as shown in **Figure 1**.

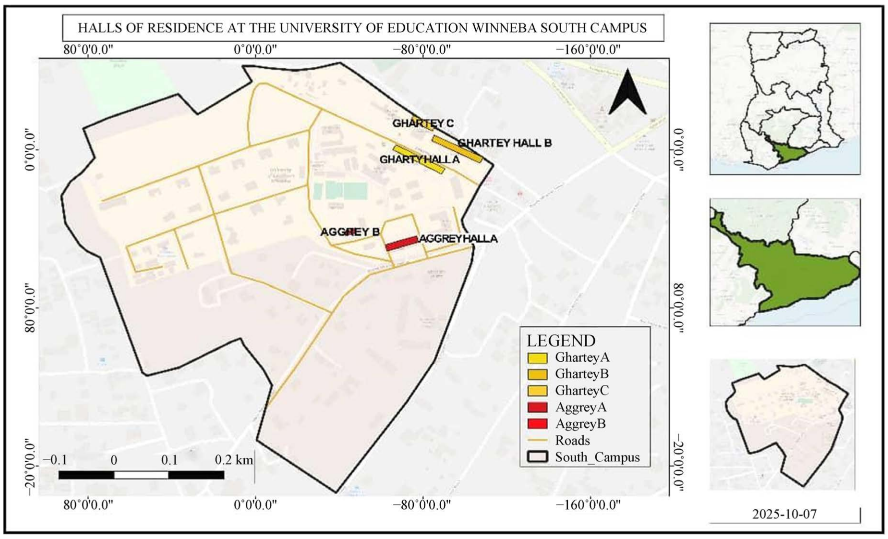

Figure 1. Map of the study area showing the sampling locations.

2.2. Research Design

A mixed-method design was employed, combining quantitative waste characterisation and qualitative thematic analysis. A proportionate stratified random sampling technique was adopted, using the specific hall of residence as the primary stratification variable, to ensure the equitable representation of all residential halls. From a total of sixty-two (62) waste bins, nineteen (19) were selected for sampling. The selection ensured that each hall's sample contribution was proportional to its total number of bins. Waste was collected daily for sixty (60) consecutive days to capture seasonal variations in waste composition. The "daily" sampling was operationalised by collecting all waste that had accumulated in each selected bin over the preceding 24-hour period. Collections were conducted each morning between 8:00 AM and 10:00 AM before the first routine waste pickup by sanitation staff. After each collection, the bins were emptied and returned to their original locations to begin accumulating waste for the next day's sample. The 60-day sampling period was designed to encompass both the major wet and dry seasons in the Winneba area. The wet season sampling was conducted from mid-April to mid-June, and the dry season sampling was conducted from late October to late December, capturing the characteristic weather patterns of the region. In addition, ten (10) participants were selected for the focus group discussion, consisting of students and sanitation staff, which lasted for twenty (20) to thirty (30) minutes.

Each collected waste sample was processed manually by sorting according to the guidelines cited by Ullah *et al.*, [17]. Before sampling, the collected samples were mixed to ensure proper representativeness.

The process followed the classification explained by Osei-Mensah *et al.*, [18]. Waste was separated by hand into the following categories: organic, plastic, paper, metal, glass, textiles, and e-waste. Before sorting, measures were taken to prevent injury and contamination. Items such as glass and e-waste were handled with extra care to ensure the safety of the researchers. Weights were measured using a digital electronic scale (Model: HF1976-6277).

The tare weight of each bin was first established, after which the gross weights of the respective waste fractions were recorded. These values were subsequently used to derive the net weight of each waste fraction, from which the percentage composition and proportional generation were calculated by Singh *et al.*, [19]. The analytical procedure employed aligns with the methodological framework articulated by Safo-Adu and Owusu-Adzorah [20].

$$\%Composition\ of\ waste\ fraction = \frac{weight\ of\ each\ waste\ fraction}{total\ weight\ of\ solid\ waste} \times 100$$

Personal protective equipment (PPE), including heavy-duty rubber boots, thick gloves, masks and aprons, was used to ensure safety.

Tools such as hand trowels, rakes, and spades were used to gather and scoop the waste into bins. Sealable bags were used to transport the samples. Waste samples were emptied from various bins into large lined buckets, each properly tagged with the location and date.

2.3. Estimation of Energy Potential using a Bomb Calorimeter

The energy potential of the organic fractions collected from the five halls of residence was determined by measuring the respective gross calorific values (GCV) using a bomb calorimeter. This provided data on the energy content of the waste samples, Elem *et al.*, [21]. To validate these measurements, predictive models based on waste composition were utilised, allowing a comparison between the experimental and estimated values. Specifically, the experimental gross calorific values (GCV) of the organic waste samples were compared with values predicted by the modified Dulong's formula, a standard model for estimating the heating value of wastes based on their elemental composition. The mean absolute percentage error between the measured and predicted values was 8.5%, indicating good agreement and validating the experimental calorimetry results.

The gross calorific values of each waste sample were calculated using the following formula:

$$GCV\ or\ HHV\left(kJ\right) = \frac{\left(W+\omega\right)\left(T_2-T_1\right)-e}{m}$$

where;

W = water equivalent of calorimeter (kg/˚C);

ω = mass of water used (kg);

$T_2 - T_1$ = change in temperature (˚C);

e = correction for fuse wire and acid formation (KJ);

m = mass of sample (kg).

The energy released was calculated using the following formula:

$$Energy\left(kJ\right) = GCV\left(\frac{kJ}{kg}\right) \times Mass\left(kg\right)$$

The process involved several steps, including sample preparation, combustion in the calorimeter, and calculation of the released energy.

2.4. Sample Collection and Preparation

Organic waste from each hall was collected during two different seasons to capture variations in composition. The collected samples were oven-dried at 105˚C for 24 h to a constant weight to reduce moisture content [22] [23]. Once dried, the samples were ground into fine particles to ensure uniform combustion during the analysis. Approximately 1 gram of the prepared sample was weighed accurately using an analytical balance with a precision of ±0.001 grams.

2.5. Bomb Calorimeter Setup and Combustion

The weighed samples were placed in a combustion crucible and positioned inside the bomb chamber. An ignition wire was aligned in contact with the samples for ignition purposes. The camber was then sealed properly and filled with pure oxygen gas to a pressure of about thirty (30) atmospheres [24]. This ensured complete combustion. The sealed bomb was then immersed in a known quantity of water in the calorimeter vessel.

Moisture, volatile and ash contents and fixed carbon were measured using the following equations.

$$Moisture\,content\,(\%) = \frac{wet\,weight - dry\,weight}{wet\,weight} \times 100$$

$$Volatile\,matter\,(\%) = \frac{Weight\,loss\,(excluding\,moisture)}{Initial\,dry\,weight\,of\,sample} \times 100$$

$$Ash\,content\,(\%) = \frac{Weight\,of\,ash}{Initial\,dry\,weight\,of\,sample} \times 100$$

$$Fixed\,carbon\,(\%) = 100 - (MC + VM + AC)$$

3. Results and Discussion

3.1. Waste Composition across Halls

The study revealed that a total of 11,859.96 kg of solid waste was generated across the five halls of residence at the UEW South Campus, in **Table 1**, with notable differences among the halls. This total represents the aggregated weight of waste collected over the 60-day sampling period from all 62 waste bins located across the five halls of residence. To derive this campus-wide total from the 19 sampled bins, the average daily waste generation per bin was calculated for each hall based on its sampled bins. This hall-specific daily average was then multiplied by the total number of bins in that hall to estimate the hall's total daily generation. These daily hall totals were then summed and multiplied by 60 days to arrive at the final campus-wide total of 11,859.96 kg for the study period. This provides a robust estimate of waste generation across the entire South Campus residential area.

Table 1. Average total waste generated in each hall.

Hall	Average Total weight of waste (kg)	Percentage %
Ghartey Hall A	1102.43 ± 68.7	9.30
Ghartey Hall B	2684.63 ± 154.2	22.64
Ghartey Hall C	2144.57 ± 131.6	18.08
Aggrey Hall A	2790.14 ± 165.3	23.53
Aggrey Hall B	3138.19 ± 190.5	26.46
Total	**11859.96 ± 465.6**	**100.00**

Source: Field survey, 2025.

Aggrey Hall B produced the highest quantity (26.46%), followed by Aggrey Hall A (23.53%), Ghartey Hall B (22.64%), Ghartey Hall C (18.08%) and Ghartey Hall A (9.30%). Based on the aggregated total and the official occupancy data provided by the university's Estates Directorate for the sampling window, the average per-capita waste generation rate was calculated to be 0.48 kg per resident per day. This figure is critical for comparing the findings with other campus studies and for accurately planning future bin capacity and waste collection frequencies. The observed quantitative variation in waste generation across the halls reflects differences in population density, students' lifestyles and availability of catering services, consistent with the findings of Nyumah, Fallah, *et al.*, [25] and Meli, Joel, and Lagat, [26] who linked waste generation intensity to occupancy, gender composition and socioeconomic factors. Waste generation varies across the halls, requiring tailored collection and storage. A high organic fraction calls for strict segregation and composting, whereas plastics and other recyclables highlight opportunities for recycling and waste reduction. The large organic content in mixed waste also indicates the need for improved storage and sanitation.

The organic fraction dominated the waste stream (60.65%), followed by plastics (28.93%), with smaller portions of paper (5.81%), metals (4.24%), glass (1.95%), textiles (0.84%), and e-waste (0.13%), as indicated in **Table 2**.

The quantitative dominance of organic waste can be attributed to food-related activities within the halls, including meal preparation and consumption of vendor-provided meals. These patterns are broadly consistent with findings from similar African universities [27], suggesting that the UEW South Campus reflects waste generation characteristics typical of large public tertiary institutions in a comparable socio-economic and climatic setting. The high plastic content, especially in Aggrey B (31.7%), indicates a growing dependency on single-use packaging and bottled water, a trend documented in other institutions and municipal studies [12] [28]. Paper waste was relatively higher in halls with higher levels of academic engagement, such as Ghartey Hall C and Aggrey Hall A, reflecting intensive use of textbooks, handouts, exercise books, and notebooks [29] [30]. Minor fractions of metals, glass, textiles, and e-waste, although small, present opportunities for recycling and resource recovery under a circular economy framework.

Table 2. Average waste composition in each hall.

Waste Type	Ghartey Hall A	Ghartey Hall B	Ghartey Hall C	Aggrey Hall A	Aggrey Hall B	Total
Organic (kg)	394.01 (71.48%)	805.21 (59.99%)	696.11 (64.92%)	772.94 (55.41%)	838.94 (53.47%)	3,507.21 (60.65%)
Plastic (kg)	94.21 (17.09%)	341.84 (25.47%)	274.65 (25.61%)	464.47 (33.29%)	497.99 (31.74%)	1,673.16 (28.93%)
Metal (kg)	15.63 (2.84%)	90.52 (6.74%)	26.68 (2.49%)	50.88 (3.64%)	61.23 (3.90%)	244.94 (4.24%)
Paper (kg)	29.79 (5.41%)	60.24 (4.49%)	64.13 (5.98%)	72.17 (5.17%)	109.73 (6.99%)	336.06 (5.81%)
Glass (kg)	10.22 (1.85%)	37.40 (2.79%)	7.99 (0.75%)	24.00 (1.72%)	32.99 (2.10%)	112.60 (1.95%)
Textile (kg)	7.21 (1.31%)	5.11 (0.38%)	1.21 (0.11%)	8.48 (0.61%)	26.39 (1.68%)	48.40 (0.84%)
E-waste (kg)	0.12 (0.02%)	1.98 (0.15%)	1.48 (0.14%)	2.11 (0.15%)	1.80 (0.11%)	7.49 (0.13%)

Source: Field survey, 2025.

Variability across halls was moderate (6% - 9%), indicating relatively consistent waste generation patterns, although organic waste exhibited the largest deviations (28 - 70 kg), suggesting fluctuations linked to irregular meal preparation and consumption behaviours.

Plastics and paper exhibited smaller fluctuations, indicating relatively stable consumption patterns that are less sensitive to short-term behavioural changes. Whereas metals, glass, textiles, and e-waste showed minor variability, reflecting occasional disposal events. These findings demonstrated that waste generation at the UEW South Campus is both quantitatively significant and compositionally suited for targeted hall-specific sustainable waste management interventions.

3.2. Energy Generation Potential of the Solid Waste Generated at the South Campus

Complementary proximate and calorific analyses revealed that the South Campus waste possesses considerable energy potential, particularly the organic fraction, which is dominant. The mean calorific value (CV) of 14.20 MJ/kg 4.14. All calorific values and proximate analysis results (volatile matter, ash content, fixed carbon) in **Table 3** are reported on a dry basis, as the samples were oven-dried at 105˚C prior to analysis. This drying process removed the moisture, meaning the reported energy content represents the potential of the solid combustible material itself. While this dry basis is standard for characterising fuel quality, the high in-situ moisture content of the waste (39.27%) must be considered when assessing the net energy recoverable from wet, as-discarded waste.

The observed calorific value aligns with institutional waste studies in similar climates [31], indicating that the energy characteristics of UEW's waste stream are not anomalous but representative of comparable university settings.

However, the high moisture content (39.27%) characteristic of tropical institutional food waste [32] [33] reduces thermal efficiency and limits direct incineration, although it enhances the suitability of the substrate for anaerobic digestion, which favours microbial decomposition and methane production [34].

The Volatile matter content (40.16%) indicates a substantial fraction of thermally and biologically reactive compounds, supporting the potential for pyrolysis, gasification, or biogas generation [35] [36]. The fixed carbon (10.34%) and ash content (10.23%) were within acceptable limits, indicating manageable post-processing residues and the possible reuse of ash for soil enrichment or composting [5] [37].

Extrapolation of calorimetric data suggests that significant renewable energy can be recovered from the organic fraction; however, given the high moisture content, anaerobic digestion represents the most immediate feasible option, while thermochemical pathways such as pyrolysis and gasification are more suitable as long-term interventions following pre-treatment [38] [39].

This can drive innovative hybrid waste-to-energy technologies, integrate with campus energy systems, and provide decentralised energy outages. Highlighting its energy potential may promote behavioural change in waste segregation, while attracting funding, partnerships, and research opportunities.

To contextualise the energy potential at a campus scale, the daily generation of organic waste was calculated. Using the per-capita generation rate and hall occupancy, the average daily organic waste generated across the campus is approximately 1045 kg (wet weight). At the measured dry-basis calorific value of 14.20 MJ/kg, and accounting for the average moisture content of 39.27%, the daily energy potential from the organic fraction is estimated to be approximately 9000 MJ/day, or 2500 kWh/day. This represents a substantial renewable energy resource. Taken together, these results indicate that while the UEW South Campus waste stream poses management challenges, it also presents a realistic opportunity for phased waste-to-energy integration within the university's sustainability initiatives.

These findings clearly demonstrate that the waste streams generated at the UEW South Campus are not only a challenge to environmental management but also a resource for sustainable energy production, reinforcing the importance of integrating segregation, pre-treatment, and conversion technologies within campus waste management.

Table 3. Average proximate and calorimetric measurements of organic waste fraction.

Variable	Mean	Std. Deviation
Moisture Content (%)	39.27	12.45
Ash Content (%)	10.23	1.61
Fixed Carbon (%)	10.34	4.39
Volatile Matter (%)	40.16	6.61
Calorific Value (MJ/kg)	14.20	4.14
Energy Released (MJ)	0.01	0.004

Source: Field survey, 2025.

Note: The "Energy Released (MJ)" value of 0.01 MJ refers to the absolute energy released from the approximate 1-gram sample during the bomb calorimetry test. It is not a per-kilogram value, nor does it represent the energy potential of the campus's daily or total organic waste stream.

3.3. Current Solid Waste Management Practices at the University of Education, Winneba

Current waste management practices at UEW are predominantly oriented toward collection, transport and disposal, with insufficient emphasis on systematic source segregation, material recovery and treatment [27].

Asare *et al.*, [6] argued that the absence of an integrated waste management framework, particularly for separating organic, recyclable and residual waste streams, limits the effectiveness of recycling and waste diversion initiatives and constrains progress toward circular economy objectives. Waste generated across the campus is deposited in communal bins without formal separation of organic, recyclable and residual fractions [12].

Collection services are carried out by contracted sanitation staff under the supervision of the university's Health and Sanitation Education department at the North Campus. Although waste is periodically removed from campus, collection frequency is often irregular, particularly in high-density residential areas, leading to bin overflow, littering, odour nuisance and pest infestation [4]. These operational gaps indicate weakness in planning, monitoring and performance enforcement, rather than purely technical deficiencies.

Bridging the gap between knowledge and practice will require formalised policy frameworks, infrastructure investment, especially for source segregation, treatment and sustainable behaviour change programmes involving students, staff and source providers [40].

Following collection, waste is transported in trucks and tricycles to municipal disposal sites where it is openly dumped. There is no formal mechanism for recycling, composting or waste-to-energy conversion, and no internal infrastructure exists for the recovery of materials [41] [42]. As a result, recoverable fractions are consistently lost, and the system remains environmentally and economically inefficient [43]. While the current waste management practices ensure basic sanitation, they are constrained by limited infrastructure, technology and weak governance of service providers.

Nevertheless, UEW occupied a strategic and commendable position as a centre of knowledge production and capacity building in environmental management. Through the activities of the departments such as Environmental Health and Sanitation Education and related research units, the university has consistently contributed high-quality research, professional training and public engagement on waste management, sanitation and environmental sustainability [16]. These efforts make UEW a national reference institution for advancing sustainable waste management in Ghana.

3.3.1. Focus Group Discussions (FGDs)

The data gathered from the focus group discussions were analysed thematically, guided by Swain's (2013) approach. Respondents were coded as ST1 - ST6 (students) and SS1 - SS4 (sanitation staff). The demographic profile of participants is summarised in **Tables 4-8**. Three (3) dominant themes emerged.

i) Structural and institutional constraints in waste management.

ii) Behaviour, awareness, and practice gaps.

iii) Latent motivation and opportunities for improvement.

3.3.2. Demographic Characteristics of Participants

Focus Group Discussions (FGDs) were conducted with ten (10) participants, comprising six students and four sanitation staff from the South Campus of the University of Education, Winneba.

The gender distribution of the participants was evenly balanced (**Table 4**), with five men and five women. Among the students, three were male, and three were female, while the sanitation staff comprised two of each. The inclusion of both genders provided a comprehensive understanding of the dimensions of waste management practices.

Table 4. Gender distribution of focus group participants.

Group	Male	Female	Total	Percentage (%)
Students	3	3	6	60.0
Sanitation Staff	2	2	4	40.0
Total	**5**	**5**	**10**	**100**

Source: Field survey, 2025.

As indicated in **Table 5**, the students were aged between 19 and 26 years, while the sanitation staff were older, between 28 and 45 years. This contrast heightened the generational differences between the participants. Students provided insights shaped by their status as temporary residents of halls, while the sanitation staff contributed perspectives grounded in their long-term, daily engagement with waste collection and disposal. Such age diversity enriched the discussion, as students often emphasised immediate hall-level challenges, whereas sanitation staff highlighted systemic and operational concerns.

Table 5. Age range of focus group participants.

Age Range (Years)	Students	Sanitation Staff	Percentage (%)
19 - 26	6	0	60.0
28 - 45	0	4	40.0
Total	**6**	**4**	**100**

Source: Field survey, 2025.

Table 6 presents the participants' academic and occupational roles in detail.

Students were drawn from Level 200 to Level 400, representing the core undergraduate population, while the sanitation staff comprised waste collectors and sweepers. This distribution reflects the two major groups involved in waste management at the university: the generators and the handlers.

Table 6. Roles of focus group participants.

Role/Level	Students	Sanitation Staff	Total	Percentage (%)
Undergraduates (Level 200 - 400)	6	0	6	60.0
Waste collectors/Sweepers	0	4	4	40.0
Total	**6**	**4**	**10**	**100**

Source: Field survey, 2025.

Table 7 shows the participants' hall affiliations. The six students were distributed across five halls of residence, with the highest representation from Ghartey C (33%), while the remaining halls each contributed one participant (16.7%). This spread across multiple halls to capture diverse experiences of solid waste generation and management on the South Campus.

Table 7. Hall affiliation of student participants.

Hall of Residence	Number of Students	Percentage (%)
Ghatey A	1	16.7
Ghatey B	1	16.7
Ghatey C	2	33.3
Aggrey A	1	16.7
Aggrey B	1	16.7
Total	**6**	**100**

Source: Field survey, 2025.

The duration of participants at the UEW was also observed (**Table 8**). Students had been at the institution for 2 - 4 years, while sanitation staff had longer service records, ranging between 3 and 10 years. This variation shaped the perspectives expressed during the FGSs.

Table 8. Years at the University of Education, Winneba (UEW) South Campus.

Years at UEW	Students	Sanitation Staff	Total	Percentage (%)
2 - 4 years	6	0	6	60.0
3 - 10 years	0	4	4	40.0
Total	**6**	**4**	**10**	**100**

Source: Field survey, 2025.

1) *Structural and Institutional Constraints in Waste Management*

One of the most persistent issues that emerged from discussions with both students and sanitation staff was the absence of source segregation in waste management practices and the irregularity of waste collection services, which frequently led to overflowing bins, foul odours, pest infestation, and widespread littering across the South Campus of UEW. In all the halls of residence, solid waste was indiscriminately mixed, with no structural or behavioural attempt to distinguish between biodegradable and non-biodegradable fractions. During the discussion, both students and sanitation staff consistently described the absence of separation and delayed collection, particularly during weekends and public holidays, as one of the most pressing weaknesses of the existing system.

From the sanitation staff's perspective, the mixing of waste was inevitable given the absence of any system of colour-coded bins or instructions. One worker observed:

"*When we collect from the hostels, everything is mixed: food, bottles, paper, even broken shoes, he said. Nothing is sorted. Occasionally, we even observe glass and electronics mixed with food waste. That makes it dangerous for us*" (SS1).

A female resident of Aggrey Hall B emphasized,

"*In my room, I sometimes keep plastics aside when I buy water, but most of the time, everything ends up in the same bin. Even if I try to separate them, the cleaners will mix them again, so it feels useless*" (ST2).

This practice illustrates a systemic failure that goes beyond individual behaviour.

Tsydenova *et al.*, [44] have argued that this systemic absence of segregation further poses the most significant barrier to effective waste management in developing countries. Without separation at the generation points, recyclable and organic fractions are contaminated, rendering them unsuitable for recovery or composting.

While waste bins are usually cleared during weekdays, waste often accumulates over weekends, leading to overflow, foul odour, and pest infestation. One first-year student recounted the following:

"*The bins are cleared during the week, but by Sunday and Monday they are overflowing. The smell in the hostel is unbearable*" (ST1).

Sanitation staff (SW1) acknowledged this issue, attributing it to limited resources.

"*We do not have trucks on Sundays, so the bins pile up until Monday before we clear them*".

In addition, many bins were in poor condition, lacked covers, or were undersized for hostel use.

"*Some bins are broken, and when it rains, the waste gets soggy and smelly*" (SS1).

The uneven distribution of bins also creates spatial inequalities in cleanliness across the South Campus. Areas such as hostels and canteens, which have relatively more bins, were described as better managed, whereas academic and recreational zones were persistently littered. This reflects the "broken windows" hypothesis in environmental psychology, which suggests that neglected spaces signal tolerance of disorder, thereby reinforcing antisocial behaviours, such as littering [45] [46].

This created operational backlogs that contributed to unsanitary conditions and encouraged improper disposal by students who avoided using overflowing bins. These accounts collectively highlight the vicious cycle created by inconsistent collection and delayed pick-ups, which leads to overflow, encourages improper disposal, creates unsanitary conditions, and erodes trust in the waste management system [47] [48].

These observations, particularly the systemic failure in waste separation, align with the systems theory perspective, which posits that inefficiencies in one component of a system can trigger failures across the entire supply chain [49]. In UEW, there are inefficiencies in transport and collection that reverberate across behavioural, environmental, and operational dimensions. Students perceive the system as unreliable and adapt by abandoning proper disposal behaviours, campus culture, and non-compliance.

The literature strongly supports these findings. Yukalang *et al.*, [50] reported that inconsistent waste collection schedules in universities in Pakistan led to increased littering and reduced compliance with disposal guidelines. Similarly, Sibe & Gobo, [51] highlighted that delayed collection in Nigerian tertiary institutions resulted in pest infestation, environmental degradation, and negative perceptions of institutional cleanliness. From a Ghanaian perspective, Ampofo [52] found that poor collection schedules in universities undermine recycling opportunities, since unsorted waste degrades rapidly under tropical conditions. The absence of visible segregation infrastructure reinforces a campus-wide norm of indiscriminate disposal, discouraging even those who might otherwise be inclined to act differently [53].

The implications of this study extend beyond environmental hygiene to public health and occupational safety. Overflowing bins create breeding grounds for flies, mosquitoes, and rodents, increasing the risk of vector-borne diseases. For sanitation staff, delayed collection exposes them to decomposing organic waste, sharp objects mixed with food residues, and unpleasant odours, all of which compromise their health and dignity. These findings mirror the conclusions of the International Labour Organisation, which emphasises that unreliable waste-handling systems directly increase occupational risks for frontline sanitation staff [54] [55].

2) *Behavioural, awareness and practice gaps*

The findings revealed that waste management behavioural, awareness, and practice gaps on the South Campus of the UEW are not only constrained by infrastructural deficiencies but also by deeply embedded behavioural, awareness, and practice gaps. While students and sanitation staff recognised the importance of proper waste management, their actual practices were shaped by convenience, social norms, and contextual realities that often undermine sustainable behaviour.

These barriers emerged as interdependent, reinforcing a cycle of poor practice despite latent awareness and motivation.

The findings revealed that behavioural patterns, awareness, and practice challenges undermine waste management, even when infrastructure exists. Peer influence is a key determinant. (ST6) explained.

"*If my friends do not sort their waste, I do not bother either. Nobody wants to be the odd one out.*"

This suggests that social norms discourage positive practices. Sanitation staff observed that apathy was common among students.

"*Sometimes bins are empty, but you still see rubbish dumped beside them. It is laziness*" (SS2).

Environmental conditions, such as overflowing bins and foul odours, further discouraged proper disposal.

"*When the bins are full, people leave their waste anywhere. That is how the campus gets dirty*" (ST4).

Such accounts indicate that poor behaviour cannot be understood in isolation but is embedded within broader cultural and social settings.

To interpret these behavioural patterns, Social Practice Theory was applied as an analytical framework. As explained by Polin *et al.*, [56], the theory conceptualises practices as the interaction of materials, competences, and meanings. At UEW, the material element is waste infrastructure.

From the students' perspective, there was widespread recognition of the lack of structured recycling systems. A participant from Garter Hall candidly remarked:

"*I once saw a recycling poster, but I never saw the bins. So, we just throw plastics with everything else in one bin*" (ST3).

Sanitation staff confirmed the absence of recycling partnerships.

"*We do not have any arrangements with recycling companies. All the waste goes straight to the dumpsite*" (SS2).

"*If plastics are sorted, companies can collect them. However, since it is all mixed, nothing is recycled*" (SS4).

These accounts highlight the institutional gaps in supporting recycling practices. The voices illustrate a shared recognition of wasted opportunities for recovery, mainly due to the absence of an institutional framework for recycling. This reflects the challenges of transitioning from a linear to a circular economy model where waste is viewed as a resource [57] [58].

There are inadequate and unevenly distributed waste bins, which restrict opportunities for proper waste disposal. Even when bins were available, they were often broken, uncovered, or overflowing, which discouraged their use by students and sanitation staff. Knowledge and skills were also weak in this study. Students had limited awareness of recycling protocols, and sanitation staff lacked timely training on resource recovery. This forms the competence element in the theory. The meaning element is also attributed to the cultural perspective of how waste is viewed. This was overwhelmingly negative, with waste being seen as something to be discarded.

The implications of this study are far-reaching. Without structured recycling, the university contributes to environmental pollution and misses the opportunity to reduce waste collection costs, generate income from recyclables, and model sustainable practices for the wider community. Recycling initiatives have been shown to reduce the volume of waste requiring final disposal by up to 40% in universities where they are effectively implemented [59]. Furthermore, campuses that integrate recycling into student life, such as the University of Cape Town in South Africa, report higher levels of environmental literacy and stronger student engagement in sustainable initiatives [60].

3) *Latent motivation and opportunities for improvement*

Despite the constraints, both students and sanitation staff expressed a willingness to engage in better waste practices if enabling conditions were provided. Students recommended colour-coded bins, recycling stations, awareness campaigns, and hall-level champions, while staff emphasised the need for additional trucks, staff, and weekend collection. (ST2) suggested that

"*If the university provides separate bins and tells us what goes where*, *students will comply*".

"*If we had more bins and regular pick-ups*, *it would make our work easier and encourage students to follow the rules*". (SW1)

These statements demonstrate the latent potential for such changes.

Students also proposed incentives to encourage compliance, such as recognition and small rewards for recycling. This shows that while the current system is weak, students remain open to behavioural change if they are supported. The staff agreed that partnerships with recycling companies would improve efficiency and sustainability.

Owusu-Ansah *et al.*, [61] and Larbi *et al.,* [62] reported similar findings in Ghanaian universities, where students' willingness to recycle was contingent on visible and convenient systems. Abdurrachman, Hamzani, and Mariyono [63] further argued that motivation must be matched with institutional investment. At UEW (South Campus), latent motivation represents an opportunity to transition from a linear to a circular waste management system, provided the university introduces infrastructure upgrades, educational programmes, and recycling partnerships.

4. Conclusion

This study was undertaken to examine the composition, energy potential and existing management practices of solid waste generated at the South Campus of the University of Education, Winneba (UEW), to help identify pathways toward sustainable waste management. The waste stream was dominated by organic waste (60.65%), followed by plastics (28.93%), with smaller but recoverable fractions of paper, metals, glass, textiles and e-waste. An average calorific value of 14.20 MJ/kg indicated viable energy recovery potential, although a high moisture content (39.27%)

limited direct thermal utilization, requiring sufficient pre-treatment. Waste management practices remained largely linear, characterized by mixed disposal, inadequate infrastructure and weak enforcement. These findings demonstrated clear opportunities for resource recovery, particularly through composting and anaerobic digestion alongside improved recycling of plastics and metals. It is recommended that UEW implement source segregation, adequate bin distribution and formal recycling partnerships, supported by clear institutional policies. Such measures will enhance efficiency and advance the level of solid waste management at UEW.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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