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Research Paper

INSTITUTIONAL BASED CHARACTERISATION AND QUANTIFICATION OF SOLID WASTE IN BENIN CITY, EDO STATE

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The characterisation and quantification of solid waste in tertiary institution was undertaken to determine the nature and amount of waste produced in such establishment. The Ekehuan campus of the University of Benin was studied to determine the nature and amount of waste generated on a daily basis as well as from the different critical sampling units of the university. The daily waste from the male and female undergraduate and postgraduate hostels and administrative block where collected and sorted over a seven-day period each during the rainy and dry seasons. Questionnaires were distributed to individuals who spend most of their time in the university premise. The four major wastes produced include food 38.61/30.20 kg, paper 29.93/26.45 kg, cellophane 23.60/17.50 kg and plastic 15.33/12.25 for the dry/rainy season. From two-way ANOVA tests carried out on the field data, there was not much disparity in variance between the daily values of waste obtained for the sorted waste components. However, it was observed that there was disparity in the amount of waste produced in the different sample locations. The study revealed that the female undergraduate and postgraduate hostel produced more waste than their corresponding male hostels. The administrative blocks comprising staff offices produces the least amount of waste for the study location. The study however revealed that the volume of waste per unit area of the location was 0.092 m^3 and 0.103 m^3 for the dry and rainy season respectively. It was recommended that a larger waste container be placed in the female hostel in comparison with a corresponding male hostel.

Keywords: Solid waste, Sample location, Disparity, Rainy season, Dry season

INTRODUCTION

Solid waste, as defined by the New York State Department of Environmental Conservation (2007), is any solid or semi-solid discarded (abandoned or considered waste-like) materials. By the singular act of existence, humans produce enormous amount of waste, which if unattended, could become a threat to public health and

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environmental nuisance. With progress in civilization, industrialization, productivity, and modernization, man has systematically polluted his environment (Uwadiegwu and Chukwu, 2013). The sharp rise in population has made solid-waste prone-pollution more rampant and severe (Ogwueleka, 2004). Some of the basic characteristics of these wastes include corrosiveness, flammability, toxicity and reactivity. Therefore, to protect public health, a systematic method needs to be devised to ensure the control of waste generation as well as disposal. Such systematic method is generally referred to as Solid Waste Management (SWM). According to Kreith and Tchobanoglous (2002), SMW is the discipline associated with the generation, storage, collection, transfer and transport, processing, and disposal of solid wastes in a manner that is in accordance with the best principle of public health, economics, engineering, conservations, and that is responsive to public attitudes (Tchobanoglous *et al.*, 1993; Kreith and Tchobanoglous, 2002; United Nations Environmental Programme UNEP, 2005; New York State Department of Environmental Conservation, 2007; and Sharholy *et al.*, 2008). Solid waste, if allowed to continue to accumulate unabated, has the capacity to engulf the entire human habitation (Cointreau, 1982; and Khan, 1994). It is therefore imperative to proffer effective and efficient management approach to waste disposal to improve the total well-being of man in his environment (Adegoke, 1990).

There is no gainsaying the fact that in developing nations, like Nigeria, the management of solid waste faces major challenges (United Nations Centre for Human Settlements (Habitat) UNCHS, 1996; Ogwueleka, 2004; Chandra and Devi, 2009; and Uwadiegwu and Chukwu, 2013). It is a well-documented fact that domestic, agricultural, and industrial wastes have literally defaced the existing landscape and have taken over schools, homes, streets, markets, and communities (Uwadiegwu and Chukwu, 2013). In Nigeria, the management of solid waste is a major problem in virtually all states of the federation. The same trend also occurs in tertiary institutions such as the University of Benin in Edo state. Increase in student population within the University of Benin, fashion trends, consumption pattern, and increasing fast food outlets, enhanced commercials in online and print media, among other factors; have contributed copiously to the increased amount of waste generated within tertiary institutions. Other sources of waste in higher institution include administrative and academic activities which daily produces tons of papers, markers and other writing materials as well as the private enterprise that produce commodities such sachet and bottle water (e.g., UNIBEN water factory) which generate lots of plastic bottles and bags. Housing waste such as clothes and human hair; electronic gadgets, glass and metal (within the hostels), proliferation of food vendors and the campus health centre also contribute the waste generated within the higher institution. This study intends to characterised and quantify the solid wastes generated in higher institutions in Benin City (which may be typical of institutions in other locations) using the Ekehuan campus of the University of Benin as a case study.

The Study Area

The Ekehuan campus of the University of Benin is the pioneer campus of the university before moving to her current location at the Benin-Lagos expressway. The campus is located along Ekehuan road about 3 km from the city centre (Ring Road) and about 12 km from the Ugbowo main campus of the university, all in Egor Local Government Area of Benin City (see Figure 1). The area of the university compound is about 228,802.20 m^2.

The campus currently houses some departments especially in the faculty of arts of the university. It also has a functioning health centre, water bottling and treatment plant, shopping complex, undergraduate and postgraduate hostels (male and female), lecture hall and office blocks, staff primary school, security post and the university consultancy services among others. It has full-scale administrative structure headed by a Deputy Chancellor. It shares all meteorological and climatic characteristics of Benin City. The Environmental Health Department of the main campus of the university takes care of the management of solid waste in the Ekehuan campus of the university.

In terms of waste generation, the area with the most waste, and for which constitute the sampling unit for his study, include the hostels, administrative blocks, especially the audit unit, and the lecture halls.

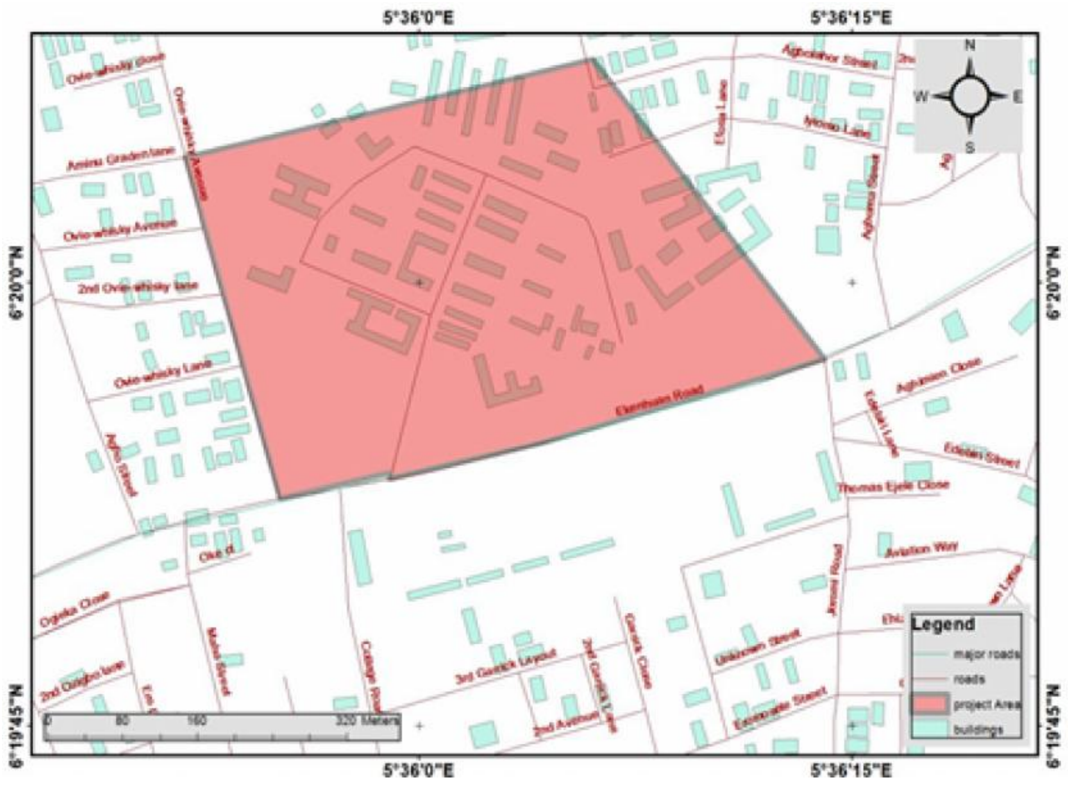
MATERIALS AND METHODS

The primary data in this study were gathered using the direct and indirect approaches. Details of these approaches are presented below:

Direct Approach

Extensive field investigations were used for the quantitative analysis of solid waste composition in the study area. These include field observation and key informants' interviews. Daily information

Figure 1: Aerial Map of the Study Area



on the weight of solid waste generated in some office blocks, classroom blocks and hostels for each constituent of the solid waste, the types of waste-collection vehicles, mode of transportation and disposal, cost of maintenance, collection and disposal, and some other information relevant to the study were obtained. Estimates of the population of students, staff were also obtained from the appropriate unit of the university.

At each sampling unit i.e. point of collection, before the waste was moved to the general storage point within the campus, a collection and separation of the waste into different compositions as well as the measurement of the weight of each composition were undertaken (Pfeffer, 1992; and Tchobanoglous *et al.*, 1993).

Study Equipment

The equipment employed for this study include

1. Plastic bags for each sampling units for the entire seven (7) days of study for the two seasons of the year.
2. Weighing scale.
3. Weighing pan.
4. Labelled Plastic sheets for waste sorting to separate the constituents of the MSW.
5. Hand Gloves for safe waste handling.
6. Protective nose masks.

Indirect Approach

This comprises the use of questionnaires to obtain a wider knowledge of the existing waste produced within the university campus. The use of questionnaires also gave gleams into some salient issues such as environmental awareness and attitude towards waste management; impediments to waste collection and solution to efficient waste management. The questionnaires were targeted at the occupants; comprising students, staff and others who depend on the University for their Livelihood. A total number of 100 questionnaires were administered in this study. All the data obtained were carefully tabulated for ease of analysis (Pfeffer, 1992; Tchobanoglous *et al.*, 1993).

Sampling Units and Waste Component Labelling

Each sampling unit and plastic bags were distinctively labelled for the purpose of data recording and analysis. The labels used in this study are presented in Table 1. The sampling units and the waste component labels were written on the plastic bag and separated by a dash. For instance, the waste bag earmarked for the collection of cloth waste and placed in the audit unit block of the study location was together labelled as ADM1-WC.

Table 1: Sampling Units and Waste Component Labelling

Sampling Labels	Meaning	Waste Component Label	Meaning
UNFH	Undergraduate Female Hostel	WXF	Food
UNMH	Undergraduate Male Hostel	WXH	Hair
UNPFH	Postgraduate Female Hostel	WXP	Plastic
UNPMH	Postgraduate Male Hostel	WXC	Cellophane
ADM 1	Audit Unit Block	WPR	Paper
ADM2	Academic Staff Block	WC	Cloth
		WXM	Metal
		WXG	Glass

Sampling Units and Collection Techniques

The areas sampled were the male and female undergraduate and postgraduate hostels, audit unit block and academic blocks. The male undergraduate hostel comprises six blocks of twenty rooms each with a total of four (4) students to a room. The female undergraduate hostel comprises five blocks of twenty rooms each, with six students to a room. Each of the male and female postgraduate hostels comprises two blocks of thirty-four rooms each with one student to a room. The audit unit block comprises seven general offices and three personal offices. The academic block principally comprises ten general offices and personal three offices. It is noteworthy to state that, in reality, the undergraduate hostels are usually overpopulated with the majority of student rustling for the few bed spaces.

Forty-eight plastic bags were shared to these sampling units daily. This is to enable seamless sorting of the waste into their various components. Wastes generated in these various units were collected daily for seven successive days (for both in the rainy and dry season of the year 2017). The plastic bags collected in each sampling unit were opened onto the plastic sheet and separated into the different compositions, namely: Organic waste (mostly food waste food), Metals, Glass (including ceramics), plastics, textiles, or clothes, hair fibres, Cellophane, and Paper (cardboard, tissue, etc.). The sorted waste samples were placed in pans and weighed. Thereafter, all wastes were dumped and equipment used, cleaned.

Method of Solid Waste Characterization

There are three methods for determining the composition of urban solid waste streams (Brunner and Ernest, 1986). They are waste product analysis, market product analysis and direct sampling analysis. The method chosen for this study involved the third method of direct sampling analysis of solid waste from specific sources, a labour-intensive manual process of sorting, classifying, and weighing all items in each sampling unit and a detailed recording of the data.

Computation of Total Waste Generated

The total volume of waste generated is a summation of the entire waste produced by each component of the solid waste and considering the collection interval and the habited area. For the study location, waste is collected twice weekly (Mondays and Thursdays). This implies that the optimum number of days for planning waste storage facilities for which spillage is not tolerated is four (4) instead of 3 and half days. The formula for the computation of volume of waste is given in equation (1).

$$V = \frac{\left(\sum_{i=1}^{n} {\circ}_i \cdot \max(W)_i\right) \times 4 \times fs}{A} \qquad ...(1)$$

where $\circ$ is the density of waste (kg/m^3); W is weight (kg); fs is factor of safety; A is area of the

Table 2: Densities of Waste Components (USEPA, 2002)

Waste Component Label	Density $\circ_i$(kg/m^3)
WXF	1029
WXH	50*
WXP	200
WXC	78
WPR	228
WC	100*
WXM	139
WXG	411

Table 3: Two-Way ANOVA Computational Procedures (Kothari, 2004)

Source of Variation	Sum of Squares (SS) (1)	Degree of Freedom (d.f) (2)	Mean Square (MS) (3)	F-Ratio (Computed)
Between column (j)	$\sum \frac{(\xi_j)^2}{n_j} - \frac{(\xi)^2}{n}$	$c-1$	$\frac{(1)}{(2)}$	$\frac{(3)}{(5)}$
Between row (i)	$\sum \frac{(\xi_i)^2}{n_i} - \frac{(\xi)^2}{n}$	$r-1$	$\frac{(1)}{(2)}$	$\frac{(3)}{(5)}$
Residual	$\sum SS-((j)+(i))$	$(c-1)(r-1)$	$\frac{(1)}{(2)}$	
Total	$\sum X_{ij}^2 - \frac{(\xi)^2}{n}$	$c \cdot r-1$		

location (m^2) is the measured weight. i is the individual summed for the entire n waste component obtained for the study area. The densities of waste as obtained from USEPA (2002) are presented in Table 2 below.

Analysis of Variance (ANOVA)

This statistical tool was used to determine the level of disparity within each component of waste generated. The two-way ANOVA approach was used to determine the degree of disparity between the waste collected for the different days as well as across the sampling units. The ANOVA techniques are as enunciated by Kothari (2004) is presented in Table 3.

where c and r represent the number of columns and rows respectively. The term $\P = \sum x_{ij}$, where the x represents the elements in the rows i and the columns j. The computed F-ratio is compared against the table values to obtain the level of significance in difference. For this study, the columns represented the days of collection while the rows represent the sampling units.

RESULTS

Waste Sampling and Characterization

The total waste collected for each sampled location and the individual SW components during

Table 4: Solid Waste Characterization for Day 1 (Dry Season)

Sampled Locations	Components (kg)								
	WXF	WXH	WXP	WXC	WPR	WC	WXM	WXG	p
UNFH	1.1	0.21	0.75	1.07	1.06	0.15	0	0.1	4.44
UNMH	1.45	0	0.71	1.26	0.99	0.11	0	0.1	4.62
UNPFH	0.4	0	0.41	0.5	0.65	0	0	0	1.96
UNPMH	0.95	0	0.5	0.62	0.62	0.12	0	0.2	3.01
ADM 1	0	0	0	0.25	1.1	0.55	0.2	0.3	2.4
ADM2	0	0.1	0.25	0.25	0.4	0	0	0	1
Σ	3.9	0.31	2.62	3.95	4.82	0.93	0.2	0.7	17.43

the dry season (see Tables 4-10) and the rainy season (see Tables 11-17) for a seven-day period are presented below. The total daily waste for each component for the two seasons is

Table 5: Solid Waste Characterization for Day 2 (Dry Season)

Sampled Locations	Components (kg)								
	WXF	WXH	WXP	WXC	WPR	WC	WXM	WXG	p
UNFH	2.55	0.45	0.75	1.01	1.05	0.15	0	0	5.96
UNMH	1.15	0	0.45	0.9	1.29	0.2	0.12	0.2	4.31
UNPFH	0.75	0.23	0.6	0.9	0.5	0	0.02	0	3
UNPMH	0.5	0	0.22	0.18	0.72	0	0	0	1.62
ADM 1	0.2	0	0.1	0.25	0.4	0	0.2	0	1.15
ADM2	0	0	0.2	0.2	1.5	0	0	0	1.9
Total	5.15	0.68	2.32	3.44	5.46	0.35	0.34	0.2	17.94

Table 6: Solid Waste Characterization for Day 3 (Dry Season)

Sampled Locations	Composition (kg)								
	WXF	WXH	WXP	WXC	WPR	WC	WXM	WXG	p
UNFH	1.3	0.56	0.45	0.86	0.91	0	0	0	4.08
UNMH	1.55	0	0.71	0.92	0.86	0	0	0	4.04
UNPFH	2.07	0	0.22	0.65	1.02	0	0	0	3.96
UNPMH	0.7	0	0.1	0.12	0.54	0.2	0	0	1.66
ADM 1	0	0	0.2	0.25	1.2	0	0	0	1.65
ADM2	0	0	0.1	0.2	0.3	0	0	0	0.6
Total	5.62	0.56	1.78	3	4.83	0.2	0	0	15.99

Table 7: Solid Waste Characterization for Day 4 (Dry Season)

Sampled Locations	Components (kg)								
	WXF	WXH	WXP	WXC	WPR	WC	WXM	WXG	p
UNFH	2.22	0.21	0.5	0.97	0.81	0	0	0	4.71
UNMH	2.3	0	0.76	1.1	1.11	0.15	0	0	5.42
UNPFH	1	0.45	0.3	0.47	0.4	0	0.25	0	2.87
UNPMH	0.73	0	0.01	0.63	0.16	0.3	0.01	0	1.84
ADM 1	0	0	0.25	1.1	0.55	0	0.2	0.3	2.4
ADM2	0	0	0.25	0.25	0.3	0.6	0	0	1.4
Total	6.25	0.66	2.07	4.52	3.33	1.05	0.46	0.3	18.64

Table 8: Solid Waste Characterization for Day 5 (Dry Season)

Sampled Locations	Components (kg)								
	WXF	WXH	WXP	WXC	WPR	WC	WXM	WXG	p
UNFH	2.55	0.45	0.75	1	1.05	0.15	0	0	5.95
UNMH	1.55	0	0.91	1.02	1.24	0	0.2	0.1	5.02
UNPFH	2.05	0	0.22	0.55	0.85	0	0	0	3.67
UNPMH	0.65	0	0.1	0.12	0.54	0	0	0	1.41
ADM 1	0	0	0.2	0.25	1	0.2	0.2	0	1.85
ADM2	0	0	0.1	0.2	0.3	0	0.2	0	0.8
Total	6.8	0.45	2.28	3.14	4.98	0.35	0.6	0.1	18.7

Table 9: Solid Waste Characterization for Day 6 (Dry Season)

Sampled Locations	Components (kg)								
	WXF	WXH	WXP	WXC	WPR	WC	WXM	WXG	p
UNFH	2.22	0.21	0.5	0.97	0.81	0	0	0	4.71
UNMH	1.55	0	0.71	0.92	1.29	0	0.12	0	4.59
UNPFH	0.55	0	0.6	0.9	0.5	0	0	0	2.55
UNPMH	0.95	0	0.3	0.3	0.52	0	0	0	2.07
ADM 1	0	0	0	0	0	0	0	0	0
ADM2	0	0	0	0	0	0	0	0	0
Total	5.27	0.21	2.11	3.09	3.12	0	0.12	0	13.92

Table 10: Solid Waste Characterization for Day 7 (Dry Season)

Sampled Locations	Components (kg)								
	WXF	WXH	WXP	WXC	WPR	WC	WXM	WXG	p
UNFH	1.4	0	0.45	0.81	0.91	0	0	0	3.57
UNMH	1.35	0	0.91	1	1.21	0.15	0	0	4.62
UNPFH	1.92	0	0.35	0.47	0.55	0	0	0	3.29
UNPMH	0.95	0	0.5	0.18	0.72	0	0	0	2.35
ADM 1	0	0	0	0	0	0	0	0	0
ADM2	0	0	0	0	0	0	0	0	0
Total	5.62	0	2.21	2.46	3.39	0.15	0	0	13.83

presented in Tables 18 and 19. Figure 2 is a bar chart showing the variation of the individual waste generated while Figure 3 is the waste generated in each sample location seasonally.

Table 11: Solid Waste Characterization for Day 1 (Rainy Season)

Sampled Locations	Components (kg)								
	WXF	WXH	WXP	WXC	WPR	WC	WXM	WXG	p
UNFH	2.2	0.21	0.5	1	1.14	0.8	0	0	5.85
UNMH	1.45	0	0.5	1.17	1.17	0	0	0	4.29
UNPFH	1.9	0	0.7	0.6	1.05	0	0	2	6.25
UNPMH	0.63	0	0	0.12	0.45	0	0.2	0	1.4
ADM 1	0	0	0.1	0.2	0.3	0	0.2	0	0.8
ADM2	0	0	0.25	0.2	0.3	0	0	0	0.75
Total	6.18	0.21	2.05	3.29	4.41	0.8	0.4	2	19.34

Table 12: Solid Waste Characterization for Day 2 (Rainy Season)

Sampled Locations	Components (kg)								
	WXF	WXH	WXP	WXC	WPR	WC	WXM	WXG	p
UNFH	1.2	0.5	0.6	1.05	1.16	1	0.2	0	5.71
UNMH	1.55	0	0.6	0.8	1	0.5	0.3	0	4.75
UNPFH	0.65	0	0.4	0.4	0.77	0.1	0.1	0	2.42
UNPMH	0.75	0	0.02	0.17	0.27	0	0	0	1.21
ADM 1	0	0	0.2	0.5	0.5	0	0.2	0	1.4
ADM2	0	0	0.15	0.3	0.35	0	0.1	0	0.9
Total	4.15	0.5	1.97	3.22	4.05	1.6	0.9	0	16.39

Table 13: Solid Waste Characterization for Day 3 (Rainy Season)

Sampled Locations	Components (kg)								
	WXF	WXH	WXP	WXC	WPR	WC	WXM	WXG	p
UNFH	1.1	0	0.35	0.5	0.95	0	0	0	2.9
UNMH	1.35	0	0.8	0.8	1.22	0	0	0	4.17
UNPFH	0.9	0	0	0.4	0.9	0	0	0	2.2
UNPMH	0.6	0	0	0.19	0.25	0	0	0	1.04
ADM 1	0.2	0	0.1	0.25	0.3	0	0.05	0	0.9
ADM2	0.2	0	0.2	0.2	0.5	0	0.05	0	1.15
Total	4.35	0	1.45	2.34	4.12	0	0.1	0	12.36

Table 14: Solid Waste Characterization for Day 4 (Rainy Season)

Sampled Locations	Components (kg)								
	WXF	WXH	WXP	WXC	WPR	WC	WXM	WXG	p
UNFH	1.5	0	0.6	1	0.95	0	0	0	4.05
UNMH	1.35	0	0.6	0.5	1.2	0	0	0	3.65
UNPFH	0.9	0	0.4	0.6	0.8	0	0	0	2.7
UNPMH	0.6	0	0.02	0.12	0.26	0	0	0	1
ADM 1	0	0	0.1	0.2	0.3	0	0.02	0	0.62
ADM2	0	0	0.2	0.2	0.5	0	0.05	0	0.95
Total	4.35	0	1.92	2.62	4.01	0	0.07	0	12.97

Table 15: Solid Waste Characterization for Day 5 (Rainy Season)

Sampled Locations	Components (kg)								
	WXF	WXH	WXP	WXC	WPR	WC	WXM	WXG	p
UNFH	1.1	0	0.5	0.7	0.95	0	0	0	3.25
UNMH	1.45	0	1.02	0.85	1.27	0	0	0	4.59
UNPFH	0.4	0	0.2	0.3	0.6	0	0	0	1.5
UNPMH	0.95	0	0	0.19	0.23	0	0	0	1.37
ADM 1	0	0	0.1	0.25	0.25	0	0.02	0	0.62
ADM2	0	0	0.2	0.2	0.2	0	0.05	0	0.65
Total	3.9	0	2.02	2.49	3.5	0	0.07	0	11.98

Table 16: Solid Waste Characterization for Day 6 (Rainy Season)

Sampled Locations	Components (kg)								
	WXF	WXH	WXP	WXC	WPR	WC	WXM	WXG	p
UNFH	1.1	0.4	0.83	0.65	1.05	0	0.15	0	4.18
UNMH	0.97	0	0.91	0.5	1.2	0.2	0.03	0	3.81
UNPFH	0.55	0.5	0	0.3	0.65	0	0.05	0	2.05
UNPMH	0.7	0	0	0.15	0.27	0	0.02	0	1.14
ADM 1	0	0	0	0	0	0	0	0	0
ADM2	0	0	0	0	0	0	0	0	0
Total	3.32	0.9	1.74	1.6	3.17	0.2	0.25	0	11.18

Table 17: Solid Waste Characterization for Day 7 (Rainy Season)

Sampled Locations	Components (kg)								
	WXF	WXH	WXP	WXC	WPR	WC	WXM	WXG	p
UNFH	1.1	0	0.5	0.7	0.95	0	0	0	3.25
UNMH	1.35	0	0.6	0.5	1.2	0	0	0	3.65
UNPFH	0.9	0	0	0.35	0.77	0	0	0	2.02
UNPMH	0.6	0	0	0.37	0.27	0	0.2	0	1.44
ADM 1	0	0	0	0	0	0	0	0	0
ADM2	0	0	0	0	0	0	0	0	0
Total	3.95	0	1.1	1.92	3.19	0	0.2	0	10.36

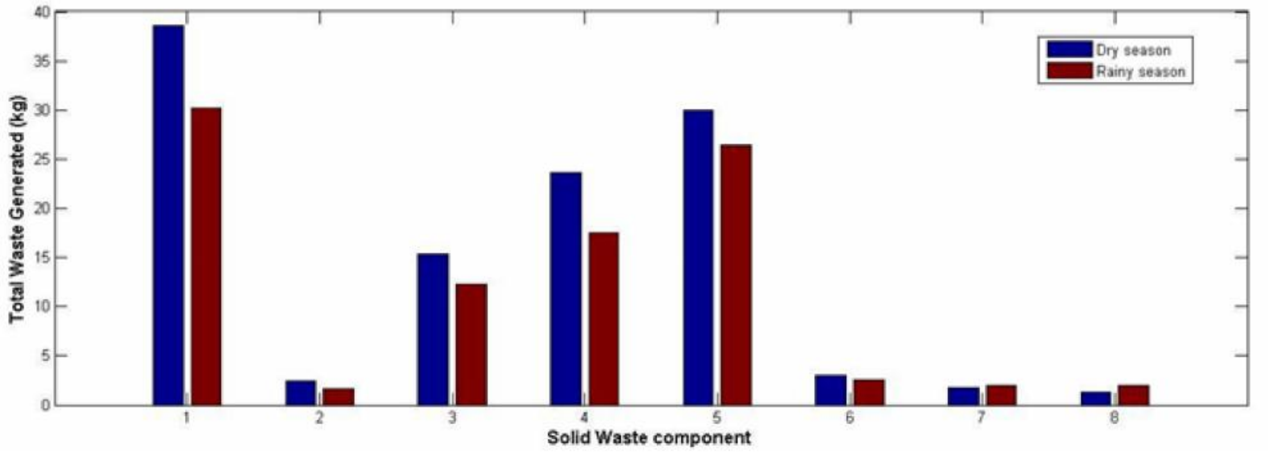
Table 18: Total Weight for Each Characterized Waste/Day for 7 Days (Dry Season)

Components	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total
Food (kg)	3.9	5.15	5.62	6.25	6.8	5.27	5.62	38.61
Hair (kg)	0.31	0.68	0.56	0.66	0.45	0.21	0	2.87
Plastic (kg)	2.62	2.32	1.72	2.07	2.28	2.11	2.21	15.33
Cellophane (kg)	3.95	3.44	3	4.52	3.14	3.09	2.46	23.6
Paper (kg)	4.82	5.46	4.83	3.33	4.98	3.12	3.39	29.93
Cloth (kg)	0.93	0.35	0.2	1.05	0.35	0	0.15	3.03
Metal (kg)	0.2	0.34	0	0.46	0.6	0.12	0	1.72
Glass (kg)	0.7	0.2	0	0.3	0.1	0	0	1.3
Total	17.43	17.94	15.93	18.64	18.7	13.92	13.83	116.39

Table 19: Total Weight for Each Characterized Waste/Day for 7 Days (Rainy Season)

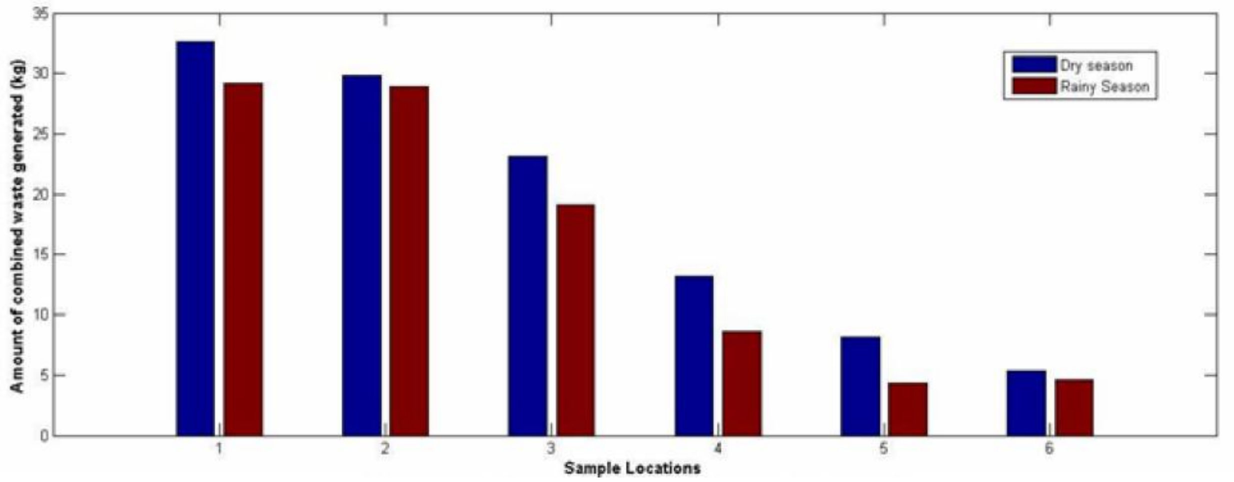
Components	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total
Food (kg)	6.18	4.15	4.35	4.35	3.9	3.32	3.95	30.2
Hair (kg)	0.21	0.5	0	0	0	0.9	0	1.61
Plastic (kg)	2.05	1.97	1.45	1.92	2.02	1.74	1.1	12.25
Cellophane (kg)	3.29	3.22	2.34	2.62	2.49	1.6	1.92	17.48
Paper (kg)	4.41	4.05	4.12	4.01	3.5	3.17	3.19	26.45
Cloth (kg)	0.8	1.6	0	0	0	0.2	0	2.6
Metal (kg)	0.4	0.9	0.1	0.07	0.07	0.25	0.2	1.99
Glass (kg)	2	0	0	0	0	0	0	2
Total	19.34	16.39	12.36	12.97	11.98	11.18	10.36	94.58

Figure 2: Seasonal Components of Solid Waste Generated



Note: Where 1-food, 2-Hair, 3-plastic, 4-cellophane, 5-paper, 6-cloth, 7-metal, 8-glass.

Figure 3: The Seasonal Amount of Waste Generated in Sampling Location



Note: Where 1-UNFH, 2-UNMH, 3-UNPFH, 4-UNPMH, 5-ADM1, 6-ADM2.

ANOVA Tests Results

Two-way ANOVA tests were carried out on each of the components to determine the level of significance in mean and standard deviation between the days in each of the seasons, and the sampled locations. This is presented in Table 20.

Volume of Bi-Weekly Waste Collection

The volume of the individual components of waste generated by the tertiary institution per unit area for a bi-weekly waste collection system is as presented in Table 21.

Questionnaire Deliverable

The research-tailored questionnaire was distributed to 100 randomly selected respondents comprising 43 males and 57 females. Over 83% of the respondents were within the age bracket of 16 and 33 years. These comprise predominantly students and low cadre staff of the university. These individuals spend the most time on

Table 20: Computed F-Ratios of Solid Waste Components

Table Values of F-Ratio	Dry Season (F_{comp})		Rainy Season (F_{comp})		Inter-Seasonal Variance (F_{comp})		
	DAV_{DS} (6,30) = 2.42	SUV_{RS} (5,30) = 2.53	DAV_{DS} (6,30) = 2.42	SUV_{RS} (5,30) = 2.53	DAV_{DS} (6,70) = 2.24	SUV_{RS} (1,70) = 3.99	Interaction (6,70) = 2.24
WXF	0.73	23	1.98	36.51	0.08	1.4	0.38
WXH	0.97	5.63	1.65	2.43	0.69	0.96	0.88
WXP	0.45	18.59	0.83	22.16	0.25	1.25	0.09
WXC	1.65	18.45	2.95	26.33	0.74	4.1	0.24
WPR	1.58	5.46	2.47	77.09	0.81	0.82	0.29
WC	1.38	0.52	1.85	2.18	1.72	0.08	1.38
WXM	1.85	2.71	2.84	0.4	2.21	0.16	2.2
WXG	2.25	1.72	1	1	1.62	0.12	0.49

Table 21: Bi-Weekly Collection Storage Capacity of Waste

Waste Components	The Volume of SW per unit Area (m^3 per m^2) Fs = 1.5	
	Dry Season	Rainy Season
WXF	0.0688	0.0594
WXH	0.0007	0.0007
WXP	0.0048	0.0053
WXC	0.0026	0.0045
WPR	0.009	0.0076
WC	0.0016	0.0026
WXM	0.0009	0.0011
WXG	0.0032	0.0216
Total	**0.0916**	**0.1027**

campus, while the older ones comprise the remaining 17% of respondents. Over 95% of respondents have either encountered or are aware of the activities of waste collection within the study area. 66% of respondents were of the opinion that the level of waste collection in the study area is between fair and good while the remaining 34% expressed concern as to the efficiency of waste collection in the campus. Most of the respondents seem to have vague ideas about solid waste management aside waste collection.

DISCUSSION OF RESULTS

The results showed that food waste constitutes the highest weight of waste with a weekly value of 38.61 kg and 30.20 kg during the dry season and rainy season respectively. Overall, with the exception of metals and glass, the other waste components were higher in the dry season than in the rainy season. Waste components generated in the dry season such as food, hair, plastic, cellophane and paper exceeded their corresponding rainy season values by 8.41 kg, 0.81 kg, 3.14 kg, 6.12 kg, 3.48 kg and 0.43 kg respectively. On the other hand, the rainy season values of metal and glass slightly exceeded the dry season figure by 0.27 kg and 0.7 kg respectively.

ANOVA test results for the dry season showed that there was no significant difference between the daily wastes generated and the computed f-ratios were less than the table value of 2.42. However, there was a significant difference in values of waste across the sampling locations studied, with the exception of metal and glass where the level of waste is stable by weekly and sample location considerations.

In the rainy season, only paper and cloth waste showed significant daily variation in waste while the others showed no significant difference in daily waste generated for the weeklong study. Between sample locations, only food, plastic, cloth and paper indicated significant variation in values. Analysis in the this study were obtained using a 95% confidence internal.

The ANOVA also showed that there was a significant seasonal variation for all components from the standpoint of daily of waste collection and sample location collection. This is particularly true of the sample locations variation for cloth waste as the computed value of 4.1 is approximately equal to the table value of 3.99. It was also observed that there was no form of interaction between the wastes generated in the rainy season with those of the dry season.

Computation of the bi-weekly volume of waste per unit-habited area gave values of 0.0925 m^3 per m^2 area and 0.103 m^3 per m^2 for the dry season and rainy season respectively. This showed that, even though the total weight of waste generated in the dry season is higher, the volume of waste is highest during the rainy season. This is due principally to the slight increase in the weight of metal and glass, which possess higher compact density than the other waste components.

The questionnaire surveys showed that 66% of respondents (students and staff) are quite satisfied with the level of waste collection in the study area while the remaining 34% are not satisfied.

CONCLUSION AND RECOMMENDATION

This study shows that, for a typical higher institution, food waste constitute the highest amount of waste generated, followed by paper, cellophane and plastic. Other wastes such as hair, metal and glass were found to be comparatively small by weight. While it can be seen that the amount of daily waste component generated were stable, the sampling location showed variation in the component of waste. From Figure 3, it is evident that the female undergraduate hostel (UNFH) produces the highest amount of waste followed by the male undergraduate hostel. The female postgraduate hostel also produces a comparatively higher waste than the male postgraduate hostel. The administrative blocks produced the least amount of waste for the study.

It is therefore recommended that a slightly larger container of waste is placed in the female hostels than in the male hostels to avoid indiscriminate discharge and littering of waste on the environment.

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