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Recycling and Reuse Technology: Waste to Wealth Initiative in a Private Tertiary Institution, Nigeria

D. O. Olukanni, O. A. Aipoh and I. H. Kalabo

Department of Civil Engineering, PMB 1023, Covenant University, Ota, Ogun State, Nigeria
Corresponding Author: david.olukanni@covenantuniversity.edu.ng +2348030726472

Abstract

The practice of collecting, treating and management of solid waste prior to disposal has become a necessity in developing and modern societies. Over the years, it is known that most wastes that are disposed have a second hand value. However, the construction cost for conventional Material Recovery Facility(s) (MRFs) has been a major barrier for implementation. These technologies require considerable technical expertise, which is often not available in developing nations to successfully operate the MRFs. Covenant University; a private mission institution through her waste to wealth scheme is focused on managing and processing used materials to reusable products. These include Pet bottles, Paper wastes, Food wastes from cafeteria, plastic food packs, nylon, tin cans and others. Specific areas chosen for the Survey include the residential areas for staff and students and the two cafeterias. The waste generated was characterized based on the waste stream so as to quantify the amount of recyclable waste generated and most occurring. The survey involved the use of structured questionnaires, on-site observations and measurements. The study reveals an average amount of recyclable waste generated per day in the institution as 13.46% pet bottles, 4.03% paper, 55.56% food waste, 12.64% plastic, 9.63% nylon and 4.68% tin cans. The study established that adequate waste characterization is a requirement for effective integrated solid waste management which would boost resource recovery, reuse and recycling.

Key Words: Municipal Solid Waste; Waste Management, Sustainable Technology, Recycling, Reuse, Waste to wealth

Introduction

Municipal solid waste management has emerged as one of the greatest challenges facing many developing countries. The day to day activities of man leads to the generation of various classes of wastes which is seen as a major environmental threat for many cities in developing nations worldwide (Arnold, 2000; Ohaka et al., 2013). The factors affecting such high rate of change in solid waste generation includes; increasing population, changing life style, increasing income, increasing use of disposable materials, excessive items of packaging and consumer habit (Olukanni and Mnenga, 2015; Olukanni et al., 2018). Inspite of the several investment opportunities that waste management provides with very high return on investment for public and private sectors, most developing countries, Nigeria inclusive, have solid waste management problems different from those found in industrialized countries in areas of composition, density, political, and economic framework, waste amount, access to waste for collection, awareness and attitude (Adebola, 2005; Olukanni et al., 2016; Olukanni et al., 2018). In developing countries, local authorities spend 77-95% of their revenue on collection and the balance on disposal (Ogwueleka, 2009), but can only collect almost 50-70% of municipal solid waste. In Nigeria, municipal waste densities generally range from 250-370 kg/m^3. Unfortunately, people in many developing countries including Nigeria, until recently, regard the concern for proper solid waste management as an unimportant issue which may distract attention from the most urgent and serious problem of achieving a fast rate of economic growth. This attitude stems from the belief that solid waste generation is an inevitable price of development (Chukwu, 2007).

According to Babayemi and Dauda (2009), there are several factors influencing solid waste collection in Nigeria, some of which are; lack of advanced technology facility for separation at

its source, strength of solid waste management policy and enforcement, environmental education and awareness, and income status of individuals among others. Mahees et al, (2011) stated that the beginning of a better solid waste management should be focused on the solid waste generation stage. Olukanni et al., (2014); Ogwueleka (2009) stated that the volume of solid waste being generated increases at a faster rate than the ability of the waste management agencies to improve on resources required to meet financial and technical resources needed to parallel this growth. According to Bowan and Tieroba (2014), solid waste needs to be characterized by sources, generation rates, types of wastes produced, and composition in order to monitor and control prevailing waste management systems while improving the existing system. A complete understanding of the composition of a waste stream as well as the activities that determine its generation is essential for effective solid waste management (Rahman et al., 2013).

However, the concept of recycling is being explored. This is the extraction and recovery of valuable materials from scraps or other discarded materials employed to supplement the production of new materials. It is the addition of value to waste to make it economically useful (Okenyi et al., 2011; Adu and Aremu, 2012; Awopetu et al., 2013). Waste recycling has enormous economic opportunities; including job creation, poverty alleviation and sustainable development (Adebola, 2005). Recyclable materials in low-, middle- and high-income countries comprise about 17%, 43% and 62% of the total waste stream, respectively (Adu and Aremu, 2012). Recyclable solid wastes include textile, construction wastes, paper, plastic, ferrous and nonferrous metals, and glass. The plastic recycling industries shred plastics into pellets to manufacture other plastics and allied products. Some recycling factories process waste paper and cardboard to tissue paper, newsprint or bulk packaging materials. Waste glass is processed by glass or terrazzo companies, nonferrous metals are processed by aluminum smelters and tin is recovered from aerosol cans (Agbaeze et al. 2014). Agunwamba (2003) observed that a well-planned recycling program in Nigeria could result in 78% savings in waste management cost and 79.5% landfill avoidance cost. Aside from the economic gains of recycling, environmental benefits such as reduction of greenhouse gas emissions, air and water pollution associated with production from virgin raw materials accrue from waste recycling (Adu and Aremu, 2012).

From to literature, it is generally reported that enormous quantities of solid waste are generated daily in major cities of Nigeria, but exact figures are difficult to determine due to the fact that proper records of collection and disposal are not kept by the authorities responsible (Kadafa et al., 2013). This project work, using Covenant University as a case study presents an overview of the amount of municipal solid waste generated and its characterization to ascertain its economic significance. Specific areas chosen include the academic and residential areas for both staff and students and the two cafeterias. The aim is to determine the quantity, composition, and generation rate of solid waste in the institution with specific objectives of gathering statistical data of waste generated, present the current state of waste management, characterize the solid waste generated, and quantify waste generated for recycling, recovery and reuse.

Study Area

Covenant University community, within Canaan Land in Ota town, is in close proximity to the city of Lagos, Nigeria. The community hosts the world largest church single auditorium with a capacity of 50,000 at once and runs five (5) worship services every Sunday. Temperatures are

high throughout the year, averaging from 25 °C to 28 °C (77° to 82 F). The institution has witnessed an increase in population since its inception in 2002 with a current population above 9000 people and a daily water requirement that was estimated at 136L/C/day. Averagely, a person consumed 4 bottles of water per day. Canaan Land has an expanse of 524 acres of land with an array of architectural masterpiece which consist of the Centre for Learning Resources (university library), college buildings, a 3,000 seat capacity student chapel, 22 duplexes with 48 chalets in the Professors' Village, 64 suites at the senior staff guest house, 64 three-bedroom flats in the senior staff quarters, 100 rooms in the university guest house, two Cafeterias, 96 two Bedroom apartments and 24 one-Bedroom apartments in the Postgraduate halls of residence. In addition to these, there are 10 blocks of student hostels, administrative offices, lecture halls, a gymnasium and four New Engineering workshops. Figure 1 shows the master plan of the institution with selected points of interest.

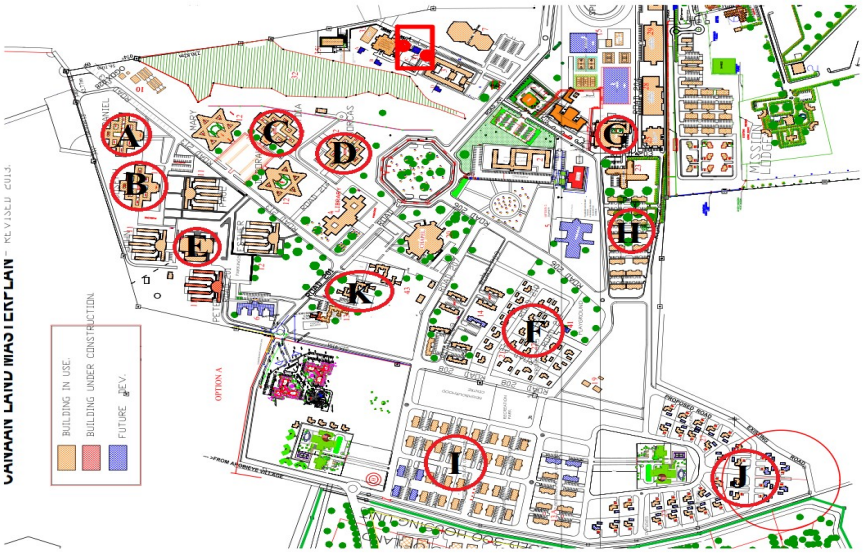

Figure 1 Master Plan of the institution.

Table 1: Areas marked on the map

Site	Building/ Block	Site	Building/ Block
A	Daniel Hall	**F**	Professor's Quarters
B	Joseph Hall	**G**	Cafeteria 2
C	Lydia Hall	**H**	University Suites
D	Dorcas Hall	**I**	New Estate (Block of Flats)
E	Cafeteria 1	**J**	New Estate (Duplexes)
		K	Post Graduate Quarters

Site-specific study

This method involved sampling, sorting, and weighing the individual components of the waste stream. The site-specific study required a large number of samples to be taken, ensuring that the results were not skewed or misleading. The procedures involved in the municipal solid waste characterization for this project using site-specific study include:

Selection of a representative sample

It is very important that the samples collected are representatives of the waste generation units under study. This involved getting the specification of the target population. The staff population as at 2018 is about 500 persons for academic staff and 600 persons for non-academic staff. Tables 2 and 3 show the staff and students residence populations, respectively.

Table 2: Covenant University staff residence population

Residence	Number of housing units	Population
New estate	241	964
Professors village	70	280
Senior staff quarters	72	288
Suites	64	256
Post graduate quarters	120	480
Total	567	2268

Table 3: Covenant University Student Population as 2018

Female Halls of Residence	Population	Male Halls of Residence	Population
Esther Hall	773	Peter Hall	728
Mary Hall	471	Paul Hall	742
Deborah Hall	726	Joseph Hall	819
Lydia Hall	567	Daniel Hall	804
Dorcas Hall	570	John Hall	815
Total	3107	Total	3904

Sample size

The size of sample to be taken is dependent on the number of solid waste generation units in the sampling area. In the senior staff quarters which consists of 72 flats (i.e.9 blocks of 8 flats), 14 flats were sampled. In the professor's village which consists of 22 duplexes and 48 chalets, 14 units were sampled. In the post graduate quarters which consists of 120 flats (i.e. 6 blocks of 20 flats, 96 number of two-bedroom flats and 24 numbers of one-bedroom flats), 24 flats were sampled. In the halls of residence which consists of 10 blocks (with each block consisting of at least 8 wings), 2 blocks with 2 wings were each sampled. 13 units were sampled among the 64 suites. In the new estate, which consists of 32 duplexes, 129 Three-bedroom flats and 80 two-bedroom flats, 48 units were sampled (i.e. 6 duplexes, 26 Three-bedroom flats and 16 Two-bedroom flats). Both cafeterias 1 and 2 were sampled.

Sample collection

In Covenant University, solid waste collection is carried out by use of trucks. The trucks are usually parkers, tippers and trucks that carry hydraulic rams to compact the waste to reduce its volume and thus can carry larger quantity; this method is known as the stationary haul collection system. The weight of the total sample was obtained before sorting and the number of sampling units (households) included in the survey recorded so that the average weight of waste per household per week can be determined. The solid waste in the institution is also sorted in terms of organic and inorganic materials; organic is in form of food waste and inorganic is in the form of PET bottles, Tin cans, metal scraps etc. The first phase of this project deals with the collection of waste in different bins; the bins with green- for food waste, red-for paper and disposable waste and the blue colors for PET bottles.

Sample analysis

The samples are sorted into types and classes of solid waste and the weight of each type and class was recorded. For this survey, the waste was categorized into the following classes; Paper, PET bottles, Nylons, Tetra packs, Plastic food packs, Tin cans, Food waste, and others. This classification was chosen as it gives a sense of the amount of waste that can be recycled from the Covenant University waste stream.

Method of analysis

The results were analyzed using the equations 1, 2, 3, 4 and 5, respectively. Bar charts were used to express primary data collected to give the weight of characterized household waste kg/household/day.

$$\text{Per Capital waste generated (kg/capital/day)} = \frac{\text{total solid waste per day}}{\text{total population that produces the weight}} \quad (1)$$

$$\text{Average solid waste generated/day (kg/day)} = \frac{\text{total weight generated /week}}{\text{7 days}} \quad (2)$$

$$\text{Characterization of waste composition (\%)} = \frac{\text{weight of segregated waste}}{\text{weight of total waste}} \times 100 \quad (3)$$

$$\text{Average waste generated in a household (kg/day, kg)} = \frac{\text{total waste generated by different households}}{\text{total number of households}} \quad (4)$$

$$\text{Average total waste generated by population of a place (kg/day)} = \text{per capital waste x total population.} \quad (5)$$

Results

Table 4 shows material percentage comparison in the students' hall of residence. Comparing the waste generated from the male halls of residence and the female halls of residence, it was observed that the female halls of residence have a higher solid waste generation rate per day than that of the male halls of residence.

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Table 4: Table showing material comparison of waste generated in the students' hall of residence

Sorting	Total mass composition of waste in male halls (kg/day)	Percentage composition of waste in male halls (%)	Total mass composition of waste in female halls (kg/day)	Percentage composition of waste in female halls (%)
Pet bottles	112.50	26.95	109.13	26.00
Tetra packs	50.00	11.98	48.75	11.51
Paper	25.00	5.99	23.75	5.61
Food waste	22.50	5.39	20.00	4.72
Plastic food packs	128.75	30.84	122.50	28.92
Nylon	50.00	11.98	72.50	17.11
Tin cans	21.25	5.09	15.00	3.60
Others	7.5	1.78	12.00	2.53
Total	**417.5**	**100**	**423.63**	**100**

Total waste generated in the female halls of residence is 423.63kg while that of the male hall of residence is 417.5kg. This could be due to the fact that females make use of more products that lead to a greater waste generation rate. Tables 5 and 6 show a comparison between the wastes generated in the staff residential areas of the University while Figure 2 shows Comparison of percentage waste generated from the staff residential areas.

Table 5: Material comparison of waste generated in the staff residential areas

Location	Pet bottles (kg/day)	Tetra packs (kg/day)	Paper (kg/day)	Food waste (kg/day)	Plastic food packs (kg/day)	Nylon (kg/day)	Metal cans (kg/day)
Male halls of residence	112.50	50.00	25.00	22.50	128.75	50.00	21.25
Female halls of residence	109.125	48.75	23.75	20.00	122.50	72.50	15.00
New estate	42.18	16.15	20.00	502.00	12.05	38.08	34.22
Post graduate quarters	15.60	6.90	8.70	306.30	6.12	21.00	16.80
Suites	8.00	4.48	4.48	167.04	3.20	12.80	8.00
Professors village	5.25	5.60	5.60	190.33	2.10	14.91	6.58
Total	292.66	131.88	87.53	1207.87	274.72	209.29	101.85

Table 6: Comparison of percentage waste generated in the staff residential areas

Sorting	Total mass composition (kg/day)	Total percentage of waste generated
Pet bottles	292.66	12.69
Tetra packs	131.88	5.72
Paper	87.53	3.79
Food waste	1207.87	52.40
Plastic	274.72	11.92
Nylon	209.29	9.07
Tin Cans	101.85	4.41
Total	**2,305.80**	**100**

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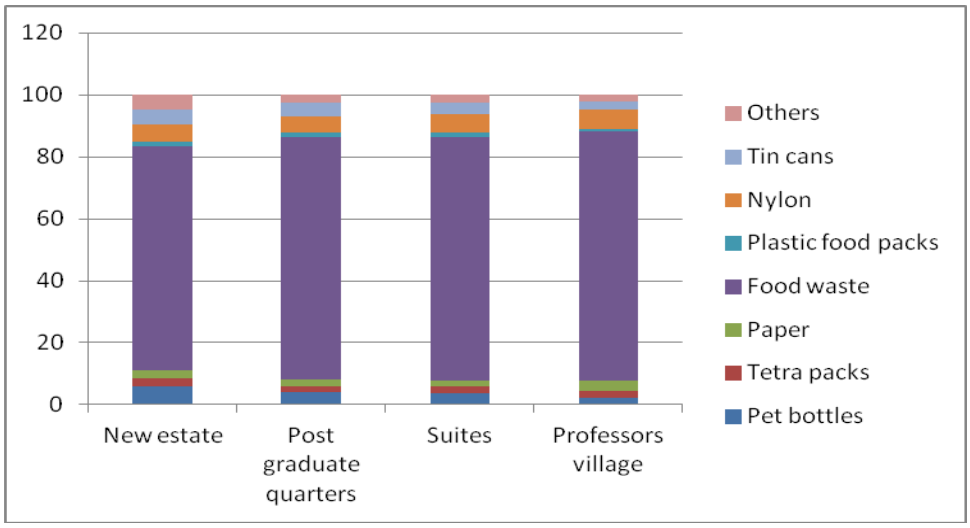

Figure 2: Comparison of percentage waste generated from the staff residential areas

Comparing the weight of waste generated in the various areas, it was observed that the staff residential areas have a larger composition of food waste. This can be attributed to the fact that members of staff cook unlike the students who just buy food in plastic food packs. Students' residential areas have a higher composition of plastic food packs, PET bottles and nylons due to the frequent buying of food and drinks. It can be said that the number of housing units (i.e. the population) is a major factor affecting the rate of waste generation in the various staff residential areas. The new estate which has the highest waste generation also has the highest population. Taking an average of four (4) people per household, various estimates for each residential area can be expressed as follows:

i. The new estate with 141 housing units and an average population of 964 people generates 696.71kg/day of solid waste.
ii. The post graduate quarters with 120 housing units and an average population of 480 people, generates 391kg/day of solid waste.
iii. The suites with 64 housing units and an average population of 256 people, generates 212.64kg/day of solid waste.
iv. The professor's village with 70 housing units and an average population of 280 people generates 236.99kg/day of solid waste.

Table 7 and Figure 3 compare the percentage of waste gotten from the two cafeterias; it was observed that cafeteria 1 has a higher amount of solid waste generated.

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Table 7: Total waste generated in both cafeterias 1and 2

Sorting	Total waste composition (kg/day)	Total percentage of waste generated (%)
Pet bottles	31.85	23.24
Tetra packs	2.30	1.68
Paper	0.00	0.00
Food waste	97.68	71.26
Plastic food packs	1.00	0.77
Nylon	1.73	1.46
Tin cans	2.50	1.83
Total	**137.06**	**100**

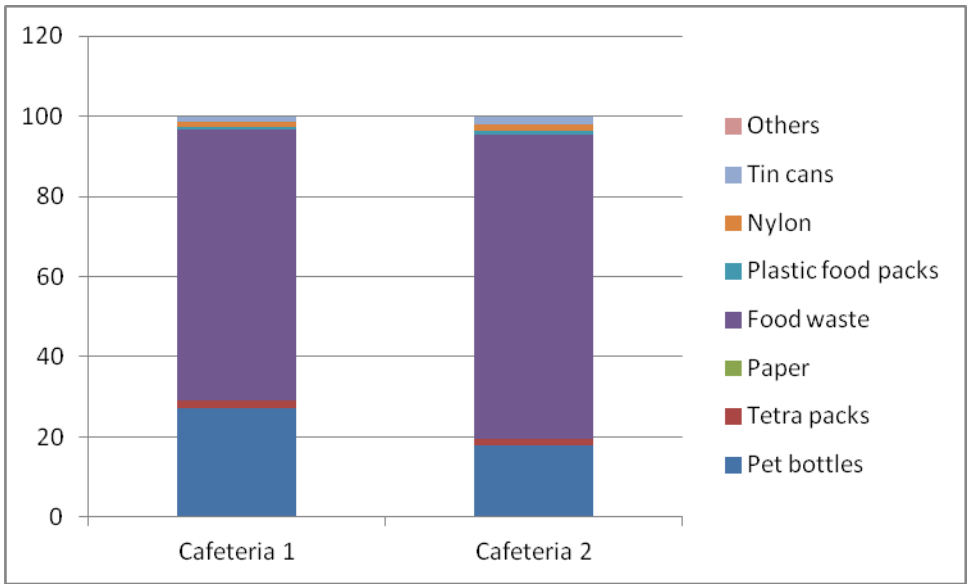

Figure 3 percentage of waste gotten from the two cafeterias

The variation can be said to be because of the difference in the number of students that visit both cafeterias, as cafeteria 1 has more consumers due to factors such as its proximity to the halls of residence. From Table 7 and Figure 3, the composition with the highest percentage in the total waste stream from the selected sites is food waste, followed by PET bottles, and plastic food packs, respectively. The high composition of food waste is mostly from the food waste generated from the staff residential areas as they process their own food which increases the rate of food waste generated. This corroborates the assertion of Sridhar (2006) and Ogwueleka (2009) who expressed that in Nigeria, 60 to 80 percent of waste generated is organic in nature. The high percentage of PET bottles and food packs is from the student residential areas, as they purchase food in the plastic food packs and drinks in PET bottles. The composition with the lowest percentage is the paper and tin cans. The low percentage of tin cans and paper in the waste

stream is due to the fact that products with tin cans are rarely sold and purchased in the University, and paper is rarely used in the residential areas and cafeterias.

Table 8: Total average weight of waste generated in selected sites

Sites	Total Average of Waste generated (kg/day)
Male halls of residence	417.50
Female halls of residence	423.63
New estate	664.68
Post graduate quarters	381.42
Suites	208.00
Professor's Quarters	230.37
Cafeteria 1	84.475
Cafeteria 2	57.575

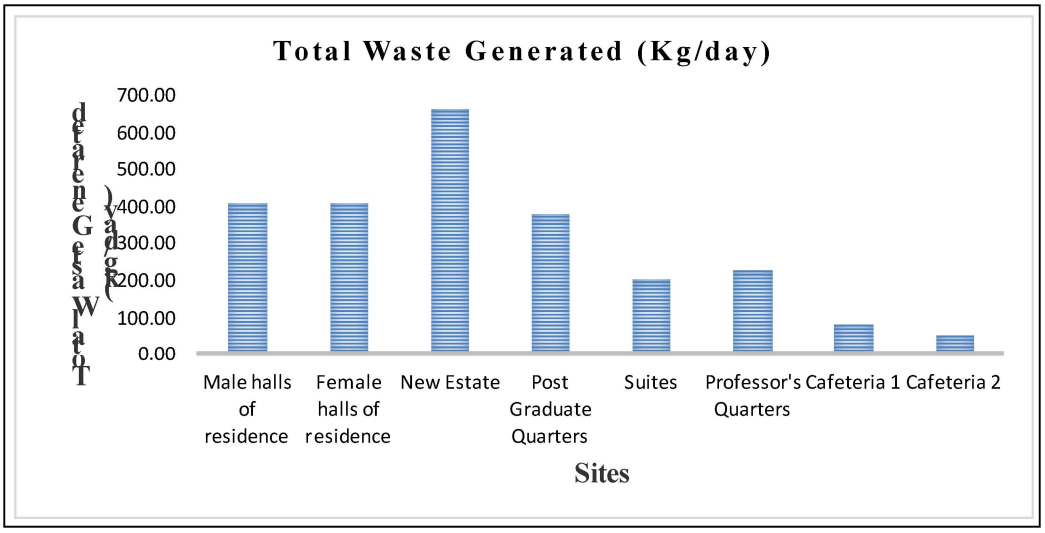

Figure 4: Comparison of total weight generated in selected areas

Table 8 and Figure 4 show that new estate generates the highest weight with 664.68kg/day, followed by the female halls of residence with 423.63kg, and the male halls of residence with 417.50kg. This could be due to factors such as consumer habits, population and others. Although the student residential areas have a higher population than that of the new estate, the higher weight of waste in the new estate compared to that of the female and male halls of residence could be attributed to the variety of waste generated from the new estate compared to that of the student residential areas. The items purchase options of the students are limited thereby reducing the weight of waste generated. The waste generated from the processing of food in the staff residential areas weighs more than other components in the waste stream. Table 9 shows that a significant amount of revenue could be generated from the recyclable materials.

Table 2: Economic value from recycling waste materials

Recyclable waste materials	Average percentage of each item in the waste stream (%)	Waste generated per day (kg/day)	Prices of recyclables in Naira / kg	Total value of waste generated (in Naira)
Pet bottles	12.69	292.66	N 55	N16, 696.30
Paper	3.79	87.53	N 5	N 437.65
Plastic food packs	11,92	274.72	N 30	N8, 241.60
Nylon	9.07	209.29	N 30	N6, 278.70
Tin cans	4.41	101.85	N35	N3, 564.75
Tetra packs	5.72	131.88	N35	N4, 615.80
Food waste	52.40	1207.87	Compostable	-
Total	100.00	**2,305.80**		N39,834.80

i. **Food Waste:** Compost/organic fertilizers can be obtained from food waste by composting, which is an aerobic process where micro-organisms decompose biodegradable waste to produce organic fertilizer in the presence of oxygen. In Covenant University, the main sources of food waste that can be used for composting come from the cafeterias and staff residential areas.

ii. **Plastic:** This includes the PET bottles and the plastic food packs. Plastic can be recycled or reused, depending on the quality. The recycling process of plastic involves sorting, washing, drying, wet grinding; extrusion, pelletizing and the final product are package and sold to consumers (Olukanni and Mnenga, 2015). Some of the products gotten from recycled plastic include office accessories, fibre for sleeping bags and duvets, polyethylene bin liners and carrier bags and many others. The major types of recyclable plastics are Polyethylene terephthalate (PET), High Density Polyethylene (HDPE), Low Density Polyethylene (LDPE), Polypropylene (PP) etc. In Covenant University, the main sources of plastic which includes PET bottles and plastic food packs are the student halls of residence and the cafeterias.

iii. **Nylons:** Nylons can be reused and also recycled into other forms of nylon like sachets for water and black bags used for waste disposal.

iv. **Tetra Packs:** Tetra Pak cartons are primarily made from paper. 75% of the Tetra Pak carton is made from paperboard, 20% of polyethylene and 5% of aluminum. These three materials are layered together using heat and pressure to form a six layered armor which protects the contents from light, oxygen, air, dirt and moisture. Furthermore Tetra Pak cartons are light weight, easy to transport and fully recyclable. The aseptic technology allows the product inside to stay fresh, without the need of any preservatives.

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v. **Tin Cans:** These include drink cans, food can and beverage tins. It is smelted in high temperature furnaces and the molten metal that results can be used to manufacture foil

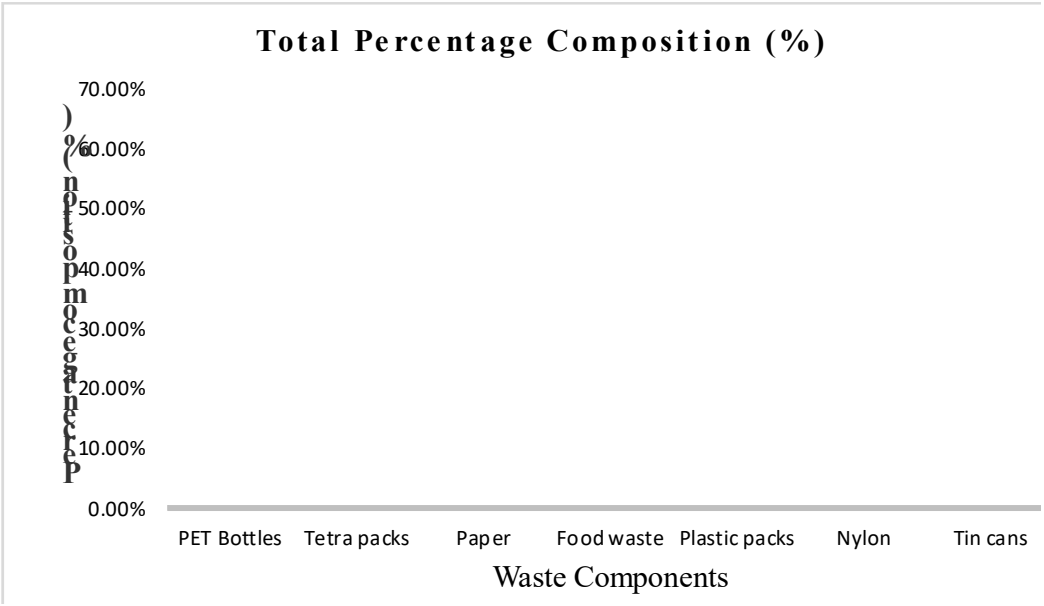

Figure 5: Comparison of total weight generated in selected areas

that are reintegrated into the manufacturing process, hence saving natural resources, energy, time and money.

Presently in Covenant University, some form of recycling activities like (the turning of PET bottles into pellets are sold and also the trading of waste paper in exchange for tissue use. Target Marketers are companies in Lagos and Ogun states dealing with Pet bottle recycled products, and the Chinese companies that use the materials to produce fabrics. The initiative generates income from the project for the university, and environmental sanitation and sustainability is at its peak. Plates 1-3 below show the processing of the collected pet-bottles.

Plate 1 collection site for all used pet-bottles

Plate 2 Crushing of pet bottles in flakes

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Plate 3 Packaging and bagging of the pet-bottle flakes for further processes

Conclusion

The waste collection system in the University is very efficient and this is evident in the university's clean environment but improvements are needed in terms of the collection times, component separation at point of collection and final disposal systems. Information on the characteristics of solid waste is important in evaluating systems, management programs and plans for the reuse, reduce, recycling, and final disposal activities in solid waste management. From the survey carried out in this project, a total amount of N39, 834 ($120 USD) per day can be gotten from the proper recycling of waste generated in the residential areas. The highest amount can be gotten from Plastic food packs with N16, 696.30 ($50 USD) and the lowest is Paper with N437.50 ($1.5USD).

From the survey carried out, it was observed that waste generation and characterization are dependent mostly on the products been supplied and sold in areas of the University such as the shopping mall, cafeteria etc. In the students' halls of residence it was observed that a sufficient amount of Plastic packs and PET bottles were generated and can be recycled. The plastic packs from the halls of residence account for about 91.46% of the total PET bottles generated in the residential area which is approximately 12.6% of the total waste generated in the residential areas. Food waste is the largest composition of the waste generated in the residential areas, accounting for about 52.40% of the total waste stream with the staff residential areas contributing hugely to this at 96.48%. An overall view of solid waste management is to collect, treat and dispose waste. Conclusively, it can be said that more can be done to improve the solid waste management in Covenant University. Considering the amount of revenue that could be made from proper recycling, the University should make more investments in the purchase of recycling equipment for nylons, plastics, paper and metals. The University can partner with

Government Agencies and Private Organizations and take this functional system to the wider society starting from the immediate Local Government and down to the State level.

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