

characterization of Solid Waste Generated on the University of Ilorin Campus and Recycling of the Paper Content.

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Abstract

This work presents the characterization of solid waste generated on the university of Ilorin main campus and recycling of the paper content with faculty of Engineering and Technology buildings as a case study. A total of 91.7kg of waste was sampled and characterized and it was concluded that various types of waste generated are: Cardboard/carton, Nylon, PET bottles, Paper, Wood, Food waste, Aluminum can, Yard waste, Glass bottle, Packaging wraps, Computer hardware, Metal scraps, Laboratory waste such as hardened soil samples, bamboo stalks, Lead acid accumulator, and ink cartridge. The most prominent ones among these waste components was found to be the Miscellaneous with a percentage component of 29.85. Miscellaneous comprises of photocopier parts, broken crates, ink cartridge and laboratory wastes. Cardboard/carton seconded with a total percentage of 20.55% while Wood was the third largest with a percentage of 12.88%. Others include: Food waste, 6.58%; PET bottles, 5.68%; glass bottles, 5.92%; yard waste, 4.26% aluminum cans, 3.11%; nylon, 2.0%; paper, 2.88%; yard waste, 2.28%. packaging wraps with a percentage composition of 1.11% was the least. Finally, some of the waste paper were recovered and recycled.

Keywords

Solid waste, characterization, recycling, paper, cardboard, metal scraps

1. Introduction

1.1 Waste Management

Ogwueleka 2009, ascertained that municipal solid waste management has emerged as one of the greatest challenges facing environmental protection agencies in developing countries. Anthropogenic activities in urban societies generate large quantities of wastes which in turn poses problem for their disposal. Improper disposal leads to spreading of diseases and unhygienic condition besides spoiling the aesthetics (Nayana and Malode, 2012).

Waste management is one of the important services provided by most urban authorities. Solid wastes need 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 (Chandrappa and Das, 2012). Also, according to Das and Bhattacharyya (2013), solid wastes are disposed either in open dumps, sanitary landfills, or by incineration. As incineration and sanitary landfilling are expensive, both in initial investment and throughout their operation, their use is mostly confined to developed countries, while open dumping is the method used in economically developing countries, mainly due to its simplicity and low cost.

According to Muller, 2002, some of the possible common reasons for haphazard waste disposals are lack of inadequate financial resources for proper disposal, lack of appropriate solid waste legislations, lack of political will and public commitment, inadequate technical expertise and lack of planning on the available resources.

One of the most important yardsticks for defining the concept of solid waste is based on the physical form of the material. The New York State Department Environmental conservation (NYSDEC, 2015) defines solid waste as, any garbage, refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded materials including solid, semi-solid or contained gaseous material resulting from industrial commercial, mining and agricultural operation. In simple term, solid wastes are any discarded or abandoned materials. Solid wastes can be solid, liquid, semi-solid or containerized gaseous materials.

The university of Ilorin has hitherto been witnessing a continuous increase in population over the years, which is not unconnected to the fact that the

university is the most sought after according to the report from JAMB. Hence, the continuous increase in solid waste generation as well as the indiscriminate dumping of solid waste proliferates all over the campus. The solid waste thus generated has always constitute nuisance to the University environment, therefore, the need to characterize and reuse some of this waste for a better purpose (that contributes to a healthy and green environment) justifies the essence of this research.

2. Description of Study Area

The University of Ilorin is a Federal Government owned tertiary institution which was established by a decree of the Federal Military Government in 1975. It is located about 300km from Lagos and 500km from Abuja, the country's administrative capital. University of Ilorin began as a university college affiliated to the oldest university in Nigeria in 1975. The institution attained full autonomous status with the then principal, Professor O.O. Akinkugbe as the first vice chancellor. The university started off on a portion of the temporary campus of the Kwara State polytechnic, known as mini campus, which was the site of academic programs in the Faculties of Arts, Science, Education, Engineering & Technology, Business and Social Sciences, and Basic Clinical Sciences. It was the only campus of the university until January 1982, when more than 1000 students studying science were moved following completion of new faculty blocks and residences for Natural sciences and Engineering on the permanent campus site. The university now has 15 faculties: Arts, Agriculture, Environmental sciences, Education, Life sciences, Social Sciences, Management Sciences, Information and Communication sciences, Engineering and Technology, Law, Pharmaceutical Sciences, Veterinary Medicine and a college of health sciences.

3. Materials and Methods

Different criteria were adhered to so that the data gathered can be used, compared, analyzed and disseminated. The methodology was developed before characterization was underway, and was adhered to throughout the process, keeping in mind that inadequate methodology leads to bias that distorts result. The methodology criteria used covered the minimum following points:

- Period and duration of sampling
- Identification of sample waste
- Evaluation and characterization
- Statistical analysis

3.1 Period and duration of sampling

Sampling covered a normal period of the year that allows for the extrapolation of data. Vacation periods such as December, statutory holidays, Festivals and special events were avoided. In general, characterization was undertaken over a period of two weeks (10 working days) from Monday, 3rd of July 2017 to Friday, 14th of July, 2017 (excluding weekends)

3.2 Identification of Sample Waste

In order to have a clear picture of the nature of waste produced, the disposal of it, and the existing condition of the waste disposal facilities situated across Faculty of Engineering and Technology, personal observation becomes very vital. This was done by visual observation and taking pictures of the waste generated at different waste collection points to ascertain the level of solid waste disposal and also get first-hand information on the composition of the solid wastes in the area as shown.



Figure 1: Disposed wastes at block 7 collection point

3.3 Evaluation and Characterization

Once each sample was acquired, the material was manually sorted into the prescribed subcategories at the disposal spots. Garbage bags were used to contain the separated components, wearing appropriate protective equipment (hand gloves, protective boots etc.). The sorted wastes were then weighed at the spot

3.3.1 Sorting

Sorting of the waste was done manually. It involves the separation of the collected waste into their various categories and placing each sub-category into separate garbage bag and tagging each bag with the corresponding name of its content and the spot number. The major challenge encountered in this process was the odour emanating from the disposal spot due to rain. However, this was curtailed to a certain extent with the use of a personal protective equipment (nose mask/cover).

3.3.2 Weighing

This involved taking accurate measurement of the already sorted waste using a weighing balance retrieved from the soil laboratory. The picture of which is shown in figure 2. The following procedures were followed:

- (i) The already sorted waste inside the garbage bag was arranged according to the spot where each belongs.
- (ii) A waste bin was placed on the weighing instrument and the instrument was returned to zero.
- (iii) Each sub- category of waste was carefully poured from the garbage bag into the waste bin taking those from spot 1 first.
- (iv) The readings were recorded in a record book.
- (v) The procedure was repeated for the remaining three spots accordingly

The following precautions were taken during the weighing process:

- (i) It was ensured that the weighing instrument was set to zero before pouring the waste into the waste bin
- (ii) Interference, due to wind, was avoided as much as possible by using a very wide carton as a cover
- (iii) Each sub category of waste was put inside the garbage bag before weighing

(iv) It was also ensured that each sub-category of waste was weighed separately



Figure 2: Sorting of the waste into sub-categories

3.4 Statistical Analysis

Statistical tools including: Totals, Averages and Percentages were used in the analysis of the data collected. These tools were used to ascertain how much of each waste component makes up each of the four spots and hence determined the predominant ones and in what proportions. Tables were provided, analyzed, discussed and the results interpreted.

3.4.1 Estimation of Total waste:

The total waste was arrived at by summing up the individual weight of each waste component for each week using the expression:

$$T = S_1 + S_2 + S_3 + \dots + S_n \quad (1)$$

Where: S_1 = weight of sampled component 1 (kg), S_2 = weight of sampled component 2 (kg), S_3 = weight of sampled component 3 (kg), S_n = weight of sampled component n (kg)

3.4.2 Estimation of Average Weight

The average weight for each waste component was gotten by adding up the weight of individual components for each week and dividing the result by 2. This is as shown in the expression in equation 2.

$$Aw = \frac{S_{11} + S_{12}}{2} \quad (2)$$

Where: S_{11} = weight of sampled component 1 at week 1, S_{12} = weight of sampled component 1 at week 2

3.4.3 Estimation of Total average weight

Once the average weight has been determined, The total average weight was arrived at by adding all the average weight of individual waste component using the expression:

$$T_{AW} = A_{w1} + A_{w2} + A_{w3} + \dots + A_{wn} \quad (3)$$

Where: Aw_1 = average weight of sample component 1, Aw_2 = average weight of sampled component 2, Aw_3 = average weight of sampled component 3, Aw_n = average weight of sampled component n

3.4.4 Estimation of percentage weight

In order to have a clear representation of each waste component at each spot considered, estimation of the percentage waste becomes inevitable. This was arrived at by dividing the average weight of each component by the total average weight and multiplying the result by 100 as shown in equation 4

$$P_w = \frac{A_w}{T_{AW}} * 100 \dots\dots\dots(4)$$

Where: P_w = percentage weight (%), A_w = Average weight (kg), T_{AW} = Total Average weight (kg)

3.4.5 Estimation of total energy

The total energy was arrived at by multiplying the energy value of each waste component with their corresponding average weights as in equation 5.

$$T_{EV} = E_v * A_w \dots\dots\dots(5)$$

T_{ev} = Total Energy (kJ) , E_v = Energy value(kJ/kg) , A_w = Average weight (kg)

3.5 Recycling of the Waste Paper Paper recycling generally involves the collecting of waste paper, sorting them by their types, processing them into raw materials and manufacturing new products using these recycled raw materials. The whole process is briefly described below. To start the paper recycling process, the waste paper needs to be sorted such as by newsprint, computer paper, magazine paper etc, as different types of paper are treated differently during the paper recycling process to make different types of recycled paper products.

The sorted paper is usually soaked in a pulper, which contain water and chemicals (caustic soda). The waste paper is shreds into small pieces. Heating the mixture breaks the paper down more quickly into tiny strands of cellulose (organic plant material) called fibers. Eventually the old paper turns into a mushy mixture called pulp. The pulp is forced through screens containing holes and slots of various shapes and sizes. The screen removes small contaminants such as bits of plastic and globs of glue. This process is called screening. The next stage in the paper recycling process involves deinking – removing the ink from the paper fibres of the waste paper. Sticky materials (referred to as stickies) like glue residue and adhesives are also removed at this stage. During refining, the pulp is beaten to make recycled fibres swell, making them ideal for paper making. If the pulp contains any large bundles of fibres, refining separates them into individual fibres. Then if white recycled paper is being made, the pulp may need to be bleached

with hydrogen peroxide, chlorine dioxide or oxygen to make it whiter and brighter. If brown recycled paper is being made, such as that used for industrial paper towels, the pulp does not need to be bleached.

3.5.1 Pulping

Pulp was made by adding waste paper with water. After using various waste paper and water ratio the best pulp was found at a ratio of 100gram paper and 4 liters of water. Pulp was made with the help of electric blender as in figure 3



Figure 3: improvised pulper



Figure 4: screener

3.5.2 Screening

After getting the pulp it was poured on the screener. As a result, the pulp slurry was settled down on the screener.



Figure 5: Screening process



Figure 6: Rolling operation

3.5.3 Rolling

After screening the pulp, it was rolled with the help of the hand roller in order to remove extra water from the pulp.

3.5.4 Drying and Paper Making

After rolling it was dried in the sunlight for about 2 hours. After drying it was pulled over the board carefully.

4. Results and Discussion

The results of the analysis of solid waste at each of the four spots are as follows :

4.1 Analysis of Solid waste at spot 1

Table 1 shows the analysis of the solid waste components at spot 1(block 7), while Figure 7 indicates that wood, having a percentage of 33.26% preponderates the spot. This was due to the proximity of the woodwork workshop to the disposal point. Other components with their respective percentage in decreasing order include: food waste (16.12%); miscellaneous (15.05%); yard waste (11.37%); cardboard/carton (8.68%); PET bottles (5.62%); glass/bottles (4.3%); nylon (1.86%); paper (1.25%). The miscellaneous in this category include wastes such as metal scraps,

photocopier worn-out parts, which were not obtainable at other disposal points.

Table 1 Component of solid waste analysed at spot 1 (back of block 7)

Waste Components	Weight (kg) 1 st week	Weight (kg) 2 nd week	Average weight (kg)	Percentage weight (%)
Cardboard /carton	2.52	3.82	3.17	8.68
Nylon	0.64	0.72	0.68	1.86
PET Bottles	1.68	2.43	2.055	5.62
Paper	0.5	0.41	0.455	1.25
Wood	11.8	12.5	12.15	33.26
Food waste	5.67	6.11	5.89	16.12
Aluminum cans	0.37	0.54	0.455	1.25
Yard waste	5.32	2.99	4.155	11.37
Glass /bottles	2.0	1.14	1.57	4.30
Packaging wraps	0.33	0.58	0.455	1.25
Miscellaneous	4.8	6.2	5.5	15.05
Total	35.63	37.44	36.535	100.0

Table 1 shows that wood, in form of chips and damaged furniture parts that are not reusable and generated from the wood workshop, made up the bulk of the waste at spot 1 with a percentage of 33.26, followed by food and miscellaneous waste with a percentage components of 16.12 and 15.05 respectively.

From the above analysis, it is imperative to state that tables 2 to 4. indicates a very high percentage of the miscellaneous waste components in three of the four waste disposal spots considered for study in the faculty of engineering and technology (blocks 7-10 only). Hence, the need to identify the contents of this (miscellaneous) waste becomes very important as they differ from one spot to the other, which accounts for why they were not listed as separate entities in the tables

- i. Spot 1 (block seven): This includes among others: photocopier worn out parts and ink cartridge.
- ii. Spot 2 (block 8): consolidated materials from the soil laboratory

- iii. Spot 3 (block 9): metal scraps, worn out lead acid accumulator
- iv. Spot 4 (block 10): worn out computer hardware and broken soft drink crates.

A careful look at the tables also shows that, cardboards/carton was also a major component of the waste sample as it took a great deal of the waste components in the range of 8.68, 17.54, 30.77 and 25.22 at each of the spot respectively In addition, Polyethylene terephthalate bottles otherwise known as PET bottles resulting from the consumption of soft drinks and its likes also constitute a major percentage to the waste samples at each of the spots.

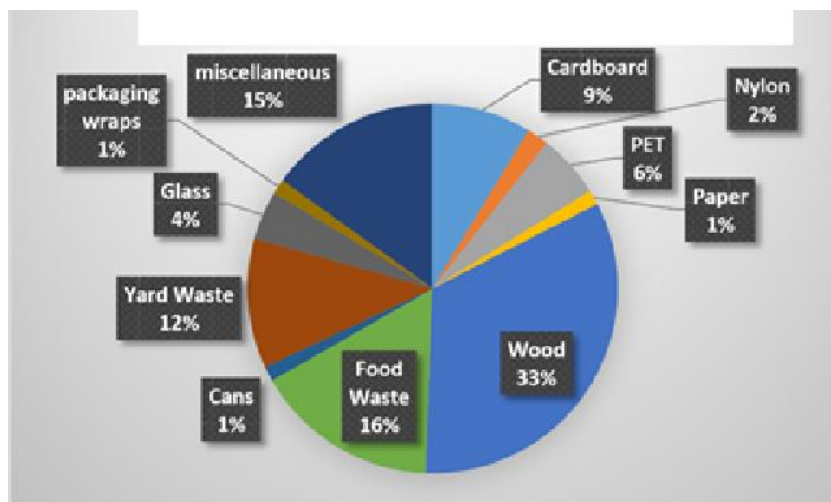


Figure 7: Pie Chart Showing Percentage Weight of Solid Waste Generated at Spot 1(Block 7).

4.2 Analysis of Solid waste at spot 2

At the second disposal point considered, the miscellaneous component, which comprises basically laboratory waste from the soil laboratory, predominated the spot with a percentage of (36.88%). This laboratory waste generally include crushed materials, bamboo stalks, used soil samples and consolidated materials among others. Other components as analyzed in table 2 and shown in figure 8 as well: include cardboard/carton (17.54%), PET bottles (17.10%); glass/bottles (11.2%); wood (5.49%); paper (3.99%); aluminum cans (2.59%); Yard waste (1.87 %) and packaging wraps (0.62 %).

Table 2 Component of solid waste analyzed at spot 2 (block 8 waste collection point)

Waste Components	Weight (kg) 1 st week	Weight (kg) 2 nd week	Average weight (kg)	Percentage weight (%)
Cardboard /carton	3.76	4.10	3.93	17.54
Nylon	0.32	0.42	0.37	1.65
PET Bottles	4.12	3.52	3.82	17.1
Paper	0.88	0.91	0.895	3.99
Wood	1.22	1.24	1.23	5.49
Food waste	0.32	0.11	0.22	0.96
Aluminum cans	0.55	0.61	0.58	2.59
Yard waste	-	0.42	0.42	1.87
Glass /bottles	3.21	1.87	2.54	11.2
Packaging wraps	0.14	-	0.14	0.62
Miscellaneous	6.77	9.76	8.27	36.88
Total	21.29	22.96	22.405	100.0

4.3 Analysis of Solid waste at spot 3

The various component in order of decreasing percentage weight at the third waste disposal point is as shown in the table below. The miscellaneous has the greatest percentage of (36.3%) while nylon has the lowest percentage (1.29%).

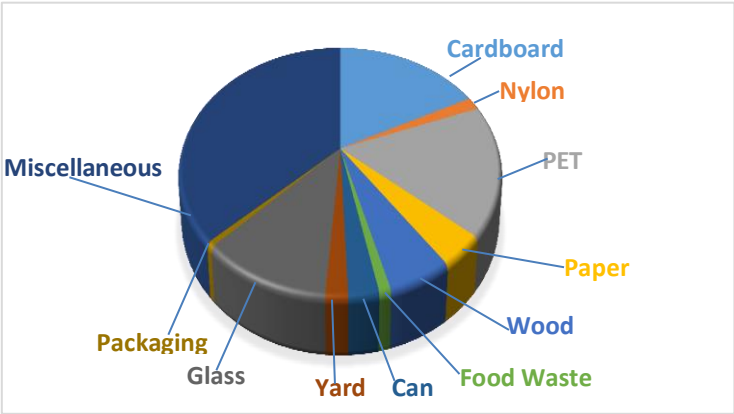


Figure 8: Percentage Weight of Solid Waste Generated at Spot 2 (Block 8)

Table 3: Component of solid waste analyzed at spot 3 (in front of block 9).

Waste Components	Weight (kg) 1 st week	Weight (kg) 2 nd week	Average weight (kg)	Percentage weight (%)
Cardboard /carton	3.65	4.92	4.285	30.77
Nylon	0.12	0.24	0.18	1.29
PET Bottles	1.33	1.87	1.60	11.50
Paper	0.55	0.43	0.49	3.52
Wood	0.85	-	0.85	6.1
Food waste	0.45	0.23	0.34	2.44
Aluminum cans	0.77	0.42	0.595	4.27
Yard waste	-	0.21	0.21	1.51
Glass /bottles	0.32	-	0.32	2.30
Packaging wraps	-	-	-	-
Miscellaneous	5.5	4.61	5.055	36.3
Total	13.54	12.93	13.925	100

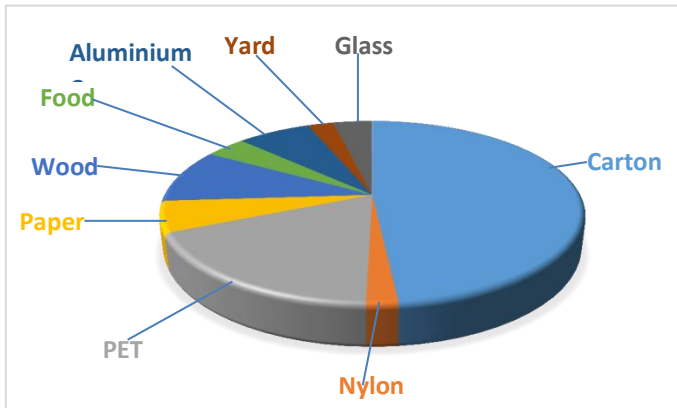


Figure 9: Percentage Weight of Solid Waste Generated at Spot 3 (Block 9).

4.4 Analysis of Solid waste at spot 4

The miscellaneous component at this disposal point, with a percentage component of 31.17% also dominates the sample with cardboard/carton following it with a percentage component of 25.22% and packaging wraps, having the least percentage component of 1.11%

Table 4: Component of solid waste analysed at spot 4 (block 10 waste collection point)

Waste Components	Weight (kg) 1 st week	Weight (kg) 2 nd week	Average weight (kg)	Percentage weight (%)
Cardboard /carton	4.3	5.2	4.75	25.22
Nylon	0.66	0.54	0.6	3.19
PET Bottles	1.89	2.11	2.0	10.6
Paper	0.55	0.49	0.52	2.76
Wood	0.69	1.82	1.255	6.66
Food waste	1.28	-	1.28	6.80
Aluminum cans	0.88	0.75	0.815	4.33
Yard waste	0.43	-	0.43	2.28
Glass /bottles	1.98	0.23	1.105	5.87
Packaging wraps	0.21		0.21	1.11
Miscellaneous	5.21	6.54	5.87	31.17
Total	18.08	17.68	18.835	100

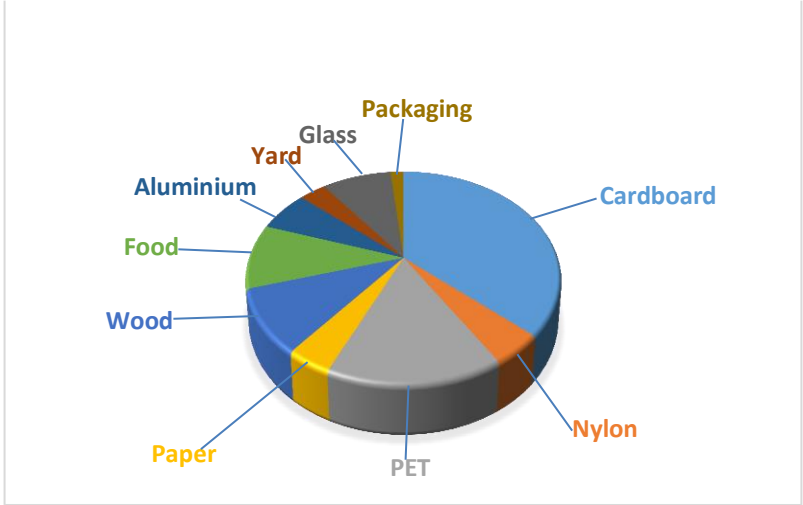


Figure 10: Percentage Weight of Solid Waste Generated at Spot 4 (Block 10).

Table 5: average weight of solid wastes at the four spots and their corresponding energy values

Waste components	Weight at spot 1 (%)	Weight at spot 2 (%)	Weight at spot 3 (%)	Weight at spot 4 (%)	Average weight (%)	Average weight (kg)	Energy value (Kj/kg)	Total energy(kJ)
Cardboard	8.68	17.54	30.77	25.22	20.55	4.03	25800	104051.4
Nylon	1.86	1.65	1.29	3.19	2.0	0.458	17400	7969.2
PET bottles	5.62	17.10	11.5	10.60	5.68	2.367	32500	76927.5
Paper	1.25	3.99	3.52	2.76	2.88	0.59	16700	9853
Wood	33.26	5.49	6.1	6.66	12.88	3.87	18600	71982
Food waste	16.12	0.96	2.44	6.80	6.58	1.93	4652	8978.36
luminum can	1.25	2.59	4.27	4.33	3.11	0.611	850	519.35
Yard waste	11.37	1.87	1.51	2.28	4.26	1.303	16500	21499.5
Glass bottles	4.30	11.2	2.30	5.87	5.92	1.384	140	193.76
Packaging wraps	1.25	0.62	0.00	1.11	0.75	0.268	23200	6217.6
Miscellaneous	15.05	36.88	36.3	31.17	29.85	6.173	28700	177186.6
Total	100.00	100.0	100.0	100.0	100s	27.02	186142	485378.2

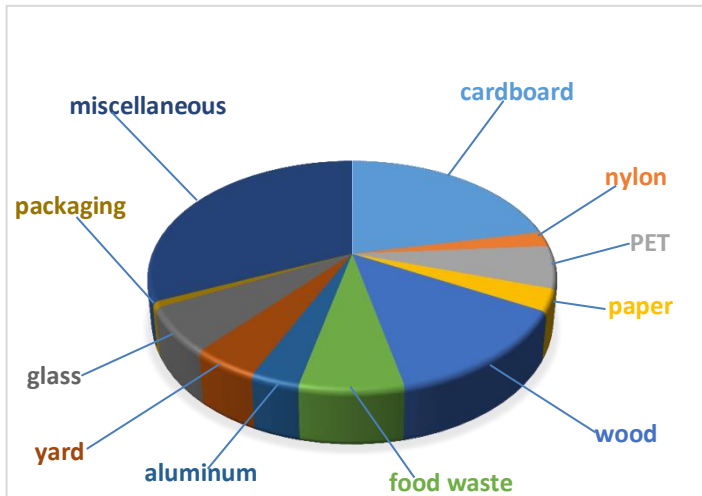


Figure 11: The average percentage composition of the various solid waste components at the four spots.

Figure 11 was plotted from tables 5 and it indicated that, apart from the miscellaneous waste, cardboard/carton predominate the four spots

4.5 Characterization

Although, paper and nylon contribute a very minute percentage to the waste composition (less than 5%) at each of the spot due to their negligible weight, their significance cannot be overemphasized. The inevitable use of nylon and papers in our everyday activities suggests the reason why they seem prevalent and which could litter the environment if not properly controlled.

4.6 Recycling

The recycled paper is as shown in figure 13



Figure 12: Recycled Paper

5. Conclusions and Recommendations

5.1 Conclusion

A total of 91.7kg of waste was sampled and characterized and it can be concluded that various types of waste generated are: Cardboard/ carton , Nylon, PET bottles, Paper, Wood, Food waste, Aluminum can, Yard waste , Glass bottle, Packaging wraps, Computer hardware, Metal scraps, Laboratory waste such as hardened soil samples, bamboo stalks etc., Lead acid accumulator, ink cartridge.

The prominent ones and hence their percentage composition are:

- i. Miscellaneous (29.85%) which comprises of photocopier parts, broken crates, ink cartridge laboratory wastes etc. took the greatest percentage
- ii. Cardboard/carton seconded with a total percentage of 20.55
- iii. Wood was the third largest with a percentage of 12.88

Others include: Food waste, 6.58%; PET bottles, 5.68%; glass bottles, 5.92%; yard waste, 4.26%; aluminum cans, 3.11%; nylon, 2.0%; paper, 2.88%; yard waste, 2.28%. Packaging wraps with a percentage composition of 1.11% was the least. Finally, some of the waste paper were recovered and recycled

5.2 Recommendation

The type of containers or bins best suited to the specific needs of the building users should be provided to aid future characterization of waste in such building such as trash bins for offices, cart and wheeled type for the walkways and the laboratories. Aluminum cans, which takes 80-200 years to decay, saves 95% of the energy required to make the same amount of aluminum from its virgin source. One ton of recycled aluminum saves 14,000 kwh of energy 40 barrels of oil, 238million Btu's of energy, and 10 cubic yards of landfill space (Stanford, 2017), harnessing the energy potential of this type of waste should also be considered There is a mass littering of sachet water nylon everywhere in the study area, this can be addressed by promoting the consumption of water from dispenser.

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