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Analysis of Solid Waste Composition and Its Treatment Potentials in University of Nigeria Enugu State, Nigeria.

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Abstract

The aim of the study is to determine the quantity, composition and treatment potentials of solid waste generated in University of Nigeria Nsukka campus. To achieve these, solid waste was sampled for 1 week from Nine (9) academic buildings, sixty-two (62) academic departments administrative offices, eight (8) corridors, and three (3) cafeterias giving a total of 82 waste sampling points. In total, 4821.1kg/week of waste were separated at University of Nigeria. The total quantity of solid waste at collection points were buildings (1034.9 kg/week), corridor (910.7 kg/week), cafeteria (502.5kg/week) and departmental offices (2373 kg/week). The mean quantities of waste generated at collection points were 114.99kg/week, 113.84kg/week, 167.57kg/week and 38.27kg/week for building, corridors, cafeteria and departmental offices respectively. This shows that on the average that the highest quantity of waste is generated from cafeteria. The weighted average amount of solid waste generated in University of Nigeria Nsukka Campus per sampling point is 58.79kg/week. The weighted average percentage of the waste fractions for university of Nigeria Nsukka Campus is 37.66%, 20.23%, 6.65%, 24.86%, 3.33% and 7.28% for paper, plastic, metal, organic, glass and others respectively. The waste fractions are generated in a decreasing order as follows: paper (37.66%), organic (24.86%), plastic (20.23%). metal (6.65%), others (7.28%) and glass (3.33%). The estimated waste generation rate for the university campus was 0.019kg/capita/day from the four sources analyzed based on current student population of 36000 and weekly generation of 4821.1kg. 28.35% of the waste is compostable while 64.49 % is recyclable and these sums up to 92.84% indicating that only a small proportion that is 7.16% of generated waste which can neither be composted or recycled will be diverted to landfill. Therefore, recovery of resources and recycling call for segregation of waste at the source, through providing separate waste containers for different waste types.

Keywords: Solid Waste, Composition, Quantity, Recycling Potentials, University, Nigeria.

1.0 INTRODUCTION

Analysis of solid waste composition and its treatment potential is extremely important [1]. The Federal Environmental Protection Agency (FEPA) in Nigeria was established in 1988 by decree Number 58 in a bid to protect Nigerian environment. The mandate of FEPA as per municipal solid waste management was highlighted by [2]. For effective implementation of these guidelines, reliable data are needed but unfortunately these data are not usually available especially in the area of waste generated from University Campus in Nigeria.

For critical decision to be made in the area of solid waste management, in depth knowledge of the composition, characteristics and sources is imperative [3, 4]. Home grown waste management program is more effective than copied program [4]. Waste management studies in university campuses such as University of Nigeria is supposed to be a special case study due to [4]: (i)very few reports are available on this matter (ii) autonomy of the university, (iii) student at all levels are involved and (iv) easy transfer of knowledge to the outside community.

Nigeria is blessed with more than sixty (60) universities and many other institutions of higher learning but from our knowledge of literature, only few research publications are available on the waste generated quantities

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and their treatment potential from these institutions.

Moreover, the administration of these institutions cannot engage in recycling program due to lack of baseline studies on the solid waste composition, quantities and recycling potentials. While waste characterization from households, markets and cities in some parts of Nigeria has been considered in numerous studies on waste management in Nigeria [2, 5-21], there are limited literature information on characterization of wastes from higher education institutions such as University of Nigeria. The objectives of this study were to: determine the quantity and composition of solid waste generated in University of Nigeria, Nsukka campus; determine the effect of source of generation on the solid waste quantities and compositions and determine the recycling potentials of the solid waste and recommend the best management strategies based on the findings.

2.0 MATERIALS AND METHODS

2.1 Description of Study Area

The University of Nigeria was established in 1955 and formally opened on 7 October 1960. It is the first Nigerian indigenous degree awarding institution. It has three campuses namely Nsukka, Enugu and Ituku Ozara but Nsukka campus is the main campus where the seat of the university administration is located (Fig.1). The campus is sited on of hilly savannah in the town of Nsukka with an area of 871 ha and about 80 km from the north of Enugu (latitude: 6º51'33.41" and longitude: 7º23'52.51") South Eastern Nigeria [22]. The University of Nigeria Nsukka (UNN) Campus is made up of Nine (9) academic faculties with a total of sixty-two (62) departments [22]. The university has three major cafeterias namely Chitis, SUG Building, and Malima cafeteria.

2.2 Solid Waste Sampling and Characterization of the Sample

The analyzed waste was sampled from four activity areas in Nsukka campus: (1) academic buildings, (2) academic departments administrative offices, (2) corridors, and (4) cafeteria. Considering Nine (9) faculties in Nukka Campus, One (1) academic building and one (1) corridor was selected respectively from each faculty in the campus making a total of Nine (9) academic buildings and Eight (8) corridors sampled. A total of sixty-two offices representing the academic departments administrative offices were sampled. Three (3) major cafeterias namely Chitis, Malima and SUB were selected.

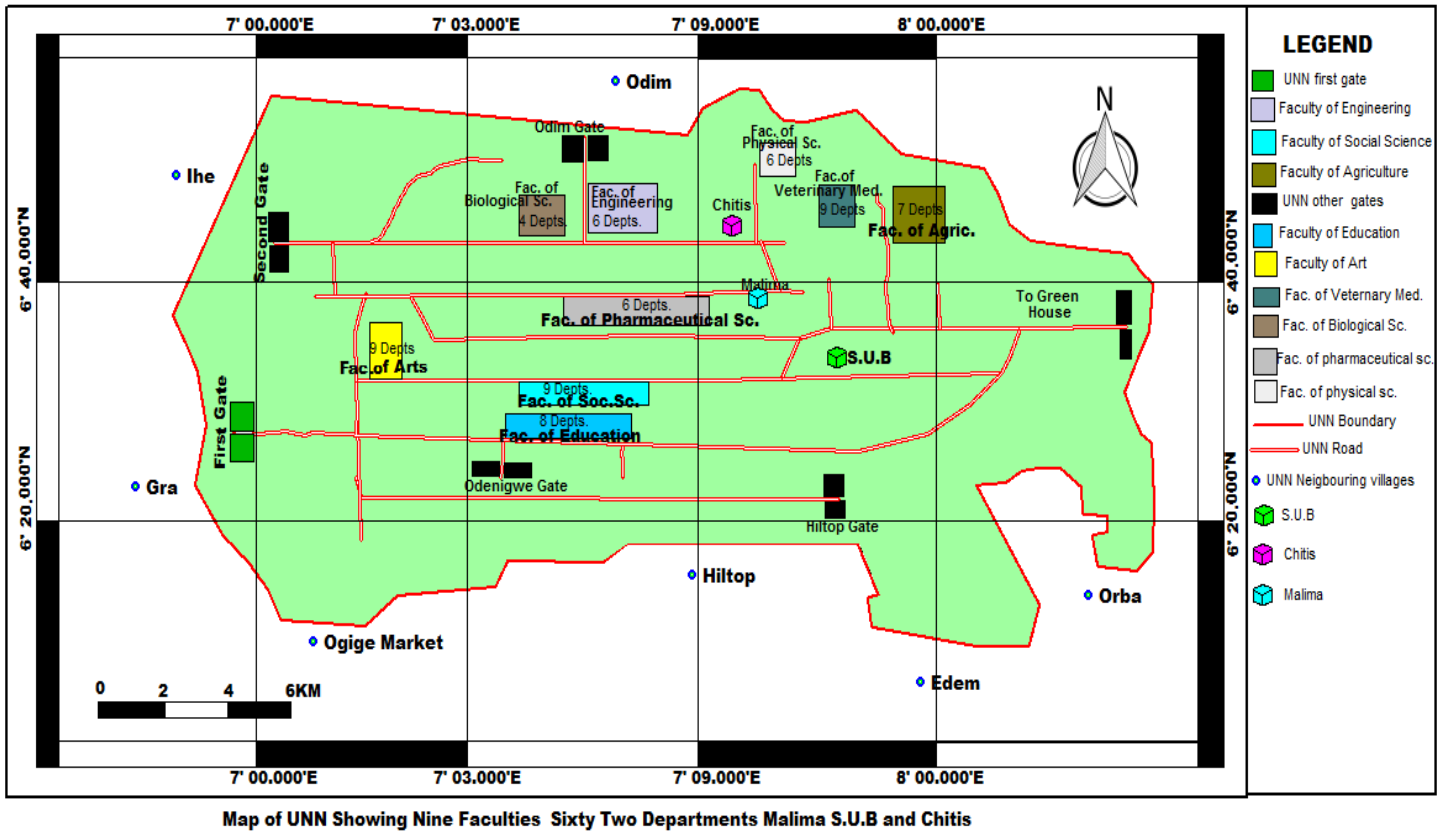

Figure 1: Delineated Map of University of Nigeria Nsukka by this study showing Faculties and Cafeteria

Therefore, samples of solid wastes were collected from four different sources with varying sampling points as follows: Building (9), Corridor (8), Cafeteria (3) and Departmental offices (62) which gave a total of 82 sampling points for a period of One Week. The percentages of each activity area where the solid waste was sampled from the institution are as follows:

1. Building (10.98%)
2. Corridor (9.76%)
3. Cafeteria (3.66%)
4. Departmental Offices (75.61%)

This fits the classical one-factor (source of waste) experimental design for the solid waste samples with responses being rate of solid waste generation and rate of waste fraction generation after One (1) week of sampling. The analysis of solid waste was done according to [4]. A total of 32 persons were involved in the waste collection and analysis exercise. The wastes were separated into six different fractions namely: paper, plastics, glass, organic, metals, and others. The percentage by weight of each waste fraction was estimated with the mathematical expression [4]:

$$Waste\ Fraction\ (\%) = \frac{Weight\ of\ \ Separated\ Fraction(kg)}{Total\ Weight\ of\ Unseperated\ Waste\ (Kg)} \times 100 \quad (1)$$

2.3 *Data Analysis*

One-way ANOVA (no blocking) was performed on the responses namely rate of solid waste generation and rate of waste fraction generation after 1week of sampling to determine their respective variations with the source of waste. Significant differences among the means were separated by Games-Howell and Tukey HSD at a 5% probability level.

3.0 RESULTS AND DISCUSSIONS

3.1 *Waste Characterization and Descriptive Statistics*

In total, 4821.1 kg/week of solid waste were sorted, of which, 1034.9 kg/week were from buildings, 910.7 kg/week from corridor, 502.5 kg/week from the cafeteria, and 2373 kg/week from departmental offices. The mean quantities of waste generated at collection points were 114.99kg/week, 113.84kg/week, 167.57kg/week and 38.27kg/week for building, corridors, cafeteria and departmental offices respectively. The weighted average amount of solid waste generated in University of Nigeria Nsukka Campus per sampling point is:

$$(114.99 \times 10.98\%) + (113.84 \times 9.76\%) + (167.57 \times 3.66\%) + (38.27 \times 75.61\%) \times \frac{1}{100\%}$$

$$= 58.79 kg/week/Sampling\ Point$$

The analyzed waste from the four collection points gave the waste composition results presented in Table 1. Table 1 also indicates that :(i) the highest percentage of paper (41.02%) comes from departmental offices, (ii) the highest percentage fractions of plastic (26.78%) and other unclassified wastes (10.49%) comes from building, and (iii) the highest percentage of metal (23.78%), organic (55.49%) and glass (13.59%) were from cafeterias. The results shows that building, produced the highest quantities of plastics and other unclassified waste fractions while cafeteria produce the highest quantities of metal, organic and glass in UNN (Table 1). The weighted average percentage of the waste fractions for university of Nigeria Nsukka Campus is 37.66%, 20.23%, 6.65%, 24.86%, 3.33% and 7.28% for paper, plastic, metal, organic, glass and others respectively (Table 1). Table 1 shows that the waste fractions are generated in a decreasing order as follows: paper (37.66%), organic (24.86%), plastic (20.23%). metal (6.65%), others (7.28%) and glass (3.33%).

The results in Table 1 entails different waste management approach for the waste sources affected the quantities and compositions [23, 24]. From Table 1, reusing and recycling of wastes from buildings is a veritable option, while composting is most suitable option for diversion of wastes from UNN cafeteria. Therefore, the potential for organic waste recovery from cafeteria in University of Nigeria Nsukka Campus is enormous if sorting of waste at source to separate the organic waste from other waste fractions is adopted by the University of Nigeria Nsukka.

It is worthy of note that some of the plastics and metal fractions identified in the wastes stream are mostly e-waste from waste office equipment such as photocopiers, scanners, computers and printers. E-waste has become one of the fastest growing waste streams in the world, and has attracted worldwide attention but very little research on e-waste has focused on waste office equipment [25]. The major causes of e-waste generation are quick obsolescence rate, poor utilizations and handlings which leads to breakage of electronic equipment. The absence of recycling possibilities and lack of awareness about the possibilities and values of recycling e-waste, lack of e-waste legislation, shortages of storage facilities, absence of recycling and refurbishing centers are some of the hindering factors [26].

The presence of these e-wastes according to [27] is

Table 1: Percentages of Generated Waste Fractions in UNN

Waste Fraction	Building	Corridor	Cafeteria	Departmental Offices	Weighted Average for UNN
Paper (%)	31.67	31.86	1.67	41.02	37.66
Plastic (%)	26.78	24.12	4.96	19.51	20.23
Metal (%)	3.45	3.70	23.78	6.66	6.65
Organic (%)	25.53	32.26	55.49	22.32	24.86
Glass (%)	2.07	1.02	13.59	3.32	3.33
Others (%)	10.50	7.04	0.51	7.17	7.28
Total	100	100	100	100	100

due to inefficiency in management of ICT e-waste by universities. To curb this problem, there should be policy on management of e-waste in University of Nigeria Nsukka Campus with emphasis on health and environmental problems associated with e-waste and all-inclusive university wide strategic recycling program [28].

3.2 Waste Generation Rate

Based on the current student population of 36,000 and a total solid waste of 4821.1kg/week. Therefore, the waste generation of the university was calculated as 0.019kg/capita/day from the four sources analyzed.

3.3 Waste from Buildings

The percentage composition of waste fractions from each faculty building is presented in Fig.2.From Fig.2 it is evident that paper, plastic and organic are generated more than the other fractions analyzed. Paper fraction is more in faculties of Agriculture, Pharmacy and Engineering. While plastics are more in School of general studies, Arts, veterinary medicine and Social sciences. Moreover, organics are more in Engineering and biological sciences. Percentage composition of paper is more in those buildings because of proximity to photocopying centers.

3.4 Wastes from Corridors.

The composition of analyzed waste obtained from corridors is presented in Fig. 3. The highest quantities of paper, plastic, metal, organic, glass and other unclassified wastes from corridors were generated from faculties of physical science, Arts, Engineering, Education, Social Sciences, and Education respectively. Littering on the corridors of the campus of the institution may be as a result of lack of waste bins and proximity of available ones to users; insufficient environmental education and ethics; improper handling and labeling of waste bins ;(4) increased population, and the various complex activities and; presence of unorganized retail outlets. Development and expansion of physical infrastructure on the campus may also have contributed to the littering of the corridors with wastes [29]

3.5 Waste from Cafeteria

The percentage distribution of waste fractions from cafeteria is as shown in Fig. 4. Organic represents the highest fraction of waste from cafeteria followed by metal. The higher value of organics in cafeteria is consistent with that reported by [30]. It is also very clear that the highest proportion of organic comes from Chitis while the highest proportion of metal comes from Malima. The large

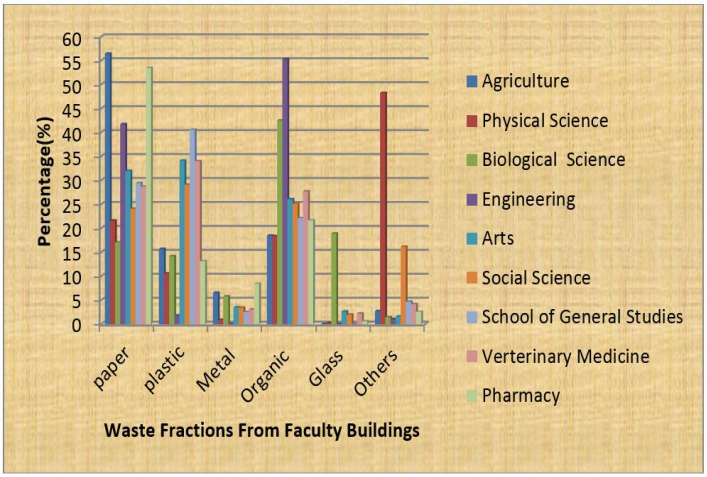

Figure 2: Percentage Waste Fractions from Faculty Buildings

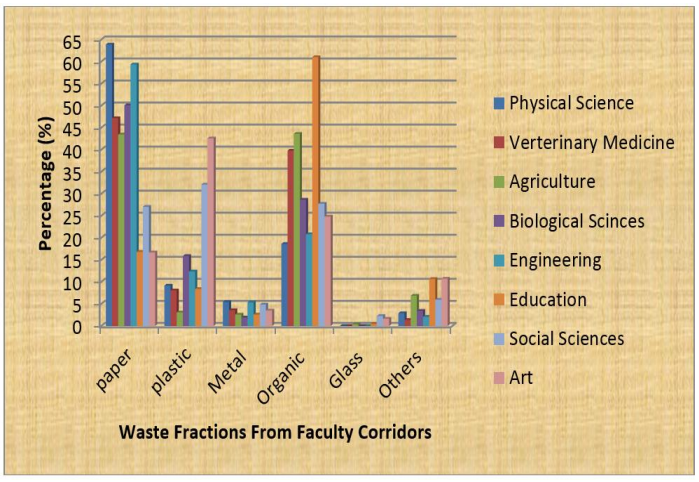

Figure 3: Percentage Waste Fraction from Faculty Corridor

variations between cafeteria show that they have different causes of food waste, but different opportunities to reduce it. The variation may be due to location of actual place of preparing the food (production unit), cooking the right amount of food, availability of storage facility for surplus food [31]. Food waste drivers in cafeteria and hotel operations has been classified as internal (poor cafeteria management and policies, lack of skills in food preparation, lack of facilities and food waste technology and absence of waste audit and waste separation), external (unsustainable food consumption patterns of the customers and risk of food ingredients spoilage ; ineffective communication and inadequate education and awareness) [32]. Detailed waste quantification for each cafeteria can therefore be the first step in the process of waste reduction. [31, 33] reported that source segregation of food wastes in office areas offer promising potential for relatively easily collectable and pure source-sorted food waste, suggesting that recycling targets for food waste could be achieved with reasonable logistical ease in office areas.

3.6 Waste from Departmental Offices

The distribution of waste fractions from the 62 departmental offices analyzed show dominance of paper, plastic and organic in the waste stream which signifies a huge potential for reuse, recycling and diversion of waste for composting (Fig.5). [33] reported that food waste (organics) in office areas offers promising potential for relatively easily collectable and pure source-sorted food waste, suggesting that recycling targets for food waste could be achieved with reasonable logistical ease in office areas.

3.7 Comparison of Average Solid Waste Quantities from the Activity Areas

The average waste stream from the activity areas studied is compared using Fig.6. The highest average proportion of waste comes from Cafeteria (38.55%). The second largest proportion comes from building (26.45%) while the third largest proportion comes from corridors (26.19%) which are a little less than that generated from buildings.

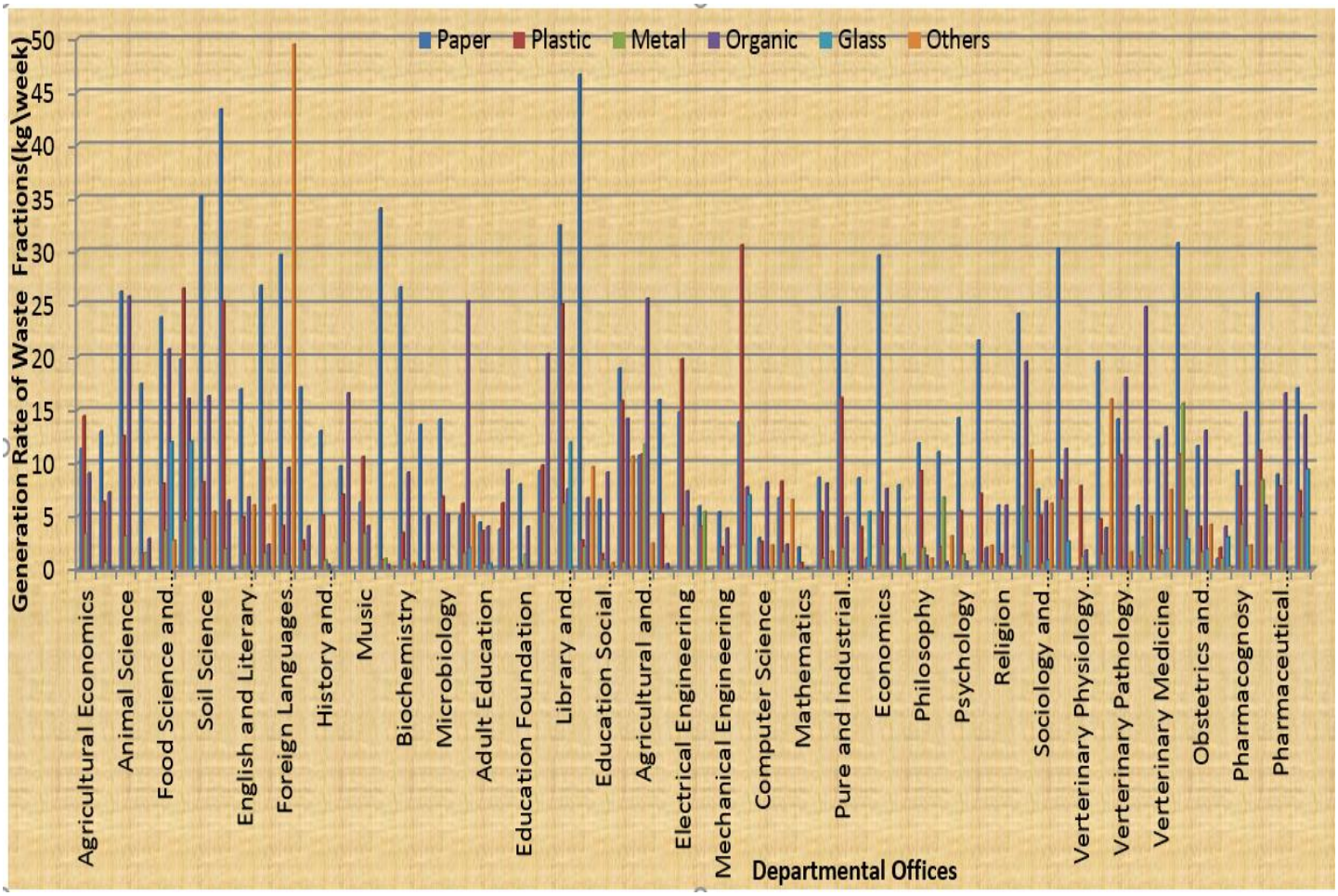

Figure 5: Generation of Waste Fractions from Different Departmental Offices

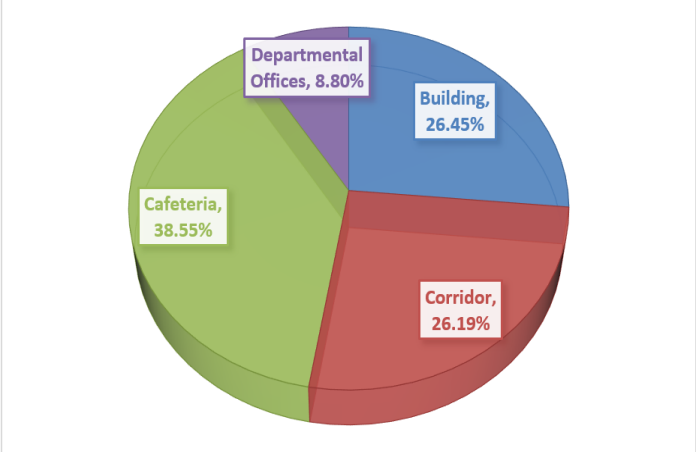

Figure 6: Comparison of Average Solid Waste Quantities from the Activity Areas in University of Nigeria Nsukka Campus.

The comparison of waste fractions from the activity areas is also presented in Fig.7. From Fig.7, the highest proportion of paper comes from the departmental offices and most of the papers were not fully utilized for printing or writing as observed, indicating non-existence of reuse of paper waste in the university campus. Consequently, the observation of partial utilization of the majority of generated paper waste also positions paper reuse as a good waste reduction strategy for effective solid waste management in UNN in addition to recycling [34-37].

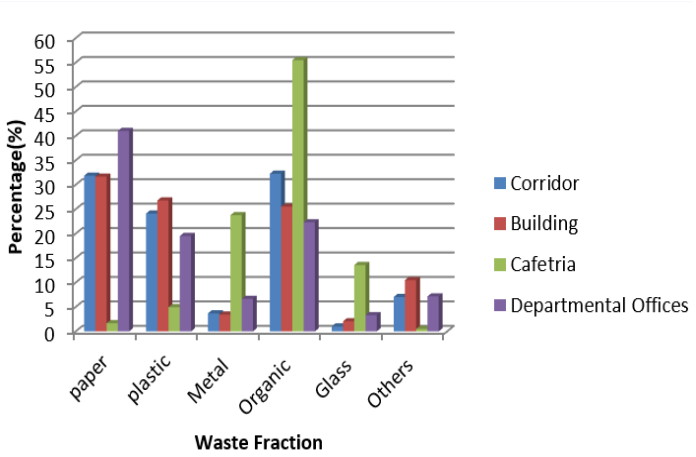

Figure 7. Comparison of Waste Fractions from Activity Areas

Moreover, the largest proportion of plastic and other unclassified wastes were found in buildings while the largest proportions of metal, organic and glass were found in cafeteria (Fig.7). Most of the plastic, metal and glass found in the waste stream were as a result of packaging and containerization of food, beverages and water.

Based on the findings from the present study and the ongoing discourse, there is urgent need to implement the waste management hierarchy of reduction, reuse and recycling for sustainable solid waste management in the study area [23]. The money saved as a results sustainable management of the campus waste through application of the 3Rs(reduction, reuse and recycling) could be invested in other areas of needs [38].

3.8 Composition (% by wt.) of Solid Waste Generated in UNN

The weighted average composition (% by wt.) of solid waste generated in UNN campus is presented in Fig.8. The weighted average of waste fractions in UNN Campus waste streams was paper (37.66%), plastic (20.23%), metal (6.65%), organic (24.86%), glass (3.33%) and others (7.28%) (Fig.8). The waste composition (Fig.8) suggests a huge potential for minimization of waste that is sent to landfill from UNN campus. Waste minimization in campus sustainability is necessary for demonstrating sustainability governance in translating the hazy idea of sustainable development in the Higher Education Institutional context into more concrete outcomes of sustainable consumption, reducing environmental impact from campus activities, and creating a conducive campus environment for behavior change [39].

3.9 Recycling Potentials of the Waste

The recyclable waste categories generated in UNN is presented in Fig.9.From Fig. 9, it can be gathered that 28.35% of the waste generated is compostable while 64.49 % is recyclable. Fig.9 also indicates that only a small proportion of 7.16% can be diverted to landfill. The implication of this finding is that it is less expensive and easy for University of Nigeria to establish a functional sanitary engineered landfill for diversion of the 7.16%

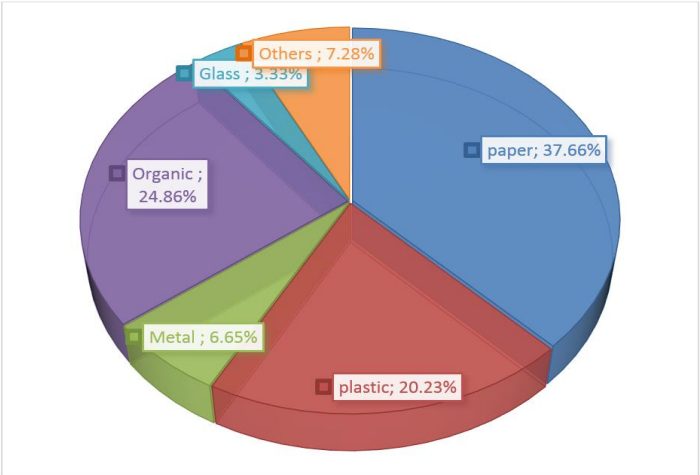

Figure 8: Weighted Average Composition (% by wt.) of Solid Waste Generated in UNN

meant for landfilling [40]. For effective recovery of the waste source separation using different containers is a

necessity [40]. [39] reported that Green Office practices intended to reduce dry waste and provide situational and systemic behavioral changes, such as Sustainable Meeting, Paper Saving and Recycling Practices in Universiti Teknologi Malaysia , led to reduction rates in campus paper of 30% to 58% between 2011 to 2013, which amounted to total paper reduction consumption of 35, 089 reams , equivalent to saving of US$ 130,563 (2009 – 2013), carbon emission reduction of 6,047.58 kg and the energy saving of 4,414,196.2 GJ/t as an environmental sustainability dimension. [39] also reported that participatory based approach, governance and institutionalization process of waste minimization contributed to the development of sustainable consumption in general and behavioral changes of the campus society, the study demonstrated and explained in detail that the adoption of waste profile data resulted from research has corrected function for better management of waste minimization as to support integrated solid waste management in campus.

3.10 Statistical Analysis Results for the Waste Stream

The result of the Levene statistics showed 0.000 <0.05 for the solid waste quantity indicating that the group variances are not equal (Table 2). The ANOVA result showed that statistically significant difference existed between the quantities of solid waste generated {F (3, 78) =26.110, p < 0.000} in different activity areas during the survey (α = 0.05) (Table 3). The Brown-Forsythe test statistic showed significant for solid waste quantity {0.002< .05}. The Welch statistic for solid waste quantity was also significant {0.01<.05} (Table 4). The result of the Welch statistic indicates that the solid waste quantities from the four activity areas are statistically not the same. Post hoc tests were carried to know the extent of each activity area on quantity. Both Turkey and Games-Howell tests were used as popular tests to separate the means of solid waste quantities in the activity areas. The Tukey test indicated that the quantity of solid waste generated from departmental offices differed significantly from quantity of solid waste generation in buildings, corridor and cafeteria, (p = .000 < .05) and there were no statistically significant differences between quantity of solid waste generation in building, corridor and cafeteria, {buildings and corridors (p = 1.000); building and cafeteria (p = .174); corridors and cafeteria (p = .169)}. Games-Howell test indicated that quantity of solid waste from departmental offices differed significantly from solid waste generated in buildings only (p = .022 < .05). and there was no statistically significant differences in quantity of solid waste generation between: building and corridor(p = 1.000); building and cafeteria(p = .634) ; corridors and cafeteria(p = .682) ;corridors and departmental offices(p = .135); cafeteria and departmental offices (p = .169 >.05).Since the Levene test (.000 <.05) confirmed the suspicion that the variances of the groups are different ,we therefore accept the result of the Games-Howell test that only the solid waste quantities between buildings and departmental offices were statistically significantly different(P = 0.022 <.05).

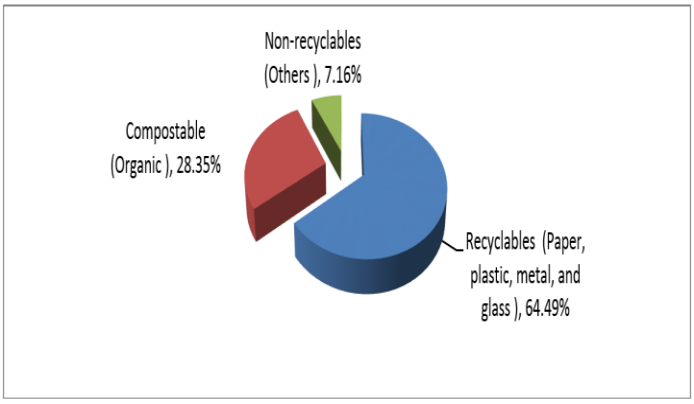

Figure 9: Recycling categories of Waste Generated in UNN

3.11 Analysis of Variance (ANOVA) Result for the Waste Fractions

The ANOVA result showed that there was statistically significance between the activity areas for paper *{*F(3, 78) = 16.737, p = 0.000 < .05*}*,

Table 2: Test of Homogeneity of Variances for Solid Waste Quantity

	Levene Statistic	df1	df2	Sig.
Quantity of Solid Waste(kg)	11.323	3	78	.000

Table 3: ANOVA Table of Solid Waste Quantity

		S.S.	df	M.S	F	Sig.
Quantity of Solid waste (kg)	Between Groups	114261.631	3	38087.210	26.110	.000
	Within Groups	113778.491	78	1458.699		
	Total	228040.122	81			

Table 4: Robust Tests of Equality of Means for Quantity of Solid Waste.

		Statistic[a]	df1	df2	Sig.
Quantity of Solid waste(kg)	Welch	9.022	3	6.613	.010
	Brown-Forsythe	8.431	3	12.717	.002

a. Asymptotically F distributed.

Plastic *{*F(3, 78) = 7.021, p = 0.000 < .05*}*,Metal *{*F(3, 78) = 125.170, p = 0.000 < .05*}*,Organic *{*F(3, 78) = 56.793, p = 0.000 < .05*}*,Glass *{*F(3, 78) = 45.332, p = 0.000 < .05*}* and other unclassified wastes *{*F(3, 78) = 3.043, p = 0.034 < .05*}*. Post hoc tests were not used.

4.0 CONCLUSIONS

Solid waste was sampled for 1 week from Nine (9) academic buildings, sixty-two (62) academic departments administrative offices, eight (8) corridors, and three (3) cafeterias giving a total of 82 waste sampling points. In total, 4821.1kg/week of waste were separated at University of Nigeria. The total quantity of solid waste at collection points were buildings (1034.9 kg/week), corridor (910.7 kg/week), cafeteria (502.5kg/week) and departmental offices (2373 kg/week). The mean quantities of waste generated at collection points were 114.99kg/week, 113.84kg/week, 167.57kg/week and 38.27kg/week for building, corridors, cafeteria and departmental offices respectively. This shows that on the average that the highest quantity of waste is generated from cafeteria. The weighted average amount of solid waste generated in University of Nigeria Nsukka Campus per sampling point is 58.79kg/week. The weighted average percentage of the waste fractions for university of Nigeria Nsukka Campus is 37.66%, 20.23%, 6.65%, 24.86%, 3.33% and 7.28% for paper, plastic, metal, organic, glass and others respectively. The waste fractions are generated in a decreasing order as follows: paper (37.66%), organic (24.86%), plastic (20.23%). metal (6.65%), others (7.28%) and glass (3.33%). The estimated waste generation rate for the university campus was 0.019kg/capita/day from the four sources analyzed based on current student population of 36000 and weekly generation of 4821.1kg. 28.35% of the waste is compostable while 64.49 % is recyclable and these sums up to 92.84% indicating that only a small proportion that is 7.16% of generated waste which can neither be composted or recycled will be diverted to landfill. However, recovery of resources and recycling call for segregation of waste at the source, through providing separate waste containers for different waste types. Paper and paper products, disposable drink containers and compostable organic material represented three of the most significant material types for targeted waste reduction and recycling efforts.

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