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Analysis and Characterization of the Solid Waste from Kabagarame Dumping site in Bushenyi District, Uganda.

[1]Mutungirehi Faisal, [2]Mustafa M. Mundu and [1]Stephen N. Nnamchi

[1]Department of Mechanical Engineering School of Engineering and Applied Sciences Kampala International University, Uganda.
[2]Department of Electrical Telecommunication and Computer Engineering, School of Engineering and Applied Sciences Kampala International University, Uganda.

ABSTRACT

Poor municipal solid waste management poses a very big threat to the environment as well as human health through the production of leachate and greenhouse gas emissions. This research focused on analyzing and characterizing solid waste at the Kabagarame dumping site in the district of Bushenyi, in Uganda. Specifically, wet solid waste samples were characterized and analyzed. The results revealed organics (45.25 %), food waste (24.17 %), inorganics (12.54 %), this was followed by plastics (11.38 %), mixed paper (2.88 %), glass of all kinds (2.36 %) and wood of all kinds (1.42 %). The findings also suggest that understanding the composition of municipal solid waste is essential for creating the best disposal strategy for recovering resources trapped in waste.
Keywords: Characterization, solid waste, Kabagarame, and dumping site.

INTRODUCTION

Globally, the rate at which the world is urbanizing is unparalleled to the rate at which people are disposing of increasing amounts of waste [1, 2, 3]. Moreover, the waste's composition has become more complex than ever, with the widespread use of polyethylene and electronic goods [4]. These have collectively made towns and cities to be stressed since they are responsible for garbage management that is both socially and environmentally friendly. However, with the formalization of waste management systems, in developed countries, the waste is managed by municipalities. Withal, a mix of formal and informal players manage garbage in less developed countries where citizens produce less waste, most of which is a bio-based waste [5].

With continuous urbanization, the generation of MSW globally is anticipated to rise to 3.4 billion tons by year 2050 [6], 1.9 billion tons of municipal solid waste is produced annually and every individual contributes 218 Kg of municipal solid waste [7].The commonest practice for disposal municipal solid waste is landfilling and this could probably be due to the fact that it requires unskilled worker and it is very economical [7]. Landfilling that is unsanitary constitutes a very big hazard to the environment due to the methane, carbon dioxide and production of leachate or leakage of greenhouse gases [8]. [9] noted that 72 percent of natural vegetation in Islamabad was destroyed due to soil degradation that was excessive as a result of open dumping. This was due to the production of pollutants that are highly toxic thereby retarding the physiology of the plant roots. Correspondingly, [10] noted that ground or surface water is contaminated as a result of pollutant leaching from solid wastes by percolating toxic elements. 14 percent of emissions of methane globally are due to landfills of solid waste [11].There should be drastic reduction of greenhouse gas emission so as to control change in climate and global warming effectively [12]. In areas where human activities are intense most especially urban areas, management of solid waste that is safe and appropriate is also very crucial towards provision of conditions that are healthy to the residents. More so, the relevance of proper management of waste is viewed as a very critical elements towards sustainable development [13].

[14] carried a survey to determine the quantity and quality of household solid waste in rural communities and found that organic and food waste formed the greater amount of the waste. In a separate study [15] carried out on solid waste sampling and laboratory analysis in a landfill in Malaysia to evaluate the composition and characteristics of municipal solid waste to obtain information about the quantity of recoverable plastic, the study revealed that the main compositions of the generated waste were food waste, plastic waste and paper. Earlier studies by [16]to determine the effectiveness of municipal solid waste recycling in an urban setting focused on the results of waste flow analysis as basic information in developing a better waste management systems, especially in applying the 3Rs of reduction, reuse, recycle model by assessing waste compositions and the potential of recycling. [17] carried out an estimation of the daily average waste generation by the, Nsukka campus, University of Nigeria to be able to provide a sustainable management strategies of the waste at the university campus. The study revealed that organic wastes and polythene represented the largest share of the dumps at the campus. That the campus per capita waste generation rate is 0.06 kg per day. Elsewhere in Nepal, [18] conducted a study to quantify and characterize municipal solid waste in their localities to establish the influence of location, population, distribution, expenditure at the household level (among others) on waste quantification and characterization. The study indicated that the average per capita household waste generation is 0.115 kg per day while at the municipal level the generation rate was estimated to be 0.180 kg per day per capita. That the larger the population in the area the larger is its per capita waste generate rate. The study also rated organics and plastics as the top composites of the waste in these areas. [19] in Malaysia stressed the much needed attention to understand the generation of construction waste especially in housing which prompted them to implement different approaches and method to review previous studies on the waste quantification in the construction sites for proper planning of future construction waste management. Similarly, [21] carried out a study to determine the effect of seasons of the year on waste generation using data obtained through quantification of different categories of waste. The study showed that average solid waste generate per person per day is 0.042 kg. That also changes in the seasons of the year had no significant influence on the characterization of waste generated in the study area.

[22], conducted a study to characterize the MSW generated and dumped at Kiteezi landfill, Kampala, between July 2011 -June 2012, covering the wet and dry months. On every day of sampling, the waste was selected randomly from 5 trucks, sorted and then weighed into various physical components. Organic waste samples from every truck were analyzed for main nutrients, overall solids and energy content. The results revealed that the waste comprised 0.7 % textiles, 88.5 % organics, 2.8 % hard plastics 3.8 % soft plastics, 0.2 % metals, 0.9 % glass, 2.2 % paper, and 1.0% others during the wet months.

More so the waste comprised 2.4 % soft plastics, 0.3 % textile, 0.7 % papers, 1.0 % hard plastics, 0.3 % glass, 94.8 % organics, 0.1 % metals, and 0.3 % others. The organic waste had a moisture content of 71.1 % averagely and an energy content of 17.3 MJ/kg. Similarly, [23], studied the characterization of the MSW in Eskisehir City in Turkey. The researchers noted that percentage of, the generation rate of, and certain properties of each component in the MSW have to be known if there is need to design a managing system of MSWC that is sustainable. MSW samples were collected for a year to determine the change in MSWC with season and socio-economic structure of residents. SPSS 10.0 statistical software on the other hand was utilized to determine the HHV and the correlation coefficients of MSWC relative to the temperature of seasons and socio-economic structure of the residents. For the determinations of the amount of waste, the waste samples were collected and separated into the groups of: food wastes, paper–cardboard, ash, glass, plastics, metals, and miscellaneous manually. The component percentages of the MSW on a wet basis were: glass 2.49 %, metals 1.26 %, food wastes 67.06 %, ash 3.86 %, paper–cardboard 10.07 %, plastics 5.62 %, and miscellaneous 9.64 %.It was resolved that local authorities have to apply these results to attain an integrated and sustainable SWMS for the analysis of all the components.

Aim of the research

The aim of this research was to analyze the wet solid waste samples so as to characterize the waste at Kabagarame dumping site.

Research Question

What are the physical characteristics of the solid waste samples?

Geographical Scope

The study was carried out from Kabagarame dumping site in the Municipality Bushenyi-Ishaka in Bushenyi district (coordinates: 00 32S, 30 11E), South-Western region of Uganda. Kabagarame is located in Ruharo ward, Central division.

Figure 1: Kabagarame dumping site

MATERIALS AND METHODS

Research Design

This study utilized quantitative research design. This was characterized by collecting data which was expressed numerically. Such data was solved by statistical tools such as bar graphs and pie charts.

Sampling Design

This involved taking samples of solid waste that are representative from the dumping site having the composition and properties of the mass of waste from where it was collected. The method of spot sampling was used in the process of sampling. Wet solid waste samples were taken from dump site from five spots where an amount of waste (1500g) was taken per spot and the total amount collected formed a sample size of about 7500g per week. The waste samples were filled in polyethene bags so that they could be weighed and then stored. The polyethene bags were labelled with identification numbers for indicating the spot from which the sample was collected and the period of sampling. Five samples of 1500g each of the raw solid waste were taken from five spots from the dump site per week and this was done during a 13-week period.

Project Implementation flow chart

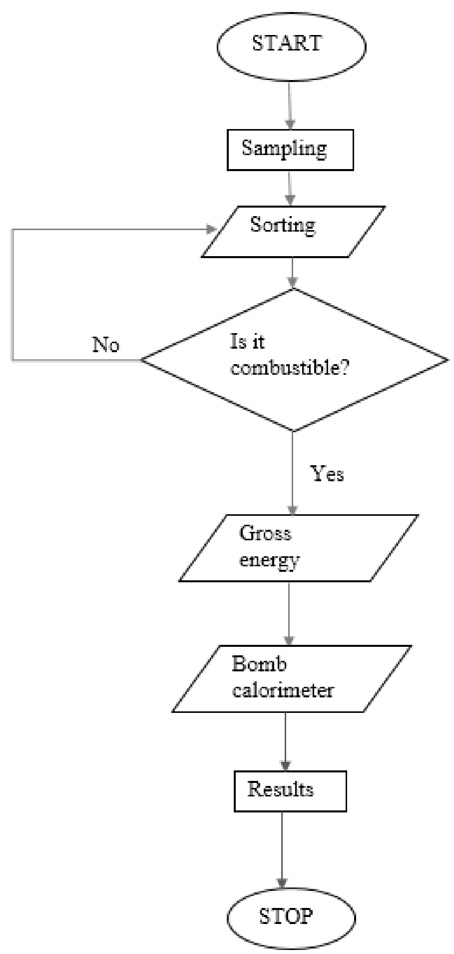

Figure 2: Project Implementation flow chart

Table 1: Broad description of the material categories according to ASTM D5231

No	Category	Description
1.	Food waste	▪ Includes all wastes of food apart from bones
2.	Mixed paper	▪ Comprises magazines, paper from office, paper from computer, paper that is glossy, paper that is waxed, other kinds of paper that do not lie on the corrugated and news print categories
3.	Yard waste	▪ Plant material such as grass, twigs, leaves, branches
4.	Newsprint	▪ Includes all newspaper
5.	Plastic	▪ Includes all kinds of plastic
6.	Corrugated	▪ Includes medium boxes or cartons, brown paper bags that are all corrugated
7.	Wood	▪ Includes furniture, products of wood, lumber ,and pallets
8.	Glass	▪ Includes all kinds of glass
9.	Ferrous	▪ Includes cans that are bi-metal, steel, tin cans and iron
10.	Aluminum	▪ Includes aluminum and cans, foil of aluminum
11.	Other combustibles, other organics	▪ Includes leather, rubber, textiles, plus other materials that are burnable
12.	Non-combustibles, other inorganics	▪ Includes sand, plaster, rock, dirt, bones and other metals that are non-aluminum and non-ferrous

Source: ASTM D5231-92(2003)

The mean and standard deviation for the governing component are selected from Table 2 The values of standard deviation and mean for various waste components that are suggested by ASTM D5231 in Table 2 below;

Table 2. Values of standard deviation and mean for various waste components according to ASTM D5231

No	Component	Standard Deviation	Mean
1.	Wood	0.060	0.06
2.	Newsprint	0.070	0.10
3.	Food Waste	0.030	0.10
4.	Corrugated	0.060	0.14
5.	Yard Waste	0.140	0.04
6.	Glass	0.050	0.08
7.	Plastic	0.030	0.09
8.	Ferrous	0.030	0.05
9.	Other Inorganics	0.030	0.06
10.	Other Organics	0.060	0.05
11.	Aluminum	0.004	0.01

Source: ASTM D5231-92(2003)

The number of samples to be sorted were estimated on the basis of ASTM D5231 method of calculation; The number of samples is then estimated for the governing component that has been selected using the value of t statistic for $n = \infty$ from Table 3 for the value of confidence interval that is selected. For the obtained number of samples, the corresponding t statistic is read from Table 3 and is then used to recalculate the number of samples. If at all the difference between the initially calculated number of samples and the recalculated sample numbers does not exceed 10%, then the bigger value of sample numbers is chosen. However, if the difference exceeds 10%, then whole calculation process is repeated. Also the values of t statistic for the confidence intervals of 90% and 95% as suggested by ASTM D5231 are provided in the table below.

Table 2: Values of *t* statistic for 90% and 95% confidence levels with the corresponding number of samples

Number of Samples (n)	90%	95%
2	6.3140	12.7060
3	2.9200	4.3030
4	2.3530	3.1820
5	2.1320	2.7760
6	2.0150	2.5710
7	1.9430	2.4470
8	1.8950	2.3650
9	1.8600	2.3060
10	1.8330	2.2620
11	1.8120	2.2280
12	1.7960	2.2010
13	1.7820	2.1790
14	1.7710	2.1600
15	1.7610	2.1450
16	1.7530	2.1310
17	1.7460	2.1200
18	1.7400	2.1100
19	1.7340	2.1010
20	1.7290	2.0930
21	1.7250	2.0860
22	1.7210	2.0800
23	1.7170	2.0740
24	1.7140	2.0690
25	1.7110	2.0640
26	1.7080	2.0600
27	1.7060	2.0560
28	1.7030	2.0520

29	1.7010	2.0480
30	1.6990	2.0450
31	1.6970	2.0420
36	1.6900	2.0300
41	1.6840	2.0210
46	1.6790	2.0140
51	1.6760	2.0090
61	1.6710	2.0000
71	1.6670	1.9940
81	1.6640	1.9900
91	1.6620	1.9870
101	1.6600	1.9840
121	1.6580	1.9800
141	1.6560	1.9770
161	1.6540	1.9750
189	1.6530	1.9730
201	1.6530	1.9720
∞	1.6450	1.9600

Source: ASTM D5231-92(2003)

$$n_0 = \left(\frac{t \times s}{e \times x}\right)^2 \qquad (1)$$

Governing component; other organics.

At 95% confidence interval;

$for: n = \infty, t = 1.960,\ s = 0.06,\ e = 0.3,$

$x = 0.05$

$$n_0 = \left(\frac{1.960 \times 0.06}{0.3 \times 0.05}\right)^2$$

$$or \quad n_0 = 61$$

From Table 3, at 95% confidence interval the value of t statistic corresponding to $n = 61$ is 2.000. Hence n' is obtained by;

$$n' = \left(\frac{1.960 \times 0.06}{0.3 \times 0.05}\right)^2$$

$$or \quad n' = 64$$

n_0 And n' do not differ by more than 10% and hence 64 samples were chosen

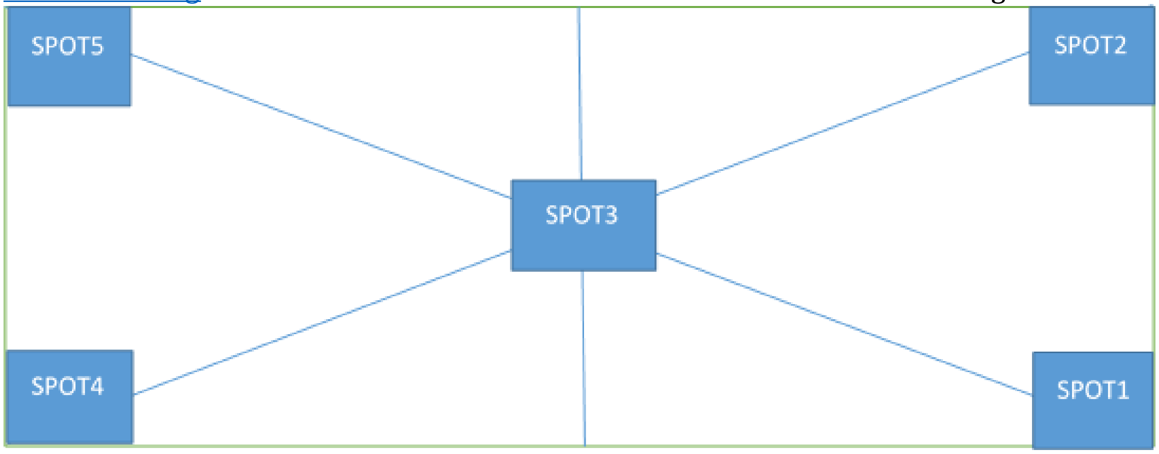

Figure 3: Illustration of sampling spots

Sorting

This involved determining the individual components available in the mass of waste and their distribution by mass. The polyethene bags containing the waste samples were emptied onto a clean flat leveled area with the electronic scale positioned on the same area. Hand Sorting was used for sorting of the Waste into various component categories as described in table below;

Table 4: Condensed Municipal Solid Waste Categories

Category	Description
1. Food waste	Comprised of all the wastes of food that include bones
2. Mixed paper	Office paper, magazines, computer paper, waxed paper and paper that lies in the corrugated and newsprint categories.
3. Wood	Comprises of all kinds of wood
4. Other organics	rubber, textiles, leather, and materials that are burnable primarily, and materials included in the yard waste category
5. Glass	Comprises of all kinds of glass
6. Other inorganics	ceramics ,sand, rock, plaster , dirt, and metals that are in the categories of aluminum and ferrous
7. Plastic	This comprises of all kinds plastic

Source: ASTM D5231-92(2003)

RESULTS

This research sought to analyze the wet solid waste samples so as to characterize the waste at Kabagarame dumping site. This was achieved by collecting sixty five (65) samples each of 1.5 kg from different spots from the dumping site for the whole sampling period. The samples were sorted per sampling week into various material categories, weighed to obtain the mass and the results tabulated as indicated in the tables below. The samples were sorted per sampling week into various material categories, weighed to obtain the mass and the results tabulated as indicated in the Tables A.1 – A.13. Furthermore, Figure 4 shows the collection, packing, and quantification of the samples.

Figure 4: The researcher collecting solid waste samples from the dumping site, packing and quantifying the samples

Table 5: Overall mean particle size and composition of municipal solid waste over a period of thirteen weeks

Category	Mean Composition By Mass (kg)					Mean Composition
	Spot1	Spot2	Spot3	Spot4	Spot5	
1. Food waste	0.1477	0.3158	0.1549	0.6192	0.5755	0.3331
2. Mixed paper	0.0230	0.0441	0.0115	0.0559	0.0817	0.0386
3. Wood	0.0361	0.0079	0.0348	0.0133	0.0140	0.0140
4. Plastic	0.0371	0.2324	0.1279	0.2561	0.2003	0.1633
5. Other organics	1.1523	0.5669	0.8100	0.4185	0.4460	0.4485
6. Glass	0.0244	0.1059	0.0175	0.0208	0.0080	0.0305
7. Other inorganics	0.0794	0.2271	0.3434	0.1162	0.1745	0.1723

Table 5 and Figure 4 shows the overall mean composition of solid waste from the different spots. The mean composition of the selected period of time (thirteen weeks) indicate that the mean composition by mass for other organics is the highest in spot 1 (1.1523 kg) with mixed papers being the lowest (0.0230 kg).

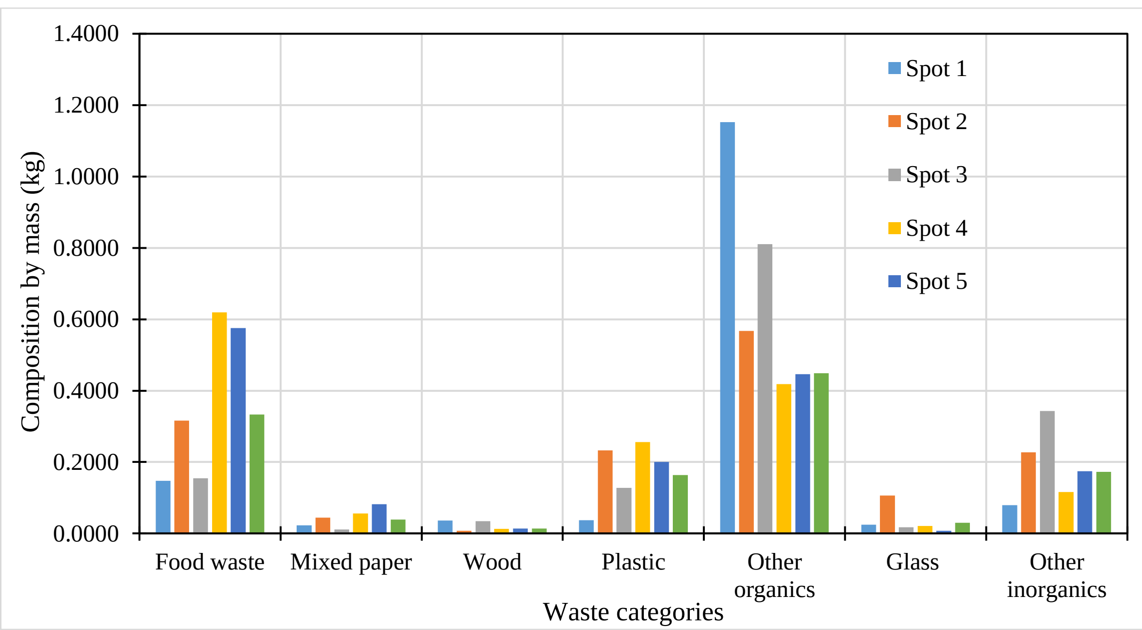

Figure 5: Overall mean composition of waste from the different spots

In spot 2, the highest mean composition by mass in still provided by other organics (0.5669 kg) with wood being the lowest (0.0079 kg). Moreover, in spot 3, like spot 1, the mean composition by mass for other organics is the highest (0.8100 kg) with mixed papers being the lowest (0.0115 kg). It is in spot 4 that food waste provided the highest value (0.6192 kg) followed by other organics (0.4185 kg). Again is spot 5, food waste has the highest value (0.5755 kg) with the lowest being glass (0.0080 kg).

Correspondingly, in the overall composition of means, other organics comes at the top (0.4485 kg) with food waste being the immediate follower (0.3331 kg). The study also sought to analyze the Wet solid waste samples so as to characterize the waste. Waste characterization is suitable for a variety of reasons, such as to determine how dumping of waste will affect the ecosystem in the long term and to discover and learn more ways and procedures that occur in proper waste management, strategies. The results on characterization of waste were presented by classifying different categories of waste by mass composition. The constituents and quantity of solid wastes are commonly determined using the composition analysis. A sample of the waste was taken, and it was divided into various categories; food waste, mixed paper, wood, plastic, other organics, glass and other inorganics. The portions were weighed individually and their percentage of the overall weight of the waste was determined. The results are tabulated as shown in Tables 6-18.

Table 6: Mean and percentage composition of waste for sampling Week One

Category	Mean Composition (kg)	% Composition
1. Food waste	0.5702	38.02
2. Mixed paper	0.0608	4.06
3. Wood	0.0274	1.83
4. Plastic	0.1113	7.42
5. Other organics	0.4913	32.75
6. Glass	0.0109	0.73
7. Other inorganics	0.2280	15.20
Total	**1.5000**	**100.00**

The mass composition in week one is dominated by food waste and other organics (Table 6).

Table 7: Mean and percentage composition of waste for sampling Week Two

Category	Mean Composition (kg)	% Composition
1. Food waste	0.4215	28.10
2. Mixed paper	0.0648	4.32
3. Wood	0.0234	1.56
4. Plastic	0.1814	12.09
5. Other organics	0.5851	39.01
6. Glass	0.0884	5.89
7. Other inorganics	0.1355	9.03
Total	**1.5000**	**100.00**

The trend in week two of the sampling period is also dominate by food waste and other organics (Table 7)

Table 8: Mean and percentage composition of waste for sampling Week Three

Category	Mean Composition (kg)	% Composition
1. Food waste	0.2266	15.11
2. Mixed paper	0.0112	0.75
3. Wood	0.0095	0.63
4. Plastic	0.2314	15.43
5. Other organics	0.8722	58.14
6. Glass	0.0028	0.19
7. Other inorganics	0.1463	9.75
Total	**1.5000**	**100.00**

In week three, other organics, plastics and food waste dominated this sampling period (Table 8)

Table 9: Mean and percentage composition of waste for sampling Week Four

Category	Mean Composition (kg)	% Composition
1. Food waste	0.2919	19.46
2. Mixed paper	0.0406	2.71
3. Wood	0.0235	1.57
4. Plastic	0.2090	13.93
5. Other organics	0.7177	47.84
6. Glass	0.0710	4.73
7. Other inorganics	0.1463	9.75
Total	**1.5000**	**100.00**

In week four, other organics and food waste had greater percentages as compared to other waste materials in this sampling period (Table 9).

Table 10: Mean and percentage composition of waste for sampling Week Five

Category	Mean Composition (kg)	% Composition
1. Food waste	0.2668	17.79
2. Mixed paper	0.0302	2.01
3. Wood	0.0183	1.22
4. Plastic	0.1670	11.13
5. Other organics	0.7414	49.43
6. Glass	0.0327	2.18
7. Other inorganics	0.2435	16.23
Total	**1.5000**	**100.00**

Meanwhile in week five, other inorganics also comes into play together with food wastes and other organics (Table 10).

Table 11: Mean and percentage composition of waste for sampling Week Six

Category	Mean Composition (kg)	% Composition
1. Food waste	0.5142	34.28
2. Mixed paper	0.0573	3.82
3. Wood	0.0333	2.22
4. Plastic	0.0802	5.35
5. Other organics	0.5313	35.42
6. Glass	0.0133	0.89
7. Other inorganics	0.2703	18.02
Total	**1.5000**	**100.00**

In week six, food waste and other organics dominated the sampling period (Table 11).

Table 12: Mean and percentage composition of waste for sampling Week Seven

Category	Mean Composition (kg)	% Composition
1. Food waste	0.4093	27.29
2. Mixed paper	0.0713	4.75
3. Wood	0.0255	1.70
4. Plastic	0.1534	10.23
5. Other organics	0.6319	42.13
6. Glass	0.0520	3.47
7. Other inorganics	0.1565	10.44
Total	**1.5000**	**100.00**

Though plastics registered a relatively larger percentage in week six, food waste and other organics still remain the leading producers of waste in this sampling period (Table 12).

Table 13: Mean and percentage composition of waste for sampling Week Eight

Category	Mean Composition (kg)	% Composition
1. Food waste	0.2301	15.34
2. Mixed paper	0.0049	0.33
3. Wood	0.0096	0.64
4. Plastic	0.2349	15.66
5. Other organics	0.8861	59.07
6. Glass	0.0041	0.28
7. Other inorganics	0.1303	8.69
Total	**1.5000**	**100.00**

Similarly, plastics, food waste and other organics competed favorably in producing waste in this week (Table 13).

Table 14: Mean and percentage composition of waste for sampling Week Nine

Category	Mean Composition (kg)	% Composition
1. Food waste	0.2767	18.44
2. Mixed paper	0.0658	4.39
3. Wood	0.0214	1.43
4. Plastic	0.2241	14.94
5. Other organics	0.6475	43.17
6. Glass	0.0652	4.35
7. Other inorganics	0.1993	13.29
Total	**1.5000**	**100.00**

In week nine, food wastes, other organics, plastics and other inorganics have all contributed immensely in waste production in this sampling period (Table 14).

Table 15: Mean and percentage composition of waste for sampling Week Ten

Category	Mean Composition (kg)	% Composition
1. Food waste	0.2815	18.77
2. Mixed paper	0.0288	1.92
3. Wood	0.0206	1.38
4. Plastic	0.1576	10.51
5. Other organics	0.8056	53.71
6. Glass	0.0283	1.89
7. Other inorganics	0.1775	11.83
Total	**1.5000**	**100.00**

In week ten, the situation is almost the same with food wastes, other organics, plastics and other inorganics contributing favorably to waste production (Table 15).

Table 16: Mean and percentage composition of waste for sampling Week Eleven

Category	Mean Composition (kg)	% Composition
1. Food waste	0.5955	39.70
2. Mixed paper	0.0562	3.75
3. Wood	0.0285	1.90
4. Plastic	0.1027	6.85
5. Other organics	0.4800	32.00
6. Glass	0.0112	0.75
7. Other inorganics	0.2259	15.06
Total	**1.5000**	**100.00**

In week eleven, waste has been generated more from food wastes, other organics, and other inorganics (Table 16).

Table 17: Mean and percentage composition of waste for sampling Week Twelve

Category	Mean Composition (kg)	% Composition
1. Food waste	0.3922	26.15
2. Mixed paper	0.0559	3.72
3. Wood	0.0252	1.68
4. Plastic	0.1572	10.48
5. Other organics	0.5406	36.04
6. Glass	0.0732	4.88
7. Other inorganics	0.2557	17.05
Total	**1.5000**	**100.00**

In week eleven, waste has been generated more from food wastes, other organics and other inorganics (Table 17).

Table 18: Mean and percentage composition of waste for sampling Week Thirteen

Category	Mean Composition (kg)	% Composition
1. Food waste	0.2374	15.83
2. Mixed paper	0.0143	0.95
3. Wood	0.0097	0.65
4. Plastic	0.2094	13.96
5. Other organics	0.8927	59.52
6. Glass	0.0061	0.41
7. Other inorganics	0.1303	8.68
Total	**1.5000**	**100.00**

In week thirteen, food wastes, other organics, plastics and other inorganics have all contributed immensely in waste production in this sampling period (Table 18).

Table 19: Mean composition (kg) of the solid waste categories for the whole sampling period

Category/ Sampling period	Food waste	Mixed paper	Wood	Plastic	Other organics	Glass	Other inorganics
Week 1	0.5702	0.0608	0.0274	0.1113	0.4913	0.0109	0.2280
Week 2	0.4215	0.0648	0.0234	0.1814	0.5851	0.0884	0.1355
Week 3	0.2266	0.0112	0.0095	0.2314	0.8722	0.0028	0.1463
Week 4	0.2919	0.0406	0.0235	0.2090	0.7177	0.0710	0.1463
Week 5	0.2668	0.0302	0.0183	0.1670	0.7414	0.0327	0.2435
Week 6	0.5142	0.0573	0.0333	0.0802	0.5313	0.0133	0.2703
Week 7	0.4093	0.0713	0.0255	0.1534	0.6319	0.0520	0.1565
Week 8	0.2301	0.0049	0.0096	0.2349	0.8861	0.0041	0.1303
Week 9	0.2767	0.0658	0.0214	0.2241	0.6475	0.0652	0.1993
Week 10	0.2815	0.0288	0.0206	0.1576	0.8056	0.0283	0.1775
Week 11	0.5955	0.0562	0.0285	0.1027	0.4800	0.0112	0.2259
Week 12	0.3922	0.0559	0.0252	0.1572	0.5406	0.0732	0.2557
Week 13	0.2374	0.0143	0.0097	0.2094	0.8927	0.0061	0.1303
Overall Mean	**0.3626**	**0.0432**	**0.0212**	**0.1708**	**0.6787**	**0.0353**	**0.1881**

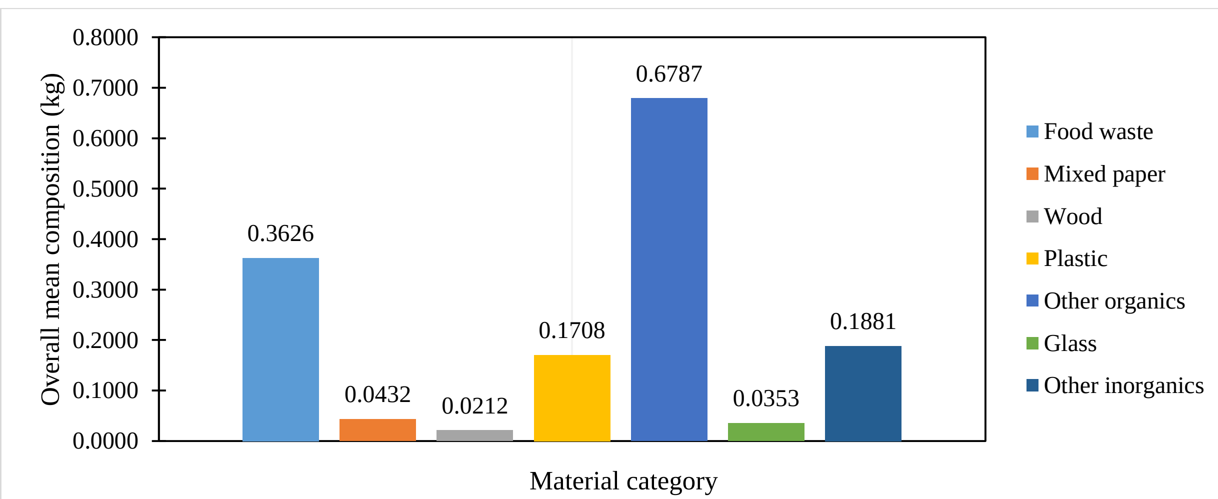

Figure 6: Overall mean composition of waste for the whole sampling period

The highest overall mean composition of waste for the whole sampling period is provided by other organics (Table 19, Figure 6).

DISCUSSION

In this research, the objective was intended to analyze the Wet solid waste samples so as to determine the physical characteristics of the waste. Appropriate waste samples that were used to determine the composition of the MSW were determined by utilizing ASTM D 5231. A compromise was made regarding the determination of the sample number to be sorted because the different components require different number of samples under varying conditions (precision and confidence level). As a result, a governing component (Other organics) was chosen to guide the estimation of appropriate number of samples. Sixty four (64) samples were obtained from the calculations that were made as the representative number of samples. However, a total number of sixty five (65) samples were collected during the whole sampling period since the whole sampling process lasted for a period of thirteen weeks and five samples were collected per week. However, in order to attain the composition of waste that is representative statistically while minimizing resources and costs, there was need to classify material categories to simplify quantification of the samples. It is difficult to attain a high level of precision and confidence while undertaking a waste composition study if the researcher assesses categories of materials that are extensive.

The results from the sorting process indicated that waste comprises ;38% Food waste,33% Other organics,7% Plastic,2% Wood,4% Mixed paper, 15% Other inorganics, 1% Glass for the first sampling week,28% Food waste, 39% Other organics, 12% Plastic,2% Wood, 4% Mixed paper, 9% Other inorganics,6% Glass for the second sampling week,15% Food waste, 10% Other organics,15 % Plastic,1 % Wood, 1% Mixed paper, 10% Other inorganics, 0 % Glass for the third sampling week,19% Food waste,48% Other organics,14% Plastic, 1% Wood,3% Mixed paper,10% Other inorganics,5% Glass for the fourth sampling week, 18% Food waste, 50% Other organics, 11% Plastic,1% Wood,2% Mixed paper,16% Other inorganics,2% Glass for the fifth sampling week,34% Food waste,36% Other organics,5% Plastic, 2% Wood,4% Mixed paper,18% Other inorganics,1% Glass for the sixth sampling week, 27% Food waste,42% Other organics,10% plastic,2% Wood,5% Mixed paper,10% Other inorganics,4% Glass for the seventh sampling week, 15% Food waste,59% Other organics,16% Plastic,1% Wood,0% Mixed paper,9% Other inorganics,0% Glass for the eighth sampling week, 19% Food waste,43% Other organics,15% Plastic,2% Wood,4% Mixed paper,13 % Other inorganics,4% Glass for the ninth sampling week, 19% Food waste,54% Other organics,10% Plastic,1% Wood,2% Mixed paper,12% Other inorganics,2% Glass for the tenth sampling week, 39% Food waste,32% Other organics,7% Plastic,2% Wood,4% Mixed paper,15% Other inorganics,1% Glass for the eleventh sampling week, 26% Food waste,36% Other organics,10% Plastic,2% Wood,4% Mixed paper,17% Other inorganics,5% Glass for the twelfth sampling week,16% Food waste,59% Other organics,14% Plastic,1% Wood,1% Mixed paper,9% Other inorganics,0% Glass for the thirteenth sampling week.

Correspondingly, for the whole sampling period of the study, it was found that in Bushenyi district, the waste material categories occur in the descending order of; (i) other organics (45.25 %) which comprises of rubber, textiles, leather, and materials that are burnable primarily, and materials included in the yard waste followed by food waste including bones (24.17 %), other inorganics (12.54 %) comprising of ceramics, sand, rock, plaster, dirt, and metals that are in the categories of aluminum and ferrous followed by plastics (11.38 %), mixed paper consisting of office paper, magazines, computer paper, waxed paper and paper that lies in the corrugated and newsprint categories (2.88 %), glass of all kinds (2.36 %) and wood of all kinds (1.42 %). This order of categorization is an indication that in Bushenyi district, the solid waste arise from different sources including; residential (single and multifamily dwellings), industrial , commercial (stores, hotels, restaurants, markets), institutional (schools, hospitals, prisons), municipal services (street sweepings; landscape, tree trimmings, wastes from parks, sludge water, e-waste, etc), agriculture (spoiled food wastes, agricultural wastes, spoilt diaries, etc.). The findings further implies that refuse collection in Bushenyi district is still infrequent, which means that occasionally uncollected waste is burned, buried, or dumped in public spaces. The big concerns here are ineffective machinery, poor, filthy working and gathering techniques, extensive improper waste disposal and burning, ineffective pollution control measures, and a public that doesn't seem worried with the trash around them.

CONCLUSION

Although several studies on characterization of municipal solid waste as well as evaluation of the potential of the waste have been conducted, these have only been limited to the region of Kampala. The waste material categories occur in the descending order of; (i) other organics (45.25 %), food waste (24.17 %), other inorganics (12.54 %), followed by plastics (11.38 %), mixed paper (2.88 %), glass of all kinds (2.36 %) and wood of all kinds (1.42 %). Also, understanding the composition of municipal solid waste is essential for creating the best disposal strategy for recovering resources trapped in the wastes.

RECOMMENDATION

The dumping site should be sectioned with each section representing a material category such that the MSW is segregated into the sections at the time of dumping. This will help ease the carrying out of any activities aimed at utilization of the waste.

LIST OF ACRONYMS

CV	Calorific Value
CC	Correlation Coefficient
IDA	International Development Association
WtE	Waste to Energy
SWM	Solid Waste Management
MOU	Memorandum of Understanding
MSW	Municipal Solid Waste
ASTM	American Society for Testing and Material
HHV	Higher Heating Value
SWMS	Solid Waste Management System
RCRA	Resource Conservation and Recovery Act
C	Carbon
H	Hydrogen
O	Oxygen
N	Nitrogen
S	Sulphur
VM	Volatile Matter
FC	Fixed Carbon
TGA	Thermogravimetric Analysis
MC	Moisture Content
RDF	Refuse-Derived Fuel
GPM	Geometric Programming Model
RMSE	Root Mean Square Error
SPSS	Statistical Package for the Social Sciences
GPS	Global Positioning System

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