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Characterization of Municipal Solid Wastes (MSW) Generated in Bayero University Kano (BUK) main campus, Kano, Nigeria

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Abstract— *Generally, the utilization of any given substance as a fuel is preceded by its classification and standardization. However, Municipal Solid Waste (MSW) is a difficult fuel in terms of generic characterization. Therefore, as a prelude to the utilization of a given MSW generated from a particular location as a fuel, the MSW must be characterized in cognizance of the area's geography and demography. The characterization study of the municipal solid waste (MSW) generated in Bayero University Kano (BUK) main campus, Kano, Nigeria was carried out within the permanent site of the university as the study area. Using ASTM standards, samples were randomly drawn from drums of MSW located at designated points and characterized in terms of; the constituent components, bulk density, and proximate analysis. The results of the study revealed that the MSW generated within the study area is composed of 55.85% organic content and 24.99% plastics with the remainder being 19.16% of inorganics and other waste. It was established that the MSW has a bulk density of 270 kg/m^3. The proximate analysis indicated; 40.28% moisture content, 46.06% volatile matter, 4.52% ash content, and 9.14% fixed carbon. The results obtained indicatd that the MSW generated from the study area can be considered as a potential complementary fuel. It is recommended that a further study should be carried out to establish its thermal properties.*

Keywords— *Characterization, Municipal, Solid, Waste, Proximate, Density, Moisture, Volatile.*

I. INTRODUCTION

Globally, an estimated 11.2 billion tons of municipal solid waste (MSW) is being generated (UNEP, 2018) with most of it only constituting pollution. It can be put to better use through incineration where a usable amount of electricity can be generated (Themelis, 2003). Nigeria with a population exceeding 170 million is one of the largest producers of solid waste in Africa, generating around 32 million tons of solid waste annually (Bakare, 2016). MSW is heterogeneous in terms of composition and characteristics (Harvey & Yu, 2012). These coupled with a poor management system in developing countries result in a meager 20-30% collection with attendant blockage of drainage networks culminating in environmental flooding, constituting a hazard to the environment which in contrast could have served as an alternative energy source (Amasuomo & Baird, 2016; Benjamin, Emmanuel, & Gideon, 2014; Oumarou, Dauda, Abdulrahim, & Abubakar, 2012; Nabegu, 2010). Generally, wastes can be regarded as any material that does not have specific meaningful use in terms of; production, transformation, or consumption and which needs to be disposed-off to prevent environmental pollution. It may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and other human activities. Waste can be defined in a generic sense "as refuse from places of human or animal habitation" (UNSD, 2007). MSW may be seen as a major sign and symbol of modernization and economic prosperity, whose management presents an increasing challenge as its production per inhabitant is growing globally due majorly to the geometrical increase in human population and affinity to industrialization. This challenge has received greater attention in developed nations where greater environmental awareness led to the implementation of systematic waste management systems that involve the separate collection of reusable waste, i.e., glass, paper, cardboard, and textiles, and dangerous toxic waste prior to combustion, among others. Reduction of up to 75% by mass and 90% by volume, ensures one of the primary benefits of municipal solid waste (MSW) incineration is achieved, as well as providing a sustainable and cost-effective alternative source of energy (Becidan, 2007). This further ensures the breakdown of hazardous, nonmetallic organic wastes and the ultimate destruction of bacteria and viruses, especially in cases involving medical wastes (UNEP, 2009).

II. MATERIALS AND METHODS

Study Area

This study was carried out at Bayero University Kano (BUK), Main campus (latitude 11° 59'N and longitude 8° 26'E) situated on the outskirts of Kano city. It is along the western city gate of Kabuga and 12km from the city center (Gidado, 2018). Kano, the capital city of Kano State, is one of the largest cities in the Sudan region with a population estimated at 3.5 million (UNDP, 2004). Kano has an MSW density of 290 kg/m^3 whose generation rate is estimated at 0.56 Kg/capita/day (Ogwueleka, 2009). The study area has a semi-arid climate of three distinct seasons in the year: hot-dry, rainy-wet, and cold seasons. The wind at the beginning of the season is northeast but gradually changes to the southwest, the maximum mean temperature is 39°C in May and the minimum is 24°C in January while its relative humidity is moderate at about 50%. Rainfall is also possible, especially in May, which is the buffer period between the dry season and the rainy season. With an annual mean wind speed of 4.53 m/s, the 2008 power demand for Kano was estimated at 475.7 MW (Murtala, Abdulhamid, Badamasi, & Ahmed, 2015; Adamu & Abdullahi, 2011). The developed areas, undeveloped land, and green areas of the study area are highly pronounced as shown in the map below in Fig 1.1 below. An aerial view of the study area reveals landmarked structures and roads within and around it. The university clinic, stadium, and students' hostels are visible. The Kano-Gwarzo Road which passes in front of the university's main gate is shown bordering the university's southern perimeter fence.

Figure 1: Google map of the study area (Source: Google map)

Experimental Materials

A. *Physical Characterization and Bulk Density*

During the physical characterization and bulk density experiment the following were used; Spring scale (analogue), EQB 50/100 Torrey electronic scale (with a capacity of 50 kg, readability of 10g, and plate dimension of 15" x 19"), Stainless Mettler PM6100 electronic scale (with a capacity of 5kg, readability 1g and plate dimensions of 5" x 7.5"), tarpaulin sheet, shovel, broom, rake, garden fork, PPEs (overalls, boots, nose mask, hand globes), first aid box, ink marker, masking tape, 0.216m^3 wooden cuboid box, plastic containers and sieves.

B. *Proximate Analysis*

The following equipment and materials were used for the proximate analysis experiment; Conical flask, Borosilicate Beaker, Borosilicate Measuring cylinder, Borosilicate Crucibles, Ceramic Spatula, Weight balance, Moisture cans, Desiccator, Drying oven, 15ml and 30ml crucible with closely fitting cover, muffle furnace and vertical electric tube furnace. These items are depicted in the figures below.

C. *Physical Characterization*

The MSW was pre-classified into eight waste components based on a preliminary study of similar studies carried out within the study area. The pre-classified components are as follows, Paper, Food waste, Yard waste, other organic, Plastics, Glass, Metals, and other waste. The Others-waste category represented waste components that were not identifiable or did not fall into the first seven categories. Collection drums are located at designated spots within the study area as shown in Appendix I from which samples were randomly drawn.

The collected waste was mixed, coned, quartered, and manually sorted into different fractions. Sorting and weighing of the collected waste sample was done at the environmental unit premises of the University. The weights of the different fractions were obtained and recorded before the proportions of the different fractions in the waste were calculated. Fresh samples, after properly mixing the categories, were collected, and taken to the laboratory where moisture content analysis was carried out.

Figure 2: Weight balance

Figure 3: Cans

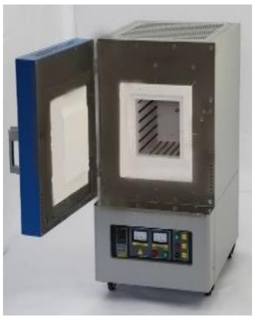

Figure 4: Muffle furnace

Figure 5: Drying oven

Figure 6: Vertical electric tube furnace

Figure 7: Crucibles

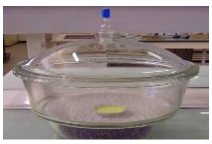

Figure 8: Desiccator

D. Bulk Density

The bulk density of the MSW was determined using a wooden cuboid box. The empty box was weighed and recorded. The MSW sample was introduced into it then the box was lifted to a height of 100mm and gently dropped, the void created by the dropping from the height was filled up without applying external pressure then the weight of the filled box was recorded. The procedure was repeated daily for 5 random days starting every day with the confirmation of the weight of the wooden container (EPA.I, 1996). The data obtained was analyzed based on equation 1 below.

$$\rho_b = \frac{(W_2 - W_1)}{V} \quad (1)$$

where: ρ_b =Bulk density (kg/m^3), W_1 = Weight of empty wooden box, W_2 =Weight of filed wooden box, V=Volume of wooden box

E. Proximate Analysis

An MSW gross sample of 10kg was collected and thoroughly mixed. The sample was coned and quartered. Three experiments were carried out for the proximate analysis as described below.

Experiment No.1: Determination of moisture content

The moisture content of the MSW sample was determined by establishing the loss in weight of the sample when heated under rigidly controlled conditions. The experiment was carried out based on ASTM standards. The empty containers were dried for 30 minutes at 104°C in the drying oven and then cooled in a desiccator to room temperature, then weighed and the result was recorded as W_C. 50g of the MSW sample was placed into the containers and an initial weight W_i recorded. Then placed in the drying oven at 104°C to a constant weight recorded as ($W_{f,}$). The procedure was replicated three times. The data obtained from the experiment was analyzed using equation 2 below.

$$M\ (\%) = \left[\frac{(W_i - W_f)}{(W_i - W_c)}\right] \times 100 \quad (2)$$

where, M = Moisture, W_i = initial weight (g), W_f = final weight (g), W_C= container weight(g).

Experiment No.2: Determination of volatile matter

The residue of the moisture content experiment was adopted, and size reduced to 1mm screen. The weight of a covered crucible was taken and recorded as crucible weight, W_{Cr}. 1g of the sample was placed into the crucible; covered, weighed, and recorded as the initial weight, W_O. Then placed on platinum wire support and inserted directly into the furnace chamber maintained at 950 °C. After heating for 7mins, the covered crucible was gently removed and allowed to cool in a desiccator after which it was weighed and recorded as final weight, W_f. The procedure was replicated three times and the data obtained was analyzed using equations 3 and 4 below.

$$A\ (\%) = \left[\frac{(W_o - W_f)}{(W_o - W_{cr})}\right] \times 100 \quad (3)$$

$$V = (A - B) \quad (4)$$

where, A= weight loss (%), B = Moisture (%), V= Volatile matter in analysis sample, W_O = initial weight (g), W_f = final weight (g) and W_{Cr}= covered crucible weigh (g).

Experiment No.3: Determination of Ash

Ash is the solid residue left after the fuel is completely burnt. The ash content determination was carried out using procedures in ASTM. An empty crucible with a cover was ignited in the muffle furnace at 600°C, and then cooled in a desiccator, the weight was recorded as W_c. then a ground 2g sample of MSW was placed into it and the uncovered crucible was placed in the drying oven at 105°C for 1 hour, thereafter it was removed, and the cover was replaced and cooled in a desiccator, this was repeated until the weight was constant, the weight was recorded as weight of oven-dry sample W_2. With the cover removed, the crucible and contents were placed in the muffle furnace and ignited at the final ignition temperature of 580°C until all the carbon was eliminated. It was removed and the cover was replaced then placed into a desiccator where it was cooled after which it was weighed. The heating was repeated for 30mins periods until the weight after cooling was constant and the weight was recorded as, the weight of the crucible and residue, W_r. Equation 5 was used to analyze the data obtained from the experiment.

$$A\ (\%) = \left[\frac{(W_1)}{(W_2)}\right] \times 100 \quad (5)$$

where: A (%) = Ash, W_1 = weight of ash (g), and W_2 = weight of oven-dry sample (g).

Fixed carbon

The fixed carbon (FC) of the sample was obtained theoretically, using equation 6:

$$FC = 100 - (M\% + VM\% + A\%) \quad (6)$$

where: A (%) = Ash, M% = Moisture, VM % = Volatile matter

III. Results And Analysis

A. MSW Physical Composition

Samples were randomly drawn for 15 days from 332Nos. of waste drums (a list of waste drums is contained in Appendix I), located at designated locations within the study area. A total of 134.66 kg was sorted during the waste collection survey and the detail is contained in Appendix II. The summary of the sorting activity is the MSW categories by percentage presented in Table 1 below.

Table 1: MSW Categories by Weights Percentage

Standard Method of Sampling	ASTM D5231-92		
Sorting Method	Mixing, Coning, and Quartering		
Frequency of Collection	Daily for 1wk & once weekly for two other months		
No. of Samples Collected	105Nos		
Category	Sub-weight (kg)	Weight (kg)	Weight (%)
Paper		31.61	23.48
Food waste		2.76	2.05
Yard waste		40.83	30.32
Textile	6.80		
Pampers	2.72		
Pads	0.19		
Other organics (textiles, sanitary fabrics)		9.71	7.21
Hard Plastics	30.29		
Soft Plastics	3.37		
Plastics		33.66	24.99

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Glass		1.49	1.11
Metals (ferrous and non-ferrous)		0.74	0.55
Other waste (HHH, bones, sand, dirt etc.)		13.87	10.30
Total sample sorted		134.66	100.00

Source: Fieldwork (2019)

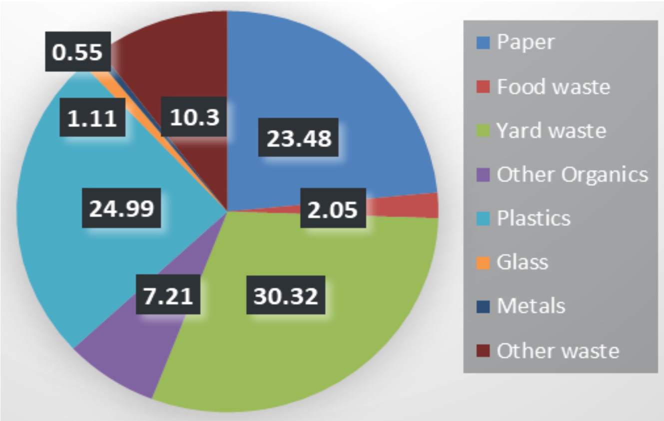

Figure 10: Pie-chart of weight percentage of MSW Component (Source: Field work 2019)

B. *MSW Bulk Density Experimental Data and Analysis*

The bulk density experiment was carried out and the data obtained, and its analysis are presented in tables 2 and 3 below.

Table 2: Data obtained during MSW Bulk Density experiment.

EXPERIMENTS	1	2	3	4	5
Volume of cuboid box (V)	$0.216m^3$				
Weight of the empty wooden box W_1	11.5kg				
Weight of the filled wooden box W_2 (kg)	73.7	75.6	65.5	70.3	63.4

Source: Field work (2019)

Table 3: MSW Bulk Density Analysis

Experiment	Dates	Bulk Density (kg/m^3)
1	29/08/2018	288
2	31/08/2018	297
3	04/09/2018	250
4	13/12/2018	272
5	19/03/2019	240
	Average	270

Source: Field work (2019)

D. *MSW PROXIMATE EXPERIMENTAL DATA AND ANALYSIS*

The above three methods employed for proximate analysis determination resulted in the following data which was analyzed.

Moisture Content Experimental Data and Analysis

The data obtained during the experiment was further utilized to enable the analysis carried out in table 5 below;

Table 4: Data obtained during Moisture Content Experiment

Type	Moisture Can (Wc)	Wet weight (Ww)	Dried weight (Wd)
sample A (g)	32.62	82.62	62.51
sample B (g)	32.58	82.58	62.475
sample C (g)	32.49	82.49	62.28

Source: Field work (2019)

Table 5: Moisture Content Average Value Analysis

Description	(Ww-Wd)	Ww-Wc	M.C (%)
sample A	20.11	50	40.22
sample B	20.105	50	40.21
sample C	20.21	50	40.42
Average Moisture content			40.2833

Source: Field work (2019)

Volatile matter Experimental Data and Analysis

Table 6: Volatile matter average value

Description	weight of covered crucible (g)	initial weight (g)	final weight (g)	**(W_i-W_f)**	**(W_i-W_c)**	Weight loss (%)
sample A	19.92	20.98	20.04	0.94	1.06	88.44
sample B	20.05	21.05	20.18	0.87	1.00	86.45
sample C	19.62	20.62	19.78	0.84	1.00	84.12
			Average weight loss (A)			86.33
		Moisture content (B)		40.28		
Average Volatile matter (A-B)			46.06			

Source: Field work (2019)

Ash content Experimental Data and Analysis

Table 7: Ash content average value

Description	Weight of crucible, WC. (g)	Weight of crucible and dried sample (g)	Weight of crucible and residue (g)	weight of ash (g)	weight of oven-dry sample (g)	A (%)
Sample A	30.6600	31.3456	30.6908	0.0308	0.6856	4.4924
Sample B	30.7800	31.5602	30.8154	0.0354	0.7802	4.5373
Sample C	31.0200	31.9750	31.0632	0.0432	0.9550	4.5236
	Average Ash content					4.5178

Source: Fieldwork (2019)

Fixed carbon

$FC = 100 - (40.28\% + 46.06\% + 4.52\%) = 9.14\%$

IV. DISCUSSION

The result of bulk density of 270 Kg/m^3 obtained correlates with results obtained from previous National waste characterization studies for Lagos, Kano, and Abuja at 294 Kg/m^3, 290 Kg/m^3, and 280 Kg/m^3 respectively as well as an average of 49% moisture content. The component composition analysis indicates that 61 % of the MSW is made up of or derived from organic materials which agrees closely with the result of a similar study done for the whole of Kano Municipal by Nabegu (2012), obtaining a total biodegradable waste of 66%. Furthermore, it concurred with previous findings on MSW in developing economies which indicated that organic content is significantly present in the waste stream (Afuno & Rabiu, 2017; Audu, Aigwi, & Enaboifo, 2015; Ayaa, Mtui, Banadda, & Van, 2014; Bichi & Amatobi, 2013; Ahmad & Jehad, 2012; Iriruaga, 2012; Ogwueleka, 2003; Dauda & Osita, 2003; Agunwamba, 1998; Cointreau, 1982;). It also agrees closely with earlier results of 65% for Kano (Ityona, Nicholas, & Kulla, 2012). However, food waste represents only 2.05% of the total waste.

Table 8: ANOVA Result

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Metals	15.00	2.94	0.20	0.07		
Glass	15.00	5.96	0.40	0.22		
Other Organics	15.00	38.85	2.59	0.52		
Food waste	15.00	11.05	0.74	0.98		
Other waste	15.00	55.46	3.70	1.88		
Paper	15.00	126.45	8.43	4.16		
Plastics	15.00	134.62	8.97	0.63		
Yard waste	15.00	163.30	10.89	40.89		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1951.01	7.00	278.72	45.18	0.00	2.09
Within Groups	690.87	112.00	6.17			
Total	2641.88	119.00				

The result of the study's comparative low food-waste content can be attributed to the current high cost of foodstuff that has made consumers to be non-wasteful. While it could be analyzed that the low food content of the waste discourages its potential for composting, it presents a beneficial attribute of lower CH_4 emissions as well as reducing the formation of HCl in the event of incineration. Plastic materials (hard and soft) constituted 24.99% of the total municipal solid waste generated in the study area. The soft plastic materials are mostly made of PET bottles, cellophane bags, sachet water, and take-away containers. While discarded broken plumbing materials constituted hard plastics etc. This reflects the daily routine of the study's area residents (mostly students) who rely on faster and easier means and modes of item haulage and containment which can be attributed to the non-existence of alternative packaging methods in the community. It also highlights the modest economic purchasing power of the residents, which militates against bulk purchases of household and feeding items. The abundance of "pure" water sachets in the study area reveals the non-existence or lack of a trusted potable public pipe-borne water system. The composition of paper in the waste stream (23.48%) is close to those obtained in similar habitations. Though a significant quantity of paper was observed being informally removed from the waste bin probably for reuse within local artisanal industries (e.g., wrapping of grilled beef popularly known as Suya, roasted corn, beans cake-Akara, etc.), it represents the third most prevalent component in the waste stream. Glass and metal contents in the waste stream is low, 1.11% and 0.50% respectively, revealing the level of replacement plastics components have achieved in our society while low metal content can be attributed to the value of recycled steel in developing economies which made metal waste a priority to waste pickers/scavengers. Table 8 below shows summaries of analysis of variance (ANOVA) used to determine if there exists a statistically significance difference in the means of sample collection among the waste categories per day of collection.

ANOVA results; where Fcrit. (2.09) << F (45.62) and P=0.001 which is less than 0.05, indicates that the null hypothesis can be rejected. The proximate analysis data obtained from the study indicated moisture content of 40.28%, a modest volatile content of 46.06% and a reasonable fixed carbon of 9.14%.

V. CONCLUSION AND RECOMMENDATION

The physical characteristics (composition and bulk density) and proximate analysis of municipal solid waste generated in the study area have been determined. The results obtained agrees with previous research works in the field with an obvious reflection on current economic realities that re-emphasized the prominent features of MSW of being lifestyle dependent among others. The composting of the waste is not encouraged given the low level of food waste in the waste stream rather the option of thermal processing of the waste should be explored. This is given the significant level of biomass in the waste stream in the form of yard waste, whose combustion is carbon neutral. It is recommended that this study should be complimented by a chemical and thermal analysis towards determining the waste combustibility potential. Furthermore, source separation of waste at the point of dumping should be adopted towards better waste management system that can incorporate reuse and recycling strategies.

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APPENDIX I

Table AI. MSW Drums and their Location in the Study Area

S/No.	MSW DRUMS		
1.	Description of Location	No. of Drums	Remarks
2.	Faculty of communication	5	
3.	Senior staff recreation	4	
4.	Along M.M road	10	
5.	Central mosque	4	
6.	Banking zone	8	
7.	Faculty of Law	5	
8.	Centre for Genders Studies	1	
9.	Centre for Dialogue and Interfaith	2	
10.	Centre for Renewables	2	
11.	Academic office	2	
12.	Centre for Qur'anic studies	1	
13.	CDA	2	
14.	Agronomy	2	
15.	Micro finance bank	1	
16.	Old Faculty of Agriculture	5	
17.	FAIS	2	
18.	Business Admin.	2	
19.	Musa Abdullahi Auditorium	2	
20.	Accounting Department	2	
21.	Physical Health Education	3	
22.	Political science	2	
23.	Management science	1	
24.	Social science	1	
25.	Sociology	1	
26.	Centre for Nigerian Languages	2	
27.	Security Division	1	
28.	Faculty of Education	6	
29.	Green shop	2	
30.	Sports Division	1	
31.	Julius Berger	1	

32.	Clinic	3	
33.	Dangote Business School	2	
34.	Ramat and Hasiya Hostels	10	
35.	Gambo Sawaba Hostel	5	
36.	Dangote Hall	10	
37.	Student Centre	2	
38.	Elkanemi and Idris Garba	10	
39.	Saadu Zungur	10	
40.	Yaradua	5	
41.	Staff quarters	184	
42.	V.C Quarter	6	
43.	No. 558b Muhammadu Alhaji Avenue	2	
		332	

Source; Field work (2019)

APPENDIX II

Table AII: MSW Categories and Weights

S/NO	Days	Dates	Metals	Glass	Other Organics	Food waste	Other waste	Paper	Plastics	Yard waste	Daily Total Sorted(kg)
1.	Wednesday	29/8/2018	0.01	0.04	0.34	0.34	0.80	2.87	1.93	5.51	11.85
2.	Thursday	30/8/2018	0.00	0.00	0.83	0.00	0.86	1.26	2.00	5.93	10.87
3.	Friday	31/8/2018	0.00	0.06	0.79	0.00	0.70	2.02	2.38	3.72	9.66
4.	Saturday	1/9/2018	0.09	0.00	0.52	0.09	0.36	1.63	1.91	3.79	8.38
5.	Sunday	2/9/2018	0.00	0.04	0.48	0.00	0.32	1.37	2.34	2.51	7.05
6.	Monday	3/9/2018	0.04	0.00	0.67	0.00	0.92	1.40	2.40	3.49	8.92
7.	Tuesday	4/9/2018	0.00	0.16	0.67	0.14	0.65	1.95	2.45	3.10	9.10
8.	Wednesday	5/12/2018	0.00	0.00	0.65	0.00	0.83	2.40	2.10	2.73	8.71
9.	Thursday	13/12/2018	0.06	0.08	0.32	0.04	0.86	2.46	2.34	2.38	8.53
10.	Friday	21/12/2018	0.08	0.01	0.71	0.00	1.44	2.15	2.49	1.87	8.73
11.	Saturday	29/12/2018	0.00	0.07	0.49	0.00	1.19	2.59	2.19	2.15	8.66
12.	Sunday	3/3/2019	0.20	0.17	0.71	0.49	1.40	1.98	2.40	1.39	8.74
13.	Monday	11/3/2019	0.00	0.25	0.85	0.75	1.13	2.42	2.10	1.16	8.65
14.	Tuesday	19/3/2019	0.17	0.39	0.86	0.45	1.35	2.43	2.19	0.68	8.50
15.	Wednesday	27/3/2019	0.09	0.24	0.85	0.47	1.09	2.71	2.45	0.43	8.33
	Category Total sorted (kg)		0.74	1.49	9.71	2.76	13.87	31.61	33.66	40.83	134.66
	Weight fraction (%w/w)		0.55	1.11	7.21	2.05	10.30	23.48	24.99	30.32	100.00

Source; Field work (2019)