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Determination and Quantification of Household Solid Waste Generation for Planning Suitable Sustainable Waste Management in Nigeria

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ABSTRACT

Determination and quantification of household solid waste generation for planning suitable sustainable waste management in Nigeria is paramount. This will not only help the government and institution to ascertain the volume of household solid waste generated on a daily basis, but it will as well go a long way to put in place a suitable technology for managing household solid waste generated. In this research work, 100 households in Sapele, Nigeria were used. A stratified random sampling method was applied. The household solid waste generated was collected weekly and sorted into food waste, metal waste, glass waste, paper waste, rubber and plastic waste and composition of other waste that comprises of textile, leather, ashes, etc. This was measured with a weighing balance after proper sorting. From the results of the waste survey carried out, a total of 229.53kg of household solid waste was generated per week by 100 households consisting of 334 persons. With the above figure, 0.2953kg (0.0002953tons) of solid waste was generated per household on a daily basis. By percentage composition, food waste has the highest (75%), the composition of food waste consists mainly of food left-over; vegetables, fish and meat waste, fruits, peels (cassava, yam, potato, orange, pawpaw, banana, plantain etc.). The proportion of food waste generated in Sapele, Nigeria can be compost through anaerobic digestion process rather than disposed of that has negative impact on the environment.

Keywords: *Solid waste generation, food waste, waste management, household, solid waste determination and quantification, percentage composition, Nigeria*

INTRODUCTION

Nigeria accounts for nearly half the total population of West Africa and more than 15% of the total population of African. She is ranks number seven in the list of countries by population after China, India, US, Indonesia, Brazil, Pakistan (Table 1). The population density of Nigeria is 205 per Km^2 and the total land area is 910,802km^2. Estimated 48.1 % of the population live in urban (91,668,667) while the rest based in the rural area with farming as their major occupation [1]. Increase in quantity of solid waste generation over a period of time is as a result of population growth, economic development and rate of urbanization of the affected region [2]. This implies that population growth, income level and urbanization are highly correlated. Therefore, as incomes and standard of living increase, consumption of goods and services correspondingly increases, thus, an increase in the amount of solid waste generated [3].

Solid waste is generated in all kind of ways and the volume of waste generation depend on the consumption pattern, industrial and economic structures in place [4]. Countries with fast economic growth rate are also faced with serious challenges in managing their rapidly increasing solid waste generation [5,6]. For example, solid waste generated in China increased 9% annually from 1979 to 1995, a period associated with rapid economic growth and this is expected to double by 2030 [7,8]. Household solid waste generated in Nigeria generally consists of food remnants, plastics, paper, textile, metal, glass and the generation rate is 25 million tons annually at a daily rate of 0.24-0.66 kg/day/person [9,10]. Table 2 shows solid waste generated in some major urban cities in Nigeria. Globally solid waste generation

levels are approximately 1.3 billion tons per year and are expected to increase to approximately 2.2 billion tons per year by 2025. This represents a significant increase in per capital waste generation rates, from 1.2 to 1.42 kg per person per day in the next fifteen years [2]. Solid waste characterization is the process by which the composition of different waste stream is analyzed [12]. Solid waste is not uniform (i.e. heterogeneous) in composition, for that reason is not expected to be consistent in composition [8, 13, 14].

Hoornweg, et al. [2] defined waste as any unwanted material intentionally thrown away. Waste is left over or already used items waiting for reuse or disposal [14]. Waste management is a major problem across the globe but more pronounce in developing country like Nigeria due to poor implementation of standards and policies [15]. Waste management means all waste activities that is require to manage waste [16]. It includes; waste collection, waste transportation, waste monitoring, waste processing and disposal [17].

Fisher et al. [17] defined waste management as the collection, transportation, recovery, recycling and disposal of waste, as well as the supervision of such operations and the after care of disposal sites including actions taken as a dealer or broker. The first phase in waste management is to properly understand the type of waste generated and this will aid the design of appropriate collection and disposal strategies.

Solid waste problem started in Nigeria with the rapid increase in urban growth resulting partly from the increase in population status [14]. There is no town in Nigeria being rural or urban that can boast of finding a lasting solution to the problem of filth and huge piles of solid waste [6]. In Nigeria, solid waste is dump indiscriminately and this had led to blockage of drainage system, thus causing environmental pollution [18]. The commonly practiced waste management option in Nigeria involves the collection of mixed waste materials and subsequent dumping at designated dumpsites [19]. To average Nigerians both in urban and rural dwellers, public hygiene starts and ends in their immediate surrounding and indeed the city would take care of itself. The situation has so deteriorated that today the menace of solid waste has become one of the nation's most serious environmental problem [11]. Nevertheless, primary processing technologies and the ability to process different biomolecules is shown in Table3.

The appropriate conversion technology for a biomass is influenced by factors such as type, quantity of biomass and the desired form of energy [11]. Also, the biomass conversion efficiency depends on the use, material, size and shape of the particles, gas flow and types of reactors [20]. The biomass conversion technology is fitted to biomass type to achieve optimum outcome. Considering the hazard of solid waste generation in Nigeria, lack of sustainable solid waste management practice, it became necessary to determine the quantity and percentage composition of household solid waste generated. The results obtained from this research work, can be used to determine the best waste management option for household solid waste generated in Sample, Nigeria.

Table1. *World population by country [1]*

	Population 2016	Density (kg/m^3)	Area Km^2	Medium Age	Urban Population (%)	World Share
China	1,382,323,332	147	9,390,784	37	57.9	18.6
India	1,326,801,576	446	2,972,892	27	32.4	17.9
US	324,118,787	35	9,155,898	38	82.7	4.4
Indonesia	260,581,100	144	1,812,108	28	54	3.5
Brazil	209,567,920	25	8,349,320	31	84.2	2.8
Pakistan	192,826,502	250	770,998	23	38.9	2.6
Nigeria	186,987,563	205	910,802	18	49	2.5
Bangladesh	162,910,864	1,252	130,172	26	34.9	2.2
Russia	143,439,832	9	16,299,981	39	73.2	1.9
Mexico	128,632,004	66	1,943,082	27	78.3	1.7

Table2. *Solid waste generation in some major urban cities in Nigeria [10, 11]*

City	Population	Agency	Tonnage per Month	Density (kg/m^3)	kg per capital per day
Benin	1,085,676	-	-	-	0.43
Lagos	8,029,200	Lagos state management authority	255,556	294	0.63
Kano	3,348,700	Kano state environmental protection agency	156,676	290	0.56
Ibadan	307,840	Oyo state environmental protection commission	135,391	330	0.51
Kaduna	1,458,900	Kaduna state environmental protection agency	114,443	320	0.58
Port Harcourt	1,053,900	Rivers state environmental protection agency	117,825	300	0.60
Makurdi	249,00	Urban development board	24,242	340	0.48
Onitsha	509,500	Anambra state environmental protection agency	84,137	310	0.53
Nsukka	100,700	Enugu state environmental protection agency	12,000	370	0.44
Abuja	159,900	Abuja state environmental protection agency	14,785	280	0.66

Table3. *Primary processing technologies and the ability to process different biomolecules [11].*

Conversion technology	Biomass resources			
	Fats and Oils	Proteins	Sugar and starch	Lignocelluloses
Direct combustion	*			*
AD	*	*	*	Cellulose only
Fermentation	*	*	*	Cellulose only
Vegetable oil transesterification	*			
Pyrolysis	*	*	*	*
Gasification	*	*	*	*

MATERIALS AND METHOD

The materials used in this research work includes; a weighing balance, hand gloves, nose mask and black polyethylene bag labeled in the following order; food waste (FW), plastic and rubber waste (PRW), glass waste (GW), paper waste (PW), metal waste (MW) and other waste (OW). A black polyethylene bag was used for the purpose of collection of generated household solid waste.

Figure 1 shows the summary of the stages and processes carried out in determination and quantification of household solid waste in Sapele, Nigeria. The household solid waste was collected randomly from different households. The number of member of family of household used was recorded after initial visitation. After weekly collection of solid waste generated by each household, the solid waste was sorted and each component weighed and recorded (Figure 2). Sapele, Nigeria was used as a case study in this research work.

Sapele is like other fast growing urbanizing towns and cities in Nigeria with a population size of 142,652 and is faces with a solid waste management problem. In each of the survey carried out with 100 households and a total number of 334 persons; a stratified random sampling (SRS) method was applied. SRS method is a sampling method base on population determination and characterization.

Stratification simply means the process of dividing members of the population into identical subgroups before sampling and in so doing, every member or element in the population is assigned to only one stratum [21] as shown in Figure 3.

The grouping continue until the required numbers is achieved. In this case, hundred (100) households were used. The generated solid waste was collected after a period of 7day (one week) and the quantity of household solid generated was measured after sorting with a weighing balance.

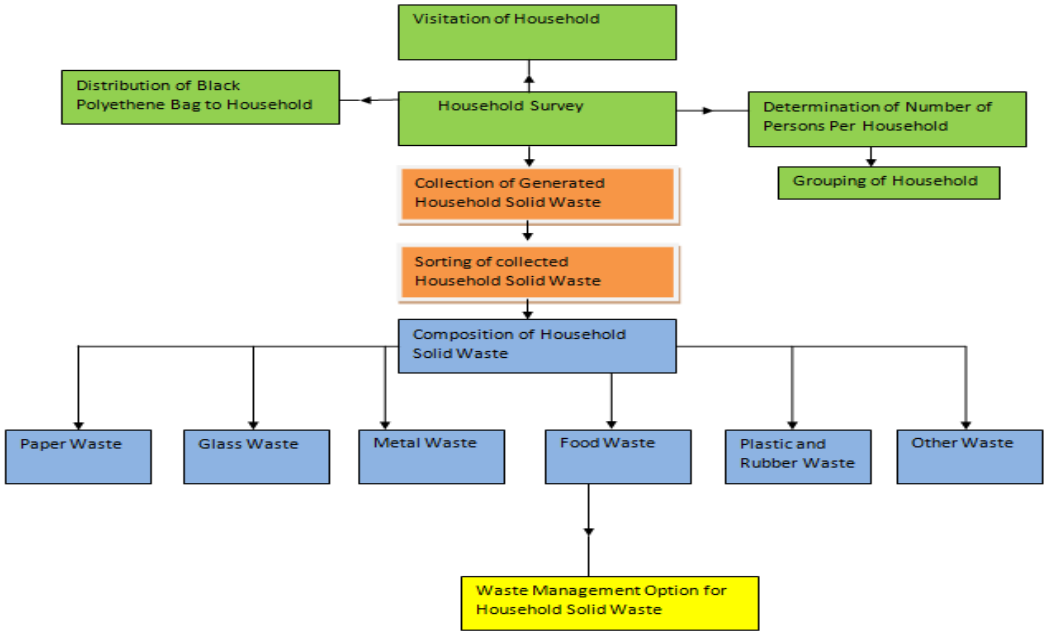

Figure1. *Summary of the process*

Figure2. *Sorted household solid waste*

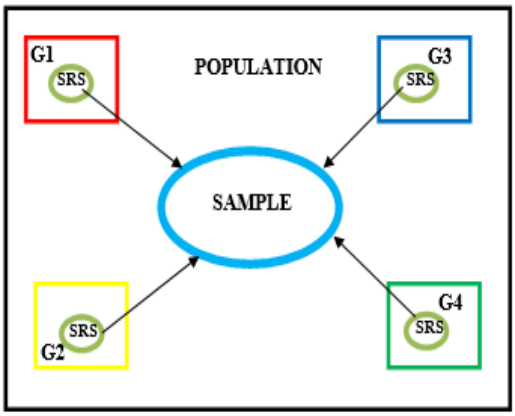

Figure3. *Stratified random sampling [21]*

where,

G1 = Group 1 = First Household, G2 = Group 2 = Second Household, G3 = Group 3 = Third Household, G4 = Group 4 = Fourth Household.

RESULTS AND DISCUSSION

Table 4 shows the results obtained from average weekly household solid waste generation in Sapele, Nigeria. Table 5 and Table 6 summarized the average quantity of solid waste generated per household per day (100 households) and per person per day respectively (334 persons).

The components of solid waste generated include food remnants, plastic and rubber, paper, wood, carbon, leather, textile material,

glasses, ferrous metals, metal cans and ceramics. From the results of the waste survey carried out, a total of 229.53kg of household solid waste was generated per week by 100 households consisting of 334 persons. With the above figure, 0.2953kg (0.0002953tons) of solid waste was generated per household on a daily basis.

Considering the population of Sapele (142,652) as estimated by Nigeria Population Commission (2006) [26], an estimated average total of 98,030kg (98tonnes) of household solid waste will be generated per day in Sapele, Nigeria. If same statistic is to be applied to Nigeria with an estimated population of 186,987,563, then, 128,497,853.3kg (128,498tonnes) of solid waste will be generated on a daily basis. By percentage composition, food waste has the highest (75%), the composition of food waste consists mainly of food left-over, vegetables, fish and meat waste, fruits, peels (cassava, yam, potato, orange, pawpaw, banana, plantain etc.). Correspondingly, the finding from this research work agreed with the work of Igbinomwanhia et al. [9] that reported seventy-eight (78%) percentage composition of food waste in Benin metropolis, Owamah, et al. [14], Eisa and Visvanathan [25], that reported percentage composition of 77% and 87% of food waste for municipal solid waste characterization in Nigeria. In all reported cases, food waste has the highest percentage composition which is more than fifty percent (50%) of total solid waste generated daily in Nigeria.

Considering the huge percentage composition of food waste recorded from this waste survey, a combined solid waste management system consisting of recovery, recycling, composting via anaerobic digestion process with energy recovery processes is the best option for household solid waste management in Sapele, Nigeria. Thus, there is the need for construction of anaerobic digester (AD) plant across Nigeria town and cities as a means of food waste management. Research had proven that AD process which is a green energy technology can be used to process food waste to energy, and organic fertilizer [22,23,24].

Table4. *Composition of Household Solid Waste Generated in Sapele, Nigeria*

S/N	NFM	PRW	PW	FW	GW	MW	OW
1	3	0.180	0.096	1.017	0.069	0.063	0.025
2	2	0.241	0.165	2.005	0.140	0.067	0.037
	3	0.257	0.204	2.341	0.126	0.078	0.043
4	4	0.228	0.142	1.600	0.088	0.052	0.029
5	3	0.295	0.145	1.630	0.102	0.080	0.033
6	4	0.204	0.112	1.340	0.096	0.064	0.037
7	2	0.245	0.135	1.675	0.025	0.078	0.029
8	4	0.209	0.144	1.348	0.004	0.059	0.034
9	2	0.189	0.180	1.705	0.092	0.085	0.021
10	4	0.144	0.108	1.568	0.107	0.066	0.053
11	3	0.249	0.140	1.500	0.132	0.091	0.103
12	3	0.219	0.112	1.244	0.076	0.061	0.029
13	3	0.281	0.145	1.605	0.092	0.073	0.069
14	4	0.295	0.140	1.284	0.096	0.062	0.046
15	6	0.207	0.170	2.532	0.035	0,053	0.054
16	3	0.168	0.132	1.912	0.064	0.081	0.057
17	5	0.249	0.160	1.270	0.093	0.095	0.063
18	4	0.276	0.129	1.180	0.106	0.073	0.027
19	2	0.313	0.166	2.495	0.081	0.067	0.047
20	3	0.177	0.103	0.867	0.072	0.053	0.029
21	4	0.268	0.137	1.256	0.104	0.073	0.026
22	2	0.245	0.176	1.570	0.110	0.077	0.071
23	4	0.214	0.117	1.156	0.082	0.053	0.081
24	3	0.171	0.085	0.897	0.073	0.062	0.019
25	4	0.236	0.109	1.196	0.065	0.083	0.049
26	3	0.295	0.181	1.475	0.115	0.095	0.065
27	4	0.241	0.118	1.016	0.084	0.062	0.071
28	3	0.275	0.151	1.490	0.112	0.085	0.063
29	4	0.192	0.115	0.912	0.081	0.064	0.023
30	3	0.243	0.177	1.530	0.121	0.077	0.041
31	3	0.129	0.109	1.963	0.072	0.061	0.037

32	4	0.219	0.163	2.605	0.031	0.085	0.057
33	4	0.228	0.132	1.200	0.076	0.067	0.087
34	3	0.295	0.171	2.960	0.097	0.054	0.032
35	3	0.183	0.106	1.023	0.054	0.067	0.025
36	2	0.119	0.058	0.674	0.035	0.036	0.010
37	2	0.096	0.099	0.670	0.056	0.032	0.018
38	3	0.219	0.120	2.630	0.115	0.076	0.039
39	4	0.198	0.100	1.600	0.084	0.058	0.037
40	3	0.294	0.156	2.341	0.082	0.052	0.053
41	3	0.177	0.096	2.171	0.062	0.049	0.047
42	4	0.293	0.162	2.005	0.021	0.039	0.101
43	3	0.312	0.165	1.695	0.123	0.023	0.067
44	4	0.241	0.136	1.356	0.004	0.009	0.033
45	2	0.219	0.180	1.604	0.009	0.046	0.023
46	3	0.245	0.182	1.951	0.097	0.069	0.041
47	4	0.172	0.108	1.561	0.016	0.068	0.061
48	4	0.191	0.119	2.610	0.093	0.065	0.036
49	3	0.144	0.072	0.976	0.067	0.059	0.023
50	5	0.269	0.125	1.675	0.118	0.037	0.035
51	4	0.237	0.104	1.348	0.106	0.072	0.034
52	3	0.261	0.181	1.705	0.084	0.067	0.041
53	3	0.307	0.162	2.352	0.118	0.076	0.062
54	4	0.232	0.141	1.200	0.064	0.079	0.046
55	3	0.287	0.175	2.555	0.099	0.047	0.071
56	3	0.332	0.198	3.926	0.113	0.059	0.063
57	4	0.234	0.144	1.284	0.003	0.054	0.032
58	4	0.249	0.125	2.530	0.075	0.048	0.043
59	3	0.136	0.072	0.456	0.048	0.021	0.007
60	4	0.187	0.128	1.192	0.084	0.063	0.033
61	2	0.345	0.121	1.270	0.118	0.046	0.064
62	3	0.171	0.099	0.894	0.082	0.067	0.032
63	3	0.312	0.172	3.495	0.132	0.028	0.007
64	4	0.172	0.128	1.356	0.098	0.037	0.043
65	3	0.287	0.161	2.015	0.085	0.003	0.051
66	4	0.325	0.165	1.961	0.125	0.008	0.034
67	3	0.236	0.128	1.403	0.006	0.027	0.021
68	3	0.196	0.148	1.308	0.096	0.067	0.033
69	3	0.277	0.106	2.576	0.120	0.039	0.042
70	4	0.241	0.107	2.157	0.099	0.033	0.062
71	3	0.255	0.201	1.447	0.091	0.045	0.053
72	4	0.235	0.132	1.192	0.076	0.012	0.031
73	5	0.313	0.165	2.295	0.075	0.035	0.049
74	2	0.087	0.072	0.628	0.052	0.036	0.035
75	4	0.141	0.190	1.017	0.063	0.045	0.043
76	3	0.159	0.099	1.047	0.075	0.067	0.019
77	6	0.342	0.187	3.409	0.032	0.052	0.053
78	2	0.305	0.169	3.952	0.106	0.079	0.071
79	5	0.099	0.212	1.645	0.095	0.067	0.108
80	4	0.101	0.055	0.622	0.047	0.056	0.221
81	3	0.189	0.132	2.605	0.076	0.067	0.046
82	4	0.196	0.128	1.193	0.097	0.028	0.035
83	4	0.252	0.132	1.244	0.083	0.063	0.043
84	2	0.138	0.068	0.784	0.056	0.033	0.053
85	4	0.267	0.104	2.340	0.089	0.067	0.028
86	5	0.279	0.145	2.634	0.051	0.073	0.045
87	2	0.312	0.175	1.645	0.070	0.034	0.041
88	3	0.245	0.166	1.953	0.079	0.082	0.035
89	3	0.295	0.187	2.567	0.073	0.076	0.105
90	6	0.342	0.192	3.836	0.071	0.064	0.078
91	3	0.179	0.109	0.987	0.063	0.003	0.032
92	2	0.279	0.111	1.568	0.089	0.045	0.047
93	2	0.249	0.165	1.605	0.059	0.078	0.097
94	3	0.294	0.222	2.046	0.101	0.089	0.127
95	3	0.355	0.167	3.172	0.121	0.082	0.073
96	2	0.221	0.197	2.184	0.079	0.056	0.023

97	4	0.249	0.189	2.495	0.099	0.067	0.076
98	2	0.423	0.298	3.675	0.133	0.073	0.063
99	2	0.354	0.204	3.067	0.114	0.053	0.057
100	3	0.227	0.165	2.089	0.104	0.055	0.067
∑	334	23.496	14.569	172.652	8.081	5.796	4.932
SWG_{PHH}		0.2350	0.1457	1.7265	0.0808	0.0580	0.0493
SWG_{PP}		0.0703	0.0436	0.5169	0.0242	0.0174	0.0148

*SWG_{PHH}- Solid Waste Generated per household, *SWG_{PP}- Solid Waste Generated per person, *NFM- Number of family member, *FW-Food Waste, *PRW-Plastic and Rubber Waste, *GW-Glass Waste, *PW-Paper Waste, *MW-Metal Waste, *OW-Other Waste

Table5. *Average percentage composition of solid waste generated per household*

Solid Waste Component	SWG_{PHH} (kg)	Percentage Composition (%)
Food Waste (FW)	1.7265	75.219
Plastic and Rubber Waste (PRW)	0.2350	10.238
Paper Waste (PW)	0.1457	6.348
Glass Waste (GW)	0.0808	3.520
Metal Waste (MW)	0.0580	2.527
Other Waste (OW)	0.0493	2.148
Total	2.2953	100

Table6. *Average percentage composition of solid waste generated per person per day*

Solid Waste Component	SWG_{PPd} (kg)	Percentage Composition (%)
Food Waste (FW)	0.5169	75.218
Plastic and Rubber Waste (PRW)	0.0703	10.230
Paper Waste (PW)	0.0436	6.345
Glass Waste (GW)	0.0242	3.521
Metal Waste (MW)	0.0174	2.532
Other Waste (OW)	0.0148	2.154
Total	0.6872	100

Figure 4 shows the chart of average percentage composition of solid waste generated per person per day. Apart from food waste with approximately percentage composition of 75%, plastic and rubber waste has percentage composition of 10%, paper waste (6%), metal waste (3%), glass waste (4%) and other waste (2%). Table 7 shows the composition of household solid waste in this survey.

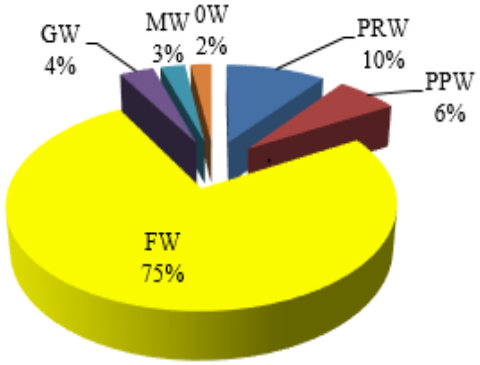

Figure4. *Average percentage composition of household solid waste generated per person per day*

Table7. *Composition of household solid waste*

Categories	Sub-Categories
Food waste	Food remnants, fish and meat waste, vegetables, peels, fruits
Plastics and Rubbers	Plastic bottles, packaging materials
Papers Waste	Office papers, Magazines and Newspaper, Envelopes, Cardboard
Glass Waste	Glass, bottles, breakable plates and cups, jars
Metals Waste	Ferrous metals, Aluminum items, , Cans, Bottle caps
Other Waste	Wood, Stone, Belt, Shoes, Batteries, Electrical and Electronic equipment, Clothes, Ash, Dust

CONCLUSION

Nigeria has poor waste management policy. Household solid waste generated from Nigerian homes are discharged into street, market, gutter, road side, adjoining streams etc. due to poor implementation of standards, thus causing environmental and public health hazards. The results obtained from this waste survey shown that food waste has the highest percentage composition of household solid waste generated. Apart from food waste with approximately percentage composition of 75%, plastic and rubber waste has percentage composition of 10%, paper waste (6%), metal waste (3%), glass waste (4%) and other waste (2%). The proportion of food waste generated in Sapele (75%), Nigeria can be compost through AD process rather than disposed of that has negative impact on the environment. These options, if fully exploited would greatly reduce the quantity of solid waste disposed and also solve part of Nigeria energy crisis.

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