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CHARACTERIZATION, DISPOSAL AND MANAGEMENT OPTIONS OF MUNICIPAL SOLID WASTE IN UNIVERSITY OF BENIN, BENIN CITY, NIGERIA

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ABSTRACT

This study assessed the amount of municipal solid waste generated in the University of Benin, Benin City, Nigeria. Direct waste analysis and a site-specific study were carried out to collect waste characterization data and determine the overall quantity of waste generated and components of the municipal solid waste in the campus. To help obtain the data for the study on a regional basis, areas were selected from residential, commercial and institutional centres to determine the total weekly generation of waste, average daily generation rate of waste and composition of waste. Results obtained revealed that average daily waste generation rate in the University of Benin was 0.455 kg/person/day which translates to 25,643.8 kg of municipal solid waste per day (per the estimated current population of over 56,360) generated in the University of Benin, from daily residential, commercial and institutional activities. Furthermore, characterization analysis of the collected waste samples showed that the municipal solid waste generated composed of 30.22% organic waste, 26.67% plastics/rubber waste, 18.65% paper, 11.08% metals, 3.70% miscellaneous, 3.10% inert, 2.39% glass/ceramics, 2.18% textile, 1.03% electronics and 0.98% leather waste. The results obtained suggests that there is a high potential for recycling, composting, biogas production and waste to energy in the University of Benin.

1. INTRODUCTION

Solid waste refers to undesired remains, residues, discarded items or by-products that are no longer needed for the initial use. Municipal solid waste (MSW) comprises vegetable and market waste, glass,

paper, plastic and other organic fractions and inert matter from various sources such as residential, commercial, and institutional areas (USEPA, 2006).
One of the major challenges confronting environmental management is MSW, generated from different activities in townships and cities. Industrialization, urbanization and modernization have contributed immensely to the increasing rate of MSW generation and disposal in many regions of the world; hence, proper waste management is a major interest in most cities, especially in developing nations of the globe (Zhen-Shan *et al.,* 2009). Actually, the population growth coupled with an accelerated exploitation of the resources and the intensification of the human activities are several factors which explain the increase of the production of waste (Yemadje *et al.,* 2013).. Solid waste materials block drainage systems, causing overflows during rainy seasons, especially in cities and towns. According to Foul *et al.* (2009), dumped solid wastes have potentials to bring about a huge amount of polluted leachate containing much concentration of harmful compounds which lead to severe destruction of the ecosystem.

Information pertaining to the composition of solid waste provides critical data for the development of waste management plans (Tchobanoglous *et al.*, 2002). Waste minimization can only be carried out efficiently and effectively with accurate waste composition data (Idris *et al.,* 2004). Adequate waste composition data is needed to ascertain the impacts of certain types of waste and to determine the life of a landfill. Waste composition varies from time to time and from place to place, depending on seasons or weather conditions (Idris *et al.,* 2004). According to Gawaikar and Deshpande (2006), characterization of MSW assists in evaluation of the amount of waste generated in a particular region or area at a particular period of the year. Also, solid waste characterization is vital to ascertain its possible environmental impacts on nature as well as on the society at large (Alagmir and Ahsan 2007). It is a subject of deep interest for proper management of MSW because its improper management is a major cause of water, air and soil pollution (Asmelash and Mohammed, 2014). Leachate from municipalities' landfills presents a potential health risk to both surrounding ecosystems and human populations (Salem *et al.,*2008). According to Bartelings and Sterner (1999), the management of solid waste from households is important for two reasons: landfill space is becoming a scarce resource in many countries and that ecological damage from hazardous components even in the efficiently collected waste by the municipality will not automatically alleviate the concern about the spread of hazardous waste into the environment.

Thus, the present study was undertaken to assess the amount of MSW generated in the University of Benin, Benin City, Nigeria, characterize them and suggest appropriate management techniques for them.

2. METHODOLOGY

2.1. Study area

The study was conducted in University of Benin Edo state, Nigeria. University of Benin is located at 6^o 20'N of the equator and longitude $5^0$36'E and covers a total land area of approximately 1032 hectares of land. University of Benin is located in Ovia North-East local government area of Edo state, Nigeria. During the last 6 years, University of Benin witnessed a tremendous growth in population. From a student population of 40,000 in 2010, it grew up to 56,360 in 2017.

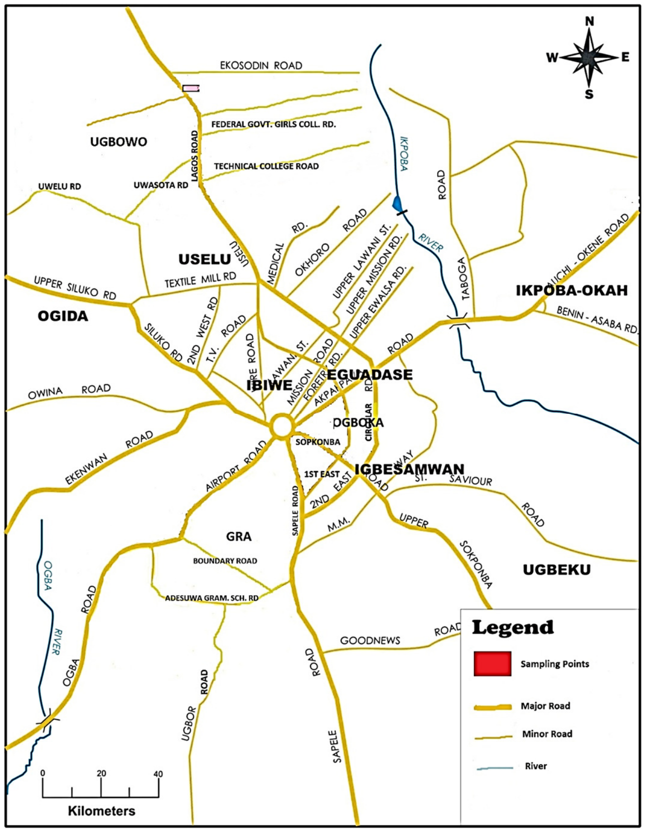

Figure 1: Map of Benin City showing the study area (University of Benin)

2.2. Waste Collection Methods

Wastes were collected by assessing communal waste collection bins at central collection points, household dust bins and open waste dumping sites in the municipality. Waste compositions and quantities were estimated by direct waste analysis method at selected waste sample source generators. An extensive field investigation was used for quantification and analysis of MSW in the selected regions. Information collected were in weight of MSW generated in a day, the composition of MSW, types of waste containers, disposal, segregation of MSW data, relevant to the study. At the dump sites, weighing, separation of waste into different categories and measurement of each category were made and recorded. Also, waste arising was estimated from each waste source. Waste generation was measured at source generator with weighing scales.

2.3. Determination of the Generation of MSW

Statistical methods were used to estimate total waste quantities from various waste sample generators. The statistical approach involved determining the number, sizes and volumes of solid collection systems. The calculation done here was: estimation of waste arising by arithmetic average of the data/sample mean. Statistical data on the quantification of waste were by weight analysis of the composition based on the source of the waste. Here, representative samples were used. This approach was suggested by Endalu and Tekilu (2014) and is given below.

$$\bar{x} = \frac{\sum x_i}{n} \quad (1)$$

$$T(MSW)_i = N_j \bar{x} \quad (2)$$

Where:
$\bar{x}$= samples mean (kg/generator/day)
x_i= amount of waste generated, in type, from each generator
n = number of samples (generator) taken
i = waste type
$T(MSW)_i$ = total "i" MSW generated from each site
j= generator
N_j= total number of "j" generator

2.4. Direct Weight Measurement Approach

This involved direct weight analysis methods and allows for high accuracy as it clearly indicates the source and area of waste and the number of generators (Ansah, 2014). Here, the percentage compositions of each of the component was calculated using Equation 3, as reported by Miezah *et al.* (2015):

$$Percentage\ composition\ of\ waste\ fraction = \frac{weight\ of\ separated\ waste}{Total\ of\ mixed\ waste\ sampled} \times 100 \quad (3)$$

The per capital generation was also determined as per the mixed or the total waste collected in a day and also the separated fractions, using the following formula, as given by Miezah *et al.* (2015):

$$Per\ capita\ waste\ generation = \frac{weight\ of\ MSW\ generated\ at\ household}{\begin{pmatrix} total\ number\ of\ persons \\ in\ the\ region/residence \end{pmatrix} \times \begin{pmatrix} total\ number\ of \\ generation\ days \end{pmatrix}} \quad (4)$$

2.5. Sampled Areas and Sampling Techniques Used

The criteria used to establish the zoning of areas for this study were based on occupation, population, consumer and social behaviour, income earned monthly and sewage infrastructure as given by Miezah *et al.* (2015) and Napoleon *et al.* (2011). In each of the residential areas and regions for the study, from the criteria stated above, three socioeconomic areas (high, middle and low-income earners) could be identified. A site-specific study was carried out as suggested by Igbinomwanhia (2012) and Ansah (2014). The site-specific study involved the following steps– selecting representative samples from specific areas, sample collection and analysis (sorting and weighing) of the individual components of the waste stream and obtaining primary information such as number of households and commercial centres, population size, etc. A multi-stage stratified random sampling method was applied for the sampling process. Six areas from commercial centres; nine from institutional areas (solely faculties) and eight residences, which constituted the majority of the total school's population, were sampled. Wastes generated in these areas were collected once a day every morning for seven successive days. The door-to-door waste collection was done only in two residences: the senior staff quarters (SSQ) and junior staff quarters (JSQ). A total of 10 households each from these two areas were sampled because the trends in waste generation were quite similar, and 140 sampling units were selected from these areas. Communal waste collection from open dump sites and central waste bins were done in the other sampled areas. Cumulatively, in all the sampled areas, 287 sampling units were used. The collected wastes were weighed on a wet basis and weights recorded in the data sheet according to the numbers assigned to the areas. Total weight of all the samples generated was then estimated and average daily generation rate in the sampled areas was also calculated, based on the population of persons in the sampled areas. A representative weight of samples generated was taken, weighed sorted into different waste categories and the average composition of the waste (in wt %) was calculated and the average total of waste generated per day in the university was estimated, using the estimated population of the school. The plastic bags from those collected in each sample area were opened onto the plastic sheet and a representation was separated into different types. The separated wastes were placed into different buckets and weighed. Each category of the separated wastes was weighed and recorded.

2.6. MSW Characterization Method

The characterization method used in this study was direct sampling analysis of solid waste from specific sources, a labour–intensive manual process of sorting, classifying and weighing all items in each sampling unit and a detailed recording of the data, as suggested by Ansah (2014). This method is also known as the site-specific study. Each of the waste sampled from the source of generation was then sorted. The collected wastes were lumped together and mixed thoroughly and representative samples were taken to comprise the composite sample. The total weight of each waste category was determined and expressed in kg and the percentage of each constituent was calculated. The whole process of sorting and weighing was carried out seven times a week for one week.

3. RESULTS AND DISCUSSION

3.1. MSW Composition

The MSW data collected in the study area were analyzed and the results from the analyses are shown in Figure 2.

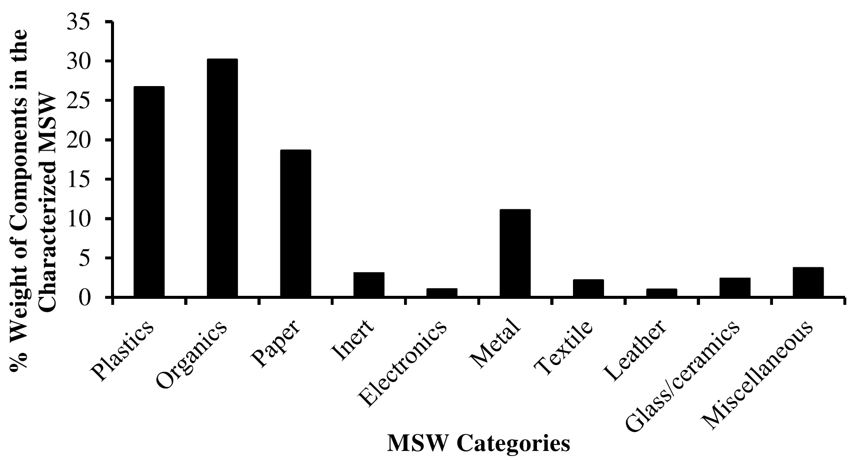

Figure 2: Percentage (wt %) Distribution of MSW Composition generated in the University of Benin.

A total sample load of 12244.37 kg was weighed, out of which an average of 30.22% of organics, 26.61% plastics, 18.65% paper, 3.10% inert, 1.03% electronics, 11.08% metal, 2.18% textile, 0.98% leather, 2.39% glass/ceramics, 3.70% miscellaneous was observed.

Out of the waste stream weighed and characterized, 4086.31 kg was organic, textile and leather wastes and therefore, belong to the energy recovery category, 7325.00 kg to the recyclable category (paper, plastics/rubber, metals, glass/ceramics, electronics), and 833.66 kg to the non-recyclables (inert, miscellaneous).

3.2. MSW Management Potentials

Table 1 provides details of composition of the sampled MSW and categorizes components of the waste according to suitable waste management technique.

Table 1: Composition of characterized MSW stream according to suitable waste management technique

Categories of MSW	Commercial centres (kg)	Institutional areas (kg)	Residential areas (kg)	Total MSW Weight (kg)	Percentage composition (% weight)
Energy recovery category					
Organics	334.65	262.65	3102.05	3699.35	30.22
Textiles	21.02	26.27	219.66	266.95	2.18
Leather	12.49	8.81	98.71	120.01	0.98
Sub Total	368.16	297.73	3420.42	4086.31	33.38
Recyclables category					
Paper	170.66	229.24	1883.75	2283.65	18.65
Plastic/Rubber	258.35	321.39	2686.11	3265.85	26.67
Metals	107.33	143.94	1105.52	1356.79	11.08
Glass/Ceramics	29.8	22.15	240.63	292.58	2.39
Electronics	9.91	12.78	103.44	126.13	1.03
Sub Total	576.05	729.5	6019.45	7325	59.82
Non-recyclables category					
Inert	29.6	36.22	314.24	380.06	3.1
Miscellaneous	46.02	24.27	382.71	453	3.7
Sub total	75.62	60.47	696.95	833.06	6.8
Total Characterized MSW	1019.83	1087.72	10136.82	12244.37	100

The entries in Table 1 are weights of randomly sampled waste in each category and their corresponding percentages. From the 4086.31 kg of the energy recovery wastes, organic waste formed 3420.42 kg which involved organic waste from which food waste was majority of the organic MSW stream. This potential source of energy in the municipality is not separated for later reuse; therefore, the waste is disposed of as a wasted energy resource. Characterization of the waste helped identify the waste fraction which could be targeted for the purpose of recycling. The major fractions were organics, plastics/rubber, papers, metals, miscellaneous, inert, glass/ceramics, textile, electronics and leather. The results obtained from the waste characterization compared well with those obtained by Igbinomwanhia (2012), who conducted waste characterization in Benin metropolis except for the fact that University of Benin generates lesser organic waste and more plastics, papers and metals. The high organic waste in the waste stream in University of Benin could be due to her dependence on agricultural products. Food waste formed the major sub-fraction of the organic waste analyzed followed by yard waste. Plastic waste was the second largest fraction in terms of weight. The plastics in the waste stream were mainly PET (Polyethylene Terephthalate), LDPE (Low density polyethylene), HDPE (high density polyethylene) and PS (polystyrene). The percentage of plastic, paper and metal combined together were quite high because of the business activities in the University of Benin, which involves the sale of items packaged with plastic and paper material and the use of articles packaged with paper, plastic and metal materials for services. The existence of the production and consumption of table water, bottled soft drinks and other materials packaged in plastics in Nigeria, has brought with it, the problem of how to contain the sudden rise in the polyethylene sachets that are discarded daily. Thus, polyethylene sachets have increased the volume of various waste plastic products requiring attention. There is a high dependence on water packaged in plastic bottles and plastic sachet for drinking water and the use of plastic bags and other plastic items for carrying provisions and food items purchased from the market. Also, the food waste content of residential waste was very high because of the heavy dependence on home prepared meals. When this trend is compared to the food waste found in USA of about 12.7% (USEPA, 2009), the cultural difference stands out as shown elsewhere (Zavodska, 2003). The biodegradables (organics) recorded in this study was 30.22% and could serve as a guide for bioconversion programmes such as biofuel production and composting. Out of the total waste stream characterized, 59.88% is potentially recyclable with financial and environmental benefits, and 33.88% of the waste stream could be reused to generate energy (i.e., energy recovery category).

3.3. Daily Per Capita Generation

Figure 3 shows the average MSW generated in each municipality sampled. It is seen from Figure 3, that the socio-economic class with highest population generated the highest waste by weight while the faculties generated the least waste. Halls of residence which were classified as low income earners residential area in the municipality with estimated total population of 12,577 and total waste generation of 37,310.08 kg from 6 residences. The waste generation rate for this low income area was 0.424 kg/person/day. JSQ (Junior Staff Quarters) and commercial centres were classified as middle income earners area. JSQ sampled areas had household size of 62, while commercial centres, 817. The sample loads were 258.73 kg and 3176.72 kg respectively from each area. The waste generation from JSQ was 0.596 kg/person/day and from commercial centres was 0.555 kg/person/day. SSQ (Senior Staff Quarters) was classified as a high income earners with a generation rate of 0.681 kg/person/day. It had a sampled total house size of 50 and waste generation of 238.25 kg.

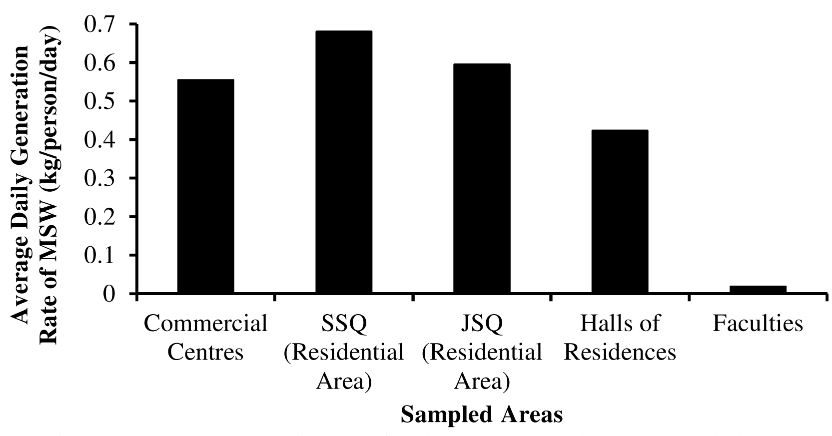

Figure 3: MSW generated per capita (kg/person/day) in each sampled areas

Average household size of SSQ was 5.0, JSQ was 6.2 and Commercial centres were 3.29. Institutional areas generated least MSW per day because waste was not generated much in all these institutional areas in all days (especially weekends) and in these areas, there are no residences; students and staff come to the faculties for academic purposes, after which they go back to their respective residences. In addition, the waste generated composed mainly of paper and plastics which don't weigh much compared to organic waste. From Figure 3, we can see that the socio-economic class with highest population generated the highest waste by weight, which clearly shows that increase in population of an area causes an increase in waste generation in that community. An average generation rate of 0.455 kg/person/day estimated in this study for the University of Benin is in line with findings in previous studies (UNEP, 2013; Friedrich and Trois 2011) that range of most cities in sub-Saharan Africa, irrespective of socio-economic status, is 0.2- 0.8 kg/person/day. The observation in the daily waste generation rate in high, middle and low income earning areas as seen in the results for this study is attributed to the fact that there is little or no reuse of used materials at the high income residential areas whereas, there is reuse at low income residential areas, thereby, extending the useful life of the used product. Due to the fact that in some areas of this study, there were some high income earners residing in low class areas and these amongst other factors contributed to the fact that no much correlation was found between income and waste generation, it was more convenient to sample areas based on municipality type (residential area, commercial area, institutional area) as given in Figure 4.

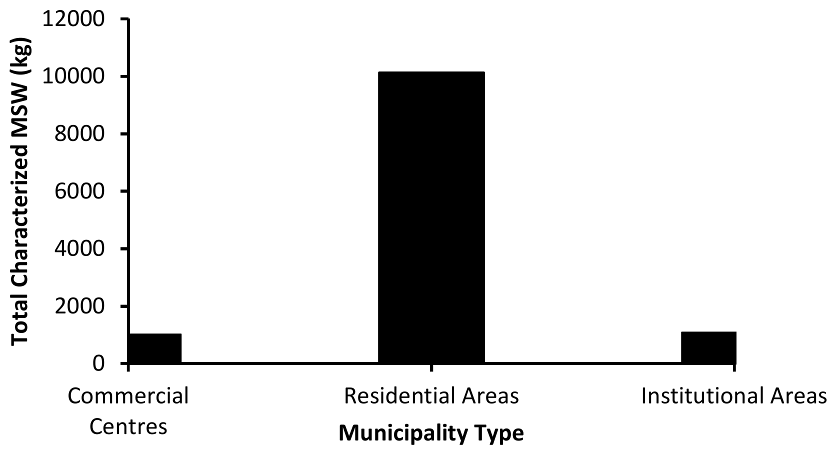

Figure 4: Total weight of characterized MSW samples in each municipality type in the University of Benin

Though waste generation trends in some areas/residences could depict characteristics of high, middle and low income earners regions, the major socio-economic factors put into consideration for sampling was basically population, norms and consumer behaviour/eating habits. It is seen in Figure 4 that institutional areas generated least MSW per day because waste was not generated much in all these institutional areas in all days (especially weekends) and in these areas, there are no residences; students and staffs come to the faculties for academic purposes, after which they go back to their respective residences. In addition, the waste generated composed mainly of paper and plastics which don't weigh much compared to organic waste.

4. CONCLUSION

MSW collection, sorting and characterization were carried out in the various municipalities in the University of Benin, Benin City. The study revealed that about 30.22% of organic waste, 26.67% of plastics/rubber waste, 18.65% of paper waste, 11.08% of metal, 3.70% of miscellaneous waste, 3.10% of inert waste, 2.39% of glass/ceramics, 2.18% textile, 1.03% electronics and 0.98% of leather are generated in the University of Benin community. The study also shows that 33.38% of the total waste generated can be suitably managed through energy recovery techniques and composting, 59.82% of the total waste which are non-biodegradable can be recycled. Hence there is a high potential for recycling, composting, biogas production and waste to energy in University of Benin.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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