CHARACTERIZATION AND COMPOSITION ANALYSIS FOR INVESTIGATION OF BIOGAS YIELD FROM MUNICIPAL SOLID WASTE: A CASE STUDY IN THE UNIVERSITY OF BENIN, UGBOWO CAMPUS

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Abstract

The main disposal method for municipal solid waste in Nigeria is open dumps. Generators of waste either burn their waste or dispose the waste in the nearest open land, road sides, or drains. This has been found to not only be unsustainable but leads to environmental, health, and aesthetic damage, as well as depletion of natural and economic resources.Systematic study was conducted in University of Benin, Ugbowo campus for quantification, determination of composition, study of existing solid waste management practices and biogas potential from solid wastes. The total waste generated over a month period is about 10,144.4kg. Based on this, the per capital waste generation rate is 0.33Kg/cap/day. 10.244tonnes of organic fraction of municipal solid waste is generated in University of Benin daily. This will result in an expected 968.30m3 of biogas to be generated in total from the organic fraction of municipal solid waste of the University of Benin, Ugbowo metropolis per day. Considering the characteristics of waste generated in the University of Benin, Ugbowo campus, a systematic blend of management options in the

waste management with biogas technology consideration as the best biowaste treatment method would be more suitable than the unsustainable collection and final dumping system that is presently been practiced. Besides the biogas and generated renewable energy, the digestate can serve ad biofertilizer which can be used to cultivate crops.

Keywords: Solid waste management, degradable waste, anaerobic digestion, biogas

Introduction

Rapidly increasing populations, economic growth and affluence have contributed positively to generation rate of Municipal Solid Waste (MSW) causing a major challenge to its management worldwide (Aguilar-Virgen *et al*., 2010; Al-khatib *et al*., 2010; Fakare*et al*., 2012; Nabegu, 2010). MSW management problems are more prominent in the middle- and low- income countries due to wealth, fast growing population and urbanization (Alam and Ahmade 2013; Damtew and Desta 2015; Tchobanoglous and Kreith ,2002: Bogner, abdelrafie, Diaz, Faaji, Gao, Et al, 2007; Johnstone and Labonne, 204; Cohen, 2004).The increase in solid waste generated per capita in Africa has not been accompanied by a commensurate growth in the capacity and funding to manage it. It is reported that less than 30% of urban waste in developing countries is collected and disposed appropriately. Improper and inefficient solid waste management lead to GHGs emission, odors problems, and high risk to public health. It has been predicted that emission of GHGs from waste management in developing countries will increase exponentially (Friedrich and Trois, 2011).

Waste Management is a vital element of environmental protection and its purpose is to provide hygienic, efficient and economic solid waste storage, collection, transportation and treatment or disposal of waste without polluting the atmosphere, soil or water system. The knowledge of the sources and types of waste in an area is required in order to design and operate appropriate solid waste management systems (Oyelola and Babatunde, 2008). Fundamental understanding of the sources and types of solid wastes is key in evaluating the composition and generation rates of MSW sources in a municipality.

Cities in Nigeria, being among the fast growing cities in the world (Onibokun and Kumuyi, 1996) are faced with the problem of solid waste generation.By 2025 with a projected population of 233.5 million, Nigeria will be generating an estimated 72.46 million tonnes of waste annually at a projected rate of 0.85 kg of waste/capita/day. This means that Nigeria annual waste generation will almost equal its crude oil production which currently stands at approximately 89.63 million tonnes per year.The main disposal method for municipal solid waste in Nigeria is open dumps. Generators of waste either burn their waste or dispose the waste in the nearest open land, road sides, or drains. These improper waste disposal practices may cause environmental, health, and aesthetic damage, as well as depletion of natural and economic resources (Cao and Wang., 2017; Babayemi and K. Dauda., 2009; Adeniran, Nubi, and Adelopo., 2017). On open dumping grounds, rodents spread disease causing pathogens in the surrounding areas. Foul odors and air pollution are also a hazard to the surroundings. Apart from these the seepage of leachate pollutes the waterways and other water resources used for human consumption.

Based on this backdrop this study characterizes and quantifies municipal solid waste with the aim of determining its potential for commercial production of Biogas as a way of waste to energy. University of Benin is considered in the present study as a sub(model)-municipality in Edo state.

Methodology

The University is located in Egor Local Government area of Edo state. Major activities on campus focuses on teaching, research and community services. In carrying out these functions, academic, administrative, residential and commercial spaces are provided. Majority of the area have permanent structures and complexes which are often purposely built for specific activity.

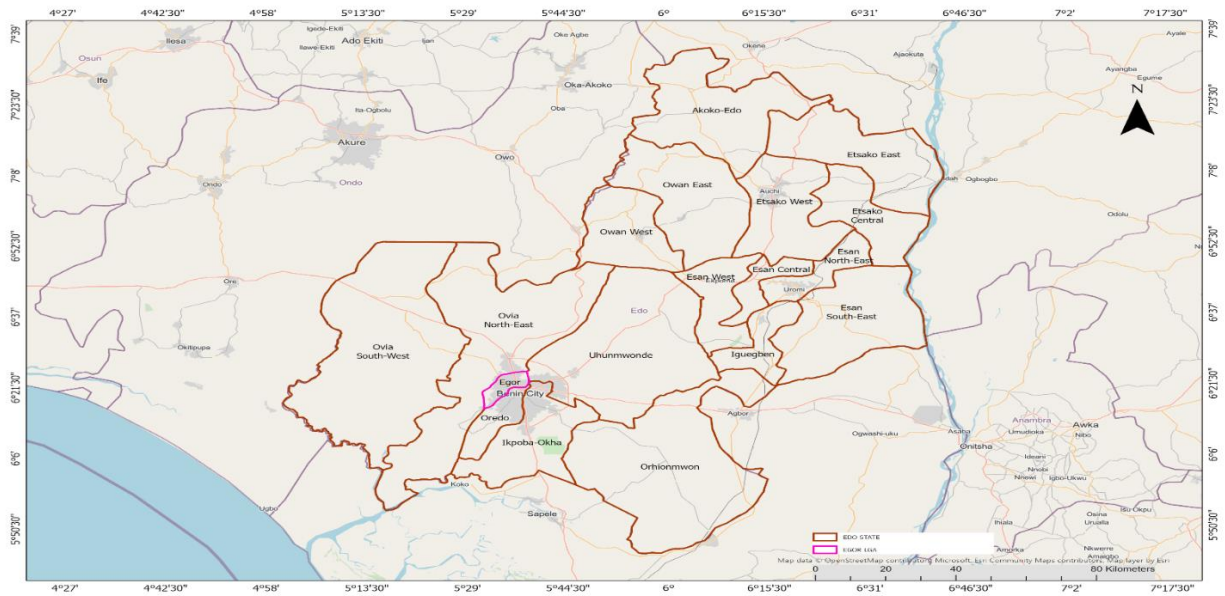

Figure 1: Map of Edo State(google Map)

Data was collected through primary and secondary resources. Primary data were collected through preliminary survey, face-to-face interviews and Questionnaire survey.Study of published and unpublished government agencies reports/records, private agency report and literature review informed the secondary data.Recognizant visits were made to randomly selected households to inform occupants about the survey work and to communicate the importance of the respondent participation and how the respondents will be involved.Also observed were size and structure of building/units, building security and accessibility to temporary waste dump sites or bins or storage.Within the university community, interviews were conducted that focused on availability of disposal site, regularity of collection of waste, problems and challenges of waste management in the communities and methods of managing the waste. Questionnaires were also administered during the study period to gather primary data.

A combined sample size of 1164 samples were collected for the duration at three(3) days interval. Ninetyseven(97) sample sites were visited which was above the minimum number of households of 50 per 500 households suggested by EPA (1996). The sample size was above what was statistically needed to help limit the margin of error, and achieve better accuracy.Stratified systematic sampling methodwas employed at each of the three stratified zones to ensure appropriate representation in the entire population.3-way

sorting (food, fruit and others) of waste was done by respondents and sanitary officers. The sorted waste was first examined to ascertain if the bags have been compromised by either rodents or scavengers, then the content was examined to determine the composition of waste before weighing using a weighing balance and the sampled bags were labelled for identification by waste managers. The bag with mixed content (others) was further sorted into various streams. Data on mass of waste was collected from the field three times a week for four weeks. Sample of sorted waste (organic) was collected into sample bottles and taken to the laboratory to ascertain moisture content and for microbial analysis.

In a second phase of the study, obtainable biogas was determinedfrom organic fraction of the waste following the same equation adopted by Akhator *et al*, (2016). Total solid (TS) and volatile solid (VS) were used to calculate the obtainable amount of biogas. Kigozi *et al*, (2014) stated that in average TS of OFMSW is about 27.14% and the VS are about 94.90% of TS. USEPA, (2008) has established that the biogas production from OFMSW is around 367m3/kgVS. The above values were then applied in the basic theory equation below for the production of biogas from organic fraction of solid waste to determine the obtainable biogas from OFSW in University of Benin.

Total biogas obtainable = Amount of food waste (t) × VS (%) × Biogas yield (m3 /t VS)

Results and discussion

Although the waste management chain in the study areabares similar characteristics with the Benin metropolis the environmental condition and attitude to waste disposal does not completely reflect the general Benin metropolis.There were sightings of dumpsters on strategic positions around the University, although there is room for improvement but the populace makes use of these wastebins to a good extent. Solid waste source segregation is not practiced by residents, commercial operators, staffs and students of the University. Some form of waste sorting was also observed in the areas that employ sanitary workers like the student hostels, administrative blocks, library and all faculties. The cleaners sort and gather the plastic bottles separately. It is assumed that the plastic bottles were sorted to be sold for monetary gains. This is not regarded as source segregation because the sorting was observed at the temporary dumpsites at faculties and student hall of residents.

Even after sensitization, the level of participation and efficiency of sorting continued to decline at the resident quarters. From observation of the attitude of the residence, they wanted monetary benefit to sort the waste. Some of them in the course of the study actually requested monetary benefits.

The data obtained through the administration of site specific sampling and interviews were analyzed using tables, pie-chartsand percentages.Amount of waste types generated from representative samples in the study area over the study period is represented in table 1.

	Mean quantity in 12 days (kg)	SE	Variance	Range of waste quantity (kg)	Total waste (kg)	No of strata	ANOVA *P*-value
Fruits waste	29.4±28.3	16.34	801.1	55.5	1058.4	3	
Food waste	78.43±67.2	38.8	4515.3	132.9	2823.5	3	
Plastic	82.03±16.5	9.5	270.9	31.5	2953.5	3	
Paper	43.2±13.9	8.02	193.4	27.2	1559.6	3	
Glass	5.92±4.47	2.58	20.0	8.7	213.3	3	0.018
Metals	4.66±1.64	0.95	2.69	3.06	162.5	3	
Combustible	29.4±46.9	27.08	2200.9	81.5	1055.0	3	
Leaves	8.03±9.3	5.4	86.9	18.26	271.1	3	
Ceramics	1.32±2.28	1.32	5.22	3.9	47.5	3	

Table 1: Statistics of waste types generated for all the strata, at Ugbowo campus Uniben
Differences in mean waste types generated for all the strata, Ugbowo campus University of Benin is statistically significant at p>0.05, d = 0.018

Although it is illustrated in table 1. that plastic waste was the most waste generatedat 2953.5kg, a combination of fruit waste(1058.4kg) with food waste (2823.5kg)in the real sense makes food waste the most generated stream of waste (3,881.9Kg). The least waste type was ceramic at 47.5kg. leaves recorded 271.1kg.

This was illustrated as Plastic waste 29%, fruit 10% and leaves 3% in figure 10. Food waste was 28% and paper waste 15% (fig2).

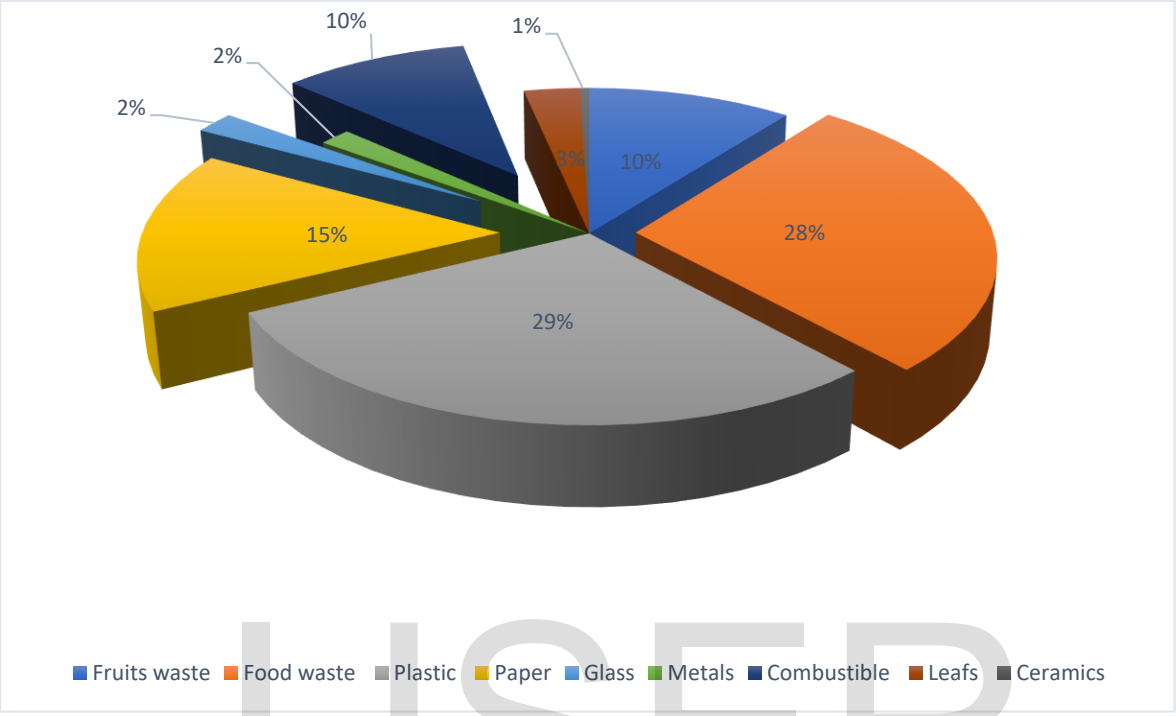

Fig 2. percentage distribution of mean waste types generated for all the strata, Ugbowo campus University of Benin

This study established that on average, about 10,144.4kg of municipal solid waste is generated in the University of Benin Ugbowo campus on a monthly basis. Based on this, the per capital waste generation rate for the study area is 0.33Kg/cap/day. This collaborates with findings of Egun (2012) who recorded per capita waste generation rate for Delta State at 0.3kg/cap/day and Babalola *et al* (2010) who also recorded similar result of 0.32kg/cap/day for Damaturu in Yobe State.

Over all, food residues were the most abundant (38% food and fruit), followed by plastic 29% and paper 15%. This is in-line with many previous research works one of which is Seshie *et al.*, (2020) that recorded same trend of highest food waste then plastic and

followed by paper in municipal solid waste study in Ghana. Mohamad *et al.,* (2020) also reported similar trend in waste composition. The abundance of food waste confirms preferred consumption of fresh whole meals as the feeding habit in the campus.

Table 2. focuses on the easily biodegradable food, fruit and leaves(lignin) waste and the percentage generation for all three strata.

Physical Composition of waste	**Commercial Area**		**Admin/Lecture Area**		**Residential Quarters**		**Total**	
OFMSW	**Weight (kg)**	**%**	**Weight (kg)**	**%**	**Weight (kg)**	**%**	**Weight (kg)**	**%**
Fruit	275.5		58.5		724.4		1058.4	
Food	805.9		211.1		1806.5		2823.5	
leaves	200.9		70.2		0.00		271.1	
	1282.3	**52**	**339.8**	**15**	**2530.9**	**46**	**4153.0**	**41**

Table 2: Composition of OFMSW

The table above illustrates that in the commercial strata 52% of the waste was easily biodegradable while the other 48% was either not easily biodegradable or non biodegradable e.g metals and plastics. The administrative and lecture hall region had low generation of biodegradables (15%) which is in line with previous studies by Igbinomwanhia (2011) revealing biodegradable waste 14.56% in administrative block of the University of Benin. 46% of the total waste generated in the resident quarters during the study period was biodegradable and food waste was the highest generated in the quarters (1806.5Kg).

Organic fraction of municipal solid waste is a biomass resource. The waste generated from Ugbowo Campus, University of Benin has a mean biomass content of 115.9 kg/per day, (food waste, fruit waste and leaf waste), 41% of the total waste can serve as feedstock for anaerobic digestion to produce biogas. According to World Bank (1999), generally, all low and middle income countries have a high percentage of organic matter in the urban waste stream ranging from 40 to 85% of the total waste. Food waste is viable resource for biogas production due to its high volatile solids (VS) content and high biodegradability (Zhang *et al*., 2007; Igoni *et al*., 2008). Volatile solid is the digestible portion of organic waste that ferments to produce biogas. From the total value of biodegradables in table 2, 0.197Kg of food waste is generated in University of Benin per person each day. With an estimated

population of about 52,000 (theeagleonline.com.ng, 2020), University of Beningenerates about 10.244tonnes of OFMSW daily. This will result in a TS of 2,780.22tonnesand VS of 2,638.43tonnes per day considering 27.14% TS and 94.90% VS. Also, considering methane yield values of 367m3 /tVS, a total of 968.30m3 biogas is expected to be generated from the OFMSWofUniversity of Benin sub-metropolis per day.

This observation also collaborates with the findings of Akhator *et al*. (2016) that there is a high percentage of putrescible waste in domestic waste in Benin metropolis. The study found that Food waste accounted for about 78.49% of the generated solid waste representing 0.281kg per person per day (ppd.) and a total daily food waste generation of 305.075tonnes. Based on this value for food waste the obtainable biogas was estimated to be 28,836.91m^3 of biogas in Benin metropolis per day.

Conclusion

As at the time of this study there was no systematic or integrated nor circular solid waste management practices followed except collection of solid waste from central dumps or houses and transferring to be dumped at far off places. This is simply moving the waste to larger dumpsites.

This study revealed that, about 10,144.4kg of municipal solid waste is generated in the University of Benin Ugbowo campus on a monthly basis. From this a per capita waste generation of 0.33Kg/cap/day was established. Characterization and quantification of solid wastes play a significant role in estimating material recovery potential and determining sources of generation, treatment methods, and final disposal. This study illustrates that of the total waste generated, 41% is easily compostable and or biodegradable under controlled conditions to produce biogas that can either be utilized directly for cooking in commercial eateries or upgraded for electric power generation. The other 59% is either recyclable or easily combustible to generate energy.

Considering the characteristics of waste generated in the University of Benin, Ugbowo campus,a systematic blend of management options in the waste management e.g biogas technology and waste recycling technologies would be more suitable than the unsustainable collection and final dumping system that is presently been practiced.Besides

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