Energy Potential of Solid Waste Generated in Landmark University, Omu- Aran, Kwara State Nigeria

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Abstract

This study aims at determining the energy content from campus wastes and estimation of electricity generation. Samples of solid wastes generated within Landmark University were collected, separated, classified, dried in the oven at 105°C till constant weight was attained, pulverized and sieved using a sieve size of 500 μ m. The moisture contents of the waste samples were determined, in triplicates. The digital bomb calorimeter (C-200 Bomb Calorimeter) was used to determine the calorific value of the prepared waste samples. Correlation analysis was carried out to determine coefficients and significant levels; while regression equations were generated, using ANOVA to relate the dependent variable - Potential Electricity Generated (PEG) with independent variables- Total Energy Content (TEC) and Specific Energy Content (SEC). The moisture contents are plastic bottles (0.78%), water sachet (0.82%), and food packs (5.37%), wood wastes and ash (5.35%), food wastes (5.95%), and paper wastes (5.56%). Calorific values of plastic bottles, polythene products, Wood wastes and ash, food wastes, paper wastes and polystyrene (food pack) are 31,246.63, 29,084.24, 17,243.56, 14,360.49, 12,975.42 and 4575.10 kJ/kg, respectively. The total energy content from the campus wastes was estimated at 32,999.30 MJ/day. This implies a possibility of about 0.38MW of electricity generation from daily steam production. There was high level of correlation between the energy value parameters ($R > 0.99$) and significant at < 0.01 . The energy content is expected to grow with the expansion of the campus.

Keywords: Campus wastes, Correlation analysis, Energy content, Electricity generation, Moisture content, Regression equations.

Introduction

The economic, social and intellectual development of any nation is hinged on energy generation. With about ninety percent of fossil fuel- derived energy, and its inimical effects on human health and the environment, great challenge was posed in meeting the demand of the global energy demand. Waste to energy (WtE) remains one of the sustainable ways of energy generation. This involves any forms of treatment that convert combustible waste materials to energy in form of electricity or heat (Adeniran *et al.*, 2019)

There are notable variations in the nature of solid waste generation with country, city, suburb, and seasons and with time as styles and patterns of living change. The variation characteristics can be determined precisely only by analysis in each particular case.

In his nationwide comprehensive waste generation survey, Oyinlola (1998) reported that higher quantities of wastes were generated by high income earners compared to the low-income households. He mentioned World Bank reports on variations in per capital waste

generation between low income, middle income and high income or industrialized countries as 0.4- 0.6 kg/day, 0.5- 0.9 kg/day, and 0.7- 1.8 kg/day, respectively. Daskalopoulos and Probert (1998) opined that there will always be concerns for the disposal of massive refuse, in some of the developing countries, where management of municipal wastes are inadequate. This bothers on the elementary and undeveloped methods and operations of municipal waste management techniques, coupled with lack of appropriate data and information about the types and quantities of wastes generated, collected, amount recovered and possible locations of wastes disposal sites (Aguilar-virgen *et al.*, 2010). The management of solid waste in Nigeria has been one of the greatest challenges facing the tiers of government. The government environmental agencies have not been able to improve on the financial and technical resources needed to match with the challenge of ever-increasing volume of the solid waste being generated.

Solid waste management in Nigeria is characterized by inefficient collection methods, insufficient coverage of the collection system and improper disposal of solid waste. As such, most cities and towns are characterized by waste disposal dumpsites situated on any available free land roads streets, drainages (Amber *et al.*, 2012). In Nigeria, for example, added to the problem of inadequate municipal waste management operations is the erratic power supply from the national grid, making the fast depleting fossil fuels and firewood remain the main nation's energy sources (Ikuponisi, 2006). The capital-intensive renewable energy sources such as biogas, solar, wind, thermal and nuclear sources have not been holistically implemented to solve the problem of insufficient energy. However, available alternative energy sources derivable from municipal solid wastes are environment friendly and cheaper. While serving presently as source of electricity generation, the environment is also made clean. Impact of waste scavengers in Ilorin, Nigeria has been investigated by Adeyemi *et al.*, (2004). The energy content of ten agricultural wastes in Nigeria farmlands was determined and reported in Jekayinfa and Omisakin (2005) in accordance with the method of Association of Official Analytical Chemists. Oladejo *et al.*, (2018) studied solid waste generation, characteristics and material recovery potentials for landmark university campus.

In our present world, many institutions of higher learning were synonymous to minor cities, with large expanse of land bigger than many towns, activities of various dimensions by humans which have numerous effects on the total environment. Many Universities in Nigeria have been said to act as their own municipalities (Adeniran *et al.* 2017). The situation in Landmark University is not an exception. Oladejo *et al.* (2018) reported that about two tonnes (1785.4 kg) total solid wastes generated per day with generation rate of 0.36 kg/person/day. Wastes generation from residential, academic/administrative and utility zones was 1599.8, 103.9 and 81.7 kg/day respectively. Oladejo *et al.* (2020) documented clean energy generation and material recovery potentials from solid wastes generated in Omu Aran community as the effect of poor waste management is inimical to the environment and our health. Some of the negative effects are foul odour, environmental pollution, respiratory problems due to air pollution, food poisoning via soil and water pollution. A major antidote to mitigate poor management of waste is characterization, as reported by Oladejo *et al.* (2018) from the previous studies carried out on solid waste characterization from Landmark University campus.

Incineration processes require the knowledge of the chemical composition of the available solid wastes. The most important properties of interest are (i) Proximate analysis (ii) Fusing point of ash (iii) Ultimate analysis (iv) Heating value. The amount of heat produced during fuel combustion at constant pressure at normal conditions of 25° and 1 atmosphere is referred to as the fuel heating value. The combustion process produces water (vapour or steam). Rominiyi *et al.* (2017). Presently, Landmark University has not adopted any energy extraction method or value addition system to address the final waste disposal options. However, the current energy gap in Nigeria calls for alternative energy sources. Thus, the aim of this study is to determine the energy contents and estimation of electricity in the solid wastes generated from Landmark University as an integral approach to municipal solid waste management.

Materials and Methods

Solid wastes generated within the study area, Landmark university campus (as described in Oladejo *et al.* 2018) were obtained from waste collection containers. The determination of weight of the physical components was carried out daily for a period of 5 days, a week within six months (between December, 2017 and May, 2018). This was from Monday to Friday. The wastes were sorted and weighed into material types which included paper, cardboard, plastic bottles, metals cans, food wastes, polythene bags, polystyrene food pack, e-wastes, sanitary and ash residuals.

To determine the percentage moisture content (MC) in the campus wastes, the solid waste samples categorized into combustible components and non-combustible components were dried in the oven at 105°C till constant weight was attained, pulverized (the organic part of the constituents) and sieved with a mesh size of 500 micron. The experiment was carried out in the Mechanical Engineering laboratory of Landmark University and was evaluated using ASTM D3173 procedure (ASTM, 1988). Samples And the % moisture content of samples determined as thus:

$$\% \text{ MC in the solid waste: } \frac{w_2 - w_3}{w_2 - w_1} \times 100 \quad (1)$$

Where:

w_1 is the container mass

w_2 is the container mass + wet mass of the solid waste sample.

w_3 is the initial mass of the solid waste.

The Calorific Value (CV) of the residual waste is expressed as energy content (E), or heat value, released when burnt in air. The Net Calorific value (NCV), or Lower Heating Value (LHV) was used in the evaluations of sample. The NCV was measured in terms of the energy content per unit mass (García *et al.*, 2012).

$$E \text{ (MJ)} = M \times \text{NCV} \quad (2)$$

Where NCV is net calorific value and M is the sample mass. i.e.

$$\text{Energy Content} = \text{Quantity of MSW generated (Kg)} \times \text{Specific Energy Content (MJ/Kg)} \quad (3)$$

The evaluation of the energy content of Landmark University solid waste was determined using ASTM E711-87- Standard Test Method for Calorific Value of Refuse-Derived Fuel by

Bomb Calorimeter (The Cal 2k-Eco Calorimeter), (ASTM, 2004) in the Mechanical Engineering laboratory of Landmark University.

$$\text{Electricity Generation Potential (MW)} = \frac{H}{24 \times 3600} \quad (4)$$

Where H is the Total Energy Content (MJ/day) of the Combustible Components of campus Solid Waste (CSW).

Correlation analysis was carried out to determine coefficients and significant levels; while mathematical equations were generated, using ANOVA to relate the dependent variable with independent variables, using Statistical Package for Social Sciences 16.0 (SPSS).

Results and Discussion

Results

This study was designed to evaluate the energy content of the solid waste in the Landmark university campus. Table 1 showed the daily solid waste generation, classification and characteristics within Landmark University campus, while the results of the moisture and energy contents from campus solid wastes was presented in Table 2. Moisture contents and energy values of combustible components of the campus wastes was shown in Figure 1. Figure 2 presented estimated electricity generation of combustible components of the campus wastes. Table 3 showed the correlation coefficients between Potential electricity generated and energy value parameters of combustible components of campus wastes, while the regression equations relating Potential Electricity Generated (PEG) with Total Energy Content (TEC) and Specific Energy Content (SEC) of solid waste generated in Landmark University campus was presented in Table 4.

Discussion

Daily solid waste generation on campus ranged between 1655.34 kg to 1947.32, with daily average value of 1785.4 kg as reported by Oladejo *et al.* (2018) and shown in Table 1.

The % moisture content (MC) of samples was presented in Table 2 and varied within 0.8% and 5.95%. This could be attributed to the effect of constituent wastes in each of the samples. As reported in Figure 1, plastic bottles and polythene sachets components which had the least MC values possessed the highest values of specific energy contents. Quaghebeur *et al.*, (2013) and Adelopo *et al.*, (2017) have attributed the non- porous nature of plastic and polythene materials as a major compositional factor affecting the moisture content of composite municipal waste. Bingham (2004) and Cheng *et al.* (2007) also identified high moisture content of waste as having significant effect on its combustibility. The % moisture content of samples in this study was within permissible condition for waste to energy of less than 45% as reported by Cheng and Hu (2010) and central pollution control, (2016).

As presented in Table 2, highest calorific value was recorded in plastic bottles, 31,246.63kJ/kg, followed by polythene products (water sachet nylons) with value of 29,084.24 kJ/kg. Wood waste and ash was 17,243.56 kJ/kg, while food waste has heating value of 14,360.49kJ/kg. 12,975.42 kJ/kg was recorded in paper and the least specific energy content of 4575.10kJ/kg was found in polystyrene (food pack) waste. Similar trend was noticed in Adeniran *et al.* (2019). All the combustible components of the campus wastes

considered in this work, except polystyrene (food pack, 4.58 MJ/kg) were above the minimum energy level of 6 MJ/kg for viable WtE feed (World bank, 1999). As at present, when the solid waste stream in Landmark University is completely burnt per day to produce steam, 0.38MW of electricity can be generated. This is quite very low to what was obtained when the municipal solid waste stream in Ado-Ekiti is completely burnt per day to produce steam, where 51.50 MW of electricity can be generated (Rominiyi *et al.*, 2017).

The energy potential of waste recoverable was affected by the variations in waste components (Figure 2). Cheng *et al.*, 2007 also observed that variations in the energy contents of waste largely affect the energy generation. Low energy content waste (4-6.7 MJ/kg) from food waste reduced the energy generation while higher energy generation were obtained from WtE due to relative higher energy content waste like polythene materials.

In community like University campus, waste generation and variations are confined majorly to the campus activities, which are expected to be minimal compared to variations expected in Municipal Solid Waste (MSW) (Okeniyi *et al.*, 2012). Hoornweg and Bhada-Tata, (2012) reported that level of education, income statute, life styles are major factors influencing the type of waste generated

The life style of people with tertiary education and thus earning income above average, which eventually traceable to the most populous within the University campus, has been reported as having attribute of generating large quantity of non- biodegradable (Irwan *et al.*, 2011). The reports of Armijo de Vega *et al.* (2008), Smyth *et al.* (2010), Okeniyi *et al.* (2012) and Oladejo, *et al.* (2018) from the studies of waste characterization within university campuses, had studied waste characterization of university campuses confirmed the generation of large quantity of non- biodegradable.

The potential energy generated could be attributed to the moisture contents, specific and total energy contents of the constituent wastes. This was investigated using a correlation studies between potential electricity generated and energy value parameters of combustible components of solid waste generated in Landmark University campus (Table 3). The study showed that moisture content had a strong negative statistical correlation of $R > -0.897$ and significant at P values of < 0.05 . This indicated that moisture content decreases with increased potential energy generated. However, the specific and total energy contents had very strong positive statistical correlations of $R > 0.885$ and 0.998 and significant at P values of < 0.05 and < 0.01 , respectively. The regression equations relating Potential Electricity Generated (PEG) with Total Energy Content (TEC) and Specific Energy Content (SEC) of solid waste generated in Landmark University campus were also expressed in Table 4.

The statistical analyses of the data generated from the combustible components of solid waste generated in Landmark University campus showed high level of correlation between the potential electricity generated and energy value parameters of the combustible components.

The total energy content and the estimated electricity value of waste in the present work is an indication of waste utilization as an alternative renewable energy source. The wastes are reflected as free source and therefore economical to use as source of energy. This is a clean source of green energy for electricity production.

Table 1: Daily Solid Waste generation, classification and characteristics within Landmark University campus (Oladejo *et al.* (2018)

Day	Paper	Organic	Wood	Polystyrene	Plastic	Polythene	Metals	Glass	E-waste	Residuals	Sanitary	Total (kg)
1-Monday	202	427.6	38.29	87.8	341.6	511.56	155.47	0.75	4.8	114.45	63	1947.32
2-Tuesday	213.49	361.6	41.76	95.81	301.45	511.85	175.97	0	9	26.27	63	1800.2
3-Wednesday	209.52	425.2	28.76	84.44	345.3	405.63	187.43	0	18.18	31.45	47	1782.91
4-Thursday	211.91	394.26	24.47	82.35	258.1	376.37	201.81	1.05	8.07	43.95	53	1655.34
5-Friday	203.72	341.71	33.71	93.66	290.24	402.85	174.46	0	22.62	66.25	63	1692.22
Total (kg)	1040.64	1950.37	166.99	444.06	1536.69	2208.26	895.14	1.8	62.67	282.37	289	8877.99
Average	208.13	390.07	34.2	88.81	316.3	441.65	179.03	0.36	12.53	56.47	57.8	1785.4
N = 5	±5.05	±38.11	±6.99	±5.80	±36.63	±64.96	±17.14	±0.50	±7.51	±35.89	±7.43	
% Average	11.7	21.9	1.9	5	17.7	24.7	10	0.02	0.7	3.18	3.2	100

Table 2: The combustible components of solid waste generated in Landmark University campus
(kg/day and the energy content (kJ/day)

S/N	Combustible Components	% Composition	Moisture content (%) N = 3	Quantity of MSW generated (kg/day) N = 5	Specific Energy Content (kJ/Kg)	Total Energy Content (MJ/day)*	Electricity generation Potential (MW)*
1.	Paper	11.7	5.54 ± 0.01	208.13 ± 5.05	12,975.42	2,700.57	0.03
2.	Food Wastes	21.9	5.95 ± 0.01	390.07 ± 38.11	14,360.49	5,600.59	0.06
3.	Wood waste and Ash	5.08	5.35 ± 0.03	90.67 ± 40.88	17,243.56	1,563.47	0.02
4.	Food Pack	5.0	5.37 ± 0.01	88.81 ± 5.80	4575.10	406.31	0.01
5.	Plastic Bottles	17.7	0.78 ± 0.01	316.3 ± 36.63	31,246.63	9,883.31	0.11
6.	Water Sachet	24.7	0.80 ± 0.1	441.65 ± 64.96	29,084.24	12,845.05	0.15
Total		85.98		1535.63	109,485.44	32,999.30	0.38

* MW = $1.15740741 \times 10^{-5}$ MJ/day

Figure 1: Moisture contents and energy values of combustible components of the campus wastes

Figure 2: Estimated electricity generation of combustible components of the campus wastes

Table 3: The correlation coefficients between Potential electricity generated and energy value parameters of combustible components of solid waste generated in Landmark University campus

	% composition of combustibles	Moisture content	Quantity of CSW	Specific energy content	Total energy content	Potential Electricity generated
% composition of combustibles	1					
Moisture content	-.563	1				
Quantity of CSW	1.000**	-.566	1			
Specific energy content	.647	-.895*	.649	1		
Total energy content	.877*	-.884*	.879*	.892*	1	
Potential Electricity generated	.858*	-.897*	.860*	.885*	.998**	1

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Table 4: The regression equations relating Potential Electricity Generated (PEG) with Total Energy Content (TEC) and Specific Energy Content (SEC) of solid waste generated in Landmark University campus

Pairs of parameters	R	Regression coefficients		Regression equations
		A	b	
PEG vs TEC	0.998	0.002	1.124×10^{-5}	$1.124 \times 10^{-5} \text{TEC} + 0.002$
PEG vs SEC	0.885	-0.025	4.847×10^{-6}	$4.847 \times 10^{-6} \text{SEC} - 0.025$

Conclusion

1. Plastic bottles, Polythene and paper products, and wood wastes have the high calorific value hence a high potential to produce steam to generate electricity.
2. The statistical analyses of the data generated from the combustible components of solid waste generated in Landmark University campus showed high level of correlation between the potential electricity generated and energy value parameters of the combustible components.
3. Based on the findings in this study, Landmark University has potentials for renewable energy recovery through incineration of the organic components of solid waste generated on campus. This eventually, contributes positively to the energy supply, and cleaner environment.
4. Detailed studies that cover various seasons should be carried out to underscore effects of seasonal variations on energy generated from solid wastes. Also, further studies need to be conducted on assessing the potential of various agricultural wastes in production of bio-fertilizer and fuels.

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