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CHARACTERIZATION AND ENERGY ANALYSES OF MUNICIPAL SOLID WASTE IN OBAFEMI AWOLOWO UNIVERSITY, SOUTHWESTERN NIGERIA

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ABSTRACT

The municipal solid waste generated within Obafemi Awolowo University (OAU), Nigeria, was quantified and characterized for the potential of generating electricity. Load-count analysis was employed to measure the daily waste generation, while sampling techniques were used to characterize the collected MSW. Ten samples, each weighing 10 kg, were gathered from the OAU dumpsite (Asunle) and subsequently sorted into combustible and non-combustible fractions. The combustible portion was homogenized, shredded to particles smaller than 3 mm, and analysed using a bomb calorimeter to determine its calorific value, following standard procedures. The results showed that the OAU community generates approximately 4.4 tons of waste daily, consisting of 34.8% paper, 18.1% textiles, 9.4% electronics, 6.2% biomass, 6.3% wood, 4.4% metal, and 20.8% miscellaneous materials. The combustible fraction accounted for 65.4% of the total waste, with an average moisture content of 19.04% (wet basis). The average calorific value of the combustible fraction was 10.77 MJ/kg. Energy analysis indicated that, with a minimum conversion efficiency of 25%, approximately 0.4 MW of electricity could be generated from the MSW. The study concludes that the MSW generated within the OAU community has the potential to produce 0.4 MW of electricity based on a daily waste generation rate of 4.4 tons and a minimum conversion efficiency of 25%.

INTRODUCTION

Providing sufficient energy is a global challenge faced by both developed and developing countries (Mehrzad *et al*., 2007). However, greater crunch of the global energy crisis is felt more by developing nations, like Nigeria, where lack of adequate energy has been identified as the source of social and economic poverty (Fagbenle *et al*., 2011). In Nigeria, addressing the energy crisis has become a critical expectation of the populace. Many political campaigns leverage this issue by prioritizing energy generation in their agendas, using it as a key strategy to attract voter support for political offices. Despite lofty promises of adequate energy provision to the populace by past governments, incessant power outages persist throughout the country. The high cost of industrial recurrent spending invested in the provision of alternative energy supply has driven many viable industries into neighbouring countries, thus aggravating the social vices of unemployment in the nation (Ajayi, 2009). The fact that the generated energy supply of about 4000 MW for the whole nation has not been sufficient for the urban areas connected to the national grid has not made the expansion of energy provision for rural communities possible. This is such that communities could remain unconnected to sustainable sources of energy provision for economic growth unless a drastic approach to energy sourcing is employed.

The challenge of inadequate energy provision in the country might have remained insurmountable because the government alone had been saddled with much of the responsibility of seeking sustainable sources of energy. This had left the government with little choice other than seeking energy provision from the unsustainable conventional sources that had weakened the country's economic growth to the detriment of its populace. However, the ability to tackle the energy crisis in the country would have to be a concerted effort, whereby communities may have to look inward to sustainable energy sourcing, through which it can partner with the government or other requisite private sector organizations for energy supplements. One such energy source could be from waste generated within the communities (i.e., municipal solid waste).

Municipal solid waste includes refuse from households, non-hazardous/hazardous solid wastes from industrial, commercial and institutional establishments (including hospitals), market waste, farmyard waste, and street sweepings (Ogwueleka, 2009). These wastes can come from durable goods (e.g., tires, furniture), non-durable goods (e.g., newspapers, plastic plates/cups), containers and packaging (e.g., milk cartons, plastic wraps), and other wastes (e.g., farmyard wastes, food, sawdust, metal, glass). Waste generation is a concomitant aspect of living; it cannot be banished but can only be managed. The volume of each type of waste produced from various sectors and areas plays an important role in determining the best waste management option.

Municipal solid waste management (MSWM) means the collection, transfer, treatment, recycling, resource recovery and disposal of solid waste. Despite the increase in waste prevention, reuse and recycling, there is still a significant volume of waste sent to landfills. In Nigeria, as in many developing countries, waste is often disposed of in open dumps, where it is frequently burned to reduce volume. However, this approach should be a last resort due to its severe environmental consequences. In particular, biodegradable waste contributes significantly to greenhouse gas emissions, highlighting the need for its diversion from landfills. The production of methane and the potential contamination of groundwater and soil during landfill usage are of great concern. These environmental impacts can continue to persist long after the closure of landfill sites. Alongside this, there are impacts on wildlife habitats, dust, odour and noise pollution, and an increasing lack of available space (Siddiqua *et al.*, 2022).

As waste prevention, re-use and recycling options improve, residual waste will eventually become a diminishing resource. This is, however, a long way off and in the meantime, there is plenty of opportunity to derive from the wastes that are currently sent to landfill through waste-to-energy (WTE), especially if more efficient technologies can be employed to maximize the energy recovered from it. The term 'waste-to-energy' covers a range of processes that recover value from the waste. Some of these processes extract the energy directly, whereas others convert waste into different types of fuel for later use. These processes include incineration, gasification, pyrolysis, plasma arc and anaerobic digestion (Ashola *et al*., 2016; Prebilič *et al*., 2024).

Energy recovery from municipal solid waste (MSW) has been identified in previous studies as a source of sustainable energy to supplement communal energy needs, reducing dependency on fuels sources (Ahmad *et al*., 2011; Klein and Themelis, 2003; Muis *et al*., 2010; Nanda and Berruti, 2021) and achieving sustainable waste management system (Traven, 2023). Energy generation from waste sources is potent not only with energy cost savings but also with attendant benefits, including reduction in landfill space requirements and unfriendly ecological emissions (Alao *et al*., 2022; Klein and Themelis, 2003; Okeniyi *et al*., 2012; Omrani *et al*., 2005). Energy recovery from waste can also constitute a system of energy sourcing, which could be replenished as more waste is generated. According to the Energy Commission of Nigeria (ECN, 2022), however, the process of waste sustainability and management as an energy resource is still non-existent in Nigeria.

From these and other endowments of waste generation potential, there is a need to harness the energy from this bonus source, a feat through which it could become the model for the replication of waste energy reclamation for the country. However, energy resource viability, utilisation and management from waste resources require detailed and adequate waste characterization for the requisite initiation of its economic assessment and development (Fobil *et al*., 2005; Nabegu, 2010). While waste characterization has been considered in recent studies for households, markets and cities in some parts of Nigeria (Nabegu, 2010; Oyelola and Babatunde, 2008). Studies involving recoverable energy analysis have not been done for any part of the nation. This study investigated the potential for generating electricity from municipal solid waste (MSW) produced within Obafemi Awolowo University (OAU), Ile-Ife, Nigeria, with waste sourced from the OAU dumpsite (Asunle). The objective was to estimate the theoretical quantity of electricity that could be generated from the collected MSW, focusing on an analysis of its recoverable energy potential.

METHODOLOGY

Study Area

The study was conducted at the Obafemi Awolowo University (OAU), Ile-Ife, Nigeria, with samples collected from the Asunle dumpsite, which serves as the university's current solid waste disposal site. The collected samples were analysed within OAU's facilities during the wet season.

Data Collection

The collection of information and data was carried out in two phases. In the first phase, information regarding solid waste management and solid waste collection details in OAU, Ile-Ife, Nigeria, was gathered from interviews carried out with Environmental Health Unit personnel, and a rough draft was documented. In the second phase, a detailed study was conducted at the Asunle dumpsite on the waste collection system and its disposal methods. The visit to the dumpsite enabled gathering of information regarding the waste type, carrier services, scavenging process and method of waste treatment at the dumpsite.

Quantification of MSW Collected on Campus

In this study, load count analysis (weight) was employed to determine the quantity of waste collected daily as opposed to volume because the weight measurements are consistent and reproducible, while the volume can vary considerably due to compaction (Amasuomo and Baird, 2016; Hassan *et al*., 2018). The approach involved the determination of the vehicular capacity as expressed in Equation (1) and the number of vehicles of that capacity. Both the field observations and the questionnaire were used in obtaining the required data for the estimation of the quantity of MSW per day as expressed in Equation (2). The questionnaire was designed and structured to capture the following information: the number of dumpsites in the institution, the number of each type of waste trucks operated by the Environmental Unit, N_t; the capacities of waste trucks of each type Ct; the number of regular collection days per month Nr and the number of truckloads of waste collected per day on regular collection days by each type of truck N_{tlr}. The questionnaires were administered to the Environmental Unit of the Health Centre of the University. The gross weight of the vehicle was estimated with the weighing bridge. Plate 1a shows the waste truck loaded with MSW on a weighing bridge, while Plate 1b shows the same truck after the content has been unloaded.

$$C_t = \text{Gross Weight} + \text{Tare Weight} \quad (1)$$

[The vehicular capacity (Ct), Vehicle weight with waste (Gross weight), vehicle weight without waste (Tare weight)] The quantity of MSW collected per day (Q_T) was estimated with Equation 2

$$Q_T = \frac{N_r[(C_tN_tN_{tlr})_1 + (C_tN_tN_{tlr})_2 + (C_tN_tN_{tlr})_3 + \ldots (C_tN_tN_{tlr})_n]}{30} \quad (2)$$

(Adekoya *et al*., 2014)

where n = number of different types of trucks used for waste collection by the University.

(a) **(b)**

Plate 1: (a**)** Loaded waste truck on weighing bridge. (b) Unloaded waste truck on weighing bridge.

Characterization

The composition of the solid waste was carried out through a sampling method. Waste collection, separation and characterization were done at Asunle dumpsite in Obafemi Awolowo University, Ile-Ife, Nigeria. Ten samples of 10 kg of freshly disposed solid waste were collected from Asunle dumpsite into a sack as shown in Plate 3(a). The collected samples were poured onto the sorting platform for sorting. The sample was then sorted into MSW types, namely bio, paper/cardboard, metal, wood/board, textile, electronics, auto, and other miscellaneous waste material. Plate 3(b) shows the sorted samples. Each component was collected in a separate container and weighed using the analogue weighing balance, a weighing scale with a sensitivity of 1 mg (0.001 g), to obtain mass-based characterizations. The weighed samples were combined into two sub-groups, namely: combustible and non-combustible. The fractions (f) for each sample were then calculated using Equation (3) as outlined by Adekoya *et al*. (2014) for each sample. Combustible wastes are the waste that catch fire and burn when subjected to fire and they are paper/cardboard, bio, wood/board and textile. One sample weighing 1 kg was then removed at random from each lot of combustible MSW and sealed in nylon bags for laboratory analysis. Waste collection and characterisation were done for six consecutive days until ten samples were obtained.

$$f = \frac{\text{weight of combustible MSW}}{\text{weight of total MSW}} \quad (3)$$

(a) **(b)**

Plate 3: (a)Collection of MSW at Asunle Dumpsite (b) Sorted samples of MSW Collected

Sample Preparation

The combustible components were thoroughly mixed manually, shredded and milled to a quality size of less than 3 mm (Lopes *et al*., 2022). These preparations were required to ensure an increase in the surface area of the samples for laboratory analysis. Plate 4 shows the prepared samples

Laboratory Tests

After sample preparation**,** tests were carried out to examine the combustion properties of the MSW. The specific experiments carried out were to determine the heating (calorific) value and the moisture content of the collected samples.

Plate 4: Prepared MSW Samples

Calorific value determination

The calorific value of each of the ten prepared samples was determined in the laboratory using an XRY-1C oxygen bomb calorimeter, shown in Plate 5, following (ISO 1928, 2020) Standard test method

Plate 5: XRY-1C bomb calorimeter.

Moisture content determination

Subsamples were taken from the composite samples and oven-dried at 105°C to a constant weight for moisture content determination. The percentage moisture content, as defined by Adekoya *et al*. (2014). It is calculated using the following equation:

$$M = \frac{w-d}{w} \times 100 \quad (4)$$

where M is the moisture content (wet basis), w is the initial mass of the sample, and d is the mass of the sample after drying

Energy Analysis

The energy content of the solid waste sample was determined following the methodology outlined by Adekoya *et al*. (2014). This estimation utilized the composition data and the average calorific (heating) values of the prepared samples, as expressed in Equations (5) and (6).

Quantity of combustible MSW collected per day, Q_C

$$Q_c = f \cdot Q_T \text{ ton/day} \quad (5)$$

$$HC_c = W_{cc} + C_{voc} \text{ (MegaJoules)} \quad (6)$$

[Heat content of combustible MSW (HC_c), Weight of collected combustible MSW (W_{cc}), Calorific value of combustible MSW (C_{voc})]

The Quantity of Electricity that Can Be Generated

By analysing the characteristics of municipal solid waste (MSW), including its energy recovery potential based on the combustible fraction and calorific value, the power generation capacity can be estimated using the approach outlined by Adekoya *et al*. (2014), as represented in Equation (7).

Power Generation Potential (PGP)

$$PGP = \frac{\eta \times \{Q_c \text{ (tpd)} \times \text{ combustible MSW Energy (kWh/tonne)}\}}{10^3} \text{ MW}$$

$$PGP = \eta \times Q_c \times NCV \times 0.049 \text{ MW} \qquad (7)$$

where η is the conversion efficiency, NCV is the net calorific value.

RESULTS

Quantification of MSW Collected on Campus

The daily amount of MSW that is transported from campus to the Asunle dumpsite is approximately 4.4 ton per day. Table 3.1 shows the estimate of the waste quantity.

$$Q_T = \frac{N_r\left[(C_tN_tN_{tlr})_1 + (C_tN_tN_{tlr})_2 + (C_tN_tN_{tlr})_3 + \ldots(C_tN_tN_{tlr})_n\right]}{30}$$

$$Q_T = \frac{21(160\times2\times6)+(470\times1\times2)+(550\times1\times3)+(430\times1\times4)}{30} \text{ ton/day}$$

Q_T = 4361 kg/day

Q_T = 4.4 ton/day

Characterization of MSW in OAU

Table 3.2 shows the composition of first sample collected on Day 1, with the paper percentage of 38%, textile 20%, electronics 20%, miscellaneous 18%, metal 4%, auto, bio and wood 0% while the Table 3.3 shows the composition of the second sample collected on Day 1 with paper percentage of 38%, textile 19%, electronics 21%, miscellaneous 19%, metal 3%, auto, bio and wood 0%. Further analysis of the sorted waste showed that constituents were quite similar except for the amount and proportion present, which differ in proportion for each sample, and this is greatly influenced by the type of activity dominant in the environment where the waste is collected and deposited. Table 3.4 shows the composition of first sample collected on Day 2 with paper percentage of 30%, bio 11%, electronics 14%, miscellaneous 26%, metal 6%, wood 13% and textile 0% while Table 3.5 shows the composition of second sample collected on Day 2 with paper percentage of 28%, bio 9%, electronics 15%, miscellaneous 22%, metal 10%, wood 16%, auto and textile 0%.

Table 3.1: Waste estimates by survey questionnaire.

S/N	Identification of Trucks	N_t	C_t (kg)	N_{tlr}
1	FG203L50	2	160	6
2	FG200L50	1	470	2
3	FG480L50	1	550	3
4	FG201L50	1	430	4

where N_t = the number of each type of waste trucks operated by the Environmental Unit, C_t = the capacities of waste trucks of each type, and N_{tlr} = the number of truckloads of waste collected per day on regular collection days by each type of truck.

Table 3.2: Composition of Day 1 sample 1 waste stream by mass (kg)

S/N	Components	Mass (kg)	Percentage (%)
1	Auto	-	0
2	Bio	-	0
3	Paper	3.8	38
4	Metal	0.4	4
5	Wood	-	0
6	Textile	2.0	20
7	Electronics	2.0	20
8	Miscellaneous	1.8	18
	Total	10	100

Table 3.3: Composition of Day 1 sample 2 waste stream by mass (kg)

S/N	Components	Mass (kg)	Percentage (%)
1	Auto	-	0
2	Bio	-	0
3	Paper	3.8	38
4	Metal	0.3	3
5	Wood	-	0
6	Textile	1.9	19
7	Electronics	2.1	21
8	Miscellaneous	1.9	19
	Total	10	100

Table 3.4: Composition of Day 2 sample 1 waste stream by mass (kg)

S/N	Components	Mass (kg)	Percentage (%)
1	Auto	-	0
2	Bio	1.1	11
3	Paper	3.0	30
4	Metal	0.6	6
5	Wood	1.3	13
6	Textile	-	0
7	Electronics	1.4	14
8	Miscellaneous	2.6	26
	Total	10	100

Table 3.6 shows the composition of first sample collected on Day 3 with paper percentage of 32%, bio 9%, miscellaneous 27%, textile 24%, wood 8%, electronics, metal and auto are 0% while Table 3.7 shows the composition of second sample collected on Day 3 with paper percentage of 47%, bio 13%, miscellaneous 18%, textile 22%, electronics, metal, wood and auto are 0%. Table 3.8 shows the composition of first sample collected on Day 4 with paper percentage of 27%, electronics 7%, miscellaneous 18%, metal 8%, textile 24%, wood 16%, bio and auto are 0% while Table 3.9 shows the composition of second sample collected on Day 4 with paper percentage of 40%, bio 10%, electronics 5%, miscellaneous 17%, metal 7%, textile 21%, wood and auto are 0%.

Table 3.5: Composition of Day 2 sample 2 waste stream by mass (kg)

S/N	Components	Mass (kg)	Percentage (%)
1	Auto	-	0
2	Bio	0.9	9
3	Paper	2.8	28
4	Metal	1.0	10
5	Wood	1.6	16
6	Textile	-	0
7	Electronics	1.5	15
8	Miscellaneous	2.2	22
	Total	10	100

Table 3.10 shows the composition of first sample collected On Day 5 with paper percentage of 29%, miscellaneous 30%, metal 6%, textile 25%, wood 10%, bio, electronics and auto are 0% while Table 3.11 shows the composition of second sample collected on Day 5 with paper percentage of 39%, bio 10%, electronics 12%, miscellaneous 13%, textile 26%, metal, wood and auto are 0%.

The average composition of the total analysed amount of waste during the field study at Asunle (100 kg) is shown in Table 3.12 and presented in Figure 1 as a pie chart. Paper is the largest waste category, representing approximately 35% of the total collected amount of waste, followed by textile (18%) and wood waste (6.3%). In the case of metals, virtually the entire waste category consists of lightweight aluminium cans. Miscellaneous consists of sand and other particles that cannot be sorted further. Table 3.13 shows the estimated combustible fraction (f) of the collected samples, which constitutes 65% of the total waste deposited in Asunle.

Table 3.6: Composition of Day 3 sample 1 waste stream by mass (kg)

S/N	Components	Mass (kg)	Percentage (%)
1	Auto	-	0
2	Bio	0.9	9
3	Paper	3.2	32
4	Metal	-	0
5	Wood	0.8	8
6	Textile	2.4	24
7	Electronics	-	0
8	Miscellaneous	2.7	27
	Total	10	100

Table 3.7: Composition of Day 3 sample 2 waste stream by mass (kg)

S/N	Components	Mass (kg)	Percentage (%)
1	Auto	-	0
2	Bio	1.3	13
3	Paper	4.7	47
4	Metal	-	0
5	Wood	-	0
6	Textile	2.2	22
7	Electronics	-	0
8	Miscellaneous	1.8	18
	Total	10	100

Table 3.8: Composition of Day 4 sample 1 waste stream by mass (kg)

S/N	Components	Mass (kg)	Percentage (%)
1	Auto	-	0
2	Bio	-	0
3	Paper	2.7	27
4	Metal	0.8	8
5	Wood	1.6	16
6	Textile	2.4	24
7	Electronics	0.7	7
8	Miscellaneous	1.8	18
	Total	10	100

Table 3.9: Composition of Day 4 sample 2 waste stream by mass (kg)

S/N	Components	Mass (kg)	Percentage (%)
1	Auto	-	0
2	Bio	1.0	10
3	Paper	4.0	40
4	Metal	0.7	7
5	Wood	-	0
6	Textile	2.1	21
7	Electronics	0.5	5
8	Miscellaneous	1.7	17
	Total	10	100

Table 3.10: Composition of Day 5 sample 1 waste stream by mass (kg)

S/N	Components	Mass (kg)	Percentage (%)
1	Auto	-	0
2	Bio	-	0
3	Paper	2.9	29
4	Metal	0.6	6
5	Wood	1,0	10
6	Textile	2.5	25
7	Electronics	-	0
8	Miscellaneous	3.0	30
	Total	10	100

Table 3.11: Composition of Day 5 sample 2 waste stream by mass (kg)

S/N	Components	Mass (kg)	Percentage (%)
1	Auto	-	0
2	Bio	1.0	10
3	Paper	3.9	39
4	Metal	-	0
5	Wood	-	0
6	Textile	2.6	26
7	Electronics	1.2	12
8	Miscellaneous	1.3	13
	Total	10	100

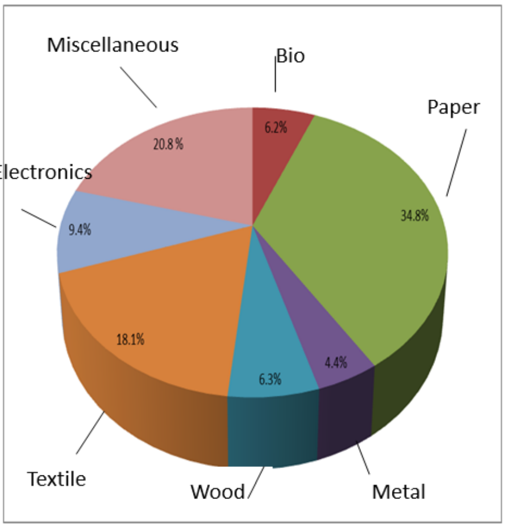

Figure 1: Municipal solid waste composition.

Table 3.12: Composition of total waste stream by mass (kg)

S/N	Components	Total sample size (kg)	Percentage (%)
1	Auto	0	0
2	Bio	6.2	6.2
3	Paper	34.8	34.8
4	Metal	4.4	4.4
5	Wood	6.3	6.3
6	Textile	18.1	18.1
7	Electronics	9.4	9.4
8	Miscellaneous	20.8	20.8
	Total	100	100

Table 3 .13: Estimated combustible fraction

Sample number	Fraction (f)
1	0.58
2	0.57
3	0.54
4	0.53
5	0.73
6	0.82
7	0.67
8	0.71
9	0.64
10	0.75
Average	0.65

Moisture Content of MSW in OAU

A previous study by Shukla *et al*. (2000) shows that waste having a moisture content of less than 45% will adequately support a thermo-chemical conversion plant. Cheremisinoff (2003), also reported that water content for municipal solid waste should be under 60% to be able to sustain an incineration without additional fuel. In this study, an average moisture content of 19.04% was obtained. Table 3.14 shows the experimental results of moisture and energy values of the collected samples. This means that the waste collected can be used as fuel to feed a thermo-chemical plant (incineration, pyrolysis or gasification) since the values recorded by this study fall within the specified range (Yao *et al*., 2023).

Table 3.14: Calorific values and moisture content of MSW

S/N	Fraction (f)	Combustible %	Moist. content % (wb)	Calorific Value MJ/kg
1	0.580	58	17.86	10.788
2	0.570	57	16.67	10.794
3	0.540	54	21.00	10.744
4	0.530	53	18.95	10.765
5	0.730	73	19.08	10.760
6	0.820	82	24.90	10.720
7	0.670	67	16.23	10.812
8	0.710	71	19.69	10.755
9	0.640	64	20.00	10.750
10	0.750	75	16.00	10.826
Av	0.654	65.4	19.04	10.771

Calorific Values of MSW in OAU

Calorific values or heating values that ranged from 10.760 to 10.826 MJ/kg were obtained (Table 4.14). According to a report by the World Bank, (1999). The average lower calorific value of the waste must be at least 6000 kJ/kg throughout all seasons and the annual average value must not be less than 7000 kJ/kg. Rand *et al*., (2000) also reported that calorific value for incinerated waste should not fall lower than 6000 kJ/kg, otherwise additional fuel is necessary to maintain efficient combustion and the lower heating value required for the waste to combust without the addition of other fuel is 7000 kJ/kg. The heating values (calorific values) of the solid waste collected from the study area are greater than the standard values for incineration of waste as fuel hence, the solid waste can be used as fuel for a thermo-chemical conversion.

Energy Analysis

By considering the characteristics of MSW, its energy recovery in terms of combustible fraction and calorific value, the power generation potential can be estimated as

$$PGP = \eta \times Q_c \times NCV \times 0.049 \text{ MW}$$

$$Q_c = 0.654 \times 4.361 \text{ ton/day}$$
$$Q_c = 2.852 \text{ ton/day}$$
$$PGP = 0.25 \times 0.048 \times 2.852 \times 10.771$$
$$PGP = 0.376 \text{ MW} \approx 0.4 \text{ MW}$$

This study revealed theoretically that the quantity of power that can be generated based on 4.4 tons of waste collected per day, with a minimum conversion efficiency of 25%, as reported by Amber *et al*. (2012). It is 0.4 MW, which can be utilised for direct thermal applications or for producing power via steam turbine generators. This fact explained the feasibility and desirability of the use of solid wastes for power generation in OAU, Ile-Ife, Nigeria.

CONCLUSIONS

This study highlights the potential of municipal solid waste (MSW) from Obafemi Awolowo University (OAU), Ile-Ife, as an alternative energy source. With an estimated 4.4 tons of waste generated daily, characterization revealed that paper constituted the largest fraction (34.8%), reflecting the institution's academic activities. The average moisture content was 19.04%, with a calorific value of 10.771 MJ/kg, indicating viability for energy conversion. At a conversion efficiency of 25%, approximately 0.4 MW of power could be generated daily, supplementing OAU’s peak demand of 5 MW. Implementing waste-to-energy technologies could enhance sustainability, reduce environmental pollution, and promote renewable energy use. This study underscores the importance of harnessing MSW for electricity generation, offering a practical solution for waste management and energy security.

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