Clean energy generation and material recovery potentials from solid wastes generated in Omu Aran community

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Abstract. The present method of waste disposal in Omu Aran is a direct open dumping and burning at various unapproved dumpsites. The study was conducted at selected five major dumpsites within Omu Aran community, to investigate the existing waste management systems, characterize solid wastes generated, and estimate the rate of solid waste generation. An exploratory study design was adopted for a period of one year, January 2018 to January 2019. Five (5) randomly selected spots of 1 sq.m were located on each of the five (5) major dumpsites in Omu Aran. For each of the dumpsites, solid wastes were collected from top to the depth of 300 mm in each of the five (5) selected one-sq.m spots. Estimated waste generated was about seventy-four tons (73,744.92 kg) with generation rate of 0.496 kg/person. Total amount of material recyclable was about thirty-two tons (32,447.76 kg; about 44%) and energy recovery material, to attain zero-waste, integrated waste management scheme was over forty one ton (41,297.16 kg; about 56%). The combustible components of solid waste generated in Omu Aran community (kg/day), energy content (kJ/day) and electricity generation potential (MW) were presented. Estimated energy content of solid wastes from the Omu Aran dumpsite was 1097.999 GJ/day. This implies that there is possibility of electricity generation up to 12.708 MW from daily steam production. Considering the high material recyclability, reusability and energy recovery potentials from solid wastes generated in Omu Aran community, it was recommended that the Irepodun Local Government Authority adopts sustainable and integrated waste management options of waste minimization from the source, reuse, recycling of solid waste generated within the large community.

1. Introduction
Population growth, urbanization and economic development are the factors which contribute to increasing in wastes generation in African Urban Cities and overburdening waste management systems [1]. Advancements in science and technology, increasing consumption of resources has culminated into accumulation of large amounts of solid waste ranging from domestic to agricultural and up to industrial activities, with increased toxicity and hazards which have threatened public health [2, 3].
Uncontrolled population, community density, consumption habits, standard of living, monthly wages, dwelling population, percentage of urban population, age, sex, ethnicity, size of housing units, geographical locations, land use patterns, productive activities and cost of living are some common factors that have the influence on waste generation, with population being the major factors influencing unit waste generation rate [4]. Estimation of the quantity of solid waste generated in a city is very important for proper solid waste management. While most developed countries regarded their wastes as resources, poor waste management became challenging issue with governments of developing countries resulting into enormous tasks in terms of collection and disposal, making solid waste hazardous, in most developing countries. Improper waste management has become serious concerns for experts from cities in the developing states [5, 6, 7, 8].

Waste management services which involve collection of waste and transportation to final disposal, is carried out, in most developing countries, by the local authorities, but was stalled by inadequate financial assistance and human resource capacity. These hindered effective waste management service [9], amounting to serious problems that impair human and animal health and ultimately result into economic, environmental and biological losses [10]. Some factors affecting effective municipal waste management in Nigeria are poor funding and uncontrolled population, lack of trained/professional waste managers [11], ineffective monitoring and control, inadequate maintenance culture towards the environment, lack of modern technology/lethargy in implementation of efficient waste management methods. Recovering energy from the waste can be better means of managing environmental pollution caused by municipal waste disposal.

Urbanization in African countries is increasing annually resulting to the generation of volumes of wastes. Municipal Solid Waste (MSW) is one source of renewable energy resource which is replenished in African urban areas due to the poor waste management in these areas [12]. One of the waste management approach is to convert waste into useful energy applications. According to [13] the following technologies can be used to convert waste into useful energy applications these are pyrolysis process, gasification process, plasma arc gasification process, incineration, /and filling, anaerobic digestion and refuse derived fuel [13, 14, 15].

Waste can be converted directly into energy in form of biogas, syngas and heat. These conversions can be done through physical, thermal and biological methods. According to [16], environmental impacts, technical aspects and socio-economic factors are the three factors which influence waste to energy technology. In Omu Aran community, the common practice of waste management basically involves the direct disposal to nearby dumping sites. Solid waste management may as well hold the key to reducing the rate of environmental pollution/degradation while improving development rate. There exists ineffective waste management, inappropriate waste disposal methods, value addition loss in forms of material recovery, reuse and energy derivation. [15] stated that most of the municipal solid wastes in developing countries are left uncollected so the first option would be to achieve 100% collection rate prior to other waste to energy options. It was also mentioned that most of the less developed countries the facility of waste management is not available to all the people in the community.

This research aimed at studying the solid waste characterization in Omu Aran major dumping sites, with the view of converting solid wastes generated into useful energy resource, in order to recommend appropriate waste collection and disposal methods that support integrated waste management concept.

1.1 Description of study area
This study was conducted in Omu-aran, a Local Government Headquarters located in the southern part of Kwara State, Nigeria and a home to two different privately owned universities namely: Orimolade University and Landmark University (LMU), with potentials for massive expansion and growth. It is an indigenous town that lies between 8° 08' 00" North, 5° 06' 00" East of prime meridian [17]. The population of the town according to the 2006 population census is 148,610 [18]. The climate of Omu Aran is tropical with average annual temperature of 24.9 °C, with annual precipitation of 1273 mm. The
The driest month is January, with 9 mm of rainfall. The average rainfall recorded in September is 235 mm [19].

2. Materials and Methods

The study was conducted in Omu Aran community, with the field work, comprising of reconnaissance survey to have general overview of major dumpsites in the study area; temporary collection and sorting points to observe the physical conditions regarding quantity and quality of solid wastes.

The community was divided into five areas based on location of the major dumpsites selected for assessment of solid waste generation, separation and waste classification and their characteristics. These are Ajisafe area (AA), Behind Muslim School (BMS), Sabo area (SA), Odo eran area (OEA) and Government College School (GCS).

2.1 Collection of the primary data

After securing permissions from appropriate quarters, an exploratory study design was adopted. The study involved physical characterization of solid wastes at the five (5) major dumpsites in the community for a period of one year, January 2018 to January 2019. Five (5) randomly selected spots of 1 sq.m were located on each of the five (5) major dumpsites in Omu Aran. For each of the dumpsites, solid wastes were collected from top to the depth of 300 mm in each of the five (5) selected 1 sq.m spots.

The collected wastes were manually separated characterized, and weighed accordingly. The mean values (n=5) and standard deviations of waste components from the five spots were calculated using descriptive statistics analysis and total estimated waste quantity (using the estimated area covered by each dumpsite) was calculated for each of the five (5) dumpsites. Wastes materials were weighed, sorted into material types which include paper, cardboard, plastic bottles, metals, cans, food wastes, polythene bags, e-wastes, sanitary and ash residuals.

Waste categories were weighed to obtain the weight-based characterizations for the waste components. Sorting into major waste categories was in accordance with College and University Recycling Council [20] grouping system, with modifications to accommodate peculiar waste stream generated on campus.

The total waste generated was determined by adding the weight of all components, while the estimated amount of waste generated per person was got by dividing the total estimated waste generated by the community population figure. Collected primary data was analyzed using SPSS statistical tools and techniques.

3. Results and Discussion

3.1 Solid waste generation at Ajisafe area

The estimated solid waste generated at Ajisafe area dumpsite, as shown in Table 1 was 9,853.92 kg (13.36 % of total solid waste in Omu Aran). Metals were the most generated component of solid waste with an average generation of 2565 kg, followed by wood, leather, and plastic, with dead animals as the least generated with values, 1246.86 kg, 1217.97 kg, 988.2 kg, and 93.96 kg respectively. The categories of waste have recycling, reusable, and energy recovery values.

3.2 Solid waste generation behind Muslim School

Total solid waste generated at this dumpsite location was 18045.00 kg (24.47 % of total solid waste). Metals were the most generated component of solid waste with an average generation of 4046.85 kg, followed by wood (3468.6 kg), leather (2995.2 kg), rags (2119.95 kg), and least in dead animals (110.25 kg) and e-wastes (105.75 kg). The dumpsite possesses significant amount of waste useful in energy recovery.

3.3 Solid waste generation around Sabo area
The dumping site located at the Sabo area of Omu Aran has the highest quantity of solid waste accumulation with an estimated value of 28035.00 kg (38.01 % of the total waste). Plastic was the most generated component of solid waste with percentage generation of 21.98 %, followed by metals (18 %), wood (12.69 %), leather (11.22 %), e-wastes (8.62 %), and least, dead animals (0.22 %). Metal waste were majorly from metal scrap business, can drinks, milk cans, and other canned foods. Plastic and metal recycling are highly feasible from this site. Element separation and recovery is possible from e- wastes, such as used electronics.

3.4 Solid waste generation at Odo Eran area

Total estimated solid waste generated at the dumpsite in this area was 13905.00 kg (18.88 % of the total estimated waste accumulated from Omu Aran major dumpsites). Metals were mostly generated components of solid waste with an average generation of 3069 kg, followed by wood (2787.30 kg), leather (2052 kg), and plastic (1176.30 kg) and rags (1170 kg), with dead animals as the least generated with value (45 kg). The wastes have potentials for reuse, recycling, and energy recovery values.

3.5 Solid waste generation around Government College School

It was shown from Table 1, that this is the dumping site with the least generated waste 3906.00 kg (5.3 % of the total estimated solid wastes from Omu Aran dumpsites). Metals were mostly generated components of solid waste with an average percentage generation of 21.7%, followed by wood (15.3 %), rags (14.77 %), leather (8.94 %), paper (6.61 %) and plastic (6.2 %) with dead animals as the least generated (1.0 %). The wastes possess potentials for reuse, recycling, and energy recovery values.

3.6 Total solid waste generated from major dumpsites from Omu Aran

Total solid waste generation in Omu Aran (which comprised of solid wastes accumulated from the five major dumping sites) was 73744.92 kg (Table 2), with waste generation rate of 0.496 kg/person (Table 3), considering estimated Omu Aran population of 148,610 [18]. Estimated solid waste generation from major dumping sites in Omu Aran ranged between 3906 kg (5.3%) to 28035 (38%). Figure1 presented total solid waste composition and quantity (kg) from Omu Aran dumpsites, while figure 2 showed solid waste characterization by percentage (%).

Generally, metal wastes, majorly from metal scrap business, can drinks, milk cans, and other canned foods appeared the highest (21.18 %) in comparison to other solid wastes. This might be due, majorly to the nature of the business and high consumption of can drinks and can packaged products in Omu Aran town, especially in Sabo, behind Muslim school and Odo eran areas and environ.

Woods and wood wastes are second highest waste generated (15.86 %). Woods and wood wastes were also prevalent in Omu Aran and major factors responsible for this was a large expanse of Government forest reserve and the establishment of small and medium scale sawmills businesses. A leather waste (13.28 %) was due to the indigenous leather bag and shoe making businesses. [21] reported the use of leather waste materials in concrete for construction purpose as to reduce pollution and disposal problem resulting in less landfill pressures and reducing demand of
| Omu-Aran Bumping Sites | Ajisafe Area (AA) | Behind Muslim School (BMS) | Sabo Area (SA) | Odo Eran Area (OEA) | Govt College School (GCS) |
|------------------------|-------------------|--------------------------|---------------|-------------------|--------------------------|
|                         | %waste composition | %waste composition | %waste composition | %waste composition | %waste composition |
| Descriptive Statistics | Mean (g/sq.m) (n=5) | Std. Deviation | Mean (g/sq.m) (n=5) | Std. Deviation | Mean (g/sq.m) (n=5) | Std. Deviation | Mean (g/sq.m) (n=5) | Std. Deviation | Mean (g/sq.m) (n=5) | Std. Deviation |
| Paper                  | 259.00            | 156.14          | 322.80        | 155.44          | 286.80        | 178.74          | 391.60        | 115.88          | 287.00        | 97.95           | 6.61          |
| Plastic                | 732.00            | 704.99          | 339.60        | 319.62          | 1956.40       | 144.25          | 522.80        | 189.47          | 269.00        | 249.96          | 6.20          |
| Nylon                  | 176.20            | 100.91          | 185.40        | 116.48          | 214.20        | 144.25          | 148.20        | 91.02           | 184.00        | 41.59           | 4.24          |
| Metals                 | 1900.80           | 1903.87         | 1798.60       | 1486.65         | 1601.00       | 1287.66         | 1364.00       | 1700.16         | 942.00        | 922.03          | 21.71         |
| Rags                   | 703.00            | 558.60          | 942.20        | 599.56          | 567.00        | 542.08          | 520.00        | 314.56          | 641.00        | 183.45          | 14.77         |
| Sanitary wastes        | 692.00            | 1547.36         | 709.60        | 1300.95         | 502.40        | 871.22          | 176.00        | 260.54          | 194.00        | 296.11          | 4.47          |
| Leather                | 902.20            | 684.26          | 1312.0        | 826.31          | 999.00        | 773.95          | 912.00        | 449.48          | 388.00        | 361.00          | 8.94          |
| Wood                   | 923.60            | 897.85          | 1541.60       | 1461.70         | 1129.20       | 1458.33         | 1238.80       | 797.20          | 664.00        | 414.28          | 15.30         |
| Ash                    | 312.40            | 318.81          | 588.40        | 449.78          | 671.40        | 539.06          | 444.20        | 281.51          | 224.00        | 147.92          | 5.16          |
| E-wastes               | 398.80            | 384.85          | 47.00         | 105.10          | 766.80        | 474.61          | 162.00        | 172.39          | 280.00        | 257.29          | 6.46          |
| Food wastes            | 230.40            | 222.76          | 164.80        | 203.96          | 185.80        | 207.50          | 280.40        | 184.92          | 223.00        | 250.29          | 5.14          |
| Dead animals           | 69.60             | 97.06           | 49.00         | 109.57          | 20.00         | 44.72           | 20.00         | 44.72           | 60.66         | 1.00           |
Table 2. Estimated total solid waste quantity from major dumpsites in Omu Aran

| Omu-Aran Bumping Sites with estimated area covered in sq.m (m²) | Ajasafe Area (AA) | Behind Muslim School (BMS) | Sabo Area (SA) | Odo Eran Area (OEA) | Govt College School (GCS) |
|---------------------------------------------------------------|-------------------|---------------------------|----------------|---------------------|---------------------------|
| Mean (g/sq.m) | Total (kg) | Mean (g/sq.m) | Total (kg) | Mean (g/sq.m) | Total (kg) | Mean (g/sq.m) | Total (kg) | Mean (g/sq.m) | Total (kg) |
| Paper | 259.00 | 349.65 | 322.80 | 726.30 | 286.80 | 903.42 | 391.60 | 881.10 | 287.00 | 726.30 |
| Plastic | 732.00 | 988.20 | 339.60 | 1956.40 | 6162.66 | 522.80 | 1176.30 | 269.00 | 242.10 |
| Nylon | 176.20 | 327.87 | 211.95 | 520.00 | 1531.15 | 1364.00 | 3069.00 | 942.00 | 24.2 |
| Metals | 1900.80 | 2565.00 | 4046.85 | 1601.00 | 5043.15 | 1364.00 | 3069.00 | 942.00 | 24.2 |
| Rags | 702.00 | 2565.00 | 1798.80 | 5043.15 | 1364.00 | 3069.00 | 942.00 | 24.2 |
| Sanitary wastes | 692.00 | 949.05 | 709.60 | 1596.60 | 5043.15 | 1364.00 | 3069.00 | 942.00 | 24.2 |
| Leather | 902.00 | 1217.97 | 2313.20 | 5043.15 | 1364.00 | 3069.00 | 942.00 | 24.2 |
| Wood | 923.60 | 1246.86 | 1541.60 | 3566.98 | 1238.80 | 2787.30 | 664.00 | 216.30 |
| Ash | 312.40 | 421.74 | 588.40 | 1238.80 | 2787.30 | 664.00 | 216.30 | 24.2 |
| E-wastes | 398.80 | 538.38 | 47.00 | 105.75 | 2415.42 | 162.00 | 364.50 | 280.00 | 25.2 |
| Food wastes | 230.40 | 311.04 | 164.60 | 370.35 | 1582.56 | 176.00 | 396.00 | 194.00 | 176.60 |
| Dead animals | 69.60 | 93.96 | 49.00 | 110.25 | 364.50 | 280.00 | 63.00 | 45.00 | 39.60 |
| Total | 7299.20 | 9853.92 | 8020.00 | 18045.00 | 28035.00 | 6180.00 | 13905.00 | 4340.00 | 3906.00 |

Estimated Total waste generated by waste composition (kg) | Estimated Total waste generated by waste composition (%) |
**Figure 1.** Total solid waste composition (kg) from Omu aran dumping sites

**Figure 2.** Total solid waste characterization by percentage (%) from Omu aran dumping sites
extraction. Plastic bottles (12.7%) and low generated volume of polythene bags (water sachets, 2.49%) were recorded, despite few water production factories situated within the town and environs.

[22] reported high volume of polythene bags as being the second largest waste after organics in some municipals in Nigeria. Desire to have potable water at reduced cost was also responsible for the high volume of sachet water, according to [23].

Food wastes (2.85%) and dead animals (0.47%) were among the least generated solid wastes in Omu Aran. These wastes may pose environmental and health challenges with the potential to release greenhouse gases and attract vectors, if not properly disposed [24]. [25] suggested three uses of organic wastes as composite production, energy generation and composting for soil nutrient, for effective organic waste management. [24] reported food waste composting programme at Camosun College, Victoria, British Columbia. Anaerobic digestion of food waste has been reported to have approximately, three times the methane production potential by volume than municipal wastewater solids [26].

Others were paper and paper products (3.93%), rags and sanitary wastes (8.98 and 6.37%) respectively, e-wastes (5.00%) and ashes (6.89%).

3.7 Physical combinations of solid wastes for recyclability potential and energy recovery

Table 4 and figure 3 showed the zero-waste concept and analysis of value addition to waste generated in Omu Aran. About Seven percent (7.24%) amounting to over 5 tonnes of waste generated were derived from food wastes, paper and paper products, and dead animals and these categories of waste could be aerobically or anaerobically digested to produce compost (organic fertilizer) or bio-fuel. This result is in line with findings of [15, 17, 27]; that large portion of solid wastes is composed of organics (fruit wastes, vegetable and food wastes).

The recyclables (polythene bags, plastic bottles, metal cans and glass) constituted 36.25% (about 27 tonnes) of solid waste generated in Omu Aran. This agreed with studies by [24, 28] of 34% and 28.2% respectively. It showed that the community has a better recyclability potential.

About fifty percentage (49.34%; over 36 tonnes) of the total solid wastes could be incinerated. These were leathers, e-wastes and sanitary pads, diapers, textiles, rags and woods. Thermal energy generated could be converted and reused. Ash produced from incineration process could be combined with residuals ash from cafeteria and bakeries (7.18%, over 5 tonnes) and disposed of to landfill or for reuse as alkaline solution to address soil acidity and other soil enhancement and treatment for agrarian policy, as non-recyclable waste. This result was different from the findings in Dhaka city solid waste generation where non-recyclable waste is 70-80% [29, 30]. According to [31], bottom ash has potential to be used in various applications, after specific treatments for each application, as depicted in It is presently used for certain applications such as in road construction, cement production as additive, concrete production as aggregate etc.

Integrated solid waste management approach adoptable to Omu Aran community was presented in table 4 and displayed in figure 4. Zero waste concept of about 44% waste material recyclable (composting, bio-fuel production and recyclables) and 56% energy recovery material (electricity generation, incineration-derived ash and residual ash for landfilling or soil enhancement).

The combustible components of solid waste generated in Omu Aran (Kg/day), energy content (kJ/day) and electricity generation potential (MW) was presented in table 5. The combustible components of solid waste generated in Omu Aran community (kg/day), energy content (GJ/day) and electricity generation potential (MW) were presented. Estimated energy content of solid wastes from the Omu Aran dumpsite was 1097.999 GJ/day. This implies that there is possibility of electricity generation up to 12.708 MW from daily steam production.

With the calorific value of waste in the present work, waste utilization as an alternative renewable energy source is reflected as free source and therefore it is economical to use waste as source of energy. This proves to be a source of clean energy for electricity production.
Table 3. Summary of Estimated total solid waste quantity from major dumpsites in Omu Aran

| Major Dumpsites in Omu- Aran Town | Estimated Waste generated (kg) | (%) |
|----------------------------------|-------------------------------|-----|
| Ajisafe Area (AA)                | 9853.92                       | 13.36 |
| Behind Muslim School (BMS)      | 18045.00                      | 24.47 |
| Sabo Area (SA)                  | 28035.00                      | 38.01 |
| Odo Eran Area (OEA)             | 13905.00                      | 18.86 |
| Govt. College School (GCS)      | 3906.00                       | 5.30 |
| **Total Waste generated (kg)**  | **73744.92**                  | **100.00%** |
| **Total Population in Omu- Aran [18]** | **148610**                   |     |
| **Waste generated rate**        | **0.496 kg/head**             |     |

Table 4. Zero waste concept and value addition analysis to waste generated in Omu Aran

| Value Addition | Waste components | Ave Waste (kg) generated | % waste generated | Zero Waste Concept |
|----------------|------------------|--------------------------|-------------------|--------------------|
|               | Paper            | 2885.67                  |                   |                    |
|               | Food wastes      | 2098.26                  |                   |                    |
|               | Dead Animals     | 351.81                   |                   |                    |
| **Sub total** |                  | **5335.74**              |                   |                    |
|               | Plastics (water bottles) | 9333.36 |                   |                    |
|               | Polythene (water sachet, nylons) | 1828.80 |                   |                    |
|               | Metals (tins, cans bottles) | 15571.8 |                   |                    |
| **Sub total** |                  | **26733.96**             |                   |                    |
|               | Rags             | 6601.95                  |                   |                    |
|               | E- wastes        | 3676.05                  |                   |                    |
|               | Sanitary (diapers, pads, rags) | 4685.96 |                   |                    |
|               | Leathers         | 9761.22                  |                   |                    |
|               | Woods            | 11657.34                 |                   |                    |
| **Sub total** |                  | **36382.52**             |                   |                    |
| Reuse         | Residuals (ashes) | 5292.70                  | 7.18              |                    |
| **Total**     |                  | **73744.92**             | **100.00**        | **100%**            |
**Table 5.** The combustible components of solid waste generated in Omu Aran (kg/day), energy content (kJ/day) and electricity generation potential (MW)

| S/N | Combustible Components | % Composition | Moisture content | Quantity of MSW generated (kg/day) | Specific Energy Content (kJ/Kg) | Total Energy Content (GJ/day)* | Electricity generation Potential (MW)* |
|-----|------------------------|--------------|-----------------|-----------------------------------|-----------------|-----------------------------|-----------------------------|
| 1   | Paper                  | 3.93         | 5.57            | 2885.67                           | 12975.42        | 37.443                      | 0.4334                      |
| 2   | Plastic                | 12.70        | 1.80            | 9333.36                           | 31246.63        | 291.636                     | 3.3754                      |
| 3   | Metals                 | 21.18        | -               | 15571.80                          | 558.56          | 8.698                       | 0.1007                      |
| 4   | Nylon                  | 2.49         | 1.82            | 1828.80                           | 29084.24        | 53.189                      | 0.6156                      |
| 5   | Rags                   | 8.98         | -               | 6601.95                           | 17445           | 115.171                     | 1.3330                      |
| 6   | Sanitary wastes        | 6.37         | -               | 4685.96                           | 15119           | 70.847                      | 0.8200                      |
| 7   | Leather                | 13.28        | -               | 9761.22                           | 19771           | 192.989                     | 2.2337                      |
| 8   | Wood                   | 15.86        | 49.40           | 11657.34                          | 17243.56        | 201.014                     | 2.3266                      |
| 9   | Ash                    | 6.89         | -               | 5061.60                           | 17243.56        | 87.280                      | 1.0102                      |
| 10  | E-wastes               | 5.00         | -               | 3676.05                           | -               | -                           | -                          |
| 11  | Food wastes            | 2.85         | 35.90           | 2098.26                           | 14360.49        | 30.132                      | 0.3488                      |
| 12  | Dead animals           | 0.47         | -               | 351.81                            | 4575.10         | 9.600                       | 0.1111                      |
|     | **Total**              | **100 %**    |                 | **73744.92**                      |                 | **1097.999**                | **12.708**                  |

*1J/day = 1.15740741 \times 10^{-5}W

**Figure 3.** Zero waste concept and analysis (%) for Omu Aran solid waste management
4. Conclusions

Waste is not well managed in Omu Aran. There is no proper collection, transportation, recycling and waste to energy processes going on in the local government headquarters. The disposal of wastes by open dumps is not effective as it pollutes the environment and does not explore the full recycling potentials of the community solid waste.

Due to the kinds and nature of businesses coupled with the standard of living among Omu Aran community, especially as affected by situation of the University; metal wastes, majorly from can drinks, milk cans, and other canned foods appeared the highest, followed by woods and wood wastes generated from small and medium scale sawmills businesses. Next was leather waste due to the indigenous leather bag and shoe making businesses? In addition, was low generated volume of plastic bottles and polythene bags (water sachets), despite few water production factories situated within the town and environs, and this may be as a result of plastic bottle reuse. These are all recyclable materials. Food wastes and dead animals were among the least generated solid wastes in Omu Aran.

These wastes pose environmental and health challenges with the potential to release greenhouse gases and attract vectors, if not properly disposed. Organic wastes which included food, vegetables, fruits and paper wastes have compostable potential when combined with other agricultural animal wastes.

The huge quantities of solid wastes generated are all alternative sources of clean energy and electricity generation. The material recovery potential-recyclable material and energy recovery potentials- of solid wastes from Omu Aran dumpsites, for recycling and re-use are very high.

5. Recommendations

The following measures, according to [15] are recommended for the integrated approach towards waste management in Omu Aran:

i. In order to improve the solid waste management situation in Omu Aran community, there should be proper strategies in the future for reduction, recycling, long term waste management
policies, involvement of private sector and a proper formal waste management system in which all the stakeholders are involved.

ii. Public campaigns and awareness among people about waste management should be created especially at the school level.

iii. Initial steps should be set to reduce the amount of waste with the involvement of the people, at source separation, 100% collection rate and then waste to energy projects if possible or sanitary landfills.

iv. Government should provide subsidies on waste to energy plants in order to attract foreign investors.

v. Specific waste to energy technologies should be compared and the one that suits the municipal solid waste composition in Omu Aran should be applied.

vi. Weight bridges should be installed at the landfill sites in order to get the exact amount of waste and more studies should be carried out on the waste characterization in other cities.

vii. A proper statistical department or unit which would get all the reliable data from local departments and analyze it for future development projects.

viii. There should be proper monitoring so that there is proper, collection, storage, transport of waste and there is no leaching from the landfills and the emissions from waste to energy projects are safe.

ix. Highly qualified officials should be appointed at the local SWM departments who have a better understanding of the local problems and the capacity to solve them.

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