Available online at www.worldnewsnaturalsciences.com

World News of Natural Sciences

An International Scientific Journal

WNOFNS 36 (2021) 75-87 EISSN 2543-5426

Sustaining a Healthy Environment whilst Utilizing Wastes as Energy Sources: Physicochemical Analysis of Solid Wastes in Awka, Nigeria

Emmanuel Onyenweife Ayadinuno[1,*], **Uzoma Benedict Njoku**[2] and **Ozioma Udochukwu Akakuru**[3,*]

[1]Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University, Awka, Nigeria

[2]Safety Council of Southwestern Ohio Middletown, OH, USA

[3]Department of Pure and Applied Chemistry, University of Calabar, Calabar, Nigeria

*E-mail address: emmaonyenweife@gmail.com , ozioma@nimte.ac.cn

ABSTRACT

The physicochemical properties of solid wastes were determined to unravel the individual components of solid wastes such as density, moisture content, and percentage mass. The chemical composition of each waste component was also determined. Methods adopted in the determination included the load count and mass volume methods, the proximate and ultimate analysis method. Collectively, the percentage chemical constituents were obtained from the different solid waste samples analyzed. Energy values obtained from the constituents are 47.6 and 47.10 kJ/kg when Dulong's and Davies' formula were applied, respectively. The results revealed that paper and cardboard, metals, plastics, and wood make up the highest composition in the five major waste dumpsites studied in Awka, Nigeria. It also showed that carbon and oxygen contents are high in most of the solid waste components when compared to other chemical constituents and that these wastes can be converted to useful energy in furtherance of sustainable development.

***Keywords*:** solid wastes, proximate analysis, ultimate analysis, elemental content

(Received 16 February 2021; Accepted 06 March 2021; Date of Publication 07 March 2021)

1. INTRODUCTION

Solid wastes refer to those wastes arising from human and animal activities which are discarded as useless or unwanted [1]. They include discarded and abandoned appliances and junk matters [2]. The physical states of such wastes are solid or semi-solid. Most of the solid wastes are grouped together as rubbish; a term meaning all non-decomposing wastes which includes cans, glass, scrap metals, discarded roofing materials [3]. In some instances, the waste materials may contain high percentage moisture [4]. The major sources of solid waste include residential, commercial, institutional, and industrial activities [5]. Some waste types cause immediate danger on exposure to individuals or the environments [6]. Such wastes are said to be hazardous [7].

The non-hazardous solid wastes that requires collection from the community and subsequent transportion to a processing or disposal site are called refuse or municipal solid waste (MSW) [8]. Refuse is a term used in describing garbage and rubbish [9]. While garbage is mainly decomposable food waste and hence putrescible, rubbish is mainly dry material such as glass, paper, plastic cloth, or wood, hence highly non-putrescible [10]. Trash on the other hand, is rubbish that is made up of bulky items such as discarded metal parts, old refrigerators, couches, or large tree stumps requiring special collection and handling [11].

The high rise in MSW in the speedily growing town/cities of developing countries have led to growing public concerns on the resulting health and environmental effects of such wastes [12]. Currently, solid wastes of over 3 billion people are still being disposed of in an un-regulated manner worldwide [12]. In major Nigerian cities, solid wastes have been so randomly abandoned that it has become nuisance to city inhabitants [10]. In Awka, the capital city of Anambra State, Nigeria, where this study was conducted, solid wastes are seen almost everywhere on the major streets and market places as a result of open dumping of wastes without due considerations on the effects of such wastes on the populace. The methods of open dumping in an uncontrolled manner are also common in many other urban cities in Nigeria where wastes are seen in open drains, streams, market places, uncompleted structures, abandoned rail tracks, channels and gutters [10].

Such random dumping of wastes ends up providing breeding ground for mosquitoes, rats, rabbits and other organisms constituting health hazards, wide spread of malaria, scabies and so on [3]. It equally leads to traffic congestion and flooding as a result of highways and waterways blockages, respectively.

Garbage materials arising from human or animal activities which are abandoned and regarded as not useful and unwanted are referred as solid wastes [3]. Collectively, it is generated from industrial, residential and commercial activities in a given area or community, and can be handled in a variety of ways [5]. Normally, waste can be classified based on materials that made it up such as paper, plastic, glass, metal and organic waste [13]. Solid waste disposal must and ought to be managed systematically to ensure environmental best practices [14]. Solid waste disposal and management is a very important aspect of environmental hygiene and needs incorporation into environmental planning strategies [15-17].

Solid waste disposal and management includes planning, administrative, financial, engineering and legal functions [18]. It is typically the job of the generator, subject to local, national and even international authorities [19]. Solid waste disposal management is referred to as the process of collecting and treating solid wastes [20]. It provides solutions for recycling items that do not belong to garbage or trash [15,16]. Solid waste management can be described as how solid waste can be converted and used as a valuable resource for the benefits of all [13].

Improper disposal of municipal solid waste usually creates unsanitary conditions, and these conditions in turn lead to polluting the environment [4,19]. Diseases spread by rodents and insects feasting on the dumped wastes become rampant [21]. The duties of solid waste disposal management are enormous with its complex technical challenges [10]. They can also pose a wide range of economic, administrative and social problems that must be identified, avoided and solved [3]. To get rid of solid wastes, many countries are working on developing their waste management agencies based on the 3Rs concept in the order of "reduce, reuse and recycle" [9-11].

The first point of consideration in waste management is the overall reduction of solid waste quantities such as food waste, packaging materials, unnecessary and careless waste of raw materials and energy loss during production processes [9]. Reducing waste significantly helps to reduce the cost of waste collection and its treatment [22]. The second point is given to the reuse of disposed waste materials in which a discarded or an abandoned product is cleaned and repaired for use again [10]. The third point in the 3Rs concept of waste management is to recycle the waste materials [18,21]. Recycling involves collection of waste and transforming it into a secondary raw material [10]. Recycling of solid waste materials such as plastic or paper usually save more energy in productions of products [11,13].

Other waste management practices include: (a) solid waste open burning, (b) sanitary landfills, (c) incineration, (d) composting, (e) fermentation or biological digestion, (f) hog feeding, (g) ploughing into fields, (h) salvaging, and (i) sea dumping process involving dumping of solid wastes in water body occurring mainly in the coastal cities [18-22]. Sea dumping procedure is very costly and environmentally unfriendly [18]. Solid wastes sanitary landfills in which layers of wastes are compressed with some mechanical equipment are covered with earth, leveled, and compacted [20]. In this process, a deep trench of about 3 to 5 m is excavated and micro-organisms act on the organic matter thereby degrading them while facultative bacteria hydrolyze complex organic matter into simpler water soluble organics [22]. Solid wastes sanitary landfills process is considered to be simple, effective and clean [5,19]. Incineration method is suitable for combustible refuse in crowded cities where sites for land filling are not available [21]. Its only shortcomings are the required high operation and construction costs. It can conveniently be used to reduce the volume of solid wastes for land filling [18].

Composting process involves open window composting and mechanical composting. It is a process in which decomposable organic matter is separated and made into compostes.[20]. The process is similar to sanitary land-filling and is most commonly used in developing countries [8]. Yields from compositing are very stable and good soil conditioners and can commonly be used as a base for fertilizers in crop cultivation [1,16]. Fermentation or biological digestion involves biodegradable wastes which are converted to compost and recycling can be done whenever possible [19]. Disposal by hog feeding whereby refuse is ground well in grinders then can be fed into sewers for disposal [20]**.** Salvaging procedure involving materials such as metal, paper, glass, rags, certain types of plastic and so on can be salvaged, recycled, and reused [22]. Disposal by ploughing into the field is a very uncommon process as it is not environmentally friendly [21].

There are several benefits of converting solid wastes to energy [3,4]. Some of the benefits that can be derived by converting solid wastes to energy include [3] electricity and heat generation from waste, giving an alternative source of energy [4]. On estimated a ton of waste can produce about 550 to 700 kilowatt hours; enough to power someone's home for almost a period of one month. Reduction of waste going to landfill and avoiding methane emissions from landfills involves converting solid wastes to energy considerably reducing the amount of waste entering landfills, which in turn control greenhouse gases and save valuable land [8]. Also the methane that would have been generated if it were sent to a dump would be avoided in the process. Utilization of by-products as fertilizers involves a process in which the by-products are obtained from some of the waste processes such as anaerobic digestion and are utilized as fertilizers which help in developing the nutrient content of the soil [1]. Recycling excess waste entails the technology used to transform waste into energy and also converts any metal remaining after combustion of wastes to further shrink the amount of unusable waste [15]. Reducing the dependence on fossil fuel will require converting waste to energy. This will reduce the reliance on energy imports and the environmental cost of transporting the energy by generating waste materials into energy [14].

Domestic harnessing of wastes leads to domestic energy production since there are tons of waste generated locally [14,22]. The wastes can be converted to energy and used at the place it was generated [5]. The benefit of useful conversion of wastes to energy to the local community would lead to the establishment of waste to energy processing plants [17]. When that is done, it would not only generate electricity but also jobs and the local community would benefit significantly [2]. The availability of waste to energy helps reduce fluctuations of price, resulting in stability of energy and its price. The process is the best in operating the latest pollution control facilities to clean and filter emissions, limiting their release into the environment, hence a green process [1,6]. In addition to the above reasons is the fact that indiscriminate dumping of solid wastes litters the environment, thereby polluting the soil, water and air environments leading to widespread of pathogenic diseases [2]. Leaching of dumped heavy metals and other organic matters to ground water causes much harm to humans and other animals [1].

In this study, the physicochemical properties of solid wastes collected at Awka, Nigeria were determined as a basis for predicting the potential of converting such wastes to energy generating hubs. This entailed a compendious evaluation of the individual elemental and physical components and energy values derivable from such wastes. These properties could provide insights into the beneficial application of such wastes, not only in the study area (Awka, Nigeria) but also pave the way for more appropriate waste conversion in various cities around the globe [23-30].

2. EXPERIMENTAL

2. 1. Collection of samples

70 kg of solid waste materials were collected from waste dumpsite in five different locations of Ifite dumpsite, Aroma dumpsite, Amawbia dumpsite, Nodu dumpsite and quarters dumpsite labelled A, B, C, D and E, respectively, for 7 days and then sorted out. Sorting was done to separate the solid waste samples into different components that make up the waste. The separated components were then placed in a cylindrical container of volume 1500 cm^3. Masses of each components were measured and readings taken.

2. 2. Determination of individual components

70.0 g of solid wastes were accurately weighed. The weighed samples were separated into the individual components using rake. The separated components were placed in a cylindrical container of known weight, height 29 cm and diameter 22 cm and then weighed separately.

2. 3. Determination of density

Accurately weighed solid waste samples were cut and placed on a cylindrical container of height 29 cm and diameter 22 cm. The density of each component was determined using the relation: density = $\frac{mass}{volume}$ with the volume of the cylinder given as $\pi r^2 h$, where r is the radius of the cylinder while h is the height.

2. 4. Determination of moisture content

5.0 g of each solid waste sample was accurately weighed into a crucible of weight 32.2 g and then placed in an oven maintained at 105 °C for 1 h until a constant weight was obtained. It was allowed to cool and reweighed to determine the loss in weight of the sample.

2. 5. Determination of volatile matter

5.0 g of each solid waste sample was accurately weighed into a crucible with a lid cover of weight 32.0 g. The crucible and the content were subjected to an oven heat source for 7 min. The setup was allowed to cool and then reweighed. Loss in weight during the short time interval gave the volatile matter present in the waste.

2. 6. Determination of ash content

10.0 g of solid waste samples were weighed into a dry crucible and carefully ignited. The weight of crucible and sample was determined prior to the ignition. The content was allowed to cool after 2 min to ensure complete combustion and then reweighed. The differences in weight of the sample plus crucible before and after burning were used as the ash content of the solid waste samples.

2. 7. Determination of fixed carbon

Percentage fixed carbon was determined by subtracting the percentage moisture, ash and volatile matter from 100.

2. 8. Determination of carbon content

15.0 g accurately weighed solid waste sample was burnt in a combustion apparatus containing KOH and complete combustion was attained within 5 minutes. As a result of the combustion, carbon present in the sample was converted to carbon(IV) oxide which evolved as a gas and absorbed by the KOH tube. Increase in weight of the KOH tube gave the amount of CO_2 absorbed. The combustion equations are as follows:

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$$

12 g   32 g   44 g   R.M.M

$$2KOH_{(aq)} + CO_{2(g)} \longrightarrow K_2CO_{3(aq)} + H_2O_{(l)}$$

Percentage carbon content (C%) = $\frac{Increase\ in\ weight\ of\ KOH\ tube\ x\ 12}{weight\ of\ solid\ waste\ sample\ x\ 44}\ x\ 100$

2. 9. Determination of hydrogen content

15.0 g accurately weighed solid waste components were burnt for 5 minutes in a combustion apparatus with known weight of $CaCl_2$. On completion of combustion, hydrogen in the sample was absorbed by $CaCl_2$ in the form of water. Increase in weight of the $CaCl_2$ gave the amount of H_2O absorbed. The equations for the combustion and absorption are as follows:

$$H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(l)}$$

$$2\ g \quad 16\ g \longrightarrow 18\ g \quad R.M.M$$

$$CaCl_{2(aq)} + 7H_2O_{(l)} \longrightarrow CaCl_2.7H_2O.$$

Percentage hydrogen content = $\frac{Increase\ in\ weight\ of\ CaCl2\ x\ 2}{weight\ of\ solid\ waste\ sample\ x\ 18}\ x\ 100$

2. 10. Determination of percentage sulphur content

15.0 g accurately weighed solid waste components were burnt in a crucible. The burnt contents were then transferred to a flask and mixed with water. It was then filtered by decanting and mixed with distilled water. 2 cm^3 of bromine and 5 cm^3 of HCl were added for oxidation of sulphites present to sulphate. Excess of $BaCl_2$ was added to precipitate sulphur in the form of $BaSO_4$. The precipitate was weighed to obtain the weight of $BaSO_4$ formed.

Percentage sulphur content = $\frac{Weight\ \ of\ BaSO4\ x\ \ 0.1373}{weight\ of\ solid\ waste\ sample}\ x\ 100$ (Gravimetric method)

2. 11. Determination of nitrogen content

15.0 g accurately weighed solid waste sample was heated in a flask with 10 cm^3 of H_2SO_4 as catalyst. A clear solution was obtained. The solution was treated with excess of KOH and a characteristic gas with choking smell were observed. 10 cm^3 of HCl in a separate flask was then added in drops until the choking smell was neutralized. The volume of acid remaining was noted.

Volume of acid used = 10 – volume of acid left.

Percentage nitrogen = $\frac{Volume\ of\ acid\ used\ x\ normality\ x\ 1.4}{Weight\ of\ solid\ waste\ sample}$ (Kjeldahl method)

2. 13. Determination of oxygen content

The percentage of oxygen was determined by subtracting the percentages of carbon, hydrogen, nitrogen, sulphur and ash from 100.

Therefore, percentage oxygen content = 100 – (%C + %H + %N + %S + %Ash)

Energy values: Energy values were determined using Dulong and I. A. Davies` formula.

The Dulong formula is expressed as $Q = \frac{1}{100}\,[8080C + 34460\,(H - \frac{O}{8}) + 2250S]$

where Q = energy value in Joule/kg and C, H, O, S are percentages of carbon, hydrogen, oxygen and sulphur, respectively.

Dulong formula can be expressed in terms of higher energy value (HEV) as:

$HEV = \frac{1}{100}\,[8080C + 34500\,(H - \frac{O}{S}) + 2240S]$, and in terms of lower energy value (LEV) as:

$LEV = (HEV - \frac{9H}{10} \times 587)$.

A.I. Davies formula is expressed as:

$Q = (3.635H + 235.9)\ [\frac{C}{3} + H - \frac{1}{8}(O + S)]$ where the terms have the same meaning as in Dulong formula.

3. RESULTS AND DISCUSSION

The results of these investigations are as presented below and discussed. The wet mass is the mass of the sample during the wet season while the dry mass is the mass of the sample during the dry season. **Table 1** depicts the composition of municipal solid wastes as collected from five different dumpsites in Awka.

Table 1. Composition of municipal solid wastes in five different dumpsites in Awka based on the individual components [%].

Components	Dumpsite A		Dumpsite B		Dumpsite C		Dumpsite D		Dumpsite E	
	Wet mass	Dry mas	Wet mass	Dry mass	Wet mass	Dry mass	Wet mass	Dry mass	Wet mass	Dry mass
Paper and cardboard	12. 80	10.20	16.00	13.10	12.30	8.22	13.70	12.60	14.60	8.50
Plastic mixed	3.40	2.40	4.40	4.00	2.20	2.10	3.30	2.28	4. 80	4.45
Textile	6.20	4.80	8.30	6.75	2.60	1.60	5.00	4.10	4.20	3.10
Rubber	3.00	2.25	4.70	4.40	5.30	3. 88	4.60	4.22	2.40	2.20
Leather	4.00	3.10	4.40	2.10	3.60	3.20	5.00	3.70	3.90	2. 82
Garbage	11.10	6.50	8.00	5.70	11.70	7.75	12.00	10.20	9.55	7.20
Wood mixed	8.20	7.30	8.40	6. 80	10.20	8.30	7.50	5.50	11.30	9.65
Glass	7.50	7.10	6.50	6.10	7.10	6.25	6.50	6.40	5.10	4.95

Metal	8.70	8.15	6.30	6.00	12.00	11. 80	9.00	8.30	9.20	8. 80
Palm kernel	5.00	3.20	3.30	3.10	3.00	2.95	3.10	1. 85	4.65	2.75
Total	70.00	55.00	70.00	58.05	70.00	56.05	70.00	59.15	70.00	54.92

The Table showed that the major components of solid wastes in the studied area are paper and cardboard, plastics, textile materials, rubber, leather, garbage, wood, glass, metals and palm kernel (mixed). The composition from the different dumpsites varies with the economic status and culture of the areas under investigation, season of the year frequency of collection, extent of recycling and salvaging. The composition of physical municipal solid wastes as collected is approximately 20% for paper, 15% for garbage, 13% for metal, 5% for plastic and 13% for wood, by mass. This showed that many inhabitants of Awka make use of paper as they are more of students, leading to high rates of waste paper generation. Large number of students equally gives rise to high garbage percentage.

The high percentage of wood and metal generation is due the use of wood and metal in the construction of tables for the inhabitants that are mainly students and market men and women and for blacksmithing which is the major occupation with which Awka people are known. Plastics were also rampant in but had low percentage value due to its light weight. About 3643 kg wet season mass and 2943 kg dry season mass were generated per year, amounting to 3.64 tons wet mass and 2.94 tons dry mass of wastes per year.

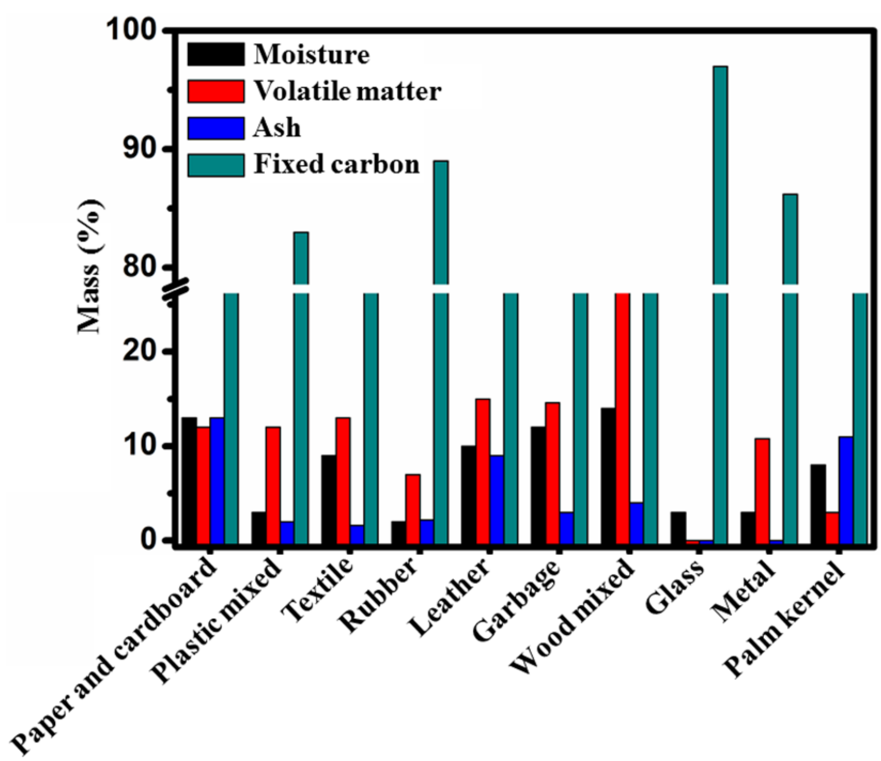

Figure 1. Proximate analysis of municipal solid wastes.

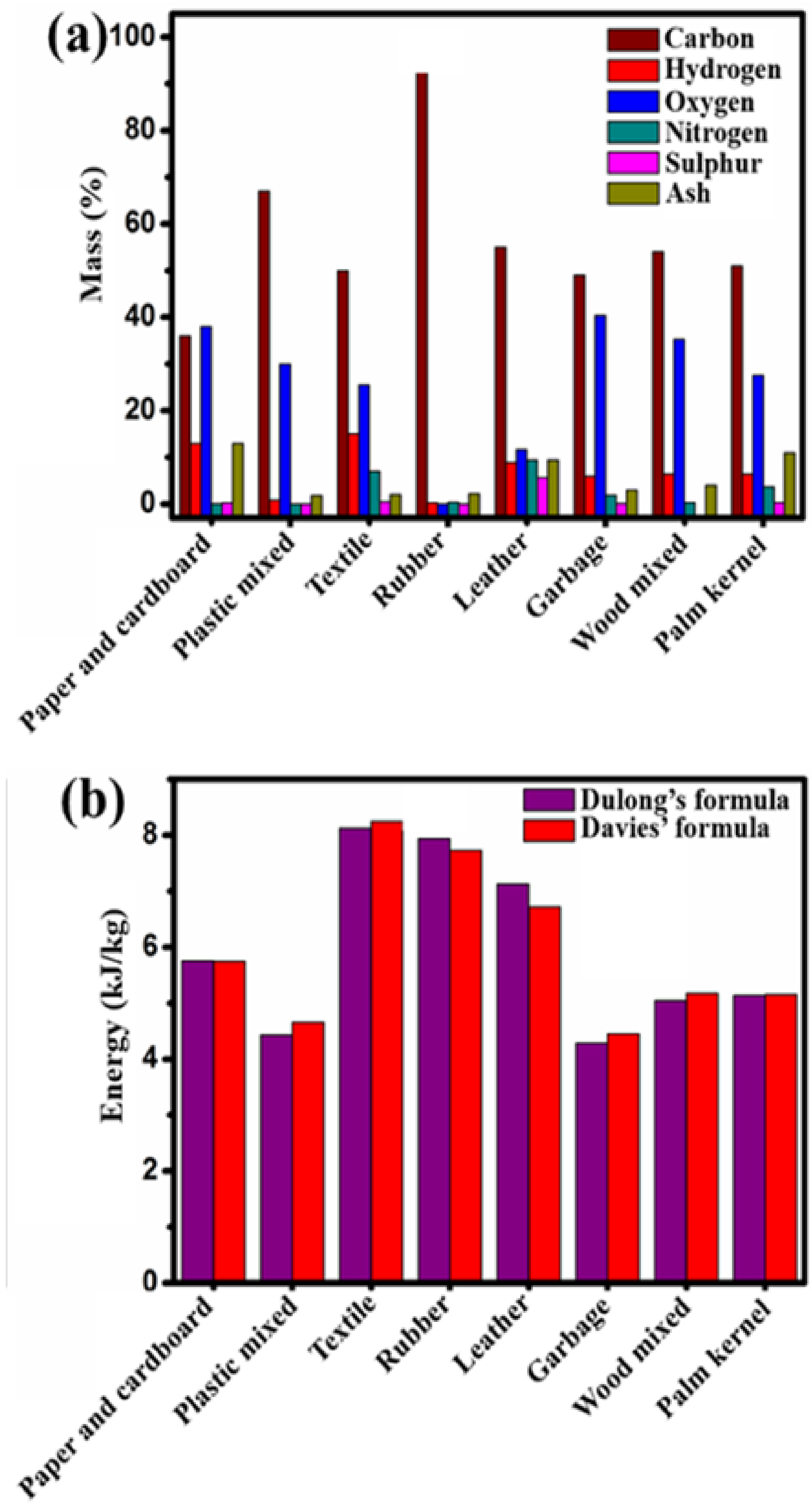

Figure 2. (a) Combustible components in municipal solid waste, and **(b)** their respective energy values.

The various results obtained for the different parameters on proximate analysis of municipal solid waste are as presented in **Figure 1**.

The obtained results showed that wood, paper, garbage and leather have the highest percentage of moisture content, with values of 14%, 13%, 12%, and 10%, respectively. This is possibly attributed to the ease with which they absorb water. Rubber, glass, metals and plastics record the lowest value of moisture content with values 2%, 3%, 3%, and 3%, respectively. The result also showed that volatile matter was the highest in wood, leather and garbage and the lowest in palm kernel.

On the percentage ash content, paper has the highest percentage with a value of 13% followed by palm kernel with a value of 10%. The results clearly showed that as the value of the percentage fixed carbon increases, the percentage volatile matter decreases.

The obtained ultimate analysis data showed that carbon has the highest percentage by mass in most of the solid waste samples collected, closely followed by oxygen (**Figure 2**). Sulphur and nitrogen have the lowest percentages and were completely absent in plastic materials investigated.

In terms of the calculated energy values, texitile materials, rubber and leather are the highest in value. This is probably due to the high carbon content of these wastes. The energy value is dependent mostly on the percentages of hydrogen, carbon, oxygen and sulphur. The energy values obtained by different methods are closely related as their trends are similar. The result showed that approximately 47. 86 kJ/kg of energy can be generated from solid wastes in Awka urban, Anambra State, Nigeria.

4. CONCLUSIONS

The research work done on the physico-chemical properties of solid wastes have provided much information about the physical and chemical properties of the solid wastes. The obtained results showed that solid wastes generated in Awka urban are made up of different components, such as: papers, cardboard, plastics, textiles, rubber, garbage, wood, glass, metals and palm kernel.

From the analyzed components, wood, glass, metal, palm kernel, paper and garbage rank the highest in the quantity of solid waste components by weight. Proximate analysis of the waste materials showed the presence of moisture, volatile matter, fixed carbon and ashes in solid waste while ultimate analysis for the chemical component of the municipal solid waste showed the presence of carbon, hydrogen, oxygen, nitrogen, sulphur and ash in the solid wastes. Carbon content and oxygen content were the highest in percentage mass in most of the waste samples.

The values obtained from the analysis carried out were used to calculate the energy value of the waste samples. The high energy values of the studied solid waste materials showed that when properly harnessed, can be used to generate electricity for the state.

This will help to solve the electricity problem of the state which experiences severe epileptic power supply by using large quantities of waste generated in both the wet mass (3.643 tons) and dry mass (2.944 tons) form per year and converting same to kilowatt hour for energy generation. It is therefore recommended that more research work be done on the waste components to harness them for alternative uses through analysis as these would lead to an efficient recovery of solid wastes and converting same to energy for the benefit of mankind and the society.

Acknowledgement

The authors are grateful to Ayaco Investment Limited, Anambra State, Nigeria for funding this study.

References

[1] Akakuru, O.U. and Onyido, I. Controlled release formulations of 2,4-dichlorophenoxyacetic acid with ecofriendly matrices for agricultural and environmental sustainability. *Macromol. Res*. 29(1) (2021) 40-53

[2] Wilson, D.C. Rodic, L. Modak, P. Soos, R. Carpintero, A. Velis, C. Iyer, M. and Simonett, O. Global Waste Management Outlook, United Nations, Environment Program and International Solid Waste Association, Osaka and Wien. (2015) 49-56

[3] Münster, M. and Lund, H. Comparing Waste-to-Energy technologies by applying energy system analysis. *Waste Manag*. 30(7) (2010) 1251-1263

[4] Brunner, P.H. and Rechberger, H. Waste to energy - key element for sustainable waste management. *Waste Manag*. 37(2) (2015) 3-12

[5] Nojedehi, P. Heidari, M. Ataei, A. Nedaei, M. and Kurdestani, E. Environmental assessment of energy production from landfill gas plants by using Long-range Energy Alternative Planning (LEAP) and IPCC methane estimation methods: A case study of Tehran. *Sustain. Energy Technol. Assessments* 16(2) (2016) 33-42

[6] Hiremath, R.B. Kumar, B. Balachandra, P. and Ravindranath, N.H. Decentralized sustainable energy planning of Tumkur district, India. Environ. *Prog. Sustain. Energy*, 30(2) (2011) 248-258

[7] Amuzu-Sefordzi, B. Huang, J. Sowa, M. A. and Baddoo, T.D. Biomass-derived hydrogen energy potential in Africa. Environ. *Prog. Sustain. Energy*, 35(1) (2016) 289-297

[8] Ahmed, S.I. Johari, A. Hashim, H. Mat, R. Lim, J.S. Ngadi, N. And Ali, A. Optimal landfill gas utilization for renewable energy production. *Environ. Prog. Sustain. Energy*, 34(1) (2015) 289-296

[9] Poma, C. Verda, V. and Consonni, S. Design and performance evaluation of a waste-to-energy plant integrated with a combined cycle. *Energy*, 35(2) (2010) 786-793

[10] Brunner, P.H. and J. Fellner, J. Setting priorities for waste management strategies in developing countries. *Waste Manag. Res*. 25(3) (2007) 234-240

[11] Ghorashi, A.H. and Rahimi, A. Renewable and non-renewable energy status in Iran: Art of know-how and technology-gaps. Renew. *Sustain. Energy Rev*. 15(1) (2011) 729-736

[12] Moghadam, M.R.A. Mokhtarani, N. and Mokhtarani, B. Municipal solid waste management in Rasht City, Iran. *Waste Manag*. 29(1) (2009) 485-489

[13] Psomopoulos, C.S. Bourka, A. and Themelis, N.J. Waste-to-energy: A review of the status and benefits in USA. *Waste Manag*. 29(5) (2009) 1718-1724

[14] Kim, S. and Dale, B.E. Global potential bioethanol production from wasted crops and crop residues. *Biomass and Bioenergy*, 26(4) (2004) 361-375

[15] Li, X. Recycling and reuse of waste concrete in China: Part I. Material behaviour of recycled aggregate concrete. *Resour. Conserv. Recycl*. 53(1) (2008) 36-44

[16] Björklund, A. and Finnveden, G. Recycling revisited - Life cycle comparisons of global warming impact and total energy use of waste management strategies. *Resour. Conserv. Recycl*. 44(4) (2005) 309-317

[17] Ardebili, M.S. Ghobadian, B. Najafi, G. and Chegeni, A. Biodiesel production potential from edible oil seeds in Iran. *Renew. Sustain. Energy Rev*. 15(6) (2011) 3041-3044

[18] Ferronato, N. Torretta, V. Ragazzi, M. and Rada, E.C. Waste mismanagement in developing countries: A case study of environmental contamination. *UPB Sci. Bull*. 79(2) (2017) 185-196

[19] Abduli, M. A. and Azimi, E. Municipal waste reduction potential and related strategies in Tehran. *Int. J. Environ. Res*. 4(4) (2010) 901-912

[20] Meraz, L. Oropeza, M. and Dominguez, A. Prediction of the combustion enthalpy of municipal solid waste. *Chem. Educ*. 7(2) (2002) 66-70

[21] Pera, J. Coutaz, L. Ambroise, J. and Chababbet, M. Use of incinerator bottom ash in concrete. *Cem. Concr. Res*. 27(1) (1997) 1-5

[22] Klinghoffer, N.B. Themelis, N.J and Castaldi, M.J. Waste to energy (WTE): an introduction in Waste to Energy Conversion Technology, Elsevier, (2013) 3-14

[23] K. G. Ugbena, A. C. Tse, Enuvie G. Akpokodje, Modeling Soluble Contaminant Migration by Advection Process in Subsurface Water in the Eastern Niger Delta, Nigeria. *World Scientific News* 139(2) (2020) 102-114

[24] Harrison Charles Ekoh, Spatial Variation of Air Quality in Mpape Area of Abuja, Nigeria. *World Scientific News* 140 (2020) 79-112

[25] Mevayerore Daniel Igbini, Natural – Resource Curse, Niger Delta Crisis and Oil Exploration in Nigeria: A Theoretical Analysis. *World Scientific News 141* (2020) 1-11

[26] Bhola Khan, Microfinance Banks and its Impacts on Small and Medium Scale Enterprises in Nigeria. *World Scientific News* 141 (2020) 115-131

[27] Amy L. Potrzeba-Macrina, Igor G. Zurbenko, Numerical Predictions for Global Climate Changes. World Scientific News 144 (2020) 208-225

[28] T. A. Adeosun, M. A. Adabanija, F. O. Akinpelu, Modeling and Simulation of Reservoir Pressure Associated with Emulsions Transport Near Wellbore for Enhanced Oil Recovery. *World Scientific News* 144 (2020) 427-449

[29] R. E. Ita, Differential Biomass Apportionments and Carbon Stocks in Vegetation of Natural and Artificial Ecosystems in Akwa Ibom State, Nigeria. *World Scientific News* 146 (2020) 1-21

[30] Gaddafi Adamu Babali, Akpensuen Shiaondo Henry, Shitu Abdulrazaq Ahmed, Ahmad Atiku Malle, Muhammed Adamu, Muhammad Goni Bukar, Best Time Series In-sample Model for Forecasting Nigeria Exchange Rate. *World Scientific News* 151 (2021) 45-63