Analysis of Heating Value of Solid Waste in High Class and Low Class Economies:

A Case Study of Ado-Ekiti Metropolitan

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Abstract: **A lot of municipal solid wastes are generated in Ado-Ekiti. Two categories of inhabitants were studied in this survey. First, the reserve areas mostly populated by the rich in the society and second are the zones populated by the less privileged in the society, hereafter referred to as 'high class economy and low class economy' respectively. Solid waste samples were separately collected. The heating value of the different samples was investigated. This research showed that huge amount of energy was available in the waste samples. Meanwhile an average of 137.77kJ/kg of energy was generated from solid waste samples in high-class economies while an average of 165.60kJ/kg of energy was generated from the economically less privileged residents. This result indicated that the Heating value from the wastes generated by the low class economies was higher than that of the high-class by about 20.2%.**

Keywords—Heating value, Solid Waste, Energy from wastes, Renewable energy

INTRODUCTION

Municipal solid waste (MSW) commonly referred to as trash or garbage, is a waste type consisting of everyday items we consume and discard as being useless or unwanted. It predominantly includes food waste, yard wastes, containers and product packaging and other miscellaneous inorganic waste from residential, commercial, institutional, and industrial sources (Wikipedia, 2011)

Inorganic wastes include: Appliances, newspaper, clothing, food scrapes, boxes, disposable table ware, office and classroom paper, furniture, wood pallets rubber tires, and cafeteria wastes.

Today the disposal of wastes by land filling or land spreading is the ultimate fate of all solid wastes, whether they are residential waste collected and transported directly to landfill site residential materials from materials recovery facilities (MRFs), residue from the combustion of solid waste, compost or other substances from various solid waste processing facilities. A modern sanitary landfill is not a dump; it is an engineering facility used for disposing solid wastes on land without creating nuisances or hazards to public health or safety, such as the breeding of insects and the contamination of ground water.

DEFINITION OF TERMS

(i) **Solid wastes:** These are all types of wastes arising from human and animal activities which are usually solid in nature and that are discarded as being useless or unwanted

(ii) **Energy content:** This is the quantity of energy that can be released by burning a certain quantity of fuel

(iii) **High –class environment:** High-class set of people are well to do people. They live above poverty line of $1 per day and are commonly found in Government reserved Area (GRA)

(iv) **Less privileged society:** These are referred to as the common people who live below poverty line of $1 per day

(v) **Waste- to – Energy (WtE**): This is the process of creating energy in the form of Electricity or heat from the incineration of waste source.

(vi) **Moisture Content:** This is the amount of moisture in a given sample of substance.

(vii) Ash Content: This is the remaining portion of a biomass substance after combustion

This research aims to determine the Energy content of solid waste generated in high-class and the less privileged economies. Municipal solid waste can be used to generate energy. Several technologies have been developed that make the processing of municipal solid waste for energy generation cleaner and more economical than ever before including landfill gas capture, combination, pyrolysis, gasification, and plasma arc gasification. While older waste incineration plants emitted high level of pollutants, recent regulatory changes and new technologies have significantly reduced this concern. EPA regulations in 1995 and 2000 under the clean Air Act have succeeded in reducing Emissions of dioxins from waste-to-Energy facilities by more than 99 percent below 1990 level, while mercury emissions have been by over 90 percent below 1990 level. While Mercury emissions have been by over 90 percent. The EPA noted these improvements in 2003 citing waste-to-Energy as a power source "with less environmental impact than almost any other sources of electricity “(Wikipedia 2011).

The heat generated by burning waste can be used directly for heating; to produce steam; or to produce electricity. Texas’ sole permitted waste-to-energy facility processed 387 tons of waste in 2006. Dyess will buy discounted energy from the contractor operating the waste-to-energy plant, saving nearly half of its current energy costs (Sarah, 2006). The Air Force contract totals over $39 million and includes the waste-to-energy plant plus diesel back-up generators.

Waste-to-energy facilities tend to be built near the landfills of large urban centers. A few facilities are modular units, smaller plants built off-site and transported to wherever they are needed. Waste-to-energy plants generate electricity by burning municipal wastes in large furnaces to produce steam, which in turn drives a steam turbine to generate electricity. On average, one ton of waste produces 525 kilowatt-hours (kWh) of electricity. This is equivalent to the energy produced by a quarter-ton of coal or one barrel of oil. (http//:www.wte.org/education/conversion factors.html, 2008) One type of waste-to-energy plant is called a *mass burn facility*. These facilities use solid waste directly off garbage trucks, without shredding or processing the materials. The solid waste is then fired in large furnaces to produce steam, which turns a steam turbine to generate electricity. A typical waste-to-energy plant generates about 500 to 600 kWh per ton of waste. Less than a fifth of the U.S. municipal solid waste incinerators recover glass,_metals and other recyclable materials and then shred the combustible materials before firing. This type of plant is called a *refuse-derived fuel* (RDF) plant. Sometimes, refuse-derived fuel is prepared at one facility and then transported to another for burning. The shredded waste also may be added as a fuel to boilers that burn fossil fuels.

Mass burn and RDF plants are the most common facilities in use today. A new technology called *thermal gasification*, however, changes waste into synthesis gas, a mixture of hydrogen and carbon monoxide. Contaminants are removed from this gas, which can then be burned as fuel.

According to a Columbia University survey published in *BioCycle* magazine, the U.S. generated about 388 million tons of municipal solid waste in 2004. Of this amount, about 28.5 percent was recycled and composted; about 7.4 percent was burned in waste-to-energy plants; and the majority, 64.1 percent, was put in landfills. (Phil Simmons et’al., 2006)

The U.S. Environmental Protection Agency (EPA), using a different methodology, estimates that the U.S. generated 251.3 million tons of garbage in 2006. Of this amount, 81.8 million tons (32.5 percent) were recycled and composted; and 31.4 million tons (12.5 percent) were burned for energy production. The remaining 138.2 million tons (55 percent) were placed in landfills.

In 2005, an official of one of the leading U.S. companies operating municipal waste combustion facilities, American Ref-Fuel Company, testified before Congress that a new facility that can generate 60 megawatts of electricity from about 2,250 tons of trash daily would cost about $350 million. Its operating costs would be about $28 million a year. This would be a very large plant; only fourteen locations in the U.S. have the capacity to combust more than 2,250 tons of trash per day. (Ted Michaels, 2007)

3.0 MATERIALS AND METHOD

Materials needed for this work are solid waste samples from high-class and the less-privileged economies in Ado-Ekiti. Solid waste samples were collected from eight different locations. Four from high-class and four from the less privileged ones.

SORTING OUT:

A STM D5231-92: standard test method for the determination of the composition of unprocessed municipal solid waste was used in sorting out the waste collected in both economies into the following components.

(i) Food waste
(ii) Paper
(iii) Plastics
(iv) Textile Materials
(v) Leather
(vi) Wood
(vii) Miscellaneous organic substances/others.

The biomass portion of the waste is selected for laboratory analysis. The moisture content, heating value and the ash content of each component was determined as follow.

3.3 DETERMINATION OF MOISTURE CONTENT

Moisture content of each component was determined based on losses on drying at an oven temperature of 105^0c. Beside water, the loss will include other matters volatile at 105^0c.

PROCEDURE:

A clean dish of silica platinum was dried in an oven and cooled in a desiccator. The cooled dish was weighed (w_1)

5 grams of the sample was introduced into the dish and spread. The weight (w_2) was accurately taken.

The dish and its contents were put in an oven maintained at 105^0c and dried for four hours.

The dish and its contents were removed from the oven and allowed to cool in a desicator. The weight was also taken.

The dish was returned to the oven and redried for a further thirty minutes. The dish was again removed, cooled and weight. The process of drying continued until a constant weight (w_3) has been reached.

CALCULATION:

% moisture content **=** $\frac{W2-W3}{W2-W1}$ **X 100**

The same procedure was followed to determine the moisture content of all samples in the economic classes.

3.4 DETERMINATION OF HEATING VALUE.

The heating value of each component in the economic classes was determined using AOAC official method 2003. 09

APPRATUS: Gallenkamp Ballistic Bomb Calorimeter.

REAGENT: Benzoic Acid

Procedure: The bomb calorimeter was first calibrated by using 0.25g benzoic Acid. 0.25g of each sample was weighed into the steel capsule of the calorimeter. A 10cm cotton thread was attached to the thermocouple to touch the capsule. The bomb was closed and charged in with oxygen up to 30 atm. The bomb was fixed up by depressing the ignition switch to burn the sample in an excess of oxygen. The maximum temperature rise in the bomb was measured with the thermocouple and galvanometer system. The rise in temperature was compared with that obtained for 0.25g benzoic value of each sample was determined as follows:

CALCULATIONS:

Mass of Benzoic Acid = w_1 gram

Calorific Value of 1.0g Benzoic Acid =6.32 kcal/g

Heat released from Benzoic Acid =6.32W_1 kcal.

Galvanometer deflection without sample = t_1

Galvanometer Deflection of Benzoic Acid = t_2 - t_1

Calibration constant = $\frac{6.32W1-Y}{t2-t1}$

The standardizing is repeated five times and average value calculated for Y

Mass of sample = 0.25g

Galvanometer = t_3

Galvanometer Deflection of sample =t_3 - t_1

Heat released from sample = (t_3-t_1) y kcal

Calorific value of sample = $\frac{(t3-t1)Y}{0.25}$ kcal/g

3.5 DETERMINATION OF ASH CONTENT.

Procedure:

A porcelain crucible was cleaned dried heated and cooled in a desiccator. The weight after cooling is taken as w_1. One gram (1g) of a sample is weighed accurately and directly into the crucible and the weight is recorded as w_2. The crucible and its content are placed in a maple furnace maintained at 550^0c until it fully turned to ashes (about 1 hour). The crucible and the ash are removed from the furnace, cooled in a desiccator and its weight is taken as w_3. This process is repeated for all samples in both economics and the readings taken accordingly.

CALCULATION: %Ash = $\frac{W3-W1}{W2-W1} X\ 100$

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

The laboratory analysis of the representative samples were out to determine the moisture content. Heating value and the ash content. The results were as shown in the tables 1.0 for the high-class and the less-privileged economies.

Table 1.0 Moisture Content of Solid Waste Generated In High Class Economies (%).

S/N	Component	State Hous'g Estate L1	G.R.A, Onigari L2	Judiciary Qtrs L3	Irewolede Estate, L4
1	Garden Trimming	38.47	28.92	__	8.66
2	Nylon	0.15	2.35	0.31	6.79
3	Food Waste	64.55	__	10.79	63.19
4	Textile Materials	4.11	__	__	__
5	Plastics	0.29	0.51	0.11	0.09
6	Debris, Sand, etc	7.56	4.01	__	13.65
7	Leader	1.53	__	__	__
8	Paper	1.47	2.23	50.97	10.90
9	Leaves	7.11	3.69	1.57	__
10	Tin cans	__	__	__	0.21
11	Glass	__	__	__	0.01
	Total	125.24	41.71	63.75	103.5

Table 1.1 Moisture Content Of Solid Waste Generated In Less -privilege Economies (%)

S/n	Component	Odo Ado, (L1)	Mathew (L2)	Okebola (L3)	Irona (L4)
1	Leaves	14.98	__	28.33	56.48
2	Paper	6.78	16.45	10.55	30.56
3	Wood	11.83	__	19.04	__
4	Nylon	ND	0.51	0.40	1.73
5	Rubber	__	__	1.92	0.53
6	Plastic	__	0.07	0.19	0.37
7	Textile Material	__	__	0.26	7.81
8	Food Waste	45.06	30.97	51.37	67.31
9	Leather	__	__	1.04	__
10	Sand, Wood ash and others.	3.14	7.99	8.31	9.43
11	Charcoal	__	7.54	__	__
12	Tin cans	__	__	__	0.37
	Total	81.79	63.53	122.41	174.59

Table 1.2 Heating Value for Solid Waste Generated in Less-privilege Economies (Kcal/Kg)

S/n	Components	Odo Ado,	Mathew St.	Okebola	Irona
1	Leaves	4538	__	4604	4144
2	Paper	4367	4364	4179	4574
3	Wood	5346	__	5418	__
4	Nylon	7186	7298	7259	7324
5	Rubber	__	__	9088	9124
6	Plastic	__	7886	8086	7994
7	Textile material	__	__	6257	6249
8	Food waste	4214	4137	4153	4314
9	Leather	__	__	7869	__
10	Charcoal	__	8126	__	__
	Total	25,651	31,811	56,891	43,723

Table 1.3 Heating Value of Solid Waste Generated in High-class Economies (kcal/Kg)

S/n	Components	State Housing L1	GRA Onigari L2	Judiciary Qtrs. L3	IrewoledeEstate L4
1	Garden Trimming	4694	4692	__	4689
2	Nylon	7366	7315	7158	7284
3	Food Waste	4205	__	4129	4226
4	Textile Materials	6307	__	__	__
5	Plastic	7988	8026	7408	7467
6	Leather	7875	__	__	__
7	Paper	4326	4563	4304	4235
8	Leaves	4621	4132	4486	__
	Total	47,382	28,728	27,485	27,901

Recall: 1 calorie = 4.19002 x 10^3 Joule and 1kcal = 4.19002J

Hence, For High-Class Economics Location 1, Garden trimmings have heating value of 4694kcal/kg. =19, 66795.95J/kg

Therefore, the heating value for other components in each of the locations in low and high economic classes are calculated using the same approach. The heating values are as presented in tables 1.4 and 1.5 respectively

Table 1.4: Heating Value of Solid Waste Generated in High-class Economies (kJ/kg)

S/N	Component	State Housing Estate L1	GRA Onigari L2	Judiciary Qtrs L3	Irewolede estate L4	Total
1	Garden Trimming	19.67	19.66	__	19.65	58.98
2	Nylon	30.86	30.65	29.99	30.52	122.02
3	Food waste	17.62	__	17.30	17.71	52.63
4	Textile Materials	26.43	__	__	__	26.43
5	Plastics	33.47	33.63	31.04	31.29	129.43
6	Leather	33.10	__	__	__	33.10
7	Paper	18.13	19.12	18.03	17.74	73.02
8	Leaves	19.36	17.31	18.80	__	55.47
	Total	198.64	120.37	115.16	116.37	551.08

Grand Total = 551.08kJ/kg

The average $(L1 + L2 + L3 + L4)/4$ = 551.08/4 = 137.77kJ/kg

Table 1.5: Heating Value of Solid Waste Generated in Less-privileged Economies (kJ/kg)

S/n	Component	Odo Ado L1	Mathew L2	Okebola L3	Irona L4	Total
1	Leaves	19.01	__	19.29	17.36	55.66
2	Paper	18.30	18.29	17.51	19.17	73.27
3	Wood	22.40	__	22.70	__	45.10
4	Nylon	30.11	30.58	30.44	30.69	121.82
5	Rubber		__	38.08	38.23	76.31
6	Plastic		33.04	33.79	33.50	100.33
7	Textile material		__	26.22	26.18	52.40
8	Food waste	17.66	17.33	17.40	18.08	70.47
9	Leather		__	32.97	__	32.97
10	Charcoal		34.05	__	__	34.05
	Total	107.48	133.29	238.40	183.21	662.38

Grand Total = 662.38 kJ/kg

The average = $(L1 + L2 + L3 + L4)/4$ = 662.38/4 = 165.60kJ/kg

Table 1.6: Ash Content of Solid Waste Generated in High-Class Economies (%)

S/N	Component	State Housing estate, L1	GRA onigari L2	Judiciary qtr L3	Irewolede Estate L4
1	Garden trimmings	2.23	4.94	__	5.69
2	Nylon	ND	1.36	2.15	4.59
3	Food Waste	4.23	__	2.59	8.36
4	Textile Materials	3.05	__	__	__
5	Plastics	2.01	1.49	0.10	0.39
6	Leather	6.81	__	__	__
7	Paper	9.27	3.29	4.11	2.84
8	Leaves	1.53	2.69	6.26	__
	Total	29.13	13.77	15.21	21.87

Note: ND = Not Detectable

Table 1.7: Ash Content of Solid Waste Generated in Less- privileged Economies (%)

S/N	Component	Odo Ado L1	Mathew St. L2	Okebola L3	Irona St. L4
1	Leaves	1.63	__	1.42	1.76
2	Paper	3.54	2.94	4.83	1.51
3	Wood	1.24	__	5.14	__
4	Nylon	2.86	0.42	1.71	ND
5	Rubber	__	__	2.32	1.55
6	Plastic	__	0.96	2.02	ND
7	Textile Materials		__	1.81	1.55
8	Food waste	3.39	3.54	7.82	2.41
9	Charcoal		4.60	__	__
	TOTAL	12.66	12.46	27.07	8.78

4.1 DISCUSSION

4.1 .1 Distribution of Waste Samples within High-Class Economies

Garden trimming was found in all economic locations except Judiciary quarters as at the point of collecting the samples. This may be due to prompt attention given to the cleanliness of this environment by the gardeners.

Nylon, plastic and paper were found in the samples collected in all locations. The sources of these items include pure water packs, Newspaper, Food packs, Fruit Juice Containers like Ribena, Lacaseral etc.

Food waste was found in all locations except GRA Onigari. The quantity of food waste collected at Judiciary quarters was more than the ones at other locations.

Debris and sand were found in all locations except judiciary quarters, while leather and Textile materials were found only in State housing Estate. Also Glass and tin cans were present only at Irewolede Estate.

4.1.2 Distribution of Waste Samples Collected Within Less-Privilege Economies

Paper, Nylon, Food Waste, Sand other organic matters present in all samples collected in the four locations covered. Leaves were present in all locations except Mathew street The sources include chaffs from locust beans, wood barks from farm and the ones that fell from trees in front of residential houses. Wood wastes were found in Odo Ado and Okebola only while Rubber were found in Oke Bola and Irona only.

Textile materials were found in Oke Bola and Irona. Only Oke Bola and Mathew have leather and Charcoal respectively while Tin Can was found only in Irona.

4.1.3 Distribution of waste samples between high-class and less-privilege economies.

The components and volume of solid waste generated in both economic classes are greatly influenced by the way of life people in the economic classes and the level of their income.

In less privileged economic class, majority of the people in the area use fire wood or charcoal as the source of energy for their cooking. As a result, wood ash form part of the waste collected in this area. But in high-class economic class ash was not found. This implies that their sources of energy for domestic cooking must have come from either kerosene stove, electric cooker or gas cooker.

The distribution of Nylon cut across both economic classes and in large proportion. Their sources include: pure water packs, polythene bags, Nylon for packing bread etc.

Plastics from fruit juice packages and bottled water was found in a large quantity in high-class economies while the few ones found in less-privilege economies were from body cream and other miscellaneous sources.

Textile materials were not so common in both economic classes. This may be due to rate of generation compared to other types of waste.

Also, leather, Tin cans and glass were not also common in both economic classes.

Paper was widely distributed in both economic classes but newspaper was more in high-classes economic classes.

4.1.4 Energy Content of Solid Waste within High-Class Economies

Total Energy content of solid collected in high-class economies was 551.08KJ/Kg. out of this; State housing estate generated the highest value with 198.64KJ/Kg followed by G.R.A Onigari with 120KJ/Kg while Irewolede Estate and Judiciary quarters generated 116.91KJ/Kg and 115.16KJ/kg respectively. Plastics had the highest value with 129.43KJ/Kg followed by Nylon with 122.02KJ/Kg while textile material (from only one location) had 26.43KJ/Kg.

4.1.5 Energy Content of Solid Waste within Less-Privileged Economies.

The sum of 662.38KJ/Kg of energy was generated in the less-privileged economic locations covered. Oke Bola, Ado Ekiti generated the highest value with 238.40KJ/kg followed by Irona with 183.21KJ/kg and Mathew with 133.29KJ/kg while Odo Ado had the least energy value with 107.48KJ/kg. Nylon produced the highest value with 121.82KJ/kg followed by plastics with 100.33 while charcoal (which was formed in only on location) had the least value with 34.05KJ/kg

4.1.6 Energy Content of Solid Waste between High-Class and Less-Privileged Economies

Total energy content of solid waste generated in less-privilege economic classes covered in this research work was found to be higher (662.38KJ/kg) than that of high-class economic classes (551.08KJ/kg).

A look at the components of waste samples collected in both economic classes showed that energy value of most components in both economic classes were relatively the same, for example, Nylon in both economies had an average value of 30KJ/kg. in the same vein, plastics, paper, leaves etc. had heating values that were comparatively the same. Hence, it could be deduced that the difference observed in the total heating value in the economic classes was due to some component (waste) that were not generated in some locations.

The total mass of waste generated in each economic class is also an area of interest as will inform the total energy value that could be derived from each economic class

5.0 CONCLUSION

This research indicated that a lot of heat energy can be generated from solid waste in Ado Ekiti. If properly handled to drive turbines, reasonable of kilowatt of electricity can be generated for domestic and industrial purposes. Other benefits that could be derived from this are: Creation of Employment for people, increase in the IGR of the State and reduction in overdependence on grid supply electricity.

An estimate 137.77kJ of energy/kg of refuse was generated from solid waste samples in high-class economies while an average of 165.60kJ/kg of energy was generated from the less privileged ones. Heating value from the less-privileged economies was higher than that of the high-class. It could be deduced that the difference observed was due to some components that were not generated in some locations in the high-class economies. If this energy is properly handled. It can go a long way at increasing electrical power available to the people in the city

5.1 RECOMMENDATION

A lot of municipal solid waste is generated in Ado-Ekiti. With the huge amount of energy that can be derived from solid waste in Ado-Ekiti as seen in the result of this research work. It is worthwhile that the government of Ekiti State to harness the prospects and potentials of waste-to-energy method of waste management.

REFERENCES

Albert Cotton F. (1972): Advanced Inorganic Chemistry, Inter-science Publisher, 3rd Edition page 60

Energy Report (2008): U.S environmental protection agency, "solid waste combustion/incineration". Hittp.//www.epa.gov/epaowae/non-hw/ muncpl/landfill/sw-combst.htm. (Assessed October 2011)

Forgiel, M. (1991): The chemistry problem solver, Research and Education Association 1st Edition page 90

J.Sudhir et'al (2010): Waste to Energy: A case study of Eluru, A.P, India International Journal of Environmental Science and Development Vol. 1 (3) pp 238-243

Olorunnisola (2007): Element of professional Engineering Practice, Bolton Publishers, Ibadan, Nigeria. 1st Edition page 171**Phil Simmon, et'al (2006):** The state of Garbage in America, Biocircle Pp. 26

Rayner Joel (1996): Basic Engineering Thermodynamics, Longman, 5th edition, pp 236-240

Sarah Kleiner (2006) "Turning Trash to cash: Dyess will save millions Burning Trash for power" http//www.reporternews.com/news/2006/may/ 25/turningtrash-to-cash. (Assessed in July 2011)

Eastop T.D & Mc Conkey A. (1996): Applied Thermodynamics for Engineering Technologists, Longman, 5th edition pp223-226

U.S. Environmental Protection Agency, Municipal Solid Waste Generation Recycling and Disposal in the United States: Facts and Figures for 2006 (Washington D.C, November 2007), Pp.8 http//www.epa.gov/epaoswer/non/hw (Assessed in October 2011)

Wikipedia 2011: Municipal Solid Waste, The free excyclopedia, Municipal waste disambiguation; https://en.wikipedia.org/wiki/Municipal_solid_waste