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COMPARISON OF EMPIRICAL MODELS FOR THE DETERMINATION OF CALORIFIC VALUES OF MUNICIPAL SOLID WASTE IN KANO, NIGERIA

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ABSTRACT

This paper compares the results of calorific values of municipal solid waste in Kano, Nigeria determined using empirical models. Comparison of the calculated calorific values from all the models shows wide variation and range from 772.38 kcal/kg - 5,034.28 kcal/kg. The physical model equation gives much higher values of calorific values of the waste than the other three model equations. The variability of the calorific values from the different models used confirms previous researches results that showed difference in calorific values between empirical models developed.

KEYWORDS: Municipal Solid Waste, Calorific Value, Empirical Models

INTRODUCTION

Several experimental and empirical approaches have been reported by researchers for the determination of calorific values and energy content of municipal solid waste. Experimental determination of calorific value by using bomb calorimeter is the most commonly reported in literature (Harker, 1981; Moh'd Abu Qudais et al., 2000; Ebru et al., 2009; Amin et al., 2011).Experimental determination of calorific value using calorimeter utilizes a sample size of 1 gram which as reported by some researchers is inadequate to account for the vast variance in municipal solid waste composition, thus requiring larger samples size (Vesileind, 1981; Reily, 1982; Amin et al., 2011). The most common methods currently being practiced to evaluate the heating value of MSW are the empirical models derived from physical composition analysis, ultimate analysis or proximate analysis of the solid waste (Liu-JI et al., 1996; Cooper and McDonald, 1999; Chang et al., 2007; Ebru et al., 2009; Amin et al., 2011; Marina and Paulo, 2012).

The aim of this paper is to compare empirical model equations in the determination of lower calorific value (LHV) of municipal solid waste in Kano metropolis, Nigeria.

METHODOLOGY

The following empirical model equations based on physical analysis, proximate analysis and ultimate analysis were used in determining the lower calorific value of municipal solid waste in Kano metropolis.

Physical Analysis Model

The determination of calorific value (heating value) of MSW by physical composition analysis is based on the composition of different components of the solid waste such as plastics, paper and food waste. The model equations based on physical composition analysis used for predicting the calorific values of municipal solid waste are as follows [11],[9],[12] (Juin et al., 1996; Chang et al., 2007; Ogwueleka et al., 2010):

$$LHV = \left[88.2\, P_{pl} + 40.5\left(P_{ga} + P_{pa}\right)\right] - 6W \quad (2.0)$$

$$LHV = 2229.91 + 7.90P_{pa} + 28.16P_{pl} + 4.87P_{ga} - 37.28W \quad (2.1)$$

Where LHV : lower calorific value (kcal/kg)

P_{pl} : plastics (wt%), P_{ga} : garbage (wt%; textiles, wood, food waste, garden waste), P_{pa} : paper and cardboard, W : moisture content(wt%).

Composition of the municipal solid waste at the disposal site was carried out according to the American Society for Testing and Materials (ASTM D5231). The procedure involved random collection of waste from the solid waste disposal sites in the amount of 20kg per unit. 100 kg sample of solid waste was collected per day and categorized. This procedure was conducted in the months of October, March and August (2012-2013) to cater for seasonal variations (wet and dry seasons).

Proximate Analysis Model

Proximate analysis models were created based on weight percentage levels of moisture, volatile combustible matter, fixed carbon and ash [4]. (Amin et al., 2011). The model equations for predicting the calorific value of MSW based on proximate analysis are the traditional model and the Bento's model (Abu-Qudais et al., 2000; Chang et al., 2007; Ogwueleka et al., 2010).

Traditional Model

$$LHV = 45V - 6W \quad (2.2)$$

Where LHV : lower calorific value (kcal/kg)

V: physically combustible component content (%),

W: moisture content (%)

Bento's Model

$$\mathrm{LHV} = 44.75\mathrm{V} - 5.85\mathrm{W} + 21.2 \quad (2.3)$$

Proximate analysis of the solid waste was carried according to ASTM 3173-3175 Standard methods which involves the determination of moisture content, volatile matter, ash content and fixed carbon of the solid waste samples from the disposal site. 2 kg samples of solid wastes were collected from the dumpsite and analyzed.

Ultimate analysis model

The ultimate analysis of solid waste typically involves the determination of carbon ((C), hydrogen (H), oxygen (O), nitrogen (N) and sulphur(S) content of the solid waste (Liu JI et al., 1996).

The model equations for predicting the calorific values based on ultimate analysis are as follows (Abu-Qudais et al., 2000; Ogwueleka et al., 2010):

Dulong's Model

$$LHV = 81C + 342.5\left(H - {}^{O}/_{8}\right) + 22.5S - 6(W + 9H) \quad (2.4)$$

Where LHV : lower calorific value (kcal/kg)

C: Carbon (wt%), H: Hydrogen (wt%), O: Oxygen (wt%)

S: sulphur (wt%).

Steuer's Kestner's Model

$$LHV = 81\left(C - 3\ {}^{O}/_{4}\right) + 342.5H + 22.5S + 57\left(3\ {}^{O}/_{4}\right) - 6(9H + W) \quad (2.5)$$

The ultimate analysis involves the determination of nitrogen, hydrogen, carbon, oxygen and sulphur in the solid waste samples. Nitrogen was determined using the Kjeldahl method, the carbon and hydrogen were determined by heating the waste sample in a current of pure oxygen gas, when the carbon and hydrogen were completely oxidized into H_2O and CO_2, these were then absorbed separately in calcium chloride and potassium hydroxide solution. The increase in weight of the absorbents gives the amount of CO_2 and H_2O formed and the amount of C and H were then calculated. The Sulphur determination involves the oxidation to sulphate which is then gravimetrically determined as barium sulphate. Oxygen is calculated by subtracting the sum of the percentages of ash, sulphur, nitrogen, carbon and hydrogen from 100.

RESULT AND DISCUSSIONS

Table 3.1 show the composition of municipal solid waste at Court Road dumpsite in Kano metropolis. The dumpsite is a borough pit (non- sanitary landfill) located in Gyadi- Gyadi Area of the metropolis. It covers an area of 43,337.93 $m^{2.}$

Table 3.1: Composition of Solid Waste at Court Road Dumpsite (2012-2013)

Category	% weight composition			
	October	March	August	Average
Plastics	21.39	23.69	38.56	27.88
Paper/ Card board	2.31	2.02	18.47	7.60
Textiles	5.20	7.56	21.69	11.48
Glass	0.58	1.01	4.02	1.87
Agricultural/Garden waste	24.86	27.22	13.25	21.78
Earth/garbage	42.78	18.15	4.02	21.65
Metals	0.58	0.00	0.00	0.19
Food waste	2.31	20.16	0.00	7.49

Results of proximate and ultimate analysis of the municipal solid waste from the court road dumpsite are shown in Tables 3.2 and 3.3 respectively.

Table 3.2: Proximate Analysis of Solid Waste from Court Road Dumpsite (2012-2013)

ITEMS	MONTHS (2012-2013)			
	OCTOBER	MARCH	AUGUST	AVERAGE
Moisture content (% weight)	46.00	60	23.87	43.29
Volatile matter content (% weight)	50.56	58.00	54.45	54.34
Ash content (% weight)	44.23	36.90	41.33	40.82
Fixed carbon content (% weight)	5.21	5.10	4.22	4.84

Table 3.3: Ultimate Analysis of Solid Waste from Court Road Dumpsite

Nitrogen (N) % wt.	Carbon (C) % wt.	Hydrogen (H) % wt.	Oxygen (O) % wt.	Sulphur (S) % wt.	C/N ratio
0.560	6.200	0.950	0.067	2.800	11.071

Using the model equations 2.0 -2.5, the lower heat value (LHV) of the municipal solid waste are computed and shown in Table 3.4.

Table 3.4: Computed Lower Heat Values (Kcal/Kg)

Model Equations	LHV (kcal/kg
2.0	5034.28
2.1	1762.09
2.2	2185.56
2.3	2199.67
2.4	772.38
2.5	785.078

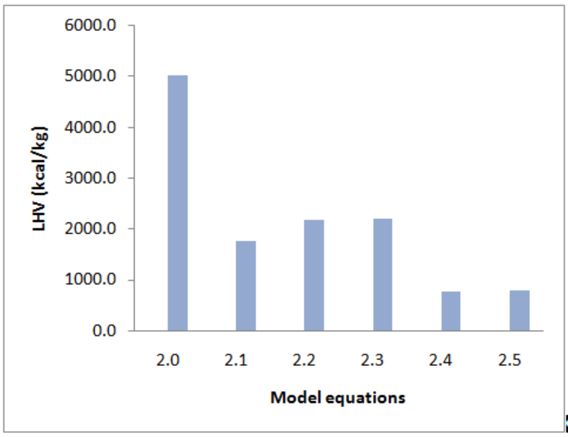

Figure 3.1: Comparison of Computed LHV Using Model Equations (2.0-2.5)

Comparison of the calculated LHV from all the models shows that the physical model equation (2.0) gives much higher values of LHV of the waste than the other three model equations as shown in figure 3.1. The variability of the LHV values from the different models used confirm previous researches results that showed difference in LHV values between empirical models developed. Vargas et al., (2012) stated that ultimate analysis models were developed through research on coal samples and these models were modified to be applicable to municipal solid waste, Magrinho and Semiao, (2008) stated that the ultimate analysis mask underlying assumptions which significantly influence the outcome due to non-homogeneity and variability of the solid waste. It has been reported that the proximate analysis model equations give an accurate estimation of the calorific values of the samples (Amin et al., 2011).

CONCLUSIONS

The result of this study had shown the variability of determining the lower heat value of municipal solid waste using empirical models developed from physical, proximate and ultimate analysis.

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