CHARACTERISATION STUDY OF SOLID WASTES: A CASE OF LAGOS STATE

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ABSTRACT

The aim of this work is to characterise solid waste for the purpose of decision making and planning as well as prevention of environmental degradation by the authorities. The study which is based on the tonnage of solid waste in Lagos State looks at parameters such as moisture content and density of the solid wastes. It also determines the chemical formula with and without sulphur, the volume of air requires to oxidising the solid waste completely, the mass of biodegradable material in the Municipal solid waste and the actual volume of methane gas expected from the solid waste which can be used for domestic purposes.

Keyword: characterisation, solid waste, planning, environmental degradation.

1.0 INTRODUCTION

A man or a woman ceases to generate waste only when he or she is in a state to be disposed off as waste (Adogame, 2009). Solid wastes are all the waste arising from human and animal activities that are normally solid and are discarded as useless or unwanted. It encompasses the heterogeneous mass of throwaways residence and commercial activities as well as the more homogeneous accumulations of single industrial activities. They are generated by almost every activities and the amount varies by source, season, geography and time (Robert, 1999). Many techniques including solid waste management using landfill techniques are used in environmental waste management in Nigeria there still exist a need for effective waste control to provide a platform for sustainable development (Susu etal, 2003). The management and control of wastes at all stages of production, collection, transportation, treatment and ultimate disposal is a relatively social imperative.

Most development countries have advance from an ethos of removing waste from point of depositing in the most expedient and economic alternative location, to control waste production, provision of appropriate treatment options and the engineering of final land disposal so as to minimise resource recovery(Alexander, 2003). Recognising that our world is finite and that the continued pollution of our environment will, if uncontrolled, be difficult to rectify in the future, the subject of characterisation study of solid waste is both timely and important. Traditionally, disposal of waste to someone else and marking it a problem is most commonly deployed for many businesses. It remained a problem until the disposal of waste became linked with ecological degradation (Pitt etal, 2002). There are three primary purposes for solid waste characterisation. First, the data became basis for planning economic analysis, design and subsequent management and operation of a disposal system or material – energy resource recovery facilities. Second, solid waste characterisations for rehabilitation or retrofit of facilities redefine the quantity and type of waste for disposal.

Third, plant optimisation and emission monitoring can be expedited by the characterisation of solid wastes being processed (Robert, 1999). Solid wastes are not homogeneous and do not have consistent characteristics (Vanden and Kirov, 1971). Fifteen years ago, 50% of landfill garbage was cardboard and paper. Now there is relatively little. If we take all wet slot out, the next major landfill gain would be diverting plastics which is 90% by volume and 17% by weight. Unfortunately there is no cost effective means for recycling allot or our plastics because they are such a chemical and process mix (Felica, 2009). This indicates that the components and composition of solid wastes have no consistent characterisation and this should been done consistently which justifies this work.

The composition of solid waste must be known for local authorities to select the most economical collection means, to design and operate an efficient central incineration plant, to plan ahead for suitable sanitary landfill sites or design a compositing plant or a central grinding plant to forecast future demand which they are likely to meet and to forecast accurately the cost and efficiency of operation when choosing a particular method of disposal which further justifies this work.

2.0 THEORY

The moisture content of solid waste is expressed as the mass of moisture per unit mass of water or dry materials. The wet – mass moisture content, M, is given by:

$$M = \left(\frac{a-b}{a}\right) \times 100 \qquad (1)$$

To obtain the dry mass of the solid waste, It is calculated using:

$$\sum\left[\left(\frac{100-C_i}{100}\right)\times d_i\right] \qquad (2)$$

To compute of each component 0f the solid waste sample, we use:

$$v_i = \frac{m_i}{\ell_i} \qquad (3)$$

To compute the density of the solid waste sample,

$$v = \sum v_i \qquad (4)$$

$$m = \sum m_i \qquad (5)$$

$$\ell = \frac{m}{v} \qquad (6)$$

The amount of oxygen requires for the complete aerobic stabilisation of the solid waste can be estimated by using:

$$C_f H_g O_h N_i + \frac{4f+g-2h-3i}{4} O_2 \rightarrow fCO_2 + \frac{g-3i}{2} H_2O + iNH_3 \qquad (7)$$

If the ammonia,NH_3,is to be oxidised to nitrate, the amount of oxygen required can be calculated with equation (8).

$$NH_3 + 2O_2 \rightarrow H_2O + HNO_3 \qquad (8)$$

Anaerobic digestion or anaerobic fermentation is a process used for the production of methane from solid wastes. To estimate the theoretical volume of methane gas that would be expected from the anaerobic digestion, equation (9) is used

$$C_f H_g O_h N_i + \frac{4f-g-2h-3i}{4} H_2O \rightarrow \frac{4f+g-2h-3i}{8} CH_4 + \frac{4f-g+2h+3i}{8} CO_2 + iNH_3 \qquad (9)$$

In practice, a portion of the waste would be for the synthesis of cell tissue of the organism affecting the microbial decomposition. The actual volume of gas would be about 85% of the theoretical value calculated.

3.0 *Characterisation of the solid waste sample*

Table 1: Lagos State Solid Waste Component and Percentage

Component	Tonnage	Percentage
Organic matter	5580	62
Plastics	1350	15
Paper	900	10
Glass	360	4
Silts	630	7
Ashes	180	2
Total	9,000	100

Source: Lagos State waste management authority

To characterise 9000 tonnage of solid waste sample, the following typical component values and composition are used (Tchobanologlous etal,1972) as shown in table 2

Table 2: Typical Component Values and Composition of Solid Wastes

Component	Moisture, % Typical	Density, kg/m³ Typical	C	H	O	N	S	Ash
Organic matter	25	240	48.50	6.50	37.50	2.20	0.30	5.0
Plastics	2	65	60	7.20	22.80	-	-	10
Paper	6	85	43.50	6.0	44.0	0.3	0.2	6.0
Glass	2	195	-	-	-	-	-	-
Silts	20	130	-	-	-	-	-	-
Ash	8	480	26.30	3.0	2.0	0.5	0.2	68.0

Basis: 100kg of solid waste sample
Using equation (2), the mass of sample after drying is gotten to be 81.96kg.
Using equation (1), the moisture content, M, is

$$M = \frac{100 - 81.96}{100} \times \frac{100}{1} = 18.04\%$$

Using equations (3) and (4), the volume of solid waste sample, as shown in table 3, is obtained to be 0.6851m³
With equation (6), the density of solid waste sample is calculated as:

$$\rho = \frac{100}{0.6851} = 145.964 \text{ Kg/m}^3$$

Table3: The volume of solid waste components

Component	% by mass	Volume,m³
Organic matter	62	0.2583
Plastics	15	0.2307
Paper	10	0.1176
Glass	4	0.0205
Silts	7	0.0538
Ashes	2	0-0042
Total	100	0.6851

The organic portion of the solid waste sample comprises the organic matter, plastics, paper and ashes.
The wet and dry masses as well as the composition of organic portion of solid waste sample is shown in table 4

Table4: The wet and dry mass as well as the composition of organic portion of the solid waste

Component	Wet mass kg	Dry mass kg	C	H	O	N	S
Organic matter	62	46.50	22.5525	0.4225	17.4375	1.023	0.1395
Plastics	15	14.70	8.820	1.0584	3.3516	-	-
Paper	10	9.4	4.009	0.564	4.136	0.0282	0.0188
Ash	2	1.84	0.4839	0.552	0.0368	0.0092	0.00388
Total	89	72.44	35.8654	2.5649	24.9619	1.0604	0.1615

The mass of moisture in the organic portion of solid waste sample = wet mass(kg) – dry mass(kg)
= 89 -72.44 = 16.56kg

Converting the moisture content in the organic portion of the solid waste to hydrogen and oxygen.

Hydrogen $= \frac{2 \times 16.56}{18 \times 1} = 1.84$ kg

Oxygen $= \frac{16 \times 16.56}{18 \times 1} = 14.72$ kg

Total mass of hydrogen = 2.5649 +1.84 = 4.404kg

Total mass of oxygen = 24.9619 +14.72 = 39.6819kg

To get the chemical formular of the solid waste with and without sulphur, we normalise the mole ratio as shown in table5.

Table5: The normalise mole ratio

Element	Mass (kg)	Kg/mole	Moles	Normalising Sulphur = 1	Mole ratios Nitrogen = 1
Carbon	35.8654	12.01	2.9862	597.24	39.50
Hydrogen	4.4049	1.01	4.3613	872.26	57.6891
Oxygen	39.6819	16.00	2.4801	496.02	32.8052
Nitrogen	1.0604	14.01	0.0756	15.12	1.00
Sulphur	0.1615	32.06	0.005	1.00	_

Hence, the formular with sulphur is $C_{597.24}H_{872.26}O_{496.02}N_{15.12}S$ and

The chemical formular without sulphur is $C_{39.50}H_{57.6891}O_{32.8052}N$

To determine the amount of oxygen required to oxidise completely 100kg of solid waste, equation (7) is used. Using the chemical formular without sulphur, equation (7) becomes

$C_{39.50}H_{57.6891}O_{32.8052}N + 36.7697O_2 \rightarrow 39.50CO_2 + 27.3446H_2 + NH_3$

To determine the oxygen required per 100kg of solid waste,

Oxygen $= \frac{16 \times 2 \times 36.7692}{(12 \times 39.50) + (1 \times 57.6891) + (16 \times 32.8052) + 14} \times \frac{100}{1} = 109.9067$ kg of O_2/100kg of solid waste

To calculate the oxygen required to stabilise the ammonia, we use equation (8):

Oxygen required $= \frac{17 \times 16 \times 4}{1070.5723 \times 17} \times \frac{100}{1} = 5.9781$ kg 0f O_2/100kg of solid waste

The total amount of oxygen required is $(109.9067 + 5.9781) = 115.8848$ kg of O_2/100kg of solid waste

Take density of air as 1.2kg/m^3(Nelkon and Parker, 1989)

Take O_2 as 21% by weight of air

The mass of air required $= \frac{115.8848}{0.21} = 551.8324$ kg of air/100kg of solid waste

Volume of air required $= \frac{551.8324 kgair/100kgsolidwaste}{1.2kgair/m3} = 459.8603$ m^3/100kg solid waste

To estimate the theoretical volume of methane gas that would be expected from anaerobic digestion of 100kg of solid waste, we use equation (9).With the chemical formular without sulphur, equation (9) becomes:

$C_{39.50}H_{57.6891}O_{32.8052}N + 9.425H_2O \rightarrow 18.3848CH_4 + 21.1152CO_2 + NH_3$

The mass of methane gas produce $= \frac{18.348(12 + (1 \times 4))}{1070.5723} \times \frac{100}{1} = 27.4766$ kg of CH_4/100kg of solid waste

Take density of methane gas as 0.7167kg/m^3

Volume of methane gas $\frac{27.4766kgCH_4/100kgsolidwaste}{o.7167kg/m3} = 38.3376$ m^3/100kg solid waste

Actual volume of methane $= 0.85 \times 38.3376 = 32.5896$ m^3/100kg solid waste

1 tonne of Municipal Solid Waste contains 0.35 tonne of biodegradable material (ABS, 2006)

Mass of biodegradable material in 100Kg of Municipal Solid Waste $= 0.35 \times 100 = 35kg$

Approximately 74% of this is dry biodegradable material (NPI, 2010)

Mass of dry biodegradable material in the Municipal Solid Waste is $0.74 \times 35 = 25.90kg$

About 42-44% of dry Municipal Solid Waste is carbon (USAPA, 2006 and Bidwell, 1979) and 57% of this can be degraded to carbon dioxide and methane (USAPA, 2006)

Taking 42% of dry Municipal Solid Waste as carbon

Mass of dry Municipal Solid Waste that can be degraded to carbon dioxide and methane is $25.9 \times 0.42 \times 0.57 = 6.20kg$

4.0 DISCUSSION OF RESULT

The Lagos solid wastes comprise mostly organic matter and plastic which are 62% and 15% respectively and a little of ashes which account for 2%. The moisture content of the waste is 18.04% which falls within the range of 10 – 35% expected from an industrial city like Lagos. The density of the solid waste is exactly 145.964kg/m^3. This is not in line with the density of solid waste of 210kg/m^3 in the literature (American Public Work Association, 1999). The use of 210kg/m^3 is misleading. The density of a particular solid waste needs to be determined if the masses of the components are available instead of using a constant value in the literature. The chemical formular with sulphur has higher number of atoms of various elements of the compound than the chemical formular without sulphur. The amount of air requires to completely oxidise the solid waste is 460m^3 per 100kg of solid wastes.

The mass of biodegradable material in 100kg of the Municipal solid waste is 35kg out of which 25.90kg is dry biodegradable material. 6.20kg was calculated as the mass of dry municipal solid waste that can be degraded to carbon dioxide and methane .The anaerobic digestion of solid wastes produces gases mostly methane and carbon (iv) oxide. These gases are known to cause global warming and ozone layer depletion. The solid wastes can produce approximately 33m^3 of methane gas per 100kg of solid waste. All the parameters identified in this work are useful for planning of Lagos solid wastes in order to prevent environmental degradation especially in Nigeria.

5.0 CONCLUSION

This study shows the characterisation of the solid waste since the composition of the solid waste must be known especially by local authorities for decision making and planning. Though solid wastes do not have consistence characteristics, this solid waste was found to have a moisture content of 18.04% and a density of about 146kg/m^3. More so, the volume of air to oxidise completely the solid waste was found to be approximately 460m^3 per 100kg of solid waste which can be used for domestic purposes. The mass of biodegradable material in 100kg of the Municipal solid waste is 35kg out of which 25.90kg is dry biodegradable material. 6.20kg was calculated as the mass of dry municipal solid waste that can be degraded to carbon dioxide and methane. The chemical formulas of the solid waste with and without sulphur were determined to be $C_{597.24}H_{872.26}O_{496.02}N_{15.12}S$ and $C_{39.50}H_{57.6891}O_{32.8052}N$ respectively.

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NOTATION

a	Initial mass of solid
b	Mass of sample after drying
C_i	Percentage of typical moisture content of each component
C	Carbon
d_i	Percentage by mass of each component
H	Hydrogen
m_i	Mass of each component of solid waste
m	Mass of solid waste sample
M	Percentage moisture content
N	Nitrogen
O	Oxygen
P	Pressure
R	Gas contant
S	Sulphur
v_i	Volume of each component of solid waste
V	Volume of the solid waste sample
ℓ_i	Density of each component of solid waste
ℓ	Density of the solid waste sample
$\sum$	Sum

Subscripts

f	Number of carbon atom
g	Number of hydrogen atom
h	Number of oxygen atom
i	Number of nitrogen atom