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Energy and Material Recovery from Solid Waste Generated at Rumuokoro Market in Port Harcourt, Nigeria

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Abstract: ***This study presents the characterisation of solid waste from Rumuokoro market in Port Harcourt, Nigeria. Exactly one-hundred-kilogram representative sample of the waste stream was characterized for a period of ten days into ten different components based on the organic and inorganic contents. The results of the study showed that plastic wastes constituted the highest proportion of 24.34% and the second highest were food wastes (18.12%). The other components were determined as paper (8.68%), metals (8.61), glass (8.49%), miscellaneous organics (8.17%), textile (7.89%), wood (6.89%), leather (5.86%) and tin cans (3.12%). The energy content of the waste was estimated at 22.14MJ/Kg of solid waste, indicating that the waste could be a source of energy. However, due to environmental risks associated with the release of dioxins on combustion of plastics, the plastic wastes could be processed and used as damp proof membranes in the construction of buildings or as geo-membrane for landfill caps and bottom liners. This represents a sustainable approach of converting hazardous waste to saleable products.***

Keywords: Plastics, Energy Content, Hazardous Waste, Landfill, Municipal Solid Waste

1. Introduction

Solid wastes are unwanted materials generated from production or consumption. Usually they are not free-flowing [1]. According to [2], solid waste is the second most important problem after water quality. However, what constitutes waste to a generator could be of value to a user either in its present state or processed state. Municipal Solid Wastes (MSW) are largely household wastes, commercial, institutional (e.g. schools, prisons), and in some cases industrial (e.g. cafeteria) although excluding industrial processed wastes.

An integrated waste management approach does not create boundaries based on the form of waste generated whether solid, liquid or gaseous waste. Rather, it involves management of solid waste in such a manner that pollution is not transferred from one environment to another.

In Nigeria, waste management is at rudimentary stage; we still practice "end of pipe" conventional approach of generation of waste, collection and removal services to preventive thinking. A proactive measure will include source reduction, recycling and other strategies for pollution prevention. Hardly is energy created from our waste stream as practiced in western countries; although it has been argued that resource recovery is often driven by statutory targets rather than by the resource value itself [3]. The essence of resource recovery from waste includes the need to reduce the volume of waste generated, to reduce the depletion of natural resources/virgin material and to reduce the cost of disposal. For the Nigerian economy to gain the benefits of renewable energy there is need to invest in waste management using appropriate technology.

Presently, there is a global drive to reduce the amount of biodegradable waste that goes to landfills [4], [3]. In Nigeria, it is common to see dumpsites set on fire and this practice increases the environmental hazards associated with improper disposal of MSW [5]. Although landfilling method has capability to control the wastes, one of the challenges of landfilling biodegradable waste is the emission of greenhouse gasses, such as carbon dioxide and methane, and leachate production [6], [7], [8]. High concentrations of carbon dioxide and methane in the atmosphere contribute to global warming [3].

A process using pyrolysis has been piloted for tires, which presents some difficult disposal problems in incineration and landfill [9]. Similar processes can be effective in recovering chemicals from plastics but have not been developed because of separation problems [10].

Approximately 20 – 30% of MSW generated in Nigeria comprises plastics [11], [12]. Plastics contain polyvinyl chlorides (PVC) and are resistant to microbial degradation. Uncontrolled burning of plastics may have toxic effects due to release of dioxins from PVC. However, energy recovery from plastics can be done in an incinerator equipped with pollution control devices to reduce any environmental hazards that could be associated with such process.

To effectively implement any change in the practice of waste management in Nigeria, there is need for guidelines to be established with regulators ensuring that generators are compliant. Such regulations could suggest reduction in emission of greenhouse gases. The calorific values of some components of municipal solid waste have been investigated [11] - [14] investigated the energy contents of solid waste generated at University of Port Harcourt, Nigeria. The energy content of the solid waste was observed to be 18.43MJ/kg. Similarly, [11] reported 1.733Kcal/g (7.251 MJ/kg) as the cumulative energy content of municipal solid waste in some zones within Port Harcourt metropolis. However, studies involving the energy content of plastics have not been undertaken for any of the markets within Port

Harcourt metropolis. Plastic bottles of all sorts are used in the market for dispensing such food items as cooking oil, vegetable oil, dried spices and so on. Usually, a prospective buyer pours the contents into his/her own container, leaving the seller with the used empty plastic bottle. The local markets in Nigeria are key players in terms of waste generation primarily due to lack of storage/material recovery facilities which encourage disposal of large quantities of plastic wastes to dumpsites around the market areas. This study investigated the waste generated at Rumuokoro in Port Harcourt. The location of the market which is along airport road was considered as a criterion for selection as a study area.

2. Methodology

2.1 Study Area

The waste receptacle investigated is Rumuokoro market in Obio local government of Rivers State, Nigeria. Rumuokoro market lies along the Airport road and its geographical coordinates are 4.8675° N and 6.9981° E in the South-South of Nigeria. Figure 1 shows the location of Rumuokoro market.

(a)

(b)

Figure 1: (a) Map of Rivers State (b) Picture showing Rumuokoro market place

2.2 Solid Waste Generation

Volume and weight are parameters used for the determination of solid waste quantities. The samples were weighed and their compositions determined on the basis of their organic and inorganic contents. Field surveys of the final dumpsite at Igwuruta (Obio/Akpor Local Government Area) were undertaken two times in a week for five weeks.

2.3 Composition of Waste

The weight of the empty truck was obtained from the refuse-disposal company while the weight of the truck load was obtained at the dumpsite from the weighing bridge at the dumpsite. To determine the composition of the solid waste, ten designated sites were randomly selected at the dumpsite. A pre-weighed 10-litre bucket was used to collect and weigh the waste. Each filled bucket was put on a weighing scale to determine the weight of the waste. After weighing, sorting of the waste was done accordingly and their individual compositions determined on the basis of their organic and inorganic contents.

2.4 Solid Waste Characteristics

The composition of different waste components generated from Rumuokoro market is represented in Figure 2. Exactly 100kg sample was used for ease of calculation. The physical composition of the waste is shown in Table 1. The ultimate analysis shows distribution of the major elements of solid waste as carbon (C), hydrogen (H), nitrogen (N), oxygen (O), Sulphur (S) and ash.

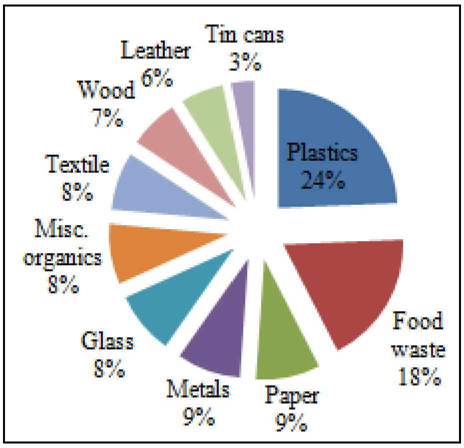

Figure 2: Composition of solid waste generated from Rumuokoro market

Table 1: Physical composition of the solid waste generated from Rumuokoro market for the determination of volume of solid

Waste components	Weight (kg)	Percentage by mass (%)	Density (kg/m^3) [a]	Volume (m^3) = $\frac{Weight}{Density}$
Plastics	24.59	24.34	65	0.3783
Food waste	18.31	18.12	290	0.0631
Paper	8.77	8.68	85	0.1032
Metals	8.70	8.61	160	0.0544
Glass	8.58	8.49	195	0.0440
Misc. organics	8.25	8.17	240	0.0344
Textile	7.97	7.89	65	0.1226
Wood	6.79	6.89	240	0.0283
Leather	5.92	5.86	160	0.0370
Tin cans	3.15	3.12	90	0.0350
Total	101.03	100		0.9003

[a]Values obtained from[15]

2.5 Energy Content Determination

The energy content of the solid waste is determined using Dulong's formula presented as Equation (1) [16].

$$E_i = 32{,}851\ C + 141{,}989\ (H - \frac{O}{8}) + 9263\ S \qquad (1)$$

Where E_i is the energy content (kJ/kg), C is the fraction of carbon, H is the fraction of hydrogen, O is the fraction of oxygen, and S is the fraction of sulphur.

3. Results

For the determination of energy content of the waste, the moisture content of the waste on dry weight basis is first determined. This is as shown in

Table 2. The ultimate analyses were determined using typical values proposed by [15] as seen in Table 3. The distribution of the major elements of solid waste is shown in Table 4 and the chemical formula of the solid waste in Table 5.

The chemical formula of the solid waste with Sulphur is $C_{868} H_{1281}O_{362}N_{28}$ S and the chemical formula without Sulphur is $C_{31} H_{46} O_{13}$ N.

The density of the solid waste sample as discarded was determined as 111.074 kg/m^3 using Equation (2):

$$\rho = \frac{M}{V} \qquad (2)$$

Table 2: Moisture content of the solid waste generated from Rumuokoro market, Port Harcourt using typical values [15].

Components	Mass (%)	Typical Moisture content (%)	Mass of Moisture	Dry Mass (kg)
Plastics	24.34	2	0.49	23.85
Food Waste	18.12	60	10.87	7.25
Paper	8.68	6	0.52	8.16
Metals	8.61	0.5	0.043	8.57
Glass	8.49	0.5	0.043	8.45
Misc. organics	8.17	25	2.043	6.13
Textile	7.89	10	0.79	7.10
Wood	6.72	25	1.68	5.04
Leather	5.86	9	0.53	5.33
Tin cans	3.12	0.5	0.016	3.10
Total	100		17.03	82.98

Table 3: Ultimate analysis of percentage by weight (on dry weight basis)

Components	C	H	O	N	S	Ash
Plastics	60	7	23	0	0	10
Food waste	50	6	38	3	0.4	2.6
Paper	44	6	44	0.3	0.2	5.5
Miscellaneous organics	49	6	38	2	0.3	4.7
Textile	56	7	30	5	0.2	1.8
Wood	50	6	43	0.2	0.1	0.7
Leather	60	9	12	10	0.4	8.6

Source: [15]

Table 4: Percentage distribution of the major elements in the solid waste

Components	Dry weight (kg)	C (%)	H (%)	O (%)	N (%)	S (%)	Ash (%)
Plastics	23.85	14.248	1.662	5.462	0.000	0.000	2.375
Food waste	7.25	3.609	0.433	2.743	0.217	0.029	0.188
Paper	8.16	3.574	0.487	3.574	0.024	0.016	0.447
Miscellaneous	6.13	2.988	0.366	2.317	0.122	0.018	0.287
Textile	7.10	3.958	0.495	2.121	0.353	0.014	0.127
Wood	5.04	2.509	0.301	2.158	0.010	0.005	0.035
Leather	5.33	3.427	0.514	0.685	0.571	0.023	0.491
Total	62.86	34.313	4.259	19.059	1.298	0.105	3.949

Table 5: Determination of chemical formula of the solid waste with and without sulphur

Elements	Mass (kg)	Molecular mass (kg/mole)	Moles	Normalizing mole ratio Sulphur = 1	Normalizing mole ratio Nitrogen =1
Carbon	34.313	12	2.8594	868	31
Hydrogen	4.259	1.0089	4.2210	1281	46
Oxygen	19.059	16	1.1912	362	13
Nitrogen	1.298	14	0.0927	28	1
Sulfur	0.105	32	0.0033	1	-

Table 6 presents the elements of the solid waste under consideration in percentage by mass. By substituting these percentages in Equation (1), the energy content of the solid waste was estimated as 22.14 MJ/kg.

Table 6: Composition of elements and ash in percentage by mass

Elements	*Mass (kg)*	*Percentage by mass (%)*
Carbon	34.313	54.4799
Hydrogen	4.259	6.7613
Oxygen	19.059	30.2610
Nitrogen	1.298	2.0601
Sulfur	0.105	0.1674
Ash	3.949	6.2704
Total	62.984	100

The heating (energy) value of the solid waste is estimated using Equation (1)

$$E_i = 32{,}851C + 141{,}989\left(H - \frac{O}{8}\right) + 9263\,S \quad (1)$$

4. Discussions

In this study, an average of one hundred kilogram of solid waste was investigated for 10 days. The results obtained reveal that the composition of plastics were high (24.34%) Although there are differences in the type of plastics, both in properties and economic values, they were collected together since separation was not required. The total percentage of biodegradable wastes (food waste, paper, wood, textile and miscellaneous organics) was 42.12%. Given the low technology involved in composting, a more sustainable approach towards management of biodegradable waste in Nigeria would be to harness the organic fraction of the MSW into compost [17], [5]. Composting process is favoured by the meteorological conditions (such as temperature and humidity) obtainable in Nigeria.

From results obtained, there is no doubt about the high calorific values of the solid waste generated from the Rumuokoro market (22.14 MJ/kg). The energy needed to illuminate a 60-watt bulb a day is 21,600 J. The total energy generated from the solid waste from Rumuokoro market is $22.14*10^6$ J/kg. Let us assume one household in Port Harcourt will use an average of ten 60-watt bulbs which requires 216000 J/day. It then means that the quantity of energy from one kilogram of solid waste generated from Rumuokoro market can power approximately one hundred and three households having ten (60 watt) bulbs turned on for 24 hours.

However, the challenge is whether there is appropriate technology in Nigeria for conversion of plastic wastes to energy. Plastics have very high energy value [18] but its combustion is associated with release of other air emissions and dioxins (a dangerous chemical compound implicated in human cancer). Since Nigeria is not yet technologically ripe to recover energy from plastics, one of the suggested ways to utilize plastic wastes includes shredding and mixing with binders to be used as damp proof membranes for foundations of buildings. This could be seen as a sustainable way of recycling plastic wastes which will improve aesthetics and reduce environmental pollution caused by piles of plastics around unoccupied sites. It will be a source of income for companies doing recycling and generate revenue for the government. The plastic wastes could also be recovered, processed and used as geo-membrane for landfill caps and bottom liners. In view of this, there is need for the government to establish appropriate organs to oversee the activities at the dumpsites and harness it to gain from what is termed "waste".

5. Conclusions

The study of solid waste characterisation is important because it helps to understand the waste stream, the proportion of different components and appropriate treatment, recovery and disposal options available. Of the ten components of the waste in this study, plastic wastes were discovered to have the highest percentage by mass as 24.34%.It could be processed into other materials or energy could be recovered from it. The public at large should be informed of the benefits of segregation of waste. This practice should be started at residences at the point of disposal.

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