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QUANTIFICATION AND CHARACTERIZATION OF MEDICAL WASTE IN PUBLIC HEALTH CARE FACILITIES WITHIN AKURE METROPOLIS, ONDO STATE, NIGERIA

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Abstract:-
This study investigated the quantity and rate of medical waste generation in purposely selected public hospitals located within Akure metropolis of Ondo State and determined the characteristics of the waste generated. The quantity of medical waste generated was measured daily in kg per day, kg per bed per day, and kg per patient per day while, the physical and chemical characteristics were determined according to standard methods. This study indicated that the quantity of medical waste generated by Ondo State Specialist Hospital Akure, and Mother and Child Hospital Akure were 124.5 kg/day and 0.44 kg/patient/day. Over two-thirds were general waste while the remainder (30.9%) were considered to be infectious and hazardous wastes. The result obtained from physical characterization of the medical waste revealed that the percentage of moisture content and bulk density of cellulose in the medical waste composition exceed other components of the waste. However, from proximate analysis of the medical waste, cellulose has the highest percentage of fixed carbon, volatile matter and ash while the result obtained from ultimate analysis indicated that the percentage content of hydrogen, nitrogen, sulphur, oxygen and carbon is higher than that of other composition of medical waste.

Keywords:- *Medical waste, public health-care facilities, general waste, infectious / hazardous waste, physical and chemical characterization, proximate and ultimate analysis*

INTRODUCTION

The fact that health-care facilities is saddle with the responsibility of providing medical care comprising of diagnostic, therapeutic, recuperative, rehabilitative and research services with the view of managing health challenges and protecting the environment from health hazards does not implies that medical waste generated in the course of performing these activities be neglected. Over the years, population increase, human activities and changes related to way of life and consumption patterns have resulted in the bulk generation of different kinds of waste materials which have threatened the continued existence of humans and other living things, as well as all of the natural resources that are essential to human survival. As a result, significant attention and a great deal of research have been conducted on waste management (Oweis *et al.,* 2005; Birpinar *et al.,* 2009).

Over the years, throughout the world health sector among other sectors has been showing improvement with the introduction of new systems and technology for handling activities related to human health issues (Birpinar *et al*., 2009). However, these activities had led to the generation of medical waste that may have adverse effects on human health and on the environment if not managed appropriately (Chaerul *et al*., 2008; Bazrafshan and Mostafapoor, 2011). Medical waste can be categorised into two major groups: general and infectious/hazardous waste. General waste constitutes 75 to 90% of the waste produced in hospitals which is similar to municipal or domestic solid waste (Pruss *et al*., 1999; Chaerul *et al*., 2008; Bazrafshan and Mostafapoor, 2010). It is not a dangerous waste, hence it requires no special handling, treatment or disposal and it can be disposed in same way like municipal solid waste (Lee *et al*., 2004; Bazrafshan and Mostafapoor, 2010; Pruss *et al*., 1999). The remaining 10–25% of medical waste is regarded as hazardous or infectious waste, according to the World Health Organization (WHO, 1999) and United States Environmental Protection Agency (USEPA, 1990a, b) definitions. The hazardous or infectious waste materials include a wide range of waste from pathological waste, genotoxic waste, pharmaceutical waste, chemical waste, waste with high heavy metal content, pressurized containers and radioactive waste, most of which are toxic, harmful, carcinogenic and infectious materials (Pruss *et al*., 1999; Marinkovic *et al*., 2008). Therefore, proper management of medical waste is warranted to ascertain that the impact on the public health and the environment is maintained at minimum (Chaerul *et al*., 2008). Although the portion of infectious and hazardous waste is relatively small, any improper waste management wherein infectious waste is mixed with general waste can render all of the waste potentially infectious and hazardous and makes the quantity of waste generated to increase (Chaerul *et al*., 2008). The objective of this study was to quantify and characterize solid medical waste generated in the two selected health-care facilities within the state capital territory.

2 MATERIALS AND METHODS

2.1 Study area

The experimental location is Akure, the capital city of Ondo State. Akure is in the Southwestern part of Nigeria. The state occupies an area of 15,500 square kilometres, bounded on the East by Edo and Delta States, West by Ogun and Osun States, North by Ekiti and Kogi States and South by the bight of Osun State and the Atlantic Ocean (IFSERAR, 2009). It has an estimated population of 3,460,877 (National Population Commission, 2015) and a population density of 218 people per sq. km (Olagunju and Akinyemi, 2015). Figure 1 is the map of Ondo State showing the study area and the various Local Government Areas (Ondo State Diary, 2012). The selected units of inquiry were two public health-care facilities within Akure metropolis namely:

(i) Ondo State Specialist Hospital Akure (OSSHA) and ii) Mother and Child Hospital Akure (MCHA).

The Ondo State Specialist Hospital Akure has latitudes 7°14'31.8"N and longitudes 5°11'44.4"E. It is the only Public Specialist Hospital in Akure South Local Government Area of Ondo State with the highest percentage of medical services i.e. a total number of 212 beds, while the only Public Referral Hospital meant for infants and pregnant mothers (Mother and Child Hospital) in Akure South Local Government Area has latitudes 7°14'26.2"N and longitudes 5°11'01.1"E.

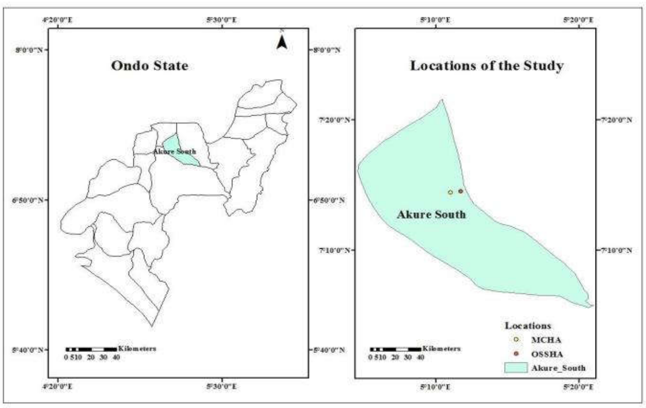

Figure 1: Map of Ondo State showing the study location

(Field Survey, 2017)

2.2 Experimental Procedures

Prior survey, the research team involved in waste management were made to undergo sensitization workshop on the importance of effective medical waste management to people and the environment and how it can be achieved. They were made to understand the objectives and methodology of the study. In addition, all waste generating units in the Health-care Facilities (HCFs) were identified and divided into different sites according to ward and the services rendered. Materials used for the experiment include a steel measuring tape, an analogue weighing scale with 200 kg capacity, screwdriver, questionnaire, recording sheets, checklist, waste bins, a sorting plates, and colour polythene bags.

2.2.1 Quantification of medical waste

In this research study, the classification criteria were based on:
i) Potential risks such as hazardous–infectious, sharps and general waste, whereby the hazardous-infectious waste was put inside red polythene bag, general waste inside black polythene bag and sharps inside yellow puncture-proof polythene bag, all inserted into different plastic buckets. These practices really enhanced easy measurement in kilogram (kg). ii) Composition of waste includes plastics, textiles, rubber, paper/cardboard, glass, food residues, metals and others. In order to determine the quantity (kg/day) and rate of waste generation (kg/bed/day, kg/patient/day), all generated waste (hazardous–infectious, general and sharps waste) were weighed separately on a 50kg capacity weighing scale. Following 24hourly collection, waste samples were measured for 7 days and on the seventh day an average of the week's data was recorded. Unit generation rate in kg/bed/day and kg/patient/day were calculated by dividing the generation rate in kg/day on the total number of beds and patient respectively in the HCFs.

2.2.2 Determination of medical waste characteristics

Physical and chemical characteristics of health-care wastes are important for purposes of defining the specific type of equipment required for the treatment. Determination of the physical and chemical characteristics of medical waste were carried out by separating the wastes into categories such as cotton, paper, textiles, plastic, tissue, glass, food residues, rubber, metal and wooden material. The separated materials were taken to laboratory for proximate and ultimate analyses. Physical parameters determined were moisture content and bulk density while the proximate and ultimate analysis were parameters determined under chemical characteristics. Proximate analyses include percentage of volatile matter, ash, fixed carbon, fat, fibre and protein content while ultimate analyses determined include percent of carbon, nitrogen, hydrogen, oxygen and sulphur content following WHO standard (1999).

2.2.2.1 Physical characteristics of medical wastes

i) Bulk density is the ratio of weight of waste (kg) to the volume of waste (m^3). It is measured in kilogram per cubic metre (kg/m^3). In order to determine bulk density of waste, the samples were weighed in terms of mass (kg) using weighing scale and the volume is determined using cross-sectional area of the container against its depth. That is,

Bulk density, 'ρ' = ____________ $Mass\ (Kg)_3$

ii) Moisture content is the ratio of dried weight to weight before drying. It is measured in percentage (%) either on dry or wet bases. In order to determine moisture content of waste, the samples were weighed (Ww), then dried at 105°C for 24-hours and weighed again (W_d).

That is,

Moisture content (M_C) = Ww __________ $-W$ X 100%

2.2.2.2 Chemical characteristics of medical wastes

i) Measurement and calculation of calorific value

The calorific value of medical waste is foundation data of incineration, which determines the design and operation parameters of incinerator. The calorific values (Upper and Lower calorific values) of the medical waste were estimated by element analysis according to equation of Japan Environmental Sanitation Centre (1981) and Abd El-Salam (2010) as follows:

$$\text{Higher Calorific value} = 81\left(C - 3 * \frac{O}{8}\right) + 57 * 3 * \frac{O}{8} + 345\left(H - \frac{O}{10}\right) + 25S \quad \text{(kcal/kg)}$$

$$\text{Lower Calorific Value} = \text{Upper CV} - 6(9H + M) \quad \text{(kcal/kg)}$$

3 RESULTS AND DISCUSSION

3.1 Medical Waste Generation, Quantification and Composition

Table 1 shows the total waste generated in MCHA and OSSHA which are 302.9 kg and 568.2 kg respectively for the two weeks (14 days) with weighted average of 435.55 kg. Daily waste generation in OSSHA (81.2 kg/day) is higher compared with daily generation in MCHA (43.3 kg/day). This could be as a result of the number of medical services rendered at the hospital, thus the average daily waste generation from both facilities is 62.25 kg/day. Furthermore, the daily inventory of patients in OSSHA (472 patients) is higher than that of MCHA which is 159 in number, however, daily waste generation per patient in MCHA (0.27 kg/patient/day) is more than that generated at OSSHA which is 0.17 kg/patient/day. This could as well be as a result of nature of medical services rendered. The average of daily waste generated per patient in both Hospitals is 0.22 kg/patient/day which is much lower than that of 4.5 kg/patient/day in USA, 2.7 kg/patient/day in Netherlands and 2.5 kg/patient/day in France.

Table 1: Waste generation and quantification in surveyed hospitals

Name of HCFs	HCFs Capacity	Total no of patient	Total no of bed	Total waste generation (kg)	Total daily waste generation (kg/day)	Total daily waste generation per patient (kg/patient/day)
MCHA	200	159	85	302.9	43.3	0.27
OSSHA	500	472	212	568.2	81.2	0.17
Weighted Average	350	315	148.50	435.55	62.25	0.22

Source: Field analysis (2017)

3.2 Categorise of Waste in Surveyed Hospitals

Results from the survey as indicated in Table 2 shows the quantity of medical waste categories generated in each of the facilities. Daily generation of general waste, infectious waste and sharps in OSSHA (386.4 kg, 147.6 kg, and 34.2 kg) were much more than what is generated in MCHA (219.7 kg, 68.1 kg and 16.1 kg). Total general waste, infectious waste, and sharps generated from both facilities were 606.1 kg, 215.7 kg, and 50.3 kg respectively, thus, making a total of 871.1 kg of waste generated during 14 days of quantification. The percentages of general waste, infectious waste and sharps generated for period of days the measurement was carried out (2 week) were 69.6 %, 24.8 % and 5.8 % respectively.

Table 2: Quantity (kg) of the categories of medical wastes

Name of HCFs	General waste	Infectious waste	Sharps	Total waste
MCHA	219.7	68.1	16.1	302.9
OSSHA	386.4	147.6	34.2	568.2
Total	606.1	215.7	50.3	871.1
Average	303.1	107.9	25.2	435.6
Percentage	69.6	24.8	5.8	100

Source: Field survey (2017)

From table 3, it is apparent that the mean waste generation rate per bed per day from surveyed HCFs is 0.75 kg/bed/day. This value does not fall within the range of waste (1 - 4.5 kg/bed/day) generated in Latin America countries like Chile, Brazil, Argentina, Venezuela (Monreal, 1991; 1993; Ahmad, 2007). Generation rate (total weight) per health institution is as follows: MCHA generates 0.918 kg/bed/day while OSSHA generates 0.581 kg/bed/day. Similar results were obtained by Abdulla *et al.* (2008) and Birpinar *et al.* (2008) in Egypt where the mean medical waste generation rates were 0.83, 0.61, and 0.63 kg/bed/day respectively. Average waste generation rate from the two facilities (0.75 kg/bed/day) is a little bit above 0.68 kg/bed/day recorded by Olagunju and Akinyemi (2015) in Ondo State and 0.66 kg/bed/day medical waste generated in Nepal as recorded by Majumder *et al.* (2007), 0.47 kg/bed/day as recorded by Franka *et al*. (2009) in Libya; but far below the 2.782 kg/bed/day recorded by Bassey *et al.* (2006) in HCFs at FCT Abuja, 1.8–2.2 kg/bed/day in Eastern Asia, 3.9 kg/bed/day in Norway, 4.4 kg/bed/day in Spain, 3.3 kg/bed/day in United Kingdoms, 3.0 kg/bed/day in Latin America, 2.5 kg/ bed/day in France and 2.76 kg/bed/day in Iran (WHO, 1985; Hassan *et al.,* 2008; Alam *et al.,* 2008; Bazrafshan and Mostafapoor, 2010).

Table 3: Percentage of daily medical waste generation per bed (kg/bed/day)

Surveyed HCFs	Daily general waste	Daily Infectious waste	Daily sharp waste	Total daily waste	% of daily general waste	% of daily infectious waste	% of daily sharp waste
MCHA	0.648	0.210	0.061	0.918	70.51	22.87	6.62
OSSHA	0.350	0.178	0.053	0.581	60.21	30.69	9.10
Average	0.50	0.19	0.06	0.75	65.36	26.78	7.86

Source: Field analysis, (2017)

Infectious waste produced at MCHA was 0.210 kg/bed/day (22.87%) while it was 0.178 kg/bed/day (30.69%) at OSSHA. General waste produced at MCHA and OSSHA was 0.648 kg/bed/day (70.51%) and 0.350 kg/bed/day (60.21%) respectively. However, table 4 shows that hazardous waste (sharp) generated at MCHA (0.061 kg/bed/day) (6.62%) was higher compared to 0.053 kg/bed/day (9.10%) generated in OSSHA. The average of general, infectious and hazardous waste (sharps) generated from the two health-care institutions summed up to 0.50 kg/bed/day (65.36%), 0.19 kg/bed/day (26.78%) and 0.06 kg/bed/day (7.86%) respectively. The percentage of infectious waste generated in the hospitals was higher, while general waste is lower than the percentage given by WHO (2010). This might be as a result of improper waste segregation from the source, whereby wastes are mixed together.

Table 4 reveals that the average waste generated daily from the surveyed HCFs is 62.25 kg/day. 69.56% (43.30 kg/day) of the waste produced is general waste and only 24.74% (15.40 kg/day) is infectious while 5.70% (3.55 kg/day) constituted the sharps. From the present study, the quantity of medical waste generated daily in OSSHA (81.2 kg/day) is higher than 17.4 kg/day recorded by Babatola (2008) in same facility. This can be attributed to the numerous health-care services recently incorporated into the health facility's system and wide acceptance of single use of disposable equipment such as gloves, plastic syringes, medical packages, bedding, tubing and containers. However, a daily generation of 72.52% of general waste is produced in MCHA compared to 67.98% of what is generated in OSSHA. The percentage of infectious waste (24.74%) in surveyed facilities is higher than that of Netherlands (5%) and Sweden (8%), and lower than that of Denmark (25%) and USA (28%). This indicated difference may be due to geographical location, living habits and standards, availability of different treatment facilities, and perhaps according to the way in which solid waste are categorized in different countries (Monreal, 1991; 1993).

Table 4: Percentage of daily medical waste generation (kg/day)

Surveyed HCFs	Total daily general waste	Total daily Infectious Waste	Total daily sharp waste	Total daily waste	% of daily general waste	% of daily infectious waste	% of daily sharp waste
MCHA	31.4	9.7	2.2	43.3	72.52	22.40	5.08
OSSHA	55.0	21.1	5.1	81.2	67.98	25.99	6.03
Average	43.30	15.40	3.55	62.25	69.56	24.74	5.70

Source: Field analysis, (2017)

3.3 Medical Wastes Compositions

In other to determine the quantity of each composition of medical waste generated from the facilities, two samples from each categories of waste (infectious, general and hazardous waste) were randomly selected through colour bags (red, black and yellow bags). These were selected to represent the total medical wastes produced in the HCFs, thus making an aggregate of six (6) samples and each of the samples weighed 20 kg to make a sum of 120 kg for each hospitals. The wastes were poured on three different circular stainless plates with flat surface and were sorted into different compositions and weighed separately. As shown in figure 2, food residues constituted largest percentage of waste from the two hospitals (19.1%) followed by under-pads/pampers (8.8%) and cans/tins (8.5%).

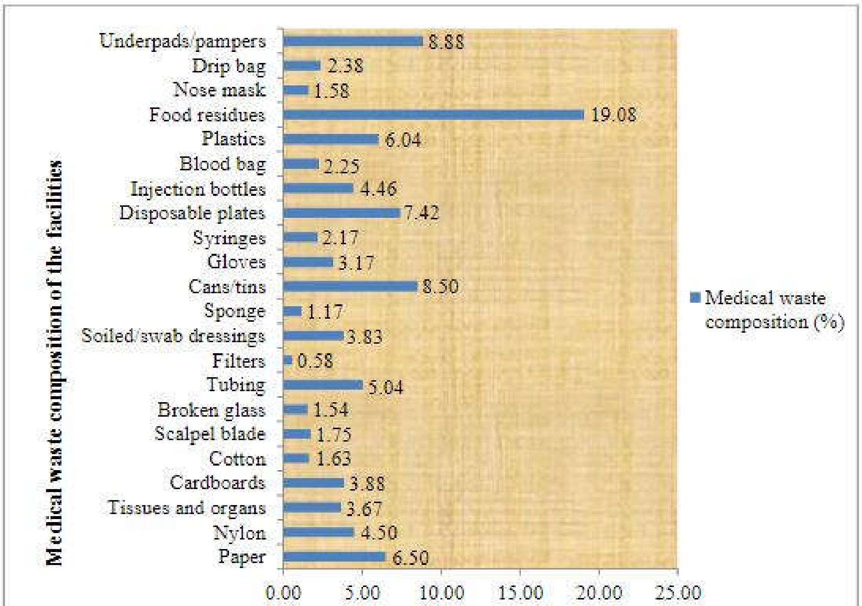

Figure 2: Percentage of medical waste composition

3.3.1 Physical components of the wastes

In other to ensure easy analysis, the compositions of medical waste generated in surveyed HCFs as listed in figure 2 were classified under the following materials as Paper (papers, cardboards, filters, and disposable plates), food residues, plastics, rubber (nylons, tubing, gloves, blood bags, drip bags, and sponges), tissues, metals (scalpel blade, syringes and cans/tins), glasses (injection bottles and broken glass) and textiles (soiled/swab dressings, cotton, nose mask and under-pads/pampers) as presented in table 5.

The composition of the whole generated waste by classification was found to be 18% with a weighted average of 22.05 kg/day (±0.071) paper, 19% with a weighted average of 22.90 kg (±3.111) food residue, 6% with a weighted average of 7.25kg (±1.202) plastics, 18.5% with a weighted average of 22.2kg (±1.86) rubber, 3.5% with a weighted average of 4.4 kg/day (±0.707) tissues, 12.5% with a weighted average of 14.90 kg (±0.566) metals, 6% with a weighted average of 7.20 kg (±0.990) glass and 16% with a weighted average of 19.10 kg (±10.182) textiles.

Table 5: Composition of hospital waste generated in selected healthcare facilities

Solid medical waste composition	MCHA Mass of waste kg)	OSSHA Mass of waste (kg)	MCHA Percentage of waste (%)	OSSHA Percentage of waste (%)	Mean	±SD
Paper	22	22.1	18	18	22.05	0.071
Food residues	20.7	25.1	17	21	22.9	3.111
Plastic	6.4	8.1	5	7	7.25	1.202
Rubber	18.9	25.5	16	21	22.2	4.667
Tissues	3.9	4.9	3	4	4.4	0.707
Metal	15.3	14.5	13	12	14.9	0.566
Glasses	6.5	7.9	5	7	7.2	0.990
Textiles	26.3	11.9	22	10	19.1	10.182

Source: Field analysis (2017)

3.4 Characterisation of medical waste

3.4.1 Physical characterisation

Moisture content is essential for leachate calculation and its migration most especially for the design of sanitary landfill and composting. From table 6, it is evident that percentage moisture of the waste samples ranged from 1.12 to 2.35% with a mean of 1.98%. Cellulose recorded the highest percentage of moisture content while plastics recorded the least. Values of bulk density obtained can be used to assess the volume of transportation vehicle, size of the treatment and disposal facilities. The bulk density of cellulose (0.82 – 0.88 %) is more than other components of the medical waste but the bulk density of the sampled waste ranged from 0.51 – 0.82%.

Table 6: Physical characteristics of medical waste

Biomedical waste composition	% Moisture contents	% Bulk density
Cellulose (food, textile & paper)	2.35	0.82
	2.24	0.88
Rubber	2.04	0.76
	2.11	0.74
Plastics	1.32	0.51
	1.12	0.51
Tissues	2.34	0.67
	2.29	0.62

Source: Laboratory analysis (2017)

3.4.2 Chemical characterization

Table 7 details the chemical characteristics of medical waste which include ash, moisture and combustible contents. The mean value of ash was 44.85%. The percentages of fibre in plastic which range between 52.61% and 52.74% are higher than the percentages of fibre in other components. Moreover, as shown in table 7, cellulose has the highest percentage of ash (63.91%) and protein contents (3.68%), while fat recorded the least. The percentage of fixed carbon content and volatile substance in cellulose is higher than other components of the medical waste.

Table 7: Proximate analysis of medical waste

Biomedical waste composition	% Moisture	% Ash	% Fat	% Fibre	% Fixed carbon	Volatile matter (%)	% Protein
Cellulose	2.35	63.91	0.00	18.96	33.23	63.91	3.68
	2.24	64.11	0.00	18.48			3.55
Rubber	2.04	37.79	0.00	43.79	19.65	37.79	1.75
	2.11	38.01	0.00	43.24			1.70
Plastics	1.32	23.64	0.00	52.61	16.09	30.96	1.93
	1.12	23.64	0.00	52.74			1.85
Tissues	2.34	54.24	0.00	24.67	3.17	37.75	2.34
	2.29	53.45	0.00	24.55			2.13

Source: Laboratory analysis, (2017)

Table 8 shows the percentage of carbon, hydrogen, nitrogen, sulphur and oxygen content in each components of sample medical waste. The carbon to nitrogen ratio (C/N) is estimated to be 8:1. The volatile matter and fixed carbon percentage in cellulose (63.91%) is higher than other components of the sampled medical waste. Similarly, tissue has the highest percentage of hydrogen, nitrogen, sulphur, oxygen and carbon in the sample. This emphasised the reason why the designed incinerator must be heated and operated at designated temperatures in other to prevent the release of highly toxic gases to the atmosphere.

Table 8: Ultimate analysis of medical waste

Biomedical waste composition	Volatile Matter (%)	H%	%N	%S	%O	%C
Cellulose	63.908	1.930	0.588	0.060	0.420	14.810
Rubber	37.792	1.539	0.280	0.010	0.501	1.950
Plastic	30.958	0.727	0.308	0.030	0.593	6.152
Tissue	37.748	4.653	4.096	0.310	0.867	19.959
Mean	42.602	2.212	1.318	0.103	0.595	10.718
±SD	14.563	1.703	1.857	0.140	0.194	8.162

Source: Laboratory analysis, (2017)

As shown in table 9, the lower Combustion Calorimetry (CV) ranged between 5.450 kcal/g to 9.117 kcal/g with a mean of 7.407 kcal/g (SD ±1.942) while the higher CV ranged from 5.956 kcal/kg to 9.121 kcal/g with a mean of 7.538 kcal/kg. The actual calorific values for the medical waste ranged from 5.703 kcal/g to 9.119 kcal/g with a mean of 7.472 kcal/g (SD ±1.860). The Higher Heating Values (HHV) were used for the design of the incinerator.

Table 9: Solid medical waste combustion calorimetry

Biomedical waste composition	Higher calorific value (kcal/g)	Lower calorific value (kcal/g)	Mean Calorific value kcal/g	Higher heating value (kJ/kg)
Cellulose	5.956	5.450	5.703	23,860
Rubber	9.042	9.036	9.039	37,820
Plastic	9.121	9.117	9.119	38,154
Tissue	6.031	6.025	6.028	25,220
Mean value	7.538	7.407	7.472	31,264
±SD	1.783	1.942	1.860	7,784.651

Source: Laboratory analysis (2017)

Result from laboratory analysis (table 9) shows that the Higher Heating Values (HHV) of sampled medical waste from the surveyed hospitals range from 23,860 kJ/kg to 38,154 kJ/kg with a mean value of 31,264 kJ/kg (SD ±7,784.651). The values obtained falls within the range of medical waste characteristics given by WHO (2010).

4 CONCLUSION

From this study, it can be concluded that daily generation of medical waste in health-care facilities increases in quantity and variety with increase in the number and nature of healthcare services rendered to the public as a result of wide acceptance of single use of disposable equipment such as tubing and containers, gloves, beddings, plastic, syringes and medical packages which has been of major concern, due to the potentially high risks to human health and the environment. There was serious mismanagement of medical waste, which is typical of many hospitals in Nigeria as improper segregation of medical waste at the point of generation was rampant which does not only increase the quantity of infectious waste generated and treated as waste, but also increase the risk associated with its handling as well as increasing the cost of management.

The main findings and recommendations of this study were:

- Of the total medical waste generated in MCHA and OSSHA hospitals, 65.36% consisted of general waste, 26.78% were infectious waste, and 7.86% were sharps waste.
- The average generation rates of total medical waste, infectious waste, general waste and sharp waste in MCHA and OSSHA were 0.75, 0.19, 0.50 and 0.06 kg/bed/day respectively.
- The estimated quantity of medical waste from the hospitals was 124.5 kg/day or 45.442 ton/year.
- The ultimate approach to medical waste management is to develop regulations aimed at implementing integrated medical waste management that is based on environmental law decrees which must be supplemented with stringent enforcement at both State and Local Government levels. To achieve this, policy makers and hospital administrators require both technical assistance and financial support.
- Segregation of general and infectious waste at the point of generation in hospitals is a practical way to significantly reduce the volume of infectious waste, because any contact between these waste materials means that the overall waste has to be considered to be infectious waste, which in turn increases the health and environmental problems and requires more attention for handling and final disposal.

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