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Full Length Research Paper

Comparative analysis of municipal solid waste (MSW) composition in three local government areas in Rivers State, Nigeria

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Rivers State is one of the major oil producing States in Nigeria. Its capital, Port Harcourt and sub-urban areas have witnessed an increased influx of migrants in recent time. Consequently, the consumption of goods and services has also increased leading to generation of unprecedented quantities of municipal solid waste. Previous efforts by relevant authorities to contain this increase in waste generation have proved abortive due largely to among other reasons, inappropriate and unsustainable municipal solid waste (MSW) management systems. The first step in a sustainable MSW management is to understand the types, composition and variation that exist in the waste generated in time and space. Previous reports have been concentrated on the characteristics of waste in Port Harcourt. This present work evaluated solid waste composition in three LGAs in Rivers State with a view of an integrated approach in MSW management in the State. Waste characteristics varied with the different locations studied. Generation rate was 0.45, 0.98 and 1.16 kg/capita/day for Emougha, Obio/Akpor and Port Harcourt, respectively. Most prominent categories were organic waste, paper and nylon. Mean percentage composition was 65, 65.5 and 59% for organic waste, 13, 11 and 6% for paper and 12, 16 and 14% for nylon in Port Harcourt, Obio/Akpor and Emougha LGAs, respectively. It is believed that given the characteristics of these waste streams, a sustainable management strategy could have several benefits including resources recovery and energy generation.

Key words: Municipal solid waste (MSW), characterization, Rivers State, integrated MSW management.

INTRODUCTION

Solid waste management has emerged as one of the greatest challenges facing municipal authorities world wide especially in developing countries. The volume of solid waste been generated has continually increased at faster rate than resources available to contain it. In developing nations, the situation is more critical since their resources are usually meagre and more priority issues like health and education beat municipal solid waste management (MSWM) to the top of the list. The consequence is ill conceived and operated epileptic MSWM systems that leave monuments of solid waste adorning the streets of urban centres in countries like Nigeria posing

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serious risk to both human and environmental health.

Municipal solid waste (MSW) includes refuse from households, non-hazardous solid waste from industrial, commercial and institutional establishments (including hospitals), market waste, yard waste and street sweepings. MSWM refers to the collection, transfer, treatment, recycling, resources recovery and disposal of solid waste in urban areas. The goals of municipal solid waste management are to promote the quality of the urban environment, generate employment and income, and protect human and environmental health and support the efficiency and productivity of the economy (Ogwueleka, 2009). Igoni et al. (2007) defined MSW as all waste collected by private and public authorities from domestic, commercial and some industrial (non-hazardous) sources. Urban solid waste is a heterogeneous material and its generation rate and composition vary from place to place and from season to season (World Resources Institute, 1996; Gidarakos et al., 2006). The composition and volumes differ between high and low-income locations (UNEP, 2002). According to Ogwueleka (2009), solid waste is wetter, heavier and more corrosive in developing nations, making its management more difficult.

The poor state of solid waste management in urban centres of developing countries is now not only an environmental problem but also a social handicap (Daskalopoulos et al., 1998). Solid waste management in Nigeria is characterized by inefficient collection methods, insufficient coverage of the collection system and improper disposal despite huge budgets that are committed to MSWM. Local authorities in developing countries spend 77-95% of their revenue on collection and balance on disposal but can only achieve 50-70% collection of MSW (Ogwueleka, 2003).

The quantity and generation rate of solid waste in Nigeria have increased at an alarming rate over the years without corresponding efficient and modern technology for managing the waste (Babayemi and Dauda, 2009). The indiscriminate and improper dumping of MSW in developing countries is increasing and is compounded by a cycle of poverty, population explosion, decreased standards of living and poor governance and low level of environmental awareness. Hence, waste generated is illegally disposed of onto any available open space hence the term "Open Dump Site". Solid waste in Nigeria poses many problems including blockage of drainage and channels causing flooding and presenting breeding grounds for mosquitoes and other vectors and pathogens (Igoni et al., 2007). According to Ogwueleka (2009), more than 25 million tonnes of solid waste is generated in Nigeria annually with average rate of generation ranging from 0.44 kg/cap/day in rural areas to 0.66 kg/cap/d in in urban areas.

Rivers state where the present study was undertaken is home to the country's wealth, usually referred to as the treasure base of the nation. It produces crude oil that accounts for 90% of the country's foreign exchange earnings and has a population of 5,198,716 people (NPC, 2006). Port Harcourt, the state capital is the major urban centre and has witnessed high influx of migrants as a result of its rapid urbanization. This has no doubt increased the consumption patterns and consequently waste generation and more pressure on the municipal authorities responsible for solid waste management. Despite efforts made by the State Sanitation Board, refuse still adorn the streets of Port Harcourt and other sub-urban areas in the state and in some cases blocking drainages, roads and channels causing flooding posing danger to public health (Ayotamuno and Gobo, 2004; Igoni et al., 2007). According to Ayotamuno and Gobo (2004), Port Harcourt has lost its glorious name of "Garden City" to Garbage City. Gobo (2002) observed that solid waste management system options that have been carried out without success to solve the problem of refuse disposal in Port Harcourt over the years include incineration, composting, transfer stations and landfilling. Solid waste collection is done by private contractors who pick up waste with trucks from usually overflowing containers stationed for residence on the street sides and disposal is at designnated open dump sites in the state where burying, burning and scavenging take place. There are open dumps right in the middle of the urban centres where burning, burying and scavenging usually take place as well. Another set of collectors comprise the cart pushers who collect from residence and dispose to the nearest open dump by the road side.

The first step towards a sustainable solid waste management is to gain understanding of the nature and composition of the waste being generated in time and space. This information is necessary for planning, designing and establishing appropriate and more sustainable collection, transportation and final disposal strategies for the waste. Ogunbiyi (2001) reported that the composition of solid refuse vary from location to location, from household to household and even in the same household, it could vary from week to week, hence solutions should be location specific. Per capita generation of solid waste in Port Harcourt has been reported to range from 0.66-1.25 kg/cap/day and the characteristics of the waste comprise organic matter, plastics, metal, nylon, glass and others (Ibiebele, 1986; Ayotamuno and Gobo, 2004; Igoni et al., 2007; Abah and Ohimain, 2010). But there has been no attempt to compare the waste stream of Port Harcourt metropolis with its sub-urban environs for an integrated catchment management. This paper aimed to present the characteristics of MSW been generated in three local government areas of Rivers State, Nigeria differing in socioeconomic activities for an integrated MSWM scheme. The major consideration was solid waste composition at open dump sites. The categories compared between the three LGA's during the study were organics, paper, plastics, metal, nylon and a category referred to as others comprising wood, diapers, sanitary pads and unidentified materials.

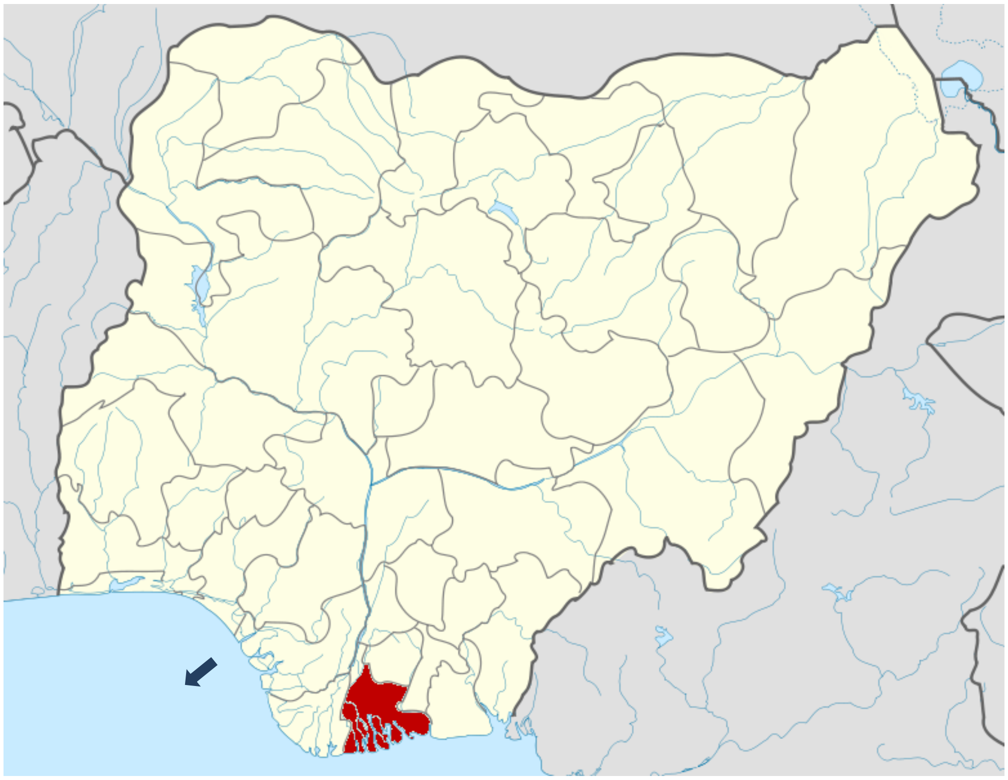

Figure 1. Map of Nigeria showing Rivers State.

MATERIALS AND METHODS

Rivers State where this study was carried out is a maritime state in the southern geopolitical zone of Nigeria (Figure 1) located on 4°45′0″ and 4.75 N and 6°50′0″ and 6°83′3″ E. It has a total population of 5,198,716 (NPC, 2006) comprising 23 local government areas with Port Harcourt, the state capital as one of the Local Government Areas (LGA) (Figure 2). Port Harcourt LGA shares boundary and commerce with the two other LGAs surveyed for solid waste characteristics in this study. The settlements in the three LGAs were chosen according to the category of inhabitants and socioeconomic activities. Port Harcourt LGA is the main urban centre in Rivers State but houses some shanties as well. Obio/Akpor is presumably the richest LGA in Rivers State and houses most of the multinationals. Emuoha LGA is made up of sub-urban and rural settlements. Detail characteristics of the settlements studied under the three LGAs in this study is presented in Table 1.

Sampling and data collection

The determination of the composition of unprocessed municipal solid waste during this study was done according to ASTM D5231 - 92(2008) Standard Test Method which involves the direct sampling of solid waste from specific sources, a labour-intensive manual process of sorting, classifying and weighing all items in each sampling unit and a detailed recording of the data. In each LGA, five distinct communities were selected and five open dumps in each community surveyed. Composite solid waste samples were taken from each dump, mixed and weighed as total weight then placed on a 1 square meter polyethylene material before sorting. The refuse was sorted into seven categories namely; organics, paper, plastic, metal, glass, nylon and others which comprise unidentified waste types. Each category was weighed and its percentage composition determined. Statistical quantities such as the mean, standard deviation and standard error were used to summarise the findings in this study. Standard deviation showed variation in the values of variables from the mean and standard error of the mean (SEM) represents the spread that the mean of a sample of values will have if one keeps taking samples.

RESULTS AND DISCUSSION

The composition of municipal solid waste in the three LGAs studied with mean ± standard error is presented in Tables 2 to 4 and the weighted mean composition is presented in Figure 3. Organic waste composition ranged from 52.08-63.2% in Emuoha LGA, 63.5-66% in Obio/Akpor and 63-69% in Port Harcourt LGA. Figure 3 shows a comparative result of the percentage mean and SEM of waste composition in the three LGAs studied in Rivers State. Organic waste was the highest category in the three LGAs with the least mean value occurring in Emuoha LGA which is a rural area. Paper was highest in Port Harcourt LGA followed by Obio/Akpor and least at Emuoha LGA. Nylon was second highest category overall but recorded the highest mean composition in Obio/Akpor LGA. Metal was highest in Emuoha LGA. Per capital generation was 0.45, 0.98 and 1.16 kg/cap/day for Emuoha, Obio/Akpor and Port Harcourt, respectively. Ayotamuno and Gobo (2004) reported 1.25 kg/cap/day for Port Harcourt while Igoni et al. (2007) reported 1.11

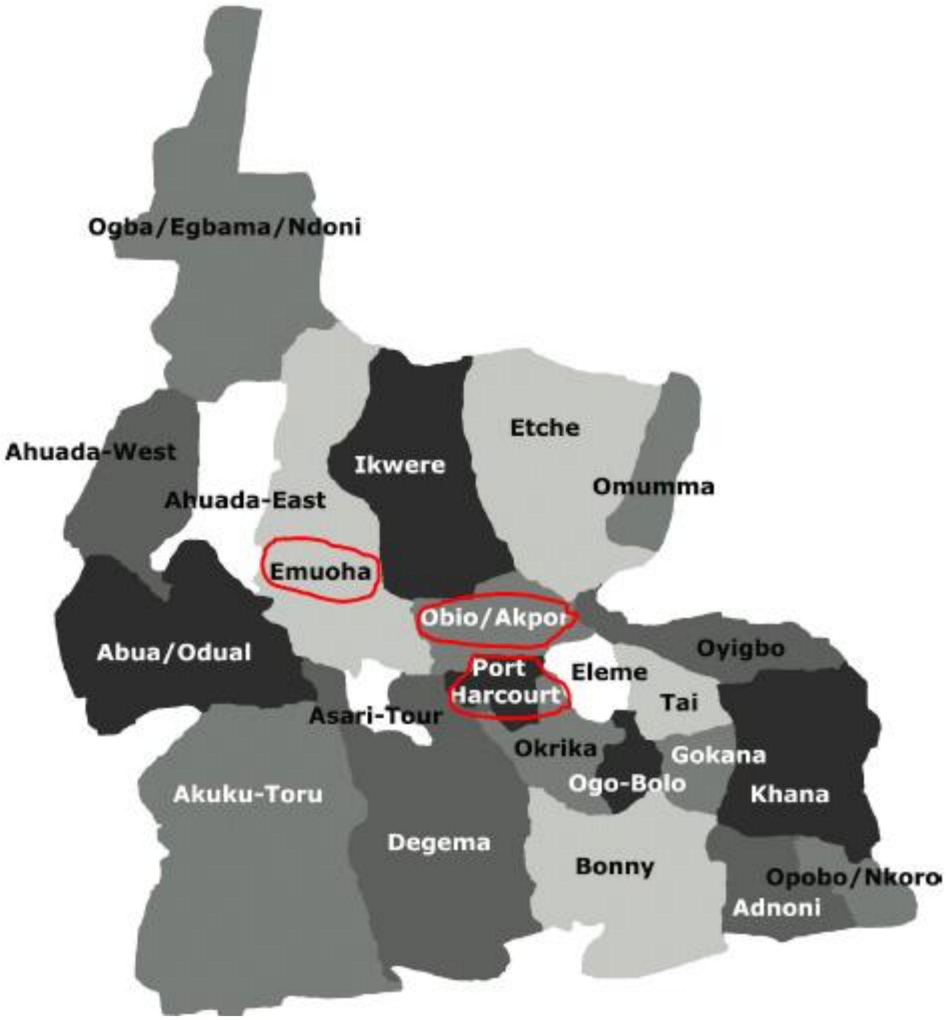

Figure 2. Rivers State showing all the LGAs with the study sites in red circles.

Table 1. The three LGAs studied and characteristics of their settlements.

LGA	Area (sq.km)	Population	Settlement	Settlement type
Port Harcourt	109	541,115	Main township	Planned
			Dioub	NP
			Elekahia/Woji	Semi-planned
			GRA/aba express way	Planed
			Trans Amadi	Industrial layout
Obio/Akpor	260	464,789	Rumuokoro	NP
			Eneka	Industrial layout
			Rumuigbo	NP residential
			Wimpey	NP residential
			Rumuodara	NP residential
Emuoha	831	201,901	Rumuohia	NP rural area
			Isiodu	NP indutrial and residential
			Oduaha	NP rural area
			Mgbutainwo	NP rural area
			Rumuji	NP rural area

*NP = Not planned. Source: NPC (2012).

Table 2: Percentage Composition of Waste categories from five different locations in Port Harcourt LGA.

Category	Elekahia	GRA	Trans Amadi	Diobu	Main township
Organic	65.0±5.5	63.0±.5.1	60±.8.0	69.0±.9.2	66.0±4.9
Paper	14±5.2	16.5±2.3	15.0±3.2	5.6±0.8	13.0±4.1
Plastics	3.3±0.5	4.0±1.2	4.8±1.2	2.2±0.2	3.0±1.4
Metals	1.6±0.1	0.5±0.0	4.0±1.1	1.5±0.1	2.0±0.3
Glass	1.1±0.1	2.5±0.6	2.5±0.3	0.2±0.0	1.0±0.1
Nylon	13.0±2.3	10.5±2.3	10.7±2.8	14.7±4.2	12.0±3.2
Others	2.0±0.5	3.0±0.6	3.0±1.0	6.8±2.2	3.0±0.9

Table 3. Percentage Composition of Waste categories from five different locations in Obio/Akpor LGA.

Category	Rumuokoro	Rumuodara	Eneka	Wimpey	Rumuigbo
Organic	65.8±3.6	63.3±5.8	64.0±4.4	66.0±8.5	66.0±6.9
Paper	12.5±3.1	13.0±2.7	9.3±2.1	10.0±2.8	9.5±2.5
Plastics	1.5±0.1	2.0±0.1	4.0±0.5	2.0±0.5	3.4±1.9
Metals	1.5±0.1	1.2±0.1	2.0±0.1	1.5±0.1	1.3±0.1
Glass	0.2±0.0	0.5±0.0	2.3±0.2	1.5±0.1	0.6±0.0
Nylon	16.3±2.6	17.0±2.4	15.2±3.1	16.0±4.2	16.0±2.1
Others	3.0±0.7	3.1±0.5	3.2±1.0	3.0±0.8	3.2±0.4

Table 4. Percentage composition of waste categories from five different locations in Emuogha LGA.

Category	Rumuohia	Isiodu	Oduaha	Mgbutainwo	Rumuji
organic	63.2±4.5	59.2±6.2	62.0±5.5	59.0±6.3	52.1±8.2
Paper	5.5±0.9	4.3±1.2	4.0±1.1	5.5±0.5	10.4±1.2
Plastic	3.3±0.5	2.4±1.1	5.3±1.5	3.5±1.2	8.3±2.5
Metal	2.6±0.6	15.0±3.1	8.1±3.1	4.2±0.2	4.3±1.1
Glass	3.4±1.1	2.2±0.2	1.2±0.1	2.5±0.2	6.3±1.0
Nylon	15.9±2.8	9.9±2.2	11.2±2.2	18.5±2.2	16.1±2.5
Others	6.1±1.0	7.0±1.8	8.1±2.1	6.8±0.3	2.5±0.2

for Port Harcourt. In 1983, Ibiebele reported 0.19 and 0.22 kg/cap/day in 1984 for the same city. Ogwueleka (2009) has reported similar per capita production of municipal solid waste obtained in this study in other cities in Nigeria. The results of per capital production obtained in the present study also agrees with that reported elsewhere in other parts of the world with similar demographic characteristics as Nigeria, such as India, Bandgladesh and China where per capita production was reported to be 0.46, 0.49 and 0.79 kg/cap/day, respectively (Chandrappa and Das, 2012). Compilation and comparison of solid waste generation in large cities of various countries showed that waste is generated at an average rate of 0.4-0.6 kg/cap/day in low income countries, as compared to 1.1-5.0 kg/cap/day in high income countries (Chandrappa and Das, 2012). In Japan and the USA, per capita municipal solid waste production was reported to be 1.47 and 2.1 kg/cap/day respectively (Chandrappa and Das, 2012; USEPA, 2008). Earlier in 1990, USA recorded up to 4.5 kg/cap/day before it decreased to 2.1 kg/cap/day (Chandrappa and Das, 2012).

The high percentage of organic waste may be attributed to the consumption of unprocessed food as compared to processed food consumed in more developed countries (Oyelola and Babatunde, 2008). World Bank (1999) reported that generally, low and middle income countries have a high percentage of combustible organic matter in the urban waste stream, ranging from 40-85%. Igoni et al. (2007) reported 69.3% of organic content in MSW in Port Harcourt and opined that the energy content of refuse generated in Port Harcourt gave 1.733 kcal/g which is sufficient for biochemical conversion to yield gas and heat for electricity. This high percentage of organic content in the waste stream in Port Harcourt and its suburbs

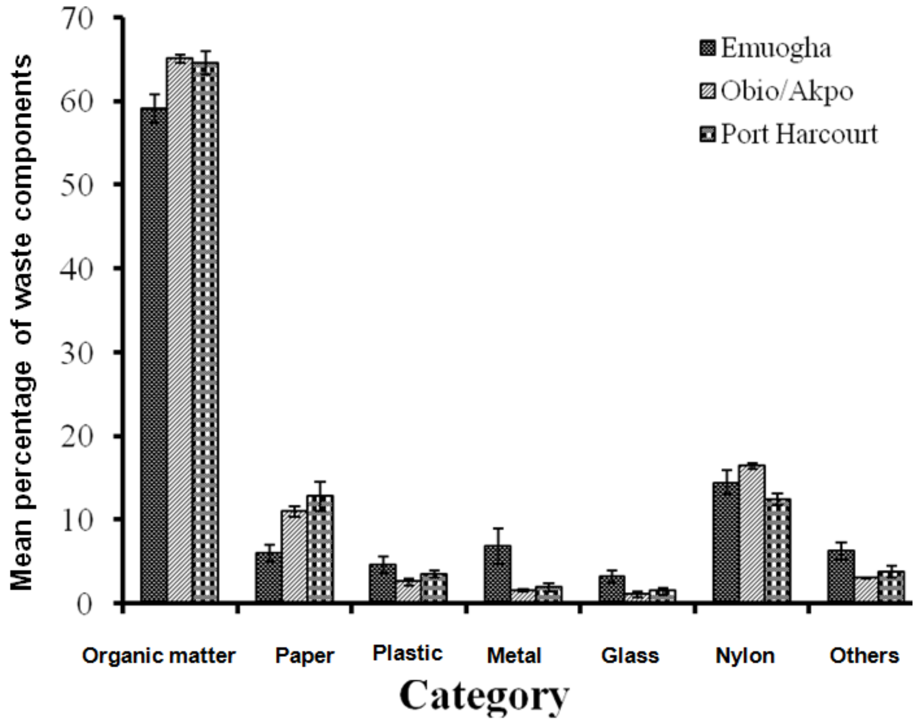

Figure 3. Mean percentage values with SEM of waste composition in the three LGA.

can be harnessed for energy generation. It is estimated that 100 tonnes of municipal refuse with 50-60% organic content can generate 1-1.5 Mega Watt of power depending on the characteristics of the waste (NEED, 2011). Apart from Port Harcourt LGA where paper was the second dominant category (5.6-16.5%), nylon was the second most prominent category in the waste of the other LGAs studied. This was due largely to the presence of nylon sachets used in packaging low cost drinking water popularly referred to as “Pure Water” and sold everywhere especially in the suburbs. Paper’s prominence in Port Harcourt could be attributed to the presence of more offices and other paper utilizing outlets. Paper waste is reuseable and recyclable and if adhered to can reduce solid waste significantly in the municipality. According to NEED (2011), one ton of paper recycled from used papers instead of fresh fibres from wood saves 7,000 gallons of water, 17-31 trees, 4,000 kWh electricity and 60 lbs of air pollutants. Metal recorded the highest mean composition of 7% at Isiodu in Emuoha LGA, this must have been due to the presence of a ship building yard at this location. Metals can also be reused or recycled for value added and the safety of the environment. Similar waste characteristics dominated by organics have been reported for countries with similar economic and demographic characteristics with Nigeria such as India, Bangladesh and Ghana (Akinwonmi et al., 2012; Chandrappa and Das, 2012). Whereas in the North such as in the USA, Germany and Japan, the waste stream s are usually dominated by paper, plastics and glass (Chandrappa and Das, 2012; USEPA, 2008).

Port Harcourt LGA recorded the highest organic waste composition at Diobu, a large suburb in Port Harcourt dominated by low income earners and lower organic waste composition was recorded at Trans Amadi and GRA which are industrial layout and high income areas, respectively. Paper recorded the highest composition at the GRA location, followed by Trans Amadi and least at Diobu. There are more offices at GRA and Trans Amadi than at Diobu, however there are several small and medium scale printing press industries at Diobu, so one would have expected high paper composition in the stream of that area. The low paper composition at Diobu could therefore be indicative of high paper reuse or recycle by operators of the printing press industries. Plastic, metal and glass recorded the highest composition at Trans Amadi, this is expected since it is an industrial layout. Nylon and the category others recorded the highest composition at Diobu for reasons of its low income status. Similar waste composition and distribution has been reported by other authors for Port Harcourt city and other cities in Nigeria (Ayotamuno and Gobo, 2004; Igoni et al., 2007; Ogwueleka, 2009).

In Obio/Akpor LGA, organic waste recorded the highest composition at Wimpey and Rumuigbo with 66% each and the least at Rumudara. These settlements are lower income places than Rumuokoro, Eneka and Rumudara. Paper recorded the highest and least composition at Rumuokoro and Eneka which is more of an industrial layout. Plastic, metals, glass and the category others re-

recorded the highest at Eneka. Nylon recorded the highest composition at Rumudara followed by Rumuokoro for reasons stated earlier in this report and Eneka recorded the least nylon composition. In Emougha LGA, organic waste composition was highest at Rumuohia, followed by and Rumuji where the least composition of organic waste was recorded. Rumuohia experiences the highest commercial activities among the five study locations in Emougha LGA. Paper, plastic and glass recorded the highest composition at Rumuji. Rumuji is a community close to the University of Port Harcourt and houses students in the residence. Metal recorded the highest composition at a statistically significant level ($P < 0.05$) at Isiodu due largely to the presence of a ship building company in that location.

The waste stream of these LGAs as observed in the present study show characteristics with high potentials for possible resource recovery and utilization and if properly harnessed, the data presented here can be utilised for a more sustainable MSWM. The results showed that the municipal solid wastes generated at the study locations were heterogeneous and can be sorted at source to ease collection, transportation and ultimate disposal problems allowing the municipalities to adequately recover and utilize the resources abundant in the waste streams. Colour coded disposal bins can be provided by municipal authorities for home sorting at residential areas, market places and offices. An organised collection system can be established by legislation which may include the cart pushers who pick up the sorted waste according to colour codes and deliver to a transfer stations designated for specific waste type under a designated contractor who uses compactor vehicle or convey the waste type to its final destination for recycle, energy generation or resource recovery. This practice has been implemented successfully by the Lagos State Waste Management Authorty (LAWMA) (LAWMA, 2011) and in other parts of the world such as the United States (Painter and Watson, 2008), United kingdom (DEFRA, 2007) and Australia (Moore et al., 1994). The multiplying effect of a sustainable solid waste management cannot be overemphasized as the benefits are indeed many. Greenhouse gases such as methane and CO_2 which are the major gases produced from waste will be substantially reduced if the waste is reduced, reused or recycled (UNEP, 2002).

Conclusion

Information on the characteristics of solid waste is important in evaluating alternative equipment needs, systems, management programs and plans especially with respect to the implementation of disposal, resource and energy recovery options. The waste streams in Rivers State have been shown in the present study to be heterogeneous different in generation rate and characteristics for the three LGAs studied. This means that for a sustainable solid waste management in the state, solutions to the waste problem should be specific to each location, an opinion shared by Igoni et al. (2007). Existing efforts by municipal authorities to manage solid waste in Port Harcourt city may have been insufficient due to lack of comprehensive data on waste characteristics for Port Harcourt and its environs. The importance of understanding the waste streams of Port Harcourt environs cannot be overemphasized as these rural and sub-urban areas are connected to the Port Harcourt main city, thus, waste generated here and not properly managed will end up in the streets of Port Harcourt in time. This will naturally punch a hole in the solid waste management strategy put in place in the main town. It is believed that the results obtained during this study will aid the municipal authorities in taking a holistic and more sustainable step in an attempt to solve the municipal solid waste problem in Port Harcourt and its environs. The benefits are many including a clean and health environment, energy recovery and possibilities of energy generation for economic reasons.

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