Status of municipal solid waste generation and disposal in Nigeria

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Abstract

Purpose – This paper examined the current status of municipal solid waste management across Nigeria. The core aspects covered are generation, characterization, collection, scavenging, open dumping, disposal and environmental implications of poor solid waste management. The purpose of this paper is to present a comprehensive overview of the current state of municipal solid waste management in Nigeria.

Design/methodology/approach – This study was executed by a combination of an extensive literature search and field study. Solid waste generation rates for 31 Nigerian cities were obtained from literature. In addition, characteristics of municipal solid waste from 26 Nigerian cities were also obtained from literature. Other aspects such as characterization of solid waste obtained from final dumpsite and heavy metals accumulation in solid waste dumpsites were undertaken first hand.

Findings – Solid waste generation rate was found to vary from 0.13 kg/capita/day in Ogbomosho to 0.71 kg/capita/day in Ado-Ekiti. Factors affecting solid waste generation rates were identified. Typically, food waste was found to constitute close to 50 percent of overall municipal solid waste in Nigerian cities. This study shows that the rate of generation of plastics, water proof materials and diapers has assumed an upward trend. Due to the dysfunctional state of many municipal waste management authorities, many cities have been overrun by open dumps. For instance, more than 50 percent of residents of Maiduguri in northern Nigeria and Ughelli in southern Nigeria dispose of their waste in open dumps. Indiscriminate disposal of waste has also resulted in the preponderance of toxic heavy metals in agricultural soils and consequent bioaccumulation in plants as well as groundwater contamination.

Research limitations/implications – The main limitation of this research is municipal waste management authorities do not have relevant data. Hence, there was heavy reliance on published materials. The status of waste management in Nigeria is very deplorable and therefore poses serious threats to public and environmental health. There is urgent need for both government and individuals to adopt holistic and sustainable waste management strategies in order to safeguard public/environmental health.

Practical implications – Findings from this paper can form a veritable resource for the formulation and implementation of sustainable municipal solid waste management framework and strategies in Nigeria.

Originality/value – While most studies on municipal solid waste management in Nigeria are focussed on selected cities of interest, this particular study cuts across most cities of Nigeria in order to present a broader and holistic view of municipal solid waste management in Nigeria. The paper has also unraveled core municipal solid waste management challenges facing Nigerian cities.

Keywords Disposal, Open dumps, Solid waste, Waste characterization, Waste generation, Waste management

Paper type Research paper

1. Introduction

The enormous challenge posed by municipal solid waste is a global issue that is not just peculiar to Nigeria. Globally, solid waste generation has soared in the past few decades resulting in overstretching of waste management facilities and inability of waste management authorities to cope with the volume of solid waste generated.

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China has overtaken the USA as the largest waste generator with an annual waste generation of 190 million tons in 2004 and a projected 480 million tons by 2030 (Minghua *et al.*, 2009). Population growth, changing lifestyles of people, development and consumption of products with materials that are less biodegradable constitute serious challenges for municipal solid waste management in various cities of the world (Asase *et al.*, 2009). Emerging kinds of waste including e-waste and polythene/cellophane materials are presenting an enormous challenge to the already overwhelmed waste management authorities. The quest to maximize profit and ease conveyance has given rise to a new tradition of disposable packaging. Nowadays, consumable products come in disposable packs which end up as waste. Unfortunately many of these packages are non-biodegradable and at the same time, of little interest to scavengers. The need for waste disposal has given rise to the proliferation of open dumps which constitute a grave environmental and health hazard. Municipal solid waste management in developing countries is often characterized by inadequate service coverage, operational inefficiencies, limited recycling activities, inadequate management of non-industrial hazardous waste and inadequate landfill disposal (Asase *et al.*, 2009). Over one billion people living in low income communities and slums lack appropriate waste management services (UNU-WIDER, 2010). Sankoh and Yan (2013) observed acute solid waste disposal problems in Sierra Leone as available facilities cannot keep pace with increasing rate of solid waste generation. Assa (2013) observed that waste generated in Lilongwe City, Malawi has exceeded infrastructural capacity of the city council which has culminated to degeneration in the quality of solid waste management. Hai and Ali (2004) also highlighted the pathetic state of solid waste service provision in Bangladesh. In India, solid waste management is poorly developed (Saha *et al.*, 2010) and has become a major environmental challenge (Devi *et al.*, 2014). In Kenya, waste collection systems are inefficient and disposal systems are not environmentally friendly such that 30-40 percent of all solid waste generated in urban areas is uncollected and less than 50 percent of the population is served (Gakungu *et al.*, 2012). In India, only 50 percent of refuse generated is collected, 33 percent in Karachi Pakistan, 40 percent in Yangon Burma and 50 percent in Cairo Egypt (UNU-WIDER, 2010).

Several research efforts have been invested in municipal solid waste management in Nigeria. Some of the studies were scientifically implemented, while others were haphazard and shallow. Individual researchers have approached the subject with a specialization-oriented bias, thus addressing only those issues which are of interest to them. Nonetheless, each of these studies has contributed a fraction to the knowledge of solid waste management in Nigeria. This paper is an attempt to galvanize many of the findings of different researchers, including those of the author, into a comprehensive report on solid waste management in Nigeria. Nigeria is a developing country grappling with so many challenges, not the least of which is the menace increasing municipal solid waste. In the past two decades, solid waste in Nigeria has been increasing both in quantity and diversity. The stages involved in municipal solid waste management are: generation and storage, collection and transfer, sorting, treatment, material recovery and disposal. The burden of waste collection and disposal is so overwhelming that hardly any thought is given to other aspects of waste management. Asase *et al.* (2009) observed that reuse and recycling of waste materials is carried out on an informal basis. It is therefore safe to infer that the status of waste management in any country is an indicator of the level of development. In fact, Sha'Ato *et al.* (2007) observed that there is a direct link between poverty and the state of the

environment. However, as important as waste management is, it is usually relegated to the background and ranked after health, employment, education, water, food, urban infrastructure and security. According to UNU-WIDER (2010), solid waste management in developing countries has received less attention from policy makers and academics than that paid to other environmental problems.

2. Brief methodology

This study was executed by a combination of extensive literature survey and field study. Data/information obtained from literature constitutes a large chunk of this study and include:

- contribution of different sectors to municipal solid waste generation;
- composition of solid waste in various cities;
- monthly variation of solid waste generation using Ogbomosho as a typical example;
- average composition of market waste from Ibadan;
- methods of domestic solid waste storage; and
- means of solid waste disposal by households.

Some of the important published works used in this research includes the following.

Sha'Ato *et al.* (2007) conducted a comprehensive study of municipal solid waste in Markudi between July and August 2003 following the methodology proposed by Cointreau (1982). This research was sponsored as part of DFID's state and local government program. The scope of work covered include: characterization of solid waste, determination of rate of solid waste generation for low-density, medium-density and high-density residential areas. Abah and Ohimain (2010) conducted a risk assessment and composition study of solid waste dump in Eneka Port Harcourt based on the method proposed by Kurian *et al.* (2005).

Afon (2007) undertook a year round study of solid waste generation and composition in Ogbomosho based on the methodology proposed by Cointreau (1982). The study, conducted in 2004 involved the use of 718 structured questionnaires to determine factors affecting solid waste generation.

Ogwueleka (2009) conducted a country-wide study from April to October 2007, using nine representative cities (Lagos, Maiduguri, Kano, Ibadan, Makurdi, Port Harcourt, Onitsha, Nsukka and Abuja). The instruments of data collection used were: review of literature on solid waste management in Nigeria; interview of scavengers, private waste management firms and staff of municipal waste management authorities; study of 20 dumpsites in seven cities and records of waste management agencies.

Dauda and Osita (2003) studied solid waste management in Maiduguri from January to March 2002. They used a combination of questionnaires, interviews, interest group discussion and field study to execute the research.

Akpen and Aondoakaa (2009) used questionnaires to study solid waste disposal practices in Gboko. Waste generation rate was determined by direct weighing of waste at selected homes for three consecutive days.

Adewumi *et al.* (2005) investigated solid waste generation and composition in five southwestern states of Ekiti, Ogun, Ondo, Osun and Oyo. They used questionnaires to determine waste generation rates while solid waste composition was determined at waste disposal sites with a total of 20 sampling exercises at each dumpsite.

Babayemi and Dauda (2009) studied solid waste collection and disposal, and peoples attitude toward sorting of waste in Ibadan using 201 questionnaires.

Lade *et al.* (2012) employed random sampling of market stalls and direct weighing of waste to obtain waste generation rates and composition in Bodija Market, Ibadan. Ibrahim *et al.* (2012) used 250 questionnaires to obtain waste generation rate and composition in Ilorin.

Ukoje (2011) used cluster and random sampling of households to study solid waste collection methods in Zaria. In the study conducted in 2009, a total of 288 questionnaires were distributed to four districts of the city. Solid waste generation rate and composition were determined by direct daily measurement.

Achi *et al.* (2012) used 430 structured questionnaires to study solid waste generation rate, composition, storage, collection, reuse and recycling in Abeokuta by stratified random sampling method.

Bichi and Amatobi (2013) employed direct collection of solid waste from 60 households in Sabon-Gari area of Kano to determine solid waste generation rate and composition.

Egun (2012) used stratified random sampling to select 200 households with a view to ascertaining sorting, recycling and composting practices in Delta State.

During the field study, solid waste samples were collected from households, curbsides and final disposal site for characterization. The characterization of solid waste from households in Nsukka Metropolis was conducted by distributing waste bags to 150 randomly selected households. A total of 119 bags were retrieved after two days and then sorted. They were weighed and average percentage compositions were determined. The same treatment was given to wastes collected from the final disposal site. Next the organic fraction of the wastes from households, curbside dump and final disposal site were separately shredded. Each was thoroughly mixed, coned and then quartered. One-quarter from each of the three waste sources was air dried and then stored for subsequent determination of heavy metals concentrations. The heavy metals measured are lead (Pb), chromium, cadmium (Cd), zinc, copper and nickel.

3. Municipal solid waste generation in Nigeria

Waste generation is an unavoidable product of human activities. These wastes range from common everyday waste such as food waste, plastics, paper, polythene, metals, batteries and textiles, to occasional and emerging wastes such as mobile phones, computers and other kinds of electronic gadget. In developing/consumer countries, domestic wastes constitute a large fraction of the solid waste, followed by commercial waste emanating from markets and other business premises. This is buttressed with data in Table I as obtained by various researchers. The rate of solid waste generation in Nigeria has been put at an average value of 0.49 kg/capita/day. The rates of solid waste generation in Nigerian cities vary widely, depending on the peculiar characteristics of the city. Ado-Ekiti and Ogbomosho (both in southwestern Nigeria) were reported to have the highest (0.71 kg/capita/day) and lowest (0.13 kg/capita/day) solid waste generation rates per capita, respectively. As shown in Table II, other important cities with relatively high per capita waste generation rates are Lagos (0.63 kg/capita/day), Port Harcourt (0.60 kg/capita/day) and Abuja (0.57 kg/capita/day).

It is obvious that there is no direct correlation between rate of solid waste generation and any specific common factor among the cities. Serious disparity has been observed in the reports of different researchers on solid waste generation rates of cities.

City	Domestic	Industrial	Commercial	Institutional	Hospital	Agricultural	Source
Umuahia	8	12	80	–	–	–	Onwughara *et al.* (2010)
Ibadan	66.1	11.4	20.3	–	–	–	Babayemi and Dauda (2009)
Zaria	49	14	23	10	4	–	Ukoje (2011)
Abeokuta	73.9	0.5	17.5	–	–	8.2	Fakere *et al.* (2012)
Akure	70.3	4.8	18.6	–	–	6.3	Fakere *et al.* (2012)
Ado-Ekiti	78.9	2.7	14.3	–	–	4.1	Fakere *et al.* (2012)
Osogbo	68.2	6.2	23.5	–	–	2.1	Fakere *et al.* (2012)

Table I. Percentage contribution of municipal solid waste from different sectors

For instance, Lawal and Garba (2013) estimated solid waste generation rate in Bauchi as 0.31 kg/capita/day while Audu *et al.* (2013) obtained a value of 0.86 kg/capita/day for the same city. Likewise Bichi and Amatobi (2013) estimated a value of 0.31 for Kano while Oumarou *et al.* (2012) obtained a value of 0.81 kg/capita/day for the same city. Generally, the factors responsible for discordant reports on solid waste generation include: time/year of report; method of research; coverage of research in terms of time and space; season of research (rainy or dry season), researcher's specialization; and source of data (primary or secondary). Afon (2007) observed that more wastes are generated (59.4 percent for suburban areas and 51 percent for the city center) between the months of July and December, with the peak occurring in December (Figure 1). The reason for this skew is understandable. The month of December is a festive period which gives rise to lavish spending and ostentatious lifestyles. In addition, the months of July-December correspond to harvest period. Seasonal variation of municipal solid waste is not peculiar to Nigeria. Gidarakos *et al.* (2006) observed a seasonal variation in the quantity of municipal waste generated in the Island of Crete.

The fraction of domestic waste constituting the total solid waste generated in Nigeria ranges from 49 percent (Ukoje, 2011) to 78.9 percent (Fakere *et al.*, 2012). Factors influencing the rate of municipal solid waste generation rate include: economic status, lifestyle/habits, gross domestic product, sensitization to environmental sanitation and population density. Sha'Ato *et al.* (2007) found that low density areas of Makurdi generated more solid waste per capita (0.62 kg/capita/day) followed by high density areas with a generation rate of 0.57 kg/capita/day and then the medium areas with a generation rate of 0.37 kg/capita/day. In the study, the low density areas were occupied by the affluent, while the medium and high density areas were occupied by the middle income and the low income groups, respectively. Waste generation rates obtained by the use of questionnaires or from waste management authorities are not likely to be correct. Among the researchers who used questionnaires to obtain waste generation rates are Achi *et al.* (2012), Ibrahim *et al.* (2012), Ukoje (2011) and Adewumi *et al.* (2005). Most respondents do not measure their waste, hence they assume suitable values. Achi *et al.* (2012) found that 58.14 percent of respondents in Abeokuta could not estimate their solid waste generation rates. Same goes for waste management authorities. Waste management authorities in Nigeria often restrict their services to areas of the city accessible to their collection trucks. Owing to poor waste collection services, most solid wastes from homes, markets, hospitals and other

Table II. Composition of waste for various Nigerian cities

Location	OW	M	G	P	WP	PP	RB	TX	W	D/C	D/S/A	OT	Rate	Source of waste	Source
Port Harcourt	38.6	10.8	23	–	–	–	–	6.4	7.6	2.1		5.6	0.6	Dump site	Abah and Ohimain (2010), Ogwueleka (2009)
Nsukka	47	4	4	4	11	6	–	3	–	–	–	21	0.39	Fresh from homes	Field work
Lagos	68.16	2.O8	1.78	3.64	7.68	12.46	–	–	–	–	–	4.2	0.63	Homes	Oyelola and Babatunde (2012), Ogwueleka (2009)
Lasos	68.98	1.77	–	1.77	3.92	23.57	–	–	–	–	–	–	0.63	Business premises	Oyelola and Babatunde (2012), Ogwueleka (2009)
Makurdi	49.2	2.09	1.62	7.08	–	3.63	–	2.24	–	–	–	32.71		Homes	Sha'Ato *et al.* (2007)
Makurdi	27.9	3.4	6.9	10.2		10.9	–	1.2	–	–	36.4	3.1	0.54	Business premises	Sha'Ato *et al.* (2007)
Makurdi	44.8	0.9	1.2	5.9		8.9	–	0.3	–	–	36.4	3.1		Institutions	Sha'Ato *et al.* (2007)
Kano	57.48	3.9	2.53	17.55	–	6.72		4.48	1.8	–	–	5.58	0.31	Fresh from homes	Bichi and Amatobi (2013)
Umuahia	52.2	3	0.6	1.5	10.2	18.5	–	–	12	–	–	2			Onwughara *et al.* (2010)
Ibadan	64.9	2.9	1.7	9.9	–	14.2	–	–	–	–	6.5	–	0.71		Adewumi *et al.* (2005)
Ibadan	17.59	2.95	2.52	0.85	21.77	10.69	0.28	2.46	3.92	–	36.96	–		Business premises	Lade *et al.* (2012)
Iloriu	24.8	5.2	3.2	10.8	p/p	20	–	2	2.8	4.8	8.4	17.2	0.48	Waste trucks	Ibrahim *et al.* (2012)
Zaria	45.2	7	7.2	8	–	17.8	–	–	–	–	12	2.8	0.295		Ukoje (2011)
Abeokuta	26.3	5.26	5.75	24.95	–	25.57	–	9.48	–	2.69	–	–	0.66		
Maiduguri	25.8	9.1	43	18.1	–	7.5	–	3.9	–		21.5	9.8	0.25	Fresh from homes	Dauda and Osita (2003)
Delta	37	10	6	21		18	–	5	–	–	–	3	0.29		Egun (2012)
Minna	44.63	3.6	1.11	5.91	–	–	0.87	–	3.01	21.09	–	19.77	0.514	Fresh from homes	Adeoye *et al.* (2011)
Damaturu	76.3	2.7	–		21		–	–	–	–	–	–	0.32		Babalola *et al.* (2010)
Onitsha	49	8.7	4.5	17.9	–	8.1		10.1		–	–	3.7	0.53		Ogwueleka (2009)
Ogbomosho	56.4	1.5		10.4	–	15.7	3.7	2.5	–	–	9.8		0.13	Homes	Afon (2007)
Abuja	52	5	2	10		11		20 + paper			–	–	0.57	Homes	DFID (2004)
Abuja	8	2	4	7		68		11 + paper			–	–	0.57	Institutions	DFID (2004)
Gboko	17.3	10	8.7	–	19	12.7	–	11.3	–	–	12	9	0.44	Fresh from homes	Akpen and Aondoakaa (2009)
Oshogbo	58.2	1.4	0.6	12.1	–		–	–	–	15.3	9.9				

(*continued*)

Table II.

Location	OW	M	G	P	WP	PP	RB	TX	W	D/C	D/S/A	OT	Rate	Source of waste	Source
Benin	78	4	3	9	–	4	–	–	–	–	1	1	0.425	Waste trucks	Igbinomwanhia (2011)
Uyo	23.93	19.85	22.72	7.58		12.76	–	9.95	–	–	–	3.25		Homes	Ukpong and Udofia (2011)
Uyo	65	4	3	10	–	8	–	3	–	–	–	7	0.54		Okey *et al.*
Calabar	41.99	15.33	–	14.7	–	16	–	–	12	–	–	–		Dumpsite	Afangideh *et al.* (2012)
Jos	27.5	7.51	9.99	6.75	7.49	14.48	–	6.87	8.47	–	–	10.94		Dumpsite	Egbere *et al.* (2001)
Awka	33.17	14.4		19.57	32.84		–	–	–	–	–	–			Modebe *et al.* (2010)
Akure	59.5	7.2	6.3	1.7	–	15.1	–	–	–	–	11	–	0.54	–	Adewumi *et al.* (2005)
Okigwe	77	1	4	2	4	12	–	–	–	–	–	–	–	Market	Etusim *et al.* (2013)

Notes: OW, organic waste; M, metals; G, glass; P, plastic; WP, water proof/polythene; PP, paper; RB, rubber; TX, textile; W, wood; D/C, drugs/chemicals; D/S/A, dust/sand/ashes/fines; OT, others. Rate is kg/capita/day

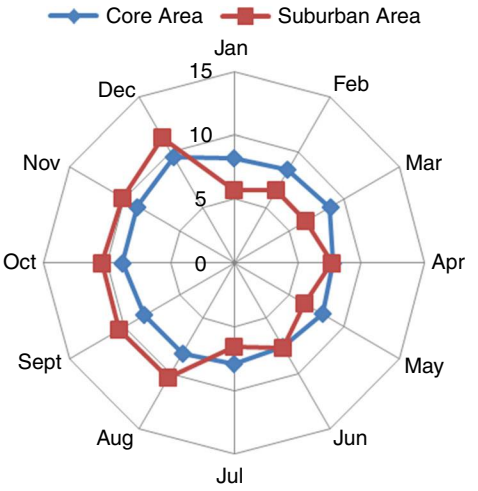


Figure 1.
Percentage seasonal variation of waste generation in Ogbomosho

Source: Data from Afon (2007)

business premises end up in unapproved open dumps. This is not just a Nigerian problem as up to 90 percent of municipal solid waste collected in Asian countries is improperly and illegally disposed (UNU-WIDER, 2010). Gidarakos *et al.* (2006) noted that there are still lots of illegal dumping sites even in Greece and Europe as a whole. Open dumping occurs when large quantities or piles of wastes are deposited in areas not designated to handle such materials (Awosusi, 2010). We recorded a total of 72 open dumps in Nsukka Metropolis of which 81 percent are illegal or unapproved.

4. Characteristics and composition of municipal solid waste in Nigeria

Solid waste characterization is an important aspect of municipal solid waste management because solid waste composition varies with location. According to Gidarakos *et al.* (2006) who observed that solid waste composition varied in different regions of Greece, the composition of waste generated depends on seasonal, lifestyle, demographic, geographic and legislation impacts. It plays a major role in waste handling, material/energy recovery and final disposal. It has long been determined that developing countries generate more of organic waste than developed countries. According to UNU-WIDER (2010), organic fraction of municipal solid waste (OFMSW) generated in developing countries is about three times that generated in developed countries. For many cities in Nigeria, OFMSW can constitute as much as 50 percent of solid waste generated (see Table II). Generally, the composition of municipal solid waste is considerably dependent on the source and age of the waste characterized. In Nigeria, the most representative solid waste sample can be obtained directly from source namely: households, offices, market stalls. This is important because of the dynamics introduced by the activities of scavengers. Scavengers grossly alter the composition of municipal solid waste as it transits from source to the final dumps via open dumps. It is therefore, an aberration to conduct municipal solid waste characterization studies based on samples obtained from transfer stations, open dumps, landfills or waste disposal vehicles. While this approach may work in developed countries where scavengers are non-existent, it usually leads to misleading

results in developing countries. To this effect, Lisa and Anders (2008) noted that proper choice of solid waste sampling source is crucial before embarking on municipal solid waste characterization study. They suggested that local seasonal variations in waste generation should be considered, and each sampling exercise should cover at least one full week. It has also been observed that municipal solid waste samples obtained from disposal sites are usually made up of mostly compostable materials and other materials with little or no value to scavengers, such as paper, polythene, broken bottles, diapers, dust/ashes, etc. In a survey of homes in Nsukka Metropolis, we found that solid waste consists of food (47 percent), nylon (11 percent), paper (6 percent), plastic, glass, metals (4 percent each) clothes 3 percent and others (19 percent). Abah and Ohimain (2010) found that municipal solid waste in Port Harcourt had an average biodegradability fraction of 0.807 and a carbon-to-nitrogen ratio of 27:1. This suggests that incorporating composting into the programmes of municipal waste management authorities will help in reducing the quantity of waste to be disposed, in addition to yielding financial benefits. According, to Lade *et al.* (2012), nylon and dust together constitute more than 50 percent of solid waste generated in Bodija market, Ibadan.

In Nigeria, the traditional packaging material in markets is the polythene bag. Waste polythene is also beginning to pose a serious threat to municipal solid waste management in Nigeria as a result of popularization of sachet water. Besides, many companies have now resorted to polythene packaging in order to make their products affordable to the poor. Though this material is highly recyclable, only a small fraction is actually recycled. This results in an ever increasing quantity of polythene released into the environment with the attendant effect of drainage blockage, clogging of farmlands and fueling of wild fires. Another emerging and very important waste item is the disposable diaper. The replacement of reusable nappies with disposable diapers has also led to an increase in the amount of solid waste emanating from homes. Disposable diapers usually contain super adsorbent materials made from sodium polyacrylate which has been purported to be carcinogenic and a predisposing factor to childhood asthma and respiratory diseases. These toxins are easily leached by rain into the groundwater. A characterization study we conducted at a disposal site in Nsukka shows that over 75 percent of waste consisted mostly of diapers (34 percent), food waste (21 percent) and polythene (21 percent) after scavengers had retrieved most of the recyclable items. Besides, fines (dust, sand and ashes) can constitute up to 30 percent of solid waste emanating from institutions and commercial centers. Table II shows that fines constituted 36.96 and 36.4 percent of solid waste from business premises in Ibadan (Lade *et al.*, 2012) and Makurdi (Sha'Ato *et al.*, 2007), respectively. The reason for this is not farfetched. Many roads and open spaces in Nigerian cities are not paved. We observed that when wastes are gathered together by sweeping before disposal, the abrasive effect of the broom detaches soil particles from the ground.

5. Status of waste storage and collection in Nigeria

Waste storage and collection form a very crucial stage of waste management. Proper waste storage makes for ease of collection. Waste storage has both environmental and health implication. We observed that waste bins are usually located within the house and provide harborage for disease vectors. Over time, these bins become heavily contaminated, depositing germs at the slightest contact. Most municipal waste management authorities encourage bagging of waste by providing polythene bags to

households. Bagging makes waste collection less messy. It can be seen from Table III that plastic bins followed by polythene bags are the most common waste storage containers. Other unconventional waste bins include paper bags, used drums and sacks. Choice of bin is usually based on the nature of waste to be stored, conveyance, durability and affordability. Storage and collection form the final link between waste generators and waste managers and thus can be used as control. It is easier to sort waste at source than after collection. Nnaji and Utsev (2011) suggested that sorting at source (SAS) can be achieved by providing different waste bins for different categories of waste. Waste can be sorted into the following broad categories: biodegradable and non-biodegradable, compostable and non-compostable, recyclable and non-recyclable, combustible and non-combustible or into generic forms as plastic, bottle/glass, ferrous metal, non-ferrous metal, paper, rubber and organic waste. Studies have shown that rudimentary SAS is already being practiced in Nigeria. Achi *et al.* (2012) observed that about 70 percent of those who sort their waste at source in Abeokuta did so for monetary benefits. They found a correlation between sorting and cultural background. While about 56 percent of households in Abeokuta southwest Nigeria have tried one form of sorting or the other, Ukpong and Udofia (2011) observed that households in Uyo, south-south Nigeria did not sort their waste before disposal. They noted that only scavengers were engaged in recovery of wastes.

Studies have shown that about 30-60 percent of solid waste generated in Nigeria is not collected (Ogwueleka, 2009). This can be attributed to: low accessibility resulting from poor road networks, technical, economic and management failures on the part of waste management authorities, inadequate facilities, refusal to pay collection bills and non-implementation of route optimization. Apart from the Federal Capital Territory, Abuja where about 56 percent of residents are served by waste management authority (DFID, 2004), about 80 percent of residents in other cities get rid of their waste by unauthorized open dumping, open air burning, burial and other unconventional means (Table IV). Most municipal waste management authorities are overwhelmed by the enormous amount of waste generated as well as inadequacy and frequent breakdown of collection vehicles, low level of manpower, poor data collection and management, poor wages and illiteracy (Awosusi, 2010). Ogwueleka (2009) observed that waste management authorities are faced with financial difficulties in meeting their large wage bills, and hardly a year goes by without threats of strikes by workers demanding

	Abeokuta	Ibadan	Abuja (domestic)	Abuja (institutional)	Abuja (commercial)	Awka	Uyo
Plastic bin	42.89	40	13	31	25	81.5	
Paper bags	6.53	–				–	71.4
Polythene bag	28.44	39.6	10	5	16	7.7	–
Used drum	15.15	28.4				–	–
Sacks	6.53	–	5	0	11	–	–
Metal bin			7	13	31	10.8	25.6
Others			5	6	17	–	3
Standard reuse bin			60	45	0	–	–
Source	Achi *et al.* (2012)	Alakinde (2012)	DFID (2004)	DFID (2004)	DFID (2004)	Modebe *et al.* (2010)	Okey *et al.* (2013)

Table III.
Methods of waste storage

Table IV. Means of solid waste disposal (percent)

	Abeokuta	Maiduguri	Ibadan	Abuja (domestic)	Abuja (Institutional)	Abuja (commercial)	Ughelli	Bauchi	Uyo
Open dump	26.28	52	31.6	19	9	17	54	30	24
Burning	47.44	41		7	29	17	7	20	18.8
Burying	6.28	4	28				13	–	–
Cart pushers/private Trucks	14.19	–	32	18	15	19	–	10	–
Waste management Authority	5.81	–		56	47	37	–	40	43.6
Others	–	3	8.4				26	–	13.5
Source	Achi *et al.* (2012)	Dauda and Osita (2003)		DFID (2004)	DFID (2004)	DFID (2004)	Efe (2013)	Ogwuche (2013)	Ukpong and Udofia (2011)

arrears of accrued wages. Chatterjee (2010) observed that waste management systems in developing countries must deal with low technical experience and low financial resources which often cover only collection and transfer costs, leaving no resources for safe final disposal. For instance, we observed that Enugu State Waste Management Authority has only two collection trucks serving Nsukka Metropolis and environs having a population of about 97,000 residents. One of the trucks was out of service in 2012 when part of this study was conducted. Refusal of residents to pay waste collection bills can be attributed to poor services from waste management authorities. Besides, some people believe they have the right to that service at no charges. We observed that many cities in Nigeria have approved open waste dumps due to inability of waste management authorities to cope with the volume of waste generated. These dumps are visited in turns by the collection vehicles. Hence, waste management authorities do not offer services at household levels, but in cells. Some of these designated dumps are painfully too far from some households and the result is that these households create an open dump close by. Some enterprising individuals have seized the opportunities presented by this grim situation to earn a living. Besides the scavengers and middlemen, there are private firms that are involved in waste collection. Sometimes, big institutions, municipalities and wealthy individuals contract waste collection to these firms for an agreed fee. Compared with the municipal waste management authorities, these firms charge much higher collection fees, but they are much more efficient. This was confirmed by Asase *et al.* (2009) who observed that in Kumasi, Ghana where the private sector is solely responsible for waste collection, as much as 80 percent collection has been achieved. These firms can afford good waste management equipment and pay their staff much better than the government. As we observed in Nsukka, private waste management firm pay their workers about twice what the Municipal Waste Management Authorities pay their own workers.

6. Impact of poor disposal practices

Waste disposal is the final step in waste management. The failure of waste management authorities has given rise to the proliferation of open dumps and associated environmental hazards. Momodu *et al.* (2011) observed that improperly sited open dumps deface several cities, thereby endangering public health by encouraging the spread of odors and diseases, uncontrolled recycling of contaminated goods and pollution of water sources. The need to dispose of waste is so pressing that people dump their waste anywhere as long as they can get away with it. Sections of roads cordoned off by waste, railways entirely overtaken by heaps of waste, drainage channels completely obliterated by waste and water bodies rendered useless by decades of waste dumping are common features of most Nigerian cities. Plate 1a is a typical representation of refuse encroachment on basic urban infrastructure. Commercial centers such as Aba, Onitsha and Lagos are the worst hit. Even the previously beautiful Garden City of Port Harcourt has been christened Garbage City because of the menace of open dumps. It therefore appears that open dumps have come to stay; and the end is not in sight.

Moreover, open dumps have far reaching implications for public and environmental health. They are characterized by offensive odor, swarms of insects and rodents and hazardous items such as used medical syringes, expired drugs, batteries, flammable and explosives. During rainy season, plumes of contaminants are transported to groundwater and surface water bodies, thereby polluting them. These wastes are readily dislodged by runoff and carried into drainage channels. Channel blockage and litters of waste on roads

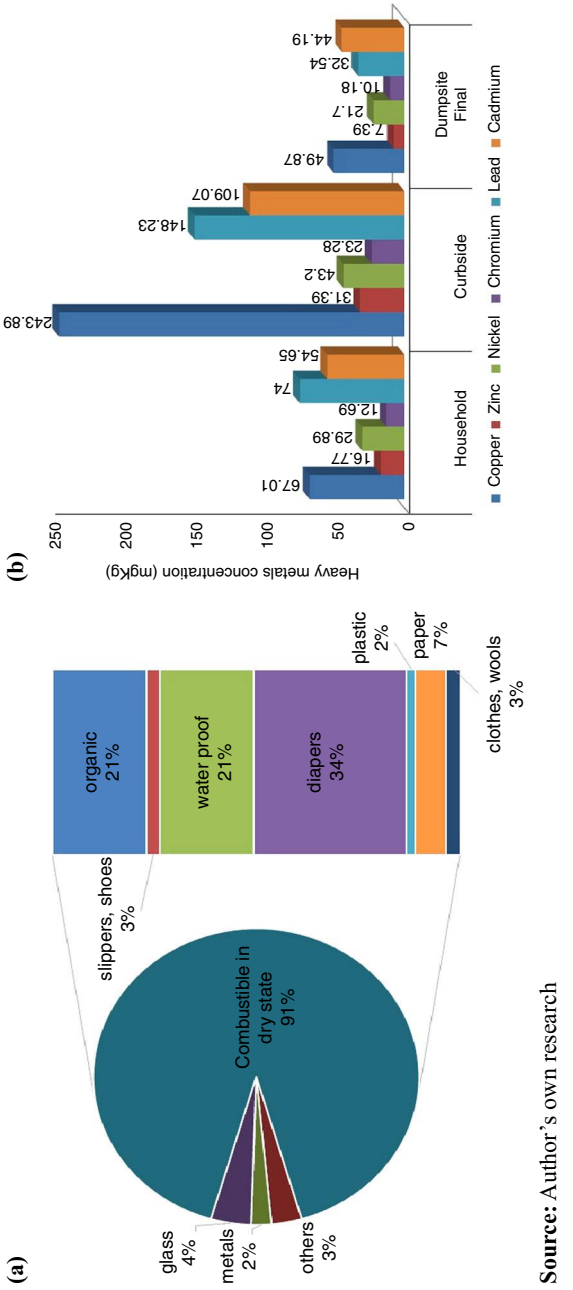
Sources: [a]Ukoje (2011); [b]photographs by the author

Plate 1.
(a) A railroad overrun by refuse[a]; (b) a typical waste disposal site[b]

have been observed after heavy downpours. Besides, deranged persons have an unusual attraction to open dumps. Hence, they are always seen loitering around or rummaging through the piles of refuse for food. This usually gives rise to dislodging and dispersal of waste into the surrounding environment. The frequent burning of open dumps results in the emission of smoke and green-house gases. Such fires sometimes get out of hand, especially in the dry season, burning farmlands and any property within the vicinity. In the Mexican City of Tampico, on the Gulf of Mexico coast, a fire burned for over six months at the local waste dump (UNU-WIDER, 2010). Also according to UNU-WIDER (2010), methane generated by anaerobic decomposition of OFMSW in open dumps can cause explosions, and also contributes to global warming. Fine particles such as dust, ashes and microorganisms are often lifted by strong winds and dispersed all over the city. Artificial traffic congestion in some cities can be attributed to reduced width of roads due to encroachment of refuse on roads. Due to the nuisance caused by open dumps, properties located near open dumps usually lose value (Momodu *et al.*, 2011; Awosusi, 2010).

Chatterjee (2010) stated that sanitary landfilling with leachate and gas collection is the recommended method for disposal of municipal solid waste. Poor disposal embraces both the constitution of the waste disposed and where it is disposed. Before disposal, it must be ensured that waste being disposed is entirely useless. Best management practice requires that waste must have undergone sorting, material and energy recovery, and treatment before disposal. This will help to minimize environmental impact and the amount of waste to be disposed, conserve resources and protect public health. The first step toward proper waste disposal is efficient collection of waste. Poor waste collection necessitates littering and indiscriminate dumping. Environmental impact assessment is hardly ever undertaken before siting these dumps. In a risk assessment of Eneka dumpsite in Port Harcourt, Abah and Ohimain (2010) found that the dump had a risk index score of 432.3 (moderate risk) and therefore needed to be upgraded to a landfill. Population explosions have given rise to extension of urban settlement boundaries with the result that lands previously considered unusable are now being reclaimed. Buildings erected on reclaimed refused dumps have been known to collapse.

These disposal sites are usually surrounded by farmlands and perpetually emit thick smoke (Plate 1b). This can be attributed to the fact that about 91 percent of waste remaining after the activities of scavengers is combustible in dry state (Figure 2a).



Source: Author's own research

Figure 2.
(a) Composition of solid waste at a typical disposal site; (b) concentration of heavy metals in solid waste from different locations

Deliberate burning of waste dumps is a common practice by scavengers in search of valuable waste materials. Studies have also revealed a preponderance of heavy metals in refuse dump soils (Adelekan and Adewode, 2011). Odai *et al.* (2008) found elevated levels of Cd and Pb in vegetables cultivated in urban waste dumps of Kumasi, Ghana. These toxic substances are dispersed by rain and runoff to groundwater and surrounding agricultural soils where they accumulate in plants and grasses. Figure 2b shows the concentration of heavy metals in organic waste we collected at different stages, between generation and disposal. High concentrations of copper, Pb and Cd were observed. Many drinking water sources such as ponds, lakes, springs and streams have been polluted by refuse dumping. This situation has further exacerbated the problem of potable water scarcity.

7. Conclusion

From the foregoing, the rate of solid waste generation varies with season. The largest proportion of municipal solid waste in most Nigerian cities is contributed by households. In most cases, as much as 50 percent of solid waste generated is organic in nature. With this amount of organic waste, adopting better composting practices will result in improvement in the status of municipal solid waste management, in addition to providing financial benefits and employment opportunities. The major hindrances to efficient solid waste management are poor funding, poorly trained manpower, inadequate equipment, inadequate dumping sites, inaccessibility to some collection centers due to unpaved or narrow streets, lack of maintenance of operational equipment, lack of precise guidelines and laws relating to solid waste management, ineffective collection technique and disposal (Dauda and Osita, 2003). Between 30 and 60 percent of wastes is not collected. Households that are not served by waste management agencies dispose of their waste by unconventional means.

This prevailing situation can be arrested by educating residents on the dangers of improper disposal methods, and by ensuring that every household is served by either public or private waste management agency. Waste collection efficiency can be increased by using smaller collection vehicles that can access areas with poor accessibility, expanding existing facilities, establishing collection points close to every neighborhood and increased participation of the private sector. Most importantly, both citizens and governments at all levels should demonstrate sufficient will power in ensuring proper solid waste management. Researchers have a duty to provide adequate body of relevant and useful data needed for solid waste management policy formulation, planning and programmes. This can be done through constant research using standard methodologies that take cognizance of the peculiarities of the country. Considering that waste management is becoming an intractable challenge to developing countries, waste management research centers should be established for the sole purpose of achieving and maintaining environmental sanitation.

The following research gaps need to be filled:

- baseline studies of solid waste management using representative Nigerian cities;
- environmental impact assessment of open dumps in Nigeria;
- performance evaluation of municipal waste management authorities in Nigeria; and
- pilot case studies on privatization of municipal solid waste management.

References

Abah, S. and Ohimain, E. (2010), "Assessment of dumpsite rehabilitation potential using integrated risk based approach: a case study of Eneka, Nigeria", *World Applied Sciences Journal*, Vol. 8 No. 4, pp. 436-442.

Achi, A., Adeofun, E., Gbadebo, A., Ufoegbunam, G. and Oyedepo, J. (2012), "An assessment of solid waste management practices in Abeokuta, south west Nigeria", *Journal of Biology and Chemical Research*, Vol. 29 No. 2, pp. 177-188.

Adelekan, B. and Adewode, A. (2011), "Contribution of municipal refuse dumps to heavy metal concentration in soil profile and groundwater in Ibadan, Nigeria", *Journal of Applied Biosciences*, Vol. 40, pp. 2727-2737.

Adeoye, P., Sadeeq, M., Musa, J. and Segun, E. (2011), "Solid waste management in Minna, north central Nigeria: present practices and future challenges", *Journal of Biodiversity and Environmental Sciences*, Vol. 1 No. 6, pp. 1-8.

Adewumi, I., Ogedengbe, M., Adepetu, J. and Fabiyi, Y. (2005), "Planning organic fertilizer industries for municipal solid wastes management", *Journal of Applied Sciences Research*, Vol. 1 No. 3, pp. 285-291.

Afangideh, A., Joseph, K. and Atu, J. (2012), "Attitude of urban dwellers to waste disposal and management in Calabar, Nigeria", *European Journal of Sustainable Development*, Vol. 1 No. 1, pp. 22-34.

Afon, A. (2007), "An analysis of solid waste generation in a traditional African city: the example of Ogbomosho, Nigeria", *Environment and Urbanization*, Vol. 9, pp. 527-537.

Akpen, G. and Aondoakaa, S. (2009), "Assessment of solid waste management in Gboko Town", *Global Journal of Environmental Sciences*, Vol. 8 No. 2, pp. 71-77.

Alakinde, M.K. (2012), "Private sector participation and sustainable solid waste management in Ibadan SouthWest Local Government", *Management Science*, Vol. 3 No. 6, pp. 887-892.

Asase, M., Yanful, E., Mensah, M., Stanford, J. and Amponsah, S. (2009), "Comparison of municipal solid waste management systems in Canada and Ghana: a case study of the cities of London, Ontario, and Kumasi, Ghana", *Waste Management*, Vol. 29, pp. 2779-2786, doi:10.1016/j.wasman.2009.06.019.

Assa, M. (2013), "Emerging solid waste market in Lilongwe, Malawi: application of dichotomous choice contingent valuation method", *Journal of Sustainable Development in Africa*, Vol. 15 No. 4, pp. 56-65.

Audu, G.B., Bogoro, G. and Nghalmi, S.M. (2013), "Potentials and constraints of household solid waste segregation in Bauchi Metropolis", *International Research Journal of Arts and Social Sciences*, Vol. 2 No. 4, pp. 99-116.

Awosusi, A. (2010), "Assessment of environmental problems and methods of waste management in Ado-Ekiti, Nigeria", *African Research Review*, Vol. 4 No. 3b, pp. 331-343.

Babalola, A., Ishaku, T., Busu, I. and Madid, M. (2010), "The practice and challenges of municipal solid waste management in Damaturu, Yobe State, Nigeria", *Journal of Environmental Protection*, Vol. 1, pp. 348-388, doi:10.4236/jep.2010.14044.

Babayemi, J. and Dauda, K. (2009), "Evaluation of solid waste generation, categories and disposal options in developing countries: a case study of Nigeria", *Journal of Applied Sciences and Environmental Management*, Vol. 13 No. 3, pp. 83-88.

Bichi, M. and Amatobi, D. (2013), "Characterization of household solid wastes generated in suburban areas of Kano in Northern Nigeria", *American Journal of Research Communication*, Vol. 1 No. 4, pp. 165-171.

Chatterjee, R. (2010), "Municipal solid waste management in Kohima city-India", *Iranian Journal of Environmental Health, Science and Engineering*, Vol. 7 No. 2, pp. 173-180.

Cointreau, S. (1982), "Environmental management of urban solid wastes in developing countries – a project guide", Urban Development Technical Paper No. 5, The World Bank, Washington, DC.

Dauda, M. and Osita, O. (2003), "Solid waste management and re-use in Maiduguri, Nigeria", *29th WEDC International Conference: Towards the Millennium Development Goals, WEDC, Abuja*, pp. 20-23.

Devi, K., Swamy, A. and Krishna, R. (2014), "Studies on the solid waste collection by rag pickers at Greater Hyderbad Municipal Corporation, India", *International Research Journal of Environmental Sciences*, Vol. 3 No. 1, pp. 13-22.

DFID (2004), "Estimates of waste generation volumes and income potential in Abuja", DFID CNTR: 00 0512A, SPLG Consultant's Report No. 805, DFID, London.

Efe, S.I. (2013), "Waste disposal problems and management in Ughelli, Nigeria", *Journal of Environmental Protection*, Vol. 4 No. 2013, pp. 4-11.

Egbere, O., Utelim, J. and Opiah, F. (2001), "Municipal solid waste segregation and their health hazard implications in Angwan Rogo of Jos, Plateau State, Nigeria", *Journal of Environmental Sciences*, Vol. 4 No. 1, pp. 1-4.

Egun, N.K. (2012), "The waste to wealth concept: waste market in Delta State, Nigeria", *Greener Journal of Social Science*, Vol. 2 No. 6, pp. 206-212.

Etusim, P., Amuzie, D., Umeham, S., Ogwo, P. and Obialor, A. (2013), "Twelve day study on characterization of waste generated at an urban market in Okigwe, Imo State Nigeria", *Journal of Physical Sciences and Environmental Safety*, Vol. 3 No. 1, pp. 17-23.

Fakere, A., Fadair, G. and Oriye, O. (2012), "Domestic waste management and urban residential environment: focus on Akure, Nigeria", *International Journal of Engineering and Technology*, Vol. 2 No. 5, pp. 878-887.

Gakungu, N., Gitau, A., Njoroge, B. and Kimani, M. (2012), "Solid waste management in Kenya: a case study of public technical training institutions", *ICASTOR Journal of Engineering*, Vol. 5 No. 3, pp. 127-138.

Gidarakos, E., Havas, G. and Ntzamilis, P. (2006), "Municipal solid waste composition determination supporting the integrated solid waste management system in the island of Crete", *Waste Management*, Vol. 26, pp. 668-679, doi:10.1016/j.wasman.2005.07.018.

Hai, F. and Ali, M. (2004), "A study on solid waste management system of Dhaka City Corporation: effect of composting and landfill location", *UAP Journal of Civil and Environmental Engineering*, Vol. 1 No. 1, pp. 18-26.

Ibrahim, S., Aworonti, A. and Ajibade, L. (2012), "Storage and treatment system of solid waste as strategy for sustainable development in Ilorin Metropolis, Nigeria", *Advances in Applied Science Research*, Vol. 3 No. 2, pp. 801-808.

Igbinomwanhia, D. (2011), "Status of waste management", in Sunil, K. (Ed.), *Integrated Waste Management*, Vol. II, InTech, Rijeka, pp. 12-34.

Kurian, J., Esakku, S., Nagendran, R. and Visvanathan, C. (2005), "A decision making tool for dumpsite rehabilitation in developing countries", *Proceedings of the Tenth International Waste Management and Landfill Symposium, Environmental Sanitary Engineering Centre, S. Margherita di Pula, Cagliari, October 3-7* .

Lade, O., Agbede, O. and Ilori, O. (2012), "Management of solid waste in a market: case study of Bodija market, Ibadan, Nigeria", *Journal of Environmental Science and Engineering B*, Vol. 1, pp. 845-850.

Lawal, A. and Garba, I. (2013), "Study of the energy potential of solid waste in Bauchi Town", *International Journal of Computational Engineering Research*, Vol. 3 No. 5, pp. 1-7.

Lisa, D. and Anders, L. (2008), "Methods for household waste composition studies", *Waste Management*, Vol. 28, pp. 1100-1112, doi:10.1016/j.wasman.2007.08.014.

Minghua, Z., Xiumin, F., Rovetta, A., Qichang, H., Vicentini, F., Bingkail, L., Giusti, A. and Yi, L. (2009), "Municipal solid waste management in Pudong New Area, China", *Waste Management*, Vol. 29, pp. 1227-1233, doi:10.1016/j.wasman.2008.07.016.

Modebe, I., Onyeonoro, U.U., Ezeama, N., Ogbuagu, C.N. and Agam, N.E. (2010), "Public health implication of household solid waste management in Awka south east Nigeria", *Internet Journal of Public Health*, Vol. 1 No. 1, pp. 13-21.

Momodu, N., Dimuna, K. and Dimuna, J. (2011), "Mitigating the impact of solid wastes in urban centres in Nigeria", *Journal of Human Ecology*, Vol. 34 No. 2, pp. 125-133

Nnaji, C. and Utsev, T. (2011), "Climate change and solid waste management: a balanced assessment", *Journal of Sustainable Development in Africa*, Vol. 13 No. 7, pp. 17-34.

Odai, S., Mensah, E., Sipitey, D., Ryo, S. and Awuah, E. (2008), "Heavy metals uptake by vegetables cultivated on urban waste dumpsites: a case study of Kumasi, Ghana", *Research Journal of Environmental Toxicology*, Vol. 2 No. 2, pp. 92-99.

Ogwuche, J.A. (2013), "Spatial location of solid waste dumpsites and collection scheduling using the geographic information systems in Bauchi Metropolis, Nigeria", *European Scientific Journal*, Vol. 9 No. 11, pp. 374-382.

Ogwueleka, T. (2009), "Municipal solid waste characteristics and management in Nigeria", *Iranian Journal of Environmental Health, Science and Engineering*, Vol. 6 No. 3, pp. 173-180.

Okey, E., Umana, E., Markson, A. and Okey, P. (2013), "Municipal solid waste characterization and management in Uyo, Akwa Ibom State, Nigeria", in Brebbia, C.A. (Ed.), *Sustainable Development and Planning IV*, Wessex Institute of Technology, Southampton, pp. 639-648.

Onwughara, N., Nnorom, I. and Kanno, O. (2010), "Issues of roadside disposal habitat of municipal waste, environmental impacts and implementation of sound management practices in developing country Nigeria", *International Journal of Environmental Science and Development*, Vol. 1 No. 5, pp. 409-418.

Oumarou, M., Dauda, M., Abdulrahim, A. and Abubakar, A. (2012), "Characterization and generation of municipal solid waste in north central Nigeria", *International Journal of Modern Engineering Research*, Vol. 2 No. 5, pp. 3669-3672.

Oyelola, O. and Babatunde, A. (2012), "Characterization of domestic and market solid wastes at source in Lagos metropolis, Lagos, Nigeria", *African Journal of Environmental Science and Technology*, Vol. 3 No. 12, pp. 430-437.

Saha, J., Panwar, N. and Singh, M. (2010), "An assessment of municipal solid waste compost quality produced in different cities of India in the perspective of developing quality control indices", *Waste Management*, Vol. 30, pp. 192-201, doi:10.1016/j.wasman.2009.09.041.

Sankoh, F. and Yan, X. (2013), "Problems of solid waste management in developing urban cities: a case study of Freetown, Sierra Leone", *American Journal of Environmental Protection*, Vol. 2 No. 5, pp. 113-120.

Sha'Ato, R., Aboho, S., Oketunde, F., Eneji, I., Unazi, G. and Agwa, S. (2007), "Survey of solid waste generation and composition in a rapidly growing urban area in central Nigeria", *Waste Management*, Vol. 27 No. 3, pp. 352-358.

Ukoje, J. (2011), "Analysis of the determinants of participation of stakeholders in solid waste management in Zaria, Nigeria", PhD thesis, School of Postgraduate Studies, Ahmadu Bello University, Zaria.

Ukpong, I. and Udofia, E. (2011), "Domestic solid waste management in a rapidly growing Nigerian City of Uyo", *Journal of Human Ecology*, Vol. 36 No. 3, pp. 229-235.

UNU-WIDER (2010), "Solid wastes, poverty and the environment in developing country cities: challenges and opportunities", Working Paper No. 2010/23 , United Nations University World Institute for Development Economics Research, Helsinki.

Further reading

National Population Commission (NPC) and ICF Micro (2009), *Nigerian Demographic and Health Survey 2008*, National Population Commission, Abuja.

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