

The review of municipal solid waste management in Nigeria: the current trends

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Abstract. The management of municipal solid waste (MSW) is essential for every community; and, it is currently a major challenge in Nigeria. This paper provides an overview of the current MSW management trends in Nigeria and proposes new sustainable MSW management systems. Across Nigerian cities, MSW management is characterized by inefficient collection and transportation to disposal sites. Collection services do not reach some unplanned areas and slums due to poor street network. Even some planned areas are not reached by collection services. The informal sector contributes to waste collection, resource recovery and recycling; however, their activities are not recognized by the governments. Markets exist for recovered materials but more efforts need to be geared towards intensive recovery of materials and expansion of these markets. Despite the high proportion of putrescible matter in MSW, the only form of treatment commonly used currently is open burning for volume reduction. The high organic fraction presents a great opportunity for composting and anaerobic digestion. Ultimate disposal is currently done in open dumpsites. This needs to be upgraded to engineered landfills that are properly sited and adequately operated by well trained personnel. There is an emerging waste stream of concern, electronic-waste (e-waste), that requires urgent sustainable management as e-waste are currently co-disposed with other waste streams or burnt in the open posing detrimental health impacts.

Keywords: e-waste; integrated waste management; municipal solid waste (MSW); Nigeria; resource recovery and recycling; scavengers

1. Introduction

Solid waste comprise all materials, normally in the solid state, arising from human and animal activities, which are discarded as useless or unwanted (Tchobanoglous *et al.* 1993). Solid waste management is a salient issue for every society (Iorhemen 2011). The need for adequate collection, treatment, and disposal of waste by man arose as populations moved away from disperse geographical areas to congregate together in communities (Williams 2005). In general, the amount of waste produced in communities is directly proportional to the population growth (Singh *et al.* 2011).

Solid waste needs to be collected, treated, and disposed of in ways that will have minimal

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effects on health and aesthetics, and comply with sustainable development. It has been emphasized that the management of solid waste should be economically affordable, socially acceptable, and environmentally effective (McDougall *et al.* 2008). This leads to the strategy of reducing the amount of waste produced and developing efficient systems to handle the inevitable waste generated. This concept is enshrined in the waste management hierarchy.

The waste management hierarchy has the following principles in order of priority: reduction of waste generation at source, direct reuse of waste materials, recycling of waste materials, recovery of energy and other products, and residual management. Reduction of waste at source refers to the reduction in the amount and/or toxicity of the waste that is generated (Tchobanoglous *et al.* 1993). Direct reuse involves finding new uses for the waste materials, in their original form, once they have served their original purpose (Williams 2005). Recycling of waste materials implies using waste materials as “raw material” input in the manufacture of other usable products. Recycling transforms the residue into a secondary raw material (Quina *et al.* 2008), leading to a reduction in the demand on natural resources and the amount of waste requiring disposal in landfill (Tchobanoglous *et al.* 1993). Recovery of energy and other products refers to the generation of energy via processes, such as incineration, gasification, pyrolysis and anaerobic digestion. Digestate, the residue from anaerobic digestion, can be cured and used in agriculture as a soil conditioner. Residual management is the ultimate disposal of the residual waste from the above processes.

A more holistic approach, the integrated waste management (IWM), evolved from the realization that only one activity (e.g., reuse or recycling of waste) would not achieve the objective of minimizing risks associated with waste (McDougall *et al.* 2008). Several inter-related activities are necessary to achieve a significant risk reduction. In IWM, waste is handled in the most effective way in resources and environmental terms rather than merely adhering to the waste management hierarchy (Clift *et al.* 2000). A life cycle analysis (LCA) is required to be conducted on waste management options in IWM in order to obtain the most sustainable approach (Mohan *et al.* 2006). LCA takes into account environmental impacts associated with all the stages of a product’s life from cradle-to-grave (ISO 14040 1997); and for waste, the cradle starts from the dustbin. In this way, the most sustainable option(s) is/are chosen having considered all the environmental impacts.

Municipal solid waste (MSW) includes waste arising from households, business outlets, institutions (schools, hospitals, universities, etc.), street sweepings and non-hazardous solid waste from industries. MSW management refers to all activities related to dealing with waste generated by a community in a manner which minimizes the quantity of waste generated and the human and environmental health risks associated with them. The key activities in MSW management are: storage at point of generation, collection and transportation, treatment (including resource recovery and recycling) and ultimate disposal.

The management of MSW is a major challenge in developing countries (Ogwueleka 2009) and Nigeria is no exception as current MSW practices fall short of sustainable development (Iorhemen *et al.* 2016). The inefficiency of MSW managers to sustainably operate is worsened by poor urban planning, inadequately formulated policies, ever increasing urban population and inadequate resources to provide the needed services (Oguntoyinbo 2012, Iorhemen *et al.* 2016).

The first attempt of environmental legislation in Nigeria was the promulgation of the Federal Environmental Protection Agency (FEPA) Act of 1988. FEPA’s main duties are to establish, monitor, enforce standards for all aspects of solid waste management and oversee waste treatment and disposal practices (Solomon 2009). The Federal Ministry of Environment took over the

function of administering and enforcing environmental laws from FEPA in 1999. Pursuant to the FEPA Act, each state and local government in Nigeria sets up its own environmental protection body within its jurisdiction, hence MSW management is also a major responsibility of state and local government environmental agencies. However, environmental protection policies have not been efficiently implemented (Kofoworola 2007).

This paper provides an overview of the current MSW management trends in major Nigerian cities and proposes sustainable MSW management systems. The scope covers the major cities in the six geo-political zones of Nigeria.

2. MSW composition across Nigerian municipalities

2.1 Nigeria

Nigeria is located in West Africa. It is the most populous country in Africa with a land area of 924,000 square kilometers and a population of about 165 million (Shaaban and Petinrin 2014). It is divided into 36 states and the Federal Capital Territory (FCT) Abuja. These states and the FCT are broadly grouped into six geopolitical regions of North-West, North-East, North-Central, South-West, South-South, and South-East. Fig. 1 below shows the map of Nigeria with the six geopolitical zones and the states that make up the zones.

Lagos is the most populous and one of the most industrialized cities in Nigeria (Solomon 2009). It is, in fact, the commercial headquarters of Nigeria. Abuja is the seat of power and a very rapidly growing city. In this paper, the MSW management situation in one city in each of the six geopolitical regions has been reviewed. These cities include Kano from North-West, Bauchi from North-East, Abuja from North-Central, Lagos from South-West, Port Harcourt from South-South, and Enugu from South-East.

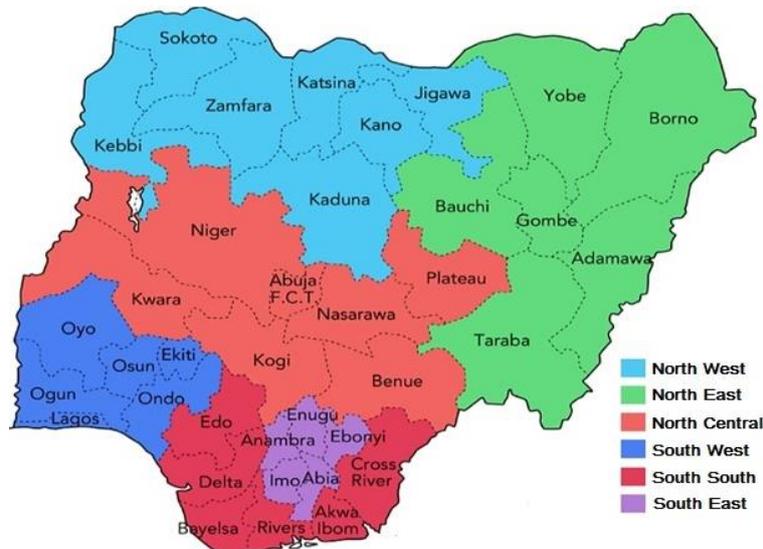


Fig. 1 Map of Nigeria showing the 36 states, the federal capital territory (FCT), and the six geopolitical zones

2.2 Current MSW composition

Generally, the rate of waste generation in a given location is highly affected by personal income, economic growth, time of the year, traditions and local culture (Ogwueleka 2009, Solomon 2009). The average MSW generation rate in Abuja is 0.634 kg/capita/day with an average bulk density of 240 kg/m³ (Ogwueleka 2013). The main components of this waste are putrescible (organic matter), plastics, paper, metals, textile, and glass bottles (Kofoworola 2007, Imam *et al.* 2008). Putrescible matter make up more than 50% while plastics constitute a significant quantity (over 15%) of MSW generated in Abuja (Solomon 2009). Similarly, in Lagos, the daily per capita MSW generation is 0.63 kg/capita/day (Abila 2014), with putrescible matter making up 68% of the total MSW generated (Solomon 2009).

Kano in the North-West is the second largest commercial city in the country after Lagos. In Kano, the daily MSW generation is 3085 tons/day with organic matter constituting 43% and paper cardboard, plastics, textile and rubber, glass, metal, ash and dirt making up the remaining percentage (Nabegu 2010). The individual rate of generation of MSW is 0.56 kg/capita/day (Abila 2014).

In Bauchi, North-East Nigeria, Usman *et al.* (2016) reported waste generation rate of 0.22 - 0.48 kg/capita/day; with the composition of the waste as 61% garbage, 13% polythene, 2.8% plastics, 4.2% paper and cardboard, 0.9% metals, 1.6% glass, 2.2% textile and 14% residues. In Port Harcourt, South-South Nigeria, MSW generation has been reported to be 0.7 kg/capita/day with the organic fraction constituting 60% (Suberu *et al.* 2013). Similarly, the MSW generation rate in Enugu has been reported to be 0.31 kg/capita/day with the organic fraction making up 58% (Suberu *et al.* 2013).

A study to determine MSW generation profile in Makurdi, a rapidly growing urban city in North-Central Nigeria, found the waste generation rate of 0.54 kg/capita/day for households, 0.018 kg/m²/day for commercial waste, and 0.015 kg/m²/day for institutional waste, as well as 0.47 kg/m²/day for small and medium scale industries (Sha'Ato *et al.* 2007). The authors further reported that 82% of MSW comes from households while 18% account for MSW arising from institutional, commercial, and industrial premises.

The per capita rate of MSW generation and the percentage of putrescible matter for major cities from each of the geo-political zones of Nigeria are presented in Table 1 below.

Table 1 MSW generation rate for major cities in Nigeria

City	Geo-political Region	Per capita waste generation (kg/capita/day)	Organic Waste Component (%)	Reference
Abuja	North-Central	0.634	63.6	(Ogwueleka 2013)
Lagos	South-West	0.63	68	(Solomon 2009, Abila 2014)
Port Harcourt	South-South	0.7	60	(Suberu <i>et al.</i> 2013)
Kano	North-West	0.56	43	(Nabegu 2010, Abila 2014)
Bauchi	North-East	0.22 - 0.48	61	(Usman <i>et al.</i> 2016)
Enugu	South-East	0.31	58	(Suberu <i>et al.</i> 2013)
Makurdi	North-Central	0.54	36-57	(Sha'Ato <i>et al.</i> 2007)

From Table 1, it can be seen that organic matter account for the highest component of municipal waste stream in Nigerian cities. Other studies have also reported this same proportion (Ogwueleka 2013). This presents a wonderful opportunity for sustainable biological treatment using composting to produce stabilized compost for use in agriculture and/or anaerobic digestion for the generation of renewable energy (through biogas).

2.3. An emerging waste stream of concern - electronic waste

Since the introduction of the Global System for Mobile Communications (GSM) in Nigeria in 2001, the use of electronic devices has increased exponentially. This has resulted in rapid advancement in information and communication technology (ICT) in Nigeria, hence making the internet more accessible to Nigerians. However, the use of these electronic devices is not without side effects. A large percentage of ICT users in Nigeria rely on fairly used electronic devices from developed countries, mainly from North America and Europe (Nnorom and Osibanjo 2008). These electronic products have a relatively short useful life (Osibanjo and Nnorom 2007), hence they easily become obsolete posing environmental concerns.

Electronic waste (e-waste) refer to obsolete electronic equipment (Osibanjo and Nnorom 2007). E-waste are a concern due to their hazardous material content; and, proper pre-treatment is required to prevent environmental problems during the waste management phase (Nnorom and Osibanjo 2008). Due to the rapid increase in the use of electronic devices, e-waste has become the fastest growing component in the solid waste stream (Li *et al.* 2006). Nigeria produces the highest amount of e-waste in West Africa (Jibiri *et al.* 2014). Common electronic devices used in Nigeria include: cathode ray tubes e.g., televisions and computer visual display units; personal computers e.g., desktops, table tops, laptops, iPads; and mobile phones. In addition to the locally generated e-waste, Nigeria is one of the destinations for the transboundary movement of e-waste (Alabi *et al.* 2012), thus increasing the quantity of e-waste in the country.

At the moment, there is no special management for this emerging waste stream. E-waste are co-disposed with other waste streams at dumpsites in Nigeria (Jibiri *et al.* 2014) or burnt as a volume reduction measure. Most of the e-waste materials contain numerous hazardous substances (Alabi *et al.* 2012) including lead (Li *et al.* 2006), copper, chromium, cadmium, etc. The burning of these electronic substances can also release toxic substances such as polyaromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs), dioxins and furans (Alabi *et al.* 2012). The toxic substances pose a serious threat to human, animal and environmental health.

3. Current management of MSW in Nigeria

3.1 Waste storage at the point of generation

Waste, once generated, needs to be stored at the point of generation for subsequent collection. Waste storage at the point of generation involves storing the waste, until collection by management corporations, e.g., local council or private waste managers. Storage is a key aspect of MSW management as it allows for ease of collection. In Abuja, the Abuja Environmental Protection Board (AEPB) is saddled with the responsibility of collecting waste from the municipality. So AEPB has provided waste storage containers (120-L and 240-L plastic bins, and 1.1 m³ metal bins)

to every household and commercial outlets (Imam *et al.* 2008, Solomon 2009) for the purpose of waste storage. Similarly, in Lagos, MSW management is the responsibility of Lagos State Waste Management Authority (LAWMA). LAWMA positions stationary containers at the points of waste generation, generally at open spaces along street ends or junctions, and about 500-800 m apart (Solomon 2009). Residents are required to deliver their waste to these waste storage containers.

In Port Harcourt, the Rivers State Environmental Sanitation Authority (RSESA) makes available large bins at market places, road junctions and street corners for residents to dump their generated waste (Ogbonna *et al.* 2007). RSESA also supervises the seven contractors appointed to collect and dispose MSW (Ayotamuno and Gobo 2004). The situation is the same in Enugu where the Enugu State Waste Management Authority (ESWAMA) provides household refuse collection bags for the storage of waste at the point of generation for collection by the appointed private service providers (Nzeadibe 2009).

Generally across the country, the provision of waste storage bins is the responsibility of the State Environmental Agencies and/or Private Companies (Solomon 2009). In some cities, storage containers are not provided and residents dump their waste at designated collection points. This creates a problem as residents use small bins that fill up quickly and overspill.

3.2 Collection and transportation

MSW collection and transportation refer to the collection of waste at the storage points and the movement of the collected waste to the treatment or disposal sites. Collection and transportation contribute a significant cost in waste management (Imam *et al.* 2008). This implies these two activities need to be carefully planned for and executed properly.

In Abuja, 12 private companies are responsible for MSW collection and disposal (Imam *et al.* 2008, Solomon 2009). These firms do house-to-house collection of MSW 1 - 3 times per week depending on the condition and availability of their vehicles (Solomon 2009). In addition, it has been reported that informal collection workers operate house-to-house collection services in Abuja; usually sorting out recyclable materials and dumping unwanted degradable waste around the area (Imam *et al.* 2008). This makes the authorities to ban them from certain areas in the FCT and impound their collection carts. Similarly, in Lagos, stored MSW is collected from house-to-house, kerbsides, communal depots, commercial centers and industrial places, and transported to disposal sites using carts, open bed trucks, trucks and compactors (Solomon 2009). However, collection of kerbside-deposited waste tends to be quite irregular.

In Kano, MSW collection is the responsibility of the Refuse Management and Sanitation Board (REMASAB). MSW are dumped at designated collection centers where employees of REMASAB collect them for disposal; but at the moment, this formal collection covers only about 20% of the town (Nabegu 2010). However, residents tend to dispose most of their waste at unauthorized empty plots, individual burning and personal bins (Nabegu 2010). In Bauchi, the Bauchi State Environmental Protection Agency (BASEPA) is responsible for the collection and disposal of the generated solid waste. BASEPA has 86 designated collection centers where residents dump their waste for collection and disposal (Babanyara and Bogoro 2011). The number of collection centers is very small compared to the size of Bauchi metropolis. This may create an avenue for residents to dump waste at any available open space.

RSESA is responsible for MSW collection and disposal in Port Harcourt (Ogbonna *et al.* 2007). In Enugu, the management of MSW is the responsibility ESWAMA (Nzeadibe 2009). Private Service Providers (PSPs) have been contracted by ESWAMA to collect MSW in their areas of

jurisdiction within the municipality at least twice a week and transport to the Ugwuaji landfill facility.

Across all the municipalities, one problem with MSW collection is that, high- and medium-class residential areas receive better services than low-class residential areas because of their readiness to pay for the services. This is also facilitated by proper planning in these areas, making monitoring and enforcement less difficult (Solomon 2009). Waste collection is poor in low-class residential areas and slums because of poor street network, unpaved or narrow streets where collection trucks cannot enter and/or turn (Dauda and Osita 2003). All these make it difficult or impossible for MSW management agencies to service the areas.

Another problem with MSW collection and transportation to disposal sites is that traffic conditions often interfere. This problem has been reported in Abuja (Imam *et al.* 2008). The situation is not different in Lagos and the other big cities. Moreover, it has been reported that informal MSW collection operations exist alongside government agencies in some major cities (Ogwueleka 2009). A fee is usually paid for this service by the residents. Furthermore, a shortage of waste collection vehicles has been reported in Abuja (Imam *et al.* 2008) and Lagos (Kofoworola 2007). The shortage in waste collection vehicles is even worse in other towns across the country. This is attributed to poor funding and inadequate maintenance of these vehicles. This results in residents, who do not pay fees to the informal waste collectors for their domestic waste collection, disposing their waste on the streets, around streetlight poles, and beside embankments along the expressways (Kofoworola 2007).

3.3 Resource recovery and recycling

Currently, there are no functioning MSW sorting centers in Nigeria. MSW is collected mainly from waste storage points and taken straight to disposal sites. Resource recovery and recycling is mainly done by the informal sector. In Abuja, Imam *et al.* (2008) and Solomon (2009) reported that only the informal sector carries out recycling. Sorting is done from their carts, by the collection crew from waste vehicles, and by scavengers from street bins and at the dumpsites. Only a limited quantity of plastics, cans, bottles and newspapers are retained in homes and sold to itinerant buyers (Solomon 2009). Scavengers collect recyclable materials such as cans, plastics and bottles from MSW dumpsites using basic implements like iron sorting rods, hand-rakes and shovels for sorting of the waste. The recovered materials are sold to small- and large-scale processing and manufacturing industries. Similarly, in Lagos, MSW recyclable materials like plastics, paper, metals and glass are considered to have high market value, and are sorted out by the informal sector (scavengers) either at source or at the dumpsites (Kofoworola 2007, Solomon 2009).

In Kano, sorting and recycling is done by the informal sector as well, where about 25,000 waste pickers collect an average of 15 kg/capita/day and sell to the ready markets existing in many industrial enterprises in Kano (Nabegu 2010). The various small and large recycling companies in Kano use the sorted recyclables as secondary raw materials. In Bauchi too, sorting and recycling is done by informal waste operators (scavengers and vendors) who sort mostly polythene and plastics from MSW and sell to the plastic recycling company established by the Bauchi State Government (Usman *et al.* 2016).

In Enugu, there is a materials recovery facility (MRF) at Uwani but it is used rather as a dumpsite (Ogwueleka 2009). Any form of resource recovery and recycling is done at the informal level by scavengers/waste pickers who assemble at the Ugwuaji landfill site to recover waste

materials that maybe reused directly or recycled (Nzeadibe 2009). The recovered materials including scrap metals, plastics, bottles, textile materials, aluminum cans, etc., are reused directly, or used as secondary raw materials, or processed into intermediate products for sale to big companies in Onitsha or Lagos. However, waste paper, cardboard and polyethylene packaging materials are usually not recovered because there are currently no market outlets for them (Nzeadibe 2009).

Little progress has however, been made in the area of resource recovery and recycling. Recently, an integrated waste recycling and treatment plant started operation in Akure, Ondo State, South-West Nigeria in 2006 (Olanrewaju and Ilemobade 2009). At the moment, the recyclables from MSW of Akure and environs, typically organic matter, metals, paper, glass and plastics, are sorted on-site by the employees of the company. Once the different recyclable materials are separated, they are then transferred to the different units of the company for processing. Public orientation is being done to educate residents on the need for source separation of their waste.

Across Nigerian municipalities, the main group engaged in MSW resource recovery and recycling are scavengers. Despite this, their role in resource recovery and recycling has not been recognized by the governments. These informal recyclers see MSW as an income source and a means of livelihood (Oguntoyinbo 2012). Hence, incorporating their services in the MSW management scheme will not only provide a sustainable synergistic waste management system from cradle-to-grave but also provide employment opportunities for them.

3.4 MSW treatment

Incineration and conversion of waste to energy is not yet practiced in Nigeria except in the hospitals where medical waste are incinerated at a small scale (Ogwueleka 2009). Functional incinerators exist at the National Hospital Abuja and National Orthopaedic Hospitals in Kano, Dala, Enugu and Igbobi, Lagos (Solomon 2009).

In Lagos, MSW is not treated but transported straight to the ultimate dumpsites for disposal (Solomon 2009). There are two incinerators located along Oshodi-Apapa Express Way and at Ebute-Meta which have never been used, leading to the treatment of MSW by open mass burning at the dumpsites (Kofoworola 2007, Solomon 2009) as a volume reduction measure. The situation is the same in Abuja as collected MSW is transported straight to the disposal sites.

In Port Harcourt, the only form of treatment done on MSW is open air burning at the final disposal site in order to reduce volume (Ayotamuno and Gobo 2004). The situation is the same in Bauchi where MSW treatment is predominantly by open burning at the dumpsite. Similarly, there is no form of treatment for collected MSW in Enugu. The PSPs contracted by ESWAMA collect MSW from individual households and transport directly to the Ugwuaji landfill facility (Nzeadibe 2009).

Across the country, burning of MSW at dumpsites for volume reduction and refuse burning at individual homes of confidential documents, rags, and tires is a common practice (Solomon 2009). This open burning has adverse effects on the environment.

However, little progress is being made. Considering the high percentage of organic matter component of MSW in Nigeria, a private company (EarthCare Nigeria Ltd) has recently set-up a composting facility in Odogunya, Lagos to produce compost from waste for agricultural use (Solomon 2009). In addition, an integrated waste recycling and treatment plant has recently been established in Akure Ondo State. The sorted recyclables are processed (Olanrewaju and Ilemobade 2009). The sorted organic fraction of MSW is composted (aerobic decomposition) to produce

compost - a stabilized organic fertilizer; the sorted plastics are shredded to smaller particles and are converted to pellets and the pellets sold out to companies on Lagos, Anambra and Oyo for use as secondary raw materials; and, the sorted scrap metals are melted in a furnace and used to produce manhole and pipe couplings cast-iron products.

3.5 MSW ultimate disposal

Ultimate disposal of waste is used to describe the disposal of residual waste mostly in landfills. In Nigeria, like most developing countries, MSW is commonly disposed of in open dumps, or uncontrolled landfills. Dumpsites are located along or beside major roads (Ogwueleka 2009). Even in Abuja, the FCT, there are no sanitary landfills for waste disposal (Imam *et al.* 2008, Solomon 2009, Ogwueleka 2013). Formally collected MSW from the various districts of Abuja is transported to dumpsites located at Mpape, Suka, Guzape (Solomon 2009, Ogwueleka 2013). The private contractors are responsible for the ultimate disposal of MSW at these dumpsites while government retains the responsibility of dumpsite maintenance (Solomon 2009). In Lagos, there are 8 landfill sites (Ogwueleka 2009) including the one located at Oloshosun, Agege (operational) and Iyana-Iba (no longer in use) (Kofoworola 2007). The MSW collected by the formal sector is transported to the landfill site for disposal; although in some cases, it is openly burnt for volume reduction.

Similarly, there are no landfills in Kano (Nabegu 2010) and Bauchi (Gani *et al.* 2013), only dumpsites are in use. In Bauchi, there exist numerous illegal dumpsites in addition to the ones designated by BASEPA. Backyard pit disposal is also practiced by some households in Bauchi (Gani *et al.* 2013).

In Port Harcourt also, MSW is ultimately disposed of in 5 dumpsites which are burrow pits from previous excavation of laterite for road and building construction works (Ayotamuno and Gobo 2004). MSW is brought in and spread over the area. The situation is exactly the same in Enugu where the ultimate disposal of MSW is done at the landfill located at Ugwuaji at the outskirts of the town, 1.6 km off the Enugu-Port Harcourt expressway (Nzeadibe 2009).

From the foregoing, ultimate disposal of MSW is at designated dumpsites across Nigerian cities. However, there are numerous side effects of open dumping including groundwater pollution resulting from leachate percolation, health hazard to scavengers at the dumpsite, transmission of contagious diseases, highly toxic smoke from continuously smouldering fires and foul odors from decomposing refuse (Ogwueleka 2009). Another worrying issue is that both hazardous and non-hazardous waste are co-disposed in these dumpsites (Solomon 2009). The non-separation of hazardous waste from other waste streams is a serious issue that needs urgent attention. These hazardous substances can leach and pollute groundwater resources posing a high risk to people since many Nigerians rely on groundwater abstraction as their main source of water.

Furthermore, illegal disposal of MSW is also common. Heaps of MSW are often found along roads, underneath bridges, in culverts and drainage channels and in other open spaces (Imam *et al.* 2008). This may be by the informal collection workers and scavengers but other residents also engage in such acts. These illegally disposed waste remain where they are disposed with the attendant effects.

4. Recommendations for improvement

Generally, poor funding is one of the main reasons for poor MSW management, especially

collection and disposal, in Nigerian cities (Dauda and Osita 2003, Ayotamuno and Gobo 2004). Inadequate funding makes State agencies saddled with the responsibility of MSW management lack adequate capacity/facilities to handle the increasing amount of MSW. Poor remuneration also results from inadequate funding which ultimately leads to job dissatisfaction on the part of the agencies' employees. To overcome this funding issue, it is recommended that a specific fee be charged per household, commercial outlet or institution for their waste management as it is currently done in the UK (council tax) and Canada (waste management charge). The problem here would be willingness to pay. But if residents receive reliable services, they will not have problem paying for them.

It has been emphasized that the legal framework supporting MSW management in Abuja is weak and waste policies lack clear strategies for realization (Ezeah and Roberts 2012). This is the same for other cities in the country like Port Harcourt (Ayotamuno and Gobo 2004) and Bauchi. Very clear policies and programs need to be put in place for effective and sustainable MSW management. These policies should have an integrated waste management approach which incorporates waste reduction strategies, direct reuse and recycling of useful waste materials, energy recovery and ultimate disposal. A clear legislation also needs to be put in place for e-waste in Nigeria. End-of-life waste electrical and electronic equipment are an emerging waste stream of serious concern and require effective management to prevent the attendant effects on human and environmental health.

Another key area of concern in MSW management in Nigeria is the non-separation of hazardous waste from non-hazardous waste. Hazardous waste is co-disposed with non-hazardous waste as there is no separation at the source. A strong policy on hazardous waste generation, separation and subsequent disposal needs to be put in place with strong enforcement. As part of the policy, special hazardous landfills should be designated.

4.1 MSW collection and transportation

In order to improve waste collection, each household should be provided with a sizeable waste storage bin by waste management authorities. In areas where this is impractical like unplanned areas and slums, central collection points to be shared by a number of households should be designated for dumping of individual household waste. The activities of the informal waste collectors can be incorporated in the MSW management system in such a way that the informal waste collectors would offer approved door-to-door collection service in inaccessible areas and the public sector would supervise their activities.

4.2 Resource recovery and recycling

As stated earlier, resource recovery and recycling is done by the informal sector across Nigerian cities. This informal waste management group see MSW as a means of income and livelihood (Oguntoyinbo 2012), hence integrating their activities with the formal sector will form a sustainable synergistic MSW management system. In addition, it is recommended that sorting areas should be created close to the MSW disposal sites where useful waste materials can be recovered for direct reuse and recycling. The residual waste can then be disposed of at the site. These sorting centers will serve as employment for the numerous unemployed youth in the country. Although markets already exist for recovered waste materials, government can still encourage the expansion of these markets.

In addition, to enhance recycling, a policy should be put in place to make industries adopt 'take-back recycling' especially for plastic and glass. A deposit fee can be included in the price of the product and centers created for returning the empty plastic or glass containers for a refund of the deposit fee. If the users fail to return the empty containers, the informal sector can collect them together and take them to designated collection centers and claim the deposit fee on each item. The refund of the deposit fee will serve as incentive to the informal waste collectors.

4.3 MSW treatment

The current method of MSW treatment across Nigerian cities is open burning at disposal sites. This is highly discouraged. The composition of MSW across the country indicates that organic matter is the highest proportion. This presents a wonderful opportunity for composting to produce ends products (compost) that would be very useful in agriculture. Windrow composting, which is easier to operate can be adopted. Anaerobic digestion can also be operated alongside composting to generate renewable energy from the organic waste. The residue from anaerobic digestion, digestate, can be stabilized in the composting system for use in agriculture.

4.4 MSW ultimate disposal

In any MSW management system, there is usually some residual waste that needs disposal. At the moment, ultimate disposal of MSW is at open dumpsites. This method of disposal is not appropriate. The ultimate disposal of MSW should be done in properly engineered landfills. These landfills should be properly designed by engineers and operated by trained personnel. Provision needs to be made for the collection and treatment of leachate in order to prevent groundwater pollution. Landfill gas collection is another very important issue that requires consideration. Since it contains methane, it has to be collected and cleaned of impurities for beneficial use.

Lastly, public education must be thoroughly done for all the above recommendations to work effectively. Training of specialized manpower in MSW is highly recommended to help drive and sustain the public waste education program.

5. Conclusions

MSW management in six major Nigerian cities (Lagos, Abuja, Kano, Bauchi, Enugu, and Port Harcourt) has been x-rayed. The management of MSW is characterized by inefficient collection and transportation to disposal sites as well as poor collection services. The informal sector contributes to waste collection but their primary target is to recover useful waste materials and once they have completed resource recovery, they dispose the waste anywhere. Resource recovery and recycling are carried out only by scavengers but their activities are not recognized by the government. Markets exist for recovered materials; however, more efforts need to be geared towards intensive recovery of materials and expansion of these markets. Despite the high proportion of putrescible matter in MSW in Nigeria, the only form of treatment commonly used presently is open burning for volume reduction. The high organic fraction presents a great opportunity for composting and anaerobic digestion. Ultimate disposal is currently carried out in open dumpsites. Properly engineered landfills need to be sited and adequately operated by well trained personnel. Another critical issue in MSW management that requires urgent attention is the

management of e-waste, an emerging waste stream of concern. There is no special management in place for e-waste in Nigeria as they are co-disposed with other waste streams or burnt openly.

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