ENERGY RECOVERY POTENTIAL AND MANAGEMENT OF MUNICIPAL SOLID WASTE IN SOME SELCETED NIGERIAN STATES: A REVIEW

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ABSTRACT

The management of MSW is a major concern in several cities of developing countries due to its public health and environmental sustainability implications. This paper thus presents an overview of the current solid waste management practices and problems in some selected states in Nigeria.In addition to the comprehensive review of MSW generation, its characterization, collection, and treatment options in the considered states, an attempt was made to evaluate the major waste–to–energy indicators such as calorific values and energy (electricity) recovery potential.The legislations in placeat the federal level to maintain healthy environment is also lucidly presented. An estimated electricity recovery potential in the range of 48.31 to 933.69 MW with a total of about 2600MW from six states was established. Evidences from literature suggested that the existing solid waste management system is inefficient due to uncoordinated and properly planned waste management system. This paper concludes that the thermochemical conversion of waste-to-energy into electricity is a feasible option in Nigeria, although this might require the input of additional quantity of fuel to initiate combustion since the lower heating values of the considered MSW fall below the optimum stipulated by World bank.

Keywords

Municipal solid waste (MSW);Energy recovery potential;Waste-to-energy; Calorific values;Legal frameworks;

1. INTRODUCTION

Nigeria is one of the Sub Saharan countries located in the western region of Africa. The countryoperates the federal system of government in which people are governed by three tiers of government, these are the Federal, State and Local Government. The country is diverse, both in its people and landscape [1].Nigerians are permanently accustomed to dirt, evidence of this can be seen every day by way of indiscriminate discharge of solid waste into drains and at times on the highways [2]. Ajani (2008) defined solid waste as a material that is no longer valuable which is not intended to be discharged through a pipe. MSW was further defined as all wastes generated in the community excluding industrial and agricultural wastes.Patel(2003)asserted that thoughMSW can be a liability if disposal is ultimate butit can also be

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seen as a considerable resource that canbe beneficially recovered through recycling of materials or through recovery operations such as composting and conversion to energy.

According to Moruff (2014), the problem of waste management has remained intractable despite the unrelenting efforts made by the government to tackle solid waste management problems.Waste management is a serious issue due to its human health and environmental sustainability implications. It isreally a pressing issue the world is facing today, since a high percentage of waste is currently disposed of by open dumping [5].In particular, solid MSW management is a major public health and environmental concern in the urban areas and many developing countries. The situation in Africa, particularly in the large urban towns is severe [6].Highpopulation growth rates, rapidly varying waste characterization and generation patterns, growing urbanization and industrialization in developing countries are the important reasons while attention has to be paid towards effective and efficient MSW management [7].

The major problem caused by wastes to the environment is pollution characterized by various types of solid wastes which include paper, textile, metals, glass, bone, wood, vegetal matter and food remnant of multiple consistency, saw dust and plastic wastes [5].In the absence of proper disposal methods, these wastes are burnt in the open air, dumped along the bank of streams and rivers or left on any available space to rot. It was estimated that the amount of sawdust generated in Nigeria is about 1.8 million tons per annum while the corresponding figure for wood waste is 5.2 million. Similarly, in Nigeria, there has been a monumental increase in the yearly generationof plastic waste with minimal percentage of it being recycled. Only 14 kg (14.24%) of 98.32 kg in 2001 and just 35 kg (13.06%) of 268 kg in 2013 were recycled [8].

Throughout most of sub-Saharan Africa solid waste generation exceeds collection capacity and most times thegeneration rates, available only for select cities and regions, are approximately 0.5 kilograms per person per day—in some cases reaching as high as 0.8 kilograms per person per day. Only a small amount of the region's collected waste is disposed of in sanitary landfills; most is deposited in open dumps or semi-controlled unlined landfills with no groundwater protection, leachate recovery, or treatment systems. The larger dumps are located on the edges of cities, towns, and villages, sometimes in ecologically sensitive areas, or areas where groundwater supplies are threatened. They serve as breeding grounds for rats, flies, birds and other organisms that serve as disease vectors. Smoke from burning refuse may be damaging to the health of nearby residents and the smell degrades their quality of life [9].

The continuous indiscriminate disposal of MSW is accelerating and is linked to poverty, poor governance, urbanization, population growth, poor standards of living, and low level of environmental awareness [10].Though it is widely accepted that the management of solid waste is a global problem but it iseven more pronounced in developing countries such as Nigeria [1], where suchis a critical issue confronting practically every state of the country [5]. Hence, there is need to putproactive measures in place towards managing waste in order to achieveeconomic, social and environmental protection [5]. In addition, energy

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generation, resource and material recovery from waste through improved MSW management is desirable [10].

The aim of this paper is to provide a comprehensive review of solid waste management in some selected states in Nigeria as depicted in figure 1.0, these states were selected because they are mostly commercial centres with huge populations. The review covers waste characteristics, existing solid waste management practices, policies and regulations as well as estimating the energy content and electricity recovery potentialof theMSW in the respective states since such information is lacking in literature.

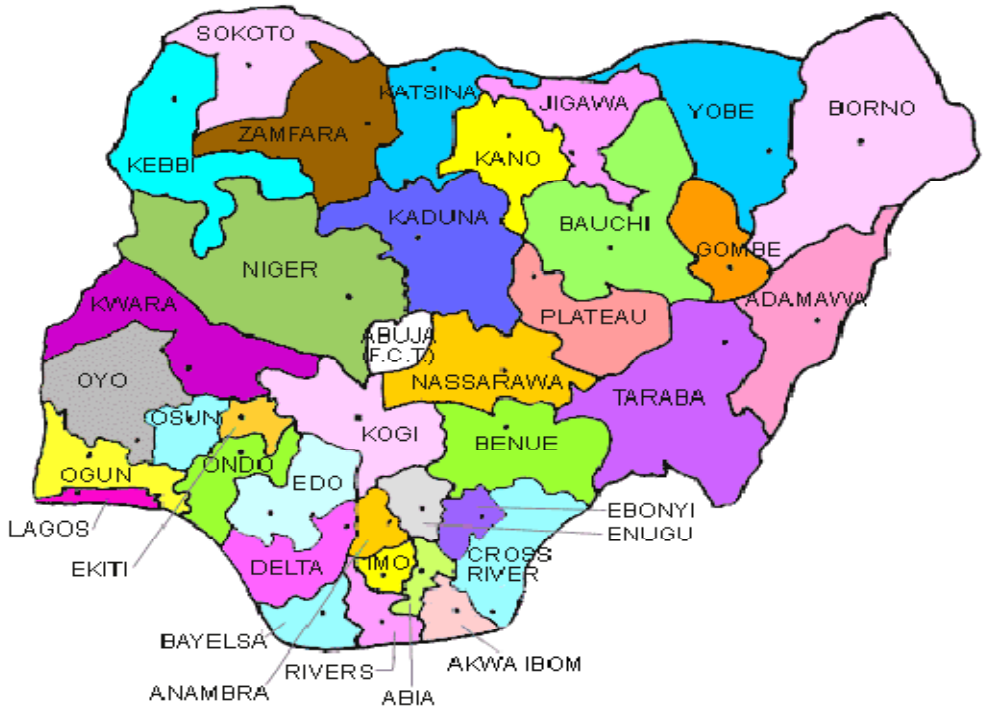

Figure 1.0: Map of Nigeria showing the various states, [11].

2. CURRENT STATUS OF MSW MANAGEMENT IN NIGERIA

In the developed countries, MSWmanagement belongs to prominent thrust areasfor pursuing research, economic and technological advancements have initiated responsiveness of stakeholders towards it [7].However, developing countries are faced with some typical problems when MSW managementis discussed, which envisage poor and inefficient coverage and operation of services, inadequate or missing recycling strategies and activities, limited or unproductive management of hazardous waste etc. [5].MSW management is a fundamental prerequisite in ensuring sustainable environment[6] and it includes collection, transportation and final disposal. The composition of wastes is a very important aspect of MSW management as it dictates the technology needed for waste processing and/or disposal [12].

Table 1.0 below gives the summary of the waste composition in the respective states that were considered for this review while the status of the MSW management in each state is highlighted in the sub sections below. In some instances, when information is lacking, waste composition for the state

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capital is used as a representation for the state. Data sources include: Oyo [13], Lagos([14], [15], [16], [17]), Kano [18], Abuja([19], [20]), Kaduna ([21], [22]), Port Harcourt [23].

Table 1.0 Composition of MSW (percentage of wet weight)

% of waste fraction	Oyo	Lagos	Kano	FCT	Kaduna	PH
Food &organic wastes	76.0	65.84	57.5	59.7	43.65	44.2
Paper and cardboard	6.6	10.62	6.7	17.75	11.33	-
Plastic	4.0	11.83	17.6	6.15	12.89	5.6
Leather and rubber	-	-	-	1.74	-	-
Textiles	1.4	3.25	4.5	2.32	5.12	6.4
Wood	-	-	1.8	-	6.92	7.6
Metals	2.5	3.27	3.9	3.17	2.73	10.8
Glass	0.6	3.20	2.5	2.8	2.85	23.3
Inert	8.9	-	5.6	6.38	14.53	-
Fines	-	2.0	-	-		2.1

*The waste composition is the average value of data reported in the cited references

2.1 Oyo State

Oyo State is located in south-western Nigeria with Ibadan as its capital. It is located on coordinates 8°00′N 4°00′E / 8.000°N 4.000°E. It is bordered by Kwara State, Osun State, Ogun State and Republic of Benin in the north, east, south and west respectively. Oyo State covers approximately an area of 28,454 square kilometers and has an equatorial climate with dry and wet seasons. The state comprises 33 Local Government Areas [11]. According to Ogunleye (2003), population increase and rapid expansion are twin problems which have brought increasing strain on urban infrastructure facilities, especially in the area of waste management where the existing system appears to be incapable of coping with the amount of waste generated by the populace. Odewumi, Okeniyi and Agbede (2016)reported that an average person generates about 0.58kg/person/day of waste within Ibadan locality, the state capital.

Studies showed that the core area of Ibadan metropolis is characterized by slum, inaccessibility, poor environmental conditions as a result of poor town planning which negatively affects the solid waste management process in the area [26].In Ogbomosho, the second largest city in Oyo state after Ibadan, Afon (2007)considered education, occupation, income and household size as factors that influence solid waste generation. As regards medical waste, Evinemi and Afon (2016)made some findings about the storage, collection and disposal practices of solid waste in private health institutions in Ibadan. Despite the potential hazards and public health risks that are characteristic of medical wastes, the management of such wastes has received little attention. Although medical wastes make up a small fraction of solid waste, the impending environmental and health hazards could be dangerous if not appropriately handled.

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Odewumi, Okeniyi and Agbede (2016)reported that wastes generated are collected by different means, ranging from on-the-ground street free dumping, to container packages or direct dumping into waste truck. From general assessment, it was noted that metal skip bins that can contain 11m^3 (about 0.0093 tonnes) of solid wastes are positioned along major roads in the Ibadan metropolis to collect waste.Evinemi and Afon (2016)also reported that perforated covered waste basket was the most prominent waste storage container used by some private institutions assessed.Odewumi, Okeniyi and Agbede (2016)concluded that the most difficult and expensive part of solid waste management is transportation as it takes more than 70% of the budget for MSW management. Also, it was concluded that the collection and transportation systems in the state is not satisfactory as there must be adequate provision for waste collection.

According toSridhar and Hammed (2014), every component of solid waste should be taken into consideration in a sound solid waste management strategy. Effort by the Oyo State Government in the collection and disposal of solid waste generated in Ibadan, the state capital, is seen by provision of skip bins at various locations across the city [30]. Ibadan Waste management board (IWMB) is a state government organization set up in 1997 to prevent or reduce the impact of waste materials on human health and local facilities. They are responsible for removing wastes from residential areas to prevent spread of diseases from waste dumpsites [3]. The activities of IWMB is complimented by the private waste collectors that servedan estimated 10,000 households in Ibadan in 1994. As at 2008, 68 private firms were registered with IWMB though only 10 were really functioning [3].

Moruff (2014)concluded that since the poor collection and disposal of waste in some areas in Ibadan results in solid waste building up in public spaces, and clogging of drainage and sewer systems, there is an urgent need to seek workable solutions to the problems of solid waste management via the application of a planned, cultural, integrated, and sustainable economic process for the development of the city and the state at large.

2.2Lagos State

Lagos is a state in Nigeria, located in the South-Western part of the country (6^o 35' N, 3^o 45' E). It is the smallest state in terms of area of land, with about 3577Km^2 of which 22% are lagoons and creeks. In the North and East, it is bounded by Ogun State, in the West by Republic of Benin and in the South by the Atlantic Ocean. Lagos State is the second most populous in the country, with about 9,113,605 people captured in the 2006 census (currently over 21 million)[11].Waste generation rate in Lagosis about 0.5kg/person/day (2008), about 9,000 – 10,000 metric tons of waste is being generated per day [31]. Majority of the generated waste are organic, however, the percentage changes from one region of the state to the other. It has been observed that high income areas like Ikoyi generate much less organic waste when compared with low income areas like Mushin, Gbagada and Ebute-Metta, which could be as a result of the nature of food consumed [32].

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Lagos State Refuse Board, 1977 was first created to manage the waste generated in Lagos. In 1980, it was renamed to Lagos State Waste Disposal Board (operated by a foreign firm). Lagos State Waste Management Authority (LAWMA) was created in 1991 and was responsible for managing all domestic, commercial, institutional, and industrial waste (including primary and secondary drain clearing). In its early years of creation, LAWMA focused on the high income areas of the state while cart pushers handled the waste collection from areas of the low income people, most of which ended up in inappropriate places. The cart pushers were then banned in 2004. In 1997, Private Sector Participation (PSP) operators were added to assist LAWMA. They go from street to street to pick up domestic, medical and industrial waste once every week or two weeks with residence paying for waste by month end [33]. To make waste transport easier and faster, LAWMA distribute waste bags to homes, medical centers and other waste generation sites. Waste from these places are meant to be gathered and packed in these bags while awaiting the agency to come pick them up [34].

There are also highway sweepers who have designated areas they clean on a daily basis, picking up waste from the road and market places. They pile them up on the road side and are then carried away by the truck [34].An average of twenty thousand truck trips was reported in 2012 for all agency involved in waste management (LAWMA, LAWMA contractor, P.S.P, Ministry of Environment and Local government) from various locations to the dumpsites [31].Also to reduce the waste transportation time, solid waste storage devices were placed in areas with high waste generation, this allows people leaving around these devices to walk there and dump their waste rather than pile it up in their buildings, the waste are later collected by LAWMA from these facilities [34].

LAWMA sends their rear loading garbage packer trucks to different streets with proper schedule, its staff patiently wait for everyone to dump their wastes and then empty the waste bins of the houses in their trucks without involving the residence [34].Waste collected in Lagos are all taking to the active landfills. There are sixteen landfills in Lagos, of which only five are active, two of which are only temporary. The three major active landfills are Olusosun (42.7 hectares), Solous 2 (7.8 hectares) and 3 (5 hectares) [31]. These wastes are then sorted and some of which are recycled. About 600 tonnes of waste are composted daily from the dumpsites (a combined total of 1500 tonnes per day was reported in 2011 from to composting facility), there are also paper baling machines for recycling of papers from the dumpsites (2 facilities), polythene is also being processed into pellets, plastic recycling (4 informal and 3 formal facilities as at 2011) [35].

2.3Kano State

Kano State is located in northern Nigeria on coordinates11°30′N 8°30′E / 11.500°N 8.500°E. Kano State borders Katsina State to the north-west, Jigawa State to the north-east, Bauchi State to the south-east and Kaduna State to the south-west. Kano State covers approximately an area of 20,131 square kilometers and has an equatorial climate with dry and wet seasons. Kano State consists of 44 Local Government Areas and has a population of 11,058,300 according to a 2011 population estimate. Subsistence and commercial agriculture is mostly practiced in the state [11]. Kano state is home to Kano

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city which is the third largest city in Nigeria after Lagos and Ibadan.Per capita generation of MSW in Kano is in the rage of 0.2 to 1.7 kg/day. The MSW was found to have a specific density of 0.31m^3 and an average weight of 564kg per cubic meter [36].

According toNabegu (2009), waste collection service does not reach the entire population of Kano with a collection ratio of 32%. Small and impoverished metal or plastic containers or enclosures, though grossly inadequate, are used for MSW storage. The major problem of effective MSW management was found to originate from the lack of technical expertise to direct the waste collection and transport systems. Another problem was found to be lack of access to most areas in the old cities and suburban areas of Kano state. Transport systems include a great range of vehicles that are not fit to negotiate narrow roads which as a result impedes smooth collection and consequently hampers the overall efficiency of the collection process. Accumulation of garbage due to infrequent and sometimes non collection of solid waste is often seen to block major drains and sometimes rivers also [12].

Nabegu (2009) stated that MSW in Kano is managed centrally by the Refuse Management and Sanitation Board (REMASAB). The functions of REMASAB are basically refuse collection and disposal, management of refuse collection points and dump sites, land reclamation, street sweeping and cleaning, environmental inspection and organization of enlightenment programs on sanitation ([36], [37]).There are several private companies in Kano participating in solid waste management. It is reported that the total number of companies operating under franchise agreement in Kano metropolis contribute greatly in terms of efficiency and effectiveness of refuse collection and disposal. The companies are obliged to pay 10% of the total amount charged monthly to Kano state government through REMASAB [38].

The current waste management technique in Kano metropolis is predominantly in unsanitary landfills where anaerobic degradation of organic material occurs [36]. As seen byNabegu and Mustapha (2014), public participation of MSW management is only observed in the limited arena of academics, NGOs, government, and high class business environments.Statistics revealed that about 79.25% of the population do not use the authorized dump sites and residents often blame their actions on the fact that adequate dump sites are not close to their residence and therefore dispose solid waste in paths, riversides and road walkways.Nabegu (2009)reported that the current solid waste management system could only cover 30% of the solid wastes generated daily mainly due to inappropriate government institutional arrangement, poor state of infrastructure and the lack of adequate funding.

Naibbi and Umar (2017)assessed 300 existing waste disposal sites and found out that Kano metropolis has fairly well-distributed waste disposal sites though they are more clustered in the metropolis than the outskirts. About 80% of the sites are either located close to roads, settlements or water bodies, about 93% of the existing waste disposal sites are open space, and only about 7% are closed dumping sites (containers). The disadvantage of open dumpsites is that they are uncontrolled and therefore pose major health threats, and also affect the landscape of urban cities. It was also found that 89% of the sites assessed were authorized dumping sites (that is, an approved disposal point by the MSW agency) and

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11% are unauthorized and illegal. However, it was observed that most of the disposal sites are not properly located considering the environmental and social well-being of the people.

2.4Federal Capital Territory – Abuja

Abuja is the capital city of Nigeria. It is located in the center of Nigeria, within the Federal Capital Territory. It falls within latitude $8.28^0$and 9.20^0North of the Equator and longitude $6.45^0$and 7.39^0East of the Greenwich Meridian. It occupies an area of about 250 km^2 within the Gwagwa Plains in the northeast quadrant of the FCT. At the 2006 census, the city of Abuja had a population of 776,298, making it one of the top ten most populous cities in Nigeria [20]. It was initially developed according to a Master Plan devised in 1979. This apportioned 2.0% of the FCT area for government activity/usage, 49.0% for residential development, and 32.5% as open/green/recreational areas to add to the aesthetics of the city, with the remaining land (16.5%) being used for ancillary services, light industries, other infrastructure and commercial activities [39].

Solid waste management remains one of the most dauntingenvironmental challenges facing the Abuja today and solution has continually remained at its lowest ebb despite huge investments in Abuja [20]. The amount of waste generated has increased in both quantity and diversity without adequate investment in collection, transport, treatment and disposal facilities. These problems are further complicated by political, economic and social factors. The average waste generation rate in Abuja is 0.55–0.58 kg per person per day. This is influenced by the time of year, local culture, traditions and personalIncome [39].

Waste collection has also been a challenge for several years with increasing generation rates, development, changes in road networks, illegal structures, traffic conditions, insufficient collection vehicles, traffic density, vehicle conditions, hauling distant, collection time, collection route, all prove a challenge in Abuja [40]. Collection and transportation are a major cost in the waste management process. There are 12 private companies currently operating that collect waste. Private firms collect house-to-house, typically between one and three times a week, depending on the availability and condition of their vehicles and it has been estimated that waste transportation, including labour and machinery, accounts for between 70% and 80% of the total cost of solid waste management in Nigeria [39]. On the spot recycling, to the reduce the amount of waste transported to the landfills, is enhanced by the activities of the informal sector collection workers; they often separate out recyclable materials and dump unwanted degradable waste around the area [40].

Despite the good intentions of the Master Plan, there are no sanitary landfills in the FCT for waste disposal. Solid waste from the formal collection system in the various districts of Abuja is transported to a single dumpsite at Mpape since others have been closed down [39]. Wastes in the dumpsites are continuously set on fire in order to reduce its volume leading to adverse environmental impact [40]. Although, problems associated with odour and air pollution from burning wastes at the site has been significantly reduced recently due to the introduction of relatively simple on-site improvements in the

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management of wastes. Illegal disposal is also common in Abuja. Piles of solid wastes are often found along roads, underneath bridges, in culverts and drainage channels and in other open spaces [39].

2.5 Kaduna State

Kaduna is a state in Nigeria, located in the North-Western part of the country (10^{o} 20' N, 7^{o} 45' E). It has an area of land, with about 46,053Km^2. In the North it is bounded by Zamfara, Katsina and Kano State, West by Niger state, East by Bauchi and Plateau state and in the South by Nasarawa state and Federal capital territory, Abuja. Kaduna State is the third most populous in the country, with about 6,113,503 people captured in the 2006 census[11]. GDP of Kaduna state is about 10 billion dollars, with per capita income of 1600 dollars. About 4,931 metric tons of waste are generated daily in Kaduna, of which only about 10% is collected by waste management bodies [41]. The amount of waste generated per year can rise up to 4,313,124 tonnes with about 114,443 tons per month [42]. Organic waste dominates the dumpsites in Kaduna state, taking up about fifty percent of the waste composition [43].

Kaduna State Environmental Protection Authority (KEPA) manages the waste in Kaduna. It was established in 1994 and revised in 1998 to ensure sustainability in the state. They are charged with the responsibility of controlling all environmental laws in Kaduna, also included in their responsibility is changing Kaduna residence attitude towards environmental management for sustainable development [44]. Solid waste management in Kaduna is operated by government appointed service contractor (ZLGA), they clean up public areas for a fee paid by the government. Industries, Businesses and residences wastes are managed by private collectors (PSPs) or the informal sector. Waste are collected from door to door by private collectors or ZLGA at fees agreed with clients. For business and industrial collections ZLGA is the only allowed company. All operations are managed by KEPA [41].

ZLGA owns and manages 38 vehicles (mainly tippers, side loaders and pay loaders). Waste are being collected from door to door; the collection company staff visits the homes, pick up their piled up/ well packaged dirt into their trucks and move them to the available dumpsites. This is usually for domestic waste. It is a similar situation with business/ industrial waste. There are also collection points (street and communal based) where households go to dump their waste. This helps reduce the number of trips by the trucks when compared to door to door service. ZLGA is also involved in street sweeping and evacuation of collection points, they eventually transport all waste directly to the dumpsites [41].

Only about 10% of waste generated in Kaduna is collected by waste management agency. There are two official dumpsites in Kaduna currently managed by ZLGA. There are several other unofficial dumpsites across the state. ZLGA also manages six materials recovery facilities and transfer stations [41]. Lekwot, *et al*., (2012)reported six methods used for disposal of hospital wastes in Kaduna, they include; selling some, burning, burying, dumping, use of containers, destruction with acid. Sampson and Ojoye (2017)affirmed that MSWis majorly disposed using open dumping, other methods used are, waste burning, and backyard burying.

2.6Rivers State

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Port Harcourt is the capital and largest city of Rivers State, Nigeria [47]. The city of Port Harcourt was established in 1912and it is located sixty kilometers up the Bonny River, where a stretch of solid land mass rises some twenty-five kilometers to the city center. The population of the city is estimated to be about 1,356,000 [48].The average rate of waste generation in Port Harcourt is about 1.25 kg/persons/household. The characteristics and rate of waste generation vary from zone to zone as a result of population difference and other socio-economic factors. However, because in Port Harcourt the difference in the level of industrialization from one zone to the other is not too significant, the characteristics of the waste are also not too different [23].Ikebude (2017)reported that the conventional method of waste management is adopted in Port Harcourt Metropolis. This method focuses largely/mainly on waste collection, treatment (composting and incineration) and disposal (landfills).

Port Harcourt city lacks adequate data on solid waste generation and this has resulted in ineffective planning for solid waste management. Furthermore, the government policies and agencies over the years have no blue print or articulated system on how solid waste management in the city can be managedwhich have greatly contributed to the attitudinal change of the city dweller to indiscriminate dump wastes on the roads, drainages, stream channels, bush lands and open spaces thus defacing the landscape of the city, causing flooding and spread of vector borne diseases [49]. Presently, solid waste management in Rivers state is coordinated by the Rivers State Environmental Sanitation Authority (RSESA). RSESA supervises the contractors appointed by the government for the collection and disposal of MSW [23].

There are seven contractors, each allocated to a zone.The modus operandi of each of the contractors is virtually the same and involves the use of personnel, vehicles (trucks) and working tools for the collection and disposal of refuse in their areas of jurisdiction. The waste management crew is equipped with shovels, forks and baskets for their daily operations. The collection is manual. No bins or containers are used and the service price charged by the contractors is related to the area covered [23]. The obstacles to an effective MSW management in Port Harcourt include unskilled manpower, lack of finance and inadequate enlightenment of the public on the need to properly dispose of their waste and the attendant health implications of doing the contrary [49]. AlthoughAjie (2014)affirmed thatwaste haulage has drastically improved due to the recent use of compactors.

The disposal patterns in most areas of the state are poor which has led to poor aesthetic and environmental degradation. The most common place for disposal is the public spaces while recycling or re-use of waste is not a common practice [47]. It could easily be summarized that what is seen as waste management in the Port Harcourt metropolis is the collection of unsorted municipal refuse from sources of generation and subsequent transportation to final disposal dump sites. For now, there are five major dump sites designated by the state government for refuse disposal. These sites are managed by a different contractor named RIV Link International Company (Nigeria) Limited. These dump sites are actually burrow pits from where laterite had previously been excavated for road and building construction works. Sometimes, open air incineration, with its attendant pollution of the atmosphere, is also carried out

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in most of the final disposal dump sites. This is done with the aim of gradually reducing the volume of waste [23].

3.0 ENERGY RECOVERY POTENTIAL OF MSW MANAGEMENT IN NIGERIA.

It was in the early 1970s that the problem of MSW disposalhad begun to look daunting as urbanization began its runaway growth, and since then extensive researches have been made to find ways and means of gainfully utilizing MSW. However,vigorous efforts are continuing to be made even as the problem is actually increasing in magnitude and complexity rather than getting even partially solved. The focus in recent years has been on generating energy from MSW, besides material recovery [51], energy can be generated through thermochemical conversion processes such as combustion.Once MSW is ignited, the ability of waste to sustain a combustion process without supplementary fuel depends on anumber of physical and chemical parameters, of whichthe lower calorific (or heating) value (LHV)is the mostimportant [52].

Kuleape et al. (2014)reported that the average lower calorific of waste to be subjected to thermochemical conversion must be at least 6 MJ/Kg throughout the season and the annual average lower calorific value must not be less than 7 MJ/Kg, the heat produced from this process can be converted to electricity for power consumption. Presently, the National energy suppliesare almost entirely dependent on fossil fuels and firewood which are depleting fast. Wastes are important source of energy presently used in the generation of electricity and at the same time making the environment clean [54].The equations below are useful in determining the energy content (E) and the electricity recovery potential (ERP).

$$E\left(\frac{MJ}{Kg}\right) = 0.051\,[F + 3.6\,(CP)] + 0.352\,(PLR) \qquad \text{Equation 1}$$

Where F = percentage weight of food, CP = percentage weight of cardboard and paper, and
PLR = percentage weight of plastic, leather and rubber in the waste [55].

$$ERP\,(MW) = \frac{H}{24 \times 3600} \qquad \text{Equation 2}$$

Where H is the Total Energy Content (MJ/day) of the Combustible Components of MSW, [54].

Ogwueleka, (2009)gave the values for the quantity of waste generated in each states while the LHV was estimated based on the procedure presented in [52]. Table 2.0 present the ERP for the various states. Though the LHVs in these states fall below the standard value of 6MJ/Kg for thermochemical conversion of waste to energy, yet a ERP in the range of 48.31 to 933.68MW is feasible.Rominiyi et al. (2017)presented a ERP value of 51.50MW for the city of Ado – Ekiti that is less metropolitan when compared with some of the considered states.There exists a very strong correlation between ERP and the quantity of waste generated as depicted in Table 3.0 and Fig. 2.0.

Table 2.0: Electricity recovery potential for the various states.

S/N	States	LHV (MJ/Kg)	Quantity of waste generated (Kg/day) × 10^3	E (MJ/Kg)	H (MJ/day) × 10^3	ERP (MW)
1	Oyo	2.82	4513.03	6.50	29315.56	339.30

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2	Lagos	4.75	8518.53	9.47	80670.48	933.69
3	Kano	5.75	5222.53	10.36	54105.41	626.22
4	FCT-Abuja	4.02	492.83	8.47	4174.27	48.31
5	Kaduna	5.37	3814.43	8.84	33719.56	390.27
6	Port Harcourt	3.46	3927.50	4.23	16595.26	192.07
Total			26488.85			2529.86

*ERPs: reported in accordance with Rominiyi et al. (2017)

Table 3.0: Correlation of ERP and quantity of waste generated

		Quantity of waste generated per day (Kg/day)	Electricity Generation potential (MW)
Quantity of waste generated per day (Kg/day)	Pearson Correlation	1	.938(**)
	Sig. (2-tailed)		.006
	N	6	6
Electricity Generation potential (MW)	Pearson Correlation	.938(**)	1
	Sig. (2-tailed)	.006	
	N	6	6

** Correlation is significant at the 0.01 level (2-tailed).

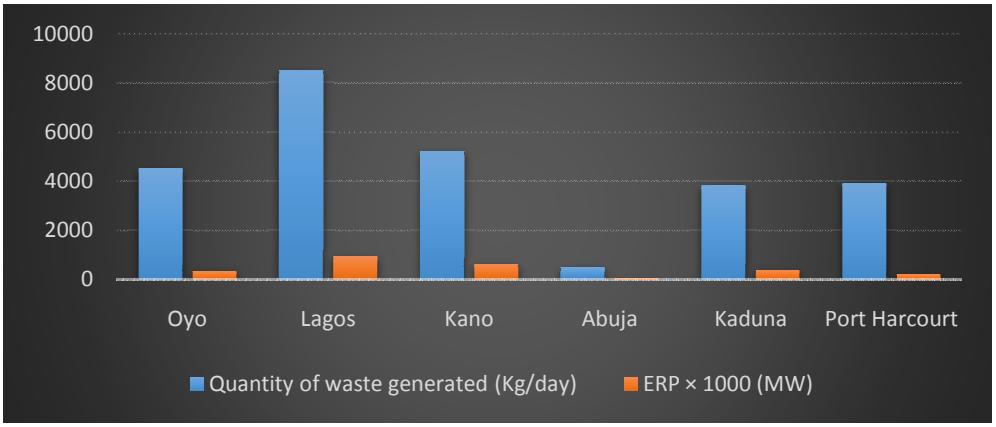

Figure 2.0: Chart showing the relationship between ERP and Quantity of waste.

4.LEGAL FRAMEWORKS FOR MSW MANAGEMENT IN NIGERIA

Nigeria has adopted the definition of environment as "… water, air, land and all plants and human beings or animals living therein and the inter-relationships which exist amongst them. The ecosystems must be safeguarded for the benefit of present and future generations through careful planning or management as appropriate [56].The need for environmental management and control arises from the fact that it brings improved health and better living conditions. Therefore, the instrumentality of Legal mechanisms cannot be overemphasized if any conscious attempt geared towardssalvaging the precarious state of our environment vis-à-vis preventing upcoming generations from suffering for present generation's reckless environmental damaging activities [57].In time past, efforts have been directed continuously to the safety, protection and the conservation of the environment at large and the economically important natural

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resources in particular. Several variations of traditional regulations can be aptly defined as customary law in Nigeria and these have been to a large extent, inadequate for the effective management of waste [56].

During the colonial era, Nigeria was not concerned about the protection of the environment; it was nota priority. Accordingly, there was no policy aimed at preserving and protecting it. The tort of nuisance was more prominent because disputes in environmental law were not viewed as public matters warranting state intervention. The few environmentally related laws that were applicable criminalized activities that could degrade the environment[57].These regulations include: Cantonment Proclamation of 1904 on Layout and Sanitation of GRA, Water Ordinance of 1913, The Township Ordinance of 1917, Public Health Laws of 1957 to check Overcrowding, Disease and Squalor, The Public Health Laws of 1917, (later amended as Public Health Law Cap 164 of 1958), Nigerian Criminal Code Cap 42, LFN, 1958, Factories Act of 1955 and later amended in 1958,etc. [56].

However, environmental regulations in Nigeria came to the forefront following national public outcry as result of illegal dumping of toxic waste in Koko, South west Nigeria by an Italian vessel in 1987. This necessitates the Federal government to create the Federal Environmental Protection Agency (FEPA) in 1988, and subsequently, each of the 36 states of Nigeria was encouraged by FEPA to establish its own environmental protection agency known as State Environmental Protection Agency (SEPA). Each state's environmental protection agency enacted their own laws and regulations[58].Agbazue, Anih and Ngang (2017) asserted that the 1980 and 1990s witnessed the most drastic and systematic development of environmental laws in Nigeria, partly owing to Nigeria's subscription to a number of international conventions and treaties, legislations on environmental development improved during this period.

Nigeria, in her efforts have made attempts to maintain a healthy environment through various programmes using the traditional regulations as a means to achieve this and it include monthly sanitation days, market cleaning days, the 'War Against Indiscipline' program amongst others[56]. In addition, there are regulations andlaws dealing with waste disposal and management; some of these are Environmental Impact Assessment Act of 1992, The Harmful Wastes (Special Criminal Provisions, etc.) Act and the National Policy on the Environment [59], Oil Pipelines Act. 1956, Petroleum Act. 1969 [57] and National Environmental Standards Regulatory and Enforcement Agency (NESREA) act enacted in 2007 –which is currently the principal legislation in Nigeria as regards to environmental protection and control.The sections below discussedthe evolution of NESREA by emphasizing on major milestones:

4.1Harmful Waste (Special Criminal Provisions, etc.) ACT (No.65)

In August 1987, an environmental catastrophe ignited and energized efforts to pass meaningful environmental legislation. An Italian company imported several tons of toxic industrial waste and deposited it in Koko, Delta State, within Southern Nigeria.The waste leaked into the surroundingenvironment and resulted in the endangerment of some residents of that community.The egregious nature of the incident forced the Federal Government to react by enacting the Harmful Waste (Special Criminal Provisions, etc.) Act.65. The Act criminalizes activities involving the sale, purchase, transportation, importation, deposit, or storage of harmful waste, either singly or in conjunction with others

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on Nigeria's soil, air, or sea.Harmful waste is defined as injurious, poisonous, noxious, or toxic substances, particularly nuclear waste that emits any radioactive substances [60].

4.2Federal Environmental Protection Agency

In December 1988, as part of the emerging coordinated approach to environmental issues, FEPA was established by decree [57]. The creation of the Federal Environmental Protection Agency (FEPA) by Decree 58 of 1988 as a parastatal under the Federal Ministry of Works and Housing was the first real attempt to give coherence and visibility to environmental issues in Nigeria. The Decree was later amended by Decree 59 of 1992, to strengthen responsibility for control over Nigerian environment and for the development of processes and policies [56].FEPA had the power to initiate policy in relation to environmental research andtechnology and in formulating and implementing policies related to environmental management. In addition, FEPA was given some enforcement powers including the right to inspect facilities and premises, search locations, seize items and arrest people contravening any laws on environmental standards and prosecuting them. The agency was also empowered to initiate specific programmes of environmental protection and establish monitoring stations or networks to locate sources of and dangers associated with pollution. It also has powers to conduct public investigations or enquiries into aspects of pollution [57].

4.3 The Federal Solid and Hazardous Waste Management Regulations

The Federal Solid and Hazardous Waste Management Regulations of 1991 made it an obligation for industries to identify solid hazardous wastes which are dangerous to public health and the environment and to research into possibility of their recycling [61].

4.4 Environmental Impact Assessment Act of 1992

In 1992, the Environmental Impact Assessment (EIA) Act was passed [60]. This Act makes it compulsory for development projects with potential environmentaleffects to undergo an environmental impact assessment before commencement. It prohibits the commencement of projects which may significantly affect the environment without first considering the environmental effects where a project may likely result in unjustifiable, immitigable, and significant adverse effects on the environment, the project shall not be permitted [62].

4.5Federal Ministry of Environment

In 1999, the Federal Ministry of the Environment took over the functions of the Federal Environmental Protection Agency. Since then, the scope of environmental legislation has become progressively more sophisticated and demonstrates an increasing awareness of the importance of environmental resources [60].

4.6National Environmental Standards and Regulations Enforcement Agency (Establishment) Act, 2007

Finally, in July 2007, the National Assembly repealed the FEPA Act,and enacted the National Environmental Standards and Regulations Enforcement Agency (Establishment) Act. The Act creates a new federal agency, the National Environmental Standards and Regulations Enforcement Agency

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(NESREA), which replaced the Federal Environmental Protection Agency [60].This is currently the principal legislation on environmental protection in Nigeria.The Agency is authorized to enforce compliance with laws, guidelines, policies and standards of environmental matters.Such standards would include the federal water quality standards and air quality standards. In carrying out its functions, it is to coordinate and liaise with stakeholders within and outside Nigeria on matters of environmental standards, regulations and enforcement.Relevant stakeholders would include the organized private sector, environmental groups at both national and international levels, and other ministries and parastatals [57].

The NESREA Act allows each State and Local Government in the country to set up its own agency for the protection and improvement of the environment within the State. Each State is also empowered to make laws to protect the environment within its jurisdiction. All the States have environmental agencies and State laws; e.g. Lagos, Abuja. The agency has the responsibility for the protection and development of the environment, biodiversity conservation and sustainable development of Nigeria's natural resources, environmental technology, including coordination and liaison with relevant stake holders within and outside Nigeria on matters of enforcement of environmental standards, regulations, rules, laws, policies and guidelines.

5.0 CONCLUSIONS

MSW management in Nigeria, especially in major cities, has been reported by several authors. It was observed that the amount of waste generated is growing while the management strategies are very insufficient, most of the states have settled for dumpsites as the preferred choice of waste disposal with it associated detrimental effects on the environment. Major reasons for the failure of MSWM in most of the states include: lackadaisical attitude towards the implementation of law and policies on the part of government, inadequate technical know-how, insufficient funding and lack of information on the status of MSW in most of the rural areas in the country. The dumpsite sites (erroneously refer to landfills) in some states have been closed as they cannot take in more waste, while those in other states are in bad shape. Hence, there is need to implement a low cost solid waste management strategies that reduce the amount of waste to be collected and transported to the landfills. Such strategies include recycling, reuse of some components, composting as well as waste-to-energy. There is a huge potential for the conversion of MSW into energy in Nigeria, an estimated amount of electricity of about 2600MW can be achieved from a total of 26,500 metric tonnes of waste generated per day in the states considered. This could supplement the power generation of the country and also help to clear the landfills faster thereby reducing the spread of diseases and other environmental impacts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

All authors made significant contributions to the manuscript compilation.Author HAS designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author JOA, Author TTB and Author C managed information gathering on the status of MSW in all the areas considered. Author OO gave the estimate of ERP in all the areas considered. Author OOO managed the

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literature searches for the legal frameworks in MSW management. All authors read and approved the final manuscript.

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