A Sustainable Approach to Municipal Solid Waste Management in Southern Nigeria

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Abstract— Municipal Solid Wastes in most towns and cities in Nigeria are disposed in open dumps or ravines which are only a few meters away from major streets and residential areas, and in other cases are dumped into drainages which eventually flows into adjoining streams which serves as a source of water supply to the resident of such locality. This unscientific and unregulated disposal pattern causes severe environmental and public health hazards. This study examines a sustainable approach to municipal solid waste (MSW) management in Southern Nigeria and recommends proven methods of MSW management. The benefit of using MSW to generate electricity is also explored. It is seen that proper waste management has the potential benefit of greatly reducing incidences of morbidity caused by indiscriminate waste disposal in such areas and can contribute to the solving the energy need of the affected communities were the waste are disposed . On the whole, proper MSW management would not only improve the air quality and minimize the associated health hazards which people residing and working in such area are subjected to, but would also reduce the rate at which green house gases and other poisonous gases which contributes to global warming are emitted into the atmosphere. The study indicates that from a daily delivery of 2,714 tons of waste in just one city, about 30 to 52 MWh of electricity can be generated. The study recommends a sustainable approach to MSW handling and the incorporation of waste incinerators with energy recovery at dump sites to effectively transform the inherent energy in MSW to electricity.

Keywords: Municipal solid wastes, sustainability, electricity, Southern Nigeria

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1. INTRODUCTION

Generally, waste is said to be any unwanted substance(s) emanating as a result of human or animal activities. Municipal Solid Waste (MSW) includes household garbage and rubbish, market spoils and rotten food stuffs, street sweeping, construction and demolition debris, sanitation residues, non-hazardous industrial refuse, treated bio-medical solid waste, etc. Cointreau [1] defines MSW as "non-air and sewage emissions created within and disposed of by a municipality, including household garbage, commercial refuse, construction and demolition debris, dead animals, and abandoned vehicles and electronics." The nature of MSW in Nigeria differs significantly. For instance a typical market waste like the one illustrated in inset B in figure 1, which is disposed on the street adjacent to a market perimeter fence would comprise of decomposable waste namely: spoilt fruits and vegetable, undigested and digested food, meats, bones, hides, hair, etc. A good percentage of packaging like plastics and cardboards is also visibly seen in such waste. No doubt, the acidic level of such waste would normally be high due to the presence of Citrus and other sour fruits like oranges, pine apple etc.

Waste collection and disposal strategy differs from country to country. Landfills, incineration, and recycling are often used in developed countries to dispose MSW. In Nigeria, these categories of wastes are often disposed in an unsustainable manner in open dumps, streets, ravines, and in other cases into drainages which eventually flows into streams which saves as a source of water to the people residing in such locality. Regrettably, this unregulated waste disposal pattern continues to pose serious health and environmental hazards. Dolk [2] and Lee & Jones [3] noted that MSW are biologically diverse, dangerous, highly putrescible and may breed zoonotic pathogens. In their study, Gaudy & Gaudy [4] revealed that most diseases which infects human are caused by protozoa including amoebic dysentery. Furthermore they also noted that MSW host a good number of fungi numbering up to 100,000 species out of which number, 100 are pathogenic to animals and humans. In table 1, some of the major living organisms in the various solid wastes have been presented. Most protozoa feed on bacteria. The free living protozoa can be found in any aerobic environment such as the ones shown in inset pictures in figure 1 in which bacteria are present to support their growth. Some of the protozoa are parasitic to humans/animals.

Table 1: Major Living Organisms Present in Various Solid Waste

Waste Category	Fungus	Protozoa	Bacteria	Insect	Rodent
Bio-medical Waste	√	√	√	√	√
Food Waste	√	√	√	√	√
MSW	√	√	√	√	√
WEEE				√	√

Source: [6]

A: A dump site situated close to residential areas in Uyo; **B**: MSW disposed indiscriminately on a street close a major market in Uyo; **C**: MSW disposed indiscriminately along Aba-Owerri Road by Eziukwu, Southern Nigeria; **D**: MSW disposed indiscriminately along Asa Road in Aba, Southern Nigeria; **E**: MSW disposed indiscriminately along Opobo Road Aba, Southern Nigeria

Figure 1: Poor municipal solid waste disposal in the study area

Solid waste is well known for attracting an array of insects, arthropod and annelids. For instance, at the various dump sites where this study was conducted, house flies, mosquitoes, cockroaches, dung beetles, ants, termites, honey bees are some of the insects that were spotted. Some of the arthropods seen in those locations were spiders and scorpions while annelids include centipede, millipede and earthworm. Besides this, solid waste dump sites also attract and play host to lizards, rats, snakes and street dogs. Ogwueleke [5] notes that the environmental problem caused by poor municipal solid waste disposal and management is due to weak institutions.

Given the health and environment hazards caused by poor management and disposal of municipal solid waste, this study aims to emphasize on the need to sustainably manage and safely dispose of these wastes to get rid of the associated environmental hazards as waste management constitute significant environmental justice issue especially to the inhabitants of such locality. This research is based on several years of the authors' observation and evaluation of how MSW are disposed in southern part of Nigeria. The remaining part of the study is organized as follows: section two discusses sustainable waste management strategies; section three proposes a waste to energy technology that should be adopted in southern Nigeria while section four provides some concluding remarks.

2. SUSTAINABLE WASTE MANAGEMENT STRATEGY AND OPTIONS

Sustainable waste management (SWM) entails the treatment and subsequent disposal of waste in a manner that will not cause any health or environmental hazard to both the present and future inhabitant of the locality where MSW are disposed. It involves the transformation of the energy inherent in MSW to a form that will be more beneficial to the society. Waste to energy (WTE) is one of the sustainable means of managing MSW. [3] noted that while it is not possible to completely eliminate the possibility of waste disposal in dump site and landfills, the fact remains that through recycling and incineration of municipal solid wastes, the amount of waste that originally would have been disposed in dump sites would have been reduced significantly, which by implication would not only reduce the harm done to the environment and the inhabitants but would also contribute to meeting her energy need. In Nigeria, according to a report by [5], the annual generated municipal solid waste is about 25 million tonnes. For some urban areas in Nigeria, the waste generation rate and breakdown density is shown in table 2. The waste generation rate ranges from 0.66 – 0.44 Kg/cap/d contrary to 0.7- 1.8 Kg/cap/d in developed country.

2.1 WASTE TO ENERGY

The conventional method of generating electricity from MSW is by direct combustion, with the heat recovered and used to propel turbines or by natural anaerobic digestion in the landfill. According to [7], the organic fraction of MSW can be anaerobically stabilized in a high-rate digester to obtain biogas for electricity or steam generation. Another method which is argued to be more efficient than energy generation from incineration is steam generation from gasification. The gasification and pyrolysis processes results in the production of synthesis gas which is often abbreviated as (syngas) which can be used to raise steam or can be further processed for direct application in gas turbines or engines which further enhances its efficiency. The potential to generate electricity from MSW through some of these processes would be discussed briefly.

2.1.1 WTE Generation Through Incineration/Combustion

Basically, the incineration process often carried out in different stages namely: drying and degassing, pyrolysis and gasification and oxidation involves the controlled oxidation of the combustible materials which is contained in waste at a temperature of 870-1200^{o}C. (1600 to 2200 ^{o}F).

Table 2: Urban Solid Waste Generation (2007)

City	Population	Tonnage per month	Density (Kg/m^2)	Kg/capital/ day
Lagos	8,029,200	255,556	294	0.63
Kano	3,248,700	156,676	290	0.56
Ibadan	307,840	135,391	330	0.51
Kaduna	1,458,900	114,433	320	0.58
Port-Harcourt	1,053,900	117,825	300	0.6
Makurdi	249,000	24,242	340	0.48
Onitsha	509,500	84,137	310	0.53
Nsukka	100,700	12,000	370	0.44
Abuja	159,900	14,785	280	0.66

Source: [5]

This very high temperature allows enough time for at least about 99% of the organic substances such as minerals, metals and water contained in the waste to be oxidized. The high pressure steam is then used for power generation. Also, flue gases (CO_2, H_2O, O_2 N_2) which are generated contains a good majority of fuel energy available as heat. [8][10], asserted that the volume of and weight of waste is reduced by 90% and 70% respectively through incineration. As sustainable as the idea of energy generation through incineration may sound, studies have shown that depending on the operating conditions, type and composition of the incinerated material, little quantity of HCl, Hl, HF, HBr, NO_X, SO2 CO, VOCs, PCDD/F, PCBSs and heavy metal compound are left over [9].

The technology for electricity generation via incineration is categorized into four processes namely: Waste collection and pre-treatment, waste combustion, gas scrubbing with pollution control and electricity/steam generation. The generated steam is fed into a steam turbine, where it is channeled to flow over a series of turbine blades that is connected to an electric generator which on rotation produces electricity. The power produced can be further increased by employing a condensing turbine technology which is used in cooling the steam [10], [11]. MSW incineration technology has been proven over time to be a sustainable system of waste disposal which is capable of not only limiting the amount of poisonous substances emitted into the atmosphere, but also contributing to sustainably meeting the energy need of the society. [8], reported that about 15% of waste was available as electricity in any MSW incineration system. They also noted that it was possible to power 12,400 cars, provide electricity for 30,900 homes and also heat 15,100 houses in Europe and United States from MSW generated from 1,000,000 persons. Inferring from this, it can be asserted that from the population figures of 1,103,335 from the three cities where part of this study was conducted and the very high volume of waste generated and indiscriminately disposed in these areas, an equivalent amount of energy can be harnessed from MSW which would contribute to improving the deplorable power situation in Nigeria and also solve the waste management problem which is currently posing a major threat to both the environment and her inhabitant.

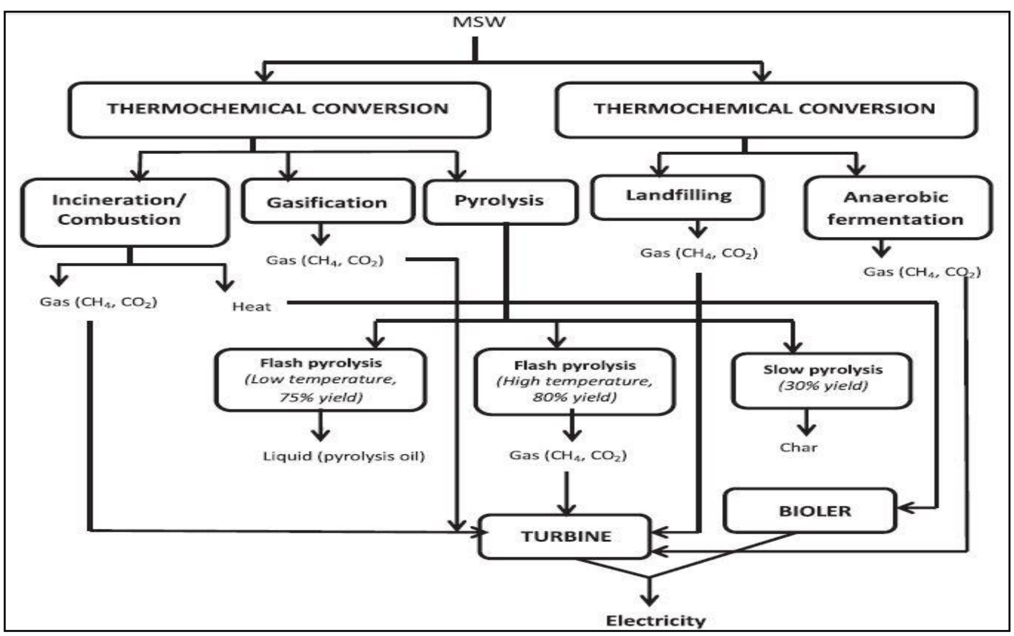

Figure 6: Schematic diagram of electricity generation from MSW by thermochemical and biochemical conversion technologies

Source : [13]

At the moment, in some parts of Southern Nigeria where this study was carried out, there are no records of any operational incineration sites with energy recovery. However, some uncontrolled incineration sites could be seen at random. This is evident by the manner in which MSW is being disposed. Ghana, a neighboring country to Nigeria recently commissioned a WTE incineration plant in Kumasi. This plant according to report in [12] is expected to generate between 30 and 52 MWh of electricity from about 1000 tons of daily MSW. It is also asserts that a 20 MW MSW power plant of efficiency 25% and availability 85% can consume about 670,000 tons of dry waste to generate about 150 GWh of electricity taking into consideration the calorific value of Ghana's waste [12]. Again, inferring from the above assertion, it could be seen that Onitsha, one of the cities in Southern Nigeria, with a population of 509,500 and monthly MSW tonnage of 84,137 of density of 310 Kg/m^2 was capable of generating an equivalent of 30 to 52 MWh of electricity or more from about 2,714 tons of daily MSW. No doubt, the investment cost of setting up and maintaining an incinerating facility may seem high. However, when considering the long term benefits and the positive impacts associated with carrying out such projects, this should out-weigh the cost. The government through Public Private Partnership (PPA) can collaborate to execute such projects. [16], gives an example of such collaboration in the financing of about USD 136 million MSW power plants which is ongoing in Ghana.

2.1.2 WTE Generation Through Gasification

Gasification can be considered to be a process between combustion and pyrolysis because of the partial oxidation of the substances involved. This partial combustion of organic substances (MSW) is done at high temperature of about (500-1800 ^oC) under controlled conditions to produce a synthesis gas which could be used as a feed sock or processed as fuel for the generation of electricity [14]. It is observed by [13] that a typical gasification system for WTE generation would normally consist of the following units: gasifier, gas scrubber (for cleaning and removal of all harmful gases from the produced gas) and an energy recovery unit for the production of electricity etc. They noted that for such a system, electricity production is more efficient when the wastes are combustible unlike materials such as rubber, glass etc. Several types of wastes cannot be efficiently combusted in this system to produce the required gas for the intended purpose. This is another sustainable method of managing MSW, but at the moment, this method may not really be feasible in some parts of Nigeria where this study was conducted because of their poor waste disposal habit. Waste sorting which was noted to be lacking in most of the dump sites visited appears to be a major hindrance to the application of this technology since it would be a daunting task to separate MSW at their various disposal sites into the various compositions before gasification.

2.1.3 WTE Generation Through Pyrolysis

Pyrolysis is thermal disintegration of waste either in the complete absence of oxygen, or with only a limited supply in order to provide the thermal energy required for pyrolysis. Moderately low temperatures (400-900 ^oC, but usually lower than 700 ^oC) are required. The products of pyrolysis according to [15] include: bio-char, bio-oil and gases (methane, hydrogen, carbon monoxide, and carbon dioxide). At low temperatures below 450 °C, pyrolysis may produce bio-char while at temperatures above 800 °C, great amount of gases may evolve. A number of different compounds numbering up to hundred are produced during waste pyrolysis, and many of these have not yet been identified. A thorough understanding of the characteristics and concentration of effluents to be processed is essential, especially when hazardous substances are concerned [15]. Just like with the case of gasification, this waste disposal technology may not yet be fully utilized in some parts of Nigeria due to some of the major drawbacks associated with pyrolysis. For instance, [15] noted that for a best yield and suitable products after reaction, MSW needs to thresh into smaller sizes (≤2 mm particle size) before pyrolysis. The poor waste disposal pattern in the study area would make threshing process quite cumbersome.

3 THE PROPOSED INCINERATION TECHNOLOGY FOR WTE IN SOUTHERN NIGERIA

As reported in a study carried out by [6], due to the variation in the quality and composition of MSW across different regions it is not completely possible to adopt a waste management system which may have successfully been implemented in other locations. In view of the severe health and environmental concerns associated with indiscriminate disposal of waste and the overwhelming benefits of sustainable waste management through WTE transformation, an incineration plant with energy recovery is proposed to be sited at the various dump sites in the location where this study was carried out. Although the plant design and configuration of incineration plant may differ considerably between different technology providers, however, the basic component of the proposed plant would comprise of the following key elements:

- Waste reception and handling,
- Combustion chamber
- Energy recovery plant
- Emissions clean-up for combustion gases, and
- Bottom ash handling and air pollution control residue handling

The proposed design is for the incineration of 3,000 tonnes of refuse daily. The plant which is similar to that of Tuas South Incineration Plant in Singapore is to be sited near the already existing dump site subject to the availability of land. The Plant which is expected to be built with state-of-the-art technology would have all the various processes highly automated and controlled via a Digital Control System to ensure a high level of efficiency and reliability. As earlier noted, incineration achieves about 90% reduction in volume of the refuse. Hence, all incinerable refuse would be sorted and disposed of at the incineration site while the non incinerable refuse and ash from the incineration plants would be disposed of at an engineered Landfill. If this proposed design is implemented, the refuse disposal needs of the region would be met in a sustainable manner while also achieving an appreciable level of energy sufficiency.

3.1 SEQUENCE OF OPERATION

Waste reception and handling: The proposed design for the waste reception and handling would incorporate a weighbridge which would weigh the waste truck carrying the sorted waste before and after disposal to determine the weight of the disposed waste. The waste would be disposed into refuse bunkers whose pressure is kept below atmospheric pressure to prevent odours from escaping. The refuse in the bunker would then be fed by refuse cranes into the waste incinerators. The design would incorporate a waste storage facility which allows for temporary holding of waste during peak intake.

Combustion Chamber: An advanced combustion control systems would be employed to control the refuse feeding and combustion rate to attain a total burn out of the refuse. The resultant heat from combustion would be used to generate steam in boilers. Of the total available energy in the waste up to 80% can be retrieved in the boiler to produce steam. The generated steam would drive two steam turbines coupled to generators to produce electricity.

Table 3: Proposed Plant Design Data

Incineration Capacity	3,000 tonnes per day
Steam Generation per Boiler	105 tonnes per hour, 35 barG at 370^{o}C
Condensing Pressure	0.17 barA
Power Generation Capacity	80 MW, 10.5 kV generator voltage

The Plant is expected to consume about 20% of the electricity it would produce while the remaining would be exported to the grid. Condenser fan would be deployed in cooling the exhaust steam from the two turbines. The condensate would then be pumped back into the boilers, which would form a closed-loop system. Emissions clean-up for combustion gases: the use of a catalytic fabric filter system would be employed and installed after a 2-zone electrostatic precipitator to clean the flue gas. The cleaned flue gas would then be channeled through a two 150m tall chimneys that would be expected to maximise the flue gas dispersion into the atmosphere.

Bottom ash handling and air pollution control residue handling: The ash and slag from the incineration process would be transported through conveyors to the ash pits. An electro-magnetic separator mechanism for detecting and picking ferrous metallic substances would be incorporated. These scrap metal would be transported via conveyors to the scrap pits where sorting for further recycling would be done. The ash and slag would be sent to where they would be transported to Landfill for disposal.

Control and monitoring system: The control and monitoring of the entire processes would be done using an advanced Digital Control System (DCS) that would be situated in a Central Control Room. The entire control operation would be over seen by a control engineer. The DCS would not only increase the efficiency of operations through a higher degree of automation, but would also permit more equipment to be operated and monitored simultaneously.

4 RECOMMENDATION AND CONCLUSION

The sustainable management of MSW which will lead to the generation of Electricity is very realistic in Nigeria taking into consideration the large amount of waste generated in only some regions where the study was conducted. The informal MSW disposal habit must be prohibited by legislation while conscious efforts should be made to educate and create public awareness about the severe health and environmental impacts caused by unsustainable disposal and management of MSW. As noted in the course of the study that although the cost of under taking such projects may appear quite high, the benefits of doing it would certainly outweigh the cost at the long run. It is therefore strongly recommended in this study that incinerating facilities with energy recovery be installed at waste disposal sites for the efficient and sustainable management of MSW. By implementing the above proposed strategy, they study believes that the current waste management crisis that is stirring the administrators and resident of most of the cities in Southern Nigeria would be greatly eliminated.

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