Waste to Energy an Effective Remediation Tool for Environmental Pollutions

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Abstract
Municipal Solid Waste are refuse generated from our daily human activities, which are disposed in the environment by the residents. Characterization revealed the major components of MSW in Nigeria are biomass-materials in the forms of food waste, paper, and wood/vegetable wastes. Six States in Nigeria generates over 9,507,577.000 kg of waste/day, from human populations of 33,468,780.00. referenced to 2011 population growth. However, no single W-t-E plant nor gas collection system are available in Nigeria to processing sustainable renewable energy from MSW. A greater pinnacle can be achieved through effective ISWM of recovery as replacement for valuable resourced materials in the use of wastes as fuels and W-t-E for the production, and generation of sustainable energy through Physical Thermal and Biological methods. ISWM is likely to be dependent on efficient W-t-E technologies, not only to generate energy, but as a measure to minimize the amount and effects of GHG emissions, prevent ecological and environmental pollutions and to enhance agricultural usage; Oil re-use, and to create a sustainable environment for biodiversity to thrive. Hence, Nigeria should explore and adopt BPEO for renewable energy through ISWM concepts for maximum sustainable energy harvesting Qualitative and quantitative analysis were the indices for the evaluation of this research work.

Keywords: *BPEO; ISWM; Municipal Solid Waste; Renewable energy; Waste to Energy.*

1.0 Introduction

SW are composition of non-liquids and nongaseous materials that exist because of regular human activities within the physical environment, these are considered as nonvaluable which exist through refuse and sludge dumping (Leton & Omotosho, 2004). However, waste definition is subjective depending on what an individual considers to be the constituent bulk of the waste. Waste may be characterised as valuable resources to someone (Saleh, 2015). Similarly, some analyst regard waste to constitute health risk to the environment, inhabitants and the general publics, while other persons consider wastes to be nuisance and inconveniences that are necessary, because waste is unavoidable and its generation remains paramount with human existence (Eddine B. T. and Salah M. M., 2012); (Saleh, 2015).

Unsustainable waste disposal are serious environmental concerns to the ecological environment and its inhabitants as a state of nation and the world at large (Ishoka 2008, Babayemi and Dauda 2009). The growing human populations and the need for urbanisations is a major contributor to the

generation of increasing bulk wastes (Hoornweg et al. 2013 and Ogu 2000). However, waste that are causing environmental pollution, endangering animal's health and forming huge ecological footprint, is also a source for satisfying energy needs of many developed countries in the world we live in, via the use of renewable energy as an index for sustainable energy production (Saleh, 2015). The bulk of SW generation can be considered as a huge opportunity forming the sources of fuel for power source or industrial utilisation. Hence, SW in the Nigerian nation are majorly biomass materials, in the form of food and agricultural vegetation materials wastes. Similarly, the quest for the use of fossil fuels contributing to GW, can drastically be reduced by utilising nonrecyclable combustible materials from SW through energy recovery process (Saleh, 2015) and (Eddine B. T. and Salah M. M., 2012).

Recent energy conservation from solid wastes in Nigeria (2011) sturdy has indicated that, about 2.26MW of power electricity can be generated from each of Nigerian cities SW disposal daily, this is equivalent to 81.36MW of power generation daily from wastes. However, this is highly important in the quest for alternative energy sources to diversify Nigerians economy for energy production, jobs and wealth creation. The Nigerian Engineering disciplines, need to have rethink over sustainable waste management system to develop effective techniques to manage Nigerian SW. Similarly, Nigerian nation has abundant SW which other nation lacks, they import SW from other countries to generate power in their own country.

Sweden for instance, generates 20% of its countries energy need through SW management of W-t-E system (using incinerator to burn garbage). According to Swedish WM, each ton of Sweden SW is used in recovering the countries energy from W-t-E plants, and energy recovery from incineration which has increased drastically over the last few years. Recently, Sweden is having 29 incinerators, and generates 3.82 million tons of MSW. Two of this incinerators in Sweden town called Boras, is having a capacity of 40MW of electricity generation per/day, and can incinerate/burn 300 tons of SW per day. Sweden is importing eight thousand tons of garbage from other parts of Europe every year for use in the countries power plants. While, Norway is paying Sweden to collect the SW off the Norway's lands (Science, Tech & Environment, 2012). W-t-E is applicable in many parts of the developed countries, which began in the UK since 1974, and others such as; Bulgaria, Italy, Lithuania Romania, etc.

Similarly, China is constructing W-t-E plant to process its garbage of 5,000 tons per day in the present city of Shenzhen, it is known to be the world largest W-t-E plans to ever exist, it will be in its full capacity operations by 2020. However, this plant is less about to generate power electricity, but more about getting an effective means of solving the existing garbage problems, with the energy produced being just a handy bonus. This plant is to put an end to the present landfills and illegal dumping of refuse that has been ravaging the city of Shenzhen. Moreover, one of these landfill site had unexpectedly collapsed in the year 2016 and killed dozens of people (World Energy Resources, 2016).

2.0 Research Aim

This Research aimed at exploring the engineering means of diversifying Nigerian Solid Waste Disposal for energy production (W-t-E), for economic productivity.

2.1 Research Materials

This research adopted the use of scholarly resourced materials in the forms of:

1) Relevant published and unpublished articles (research projects, journals, conferences, seminar proceedings, and internet resourced materials) as well as
2) Developmental Questioner.

2.2 Research Methods

Both qualitative and quantitative analysis were adopted in this research work, with the view to draw and develop logical, but effective economic benefits of MSWM for the production of renewable energy (W-t-E).

2.3 Research limitation

There is no research work that is termed drawback free. The drawback to this research work is the unavailability of most recent and real data and figures for 2019 population figures and the actual volumes of solid waste disposed off in the selected Nigerian cities. Similarly, there is no functional agency charged with the responsibility of ensuring the volume of waste disposed in any of the research cities.

3.0 Results and Discursions

3.1 Results

3.1.1 Economic Evaluation and Management of wastes in Nigeria

The economic evaluation of Nigerian waste *table 3 & figure 3* depends on the volume and the nature of waste generated daily from both urban and rural population figures, *table 1 & table 2*.

Table 1: Characterised solid wastes generation in selected regions per day

Research locations (cities)	Population figures per research cities	Daily generated wastes (kg)	Organic waste components (%)	Combustible waste components (%)
Abuja	1,406,239.000	322,107.000	56.400	36.400
Kano	9,401,288.000	1,970,920.000	43.000	50.000
Lagos	9,113,605.000	5,747,616.000	68.000	21.000
Maiduguri	4,171,104.000	222,044.000	25.800	29.500
Onitsha	4,177,828.000	530,530.000	30.700	53.900
Port Harcourt	5,198,716.000	714,360.000	39.400	29.900
Grand Total	**33,468,780.00**	**9507577**	**263.3**	**220.7**

***1kg = 0.00110231tons ∴ 9507577kg daily = 10480.30967tons daily**

Note: Research areas trend of Population Growth 1999 to 2011. **Source:** (Nigerian National Bureau of Statistic, 2015).

Waste Data Source: (Beatrice A., et al., 2013; Abila, 2014; and Saleh, 2015).

Fig. 1: population Vs Daily Waste Generation by Cities (kg)

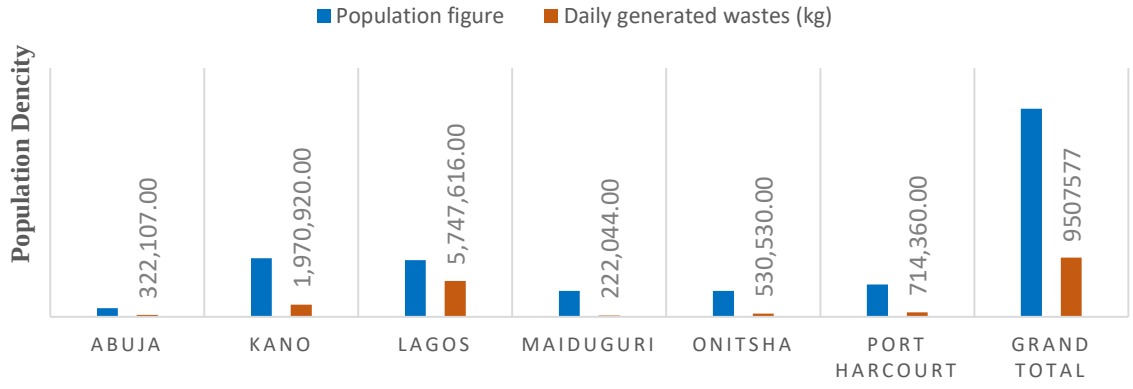

Fig. 2: Percentage Volumes of Daily Organic & Combustible Wastes Generation by Cities

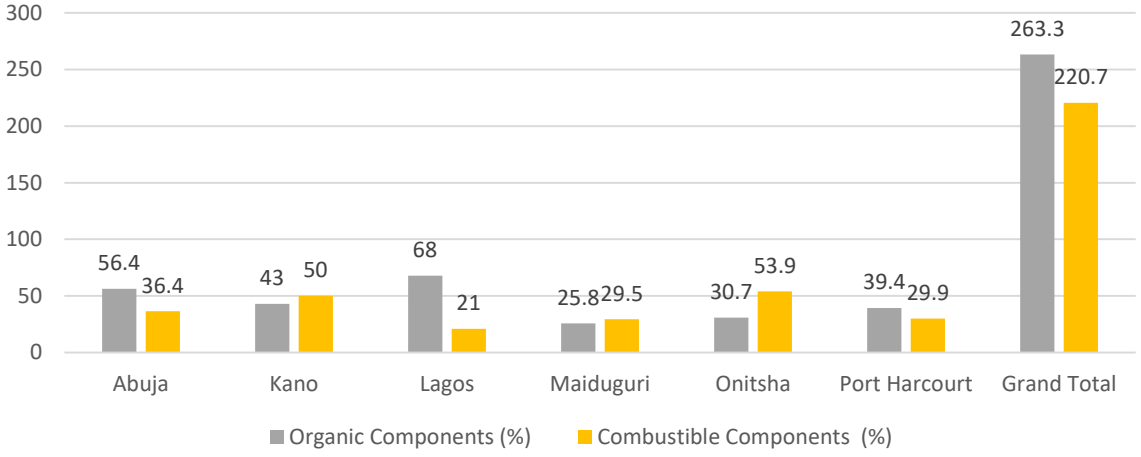

Table 2: Percentage volume of wastes streams generated in Nigeria per day

Waste Types	Abuja	Kano	Lagos	Maiduguri	Onitsha	Port Harcourt	Total volume of Wastes (per day)
Glass	3	2	3	4	9.2	13.5	34.7
Metal	3.14	5	4	9.3	6.2	17.2	44.6
Paper	25.3	17	14	7	23.1	12.4	98.8
Plastic	3.4	4	4	18	9.2	9.9	48.9
Putrescible	42.6	43	56	25.8	30.7	31	229.3
Textile	3.3	7	-	3.9	6.2	7.6	28.0
Others	19.53	22	19	31.8	15.4	8.4	115.6
TOTAL	**100**	**100**	**100**	**99.9**	**100**	**100**	**599.90**

Table 3: Percentage Nigerian MSWM systems.

Research Locations	W-t-E process plant (%)	Incinerated wastes (%)	Gas collection system (%)	Land uses (%)	Agricultural uses (%)	Total (%) Usage	Total (%) unused
Abuja	00	15.6	00	13.4	18.0	47	53
Kano	00	18.0	00	15.2	24.8	58	42
Lagos	00	21.0	00	21.6	18.9	60.7	39.4
Onitsha	00	15.8	00	14.6	15.3	45.7	54.3
Port Harcourt	00	15.5	00	21.0	13.2	49.7	50.2
Maiduguri	00	20.3	00	09.8	19.6	49.1	50.9

Source: (Authors industrial R&D, 2019)

3.2 Discursions

Its eminent that there are thousands of unemployed jobless youth in Nigeria. While the developed countries of the world have abundant jobs to employ their youths, this so because, there are industrious sectors of employment virtually all around their local communities.

The backbone to effective and meaningful development leading to employments, is the abundancy of power source to operates all industrial sectors of life. Hence, this is lacking in Nigeria. Therefore, the Nigerian engineering sector needs to diversify the Nigerian economy, by introducing and adopting newer source of sustainable energy generation, to power machineries and processes, which will provide for the enabling environments for development to thrive, create abundant jobs with surplus wealth for the Nation. Thereby, making the investors to seek for investment in Nigeria and not Nigeria looking for investors to come and invest, as we are blessed with abundant mineral and other natural resources yet on exploited for the general development and the wellbeing of the Nigerian nation and the world at large.

3.3 Source of energy generation

Its worthy to draw the attention of the engineering sectors towards the availability and abundancy of several SW around our environment for renewable energy generation to producing power electricity in Nigeria, from our day-to-day household MSW (garbage/refuse); agricultural vegetation such as cereal and leguminous crops (sorghum, millets, maize, wheat, cowpea, groundnuts, etc.); fruits and vegetables (onion, tomatoes, oranges, bananas, mangoes etc.) and sugarcane bagasse, which has been proven by researchers to having enormous amount of energy in biomass form (Yang, et al 2002).

3.4 Method of energy recovery from MSW

MSW is a vital energy source that can be converted into biogas or heat for the generation of electric power. The common technological methods employed in this process are basically:

1) Physical methods;
2) Thermal methods; and
3) Biological methods.

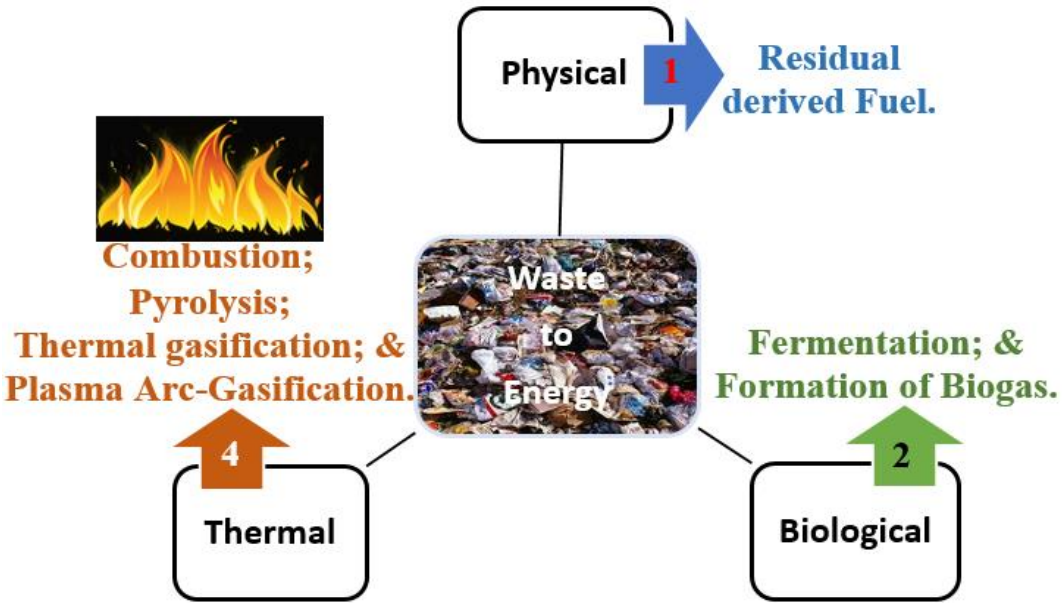

Figure 3: Method of energy recovery from SW

Source: (Authors industrial research, 2019)

Table 4: MSWM methods and resultant outputs

S/N	Fundamental method	Derived methods	Description
1	**Physical process:** The mechanical processing of waste to produce abundant and suitable solid fuels for energy.	**Residual derived Fuel**	Processed pellets, wood chips and briquettes via heat combustion to produce energy
2	**Biological process:** Technological application of microbes to convert & produce fuel form waste.	**Biogas**	Production of gas through anaerobic digestion, by placing the waste in an air tight digester cylinder. The biogas is directly burnt or its used as natural gas.
		Fermentation	Application of fermented MSW biomass fraction on addition of yeast to produce ethanol, which is then used in running internal combustion engines.
3	**Thermal process:**	**Combustion/Incineration or Mass burning**	**Application of heat generated from MSW by combustion to produce steam from water to run steam turbine to generate power electricity.**
			Utilizing broken-down materials in the absence of oxygen to produce liquid, oil, combustible gases & solid residues (biocoal). End products of

	The application of combusted heat to technically treat MSW for energy production.	**Pyrolysis**	Pyrolysis includes: hydrogen, hydrocarbons, carbon monoxide and methane. **Pyrolysis oil** can be upgraded to produce diesel and petrol with the application of oil refining techniques.
		Gasification and plasma arc gasification	**Gasification** is the producing of energy with limited amount of oxygen. while **Plasma arc-gasification** is the typical application of plasma arc-torch to generate high temperature arc to break down SW to produce Syngas & Slag. Uses of this gas is to heat-up boilers to produce combustion in internal combustion engines.

Source: (Authors industrial research, 2018)

4.0 Incineration of MSW in Power Plant

Incineration technology is commonly used in developed countries to produce power electricity and heat. MSW is the raw material incinerated at 1,200°C to produce a flue gas above a temperature of 800ºC. The energy in this case, is used in producing high pressurised steam, which passes through two different turbines, and subsequently produces power electricity. While the rest of the energy produced from the low-pressure steam, is then utilized for heating up houses, hot and warm water for distribution via pipelines for domestic and industrial consumptions. Feeding MSW into the fuel storage, provides immediate separation of the waste in to two categories. The first is the dry waste, this goes directly for incineration, while the second is the wet waste, that goes into the anaerobic digestion section for separate processing of energy. However, the optimum thermal caloric energy conversion of waste to energy (electric power and heat) has lesser amount of emission of pollutants into the environment.

4.1 MSW Characteristic for W-t-E Process

The incineration process of MSW in W-t-E plants are being influenced by the composition of Waste stream referred to as “refuse derived fuel (RDF)”, such as; cardboard, foils, paper, textiles, wood etc. And are subsequently processed in the MBT plant. The capacity of energy production in the plant, depends on High heating values of the material comprising the waste, while the volume of moisture content available in the waste affects the capacity of W-t-E plant. Similarly, the plastic content in the waste negatively affects incineration in the W-t-E plant, while an increased calorific value implies reduction in production capacity of W-t-E plant. However, main function of the MBT is to mechanically prepare the waste, and to treat aerobic microbiological wastes (biological stabilization and drying of wastes), followed by mechanical separation of both the combustible and noncombustible wastes. The combustible RDF has 15 to 20 MJ/kg of heat generation values.

5.0 Nigerian MSW management Problems

Nigerian MSW management problems are basically psychologically driven, lack of technological advancement, politically motivated with economic barriers. Leading to the combinations of; insufficient funding, week legislative system to promulgate effective policies and laws, scarcity of

infrastructures and professional in the fields, enlightenment and awareness is lacking, ineffective disposal technics and recovery process as the major source to ecological and carbon footprints leading to, among others are:

1) Gross environmental degradation and pollutions of soils and surface water bodies. Whereby 96% of the waste disposal site in Nigeria, has become an easy avenue for people to use as defecation ground and dumping of dead animal bodies. The resultant consequence is that, the defecations are washed down into the streams, lakes, and rivers for immediate utilization in both agricultural fields, domestic and even industrial uses with just little or no treatment in totality. Hence, this subsequently constitutes out breaks of rampant cases of diseases for both animals and plants.
2) Gross leachate collections, which subsequently pollutes soil starter and underground aquifers, reference to shallow water table sources that supplies our existing open dug wells, constituting 83% of the source to domestic water consumptions and uses in virtually all our environments, with the presence of pathogenic bacterial. If this phenomenon is not curtailed, there will be virtually only just smaller quantity of portable and palatable water is left for drinking for a population of over 200,000,000 people;
3) It's a general phenomenon in Nigeria that people dispose of their wastes on an open dump sites legally and illegally, and this however remains to be silent and on prosecuted of, as observed by most authorities at both the states and local levels. People use most of the available undeveloped sites and water ways to disposed of their waste. 28% - 32% of our culverts and bridges as well at streets have been characterised by refuse disposal, thereby constituting the second largest source of GHG emission after hydrocarbon processes. However, GW and the depletion of the Ozone layer will remain to be a serious threat to environmental sustainability, characterised by the excessive release of toxic gases in to the atmosphere such as; CO_2, CH_4, VOCs resulting from uncontrolled waste disposal best practice culture; and
4) Absolute blockage of water channels and facilities, does pave ways for over-flooding within host communities and its environs; thereby, causing loss of billions of dollars annually. The quest of illuminating the disposed waste in Nigeria is by direct open burning, leading to the destruction of the Ozone layer and subsequently weakens the ambient strength of civil engineering structures such as bridges, culverts and other utility structures.

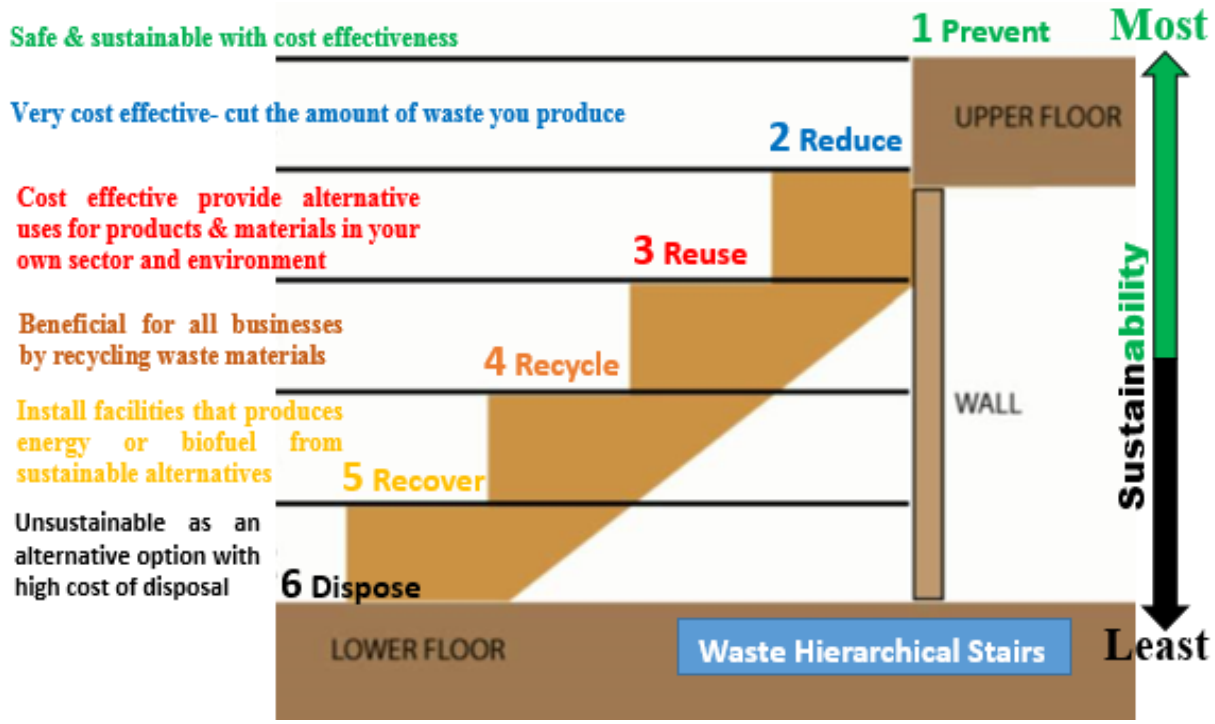

Figure 4: Integrated solid waste management (ISWM) hierarchical structure an alternative Solution to the bulk of Nigerian waste problems

Source: (Saleh, 2015)

5.1 Alternative Solution to MSW management in Nigeria

Sustainable ISWM *figure 4 above*, is the only fundamental means to solving Nigerian MSW problems effectively, by considering an integrated approach for waste disposal, segregations, transferring, sorting, treatments process and recovery to generate power. With the intent to maximise efficient use of resources for economic diversification and alternative means for energy source, empowerment and jobs create among others.

5.2 Economic importance of Municipal Solid waste

1) Renewable energy can be generated from municipal solid waste, which will significant play a greater role in clean energy harvesting. However, chemical and biological processes are present in the disposed SW, containing (50% - 60%) of methane (CH4) components and (40-50%) carbon dioxide (CO2). Both methane and carbon dioxide are the major greenhouse gases (GHGs) which poise a great threat and danger to our global environments. But, when effectively managed, it serves as valuable resources for clean energy production, with 18-22 MJm-3 of energy value resulting from methane content. But we should adopt active Landfill practice for Gas to Energy process;
2) Scavengers (waste pickers), craftsmen, middlemen and small-scale entrepreneurs that use to recovers and reuses all the valuable waste constituents such as: different plastic grades, aluminum containers, copper, brass, metal scraps, cans, bottles, textiles and various kinds of shoe soles etc.
3) Agriculturalist who raises plants by applying biodegradable solid wastes as soil conditioning that undergoes biological breakdown through aerobically controlled process;

4) Mechanical, Chemical, Civil & Electrical engineers use waste to generate heat and power via W-t-E and gas collection processes;
5) Civil Engineers uses SW materials for landfills, control of incidences eroded lands, and used for land reclamations from mining works etc.;
6) SW serves as secondary raw material for direct use in the manufacturing industries as raw materials to produce finished and intermediate products for consumer utilization in various forms and processes.

However, it can be evaluated herein that, there is virtually no waste in solid wastes except wealth, following effective management principles of the 3Rs (recover, recycle and reuse) to creates:

a) Sustainable means to mitigates several sources of GHGs emission, water pollution, environmental degradation and health problems, coupled with ecological and carbon footprints;
b) Expanded research opportunities for R&D for Greener technology developments;
c) Power and energy conservation for the nation;
d) Sustainable growth of industrial activities and operations;
e) Robustic and stable Nigerian economical growths;
f) Job for the labour markets with diversifying entrepreneurial developments; and
g) Less needs for newer landfill sites.

6.0 Conclusion

Its eminent that SW are the unwanted household and the immediate environmental wastes that we discard in the waste bins and subsequently sent on to the landfills. However, when properly managed, it's a source of wealth for economic developments of a nation through collaborative engineering practice. This means there is virtually no waste in solid wastes but resources for wealth creation. Failure to understanding this phenomenon in line with its effective utilization, wastes in our environments will constitute an enormous environmental degradation, ecological and Carbone footprints with Sevier health implications for both plants and animals. It's evident that wastes present source of resources for energy generation through ISWM process, to create power and heat for the present demands of the manufacturing industries and the teaming population of the household uses. Similarly, future SWM is likely to be dependent on efficient W-t-E technologies, not only to generate energy, but as a measure to minimize the amount and effects of GHG emissions, ecological, environmental pollutions and to create vibrant environmental sustainable for the future yet unborn.

7.0 Recommendation

1) Nigeria should explore and adopt BPEO for renewable energy through ISWM concepts;
2) Nigerian government should come up with effective legislative laws and policies to champion the cause of general waste disposal and management;
3) The Nigerian government should introduce, encourage and support with the required necessary resources at all levels of educations, to extensify researches to maximise wealth from waste, for economic recovery of the nation;
4) Nigeria should also adopt Polluters Pays Principle (PPP). polluters will be fully responsible for the financial implication of any measure required to protect the environment as a result of their products, processes and actions;
5) The National Environmental Standards and Regulation Enforcement Agency (NESREA) with other relevant stakeholders should enforce the constructions of central waste disposal facilities/units in all rural and urban settlements, for subsequent processing to generates energy and wealth; and

6) The Nigerian Government should utilise its vast organic generated waste for economic production to be used for agricultural practices. And the volume of combustible waste as RDF for W-t-E generation; and
7) The Nigerian government should enforce an effective system of the polluter pays principle (PPP), in order to combat all form of waste materials.

8.0 Nomenclature

Acronyms	Descriptions	Acronyms	Descriptions
BPEO	Best Practice Environmental Options	CH_4	Methane
CO_2	Carbon dioxide	RDF	Refuse Derived Fuel
GW	Global Warming	SW	Solid Waste
GHG	Green House Gas	MSW	Municipal Solid Waste
ISWM	Integrated solid waste management	R&D	Research and Developments
Kg	Kilogram	SWM	Solid Waste Management
MBT	Mechanical Biological Treatment	VOCs	Volatile organic compounds
MSWM	Municipal Solid Waste Management	WM	Waste Management
MJ/kg	Mega joules per kilogram	W-t-E	Waste to Energy

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