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Zero waste: an innovation for less polluting emission processes, resource management practices and policies

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ABSTRACT

The rising levels of greenhouse gases (GHGs) in the Earth's atmosphere have the potential to cause changes in our climate. Some of these emission increases can be traced directly to solid waste. Landfills are among the largest emitters of carbon dioxide and methane, the key GHGs. Thus, effective mitigation of these emissions through formalization of waste reduction into the waste management system to reduce land filling could provide environmental benefits of reducing the adverse impacts of climate change. This paper therefore proposes waste prevention and recycling-jointly referred to as *waste reduction* as better and most potent strategies for the management of solid waste and for reducing greenhouse gases and calls on both the government and private agencies to check or control the increasing pollution and abuse of the environment by enforcing compliance with the laid out Policies, Pronouncements, Regulations and enacted Legislation especially in the developing countries. The study concludes that by choosing to prevent waste and recycle, less waste will be generated, the need for landfill will be minimal, energy demand will decrease, fewer fossil fuels will be burned and less methane and carbon dioxide will be emitted to the atmosphere which helps to curb climate change.

Keywords: greenhouse gases; climate change; municipal solid waste; biodegradation; resource management

1. INTRODUCTION

In the last decades the greenhouse gases produced by human activities have been predominating over those of natural origin (Intergovernmental Panel on Climate Change-IPCC, 2000), thereby upsetting the natural atmospheric balance. This increased concentration of greenhouse gases (GHGs) raises global temperatures which have adverse impacts on our environment and public health. The waste sector is a significant contributor to GHGs emissions and is accountable for approximately 5 % of the global greenhouse budget (IPCC, 2006). The majority of these emissions are a result of landfills, which remains the primary waste disposal strategy globally (Attenborough, Gregory,& McGeochan, 2002). Municipal solid waste (MSW) contributes to greenhouse gas emissions through decomposition and life-cycle activities/ processes (Farguhar and Rovers, 1973). The greenhouse gases emissions related to waste deposits are mainly due to methane (CH_4) and carbon dioxide (CO_2) present in the biogas produced by anaerobic bacteria using as carbon source the biodegradable carbon contained in the waste (Hoeks, 1983; Barlaz, Ham & Schaefer, 1990). In particular the disposal of waste in landfills generates methane that has high global warming potential (Yesiller, Hanson and Liu, 2005). Energy consumption contributes directly to climate change by adding carbon-based molecules to the atmosphere in excess of naturally occurring amounts. Carbon molecules, primarily carbon dioxide from burning petroleum products, trap radiant heat and keep it from escaping from the Earth's atmosphere (IEA, 2005). The resulting warming of the air is changing our global climate. Thus, landfills are among the nation's largest emitters of CO_2 and CH_4, the key greenhouse gases (GHGs) which modify the Earth's climate, and as such effective mitigation of these greenhouse gas emissions is important and could provide environmental benefits and sustainable development, as well as reduce adverse impacts on public health (Sheehan, 2000; Briney, 2013). Methane is regarded as one of the most important GHGs because its global warming potential has been estimated to be more than 20 times that of carbon dioxide. Although there is no immediate danger from the methane emitted in atmosphere from landfills, over time it could accumulate inside the landfill mass, thus increasing its concentration with attendant potential to modify the Earth's climate. 36 percent of human caused methane releases come from our municipal solid waste landfills (USEPA, 1999). A ton of municipal solid waste land-filled produces 123 pounds of methane- a potent greenhouse gas, 20 times more effective at trapping heat in the atmosphere than carbon dioxide (EA, 2008).

Hulme *et al.* (1995) list the adverse impacts of the increased concentrations of greenhouse gases in the atmosphere to include a threat to disrupt the diversity of habitats and the life dependent on them. In particular, our health, agriculture, water resources, forests, wildlife, and coastal areas are vulnerable to the changes that global warming may bring. It further state that a rise of only a few degrees in the Earth's average temperature could result in more frequent and intense storms, flooding of beaches, bay marshes, and other low-lying coastal areas; more precipitation in some areas and not enough in others and wider distribution of certain infectious diseases. Such significant changes, note NEST (1991), Hulme *et al.* (1995) and Nicholson (2001) could damage communities and national economies as well as alter the natural world.

2. MUNICIPAL SOLID WASTE AND GREENHOUSE GASES/ EMISSIONS

Various studies have indicated that waste generation has increased globally over the last twenty decades (United States Environmental Protection Agency-US EPA, 1998a; b; EPA, 2009). Global temperatures have increased as well (Yesiller *et al.*, 2005). In particular the disposal of waste in landfills generates methane that has high global warming potential. Globally, the atmospheric concentration of methane has increased by 151 % since 1750 and its concentration continues to increase and has been increasing in the range of 1-2 % per year (US EPA, 1998b; 1999; 2002; IPCC, 2000). Concerned with these developments, the United Nations Framework Convention on Climate Change (UNFCCC) called on countries to reduce their greenhouse gases emissions. Global greenhouse gas emissions in 2005 from waste based on reported emissions from national inventories and national communications, and (for non-reporting countries on 1996 inventory guidelines and extrapolations) was 750 million metric tons of carbon equivalent (MMTCE), the basic unit of measure for greenhouse gases, while that based on 2006 inventory guidelines and projections was 520 MMTCE (IPCC, 2006).

Nigeria's national communication based on emission per unit human population (based on gross population of 96.7 million for the year 1994) indicates a gross per capita CO_2 emission of 0.5 t C/cap. Per capita, non-CO_2 GHG and precursor gases were between 2 to 4 orders of magnitude lower than CO_2 per capita emissions. An overview of gross carbon emissions by sources and removal by sinks indicates gas flaring, transportation, and electricity generation as the most significant energy consumption processes leading to GHG emissions. Energy and land use change sectors are the main contributors to CO_2 emissions, while energy, agriculture and solid waste are the main contributors to CH_4 emissions (IPCC, 2006).

However, although the total generation of GHGs based on the1994 population data at the then growth rate of 3.5 % per annum for Nigeria is low when compared to emissions from the United States and other developed economies; Nigeria's gross emissions may approach those of these countries if its population continues to grow above the current estimate of 160 million with a growth rate of 3.97 in 2010 (UN WUP, 2010), representing more than 20 % of the entire population of Africa and would invariably fuel increase in the generation of solid waste which may subsequently contribute significantly to global greenhouse budget since per capita emissions are also likely to increase.

2. 1. Municipal Solid Waste (MSW): Generation, Categorization and Disposal Strategies

Municipal waste, commonly known as trash or garbage, is a combination of all of a city's solid and semi-solid waste. It includes mainly *household* or *domestic waste*, but it can also contain *commercial* and *industrial waste* with the exception of *industrial hazardous waste* (waste from industrial practices that causes threat to human or environmental health) (Briney, 2013). The types of waste that are included in municipal solid waste can be grouped into five different categories and include:

Biodegradable: This includes things like food and kitchen waste such as meat trimmings or vegetable peelings, yard or green waste and paper;

Recyclable materials: Paper is also included in this category but non-biodegradable items like glass, plastic bottles, other plastics, metals and aluminium cans fall into this section as well.
Inert waste is the third category of municipal waste. For reference, when discussed with municipal waste, inert materials are those that are not necessarily toxic to all species but can be harmful or toxic to humans. Therefore, construction and demolition waste is often categorized as inert waste.
Composite waste is another category of municipal waste and includes items that are composed of more than one material. For example, clothing and plastics such as children's toys are composite waste. ***Household hazardous waste*** is the final category of municipal waste. This includes medicines, paint, batteries, light bulbs, fertilizer and pesticide containers and e-waste like old computers, printers, and cellular phones. Household hazardous waste cannot be recycled or disposed of with other waste categories so many cities offer residents other options for hazardous waste disposal (USEPA, 2000; Briney, 2013). Wastes generated at domestic, commercial, industrial or agricultural levels in the form of solid, liquid, gas or hazardous wastes are harmful to both health of human beings and animals and the environment. Such wastes either end up in our streams, rivers and oceans and cause water pollution or find their way into the air where they cause air pollution (FMHE; Cointreau, 1982). The dangers caused by wastes, irrespective of their source, to ecological and human

health cannot be underestimated. This calls for proper waste management in “Our Environment to secure Our Future”.

2. 2. Municipal Waste Disposal and Landfills

There are a number of different ways in which cities dispose of or treat their waste:

Refuse dumps: These are the most widely practiced waste disposal method especially in developing nations. These are open holes in the ground or ground surface where waste is disposed of and has little environmental regulations.

Landfills: These are any land areas serving as depository of urban, or municipal solid waste. More commonly used today to protect the environment, these facilities are specially created so waste can be put into the ground with little or no harm to the natural environment through pollution (Cointreau-Levine, 1996). Today, landfills are engineered to protect the environment and prevent pollutants from entering the soil and possibly polluting ground water in one of two ways: first, with the use of a clay liner, these are specially designed and constructed according to engineering specifications, to block pollutants from leaving the landfill. These are called ***sanitary landfills;*** second, with the use of synthetic liners like plastic to separate the landfill's waste from the land below it. This type is called a ***municipal solid waste landfill***. Once waste is put into these landfills, it is compacted until the area is full, at which time it is buried/ closed. This is done to prevent the waste from contacting the environment but also to keep it dry and out of contact with air so it will not quickly decompose. Thus, current ‘state of the art’ landfill design aims to entomb waste disposed into them and keep it dry forever. This is unsustainable since landfills will eventually leak and pollute the geo-environment.

Methane-Recovery Landfill: Some landfills operators try to recover methane. However, 60 % is about the best recovery of methane being reported; most landfills that collect methane recover somewhere around 40 % (US EPA, 1999). In 1996, only 14 percent of landfill methane was captured (most landfill methane is flared on-site while some is used to produce energy).

Leachate Recirculation Land fill: Experiments showing an increase in biological degradation after addition of water have led to the assumption that traditional landfills are too dry and additional water is required to increase biological degradation which has led to the development of irrigation and leachate recirculation landfill concepts also called bioreactor landfills (Grellier *et al*., 2008).

Bioreactor Landfill: Recently, new systems of waste treatment are being developed for landfilling waste, called ***‘bioreactors’***, to try to capture methane more effectively. A bioreactor landfill is operated to enhance waste decomposition, gas and leachate production as well as refuse stabilization. By re-circulating leachate and adding water, decomposition rates can be increased, making methane recovery more economical. These processes also compact waste further increasing the operational capacity of the landfill (Hoeks, 1983; Barlaz *et al*, 1990). Municipal solid waste landfills and Methane-recovery landfills are the top human-caused source of methane in our atmosphere.

Waste combustors: In addition to landfills, waste can also be disposed/treated using *waste combustors*. This involves the burning of municipal waste at extremely high temperatures to reduce waste volume, control bacteria, and sometimes generate electricity. Air pollution from the combustion is sometimes a concern with this type of waste disposal. However in the developed worlds, governments have regulations to reduce pollution from this waste treatment device.

Transfer stations are another type of municipal waste disposal/handling technique currently in use. These are facilities where municipal waste is unloaded and sorted to remove recyclables and hazardous materials/components from collected waste. The remaining waste is then reloaded into trucks and taken to landfills while the waste that can be recycled for example is sent to recycling centres.

Landfill Processes: Biodegradation Processes, Landfill Gas Production/Emission from MSW The greenhouse gases emissions related to waste deposits are mainly due to methane (CH_4) and carbon dioxide (CO_2) present in the biogas produced by anaerobic bacteria using as carbon source the biodegradable carbon contained in the waste (Hoeks, 1983). Organic materials (derived from living organisms) produce methane in landfills when they decompose without oxygen (anaerobic), under tons of garbage (Barlaz *et al*., 1990). Cellulose and hemi-cellulose are the major biodegradable constituents of MSW and account for 90 % of its methane potential. Thus, municipal solid waste (MSW) contributes to greenhouse gas emissions through anaerobic decomposition and life-cycle activities/processes (Farguhar and Rovers, 1973). Generally, the degradation of organic material is described as a sequential (cum simultaneous) process of : (i) Hydrolysis of the solid organic material (example, hemi-cellulose/cellulose) into larger soluble organic molecules; (ii) Fermentation of organic acids and (iii) Methanogenesis (Barlaz *et al*., 1990). Thus, when organic waste is land-filled, organic materials in the waste will be biodegraded by microorganisms and when conditions are favourable, solid organic material is decomposed to soluble materials, a bio-film will develop, in which the degradation products ultimately are transformed to biogas- a mixture of Carbon dioxide and Methane- and released as a by-product (Farguhar and Rovers, 1973; Hoeks, 1983; Barlaz *et al*., 1990). Therefore, three major groups of bacteria are involved in methane production from refuse: the hydrolytic fermentative and methanogenic bacteria. The first two convert cellulose and hemi-cellulose contained in the waste to sugars; the sugars are then fermented to carboxylic acids, alcohol to acetate, hydrogen and Carbon dioxide; while the third converts the acetate and hydrogen plus carbon dioxide to methane. On the whole, the biodegradation rate depends on aspects such as waste composition, waste management practices, compacting, temporary and final lining and local climatic conditions (temperature and rainfall) (Barlaz *et al*., 1990).

3. GHGS EMISSIONS, CLIMATE CHANGE AND WASTE MANAGEMENT

Globally, efforts are being made to control greenhouse gases (GHGs) emissions from various sources including the waste sector. The Kyoto protocol in Europe foresees the reduction of the principal anthropogenic emissions of the gases responsible for altering the natural greenhouse effect. In particular, in the period 2008-2012, the industrialized countries should reduce the emissions by 5 % in respect to the 1990 values. By 2010, the U.S. expects to further reduce greenhouse gas emissions by 5.6 million metric tons of carbon equivalent (MMTCE), the basic unit of measure for greenhouse gases, through waste prevention and recycling. These reductions are the carbon equivalent to taking more than 4 million cars off the road for one year (Briney, 2013).

To help measure the climate change benefits of waste reduction, EPA conducted a comprehensive study of greenhouse gas emissions and waste management (US EPA, 1998a). The study estimated the greenhouse gas emissions associated with managing 16 types of waste materials. Management options analyzed in the study included waste prevention, recycling, composting, incineration, and landfilling. The study found that by increasing her national recycling rate from 30 percent in 2000 to 35 percent would reduce greenhouse gas emissions by another 10 MMTCE compared to landfilling the same materials and that together these levels of waste prevention and recycling would be comparable to annual emissions from the electricity consumption of nearly 4.9 million households. The study concludes that reducing the GHG emission from landfills contributes to stabilizing GHG concentrations in the atmosphere at a level that would prevent the dangerous anthropogenic interference with the climate system and that waste prevention can make an important difference in reducing emissions. In various other studies US EPA (1998b; 1999; 2002) estimates that by cutting the amount of waste they generate back to 1990 levels, they could reduce greenhouse gas emissions respectively by 10, 12 and 18 million metric tons of carbon equivalence (MMTCE). The researches indicate that, in terms of climate benefits, waste prevention is generally the best management option. Recycling is the next best approach. The research enables waste managers to analyze their potential to reduce GHG emission based on the characteristics of their community's waste stream and the management options available to them. Briney (2013) affirms that waste reduction and recycling are potent strategies for reducing greenhouse gases.

3. 1. Municipal Solid Waste Management/Reduction Strategies

The issue of waste management therefore concerns with the interplay among generation, storage, collection, treatment and disposal of waste. Waste management has been defined as the organized and systematic dumping and channelling of waste through or into landfills or pathways to ensure that they are disposed of with attention to acceptable public health and environmental safeguard (Cointreau, 1982). It has also been considered to mean the collection, keeping, treatment and disposal of wastes in such a way as to render them harmless to human, plant and animal life, the ecology and the environment in general. Waste management is therefore the collection and proper handling of wastes from the point where they are generated to where they are disposed of to achieve maximum environmental safety. The term 'waste management' can be said to extend to the after-care of sites and equipment used in the management of waste (Ikom, 2010). In addition to the proper disposal, some cities promote programs to reduce overall waste including:

Recycling: The most widely used program is recycling through the collection and sorting of materials that can be re-manufactured as new products (GRRN, 2000).According to GRRN website recycling reduces emissions from energy consumption. Recycling saves energy as manufacturing goods from recycled materials typically requires less energy than producing goods from virgin materials.

Composting: This can also promote municipal waste reduction. Compostable waste is comprised solely of biodegradable organic waste like food scraps and yard trimmings. Composting is generally done on the individual level and involves the combination of organic waste with microorganisms like bacteria and fungi that break down the waste to create compost (Hoornweg *et al.*, 1999). This can then be recycled and used as a natural and chemical free fertilizer for personal plants. Composting is a well-established aerobic treatment method of organic waste (Barlaz *et al.*, 1990). Injection of air in landfill will result in a process that is similar to composting. Under this condition organic matter will be degraded to humus substances. However, aerobic degradation will produce heat and as a result, temperature will rise in the landfill body (Yesiller et al., 2005)

Source Reduction**:** This involves the reduction of waste through the alteration of manufacturing practices to reduce the creation of excess materials which get turned into waste. For example, the United States consumed 30 percent of the materials produced globally in 1995, while it accounted for less than 5 percent of the world's population; and only 1 percent of the materials used in products are 'durable' enough to still be in use six months later (Sheehan, 2000). Such wasteful consumption of materials wreaks havoc on our land and water resources. What's seldom appreciated is that it also wreaks havoc on our atmosphere and contributes to climate change.

Waste Prevention**:** This is even more effective. When people reuse things or when products are made with less material, less energy is needed to extract, transport, and process virgin materials and to manufacture products. The benefits of waste prevention include *(1) Reduced Emissions from Incinerators:* Recycling and waste prevention allow some materials to be diverted from incinerators and thus reduce greenhouse gas emissions from the combustion of waste. *(2)Reduced Methane Emissions from Landfills:* Greenhouse gases are emitted as waste decomposes in landfills. Waste prevention and recycling reduce the amount of waste sent to landfills, lowering the greenhouse gases emitted during decomposition. Waste prevention and recycling (including composting) divert organic wastes from landfills, reducing the methane released when these materials decompose. *(3)Carbon Sequestration:* Trees absorb carbon dioxide from the atmosphere and store it in wood, in a process called "carbon sequestration." Waste prevention and recycling of paper products allow more trees to remain standing in the forest, increase storage of carbon in trees where they can continue to remove carbon dioxide from the atmosphere. Manufacturing products release greenhouse gases during processing and as energy is expended during product use. Waste prevention means more efficient resource use, and making products from recycled materials requires less energy. Waste prevention and recycling are critical to stopping climate change. Both lower greenhouse gases emitted during manufacturing and product use. Together waste prevention and recycling can make a significant contribution to reducing our nation's greenhouse gas emissions

4. ZERO WASTE: GHGS EMISSIONS AND CLIMATE CHANGE

To further reduce waste, some cities are currently promoting policies of **zero waste**. Zero waste itself means reduced waste generation and the 100 % diversion of the remainder of waste from landfills to productive uses via materials reuse, recycling, repair and composting (USEPA, 2000).

For example, the GrassRoots Recycling Network (GRRN) - a growing international Zero Waste Movement calling for radical resource efficiency and eliminating rather than managing waste with strategies that have major benefits for slowing climate change - has been spearheading the North American arm of a growing international movement, Zero Waste International Alliance that promotes Zero Waste as essential to reversing current unsustainable resource practices and policies.

Zero Waste is a goal for how we should responsibly manage materials and the energy required to make them. It is a 'whole system' approach to resource management that maximizes recycling, minimizes waste, reduces consumption and ensures that products are made to be reused, repaired or recycled back into nature or the market place (Sheehan, 2000). According to Sheehan (2000), implementation of Zero Waste resource management systems is arguably one of the most important steps to the sustainability of the Earth's atmosphere and ecosystems. Zero Waste confronts the whole idea of endless consumption without needing to say so, by enabling even those who are locked into the system to challenge their own behaviour in a positive way without immediately threatening it. However, zero waste products should also have minimal negative environmental impacts over their lifecycles. GRRN has identified the following outcomes as essential moves towards a Zero Waste society: (a) Extended Producer Responsibility for Waste; (b) Consumer Action Against Wasteful Corporations; (c) Deposit Programs; (d) Jobs Through Reuse and Recycling; (e) Incentives for Reducing Waste; (f) Full-Cost Accounting and Life-Cycle Analysis; (g) Minimum Recycled Content; (h) Ending Subsidies for Extracting Virgin Resources; (i) Shifting Taxes from 'Goods' to 'Bads'; (j) National Resource Policy; and (k) Campaign Finance Reform (GRRN,2000).

According to GRRN website, "Zero Waste is a goal that is ethical, economical, efficient, and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use". It further states that "Zero Waste means designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them", and that "implementing Zero Waste will eliminate all discharges to land, water or air that are a threat to planetary, human, animal or plant health."-- Internationally accepted, peer-reviewed definitions adopted by the Zero Waste International Alliance - 29 November 2004. The ultimate goal of Zero Waste systems – including waste prevention and recycling – is, therefore, to reduce greenhouse gases.

Sheehan (2000) lists the benefits of waste reduction/minimization in the context GHGs emissions reduction to include:

Saving energy: especially by reducing energy consumption associated with extracting, processing and transporting 'virgin' raw materials. Manufacturing with recycled materials uses less energy overall compared with manufacturing using virgin materials;

Natural resources preservation/conservation: By recycling paper for example leaves more trees standing and increases carbon uptake by forests (they breathe in our carbon dioxide) which also leads to;

Reduction of waste generation and eventually;

Elimination of the need for landfill: By diverting organic materials (which releases methane from landfills) and **incinerators** (which waste energy relative to recycling). Both lower greenhouse gases emitted during their lifecycles.

4. 1. Implication of the Solid Waste Management Options on GHGs Emission/Climate Change

Almost every step of solid waste management can contribute to reduction of greenhouse gases. The management of municipal solid waste presents many opportunities for GHG emissions reduction. Source reduction, in general, represents an opportunity to reduce GHG emissions in a significant way. Source reduction and recycling can reduce GHG emissions at the manufacturing stage, increase forest carbon sequestration and avoid landfill CH_4 emissions. Landfill CH_4 emissions can be reduced by using gas recovery systems and by diverting organic materials from landfills. Landfill CH_4 can be flared or utilized for its energy potential. When used for its energy potential, landfill CH_4 displaces fossil fuels, as with MSW combustion. Using compost as landfill cover on closed landfills provides an excellent environment for the bacteria that oxidize CH_4 and offers the possibility of controlling these emissions in a cost-effective manner. Under optimal conditions, compost covers can practically eliminate CH_4 emissions. Use of Bioreactors can accelerate the decomposition process of landfill waste through controlled additions of liquid and leachate recirculation, which enhances the growth of the microbes responsible for solid waste decomposition. The result is to shorten the time frame for landfill gas generation, thereby rendering projections of landfill gas generation rates and yields that are much more reliable for landfill gas recovery. However, from the limited perspective of *managing waste*, this may seem reasonable; but from a Zero Waste perspective of *managing resources*, bioreactors make little sense. This is because micro-organisms live in the water phase as single organisms but more generally as consortia in bio-films. Water is essential for the survival of these organisms as it is the means of transport of nutrients to the micro-organisms and waste products from these consortia of micro-organisms thereby sequestrating the pollution potentials of landfills. Besides, over [illegible] percent of what gets buried in municipal landfills is readily recyclable or compostable organics, including paper and wood (USEPA, 1998). Organic material is needed to replenish our depleted, eroding and artificially-fertilized soils.

5. SOLID WASTE MANAGEMENT IN NIGERIA

Nigeria, endowed with abundant and diverse resources, is committed to protecting its environment. However, the country's climatic and ecological diversity has implications on the intensity of human activities, nature and character of waste generated and environmental management. It has therefore become imperative that the settlement environment and its resources should be managed judiciously to enhance sustainable national socio-economic development. However, many constraints and problems, ranging from socio-cultural, economical and management/democratic problems hinder effective waste management practices in Nigeria. Some of these constraints include:

Lack of clear policy assigning responsibilities for environmental issues within the levels of Government; Poor perception of waste management as an essential service and a major determinant of health and good standard of living; Weak and poorly enforced Environmental/Solid Waste Management and Public Health Laws, and State Laws; Lack of adequate professional manpower especially at the State and Local Government Area levels; Inadequate research activities; Inadequate Environmental Education and awareness; Inadequate sensitization and mobilization of the private sector in the delivery of waste management services; and low literacy level.

Moreover, by virtue of its regional extent, Nigeria encompasses multiple climatic regimes & various ecological zones that influence the intensity of human activities and this has implications on waste generation patterns, environmental degradation and pollution. A national environmental management policy was therefore being put in place, to serve as a veritable instrument for securing quality environment for good health and social well being of present and future generations (NPE, 1999).

However, it is a common observation that waste management is at the lowest ebb in most towns and communities in Nigeria. This is evident on the alarming rate at which heaps of solid waste continue to occupy our cities, coupled with the fact that about 87% of Nigerians use disposal methods adjudged as insanitary (FME, 2005), which have not only constituted visual blight and odour nuisance, but also encouraged the breeding of rodents, mosquitoes and other pests of public health importance, with attendant disease outbreaks. Most parts of the city centres do not benefit from public waste disposal services and therefore, have to bury or burn their waste or dispose it haphazardly. In most cities and peri-urban centres, refuse heaps are left unattended and where the Local Government Authorities do the collection, it is often irregular and sporadic. The recycling of waste is negligible while methods of storage, collection, sorting, transportation, compaction and final disposal are very unsatisfactory. Furthermore, some of the waste materials are toxic; others are either non-biodegradable or not readily degradable such as water sachets and polythene shopping bags. Also included are various types of industrial/ chemical waste that can contaminate air, soil and ground water sources if not properly disposed. Another major concern is the generation of waste from health care institutions/ facilities, which contain infectious/ hazardous materials that pose potential hazards to human and environmental health when improperly disposed.

6. LEGAL FRAMEWORK AND INSTITUTIONAL ENFORCEMENT FOR WASTE MANAGEMENT IN NIGERIA

Pronouncements of the law court in the form of decisions, judgements, orders, policies etc. are meant to be obeyed by the citizens. In most cases, judicial decisions are the interpretations of the relevant Legislation/ laws, National Policy, Guidelines/Action Plans, Official Statements/Decisions and Regulations enacted by the legislature, or Decrees and Edicts which establish specific or general limits to which various environmental activities must comply to assure safety of the populace. In the current dispensation (1981 to date), all tiers of the Nigerian Government have developed legislative/regulatory instruments to better address environmental issues. Examples include:

Federal Environmental Protection Agency (FEPA) Decree No.58 of 1988 and No.59 of 1992 as amended; National Policy on Environment (1989) and (1999) as amended; Blueprint on Handbook on Municipal Solid Waste Management in Nigeria (2001); and the most recent National Environmental Standards and Regulations Enforcement Agency (NESREA) Act No.25 of the Federal Republic of Nigeria contained in the Official Gazette No.92, vol. 94 of July, 2007. Others are the Legislation enacted by the Federal and State Governments of Nigeria, Promulgation of States Edicts/Laws , International Treaties and Conventions (of International Organisations on Environment to which Nigeria is a member, some of which are: the 1972 Stockholm Conference on the Human Environment; the 1992 United Nations Conference on Environment and Development (UNCED) (the popular rio de janeiro conference); the 1989 Convention on the Control of Trans-boundary Movements of Hazardous Wastes etc. Other conventions and treaties ratified by Nigeria include:
The 1968 African Convention on the Conservation of Nature and Natural Resources: the 1972 Convention on the Marine Pollution by dumping of waste; the 1982 UN Convention for Protection of the Ozone Layer; the 1985 Vienna Convention for Protection of the Ozone Layer; the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer: the 1992 United Nations Framework Convention on Climate Change (UNFCCC); etc are the examples of Government Agencies, Legislation and Policies that bother on environmental matters; and as such, are the major sources of environmental law in Nigeria.

Section 38 of the Federal Environmental Protection Agency Act (FEPA, 1992) defines environmental pollution as "man aided alteration of chemical, physical or biological quality of the environment to the extent that is detrimental to that environment or beyond acceptable limit." This thus spells out the need for a renewed derive in the appreciation of annihilating the effects of unchecked environmental degradation because the natural ecosystem and its subsistence serve as the base for human life support (Ikoni, 2010). There is also a new derive by both the government and private agencies to check or control the increasing pollution or abuse of the environment by enforcing compliance with the laid out policies, pronouncements and enacted regulations.

The law regulating the National environmental standards and regulatory enforcement on solid waste disposal /management in Nigeria is currently encapsulated in the National Environmental Standards and Regulations Enforcement Agency (NESREA) Act saddled with the responsibility and powers to enforce compliance with Policies, Laws and Regulations on Environmental Issues. The highlights of the functions of the agency specifically related to solid waste management as contained in the Act are to:

- Enforce compliance with laws, guidelines, policies and standards on environmental matters;
- Coordinate and liaise with stakeholders, within and outside Nigeria, on matters of environmental standards, regulations and enforcements;
- Enforce compliance with the provisions of international agreements, protocols, conventions and treaties on the environment, including climate change, biodiversity, conservation, desertification, forestry, oil and gas, chemicals, hazardous wastes, ozone depletion, marine and wild life, pollution, sanitation and such other environmental agreements as may from time to time come into force;
- Enforce compliance with policies, standards, legislation and guidelines on air and water quality, environmental health and sanitation, including pollution abatement;
- Enforce compliance with guidelines and legislations on sustainable management of the ecosystem, biodiversity conservation and the development of Nigeria's natural resources;
- Enforce environmental control measures through registration, licensing and permitting systems other than in the oil and gas sector;
- Conduct environmental audit and establish data bank on regulatory and enforcement mechanisms of environmental standards other than in the oil and gas sector;
- Create public awareness and provide environmental education on sustainable environmental management, promote private sector compliance with environmental regulations other than in the oil and gas sector and publish general scientific or other data resulting from the performance of its functions;
- Carry out such activities as are necessary or expedient for the performance of its functions.

Along with its statutory functions as outlined above the agency is given certain powers to enable it carry out these functions as listed in the Act.

However, whether or not the institutions/agencies saddled with the task of waste management in Nigeria are living up to their expectations as obtained in other developed and developing nations is one issue this paper would have loved to examine or address if time and space had permitted.

The problems/constraints militating against the effective execution of these functions with the proffered solutions to the problems of waste management in Nigeria are, however, discussed elsewhere by some of the current contributors where some of these institutions and how they have tackled the management of waste in Nigeria are considered. The significant summaries of that study are that the actual enforcement of these provisions by the authorities or agencies saddled with the responsibility of waste management at all tiers of the Nigerian Government will depend on the many constraints and problems, ranging from socio-cultural, economical and institutional problems which hinder effective waste management practices in

Nigeria; including, among others, the foresight of the management agencies, the resources available at their disposal and the human and material resources provided by the parent Ministry of the Federal or State Government of Nigeria. The overall factor however is the level of awareness of the Federal or State Government of the environmental problems and its preparedness to tackle same. The study however came to a conclusion that the problem of waste management in Nigeria is, however, not that of the law, but that of the enforcement of the law.

To this end, it is recommended that awareness should be raised on the disposal of waste and its impact on the climate change with a view to drawing the attention of adaptation experts and policy makers on the possible role of waste management research in adaptation and mitigation to climate change especially in the developing countries. Household residents should be motivated to segregate recyclable materials from organic materials. It has also been recommended that Local and state governments should initiate action plans, which set steps to reduce emissions and incorporate the reduction of waste into their GHG mitigation strategies. States should implement a series of voluntary initiatives to achieve reductions in greenhouse gas emissions from all sectors of our economy. Taking climate change mitigation efforts one step further, governments should update general plans to reflect solid waste sustainability issues such as green house gas (GHG) reduction goals, landfill gas recovery and programmes based on specific targets; and on line with these developments, it is further recommended that community-based waste disposal facilities (mostly open dumps) should be changed from waste storage facilities to waste processing facilities in order to utilize the resource potential of landfills and reduce its adverse impacts on Earth's environment and humanity. The landfill site should be designed taking into consideration the tapping of landfill gas. Introducing the alternative community-based waste management techniques which involves waste minimization at household level with local level recycling would be a low-cost in-house mechanism to manage the waste at local level. The monitoring and update of records should be done on a regular basis to check performance of reduction strategies. There should also be a new derive by both the government and private agencies to check or control the increasing pollution or abuse of the environment by enforcing compliance with the laid out Policies, Pronouncements, Regulations and enacted Legislation.

7. CONCLUSION

This paper presents a review on the current solid waste generation, management practices and the future potentials or the impact of greenhouse gases (GHGs) emission particularly contribution by the solid waste sector, and the implication for climate change. The review reveals that based on the current scenarios, the waste sector will be a significant contributor to GHGs emission. As a mitigation option the study recommends formalization of waste reduction or minimisation (a concept dubbed Zero Waste) through recycling into the waste management system to reduce land filling. Practical strategies and actions can be taken by all sectors of society in all institutions.

The study concludes that by choosing to prevent waste and recycle, energy demand will decrease, fewer fossil fuels will be burned and less carbon dioxide will be emitted to the atmosphere which helps to curb climate change.

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