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Climate Change Mitigation and Adaptation through Strategic Waste Management Options

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Abstract-This paper describes various types of wastes generated in Nigeria, of which about 50 to 70 per cent is organic and the rest recyclables. These wastes contribute to Green House Gas (GHG) emissions and leave a garbage footprint. The waste management practices and procedures used in Nigeria also contribute to GHG emissions and these include transportation using worn out vehicles, open dumping of waste and indiscriminate burning. These contribute to Greenhouse Emissions either directly or indirectly. The existing practices such as open dumping or burning can contribute to methane or carbon dioxide emissions. In addition, waste transportation, reuse, and recycling activities also produce the carbon emissions. It is suggested that depending on the nature of wastes generated, appropriate treatment or disposal methods should be adopted which have low carbon emissions. The high carbon emitting technologies should be avoided through policies, advocacy and developing locally developed viable technologies.

Keywords- *Climate Change, Municipal Solid Wastes, Composting, Landfill, Incineration*

I. INTRODUCTION

Wastes are characterized into liquid, solid and gaseous. Waste management is the discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal of wastes in a manner that is in accord with the best principle of public health, economics, engineering, conservation, aesthetics, and other environmental considerations. It is also responsive to public attitudes. In Nigeria, management of solid wastes has taken a lot more curiosity and interest among the governments and communities. This is mainly because of its impact on immediate human environment. In the past, management was limited to the removal of waste from the immediate surroundings, out of site. However, over the years, it has taken a new dimension due to various emerging environmental problems such as climate change. Integrated Solid Waste Management (ISWM) is currently in vogue and is defined as the selection and application of suitable techniques, technologies, and management programs to achieve specific waste management objectives and goals. If not properly managed, waste can cause a variety of impacts. One of these impacts is the threat of climate change. Buried or landfilled waste produces carbon dioxide and methane, both greenhouse gases, which when emitted will enhance the natural greenhouse effect. Protecting the environment over the long term is the major challenge for waste management design professionals today.

In the waste management strategies, a variety of methods are in practice depending on the type of waste to be disposed of, the level of economic development of the country and the commitment of the Government. Solid Waste management methods include waste minimization (or reduce), reuse, and recycling before thinking of disposal. Thousands of tons of solid waste are generated daily in Nigeria. The wastes are similar to those produced in other developing countries. Most of it ends up in open dumps and wetlands, contaminating surface and ground water and posing major health hazards [1]. In Nigeria daily waste generation rate is estimated between 0.4-1.0 kg/person/day [2, 3]. Variations occur depending on the socio-economic conditions, climate, rural-urban differences, and other factors. In industrialized countries, however 0.7 to1.8 kg/person/day generation rate is common. Most of the waste generated in Nigeria is not collected by Municipal collection Systems, the ones collected are usually mixed with various types, not separated and eventually dumped in open dumps (Fig. 1). Indiscriminate disposal of solid wastes (including the hazardous or infectious wastes) also has impact in several other ways:

- Blockage of drains and stream flows resulting in flood disasters (e.g. Ogunpa floods of Ibadan, Asa River in Ilorin)
- Fire hazards when the wastes are dry
- Obnoxious smell, gaseous and smoke emissions including GHGs
- Breeding site for rodents, flies and other vectors of public health importanceHarbours and act as reservoir of infectious agents
- offers a venue for stray animals, destitutes, and lunatics
- Eutrophication of water bodies through leachate flows,
- Biodiversity loss due to death of useful flora and fauna of aquatic or terrestrial systems, and
- Morbidity and mortality of populations due to injuries and infections

Figure 1. Contribution of several waste to GHG

II. NIGERIA'S GARBAGE FOOTPRINT

The solid wastes, particularly the municipal solid wastes, crop residues from agriculture and agro-based industries, and livestock dung and droppings are rich in organic matter and other plant nutrients such as nitrogen, phosphorus, potassium and micronutrients [4]. They are highly putrescible and favor breeding of flies, besides harbouring infectious agents like Tetanus, Clostridium, and others. The leachates from these wastes may promote mosquito breeding when stagnant or contaminate water bodies and irrigable land. These wastes also contain other non-biodegradable wastes such as metals, glass, plastics and a host of others arising from industrial activities. However, some or most of these discarded wastes have great recyclable values if properly collected and utilized. A typical solid waste has the following composition (Fig. 2). Also, the composition of wastes at the dumpsites in the megacity of Lagos in particularly shows that combustible matter is more than the non-combustibles (Table 1). This has the potential of releasing GHGs into the environment if not properly managed. Food waste was not conspicuous at the dump site and was not recorded. However, food waste assessed from freshly dumped wastes ranged from 45% to 68% and Number of trucks delivered at the sites ranged from 350 to 487 with 3500 tonnes to 4870 tonnes of waste.

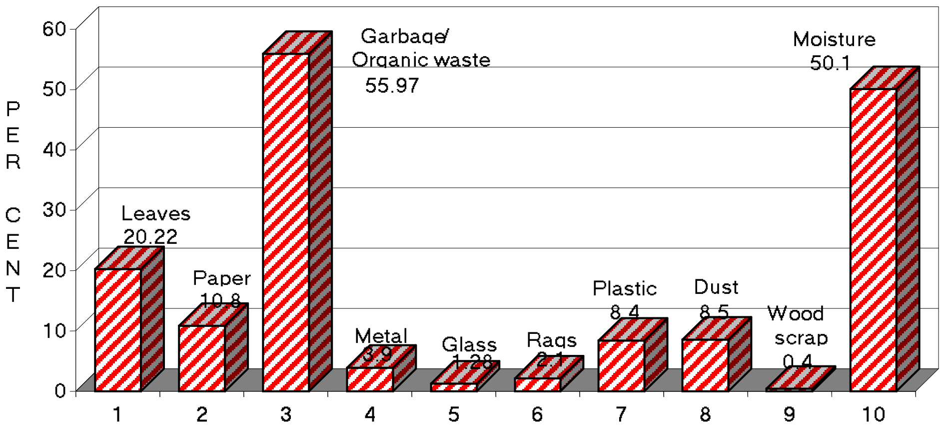

Figure 2. The components of a typical municipal solid waste in Ibadan (Mean of 25 years data)

TABLE I. COMPOSITION OF THE WASTE AT THE DUMP SITES IN LAGOS (RESULTS EXPRESSED AS MEAN, %; (SRIDHAR, UNPUBLISHED REPORT MAY/JUNE 2008)

Waste Composition	Olusosun	Abule-Egba	Solous
Combustibles, %			
Textile	3	6	2
Wood	2	1	4
Plastic/Nylon	22	18	30
Rubber	18	27	25
Leather	25	23	21
Total	70	75	82
Non-combustibles, %			
Metal	14	18	12
Glass	5	7	5
Grit (Stone)	1	0	1
Total	20	25	18

III. WASTE AND THE GHG EMISSIONS

By burning or burial, Greenhouse Gases (GHGs) are emitted. The most important GHGs in waste management are CO_2, CH_4, N_2O, and perfluorocarbons (PFCs). Of these, CO_2 is by far the most common (Box 1). Carbon dioxide emitted from waste disposal is not considered to represent a man-made source of greenhouse gas, because the process returns to the atmosphere, which has been stored as biomass. This may be contrasted with the burning of fossil fuels, where carbon is released back to the atmosphere after underground storage, as coal, oil or gas, for hundreds of millions of years. Consequently, the conversion of atmospheric carbon dioxide to atmospheric methane through the waste life cycle will have a man-made influence on the natural greenhouse effect, and global climate. Most CO_2 emissions result from energy use, particularly fossil fuel combustion [5, 6]. A great deal of energy is consumed when a product is manufactured and then discarded. This energy is used in the following stages: (1) extracting and processing raw materials, (2) manufacturing products, (3) managing products at the end of their useful lives, and (4) transporting materials and products between each stage of their life cycles. The energy consumed during use would be about the same whether the product is made from virgin or recycled inputs.

Methane, a more potent GHG, is produced when organic waste decomposes in an anaerobic environment, such as a landfill [7, 8]. One ton of biodegradable waste produces between 200 and 400 m^3 of landfill gas. Methane is also emitted when natural gas is released to the atmosphere during production of coal or oil, production or use of natural gas, and agricultural activities. Fifty per cent of landfill emissions, however, include methane, a more potent greenhouse gas. Global emissions of methane from landfilled waste have been estimated at approximately 40 million tons per year. In the UK, almost half the emitted methane comes from landfilled waste. N_2O results from the use of commercial and organic fertilizers and fossil fuel combustion, as well as other sources. Although the quantities of perfluorocarbons emitted are small, these gases are significant because of their high global warming potential.

EPA conducted a comprehensive study of greenhouse gas emissions and waste management. The study also estimated the life-cycle greenhouse gas emissions associated with managing a total of 23 types of waste materials: aluminum cans, carpet, clay bricks, concrete recycled as aggregate, copper wire, corrugated cardboard, dimensional lumber, fly ash, food discards, glass, magazines/third-class mail, medium-density fiberboard, newspaper, office paper, personal computers, phonebooks, plastics (HDPE, LDPE, PET), steel cans, textbooks, tires, and yard trimmings. In addition, the study included six mixed waste categories: metals, MSW, organics, paper, plastics, and recyclables. Management options analyzed in the study included waste prevention, recycling, composting, incineration, and landfilling

IV. THE GHG MITIGATION METHODS

A number of processes lead to *negative* fluxes of greenhouse gases (Fig. 3). These are as follows:

- Avoidance of emissions that would have been produced by other processes – for example:
  - Energy recovered from incineration avoids the use of fossil fuels elsewhere in the energy system;
  - Recycling avoids the emissions associated with producing materials recovered from the waste from primary resources; glass, plastics, ferrous metal, textiles and aluminum, recycling offers overall net greenhouse gas flux savings of between about 30 (for glass) and 95 (for aluminum) Kg CO_2 eq/ton MSW, compared with landfilling untreated waste. For these materials, the benefits are essentially independent of landfill standards and carbon sequestration.
  - Use of compost avoids emissions associated with the use of any peat or fertilizer that it displaces

- Recycling 1 ton of aluminum is equivalent to not releasing 13 tons of CO_2 into the air. The energy saved from recycling 1 glass bottle will operate a 100-watt light bulb for four hours.

- Carbon sequestration is particularly important for landfills where the anaerobic conditions enhance the storage of carbon. Carbon sequestration plays a relatively small role in the overall greenhouse gas flux attributed to composting, because of the relatively rapid rate of decomposition of the compost after its application to (aerobic) soils.

Common GHGs in Waste Management

Carbon dioxide- is released to the atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), and wood and wood products are burned. ***Methane-*** is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from the decomposition of organic wastes in solid waste landfills, and the raising of livestock. ***Nitrous oxide-*** is emitted during agricultural and industrial activities, as well as during combustion of solid waste and fossil fuels.

Greenhouse gases that are not naturally occurring include byproducts of foam production, refrigeration, and air conditioning and are called *chlorofluorocarbons* (CFCs), as well as *hydrofluorocarbons* (HFCs) and *perfluorocarbons* (PFCs) generated by industrial processes.

HFCs and PFCs are the most heat-absorbent. Methane traps over 21 times more heat than CO2, and N2O absorbs 270 times more heat than CO2. Often, estimates of greenhouse gas emissions are presented in units of millions of metric tons of carbon equivalents (MMTCE), which weights each gas by its GWP value, or Global Warming Potential.

Emissions of greenhouse gases associated with transportation of waste, residues and recovered materials are small in comparison with the much larger greenhouse gas fluxes in the system, such as those related to avoided energy / materials, landfill gas emissions and carbon sequestration [9]. Variations in emissions due to alternative assumptions about transport routes and modalities will therefore have a negligible impact on the overall greenhouse gas fluxes of the waste management options. Reductions in greenhouse gas fluxes (to about –490 kg/CO_2/ton) could be achieved through investment in recycling, incineration and Mechanical Biological Treatment (MBT). Alternatively, a scenario with no incineration and maximum biological treatment of waste achieves an overall greenhouse gas flux of –440 kg CO_2 eq/ton.

V. THE ZERO WASTE CONCEPT

Global emissions from landfills are projected to increase from 340 Tg CO_2 eq in 1990 to 1500 Tg CO_2 eq by 2030 and 2900 Tg CO_2 eq by 2050 in a baseline scenario. A far better approach is known as Zero Waste, which aims to close the loop on all material used in the economy. Under Zero Waste, each element of a source-separated waste stream is subjected to minimal treatment so that it can be reused. Clean, source-separated organics (including kitchen discards) are composted or subject to anaerobic digestion; Reusable wastes are repaired and re-used; other materials are recycled. However, a small percentage cannot be usefully recycled or composted. Zero Waste handles these materials by going upstream, requiring the redesign of manufactured goods to eliminate this small residual. A variety of policies, such as Extended Producer Responsibility, Clean Production, packaging taxes, and material- specific bans (such as plastic bags, Styrofoam, PCBs, etc.) have proven effective at reducing problematic materials in different locales. As the residual portion shrinks, the system approaches its goal of zero waste to disposal. Achieving Zero Waste is a process, and may take years but an attempt has to be made to sensitize the people on the advantages and long term gains. Australia and New Zealand are setting examples for the world.

VI. THE ZERO SUSTAINABLE WASTE MANAGEMENT AND CLIMATE CHANGE ACTION PLAN

Sustainable waste management should be the goal in reducing the GHG emissions. The components of this are illustrated in Fig. 3. For materials that require intensive primary processing, such as steel, plastic, and aluminum, recycling reduces emissions most significantly. In the Connecticut (USA), climate change action plan, listed 55 strategies. Of these, recycling (40 per cent of MSW) and source reduction (aims at 58 per cent) are in the top 10 priority actions.

In Nigeria, historically, reuse and recycling have been in vogue. However, these are in the informal sector. Every city has a recycle market. Kishi is noted for its Aluminum recycling. Many roadside plastic recyclers have emerged who collect, clean and grind or convert plastic waste into pellets for reuse in industry. A slaughterhouse recycles all the waste generated and the bones find their way to Texas in USA. There has been practically no encouragement or support from the Government. A few examples of local technologies are evident from Ibadan, Akure, Forcados, Minna and other areas. Here the concept of waste recycling was introduced. But the major constraints have been lack of infrastructure, commitment in Government circles and continuity and sustenance [10, 11, 12, 13, 14, 15, 16]. Several factors particularly the human component is very vital in the sustainability. This needs to be addressed with added incentives and rewards. The global concept of “Carbon Credit” schemes are yet to take off in Nigeria on a large scale though a lot of talk has been made in recent years.

Figure 3. Sustainable Waste Management and GHG Mitigation Strategies

VII. CONCLUSIONS AND ECOMMENDATIONS

A landfill dominated strategy is no longer acceptable for biodegradable wastes, leading to a change in culture with greater emphasis being placed on treatment options further up the waste hierarchy. Generally, the least favorable environmental option in terms of potential climate change emissions is landfill. Under Nigerian scenario, advanced waste management technologies being tried in other developed nations will not be practicable. For example, MBT, Autoclaving, Advanced Thermal Treatment, gasification at higher temperatures (800 to 1200 ^{0}C) are not feasible at this stage of development. As the International Panel on Climate Change (IPCC) has stated, increased composting of municipal waste can reduce waste management costs and emissions, while creating employment and other public health benefits. Yet the waste industry does not use these technologies particularly in developing African countries. There is therefore need to develop programs to sensitize and sustain the waste management concepts among communities through media and established models through:

- Practice segregation at source through source separation involving communities;
- Reduce waste production through unnecessary packaging, and adopting practices that reduce waste toxicity.

- Reuse materials through reusable products, maintenance and repair of durable products, reuse of bags, containers, and other items, by borrowing, renting, or sharing items used infrequently, and selling or donating goods instead of throwing them out.
- Recycle waste trough choosing recyclable products and containers and recycling them, selecting products made from recycled materials, and composting organic components (yard trimmings and food scraps). Small scale composting involving communities and farming populations is a viable strategy.
- Bring dumpsite scavengers into mainstream waste management strategies and encourage them to collect recyclables from generation sites;
- Institute outlets for buying of recyclable wastes in every community with job creation or entrepreneurial development schemes.
- Approach waste management through community structure and encourage at various levels: individual, household, community, LGA and State.

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Mynepalli Sridhar was born on 8th December 1942 in Vellatur, Andhra Pradesh, in India. He obtained BSc in chemical and biological Sciences and went for MSc (Biochemistry with Fermentation chemistry specialty) at MS University, Baroda, India. He obtained PhD from Indian Institute of Science, Bangalore, India, worked on wastewater treatment for 13 years years before moving to University of Ibadan, Ibadan in 1977.

His research projects ranged from water resources, eutrophication and pollution control, water treatment, low cost wastewater treatment, Phytotechnologies, waste management, environmental toxicology, and community mobilization. Developed waste to wealth projects since 1980s particularly compost and organo-mineral fertilizers, biogas for communities using stakeholder approach. He established several pilot scale or demonstration projects on waste to wealth which include organic fertilizer, plastics recycling, biogas, smokelsss charcoal/biochar and several other innovative processes in communities.

Professor Mynepalli Sridhar was a consultant to UNDP, UNICEF, World Bank, several NGOs and Government bodies and agencies. Traveled extensively and visited several waste management facilities in India, Switzerland, Sweden, Finland, Denmark, and USA. Trained various categories in environmental field and published over 400 scientific papers in books, journals and Technical Reports. He was awarded 'Outstanding Researcher Award 2016' by the College of Medicine, University of Ibadan.

Taiwo Babatunde Hammed was born in November 23rd, 1974 in Saki Oyo State, Nigeria. He has bachelor degree in Environmental Management and Toxicology from the University Agriculture, Abeokuta, Ogun state and a master degree in Public Health (Environmental Health) from the University of Ibadan, Nigeria. Currently, he is a lecturer in the Department of Environmental Health Sciences, University of Ibadan.

He has worked in different capacities with NGOs that deal with environmental sanitation and management since 1998. In conjunction with Prof M. K. C. Sridhar, he has taken part in various consultancy services for national and international organizations. Among these are: World Bank- assisted National Malaria Control Programme (NMCP) in Nigeria, Abidjan–Lagos Corridor Organization supported by the World Bank and UNAIDS and various biogas and smokeless charcoal plant installation and hands-on- training across the country, including the university of Ibadan.

Dr. Taiwo Babatunde Hammed was Netherlands Fellowships Programmes (NFP) award winner for UNESCO-IHE online course on Solid Waste and Engineering (2008) and short course on Solid Waste Management (2011). Dr. Hammed received Roy F. Weston Award, Widener University, Philadelphia, Pa, USA, 2016 in recognition of his contributions to the field of Solid Waste Technology and Management. He is currently undertaking a Post-Doctoral Fellowship at University of Nairobi, Kenya. His research interests span areas such as: solid waste recycling, renewable energy and climate change. He has published in both local and international journals.