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Composting as A Sustainable Waste Management Technique in Developing Countries

Adewale M. Taiwo
Department of Environmental Management and Toxicology, University of Agriculture, P.M.B 2240, Abeokuta, Ogun State

ABSTRACT

Attaining sustainability in waste management requires an option that employs environmental friendliness. Such a technique must be effective, efficient and less costly than many options. Solid waste management is an enormous task in developing nations all over the globe due to factors like poverty, population explosion, urbanization and lack of proper funding by the government. Disposal methods such as incinerator, landfill, pyrolysis and gasification are efficient but have negative impacts on the environment as well as threat to public health. Composting when properly handled is sustainable with various advantages such as production of biofertlizer, relatively low air and water pollution, low operational cost and income generation. The use of composting for bioremediation of contaminated soil has gained much ground in many developed countries of the world. However, composting when improperly designed could lead to methane production, odour emission and heavy metals build-up in the final product. Therefore, this study reviewed sustainability of composting and its numerous advantages over other waste disposal options in developing countries.

Key words: Sustainability, public health, disposal methods, bioremediation

INTRODUCTION

Solid waste management is the second most important problem after the water quality in developing countries all over the world (Senkoro, 2003). Most of the populace lack access to proper and routine removal of garbage (Awomeso *et al.*, 2010). According to UNEP (2002) and Doan (1998), disposal of solid wastes is a major issue of concern in less-developed nations due to population explosion, poverty and high urbanization rates combined with ineffective and under-funding by government to proffer efficient management of waste.

Factors such as waste composition, technologies and lack of infrastructure have been found to set apart the good management of solid waste in developing nations (Cointreau, 1982; Daskalopoulos *et al.*, 1998; UNESCO, 2003). Collection and disposal of waste differ from nation to nation and from community to community. For instance, in USA, the methods of disposal are landfill (true disposal) and incineration. In developing nations like Nigeria, the only feasible method of disposal is open landfills, which are set on fire seasonally. The resultant effect of this action is air pollution as well as leachate production (El-Fadel *et al.*, 1997).

Municipal solid waste can be defined as non-air and sewage emission created within and disposed of by a municipality (local government), including household garbage, commercial refuse, construction and demolition debris, dead animals and abandoned vehicles (Cointreau, 1982). USEPA (2003) observed that the majority of substances that are municipal solid waste include: paper, vegetable matter, plastics, metals, textiles, rubber and glass.

The wastes generated in communities are the reflection of their ways of life, wealth and culture (UNCHS, 1989). In developing nations certain medical and hazardous wastes streamed into municipal solid waste and may pose health risks to waste handlers and the general public. Waste generation in developing countries has average 0.4-0.6 kg/person/day against 0.7-1.8 kg/person/day in developed countries (Cointreau, 1982). Blight and Mbande (1996) observed that high density, large amount of organic content, small sized particles and large amount of dust and dirt characterize wastes generated in developing countries.

Composting is a biological process whereby regular introduction of air by mechanical turning stimulates aerobic microorganism to reduce organic materials such as manure to a more stable materials similar to humus (Rynk, 1992). It is a suitable way of recycling organic wastes in an environmentally friendly manner. As a result of the types, nature and compositions of waste in developing countries, composting remains the most economical and efficient management technique among other management options. In Nigeria, organic manure resources are no longer explored to its fullness (Sridhar and Adeoye, 1995) due to petroleum resources, which has 'slaughtered' the agricultural sector of the economy. In a country of over 140 million people, only four composting plants are functional: The pacesetter's organic fertilizer plant at Bodija, Ibadan (Oyo state); Ayeye community organic fertilizer plant (Oyo state); a food waste composting plant at Forcadoes, Warri (Delta state) and Lagos state compost plant, Ikorodu (Lagos state). The aim of this study is to highlight sustainable advantages of composting over other solid waste management techniques.

WASTE MANAGEMENT TECHNIQUES

Waste management is the collection, transportation, processing, treatment, recycling or disposal of waste materials to reduce their adverse effects on human health or amenities (www.wastewikipedia). Waste can be liquid, gas, or a solid substance and it is an unwanted material the owner is about to discard or has discarded. The management of waste in developing countries differs greatly from what is done in advanced communities and also from urban to rural and from residential to industrial settings. In developing country like Nigeria, there are less of metal and plastic wastes compared to high organic wastes (Cointreau, 1982). Problem of waste management in developing countries include: less effective garbage trucks, low technology and unplanned and haphazardly constructed sprawling slums with narrow roads (Cointreau, 1982). Political and economic framework is another major problem of waste management in developing countries. Non-hazardous residential and institutional waste is the responsibility of local government authorities in Nigeria. But the unholy sights of refuse, dirts, wastes, loitering our streets, highways and neighborhood a confirmation of inefficiency on part of the local government; even though they claimed responsibility of spending huge amount of money on waste related issues.

Table 1 shows the percentage of waste compositions in all the continents of the world. Food wastes carried the highest percentage followed by paper-cardboard and wood, respectively. The

Table 1: Percent waste compositions in all the continents

Continent	Food	Paper/cardboard	Wood	Textile	Rubber/leather	Plastic	Metal	Glass	Others
Asia	37.8	20.3	7.8	2.9	0.8	8.6	2.8	3.2	12.8
Africa	42.4	15.2	7.0	1.9	1.1	4.3	2.5	2.1	4.9
Europe	28.9	24.2	9.8	3.4	1.4	9.6	5.3	9.0	14.6
Oceania	51.8	18.0	13.3	-	-	-	-	-	-
North America	33.9	23.2	6.2	3.9	1.4	8.5	4.6	6.5	9.8
South America	45.2	15.9	6.7	5.2	1.5	9.1	3.5	4.2	3.2

Adapted from Inter-Governmental Panel on Climate Change (2006) type of waste management techniques that should be applied for proper management of waste depend on the composition of waste. Although, composting will be appropriate for all organic wastes: wastes such as plastic, metals and glasses are better handled through recycling.

Waste management techniques take place in many ways viz., landfill, incineration, pyrolysis and gasification, composting and anaerobic digestion.

Landfilling: Landfilling is an economical method of wastes disposal in developing countries involving pitching refuses into a depression, abandoned, mining void, excavated land, or borrowed pits (Daskalopoulos *et al.*, 1998). It is the most traditional way of true waste disposal practiced in many countries. The following are various forms of landfills:

Open-dump system/ordinary landfill: This disposal of waste materials is in pits, excavated lands, canals, sloping landscapes or flat surface without covering the waste. From time to time, open dumps burn leading to air pollution. Other environmental implications of landfill are the site's eyesore, windblow of litters along the landscape, presence of faecal matters, intrusion of vermin such as mice and rats, odor, smoke with resultant effects on human health and breeding ground for disease vectors (cockroaches, flies and mosquitoes).

Sanitary landfill: This engineering means of disposing solid wastes uses thin layers, compacted into the smallest practical volume and cover with inert ash at the end of each working day. Environmental effects of sanitary landfill are production of Landfill Gases (LFGs), leachates and leaving heavy metals. LFGs are produced when methanogens are decomposed primarily into methane (CH_4) and carbon dioxide (CO_2) and other gases such as carbon monoxide (CO), nitrogen (N_2), alcohols, hydrocarbons and organo-sulfur compounds (El-Fadel *et al.*, 1997). CH_4 and CO_2 are green house-gases (Seo *et al.*, 2004; Johannessen, 1999). Leachate production is a phenomenon in sanitary landfill and is one of the major problems unless a collection system is designed. Leachate could contain high levels of nutrients (nitrogen, phosphorus and potassium), heavy metals and toxins like cyanide and dissolved organics (El-Fadel *et al.*, 1997). Leachates may infilterate into groundwater resource and pollute it thereby leading to public health problems (Adekunle *et al.*, 2007; Orebiyi *et al.*, 2010). Heavy metals in plants and animals could be deleterious to health. Other potential problems of sanitary landfill are high cost of designing, loss of biodiversity and impact on landscape.

Secured landfill: This landfill is constructed mainly for hazardous wastes disposal such as hospital and radoiactice wastes. If it is not designed properly, the resultant effect could be similar to that of a sanitary landfill.

Incineration: Incineration refers to high temperature combustion of waste in a high-efficiency furnace to produce steam and ash (EPA, 1995). The benefits of incineration are a major reduction in waste volume and production of energy in form of electricity and heat production (Seo *et al.*, 2004). However, the problems of waste incineration cannot be overemphasized in the light of the following: construction and start up costs of facilities, which could be too expensive for developing countries (Rand *et al.*, 2000); acid gases production (sulphur oxide (SO_x), hydrochloric acid (HCl), nitrogen oxide (NO_x)); ash management; non-combustible waste such as metals and toxicants like metals ((lead (Pb), mercury (Hg)), organics (dioxin, polychlorinated biphenyl), CO and dust (UNEP, 1996).

Pyrolysis and gasification: These are methods for managing wastes by heating under controlled conditions to produce low to medium heating fuel gases, tars, char and ash; under a high temperature with limited oxygen (Heimlich *et al*., 2005). Usually, the process takes place in a sealed vessel under a high pressure. Whereas pyrolysis converts the solid wastes into solid, liquid and gas products, gasification converts organic materials into a syngas (CO and H_2). In Nigeria, pyrolysis is used to convert wood to charcoal that is used for domestic cooking. The effect of pyrolysis to the environment is loss of biodiversity, desertification and emission of acid and green-house gases. Generally, the use of pyrolysis and gasification for waste management is uncommon in developing countries because of the expense of equipment. Another reason why pyrolysis and gasification may not be sustainable is the emission of green house gases during thermal treatment.

Composting and anaerobic digestion: Composting is a controlled method of using microbial organisms to decompose the organic fraction of solid waste (Seo *et al*., 2004). Solid wastes in developing countries are composed of over 50% organic materials (Hoornweg *et al*., 1999). Incineration of such waste is a waste of time whereas disposal in landfill will be a waste of resources. The only viable option to sustainably manage wastes in developing nations is composting because of the following advantages: lower operational cost (Airan and Bell, 1980), decreased water pollution, lessened environmental pollution and beneficial use of end products (Poincelot, 1974). Cointreau (1982) found that in developing nations such as Indonesia, Colombo and Sri Lanka, residential wastes are 78, 81 and 89% compostable, respectively. Waste compositions in different countries of the world are depicted in Table 1. Sustainable waste management should be employed to maximize wastes generation while maximizing the ability to reuse and recycle. In composting, a strategy of sustainable waste management is recycling of organic wastes to a useful and valuable end point. Composting as a waste management option has little record of operation in Africa, Latin America and in places where most of the facilities failed worldwide (UNEP, 1996). The failures were attributed to lack of understanding and maintaining biological conditions, high cost of mechanization, higher economic cost, poor presorting of incoming wastes and failure to understand market condition (Hoornweg *et al*., 1999).

In Nigeria and in other developing countries most of the composting plants have failed. For instance, nine out of eleven plants have been closed in India and eighteen out fifty-four facilities failed in Brazil between 1974 and 1996 (UNEP, 1996; Hoornweg, 1999).

Composting has been used effectively to remediate soils and sediment with hydrocarbons (Williams and Keehan, 1993). Beaudin *et al*. (1996) found that 73% PAH was degraded by composting. Barker (1997) and Chaney *et al*. (2001) reported that explosive-contaminated soil, toxic organic compounds, metals in organic residues, wastes and by-products were remediated successfully through composting. The use of composting accelerates destruction of contaminants (Briggs *et al*., 1998). However, problems like heavy metal accumulation and health hazards related to pathogen (Anid, 1986) cannot be found wanting in this method despite the numerous advantages. These problems can be circumvented through proper wastes sorting at the source, addition of lime (reduces heavy metals availability) and proper compost maturity (Petruzzelli, 1989; Ciavatta *et al*., 1993).

INTEGRATED WASTE MANAGEMENT

Arowolo and Sridhar (2005) defined Integrated Waste Management (IWM) as the selection and application of techniques technologies and management programmes to achieve specific wastes management objectives and goals. IWM can also be defined simply as the combination of all the waste management techniques in order to minimize waste generation. The waste hierarchyin IWM

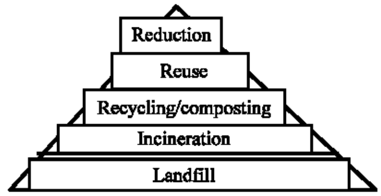

Fig. 1: Integrated waste management hierarchy (Heimlich *et al.*, 2005)

includes reduction, reuse, recycling, incineration and landfill (Fig. 1). The list starts with reduction meaning using less and re-using more in order to safe materials production, resource cost and energy. At the bottom of the list lies the ultimate disposal, which is the final resting place of wastes.

Waste recycling through collection, scavenging and processing with a high proportion of reuse is an efficient IWM. However, there is need to create markets and market incentives to encourage scavenging, recycling and composting. A reduction strategy is to lower the amount of wastes being produced, e.g., through surcharge of excess bags, containers, or household refuse in order to save energy, conserve resources and reduce waste stream volume.

A reuse strategy is to encourage the use of a product more than once either for the same purpose or for alternative purpose i.e., through donation to charity and reusing packaging. The third is material recovery, which has to do with composting and recycling. It entails reprocessing of waste material into either same form as the original or into other different products (Heimlich *et al.*, 2005). The fourth is resource recovery, which has to do with incineration of waste and the use of heat for energy. Material recovery when combined with energy recovery often extends the lifespan of incineration. The ultimate disposal is the last option in IWM in which residuals from other processes and material that can't be recoverable are disposed off in landfills.

Since, municipal solid wastes in developing countries have a large portion of organic materials (Awomeso *et al.*, 2010), composting could be seen as best sustainable option that would reduce waste volume. Notwithstanding, it is just a subset in IWM, which encompasses other waste management techniques. Scavenging of landfills and open dumps, a common phenomenon, helps in salvaging materials that could be sold in the recycling market. According to Kasseva and Mbulgwe (2000), there is a high demand for scavenging materials.

No single approach can apply completely to waste management due to waste and community diversity. Therefore, every waste management technique must be utilized fully in an environmentally sustainable manner. Composting in this case is sustainable and environmentally friendly and a viable technique.

COMPOSTING BIOREMEDIATION TECHNOLOGY

Composting has been used widely for remediation of organic contaminants as it accelerates destruction of contaminants (Buyuksonmez *et al.*, 1999; Williams and Keehan, 1993; Rao *et al.*, 1995). With proper aeration, water, C:N ratio and duration, composting can degraded various organic compound present in feedlot (Sikora, 1998). Strom (1998) reported a decomposition of organophosphate and carbamate pesticides during composting. However, organochlorine insecticides are resistant to degradation (Buyuksonmez *et al.*, 1999). Organochlorine insecticides have been banned in most countries.

Degradation of pesticides during composting depends on the pesticide and the substrate in which the pesticide is been co-composted along with (Baker and Bryson, 2002). For instance, a wood containing Polynuclear Aromatic Hydrocarbon (PAH) after composting for 61 days had PAH concentration greatly reduced. 1000 mg kg^{-1} of each PAH (phenanthrene and pyrene) was reduced to 26 mg phenanthrene kg^{-1} and 83 mg pyrene kg^{-1} (Baker and Bryson, 2002).

In the study of Raymond *et al.* (1997), paraffin wax-coated corrugated cardboard decomposed well during composting. In a similar manner, Williams and Keehan (1993) demonstrated a destruction of explosives on composting (trinitrotoluene and nitrocellulose). Soil contaminated with 212 mg kg^{-1} chlorophenols on composting recorded a level of 30 mg kg^{-1} within 48 weeks of composting (Valo and Salkinoja-Salomen, 1986). Hydrocarbon contaminated soil had been degraded on composting (Beaudin *et al.*, 1996).

Apart from organic contaminants where composting had been used extensively to bioremediate, composting bioremediation has also been demonstrated with inorganic contaminants (Chaney and Ryan, 1993). According to Pare *et al.* (1998, 1999), stabilized organic matter forms complexes with metals, thereby inhibit their mobility and the availability for plants sorption. However, composting may release metals from organic combination through organometallic complexes degradation and increasing metals bioavailability (Heyes *et al.*, 1998). Addition of lime to compost and increase in pH of compost could help reduce the availability of metals (Fang and Wong, 1999; Petruzzelli, 1989; Ciavatta *et al.*, 1993).

COMPOSITIONS OF COMPOST

Compost compositions will determine its quality. Addition of compost should not lead to soil pollution. According to World Bank (1997) compost must be of high quality such that no leaching or heavy metal uptake by plants can occur even under acidic soil conditions. Compost should be directed to develop and maintain soil structure, improve physical properties of soil, decrease soil-susceptibility to erosion, encouraging microbial activity as well as providing potentially available plants nutrients (Hesse, 1998). Richard (1990) and Walker and O'Donnell (1991), reported that compost quality is a major factor that could affect both societal acceptability and economic value of compost. The composition of some selected composts in various developed nations of the world is presented in Table 2.

The recommended C:N ratio of a good compost is between 25:1 and 40:1. Inappropriate use of wastes with high C:N ratio can lead to reduced soil fertility (Harris *et al.*, 2001).

ENVIRONMENTAL BENEFIT OF COMPOSTING

A properly managed compost operation promotes clean and readily marketable finished products, minimizes nuisance potential and is simple to operate (World Bank, 1996). There is a reduction in landfill space where composting is operated as waste management technique (He *et al.*, 1992, Awomeso *et al.*, 2010). There is also a reduced surface and groundwater contamination, which is a phenomenon in landfill. According to WHO, 900 million people experience diarrhea or contact diseases such as typhoid and cholera through contaminated water (WHO, 2008). Through composting waste blocking of rivers, canals, drainages could be reduced (World Bank, 1996). As a flexible waste management, composting enhances recycling of materials, low transportation cost. In composting there is a minimal emission of greenhouse gases with subsequent effect on climate change and global warming (Seo *et al.*, 2004). Moreover, addition of compost to soil reduces soil erosion as well as improvement of soil's structure, aeration and water retention. The use of chemical fertilizer could lead to groundwater pollution. But the use of compost discourages this water pollution.

Table 2: Chemical composition of some selected composts (on dry weight basis)

	Source					
Element	USA*	USA#	Italyβ	Spainγ	Franceδ	Netherlandδ
C (%)	27.00	33.80	39.50	28.40		
N (%)	1.30	0.51	1.78	1.40	0.90	0.96
P (%)	0.26	0.15	0.27	0.60	0.26	0.33
K (%)	0.97	0.14	0.07	0.70	0.25	0.27
Ca (%)	4.60	1.20		7.50	4.00	2.14
Na (%)	0.67	0.20			0.30	0.30
Mg (%)	0.60	0.08		0.50	0.30	0.17
Fe (%)				0.22		
Cl (%)					0.50	0.32
S (%)		0.20	0.2	0.20	0.60	0.32
Cu (mg kg^{-1})	100.00	200.00	422.0	200.00	250.00	630.00
Ni (mg kg^{-1})				0.76	190.00	110.00
Mn (mg kg^{-1})		300.00		500.00	600.00	400.00
Zn (mg kg^{-1})	1500.00	500.00	857.0	700.00	1000.00	1650.00
B (mg kg^{-1})				3.00	60.00	60.00
Hg (mg kg^{-1})					4.00	5.00
Pb (mg kg^{-1})			605.0	9.00	600.00	900.00
Cd (mg kg^{-1})		100.00	8.0	0.04	7.00	6.00
Cr (mg kg^{-1})			215.0	2.00	270.00	220.00

*Terman and Mays (1973). #Bengston and Cornette (1973). βPetruzzelli *et al*. (1985). γGonzalez-Villa *et al*. (1982). δDe Haan (1981)

CONCLUSION AND RECOMMENDATION

From this review, composting could be been as an option of waste management operation that is cheap, environmental friendly, wealth creating and sustainable. The technique has been used extensively for bioremediation of polluted soils and sites. However, composting requires proper handling and appropriate technology for its sustainability.

It is in this light that I will recommend that composting of organic wastes should be encouraged in all the developing nations of the world by the appropriate waste management authorities. This action will lead to waste reduction at landfill, job creation and production of organically produced food crops. Organic agriculture has continued to gain more ground all over the world for its sustainability and safety of the farm produce. The crops produced from this organic agriculture are expensive. But with the encouragement of compost fertilizer at high rate and low price to the farmers, the price of organic food could drop drastically.

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