Exploring the Resource Recovery Potentials of Municipal Solid Waste: A review of solid wastes composting in Developing Countries

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Abstract:

Population explosion, high urbanization and improved living standards have induced rapid changes in quantities and material compositions of solid waste generation globally. Until recently solid waste disposal in landfills and open dump sites was considered more economical and it is the most widely used methods in developing countries. Hence the potentials in the other alternative methods such as the resource recovery and recycling and their integration into waste management have been scarcely assessed. However, the ever growing challenges posed by the rapidly increasing quantities and compositions of solid wastes in developing countries led to the searching for alternative waste disposal methods. In this regard the paper presented an assessment of the resource potentials of municipal solid waste materials arising from cities in developing countries as a strategy for sustainable solid waste management. Using published data on solid waste composition the paper has identified that there is high potentials of composting in the solid waste stream from cities in developing countries. In conclusion, it recommended the recovery of organic waste material and papers for composting and the recycling of plastic, metals, textiles and others to explore their resource recovery potentials. This will largely reduce the ultimate quantities of solid waste for disposal and lower the operating costs. This strategy will achieve sustainable waste management in developing countries. It is hoped that the paper has provided a useful guide for wastes management policy decisions in developing countries.

Keywords: Resource potentials, Organic waste composting, Municipal solid waste composition, Sustainable waste management, Developing countries

Background

Rapidity of population, urbanisation and economic growths has increased solid waste generation rates and material composition (Guerrero, Maas & Hogland, 2013 in Harir, Kasim & Ishiyaku, 2014). Finding sustainable option of solid waste disposal remains a major challenge to waste management industry (Farrell & Jones, 2009). Thus, in most developing countries public authorities face the challenges to determine the appropriate option among alternative policies for sustainable solid waste management in cities. Gomez et al., (2011) observed that composition analysis is very essential to determine appropriate policy option for solid waste management in any city. Similarly, Dangi et al., (2011) emphasised that solid waste management policy should relate directly to waste composition. Thus, composition analysis should guide the choice of appropriate policy for solid waste management in developing countries.

Municipal solid waste management is an important issue worldwide (Chang et al., 2013). The disposal and management of municipal solid waste are a global challenge, especially in developing countries due to its adverse environmental effects (Butu, Ageda & Bichi, 2013). Public authorities in developing countries spend 20-50% of their annual budget on solid waste management, but services covered less than 50% of the population in the cities (Nzeadibe & Ajaero, 2010 and Kadafa, et al., 2013). In addition, Bhalla, Saini & Jha (2013) and Alagoz and Kocasoy (2008) observed that in developing countries, collection alone drains up 80-95% of the total expenditure on solid waste while in the advanced countries it costs less than 10% (Kadafa, et al., 2013). Therefore, a high public expenditure profile with low service output is a major constraint to efficient waste management in developing countries.

The shortcomings of solid waste management systems led to environmental reforms in many countries with remarkable advances in sustainable solid waste management (Ezeah, 2010). As Yuan et al (2006) in Zang et al. (2010) stated the United States, Japan, Sweden and Germany have achieved remarkable performance in waste recycling. However, in the developing countries, even though about 60% of the municipal solid waste stream compositions are compostable material composting is not formally integrated in urban solid waste management. Therefore, there is need to evaluate the resource potentials of composting organic solid wastes as a strategy for sustainable waste management in developing countries.

Compositions of municipal solid wastes from cities in developing countries

Most studies in cities of developing countries showed that the solid waste composition is high in organic materials and less of metal and plastic and other wastes (Cointreau, 1982). Forouhar & Hristovski, (2012), revealed a solid waste composition in Kabul city, Afghanistan is about 70% organic materials. In Asian cities, solid waste is 70 to 80% organic materials, dirt and dust (Narayana, 2009). A similar study in China (Zhang, Tan & Gersberg, 2010) showed solid wastes are about 60% organic material. In Dhaka, city of Bangladesh, municipal solid waste is 60 to 75% organic materials (Matter; Dietschi & Zurbrugg, 2013 citing Enayetullah et al., 2006). Zia & Devadas (2007) studied waste in Kanpur city of India found that wastes from households and institutions are mostly organic materials. A study of 28 urban centres also in India Asnami (2006) found high compositions between 48 to 54% of municipal solid waste are organic materials. In other studies Muniafu and Otiato (2010) found 75% organic waste in Kenya. Downmore et al. (2011) also found 47% of municipal solid wastes are organic materials in the Chinhoyi Town, Zimbabwe. In the Gaza strip solid waste stream is 52% organic and 13% papers (AbdAlqader & Hamad, 2012). Another study in Ghana, Robert & Reiner (2012) reported about 60% of the solid waste stream are organic materials. Many of the authors identified potentials in composting organic waste to produce compost manure or domestic energy as a sustainable waste management option. In Nigeria, studies showed similar results to these findings. Abimbola & Ipadeola (2000) found in the cities of southern Nigeria that 64% of waste generation are organic and biodegradable. Similarly, Cristina (2013) study residential solid waste in eight cities in Nigeria revealed that the average majority (about 57.5%) is organic materials. In a summary of data on waste composition for some cities across Nigeria Ogwueleka (2009) also revealed the mean fractions of organic materials is the highest (49.78%) and next is papers (12.79%) while other waste materials are relatively lower. The overview of published literature on municipal solid waste composition in this paper showed organic waste and papers which are both compostable materials constituted majority of the waste streams generated in cities of developing countries. However, government policy initiatives to encourage solid waste composting are virtually absent in developing countries.

Municipal Solid Waste Management in Developing Countries

Municipal solid waste includes waste from households, non-hazardous wastes from industrial, commercial, institutional sources such as markets, schools, street sweepings, and yard wastes (Schübeler, Christen & Wehrle, 1996). Solid waste management is the functions of collection, transport, processing, treatment and disposal of solid waste (Prasad et al., 2013 and Zia & Devadas 2007,

citing Robinson, 1986). Downmore (2011) identified five stages in the process, namely: generation, sorting, storage, collection, transport and disposal. Thus, solid waste management generally refers to the sorting, storage, collection and transport of discarded materials either for recycling or for final safe disposal usually in sanitary landfills. The term generally relates to the system of managing discarded materials generated from various land use activities within human settlements. Waste management, therefore, seeks to deliver clean, safe and healthy environment for human habitation. The primary objective of solid waste management is the protection of public health (Ross, 2013) and environmental safety. Schübeler, Christen & Wehrle (1996) elaborated further that the goals include: to protect public health and safety, promote environmental quality and sustainability, support economic productivity and employment generation. Therefore, solid waste management has a crucial role in human wellbeing and sustainable development. Poor management of solid waste can be a potential source of disease and infections. Aliyu, Kasim & Martin (2011) noted the potential risks to health associated with the exposure to hazardous materials, polluted air, and contaminated water are greater with residences location within the vicinity of hazardous waste treatment, storage, and disposal facilities (TSDFs) in Los Angeles County in USA. Many authors, (Downmore et al. 2011 and Ross, 2013) associated disease incidences with inefficient solid waste collections in Zimbabwe and India respectively. Similarly, Nzeadibe & Ajaero (2010); Kadafa (2012) and Nabegu (2010), also cited incidences of disease associated with poor management of solid waste in African cities. These include citations of incidences of disease from Nigeria (Stephens & Harpham, 1992; Ekugo, 1998 and Ogbonna et al., 2002); Ghana (Songsore & McGanahan, 1993) and Tanzania (Yhdego & Majura, 1988) respectively. Therefore, to ensure the safety of public health and the environment, efficient waste management must be maintained in the cities.

One of the challenges in developing countries is the lack of adequate provision of infrastructure and services including solid waste management. The management of municipal solid waste disposal is a global challenge (Butu, Ageda & Bichi 2013) which constitutes a growing concern for cities in developing countries (Bhalla, Saini & Jha, 2013). The efficient collection and safe disposal of wastes in cities are most important, but are seemingly the most difficult and expensive aspect of waste management in developing countries. In Asia, municipal solid wastes consume about US$25 billion per annum, and it is projected to cost about US$47 billion by 2025 (Bartone, 2000 in Pratap, et al., 2011). Therefore, it is a major component in determining the cost of waste management systems. Therefore, ineffective collection systems are cited in most cities of developing countries. In India, solid waste collection is less than half of the generating quantity in many cities (Jha, 2001in Agarwal, 2005) and in Dhaka city, Bangladesh between 40 to 50% is collected (Matter, Dietschi & Zurbrugg, 2013). According to Barton, Issaias, & Stentiford (2008) in Nairobi, Kenya only 25% of solid waste is collected. A study by (UN HABITAT 2001 in Barton, Issaias & Stentiford, 2008) in the cities of Accra, Kumasi, Tema, Tamale and Sekondi-Takoradi in Ghana found average waste collection rates is about 40%. Similarly, Achi (1993) in Bogoro & Babanyara, (2011) cited 25-40% of solid waste is not collected in Nigerian cities. Consequently, solid wastes are disposed into the drainages, streams or valleys, roadsides and other open spaces. All these disposal habits are potential sources of air, water and land pollution and also serve as agents of infections and disease. In a more comprehensive data (Table 1) United Nations, (2005) in Bogoro & Babanyara, (2011) showed the annual collection rates of solid wastes across regions of the world. In Africa, Asia and the Arab regions which constitute mainly of developing countries solid waste collection rates range from 36.2% to 67%, which is lower than (68.7%) the average collection rate for cities across the world. In the developing regions solid waste collection rates are far lower than generation rates.

Table 1 solid waste collection rates in regions of the world (Adapted: Bogoro & Babanyara 2011)

World Regions	African*	*Arab States	Asia*	Latin America	Industrial Nations	Transition Nations	All Cities Average
Waste Generation Tons/Cap/Year	0.27	0.28	0.29	0.30	0.51	0.49	0.35
Collection Rate %	36.2	64.9	67.0	84.8	99.4	91.4	68.7

***Constitutes mostly the developing countries**

In many developing countries open dump sites are the most common facilities provided by public authorities for solid waste disposal. Many Scholars (Bhalla, Saini & Jha 2013, Musingafi et al. 2014, Moghadam et al., 2009 and Saheri et al. 2009) cited open dump sites and landfill as the most common methods of solid waste disposal in developing countries. Wastes in the open dumps are subsequently burnt with open fire to reduce their volume and create space for more deposits. Disposal of solid wastes through burning in open dump sites are not sustainable from many perspectives. These include air pollution by smoke and foul odour emissions from wastes decomposing process and ground water pollution by leachate. In addition open dump sites constitute a potential health hazard and agents of infections and disease to scavengers and to the population residing within the vicinity. However, both surface and groundwater pollution created by landfill disposal can also be avoided through composting.

The benefits of solid waste composting

Composting is a controlled biological process that uses natural aerobic processes to increase the rate of biological decomposition of organic materials (Saheri et al., 2012). The process of composting simply involves the piling of organic materials such as food waste, leaves and others under suitable moisture and temperature which allows the materials to decompose naturally into humus within short periods of weeks or months.

There are numerous environmental benefits of waste composting as an alternative to disposing of waste in landfills and open dump sites. The emissions of GHGs in the atmosphere, particularly Carbon dioxide (CO_2) and Methane (CH_4) are responsible for the global warming which induced extreme climate events (Khatib, 2011). Extreme climate like drought conditions have severe consequences for crops and animal production, thereby affecting the majority of the rural population in developing countries who depend on agriculture as their main source of income. Similar studies (US EPA, in Batool & Chuadhry, 2009) cited landfills as the largest source of CH_4 in USA and Nabegu (2011) and Bhalla, Saini & Jha (2013) asserted that open dump sites are the major sources of GHG emissions. According to Adani et al. (2004) in Farrell & Jones (2009) waste composting produces about 82% less GHG emissions than untreated waste disposed in landfills. Therefore, waste composting has relevance in reducing GHGs emissions in developing countries because it can divert the large quantities of organic materials from the municipal solid waste stream flow in the regions.

Studies also revealed composting can reduce both air and ground water pollution by avoiding the large fraction of organic waste materials in developing countries (Table1) from ultimate disposal into the landfills. In addition, substituting of chemical fertilizers with compost manure in urban agriculture can reduce pollution of ground water by leachate (Downmore, et al., 2011). Kisner (2008) in Downmore, et al., (2011) reported the use of chemical fertilizers in urban agriculture in Harare resulted in the underground water pollution through eutrophication and leaching. The study recommended using compost manure in urban agriculture to mitigate the pollution effects. Babu et al., (2013) observed that leachates arising from urban solid wastes contributed to the high presence of pollution elements in groundwater around Andhrapradesh, area in India. However, Pratap, et al., (2011) observed that compost manure can be applied to restore nutrients in soils and maintain the sustainability of ecosystems. Similarly, Farrell & Jones (2009) stated that organic wastes are most useful in land remediation and restoration by compost manure which ameliorate soils with heavy metals or acidic substances. Another study by Taiwo (2011) stated that the use of composting for bioremediation of contaminated soil has gained much ground in many developed countries of the world and Nottidge et al. (2005) in Dania1, Fagbola & Isitekhale (2012) also observed that using organic materials such as plant residues, animal dung, mulch materials and sawdust improves the physiochemical properties of the soil and reduced environmental pollution. These views were further corroborated by Tuomisto, et al. (2012) study in Europe which showed that organic farming practices generally have positive impacts on the environment and organic farms have higher soil organic matter content and lower nutrient losses such as nitrogen leaching, nitrous oxide emissions and ammonia emissions per unit of field area.

Solid waste composting can reduce significantly the mass of solid wastes. Renkow et al. (1994) in Saheri, et al. (2012) observed that the loss of water and carbon dioxide through composting of organic waste material will typically reduce the volume by 25–60%. Solid waste composting also reduces the quantity of waste for disposal leading to lower operating costs (Guerrero, Maas & Hogland, 2013). The collection and transportation of solid waste for disposal represents a high fraction of the total cost profile of waste management in developing countries (Alagoz & Kocasoy, 2008). Therefore, the recovery and composting of the high fractions of organic solid wastes (Table 1) can have significant benefits on waste minimisation and in cost reduction. This implies composting has high economic potentials and hence very relevant in achieving sustainable waste management in developing countries.

Production of compost manure will reduce demand for chemical fertilizer and save foreign exchange and improve economic productivity in developing countries. The process of composting manufacture and marketing involved a chain of economic activities that will engage labour for production, sales and transport and others which will create employment and generate income. The use of compost manure as a substitute to chemical fertilizer will yield savings in production cost of agriculture and consequently improve farmer's income. This will enhance poverty reduction in developing countries considering that 70% of the world's poor earn their main income from agriculture; and the majority about 69% are from the least developed countries (World Bank, 2014). More so, improving agriculture is one of the most important ways to alleviating rural poverty (Khan, 2000).

In many developing countries (Glawe, Visvanathan & Alamgir, 2005 and Ezeah, 2010) solid waste composting is being practiced. Olowomeye (1991) observed in Nigeria that in many communities' solid organic wastes like yam peels, banana leaves and maize cobs were usually composted within the house and applied as fertilizer in farm gardens. However, the composting system by households is inadequate to realise the potentials in the huge quantities of organic solid wastes generated in Nigerian cities. For instance, Lewcock (1995) in Ezeah, (2010) stated that in Kano City, Nigeria, the potentials for composting solid wastes have not been optimally utilised. This situation may apply to many cities in developing countries.

The application of solid waste recycling and composting has huge economic potentials in many developing countries (ADB, 2002; Ahmed & Ali, 2004 in Ezeah, 2010). In addition, organic materials constitute the largest fraction (about 60%) of the municipal solid waste stream in developing countries and composting can largely reduce the quantity generated and lower the costs of collection, transport and disposal in the waste management. Many studies on solid wastes (Afon, 2007 and Kofoworola, 2007) also revealed numerous benefits of composting and recycling to the economy and the environment.

The recovery potentials of municipal solid wastes in Developing countries

The composition of municipal solid waste in developing countries showed organic materials and paper as the dominant factions across the world. This implied high potentials for composting in developing countries. Solid waste composting is the lowest costing, low technology, and less pollution impact and more environmentally acceptable method compared to the current system of waste disposals in open dumps as currently practiced in the developing countries. It also suggests composting is the most appropriate for organic materials and papers while recycling is the most suitable for others wastes materials like plastic, metals and glasses as found in the solid waste stream in developing countries.

Conclusion and Recommendations

Composting is sustainability in developing countries considering the numerous benefits such as production of organic compost, reduction of waste quantity for final disposal, reduced air pollution and ground water leachate and also creates employment and income and others. Composting is the most suitable for developing countries due to the low costing; low technology; low

pollution effect and it has more benefits to the environment and the economy when compared to the disposal of organic waste into open dumps as is widely practiced in developing countries. However, while composting is the most appropriate for the organic waste materials the other waste like plastics, metals, leather, textiles are best to be recycled. The huge organic materials and other recyclables in the total wastes stream compositions in addition to the numerous multiplier benefits of composting and recycling reviewed in this paper are evidence that high resource recovery potentials are inherent in the municipal solid waste stream from cities in the developing countries. However, to actualise the potentials, will require the compliment of appropriate government policy on composting and recycling in addition to an adequate public education on the need to mitigate poor waste management. Therefore, the paper recommended composting and recycling as a policy for sustainable waste management in developing countries.

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