International Journal of Development and Sustainability
Online ISSN: 2168-8662 – www.isdsnet.com/ijds
Volume 2 Number 3 (2013): Pages 1937-1952
ISDS Article ID: IJDS13062201

Sustainability of sanitary landfill management in sub-Saharan Africa: The case of Ghana

Kwaku Oduro-Appiah [1*], Thomas Atteh Donkor [2], Kwame Agyei Ampim-Darko [1]

[1] *Water and Sanitation Group, University of Cape Coast, Cape Coast, Ghana*
[2] *Local Government Service Secretariat (LGSS), Accra, Ghana*

Abstract

Investigations were conducted over a twelve-month period in 3 years on the operational strategy of the larger of the only two sanitary landfills and leachate treatment ponds in Ghana and sub-Sahara Africa. The purpose was to examine and evaluate the sanitary landfill and leachate stabilisation ponds against the backdrop of technically sound and sustainable management options. Routine operational observations, interviews and analytical examination of samples from the site call for a management classification of the sanitary landfill and associated stabilisation ponds as semi-controlled. While treatment efficiency within the various ponds is high, most parameters ($NO_3^-, PO_4^{2-}, and\ TDS$) do not meet the effluent requirements of the Environmental Protection Agency (EPA), Ghana, and the World Health Organisation (WHO) for discharge of treated leachate and blackwater into river bodies. The success of the management of the Kumasi Sanitary landfill and future landfills calls for sound planning and administration of the entire solid waste management system in the country and the sub-region. The management system must be based on integrated and sustainable principles that can deliver environmental, social and economic stability. It must begin with the appreciation of solid waste as a resource from which management cost can be recovered. The system must be funded innovatively according to the needs of the system and coordinated to protect human health and the environment. In all circumstances, practitioners and stakeholders in countries with developing economies must appreciate and comprehend existing waste management issues and find indigenous solutions that are appropriate to specific local situations.

Keywords: Sanitary landfills, Sustainable and integrated solid waste management, Leachate stabilisation ponds, Kumasi, Ghana, Sub-Saharan Africa, Developing economies

Cite this paper as: Oduro-Appiah, K., Donkor, T.A. and Ampim-Darko, K.A. (2013), "Sustainability of sanitary landfill management in sub-saharan Africa: The case of Ghana", *International Journal of Development and Sustainability,* Vol. 2 No. 3, pp. 1937-1952.

* Corresponding author. *E-mail address:* koduro-appiah@ucc.edu.gh, oduroak@yahoo.co.uk

1. Introduction

Sanitary landfills form an essential component of well designed Sustainable and Integrated Municipal Solid Waste Management (SIMSWM) systems. “They are the ultimate repository of a city’s Municipal Solid Waste (MSW) after all other Municipal Solid Waste Management (MSWM) options have been exercised” (UNEP, 1996). Globally, properly designed and operated landfills are the most cost-effective and environmentally acceptable means of solid waste disposal in areas where land availability is not an issue (ADB, 2002). Depending on design and management strategy, landfills are classified as open dumps, semi-controlled dumps, and sanitary landfills with facilities in most developing countries falling somewhere between open dumps and semi-controlled dumps (Warmer Bulletin, 2000; UNEP, 2002). While sanitary landfills are regarded as the last management option in most developed countries of the world, the open dump (uncontrolled landfill) has been the most preferred MSW disposal alternative available after solid waste is collected in countries with developing economies (Nartey et al., 2012; Mangizvo, 2010). These dumps make very uneconomical use of available land space; allow free access to waste pickers, animals and flies, and often produce unpleasant and hazardous smoke from slow-burning fires (Zurbruegg, 2002). Degrading waste in such dumps emits greenhouse gases. Toxic leachate pollutes subsurface and surface waters and enhances the risk of disease transmission to nearby residents (Eawag, 2008). Financial and institutional constraints have been the major reasons for the continuous use of open dumps in developing countries (Zurbruegg, 2003).

Ghana, as a developing economy, has had her own share of problems with solid waste disposal. The practice of open dumping has been and still is a dilemma for almost all communities in the cities and towns of the country (MLGRD and EPA, 2002; MLGRD, 2010a). Open dumps have been of environmental concern with respect to the nuisance they have created and continue to create. Uncontrolled landfilling, as a method of final disposal of solid waste, is environmentally and socially unacceptable as it does little to protect the environment and public health (McDougall et al., 2001). Open dumps provide very poor living conditions for waste pickers and pose current and future health risks. In addition, the cost of remediating these sites can easily exceed their total lifetime capital and operating cost. They are and have been the source of pollution to the very ground water systems used by most of the citizens. The repercussion of such management practices has been poor health. Sanitation inadequacies contribute to more than fifty percent (50%) of diseases in the country with attendant socio-economic costs (MLGRD, 2010b). Sanitation related diseases such as malaria, diarrheoa, dysentery, intestinal worms and acute upper respiratory tract infections have been among the most frequent health problems reported at outpatient health facilities in the country with seasonal epidemic outbreaks of cholera. Clearly, the practice of open dumping of MSW is neither integrated nor sustainable. It is neither environmentally friendly nor economically viable. The practice has become more challenging in recent times with rapid population growth and diminishing availability of disposal sites especially in urban centres of developing countries. A more sustainable and integrated approach has been the recommendation to phase out uncontrolled disposal and to progress to adopt and implement sanitary landfills in developing countries (McDougall et al., 2001; UN-HABITAT, 2010).

In order to reduce environmental degradation and risk posed by uncontrolled solid waste disposal sites, the government of Ghana, with assistance from the World Bank, under the Government’s Environmental Action Plan (EAP) and the Banks’ Urban Environmental Sanitation Project (UESP), has, since 2003, developed and adopted as a pilot project, properly planned sanitary landfill and leachate stabilisation ponds in Kumasi (Ghana's second largest city) and Tamale (MLGRD, 2010a). The implementation and practice of sanitary landfilling are severely constrained in countries with developing economies (UNEP, 2005). Such constraints fuel the perception that most sanitary landfills in sub-Saharan Africa finally end up either as semi-controlled or uncontrolled dumpsites. Lack of reliable information specific to these countries, limited technical, human, and financial resources have been cited as major reasons (EPA, 1998; UNEP, 2005).

This study assesses the management strategies of the largest amongst the only two operational sanitary landfills in Ghana and sub-Saharan Africa. The purpose is to critically examine the management strategy of the sanitary landfill ten years down the line and establish its classification scheme. It further seeks to investigate and evaluate the management strategy of the fill and ponds against the backdrop of technically sound and sustainable management options. The outcome is to guide decision-makers, practitioners, and all stakeholders to effectively and efficiently manage newly constructed sanitary landfills in Ghana and the West African sub-region.

2. Overview of Kumasi

Kumasi is the second largest city in Ghana, after the national capital city, Accra. It is located in the transitional forest zone and is about 270 km north of the national capital. It is between latitude 6.35°–6.40° and longitude 1.30°–1.35°. The metropolis is about 300 m above sea level with an area of about 254 km^2 and shares boundaries with Kwabre East District to the north, Atwima District to the west, Ejisu-Juaben Municipal to the east and Bosomtwe to the south. It has a minimum temperature of about 21.5° C and a maximum average temperature of 30.7°C. The average humidity is about 84.16% at 09:00 GMT and 60% at 15:00 GMT. The city has a double maxima rainfall of 214.3 mm in June and 165.2 mm in September. It has a population of 2,035, 064 with a growth rate of 2.7% (GSS, 2012). The growth of industries and the large volume of commercial activity in and around the metropolis account for high urban population (Asase et al., 2009). The Metropolis falls within the wet sub-equatorial climate and is traversed by many streams and rivers (Ghanadistricts, 2013).

3. Overview of solid waste management in Kumasi

The Waste Management Department (WMD) of the Kumasi Metropolitan Assembly (KMA) is responsible for the management of waste in the metropolis. The main management strategy has been collection, transportation and disposal of commingled municipal solid waste on dumpsites. Collection of MSW - largely undertaken by private contractors- has been house-to-house (HH) mostly in low-density, medium to high-income areas where compactor collection vehicles move from one house to the other collecting stored solid waste at least once a week at a monthly cost to service beneficiaries (Oduro-Appiah et al., 2013; Oteng-Ababio, 2011). The other mode of collection has been central communal container collection in highly populated low-income areas where skip trucks go in to hoist skip containers that have been placed at sanitary sites within the communities. Such containers are filled with waste by householders who cannot afford the house-to-house services. The frequency of collection here depends on the rate at which the containers become full. Collected MSW is transported over an average distance of 18 km to the sanitary landfill site.

The total available site area is 100 acres. About 60 acres of the available land area is covered by the existing sanitary landfill and circular leachate and blackwater stabilisation ponds. The ponds are arranged in parallel with four anaerobic ponds, one facultative pond and two maturation ponds. The existing sanitary landfill area is the first phase of three phases and receives a daily non-segregated municipal solid waste of 1000 tonnes. It has been in operation since 2003 and has been managed by a private contractor since 2006 on behalf of the Assembly. Any salvageable items are removed from the waste by 20 to 30 waste pickers operating at the site. The estimated monthly cost of operating the landfill is US$ 250,000, excluding the cost of land use and facility closure (Asase et al., 2009). Ghana government bears 95% of the landfill management cost. Industrial establishments are responsible to dispose of solid waste in their own terms. No waste transfer station exists in Kumasi. Waste recovery and recycling of metals, glass and certain types of plastics are carried out on a small scale by waste pickers. Plastic recycling companies hardly exist in the metropolis.

4. The concept of sustainability and sustainable development

Sustainable development is defined as “development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs” (WCED, 1987). The concept of sustainability and sustainable development has its origins as far back as 1798, when Malthus, an economist, argued that planet earth would not be able to sustain life with time if population growth and attendant consumption was allowed unchecked (Rogers et al., 2008). The concept however gained much significance in the late 20th century when the United Nations explored the connection between environmental quality and quality of life. Sustainable development embraces the idea of ensuring that future generations inherit an earth which will support their livelihoods in such a way that they are no worse off than generations today (Pearce and Atkinson, 1998). According to the CEE (2007), sustainable development requires the maintenance of balance between human need to improve lifestyle and felling of well-being on one hand, and the preservation of natural resources and ecosystems, on which current and future generations depend, on the other hand. The concept assesses the success of all developmental programmes in three components, namely, economic maximisation, environmental robustness, and social and cultural stability (Rogers et al., 2008).

Sustainable development is thus viewed as a three-dimensional model of development which addresses the need to sustain the environment, economy and society (Rogers *et al.,* 2008). Kajikawa (2008) describes the model of sustainable development as three pillars in which the pillars refer to the economy, the environment, and society. Obeng and Agyenim (2011) argues that a “sustainable system or development is one which satisfies environmental sustainability (the sustainability of the planet), economic sustainability (the sustainability of prosperity or profit) and social sustainability (the sustainability of the values and cultures of people)”. A sustainable integrated solid waste management (SISWM) option is one thus aligned to all three pillars of sustainable development where the three components complement each other towards the attainment of a sustainable outcome (McDougal et al., 2001; Rogers et al., 2008). It is a waste management system that best suits the society, economy, and environment in a given location. SISWM stands for a strategic long term approach that does not only take technical and financial sustainability into account as is conventionally done but it also includes socio-cultural, environmental, institutional and political aspects that influence overall sustainability of waste management (van de Klundert and Anschiitz, 2000).

5. Framework for sound and sustainable sanitary landfill management practices

The objective of sanitary landfilling is to minimise the adverse effect of solid waste disposal on the environment and public health (UN-HABITAT, 2010b). Lee and Jones-Lee (2011) recommend sanitary landfilling approach that provides for high degree of public health, groundwater resource and environmental protection. Two most important environmental quality and public health considerations in the design and operation of MSW sanitary landfills are the protection of the environment from pollution by green house gases and protection of groundwater from leachate contamination as long as the waste in the fill poses a threat to the environment (Lee and Jones-Lee, 2013). Globally, landfills account for almost 5% of green house gas emissions (WB, 2012). The installation of an active gas collection and treatment system coupled with the flaring and or use of landfill gas as fuel to produce electricity and thermal energy are essential measures of reducing its effect on the environment (ISWA, 2009). Compaction, daily covering of tipped waste with soil material, and control of the negative impacts on public health and the environment are three most important operational requirements of a sanitary landfill (UNEP, 2005; SPREP, 2010).

Ham (1999) recommends evaluation of sanitary landfills in five thematic areas, namely, aesthetics, groundwater protection, surface water protection, landfill gas and on-site workers health and safety. Sanitary landfills must be well planned to capacity with a well designed cell department (Tchobanoglous et al., 1993; UNEP, 1996). Daily operation must encompass the taking of records on type of waste, volume, and source. There must be regular inspection of all waste to the fill with supervisors ensuring compaction and daily covering (WB, 1999; UNEP, 2005). Confinement of the inspected and tipped solid waste to a small working face followed by compaction and daily covering to reduce odour nuisance and substantial leachate production rates are sound practices (UNEP 2000; ISWA, 2013). Groundwater and surface water must be protected from pollution by leachate by using single composite liner systems of at least 1m thick in addition to the adoption of a full leachate collection and treatment system. Lee and Jones-Lee (1998) however recommend a double composite liner system with a leak detection layer in between the two composite liners. They argue that such a double composite liner system will provide landfill managers enough time to exhume the landfill waste or install a leak-detectable cover that can be operated and maintained in perpetuity.

To promote long lifespan and leachate recycle as sustainable and sound operational procedures, only shredded non-recyclable solid waste must be deposited in the fill (Lee and Jones-Lee, 2011; Warith, 2003). Whilst strict prevention of the activities of waste pickers on cells of sanitary landfills is considered a sound option (Tchobanoglous and Kreith, 2002; Bagchi, 2004), there is an increasing advocacy for organised waste picking on landfill sites in developing and transitional countries since it is a source of livelihood to the urban poor and a vehicle to reduce municipal budgets and increase the lifespan of landfills (UN-HABITAT, 2010a). Bagchi (2004) also recommends the adoption of routine workers safety training and operational procedures on sanitary landfills with extensive protection. There must be a closure and post closure environmental monitoring for 30 years by the owners or operators of sanitary landfills (US EPA, 1991). This is to ensure that the integrity and effectiveness of the final cover, leachate collection and treatment systems, gas collection and management systems, and groundwater bodies are monitored and maintained. There have been arguments to the limited 30 year period of post closure monitoring since the tendency of the landfill to continuously pollute the environment over this period is viable as far as the waste in it poses a threat (Lee and Jones-Lee, 2005; Lee and Jones-Lee, 2012). They recommend the payment of tipping fees in a dedicated fund that will provide for the full cost of proper, reliable and protective management of the waste. It is estimated that such an approach could double or triple the cost of garbage disposal for generators of the waste, but it would more likely result in people paying the true costs for the disposal of the wastes they generate.

6. Materials and methods

6.1. Research design

The research was designed to investigate the management strategy and evaluate the performance of the Kumasi sanitary landfill and leachate stabilisation ponds against technically sound and sustainable management options. The evaluation was to determine whether the effluent discharges from the leachate and blackwater treatment ponds met the Environmental Protection Agency (EPA), Ghana and the World Health Organisation (WHO) guidelines for discharge of treated wastewater effluent into receiving water bodies. The performance and efficiency of the ponds were assessed analytically by means of laboratory tests on samples of wastewater taken from anaerobic, facultative, and maturation ponds. Of importance to the study was the need to fully establish how gas and leachate are managed so far as the waste in the fill remained a threat to groundwater resources and the environment.

6.2. Interviews, fieldwork and sampling

Interviews were conducted to obtain first hand information on the operations and maintenance of the sanitary landfill. The target respondents included the director of SWM, the landfill manager and the landfill supervisor. Focus group discussion was held with some selected private service providers and waste pickers on the landfill. The wide range of respondents was to ensure consistency. Questions were categorised into six lots and they ranged from history, planning, design, construction, finance, operations and management, workers motivation and safety, monitoring, to closure and post closure care and maintenance of the site. Information on leachate generation rates, method of collection, and pathway of leachate to stabilisation ponds were obtained. Liners used during construction as a barrier to prevent leachate from infiltrating to join groundwater was also sought. Laid down procedures for present and future gas management was also of major concern in the interview and discussion. The study also sampled and analysed leachate in the various stabilisation ponds during the dry (December-February) and rainy (April to June) seasons. Samples were collected at entry points to the three ponds (anaerobic, facultative, and maturation) once every month in accordance with protocols on sampling by APHA (Eaton and Franson, 1998). Another sample was, however, taken from the exit point of the maturation pond.

Two sets of samples were taken at each sampling point namely: 1500 ml samples for physico-chemical analysis and samples in a standard “OxiTop” bottle for analysis of oxygen demand parameters. All sampling bottles were thoroughly washed with detergent solution and rinsed with clean potable water and methylated spirit before sterilising them in an autoclave.

6.3. Analysis of samples

All samples were examined analytically in the Chemistry laboratory of the Kwame Nkrumah University of Science and Technology (KNUST) according to standard methods for examination of waste and wastewater (Eaton and Franson, 2005). In-situ measurements were done for pH and Total Dissolved Solids (TDS) using pH and TDS meters respectively. At each determination, the meters were calibrated before putting the electrodes in 100 ml samples to read the appropriate values on each meter. Analysis for nutrient parameters such as Total Nitrogen, Ammonia Nitrogen, Nitrate Nitrogen, and Total Phosphate were carried out within an hour by means of the Hach Nessler method on a Hach DR/2500 Spectrophotometer after sample collection to avoid sample deterioration. Corresponding indicator solution (Nessler reagent) for each nutrient was mixed with 25 ml samples after the appropriate stored programme for the nutrient has been entered on the Hach Spectrometer. The machine was zeroed with blank samples after which prepared samples were placed in cell holders to read displayed values. Biochemical Oxygen Demand (BOD) was determined by diluting portions of the sample and incubating for 5 days at 20°C. The BOD over the 5 days was determined as

$$BOD_5 = BOD \times D_1 \times D_2$$

where

BOD_5 = BOD recorded on the fifth day from the OxiTop
D_1 = Dilution factor
D_2 = Factor dependent on total volume of diluted sample put in OxiTop bottle

Chemical Oxygen Demand (COD) was determined by refluxing the sample in concentrated sulphuric acid with a known excess of potassium dichromate ($K_2Cr_2O_7$) for two hours. After digestion, the remaining reduced $K_2Cr_2O_7$ was titrated with ferrous ammonium sulphate to determine the amount of $K_2Cr_2O_7$ consumed and the oxidisable matter calculated in terms of the oxygen equivalent. Microsoft Excel (version 2007) was used to correlate measured physico-chemical, oxygen consuming and nutrient parameters with standard limits of WHO and EPA, Ghana.

7. Results, observation and discussion

7.1. Physico-chemical and oxygen demand data on wastewater stabilization ponds

Data on measured parameters from leachate and blackwater during the research study period are presented in Table 1 below.

Table 1. Average Physico-chemical and oxygen demand data for Kumasi landfill stabilisation ponds

Parameters	LHT	AP	FP	MP	WHO/EPA	% Removal
pH	8.31	8.05	8.17	8.17	**6.5-8.5**	
TDS (mg/l)	10,800	15,750	5670	5050	**1,000**	63.41
NO_3^- (mg/l)	2,376	7,152	2,880	252	**50**	96.46
PO_4^{2-} (mg/l)	251	1,128	290	246	**2**	96.48
NH_3-N (mg/l)	81	2117	551	390	**1**	81.58
BOD_5 (mg/l)	492	744	60	30	**50**	95.57
COD	3,840	26, 880	3,840	1,920	**250**	92.86

LHT = Leachate, AP = Anaerobic Pond, FP = Facultative Pond, MP = Maturation Pond, WHO = World Health Organisation, EPA =Environmental Health Association, Ghana

The pH of leachate emanating from the fill remained uniform throughout the sampling period with values ranging from 8.05 in anaerobic ponds to 8.31 in landfill leachate. Significantly higher concentrations of Total Dissolved Solids (TDS) in the Anaerobic Ponds (AP) are as a result of the mixture of blackwater and leachate. Blackwater is known to have relatively higher TDS, Ammonium-Nitrogen BOD_5, and pathogens (Tilley et al., 2008). With the exception of pH and Biochemical Oxygen Demand (BOD_5), all other measured parameters $NO_3^-, PO_4^{2-}, and\ TDS$ failed to meet the WHO and EPA, Ghana minimum effluent requirement for disposal of treated wastewater into receiving water bodies. The effect of this is that receiving streams and river bodies are likely to be polluted with nutrients to levels that may lead to eutrophication and growth of de-oxygenated dead zones in seas and oceans (UNEP and UN-HABITAT, 2010). The public health effect becomes more pronounced in areas where such water bodies are used by the citizenry. Lack of adherence to operational procedures of the stabilisation ponds may be a major reason to why minimum requirements are not achieved. The anaerobic ponds are hardly desludged, creating gas buildups and highly anaerobic conditions even in the facultative ponds. Oxygen is not able to diffuse into the ponds, preventing the efficient breakdown of biodegradable organics and probable nitrification and denitrification processes. Though there is a high performance efficiency of the various ponds with respect to nitrate and phosphorus removal, there may be the need to combine the maturation pond with algae and or fish harvesting to improve upon the effluent. Poor operational supervision and monitoring have led to the witnessing of drivers empting their cesspits in complete disregard to laid down rules and procedures.

7.2. Observational procedures on the sanitary landfill

Only registered companies and organisations with the WMD of KMA are allowed daily access to the site by security personnel stationed at the entrance to the fill from 6:30 GMT to 17:30 GMT. Ramps installed to enable the checking of the contents of the vehicles are rarely used. Electronic weighbridge installed to determine the weight of solid waste has experienced frequent breakdown over the years. Attendants estimate the weight of waste using the volume of refuse containers as a guide. Such estimations most often vary significantly from real weights with a resultant effect on reported available void space and lifespan of the fill.

Solid waste is tipped at the working face of the fill at no cost to generators and companies and pushed to spread by a bull dozer on the working face. Compaction of solid waste is not always a routine procedure due to continuous breakdown and lack of maintenance of the only steel-wheeled compactor which was provided as part of the investment cost on equipment by the World Bank. The compactor was used on other dumpsites in the metropolis even before the construction of the sanitary landfill. 300,000 m^3 of stockpiled soil cover is 300m from the working face of the fill but inadequate funds to transport and spread it have left the landfill to go uncovered for years (figure 1). Gravel seams initially constructed to enable the future flaring of landfill gas has been covered up with waste without the continuous construction thereof as waste is placed within the cells (figure 2). The effect of this practice and or negligence is that there may not be an escape route for future gas build-up with the potential danger of gas explosion and fires on the fill. Leachate from the fill is treated together with blackwater in wastewater stabilisation ponds on site.

Samples analysed have shown that not all expected effluent requirements are attained. Manholes for leachate monitoring are hardly checked. Scavengers on the fill are not organised and they put themselves to public health risk of heavy machines and sanitation related diseases. They search through tipped waste with bare hands and no safety and protective gadgets. Their main waste of preference has been metals and plastic. 32 workers on site hardly enjoy any form of in-service training on the management of the fill and this has had a negative bearing on their output. Most workers do not understand the basic principles of landfill procedures and their effect or otherwise on the environment. The landfill manager however reports monthly on the total tonnage of waste and cesspit emptiers' to the site. The lifespan of the first phase of the fill, according to the operations and maintenance manual, is 5 years which happened to be 2008 but it is still in use as of now without the construction of the second and third phases. Though there exist an extensive and thought through closure and post closure care for the fill, there is no guarantee that laid down procedures will be followed (O and M, 1999).

Figure 1. Uncovered tipped solid waste within cells of the Kumasi sanitary landfill

Figure 2. Seams for future flaring of gas covered with solid waste

7.3. Sound management of the Kumasi sanitary landfill

Inadequate managerial and funding capabilities have been the main constraint to sound management of the Kumasi sanitary landfill. The main financier of landfills in Ghana and other solid waste management activities has been the central government through the Ministry of Local Government and Rural Development and other project specific interventions by development partners with more than 80% of service beneficiaries (mostly within the middle-income to low-income bracket) paying no user fee towards the financial sustainability of the system (MLGRD, 2010c). Inadequate funding for capital investment and poor cost recovery capabilities have always been a frequent challenge to waste management authorities in Ghana and other countries with developing economies (Asase et al., 2009). In many instances, the single largest impediment to efficient and environmentally sound handling of MSW has been managerial, rather than technical (UNEP, 2005). Improving the operational and management capabilities of individuals and organisations involved in MSWM at the local level will be a sustainable practice. According to Antipolis and Ogawa (2000), strengthening the operational and management framework of institutions involved in solid waste management has a strong correlation to financial sustainability.

The current system of waste management in cities of developing countries where substantial portions of commingled waste is collected and transported to the landfill site for disposal is neither environmentally friendly nor socially acceptable. It comes with huge unsustainable environmental and financial burdens. A more sustainable approach will be the need for solid waste practitioners to adopt an integrated solid waste management system where all types of MSW and all facets of the waste management process are considered together (EGSSA, 2009). A bigger technical picture of sustainable integrated solid waste management (SISWM) whereby waste minimisation; source separation; hygienic storage, efficient collection, transfer and transportation, composting, recycling, incineration and sanitary landfill disposal would complement each other in an economically viable, socially acceptable, and environmentally friendly manner will be a sound option (McDougall et al., 2001). Such a SISWM system will be aligned to the three pillars of sustainable development and all three components (economic minimisation, environmental robustness, and social and cultural stability) will complement each other towards a sustainable outcome (Roger et al., 2008).

The necessity of reducing the level of emission and the cost of managing the Kumasi sanitary landfill and other landfills in countries with developing economies calls for a comprehensive review of the state and category of solid waste that ends up in them. Solid waste practitioners in Ghana and the West-Africa sub-region must adopt an integrated solid waste management system where source separation of waste into various components will play a central role. The source separated materials will readily make available necessary raw materials for informal and formal recycling and composting. A relatively small portion of generated solid waste in addition to the inevitable by-products of composting and recycling will eventually end up on landfills. Separation of organic waste from the MSW stream represents an opportunity to reduce the quantity of waste entering landfills in developing countries by up to 50% by weight (McDougall et al., 2001; van de Klundert and Anschiitz, 2001). The practice will increase the value of MSW and promote cost recovery schemes in addition to prolonging the lifespan of the landfills. Such practices will definitely bring about employment and environmental sustainability. In all scenarios, waste management authorities and stakeholders must adopt a good system management that considers an overall approach to solid waste management with vision and sustainability. Such a system must be developed with well defined short-term to long-term goals and laid down strategic framework for the attainment of set goals.

Waste management practitioners must encourage and promote research that can make basic data available to enable effective planning and monitoring of the system. Politicians may need to develop and implement a framework that provides technocrats with a free hand in making critical waste management decisions without fear of victimisation and interference. Furthermore, all metropolitan and municipal staff including management staff should be paid-employees other than appointed staff by government.

Beneficiaries of MSWM services must be made to pay social or economic fees to offset some of the financial burden of management on municipal governments. Willingness and ability of beneficiaries to pay for solid waste collection services towards financial sustainability have been established in Ghana (Oduro-Appiah et al., 2013; WB, 2010). International financial institutions, developing partners and donor agencies and their governing boards must look again at their policies, particularly at the insistence on international standards as a condition for financing solid waste management investments. Management of modern sanitary landfills to donor standards is most times well beyond the capacity of municipalities in developing economies leading to the eventual reversions of such fills to open dumps. Even where some success has been achieved with management, the maintenance and continuous construction and sustainability of the investment become a daunting task. In all scenarios, solid waste management staff, technocrats, and financial institutions must strive to appreciate and understand existing waste management issues and find indigenous solutions that are appropriate to specific local situations (UN-HABITAT, 2010a).

“The success of any sanitary landfill depends largely on its management (UNEP, 2000). The efficient and effective operation of landfills will depend on the soundness of the planning, administration, and management of the entire MSWM system. There must be in place an institutional and policy matrix that considers MSWM as an important component in the sustainable development plans of a country. The system must go with funding that is driven by the needs of the system rather than political expediency. It should then end with the coordination of MSWM programs, from waste reduction and resource recovery through source separation, collection, transportation and transfer, and eventual disposal into an integrated and sustainable system. Such a system must be pursued to always provide a vital public service at no cost to public health and the environment.

8. Conclusion

This study has clearly established that the Kumasi sanitary landfill is not managed on sound and sustainable practices. The engineered landfill can best be classified as semi-controlled other than sanitary. The very problem of open dumps to which the sanitary landfill was constructed to eradicate has been defeated. The landfill remains a threat to groundwater and surface water. Its current management strategy poses a serious environmental and public health concern to all in the Kumasi metropolis. The outsourcing of the management of the fill to private contractors has not lived to its expectation. There is no defined landfilling method in existence, no regular compaction of tipped solid waste, no daily cover, and no strict supervision of various activities. The stabilisation ponds for the treatment of leachate have been mismanaged. Despite the fact that the ponds themselves have high treatment efficiency, most parameters analysed d0 not meet the effluent requirements of the Environmental Protection Agency (EPA), Ghana, and the World Health Organisation (WHO) for discharge of treated leachate and blackwater into river bodies. Sustainable operation and maintenance procedures for future management of landfill gas have not been adhered to and there is no guarantee whatsoever that procedure for closure and post closure monitoring and care will be implemented. The construction of the second phase of the fill expected to be completed in 2008 has not yet been undertaken and there are no plans for its design in the next five years. The first phase of the fill has already exceeded its designed life span by five years. For the country and the sub-region to reduce poverty and improve upon growth and development, there is the urgent need for all stakeholders to critically evaluate current waste management systems and move towards more sustainable and integrated options.

Acknowledgements

The Waste Management Department (WMD) of the Kumasi Metropolitan Assembly (KMA), the Environmental Protection Agency of Ghana (EPA, Ghana), and the Chemistry Department of Kwame Nkrumah University of Science and Technology (KNUST), who contributed in diverse ways towards data collection and analysis t are all gratefully acknowledged. We are also grateful to two anonymous reviewers, whose diligent proof-reading and constructive criticisms contributed to improving the quality of this paper considerably.

References

Africa Development Bank (ADB) (2002), *Study on Solid Waste Management Options for Africa*, ADB, Abidjan.

Antipolis, S. (2000), *Policy and Institutional Assessment of Solid Waste Management in Five Countries, Cyprus, Egypt, Lebanon, Syria and Tunisia,* Blue Plan Regional Activity Centre, Valbonne.

Asase, M., Yanful, K.E., Mensah M., Stanford, J. and Amponsah, S. (2009), "Comparison of municipal solid waste management systems in Canada and Ghana: A case study of the cities of London, Ontario, and Kumasi, Ghana", *Waste Management*, Elsevier, Vol. 29 No. 2, pp. 779-786

Bagchi, A. (2004), *Design of Landfills and Integrated Solid Waste Management,* John Wiley & Sons, Hoboken, New Jersey.

Centre for Environment Education (CEE) (2007), *Sustainable Development: An Introduction,* CEE, Gujarat, India.

Eaton, A.D. and Franson, M.A.H. (1998), Standard Methods for the Examination of Water and Waste Water, American Public Health Association, Washington DC.

Eaton, A.D. and Franson, M.A.H. (2005), *Standard Methods for the Examination of Water and Waste Water*, American Public Health Association, Washington DC.

Environmental Guidelines for Small-Scale Activities in Africa (EGSSAA) (2009), *Solid Waste Generation, Handling, Treatment and Disposal*, The Cadmus Group, USA.

Ghana Statistical Service (GSS) (2012), *2010 Population and Housing Census: Summary Report on Final Results*, Government of Ghana, Ghana.

Ham, R.K. (1999), "International guidelines for landfill evaluation", *International Solid Waste Association (ISWA) Times*, Issue 1, pp. 22-3

International Solid Waste Association (ISWA) (2009), *Waste and Climate Change*. ISWA, Vienna, Austria.

International Solid Waste Association (ISWA) (2013), *Guidelines for Design and Operation of Municipal Solid Waste Landfills in Tropical Climates,* ISWA, Vienna, Austria.

Kajikawa, Y. (2008), "Research core and framework of sustainability science", *Sustainability Science,* Vol. 3 No. 2, pp. 215-239

Klundert, A., van de and Anschiitz, J. (2000), "The sustainability of alliances between stakeholders in waste management", working paper, WASTE, Advisers on Urban Environment and Development. Gouda, The Netherlands, 30 May.

Klundert, A., van de and Anschutz, J.M. (2001), *Integrated Sustainable Waste Management: The Concept*. WASTE, Advisers on Urban Environment and Development, Gouda, The Netherlands.

Lee, G.F. and Jones-Lee, A. (1998), "Assessing the potential of minimum subtitle D lined landfills to pollute: alternative landfilling approaches," paper presented at the 91st annual meeting of the Air and Waste Management Association, 14-18 June, *San Diego*, California, available at: http://www.gfredlee.com/Landfills/alternative_1f.html (accessed 23 March 2013).

Lee, G.F. and Jones-Lee, A. (2005), "Municipal solid waste landfill closure and post closure issues" available at: http://www.gfredlee.com/Landfills/SubtitleDFlawedTechPap.pdf (accessed 20 January 2013).

Lee, G.F. and Jones-Lee, A. (2011), "Solid waste management: US EPA lined-landfill approach not reliable for protecting public health and environmental quality", paper presented at the XI International Congress on Solid Waste Disposal and Environmental Perspectives, 24-26 August, Pereira, Columbia, available at: http://www.gfredlee.com/Landfills/Coomblandfillsupdate.pdf (accessed 5 March 2013).

Lee, G.F. and Jones-Lee, A. (2012), "Review of potential impacts of landfills and associated postclosure cost issues", available at: http://www.gfredlee.com/Landfills/Postclosure_Cost_Issues.pdf (accessed 5 March 2013).

Lee, G.F., and Jones-Lee, A. (2013), "Flawed technology of subtitle D landfilling of municipal solid waste", available at: http://www.gfredlee.com/Landfills/SubtitleDFlawedTechnPap.pdf (accessed 4 February 2013).

Mangizvo, R.V. (2010), "An overview of the management practices at solid waste disposal sites in African cities and towns", *Journal of Sustainable Development in Africa*, Vol. 12 No. 7, pp 233-239

McDougall, F., White, P., Franke, M. and Hindle, P. (2001), *Integrated Solid Waste Management: A Life Cycle Inventory*, Blackwell Science, Oxford, UK.

Ministry of Local Government and Rural Development (MLGRD) (2010b), *National Environmental Sanitation Policy (ESP)*, Government of Ghana, Accra.

Ministry of Local Government and Rural Development (MLGRD) (2010a), *National Environmental Sanitation Strategic Action Plan (NESSAP)*, Government of Ghana, Accra.

Ministry of Local Government and Rural Development (MLGRD) (2010c), *Strategic Environmental Sanitation Investment Plan (SESIP)*, Government of Ghana, Accra.

Ministry of Local Government and Rural Development (MLGRD) and Environmental Protection Agency (EPA) (2002), *Landfill Guidelines*, Government of Ghana, Accra

Nartey, K.V., Hayford, K.E. and Ametsi, K.S. (2012), "Analysis of leachate from solid waste dumpsites: a tool for predicting the quality of compost derived from landfills" *Journal of Environment and Health Science*, Vol. 2 No. 11, pp. 8-20.

Obeng, P.A. and Agyenim, J.B. (2011), "Institutional matrix for sustainable waste management", in Kumar, S. (Er.), *Integrated Waste Management, Vol. 1,* InTech, Croatia pp. 23-40.

Oduro-Appiah, K., Aidoo, D.O. and Sarbah, G. (2013), "Fee-based solid waste collection in economically developing countries: The case of Accra metropolis", *International Journal of Development and Sustainability*, Vol. 2 No. 2, (In Press).

Ogawa, H. (2000), "Sustainable solid waste management in developing Countries", available at: http://www.gdrc.org/uem/waste/swm-fogawa1.htm (accessed 2 May, 2013).

Operations and Maintenance Guidelines (O and M) (1999), *Proposed Sanitary Landfill and Septage Treatment Facility for Kumasi, Design Phase II*, Ministry of Local Government and Rural Development, Accra, Ghana.

Oteng-Ababio, M. (2011), "Governance crisis or attitudinal changes? Generation, collection, storage and transportation of solid waste in Ghana", in Kumar, S. (Er.), *Integrated Solid Waste Management*, *Vol. 1*, InTech, Croatia, pp. 3-22.

Pearce, D.W. and Atkinson, G. (1998), *The Concept of Sustainable Development*: An Evaluation of its Usefulness 10 Years after Brundtland, Centre for Social and Economic Research on the Global Environment (CSERGE), London.

Rogers, P.P., Jalal, K.F. and Boyd, J.A. (2008), *An Introduction to Sustainable Development,* Earthscan, London.

Secretariat of Pacific Regional Environment Programme (SPREP) (2010), A Practical Guide to Landfill Management in Pacific Island Countries, Vol.1, SPREP & JICA, Apia, Samoa.

Swiss Federal Institute of Aquatic Science and Technology (Eawag) (2008), "Global waste challenge", available at: http:www.eawag.ch/forschung/sandec/publikationen/swm/dl/Eawag_ Sandec_2008.pdf (accessed 12 February, 2013)

Tchobanoglous, G. and Kreith, F. (2002), *Handbook of Solid Waste Management*, McGraw-Hill, New York, NY.

Tchobanoglous, G., Thiesen, H. and Vigil, S. (1993), *Integrated Solid Waste Management: Engineering Principles and Management Issues*, McGraw-Hill, New York, NY.

Tilley, E., Luethi, C., Morel, A., Zurbruegg, C. and Schertenleib R. (2008), *Compendium of Sanitation Systems and Technologies,* Swiss Federal Institute of Aquatic Science and Technology (Eawag), Duebendorf, Switzerland.

United Nations Centre for Human Settlements (UN-HABITAT) (2010a), *Solid Waste Management in World's Cities*, UN-HABITAT, Malta.

United Nations Centre for Human Settlements (UN-HABITAT) (2010b), *Collection of Municipal Solid Waste in Developing Countries,* UN-HABITAT, Malta.

United Nations Environmental Programme (UNEP) (1996), "International source book on environmentally sound technologies for municipal solid waste management", available at: http://www.unep.or.jp/ietc/estdir/pub/msw/ (accessed 13 December, 2012)

United Nations Environmental Programme (UNEP) (2002), *Solid Waste Management*, *Vol. 1,* UNEP, Kenya.

United Nations Environmental Programme (UNEP) (2005), *A Directory of Environmentally Sound Technologies for the Integrated Management of Solid, Liquid, and Hazardous Waste for Small Island Developing States in the Pacific Region*, UNEP, Kenya.

United Nations Environmental Programme (UNEP) and United Nations Centre for Human Settlements (UN-HABITAT) (2010), *Sick water? The Central role of Wastewater Management in Sustainable Development*", UNEP & UN-HABITAT, Norway.

US EPA (1991), *Solid Waste Disposal Facility Criteria: Final Rule*, Part II, US EPA, Washington, D.C.

US EPA (1998), *Guidance for landfilling Waste in Economically Developing Countries,* US EPA, Washington, D.C.

Warith, M.A. (2003), "Solid waste management: new trends in landfill design" *Emirates Journal for Engineering Research* Vol. 8 No. 1, pp. 61-70.

Warmer Bulletin (2000), ''Landfill'', available at: www.resol.com.br/textos/wb72-IS(Landfill).pdf (accessed 8 January 2012)

World Bank (WB) (1999), *Observations of Solid waste Landfills in Developing Countries: Africa, Asia, and Latin America*, WB, Washington D. C.

World Bank (WB) (2012), "What a Waste: A Global Review of Solid Waste Management" Urban Development and Local Government Unit, World Bank, Washington D. C. , USA, pp.100

World Commission of Environment and Development (WCED) (1987), *Our Common Future*. Oxford University Press, United Kingdom UK.

Zurbruegg, C. (2002), "Solid waste management in developing countries", available at: www.eawag.ch/forschung/sandec/publikationen/swm/dl/Zurbrueg_2002 (accessed 6 November, 2012).

Zurbruegg, C. (2003), "Urban solid waste management in low-income countries of Asia: how to cope with the garbage crisis solid waste management in developing countries, paper presented at the Scientific Committee on Problems of the Environment (SCOPE), November 2002, Durban, South Africa, available at: http://slunik.slu.se/kursfiler/TN0280/20155.0910/Zurbrueg_waste_dev_.pdf (accessed 10 April, 2013).