LUMES

Lund University International Master's' Programme in Environmental Science

INTEGRATION OF MUNICIPAL SOLID WASTE MANAGEMENT IN ACCRA (GHANA): BIOREACTOR TREATMENT TECHNOLOGY AS AN INTEGRAL PART OF THE MANAGEMENT PROCESS

By

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ABSTRACT

The increasing solid waste generated in the Accra metropolis has not been accompanied with adequate sanitation facilities and management programs. Notable among the waste management problems is inadequate operational funding from the municipality's budget allocation for the collection and disposal processes. The disposal methods mostly depend on the obsolete dumping with the associated environmental and social risks. Recycling of waste that reduces the waste dumping has also not been effective.

With the problem of inadequate operational funding it is possible that the sanitary landfill under construction by the AMA may revert to a dump. This project however, is an opportunity to introduce the bioreactor waste treatment technology. This technology converts only degradable organic matter into useful fuel and reduces the environmental impact of organic wastes, and therefore not all the solid waste components are treated.

The integration of this technology with collection and supply for recycling and composting is therefore important in order to cater for other components. Three levels of integration are proposed here. One level is to link the collection of materials for recycling and composting with available markets. The waste collection is also to be integrated with the bioreactor treatment process. The third level is to bring the biological treatment facility, collection, recycling and composting programs in co-operation with the stakeholders (the management authorities, the public and the private investors). The underlying purpose of this study is to develop a conceptual methodology for MSWM strategies in Accra that demonstrates the ability to include social, environmental and economic compatibilities as the dimensions of a sustainable waste management system.

KEY WORDS:

Level of integration, Bioreactor treatment, sustainable solid waste management, waste collection

LIST OF ABREVIATIONS

AMA	Accra Metropolitan Assembly
BOD	Biological Oxygen Demand
CLD	Causal Loop Diagram
DFID	Department For International Development
EEA	European Environmental Agency
EKC	Environmental Kurznet Curve
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EU	European Union
ISWM	Integrated Solid Waste Management
WMD	Waste Management Department
LFG	Landfill gas
MLGRD	Ministry of Local Government and Rural Development
MSWM	Municipal Solid Waste Management
RCRA	Resource Resource Conservation and Recovery Act
UNCED	United Nations Commission on Environment and Development

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1 INTRODUCTION

1.1 Background

The high population and its associated increase in urbanization and economic activities in Accra, has made the impact of the society's solid waste very noticeable. The urban areas of Accra produce about 760,000 tons of municipal solid waste (MSW) per year or approximately 2000 metric tons per day (EPA, 2002). According to the EPA report, by 2025, this figure is expected to increase to 1.8 million tons per year, or 4000 metric tons per day. These are estimates and the real values are probably more than these quantities. According to the Government of Ghana (2003), the Accra Metropolitan Assembly spends about two billion Cedis per month (about $227,000) on waste collection alone and about 12 billion Cedis per year on urban solid waste management. This amount does not however cater for about 30 per cent of solid waste in the metropolis (EPA, 2002).

Johannessen and Boyer (1999) observed that the design and optimization of solid waste management technologies and practices that aim at maximizing the yield of valuable products from waste, as well as minimising the environmental effects have had little or no consideration in the Africa region. They also noticed that while there is potential for productive uses of landfill gas for instance, most landfills in Africa do not practice gas recovery except one landfill in South Africa where active pumping and flaring of landfill gas is practiced. These observations are not different in Ghana. At the national and municipal levels, Ghana has not taken steps to construct, operate, or maintain sanitary landfills. Johannessen and Boyer (1999) again found out that in the major cities of Ghana (Accra, Kumasi, and Takoradi) open dumps were the means of solid waste disposal. It is under the World Bank's Urban Environmental Sanitation Project that Ghana developed plans to build its first sanitary landfills in these three major cities (Government of Ghana 2003).

The inadequate information on quantification and characterisation of waste; health, social, economics and environmental impact of municipal solid waste management is a common occurrence in Ghana. The problem is only compounded by insufficient funding. The waste management system so far in Ghana has not properly integrated other solutions as collection, treatment, and supply for re-use, reprocessing and final disposal. The system has also not delivered the optimum economic and environmental result for now and has not provided enough room to adapt to future pressures (increases in waste quantities and composition). From the observations of the Ghana Landfill Guidelines (2002), municipal solid waste disposal practices in the country have not been environmentally friendly.

Problems associated with utilities such as water, electricity and communication services are treated with importance so that society may have clean and adequate water, constant energy flow at homes and offices and constant communication for effective business. Nevertheless, the problems associated with solid waste have not been handled in a similar manner. Röhrs et al (1999) identified that in addition to the low level of infrastructure in developing countries, waste management is perceived to be less important than the provision of other municipal services. “Waste management is one of the public infrastructure that is based on a specific type of physical infrastructure to provide the goods or services, and in this respect it resembles the electricity, natural gas, and water sector” (Dijkema et al, 2000). The problem of solid waste in Accra has been characterized by single and ad hoc solutions such as: mobilizing people to collect waste and desilt chocked gutters after a flood disaster or for an occasion; temporal allocation of waste collection contracts and damping or building a central solid waste composting plant. Read (2003) observed that solid waste is characterized by ready-made prescribed answers, with single-issue interest groups promoting a single solution, at the expense of others. The truth, he contended, is that no single solution can manage society’s waste adequately.

The AMA is also faced with the problem of land acquisition for citing landfills as residents reject the citing of this facility – the ‘Not In My Back Yard’ or ‘Build Absolutely Nothing Anywhere Near Anything’ attitudes (Morrissey and Browne 2004). This makes the siting of waste treatment facilities quite difficult. With the gradual exhaustion of ‘formal’ dumping sites at Mallam, Djanman and Oblogo, and the ever increasing waste generation in the Accra metropolis, the AMA saw the need for the development of a landfill to cater for the solid waste. However this landfill may be filled even before the estimated lifetime and may revert to a dump site if proper management system is not put in place. It is time therefore to establish a paradigm of waste management with a necessity of an integrated waste management system whereby collection/sorting, bioreactor treatment, recycling and composting of the municipal solid waste are incorporated. Read (2003) proposes that in practice solid waste management must combine many different methods based on an integrated system.

1.2 Objectives

This work is aimed at examining the municipal solid waste management system in the city of Accra Ghana, and to provide a basis for addressing some of the lapses through an integrated solid waste management approach incorporating biological or anaerobic waste treatment as one of the components.

The specific objectives are to:

- Examine current waste management practices in Accra.
- Identify problems associated with the current waste management system
- Access the suitability of biological waste treatment as a useful and potentially applicable method of handling the city’s waste.
- To recommend practices that will improve and yield benefits in municipal solid waste management process in the city.

1.3 Rationale for the studies

The rapid increase in volumes of unattended to solid wastes with the associated risk to human health is a source of concern. There is also a steady increase in the cost and logistical difficulties of municipal solid waste management. This has put increasing pressures on the infrastructure and authorities responsible for the management of solid waste. Landfill or dump spaces are diminishing and there is difficulty in finding suitable locations and getting public approval. Large investments are required for constructing the new landfill facilities. It is therefore prudent to look for and implement long-term integrated waste management strategies that ensure a sustainable approach for waste management services.

Also, the study is to provide an understanding of the fact that a substantial percentage of the urban waste in Accra is biodegradable and therefore potentially re-useable or re-cyclable for energy extraction. To convert the waste into useful resources, the appropriate technology and resources have to be employed. Dijkema et al. (2000) assert that waste is a subjective concept and that what is considered waste presently, may become a resource in the future because the 'waste' has not been put to its full potential use. Even in properly networked industrial set ups, the waste from one factory becomes the raw material of another. Therefore "the rearrangement and closing of material cycles, for example, opens the way to reduce landfills of wastes and contributes to the conservation of resources" (Dijkema, et al 2000).

Another rationale for the study is to elicit the fact that anaerobic treatment of the solid waste in Accra provides the optimum benefits to society and the environment. With the present system of dumping, organic waste has the potential to cause significant pollution through leachate production which can seriously affect water courses. Uncontrolled emission of methane gas to the atmosphere also adds to global warming and fire outbreaks. This dumping is also a source of transmission of pathogens to animals and soil as well as production of odours and flies. Thus anaerobic digestion of solid waste, which is an engineered process of solid waste management when practiced, can provide a range of benefits in addition to the valuable renewable energy from the biogas. These added benefits include: waste treatment, reducing pollution, odours and disease; recycling of nutrients back to the soil; reducing the spread of soil-borne pathogens due to the high temperature and chemical environment of the anaerobic digestion process (Wheeler, 2000). The anaerobic digestion's potential to become a major part of the waste management system is dependent on the value of the landfill gas as a source of useful energy, solid and liquid residues to agriculture and the environment. With these benefits, the logic for digestion over other techniques becomes superior.

1.4 Theory of waste management

In industrialised nations the waste management practices evolved with the 1970's focusing on reducing environmental impacts (Tanskanen 2000). This was done by creating controlled landfill sites (Read, 2003), establishing waste transfer stations or redirecting waste collection vehicle routes (Truitt et al. 1969). The 1980's and early 1990's focused on new technological solutions for waste management while the mid 1990's until today, the focus is on resource recovery (Read, 2003). In this regard recycling, incineration, composting and bioreactor treatment for energy and nutrient recovery methods are included in MSWM systems (Chang and Wei 1999 and MacDonald 1996a).

Changes in waste management policies in recent times have shifted waste management planning from reliance on landfill towards Integrated Solid Waste Management (ISWM) approaches (Read 2003). New directives/legislations are being promulgated in the EU and the US on waste disposal in the interest of the environment. Examples among them are; the January 1st 2003 increase in tax to 370 Swedish Kronor per ton of landfilled waste in Sweden (RVF 2003); and the 1993 United States' Resource Conservation and Recovery Act (RCRA) Subtitle D which requires landfills to be impermeably lined and equipped with leachate and gas collection equipment (Pacey, 1999). These policies and their enforcement have helped the developed nations in implementing the waste hierarchy; prevention, materials recovery, incineration and landfill. For instance the 1993 Government Action Plan on Waste and Recycling in Denmark set out to achieve targets of 54% recycling, 25% incineration and 21% landfill by the year 2000 (Sakai et al 1996). In the developing world however, poor enforcement or non-existence of waste management policies have resulted in the dependence on open dumping. Improvements in the area of constructing sanitary landfills in these regions have most often been supported by the World Bank and other bilateral donor agencies (Johannessen and Boyer 1999)

To achieve waste management objectives and abide by these policies, model or systems of waste management have evolved. These decision support models involve the use of methods and tools such as cost benefit analysis (CBA), life cycle analysis LCA and integrated waste management (Morissey and Browne 2004; Read, 2003). Waste management systems based on CBA usually convert all economic, social and environmental impacts into monetary terms (Berkhout and Howes 1997). In this case economic impacts are readily obtained by the cost of building waste management facilities and the revenues generated from such facilities. Social and environmental impacts are estimated by the cost of abating pollution from a waste treatment facility and or how much the public is willing to pay for an environmental improvement (ISO 14040: 1997). These estimations go into deciding which waste management option offers the best benefit and has been adapted in the Irish waste management plans (O'Sullivan 2001). Maximizing economic efficiency is usually the dominant factor in CBA at the costs of environmental and social criteria, which is not a sustainable approach to waste management (Morissey and Browne 2004).

Those waste management practices based on the LCA of products involve the "evaluation of the environmental aspects and potential impacts throughout a product's life from raw material acquisition through production, use and final disposal" (ISO 14040: 1997). Very recent waste management systems are concerned with the whole life cycle of products (Brorson and Larson 1999; McDougall et al., 2001) with the aim of making a complete assessment of the systems environmental impact. This approach is essentially for waste minimization as it affords the producers the opportunity to alternative production routes and waste reduction strategies (Berkhout and Howes (1997). LCA is however, a specific and technical environmental accounting process that is unable to deal effectively with social issues. Petts (2000) observes that LCA though covers environmental and economic sustainability does not consider social aspects such as health effect predictions and therefore, cannot be considered a sustainable waste management system.

Other waste management systems are based on integration of different waste management practices. The concept of integrated waste management developed by

McDougall et al. (2001) links waste streams, waste collection, treatment and disposal methods with the LCA concepts while aiming at achieving environmental benefits, economic optimisation and social acceptability. “For a waste management system to be sustainable, it needs to be environmentally effective, economically affordable and socially acceptable (Nilsson-Djerf and McDougall 2000). This point is buttressed by Petts (2000) who stressed that the best MSWM must be related to local environmental, economic and social priorities and must go further to involve the public before important waste management decisions are made. Social, environmental and economic compatibilities are therefore observed to be the dimensions of sustainable waste management models or strategies (Joos et al 1999; Morrissey and Browne 2004).

In this paper the proposed solid waste management concept is based on integrated waste management system that brings together a range of management options, considering the local conditions, while aiming at social, economic and environmental aspects of sustainability. For, the waste management system as it aims at sustainability, should function within the principles of Agenda 21 (established at the UNCED World Summit in Rio in 1992) and within its local manifestation (Local Agenda 21).

1.5 Conceptual Framework

Concepts are sometimes seen as foundations of communication which are abstracted from perceptions and are used to convey and transmit information (Nachmias and Nachmias 1996; Lundeqvist 1999). This study is based on the conceptual development of an integrated waste management system that has the ability to include social, environmental and economic compatibilities as the dimensions of a sustainable waste management system. This focuses on the existing waste management system, the feasibility of anaerobic waste treatment and the integration of waste management practices. In the development of this concept, system thinking plays an important role. System Thinking is defined as “a science that deals with the organization of logic and integration of disciplines for understanding patterns and relations of complex problems” (Haraldsson 2004). Understanding the connections and relations between systems or factors which are apparently remote is the basis of system thinking.

The practical application of system thinking, System Analysis,is explored understanding of the existing waste management system, the suitability of anaerobic waste treatment and the integration of waste management “System Analysis is about discovering organizational structures in systems and creating insights into the organization of causalities. It is also about taking a problem apart and reassembling it in order to understand its components and feedback relationships” (Haraldsson 2004). In that respect Causal Loop Diagrams (CLDs) are used to reflect the interactions of the various systems. The CLD “is a group of interacting, interrelated, or interdependent components that form a complex and unified whole” (Anderson et al. 1997) and is used here to describe the interactions through cause and effects (causalities) between variable systems and their active circular influence and the extent to which these systems are interconnected. In the CLD language, a ‘+’ sign at the head of an arrow shows a positive relationship between the two connecting variables at the arrowhead and the tail. For instance a ‘+’ sign connecting population and total waste in the environment shows that an increase in human population increases the amount of waste in the environment or a decrease in human population leads to a decrease in the amount of waste in the environment. Also, a '-' sign shows an opposite relationship between the two connecting variables. As an example, the more landfilling or dumping of waste occurs, the less the available landfill or damp space.

1.5.1 Waste management in Accra

In figure 1.1 the top left loop, population has driven the waste generation through the resource use in production and products consumption. The amount of waste collected and disposed of also has determined the waste in the environment. Taking the right loop, the collection and disposal processes depend on the available revenue for the supply of collection and disposal equipment.

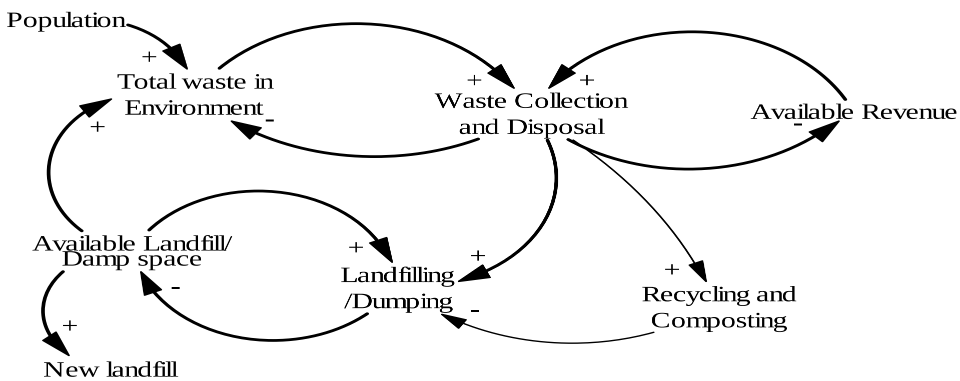


Figure 1.1 CLD for the existing waste management system

The lower loop shows that most of the waste collected and disposed of goes to land filling and dumping with less recycling or composting. Increased land filling and dumping have lead to a decrease in the available land space, and so the amount of waste collected and dumped has also reduced. This has lead to a flow-back of waste into the environment and the hence need for the construction of a new landfill. It is important to note here that the waste management system makes no provision for income generation to support its activities. The waste management is therefore limited by the revenue from the Municipal Assembly's budgetary allocation. There is the need therefore to introduce waste treatment and management systems that will optimize land-use, reduce emissions to the environment and generate revenue that can maintain infrastructure and hence offset the cost of collection and disposal.

1.5.2 Introducing biological treatment of solid waste

There exists a plan to construct a sanitary landfill, the feasibility studies of which have been done. The profile below shows that what need to be done with the already planned engineered sanitary landfill is to construct reactor cells for effective waste digestion and install vertical pipelines for useful landfill gas collection (Appendix1).

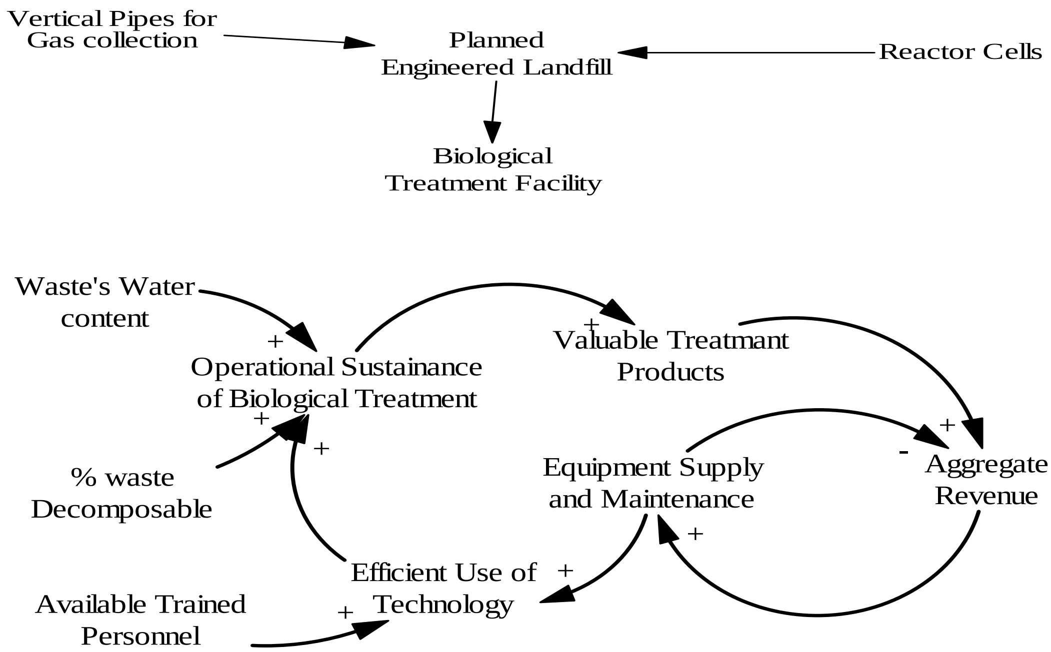


Figure 1.2 CLD for the suitability of the bioreactor treatment of solid waste

In figure 1.2, the sustainability of the biological treatment system depends on the nature of the incoming waste and the use of the technology. High proportions of decomposable waste and water content promote the use of this technology since these enhance the biological degradation process (Bramryd, 1997; Binder and Bramryd, 2000; Fricke et al 2001). The efficiency with which the technology is handled relies on the availability of trained personnel and equipment supply. The equipment supply is supported by the aggregate revenue from the recovered landfill gas as well as sales from harvested biomass obtained through leachate circulation in vegetation.

1.5.3 Integrating the waste management process

The collection and sorting program is vital since it is central to linking with recycling, composting and bioreactor treatment as shown in figure 1.4 below. From the top right good collection and sorting arrangements would yield less polluted materials for recycling, composting and treatment and subsequently high economic values of products from these processes. The other level of integration is shown from the top left where the stakeholder consultation and education in the waste management plans is linked to collection, recycling/composting and bioreactor treatment. This brings about stakeholder conviction, acceptability and citing of the bioreactor treatment facility. The useful treatment products (methane gas and leachate) also are sources of revenue through their economic values. This revenue then becomes part of the operational funds for the maintenance of the facility. The stakeholder involvement and their subsequent conviction bring about environmentally responsible behaviour in the public.

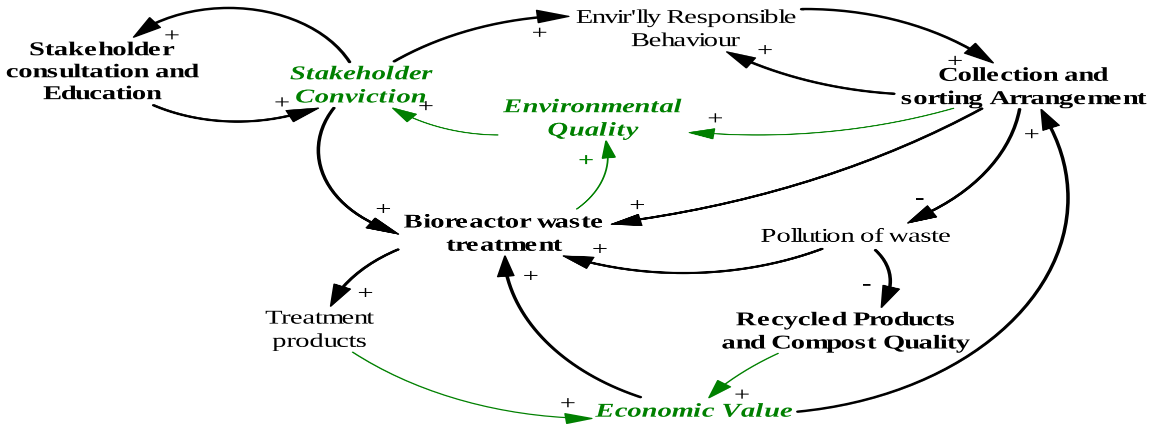


Figure 1.3 CLD for the integration of collection, recycling, composting and biological treatment of solid waste

This behaviour increases the effectiveness of the collection and sorting arrangements. The improvement in environmental quality due to bioreactor treatment of waste and the good collection and sorting arrangements that arise out of the integrated system reinforces the public's conviction of the workability of the waste management system and hence their active involvement in the waste management system.

There is an increasing awareness by managers and planners especially in Europe and America to follow a sustainable approach to waste management and to integrate strategies that will produce the best practicable option. It is a duty that requires properly taking into account economic and social aspects, with particular attention to environmental issues (Read 2003; RVF 2003). It is essential therefore to consider the possible benefits originating from a well organized waste management system.

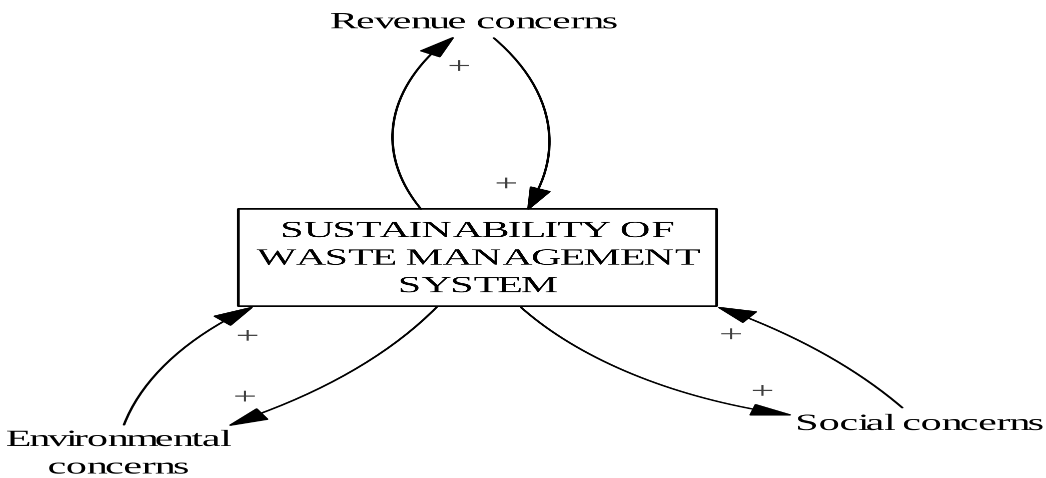


Figure 1.4 Complementary interactions of Economic, Social and Environmental concerns in the sustenance of an integrated waste management system.

In figure 1.4, the IWMS addresses the economic concerns in terms of revenue generation else the system collapses due to lack of funds. This is because inadequate funding limits all aspects of solid waste management including collection, transport as well as the operation of the compost and bioreactor treatment. The system's sustainability also depends on equally addressing both environmental and social concerns. The system thus, will not make room for trade-offs among these three concerns. The system that addresses these three concerns without trade-offs is in turn sustained by them.

2 MATERIAL AND METHODS

2.1 Sources of data

Primary data was obtained from contracted waste collecting companies in Accra. Secondary data has been the main source of information for the study. The secondary sources of data included books, published articles both on the internet and in journals and government publications.

2.2 Instruments

Questionnaires were administered together with personal interviews with managements of the waste collection companies in Accra. These were intended to find out the level of collection, sources of operational funds, status of logistics and the problems confronting their operations. Data collection from the Waste Management Department (WMD) of Accra Metropolitan Assembly (AMA) was done through personal interviews and extracts from their records. The data collected here was on waste stream information including waste type and composition, waste collection, volume generated versus volume collected. The data also include the existing methods of waste disposal and the ground work on the proposed Kwabenya landfill.

Study visits were made to the WMD's solid waste management facilities at Mallam, Djanman and Oblogo waste dump sites, the composting site at Teshie and the new sanitary landfill site under construction at Kwabenya all in Accra. Study visits were also made to the solid waste storage facilities available in the various residential areas in Accra. A study visit was also made to a landfill and bioreactor treatment facility at Hyllstofta in the community of Klippan in North-East Scania in Sweden. Though no specific data were collected from these visits, these were done to get first hand knowledge on the status of the facilities at the various sites in Accra and of the bioreactor waste treatment of waste.

2.3 Data Analysis and Presentation

In the analysis of the data, qualitative approach is employed. In the process, comparative analysis is done on the data collected in Ghana with information obtained from literature. Causal Loop Diagrams (CLD) are also used in the theoretical framework to give insight to the analysis.

2.4 Scope

The study centres on the solid waste management in the Accra metropolis of Ghana and the need to restructure the process. Even though in considering the suitability of anaerobic bioreactor treatment of waste in Accra, site selection/acquisition and resettlement of people and detailed technical description of the reactor cell are important parameters, these are not considered here. These processes are so broad (including Legal and Institutional framework, Eligibility for compensation, Valuation of compensation, and Resettlement measures) that they cannot be covered though they constitute part of the social concerns that the paper hopes to be addressed by a proper waste management system. What is rather considered here is the significance of converting the already planned engineered sanitary landfill into a biological waste treatment facility by building in reactor cells. However for the purpose of this study, a brief discussion of the initial feasibility studies on the design and construction, leachate and landfill gas management of the proposed landfill would be made. The economic feasibility for the construction of the facility cannot be overemphasized. Here again it is assumed that the external funding agent which is the World Bank would take care of the constructional phase and will not hesitate to provide additional funds necessary to convert the landfill into a bioreactor treatment facility. For the purpose of this study the economies of the operational phase is considered vis-à-vis the facility's ability to serve as a source of recurrent income and therefore be 'self-sustaining'. Components included in the integration of waste management are waste collection, recycling, composting and anaerobic digestion. Admittedly this model is associated with waste already generated although as Boyle (1989) pointed out, waste minimization or prevention is the most rational and cleanest means of solid waste management. Waste prevention and minimisation are not considered here since these aspects belong to a broad spectrum of Environmental Management Systems.

2.5 Outline of report

The report has five sections. The first section comprises introduction to the problem, objectives, rationale for the study and theoretical framework. Materials and methods, instrument, data analysis and presentation, scope of the study and the report outline of the report constitute the second section.

The third section deals with the waste generation and management systems and comprises population and waste, waste stream information that is the amount generated versus amount collected, waste composition, current waste management system in the Accra metropolis of Ghana (collection and disposal), and the problems associated with it. The proposed improvement in the area of constructing a sanitary landfill at Kwabenya in Accra is also discussed here.

The forth section deals with the suitability of introducing anaerobic method of solid waste treatment. This includes ground work at the Kwabenya landfill project site, waste type, composition and suitability; comparative advantage of the system over conventional landfill and the availability of trained personnel.

The fifth and final section entails discussion, recommendation and conclusion. The discussion and recommendations are on the integration of alternative waste management methods namely, collection, recycling, composting and bioreactor treatment. It also includes resources available for running the waste management program and lessons to be learnt.

3 WASTE MANAGEMENT PRACTICES IN ACCRA

3.1 Population and waste

Population dynamics have significant influence on the amount of waste generated and its proper handling in the municipality. The population of Accra is rapidly increasing because of the rural-urban migration among other factors. The population of Accra has grown from a mere 450,000 in 1960 to 1.6million in 1990 (Leitman 1993), and presently stands at 3 million with a floating population of 300,000 (Ghana Statistical Services 2002). The statistical service observed that approximately 50,000 economic migrants come to Accra daily and about 5,000 stay behind after close of business for weeks or months. Whiles the national population growth rate as at the year 2000 stood at 2.7 per cent that of Accra stood at 3.5 per cent. This population growth has not been accompanied by increase in housing and basic sanitation facilities. The implications of these are increases in population density with low income settlements, large waste generation and increased pressure on waste management facilities. The UN-habitat (2003) observes that today's true builders and planners of cities in developing countries are the urban poor who build houses and establish legal or illegal settlements where they can to make life comfortable no matter what. "Slums have been the only large-scale solution to providing housing for low-income people. It is the only type of housing that is affordable and accessible to the poor in these cities" (UN-habitat, 2003). People in the slum most often do not pay for waste services and the nature of these settlements make no room for access roads for effective waste collection.

Associated with the increasing population are rising levels of affluence, shorter product cycles, and the large number of packaging, consumption and the demand for portable products that have brought increases in the waste stream. Ehrlich and Holdren (1971) established a relationship between the human environmental impact (I) (solid waste generation in this case under review), sub-national population size, growth, and concentration (*P*), people's affluence (*A*), and the methods (*T*) it employs to obtain its livelihood and dispose of its consumed products. This relationship they expressed through a mathematical model, I = PAT. Translating this into real life situation, this means that greater waste generation and its environmental impact would accompany a large, rapidly growing, and high density population. And this is what has been the situation in Accra.

3.2 Waste stream information

According to the WMD of AMA[1], about 1800 tons of municipal solid wastes are generated per day in the metropolis and the average waste generated per capita per day is estimated at 0.5 tons. Holding change in production and consumption patterns constant, future projections are subject to population growth, taking into account the present population of 3million and growth rate of 3.5 per cent.

Waste from domestic sources include, food waste, garden waste, sweepings, ash, packaging materials, textiles and electric and electronic waste (here classified under

[1] According to WMD indicate personal interview with the officials of Waste Management Department in Accra.

metals). Waste from industrial sources include metals, wood, textiles, plastic; food waste from slaughter houses, cocoa processing factories, fruit processing and grain mills. The central business districts generate waste with high food and plastic contents while waste from schools and offices have high paper and plastic contents. These wastes are classified with their composition in the table 3.1 below.

Table 3.1: The waste type and composition in the Accra metropolitan area

Waste type	Organic i.e. Food and plant	Paper	Textile	Plastic	Glass	Metal	Inert	Others
Proportion	65%	6%	1.7%	3.5	3%	2.5%	17.1%	1.2%

Source: Waste Management Department of AMA (1999*)*

The high proportion of food and plant waste is due to the fact that Ghana's economy largely depends on agricultural products for export and domestic consumption. Apart from the food waste from consumption and food processing factories, post harvest losses due to inadequate storage facilities and ready market for the farm produce contribute the greater percentage of the food and plant waste (Ministry of Food and Agriculture, 2000). Inert waste including rubbles from demolition and construction works are rarely disposed of as waste in Ghana since they are used on site roads in areas of housing and road construction. According to EPA and others (2002), hazardous solid wastes generally occur in small quantities, except in the case of specific industrial operations for which the industry concerned takes responsibility and is assisted to put in place management plans guided by standards on effluent and discharges set by the EPA. These wastes though important, are not included in this discussion. The waste generated per day in the metropolis are however, not totally collected from their sites of generation.

3.3 The solid waste management system in Accra

In the Accra metropolitan area, solid waste collection and disposal is the responsibility of AMA's WMD. The department therefore sees to the collection, transport, treatment and disposal of municipal solid waste. The WMD is thus responsible for the management of the solid waste disposal sites at Mallam, Djanman and Oblogo waste dump sites, the composting site at Teshie and the new sanitary landfill site under construction at Kwabenya in Accra.

3.3.1 Solid Waste Collection

For the purpose of waste collection, the city has been demarcated into waste collection districts (Appendix 2) where a company is contracted by AMA to collect waste in one district or two. 15 waste collection companies have been contracted, some of which are Liberty Waste Service Company, Vicma Waste Construction, Ako Waste Management Limited, Gee Waste Limited and Daben Cleansing Construction Services Limited. The main types of vehicles currently in use by AMA are compaction and skip trucks. The wastes are taken by road directly to the disposal sites. There are no waste transfer stations.

According to WMD sources, solid waste collection in the city is both on franchise and contract basis. On the franchise basis, a house-to-house collection is done in high income areas and the contractors charge the households some fees with weekly collection frequency. These areas are well-planned residential areas with access roads described as first and second class areas and include areas as Airport residential area and Cantonments. Each household has plastic containers with covers. These contractors then pay a tipping fee to the AMA for the use of its dump site. The user fees charged form about 20 per cent of general service[2] to the beneficiaries whose wastes are collected. On contract bases, waste contractors are paid by the AMA to perform both block and communal container collection. Block collection occurs in middle-income residential areas including Dansoman, Adabraka, Kaneshie and other parts of Accra. According to the WMD sources, approximately 75 per cent of the waste generated is collected in these areas.

Central communal container collection occurs in low income high population density and deprived residential areas such as James Town, Nima and other parts of Accra where houses are not well planned with poor or even no access roads (third class areas). Market places are also covered under this arrangement. Residents deposit their waste in such communal containers and the frequency of collection is at least once daily. Waste generators here do not pay user charges.

Despite the strategies put in place for the collection of waste in Accra, all is not well for maximum waste collection. According to the WMD of AMA, between 65 and 75 percent of waste is collected everyday over the past six years. Table 3.2 shows the average waste collection over the past 6 years.

Table 3.2: Volume and Daily tonnage of waste collected in Accra over the past 6 years.

Year	Average tonnage generated/day	Average tonnage collected/day
1998	750	450 - 600
1999	960	600 -800
2000	1650	1200 – 1500
2001	1700	1300 - 1500
2002	1720	1300 – 1500
2003	1800	1300 – 1500

Source: AMA Waste Management Department (August 2004)

It is observed that while the waste generated keeps increasing, the amount being collected remained almost unchanged for some time now (2000 to 2003). For the year 2004, AMA sources indicated that, the average waste generation has exceeded 1800 tons per day while the average daily collection has remained virtually the same as the previous years at between 1200 and 1500 tons. The effect of these left over garbage is a daily

[2] This was obtained from personal interviews with some of the waste contractors.

accumulation that has littered parts of the city with the associated adverse environmental effects.

3.3.2 Problems militating against the efficient collection of waste

The main difficulties identified include; inadequate logistics, inadequate funding, the difficulty in applying service charges especially in low-income areas and the nature of roads within the city.

Inadequate logistics

The state of infrastructure and facilities for storage (containers), collection, transportation (vehicles and frequency of collection) of solid waste is inadequate. Visits made to various residential areas and interviews held with waste contractors revealed the use of few and old age vehicles, few waste containers for residents and inappropriate collection technology. A survey carried out in low income high density population areas in 365,550 households in Accra revealed only 41 per cent of these households have solid waste disposal facilities provided in or around their houses (Statistical Service, 2002). Residents at Chorkor for instance, with a population of 45,379 (Statistical Service, 2002) have only two collection points where each of these points has two old containers. These are filled to the brim in the early hours of the morning and latecomers are turned away by the attendants. In the absence of attendants, garbage is left there and accumulates on the ground.

Inadequate funding

The main operational cost to the AMA in waste collection is service provided in the low class areas and which, according to the WMD sources, forms 80 percent of total waste service delivery free of charge. The AMA pays 60,000 Cedis per ton (about $6.80) of waste discharged at the landfill site to the private waste collecting companies. The total per month paid to contractors is estimated to be over two billion Cedis per month (over $227,000) (AMA sources, 2004). Since the WMD's activities are not geared towards income generation (the dumping brings no income, low tipping fees from the few waste contractors operating on franchise), operational funds come from government subsidy. The Municipal Assembly has not been unable to provide funds for replacement and maintenance of equipment. Resource allocation to the WMD has not been based on the requirements for service provision but had been based on the available funds which most often are inadequate. Coupled with inadequate logistics therefore, the contractors are unable to collect waste efficiently. Passive political commitment and support has also worsened the situation.

Difficulty applying service charges

A good data base for raising taxes in the city and the country as a whole is weak and even in some cases nonexistent (Statistical Service 2002). Data from the Births and Deaths Registry are often unreliable as births and deaths most of which occur at homes are hardly registered. There is little coordination among the agencies such as: the Statistical Service Department whose population and housing census data could provide the basis for the type and amount of waste services needed in different areas and for tax purposes; the Births and Deaths Registry whose data could be used to include or exclude people in the tax net; and the Internal Revenue Services that can use data from these two agencies to raise waste taxes effectively. These lapses ca be attributed to "lack of a comprehensive policy assigning responsibilities for environmental sanitation to the relevant Ministries and agencies, resulting in overlaps, gaps and poor co-ordination in the management of programmes and services" (Statistical Service 2002).

These inadequacies coupled with the notion carried by the people that waste collection and disposal services are not working properly, provide the leeway for non-payment of waste taxes. Hens and Boon (1998) found out that tax revenues in Ghana are constrained by a narrow tax base, low incomes and limited tax collection capacity, which are principal reasons for the country's budget deficits. They also discovered that the revenue aspect of environmental taxes has a special appeal to governments in developing countries. The governments therefore find it difficult to add the cost of an environmental management and its policy objectives to the national budget. The weak public awareness and lack of education of the public on their responsibilities in this field (environmental tax) is therefore worrisome. Hence there are virtually no costs to waste generators such as pay as you throw, collection fees, tipping fees at the landfill to recover operational costs.

Nature of roads within the city

Access to waste collection areas has been hampered by the poor nature of roads and hence the low quality of service provided to some particular communities. It is a common occurrence to see waste trucks being stuck in muddy potholes for several hours and even sometimes days while on their way to or from collection points. The inaccessible nature of roads in the poor areas makes collection difficult. Waste in some communities is left uncollected for even up to a month or more with subsequent scattering by animals whiles some is swept away by rain (interview with residents).

Interviews held with 11 of the 15 waste collection companies on various issues on waste collection gave the results summarized in table 3.3 below. These included the 4 companies operating on franchise and 7 on contract basis. The issues included the level of collection, sources of operational funds and status of logistics.

Table 3.3 Results of interviews with waste collection companies on problems of collection

Issues	Response	Problems
Collection Complete : incomplete	2 : 9	More waste than company capacity Inaccessibility to waste points
Funding by: a. user charges b. AMA	4 7	Fees paid by residents are too low Irregular payment
Adequate : Inadequate logistics	2 : 9	Few vehicles and storage containers

From the responses, there is more incomplete waste collection by the companies. According to the other 2 franchise companies that are unable to completely collect the waste, it is rather a reduction in collection frequency from weekly to bi-weekly. The common problems identified here include higher rates of waste generation than the companies' logistics and financial capabilities can cope. Asked on the way out, the franchised companies suggested the enactment of legislation to enable them increase user fees to economic levels. The contracted companies also suggested the privatization of the collection system to enable them organize the collection using the local people. The impression created by the companies is that they would perform better under privatised conditions.

3.3.3 Solid waste disposal in Accra

The disposal system is characterized by inappropriate location and engineering of disposal sites coupled with uncontrolled, non-ecological landfilling. At present, the dumping grounds are not engineered to serve as sanitary landfill sites. They therefore constitute high potential for the spread of infections through run offs during rains and contamination of underground water.

Between 1991 and late 2001, the AMA's Municipal solid wastes in the Accra metropolis were deposited at Mallam, a suburb of Accra. This dumping at the Mallam site however was stopped in late 2001 as the dump capacity has been exceeded and objections from nearby residents. Waste dumping was henceforth shifted to Djanman which unfortunately could not last as it was filled to capacity in just three months (WMD sources). These abandoned Mallam and Djanman sites are mountains of damps and since they are neither landfills nor are there controls to their spread and emissions, they are of great concern as a result of their threat to human health, leachate and landfill gas formation.
The current municipal solid waste dumping site is an old stone quarry at Oblogo in the McCarthy Hills of Accra. Before it begun to be used in early 2002 there was an installation of clay lining. The site has no engineered containment of leachate. The AMA is only able to compact the waste to guarantee some level of proper dumping and hence "this site is considered a controlled dump rather than a properly engineered landfill" (Government of Ghana, 2003).

Since the formal systems of solid waste disposal cannot cope with the ever-increasing volume of solid waste being generated in Accra, the public itself employs various means of waste disposal. Waste is thus disposed off indiscriminately especially in watercourses and drainage channels and also through burning. Some residents interviewed admitted disposing their solid waste into drainages or burning. In the 2000 Population and Housing Census, 625,746 members of the public in Accra interviewed on their means of solid waste disposal gave results in table 3.4 (Statistical Service 2002):

Table 3.4: Other means of waste disposal by the public

Disposal means	Population	Percentage
Waste collected by agents	122,034	19.5 %
Burned by household	76,359	12.2 %
Public dump	321,824	51.4 %
Dumped elsewhere	72,016	11.6 %
Buried by household	28,948	4.6 %

Other	4,565	0.7 %
Total	**625,746**	**100%**

Source: Statistical Service (2002)

These statistics though did not cover the whole population of Accra, are a fair representation of what goes on as far as solid waste disposal is concerned. From the table the 19.5 per cent whose wastes are collected by agents (here called the contracted waste collectors) in addition to the 51 per cent publicly dumped waste go to the AMA's official dump site. The public dumps include the communal containers and some unofficial dumps doted in the city. Those dumped elsewhere and others include gutters, drainages, streams and lagoons. The Government of Ghana (2003) reported that much of the waste generated is disposed of on land and into the sea and other water bodies with little or no treatment before being disposed.

3.3.4 Recycling and Composting

The following are the recycling arrangements and the amounts the industries are able to recycle. There are existing waste processing arrangements. Table 3.5 shows the waste type and percentage recycling taking place.

Table 3.5 Waste recycling in Accra

Waste type	Metal	Paper	Organic	Plastic	Glass
% Recycling	90	40	15	2	5

Source: WMD (August 2004)

Metal: Recovered metals are processed by the Tema Steel Works and some other local aluminium factories.

Paper: This amount of waste paper is usually processed daily by the tissue factories such as the Super Paper Product Company (WMD/AMA sources).

Organic: The composting plant being managed by the WMD of AMA at Teshie, a suburb of Accra, was established in 1980 to produce compost fertilizer from household waste primarily organic, from the eastern part of Accra. Some of the compost fertilizer has been used for re-grassing lawns, in parks and gardens and by estate developers. The fertilizer has not been patronized by vegetable growers. This could be attributed to the poor quality of the fertilizer produced and therefore not suitable for vegetable cultivation in and around the city. Though it is gratifying to know that such fertilizer has not been used by vegetable growers and hence there is little danger of food pollution, the increasing number of vegetable growers, over cultivation of land, the high cost of inorganic fertilizers and the demand for organically grown vegetables will in no doubt increase the demand for such compost fertilizers and this will entice people to use them. Of late the plant has been operating irregularly and far below capacity. Composting of organic wastes using centralized and highly mechanized approaches in the city of Accra is failing. This is as a result of constant mechanical failure, equipment breakdown and lack of operational maintenance and as well as the production of low quality compost to market for revenue generation. The composting site has therefore almost turned into a waste dumping ground (Appendix 3). Kadmus Limited is one of the private companies engaged in composting in Accra and its product has similar qualities as that of the AMA at Teshie since the company also lacks the scientific and technical support to monitor their final product (WMD sources).

Plastic: Currently two plastic recycling companies, Creative Plastics and City Plastics based at Abose Okai and Pokuase respectively (all suburbs of Accra) are engaged in collecting and recycling of plastic waste into pellets. These companies are relatively new and have low capacities. They usually depend so much on manpower and their workers could be seen cutting the plastic materials with knives into pieces for the machine to process. These pellets are then sold to plastic products manufacturing companies. The amount indicated is average recycled daily (WMD).

Glass: The waste glass is recycled in glass and terrazzo factories.

What is so worrying here is that the recycling base in the country is very weak. Kocasoy (2001), noted that while developed countries have realized the non-limitless nature of natural resources and so finding new and efficient ways for recovery and recycling of valuable materials from waste, developing countries have not realized the importance of having recycling and recovery programs to the development of industry and strengthening of the economy. In general, sorting for recycling or recovery for valuable materials in Accra has depended on scavenging. Scavengers can therefore be seen on dumps and by refuse containers searching through the garbage in unhygienic manner putting their health at risk. While scavenging in containers, solid waste is spread around contaminating the environment. The sorted wastes are also contaminated with decomposing materials. Such wastes recovered in this manner when sold to the processing factories result in increased cost of processing since they must be cleaned before processing. Some even end up not being processed and therefore go back into the environment.

3.3.5 Effects of the waste

The sight and smell of inadequately managed wastes constitute a major discomfort to residents and visitors. Pollution of water resources increases the technical difficulty and cost of providing water supplies and the environmental health situation also has serious health impact, with attendant social and economic costs. Flooding with its associated damage to public infrastructure and private property increases with improper solid waste management.

Impact on aesthetic of the environment

As a result of no cover at most of the dump sites, and the uncollected waste, adverse aesthetic impacts on the environment occur from windblown litter. The waste, which contains a high amount of plastic bags are blown about by the wind. This windblown litter makes the area unsafe and creates unsightly conditions in the environment. The litter and plastics make parts of the city very untidy and unhygienic. Also the dumps themselves have very un-aesthetic appearance. The locations of the dumps raise the problem of decreasing value of land and landed property. According to the Government of Ghana (2003) report, assets such as land and houses around the dump sites have lost value as a result of the presence of the leachate from waste, odour, rodents and flies, which make people to avoid such environments. It is not surprising therefore when residents of the proposed new sanitary landfill site oppose the project with the fear of the same fate befalling them.

Water pollution and flooding

Waste in the environment constitute high potential for the spread of infections through run offs during rains and contamination of underground water. Serious leachate generations occur at the Mallam dump site especially after rainfall as the leachate can be seen gushing out into areas at the foot of the waste dump (Appendix 4) where houses are built and the leachate floods enter the residents' compounds (Government of Ghana, 2003). These leachates which obviously contain pathogens are a direct risk to human health and a source of contamination to groundwater and surface waters. It is also important to note that the dump at Oblogo in the McCarthy Hills of Accra is within an earthquake-prone zone and so earthquake activities could allow leachates to easily contaminate underground water.

The presence of chemicals as well as some micro organisms has increased the Biological Oxygen Demand (BOD) of the water bodies within the city. "*Ascaris* eggs, which require a lot of oxygen for their development have been identified (EPA 2001) in various water bodies in Accra. This parasite is found where human waste disposal and sanitation practices are poor as in the case of the Korle lagoon. Heavy metals have been identified in this lagoon. The levels of heavy metals notably cadmium, lead and copper in the Korle Lagoon in Accra were found to exceed the World Health Organization's recommended levels (Nyarko, Evans 1998).

Due to the siltation of the water bodies their capacities as central drainages and the cleansing action of the sea's tidal waves have been overstretched by solid waste pollution. The Korle Lagoon for instance is totally dead and is currently under dredging for ecological restoration. The result of this silt is heavy flooding during raining seasons and loss of lives and property. Severe perennial flooding is attributed to, among other factors, accumulation of silt and garbage blockage in the major drains and in most rivers and lagoons in the city. Sam (2002) reported that in the 1995 floods in Accra, seventeen (17) lives were lost and there was disruption of commercial and industrial activities including infrastructure services like water supply, telephone, electricity and roads.

Human health and social effects

The prevalence of parasites, cholera, diarrhoea and malaria, in the parts of Accra has been as a result of unsanitary conditions in and around these areas. "Common infectious diseases like malaria, intestinal worms, and upper respiratory infections are among the most common health problems reported at the out-patient facilities in Accra, and majority of these cases are residents in and around the slums" (Songsore, McGranahan, 1993) where sanitation is poor. Choked drains and gutters have created stagnant waters that act as breeding grounds for mosquitoes, which transmit, among other diseases, malaria

(EPA, 2002). The nearness of the Oblogo waste dump site to the Densu River at Weija which is a source of drinking water and where treatment of the drinking water takes place is of great concern. The usually high temperatures associated with the dump sites undoubtedly facilitate high decomposition rates and degradation of organic components of the waste to produce landfill gases. Unhealthy odours almost often emanate from these sites spreading to the surrounding residences.

3.3.6 The AMA's plan for improvement in waste management

Having exhausted the dumping grounds at Djaman and Mallam, the attention shifted to the Oblogo dump site. This site has been receiving an average daily waste load of about 1200 metric tons, according to the WMD of AMA. The dump at Oblogo whose capacity was estimated to allow its use up to July 2004 (Government of Ghana 2003), was still in use as at the time of visit to the site in September 2004. Among other factors, the AMA identified the following as justifying the need for constructing a sanitary landfill for the management of solid waste in the city:

- The dump sites have been used because of inadequate capacity for collection of waste and the lack of suitable disposal sites.
- These temporary/ad hoc sites are unsightly and represent a risk to public health.
- Wastes deposited at these sites are picked over by scavengers and fed on by animals.
- If no action is taken, solid wastes would collect in uncontrolled dumps in several locations within the city and the number and size of such dumps would go sky-high.
- The waste would attract pests and represent a risk to public health.
- The waste dumps would also constitute a risk to the environment and would significantly impair environmental quality within the city. (Source: WMD records)

The AMA thus identified a site at Kwabenya in the Ga district of Accra for the development of a new landfill. The proposed new landfill site is expected to receive all the solid waste collected in the metropolis. The 1999 Environmental Impact Statement (EIS) therefore submitted a plan for waste disposal in the region of 23 million cubic metres which is projected to meet the landfill needs of Accra for about 30 years with a further expansion of 10 million cubic metres to be made later if possible (WMD sources). As a means of generating funds, the AMA has in its plan to introduce the Polluter Pays Principle.

4 THE SUITABILITY OF BIOLOGICAL WASTE TREATMENT IN ACCRA

The aim of this section is not to play down on the idea behind constructing the sanitary landfill. The idea is rather commendable. Here the paper rather tries to bring to the limelight the existing conditions for, and the increased advantages of modifying the landfill into a bioreactor waste treatment facility. "A bioreactor landfill is a sanitary landfill site that uses enhanced microbiological processes to transform and stabilise the readily and moderately decomposable organic waste constituents" (Warith, 2002). Operating a biological landfill increases degradation and stabilization of waste and improves the conversion of waste to useful energy (landfill gas) as well as reducing emissions into the atmosphere or pollutants in leachates (Bramryd, 1997; Bramryd and Binder, 2001; Röhrs, Fourie and Blight, 1999; Pacey, 1999).

Waste management must be innovative and cost-effective. Fricke et al (2001) observe that the requirements for well-modified and cost-effective technology can be satisfied in waste management by biotechnology which has become one of the key elements in environmental protection efforts. They also assert that the relatively low costs are particularly advantageous if such technology is applied in developing countries. The anaerobic digestion technology development has been underway in Europe for food residuals for over 30 years driven by the issue of dwindling landfill space (Egigian, 2004). Therefore the modification of this landfill in Accra to achieve these goals should be seen as a laudable venture. For it is important to evaluate a range of alternative options for meeting waste management needs alongside opinions under appraisal. EEA (2001) advocates this kind of evaluation, hopeful that this promotes a more robust, diverse and adaptable technologies and minimises the costs of surprises (such as the reversal of landfill to a dump as a result of lack of operational funds) and maximises the benefits of innovations.

4.1 The ground work at the Kwabenya project site

The construction of the new landfill near the village of Kwabenya in the Ga District 18 km north of the Accra city centre has began and is expected to serve Accra in addition to the urban areas of Ga District. Detailed designs, EIS and resettlement plan known as Phase I of the landfill have been carried out and construction work started in the year 2000 with DFID providing the funds (WMD Sources). The area to be used for landfilling (Landfill footprint) is about 75 ha while the buffer zone including the compound was originally 119 ha giving a total land acquired to be 194 ha. The problem of land litigation and the objections from the nearby residents on the citing of the facility however arose leading to a hold up of the project and the withdrawal of the assistance of DFID. A technical committee set up came out with recommendations[3] for resolving the problem and now funding for the project will be provided by the World Bank (WMD Sources).

[3] Further information on the recommendations could be obtained from the Ministry of Local Government and Rural Development, Accra Ghana.

4.2 Infrastructure

The infrastructure provided includes tarred access roads, a double weighbridge and a 250 meter long covered culvert for storm water evacuation. Also to be made available at the site are water, electricity and communication utilities. About 250 m radius of a buffer zone is created where buildings are not allowed so as to avoid the danger of emissions of landfill gas. A 1.8 m high fence against litter and intrusion of larger animals and the public has also been erected (WMD sources).

4.3 The operational Design and Construction

According to the WMD of AMA, the new site has been designed in respect of the EPA landfill guidelines as well as other international landfill development requirements. The design considered the following major aspects and specific areas (selected for the purpose of this paper):

Leachate containment and management

According to the design, a landfill liner with a low permeability in the range of 10^{-9} m/sec is to be used so as to contain leachate within the landfill site. The 1999 EIS estimated a maximum leachate generation of 113000 m^3 of leachate/year and a worst case estimation in the wet season of 6litres/s and so provision is made for a drainage system in the landfill to transport leachate for collection by the following treatment options:

a. Treatment on site by an anaerobic or aerobic pond and discharge to surface water.

b. Discharge to the closest sewer 10 km away transported by trucks or pipes.

Recirculation has also been proposed in the 1999 EIS for leachate handling (Government of Ghana, 2003)

Landfill Gas Management

From the EIS carried out, a significant generation of landfill gas is expected and therefore flaring or utilization of the energy is expected to account for the active withdrawal. It is however not yet decided which option is feasible.

Maintenance and Site control

Arrangements are made to keep infrastructure in good order by daily control and maintenance. Periodical maintenance is expected to be done for specific provisions such as ditches, drains, culvert, pits and pumps while there will be organized and registered scavengers. Self –haulage will be permitted but monitored.

Record keeping

This will include registration data of the weighbridge; cells for any special waste; quantities of reclaimed waste; accidents and their causes; personnel data; Equipment data; Maintenance and Monitoring data.

Financing

Table 4.1 below shows that the operational management costs dependent on funds provided by the Municipal Assembly’s budgetary allocation.

Table 4.1 The operational costs management and time frame

Activities/Items	Cost/Funding	Time Frame
Operation • Investments • Waste operation • Maintenance	To be covered under the municipal budget	From 2005
Closure	To be covered under the municipal budget	2030-2035
Aftercare	To be covered under the municipal budget	

Source: Government of Ghana, (2003)

In effect the plan for the landfill has an elaborate Environmental Management and Monitoring Plan[4] from the site selection through the construction, operation to closure and post closure periods. It includes:

- Assessment of Impacts/Risks to the society and the environment;
- Mitigating Provisions for the impacts
- Management Actions to be taken
- Institution(s) responsible for the management action
- Improvement in the management action
- Monitoring Plan
- Training of personnel (Source: Ghana government 2003)

These infrastructural, constructional, operational design, environmental management and monitoring arrangements that have been made for the conventional landfill are not different from those of a bioreactor landfill. The planned landfill is therefore not far from becoming a biological treatment facility. What is missing in the plan is the arrangement to build reactor cells into the landfill for effective digestion of waste and vertical pipelines for effective gas extraction (Appendix 1) as well as the useful applications of leachate and landfill gas. Table 3.1 shows that, almost all of the operational costs are to be covered under the municipal budget without making provision for landfill management system to generate enough income to support its operational activities. The Ghana Government (2003) reported that the operations of sanitary landfills constructed in other regions of the country are expensive for the Assemblies to afford under their current revenue generating arrangements. Hence there is a risk for the landfills reverting to dumps and may fill up much faster in short periods if inadequate financing does not allow the operating principles of sectional filling, compaction and covering to be followed. This will mean that when the Municipal Assembly's budgetary constrains and unfavourable political deliberations occur, environmental improvement would be deferred. In this case it will lead to the collapse of the landfill project at the critical stage which is the operational phase.

[4] Details of the plan could be found in Government of Ghana, Ministry of Local Government and Rural Development (2003): *Second Urban Environmental Sanitation Project (UESP II). Environmental and Social Assessment* volume 1,

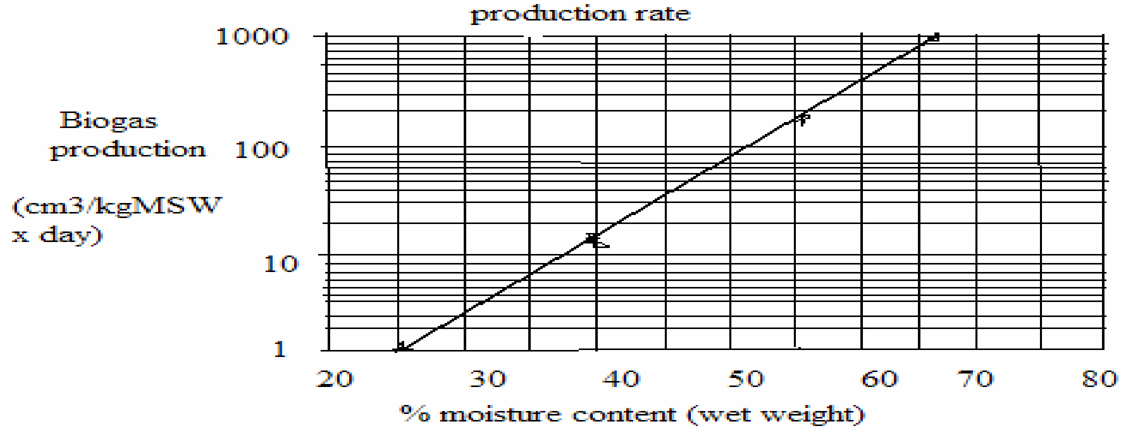
4.4 Waste amounts, composition and suitability

Johannessen (1999) suggested that in considering commercial recovery of LFG in a reactor treatment, it is important to assess the waste composition, with an indication of the expected proportion of biodegradable organic components and moisture content.

The expected average waste delivery at the landfill is about 1,200 tons per day. By extrapolation, a yearly average of 438,000 tons of waste is expected to be delivered at the facility. These amounts of waste are enough to operate a bioreactor landfill. The "size of a reactor cell depends on the total amount of waste treated per day. As a rule, one reactor cell should be filled within two years" (Bramryd, 1997). Different dimensions and numbers of the cells can therefore be constructed to cater for the incoming waste. For instance, a reactor cell of 60 x 170 x 20 m with a volume of 200 000 m^3 could contain 170, 000 tons of waste (Binder and Bramryd, 2000). A larger size or more of the smaller reactor cells can thus be constructed to take care of the volume of incoming waste.

From the waste composition data shown in chapter two (Table 2.1), the biodegradable content of the municipal waste comprises the food and plant waste (65%), paper (6%) and textile (1.7%) giving a total of 72.7% there of. Water content ranges between 45 and 60% with the maximum in the rainy season and the minimum in the dry season between November and March (WMD records). According to Fricke et al (2001), the proportion of waste fractions suitable for biological treatment processes is in the range of 60 to 77% of biodegradable waste while the water content is within the range of 60 to 65%. Reddy and Bogner (2003) found out in their work with bioreactor landfills that optimum moisture content required is above 45%. They observed that increased moisture content and leachate recirculation enhances waste degradation and yield of methane gas. A linear relationship has been established between LFG generation and for a range of 20% to 70% waste moisture content (Steyer et al 1999). This is shown in figure 4.1

Figure 4.1 Effect of waste moisture content on biogas production rate



Source: Lardinois et al (1999)

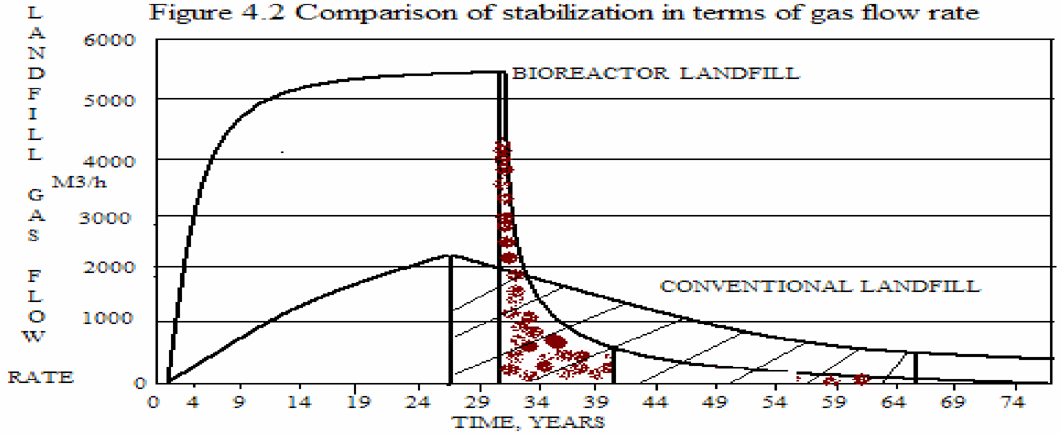
This indicates that the higher the moisture content of waste the more LFG is generated as a result of increased degradation. The high proportion of biodegradable and water components in Accra's solid wastes is therefore an "index for high biogas generation" (Fricke et al 2001). Reddy and Bogner (2003) observed that when anaerobic decomposition occurs at optimum conditions, the amount of useful methane gas is directly proportional to the mass of the degradable content of the waste. Estimates and field results have shown that the yield of methane gas is in the range of 40 – 60% CH_4 (v/v) (Reddy and Bogner, 2003; Johannessen 1999). These results are however from the developed countries where biodegradable components of waste are less than in Ghana[5]. This will mean a projection of higher landfill gas in the Accra project that will improve the economy of operating a reactor landfill.

4.5 Comparative advantages of bioreactor landfill over the conventional landfill

4.5.1 Waste stabilization and settlement

Waste stabilization as explained by Reinhart and Townsend (1998) occurs when the gas generation rate in a landfill is less than 5 percent of the peak rate or when the leachate strength remains low (below 1000mg/l with BOD below 100mg/l). It has been proven that stabilization occurs more rapidly in the bioreactor cell treatment than in the conventional landfill as shown in figure 4.2 below.

Figure 4.2 Comparison of stabilization in terms of gas flow rate



Source: Pacey (1999)

This shows the results obtained in landfill gas model developed where bioreactor and conventional landfills were each filled with municipal solid waste at the rate of 200,000 tons per year. A shorter stabilization period (between 31 and 41 years – about 10years) would occur for the bioreactor landfill as opposed to the conventional landfill which would take about 40 years (between the 27 and 67 years) (Pacey 1999). Pacey (1999) again observed that the rate of settlement follows indirectly the rate of gas generation where settlement occurs faster in the bioreactor landfill, with about 80 per cent waste stabilization in the 30 year operational period prior to closure. Conversely, the

[5] Detail information on solid waste composition in developed countries could be obtained in the publications of:
Kocasoy, G. (2001)
Sakai et al (1996) *World Trends in Municipal Solid Waste Management* Waste Management, Vol. 16, Nos 5/6, pp. 341-350

conventional landfill achieves only about 30 per cent stabilization as at the time of closure.

4.5.2 Landfill space for re-use

Due to the faster stabilization and settlement in the bioreactor landfill, space is created for refilling of the landfill as opposed to the conventional landfill which takes a longer time to stabilize and therefore little or no refilling can take place. “The change in setting that occurs in bioreactor landfills could create an additional 50% landfill space which can be used to construct new reactor cells on top of the old ones” (Bramryd 1997). Most especially when leachate is re-circulated in the biological treatment of waste, the benefits include among others, landfill volume reduction (Warith 2002). Reinhhart (1996) showed that the time required for landfill stabilization can be reduced from several decades to 2 – 3 years when leachate is re-circulated.

4.5.3 Landfill gas generation

Experiments and field results have shown that the bioreactor landfill generates more of the useful biogas than the conventional landfill (Pacey 1999; Warith 2002). Due to the faster gas generation rate which occurs in the bioreactor landfill, a larger volume of gas is harvested than in the conventional landfill (Figure 3.1) where the gas generation rate is slower with most of it generated during the post closure period.

4.5.4 Reduced environmental and social risks

One of the major aims of a biological waste treatment is to mimic natural ecological processes and to achieve as close a system as possible (Bramryd 1997). Wheeler (2000) observes that though anaerobic digestion is a technology that is generally perceived as a waste treatment technology, it is a natural process exploited by man to protect the environment. The higher rate of stabilization which occurs in the reactor implies that the environmental performance measurement indicators – landfill gas composition and generation rate, leachate constituents and concentration – would remain at steady levels and would not increase even if containment system failures occur beyond the bioreactor’s life time (Warith, 2002). Also the stabilized anaerobic conditions in the bioreactor landfill results in the immobilization of heavy metals into insoluble forms while alkali metals form soluble nutrients in the leachates (Bramryd 1997; Binder and Bramryd, 2000). The extraction of high energy methane as a source of clean fuel, instead of flaring or allowing it to escape into the atmosphere, not only eliminates fire outbreaks but also reduces the risk of its greenhouse effect. These reduced environmental impacts also improve social issues like reduce disease to animals, crops and humans, reduction of odours, flies and vermin and the reduction of plant and animal pathogens that can spread through wastes.

4.5.5 Financial impact

The opportunity of re-using the bioreactor landfill space created after settlement improves the economics of the technology. There are overall savings from re-using the created pace and not siting new landfills which would occur when a conventional landfill is filled to capacity. There is also a reduced post-closure care cost, maintenance because most of the settlement, gas and leachate generation would have occurred during the operational period and hence post-closure monitoring and long term liability are reduced (Warith, 2002; Pacey, 1999).

The solid residue from anaerobic digestion contains those materials that are inert or slowly biodegradable, such as lignin. If this material is from an uncontaminated source, it can be used as compost to improve soil quality. The benefits of using composts on soil include improved water retention, porosity, workability and fertility (Wheeler 2000).

The fact that more gas is obtained with respect to anaerobic treatment than the conventional landfill, commercial use of this product brings more direct income for the operational funding. This gas can be used directly as fuel for domestic as well as commercial food preparation. It could be upgraded and used as vehicle-fuel or used for electricity generation.

Table 4.2 below shows the economics of investment in the LFG recovery for bioreactor and conventional landfills. These were based on an average generation of 8 m^3 of LFG/ton of waste per year for a period of 10 years for the bioreactor and 4 m^3 of LFG per year for 20 years in a conventional landfill (Johannessen 1999). These calculations were based on 1million tons of municipal solid waste in both landfills (Johannessen 1999).

Table 4.2 Economics of a Bioreactor landfill and a Well-Operated conventional landfill

	Bioreactor treatment		**Conventional Landfill**	
Investments	**US$**	**US$/ton**	**US$**	**US$/ton**
Gas collection system	400,000	0.40	200,000	0.20
Pumps, monitoring, regulators	300,000	0.30	200,000	0.20
Utilization system, gas engine	I,500,000	1.50	800,000	0.80
Planning, design, engineering	400,000	0.40	240,000	0.24
Total investments	2,400,000	2.80	1,440,000	1.44
Operation and maintenance				
Annual operation and maintenance costs	210,000	0.20	140,000	0.14
Total operation and maintenance costs	2,100,000	2.10	2,800,000	2,80
Revenue				
Scrap value after 10 years	1,200,000		0	
Total revenue for sold power (0.055US$/kWh)	7,150,000	7.15	7,150,000	7.15
Balance of revenue	**3,850,000**	**3.85**	**2,910,000**	**2.91**

Source: Johannessen (1999)

From the table there is a better overall balance of revenue for the bioreactor landfill than the conventional landfill. Assuming the investments and operational costs and revenues are the same for Ghana, it is more beneficial to operate a bioreactor landfill than the conventional landfill. Information from the table could be interpreted that additional benefits for the bioreactor landfill comes from LFG and leachate revenues after 10 years

(Scrap value after 10 years)[6]. This also supports the fact that, re-using the bioreactor landfill space improves the economy of the waste management.

4.6 Availability of trained personnel

All is not however rosy for the implementation of the biological waste treatment program. One major problem is the unavailability of qualified personnel with the technical know-how and experience to handle this new technology. Fricke et al (2001) observed that most educational institutions in developing countries do not offer curricula in solid waste management and this neglect has resulted in a serious lack of properly trained human resources necessary for the planning and implementation of waste management systems. "Landfill operators need more advanced operational skills and technical know-how. If the operator does not have the necessary skills, the full benefits of the bioreactor landfill may not be achieved" (Johannessen 1999). In that respect, there is a big gap between good management vis-à-vis handling of equipment, planning/implementation and the availability of qualified personnel.

Anaerobic digestion though a useful technology admittedly cannot solve all the problems of waste since it only degrades the organic fraction of the waste and so not all waste streams are susceptible to anaerobic digestion. It can be successful if it is an integral part of other systems such as waste collection and supply for recycling. It is therefore important to integrate other waste management options for effectiveness.

[6] The bioreactor landfill has only bee used for 10 years and can be used for another 10 years.

5 DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussions: The Integration of Waste management

The issue of what integrated waste management is, and what is to be integrated is of great importance in deciding the principal foci of the waste management system. Integrated solid waste management has been considered in many different perspectives. The International Energy Association sees integrated solid waste management as an optimised system of waste management practices based on the sound evaluation of environmental, energy, economic and socio-political considerations that includes a combination of two or more components of the waste; the European Resource Recovery Association (ERRA) views Integrated Resource Waste Management as the management of resources and waste in an optimised way, that considers environmental, economic and social aspects (ERRA 1991). Sustainable waste management means that waste is managed at present in a manner that does not leave any unnecessary management or environmental problems for future generations by recognising the fact that no single method of waste treatment or disposal can deal with all the materials in the waste stream.

As stated in the theory of waste management, the integrated solid waste management in this paper is based on a combination of different methods with no contradiction between the methods but complementing each other. In this approach therefore, waste collection, recycling, composting and anaerobic digestion are the important components of the integration process.

5.2 Levels of integration

Three levels of integration of waste management are proposed here. These include: the integration of waste collection for recycling and composting with available markets for these products; the integration of material collection with treatment for disposal (bioreactor treatment) and; bringing these integral parts of waste management in close co-operation with stakeholders.

5.2.1 Linking collection of materials for recycling and composting with available markets

One level of integration is to link the collection of materials for recycling and composting with available markets for these materials, so that material value is recovered where there is a demand, so that a situation of recycling for recycling sake does not arise (Read 2003). Waste collection (and the subsequent sorting) plays a vital role in the waste management system since it determines the feasibilities of recycling and composting in an economically and environmentally sustainable way. It also significantly influences the quality of the recovered materials, and in turn the quality of the recycled products and their market values. Since collection is the contact point between waste generators and the waste management system, this crossing point requires careful management. According to Read (2003) the householder–waste collector interface is like a customer-supplier relationship where the householder's solid waste must be collected with a minimum of inconvenience and the collector must also be given the waste in a form well-suited with intended treatment methods.

For the city of Accra that has not much experience in sorting at source, a householder collection of food waste, garden waste textile and paper together; glass, plastic, scrap metals, electric and electronic equipment also together is recommended for the start, else there would be disorder in introducing several containers for different materials. However those businesses that produce large uniform waste at a spot such as the book binding industry could be linked up with the appropriate recycling industry. This will make it easier and healthier for the scavengers to sort at the deposit site rather than scavenging through decaying matter. It will also reduce the contamination of the recyclable wastes with food and oil and thus improve their quality as well.

Another way of getting good quality recyclable material is to employ financial incentives and educational systems such as deposit-return charges to encourage an increase in the return of valuable waste materials. When for instance poor communities are motivated in this manner, they can recover most valuable items from waste. In this regard, major distributors should become increasingly involved in the separate collection and recycling of products and materials. This has been in existence with the Guinness, Beer and soft drink bottles and need to be extended to other products.

Recycling is possible for heavy plastic, plastic bottles, plastic bags, metals, and glass in the country. Plastic waste for instance could be recycled into waste bins to make for the shortage in waste storage containers.What will be needed here is increased capacities for recycling. The organic material collected for recycling can be directly sent to a composting plant because it is pure enough to produce compost for agricultural use. In this regard it is important to maintain purity because using compost from wastes for the cultivation of food increases the possibility of disease transmission, which would nullify the purpose of its application. The use of compost in urban cultivation in Accra is a potentially powerful, locally responsive approach to addressing waste disposal problems. Tetteh and Botchwey (1989) revealed that subsistence farming is noticeable in almost all homes and unused spaces in the city of Accra to supplement the income of the metropolitan dweller. Amuzu and Leitmann (1991) estimated that about 90% of Accra's vegetable supplies, such as cabbage are produced by urban farmers. Promoting the use of organic waste in food cultivation will therefore not only benefit urban cultivators but also minimize the need for expensive imported chemical fertilizers (Ministry of Food and Agriculture 2000) and help to reduce solid waste collection and disposal problems.

5.2.2 Integration of waste or materials collection and handling with the treatment, processing and disposal methods

Integration should also be done in which case waste collection and handling is integrated with the treatment, processing and disposal activities (Read 2003). Treatment is of key importance to recover waste or treat it in such a way that in the longer term it only causes insignificant, and therefore tolerable, pollution. Because untreated municipal waste in landfill sites forms leachate and gases over a period of decades and pollutes the infiltrating water over a period of centuries (Joos, et al, 1999).

The kind of treatment and expected treatment results must be linked to the collection arrangement. The biological treatment of solid waste that is being proposed in this text is suitable for both sorted and unsorted waste. If in addition to leachate and gas harvest it is intended to use the solid residue as a soil improver, then the collection and sorting arrangement must aim at avoiding materials such as heavy metals which would remain in the solid residue after treatment and contaminate the soil when the residue is used as a soil improver.

The market values of the products of the anaerobic digestion (namely methane gas and leachate) in the Ghanaian society cannot be overemphasized. Most city dwellers now use the liquefied petroleum gas as fuel for domestic cooking. Restaurants, chop bars, hotels and boarding schools use this gas for large scale food preparation as it is estimated to be less expensive than using the hydroelectric power. The landfill gas that would be generated in this bioreactor treatment process therefore has a high market value.

Haulage distance between the site of waste generation and intermediate and or final disposal sites affects the effectiveness of the programme. In the case of the biological treatment at the Kwabenya landfill which is about 18 Kilometres from the city centre, there is the need for considering a waste transfer station where the waste can be temporarily stored before final delivery at the treatment site. This arrangement is to ensure that waste is not left at distant places and for a long time to begin decomposing before bringing it to the treatment site.

5.2.3 Bringing waste management processes in co-operation with stakeholders

Read (2003) again suggests that one other level of integration of solid waste management is to bring the waste treatment facility in close co-operation with the management authorities and the public. In addition to the treatment facility (as suggested by Read), it is important to include the other integral parts of the waste management which are collection, recycling and composting programs. It is vital to involve a wide range of stakeholders (the general public who are the waste generators, the private investors and the management authorities), taking account of their values and interests. This is done at the earliest stage of appraisal and choice of technological and social options for meeting such waste management needs. This augments the information available to policy-making and may also improve public trust in society’s capacity to control hazards (of waste), without necessarily oppressing innovations or compromising science (EEA, 2001).

Giving the people maximum flexibility and value for money and or land sacrificed with regards the waste management services helps in promoting environmentally responsible behaviour. Consensus building on what is or what the solution on solid waste should be is important for social acceptability. In this wise, simple and realistic survey could be carried out to determine: problems the people experience with MSWM; the kind of changes they would like to see; whether they would be willing to make some adjustments in order to support a more functional MSWM plan; their willingness to pay a fee for reliable collection and disposal; financial penalties for those who do not comply with regulations (Závodská and Knight 2002). Findings from such consultations would help provide clues to management authorities as to how people feel about current MSWM practises and to what extent they would support changes. This kind of consultation by informed consensus, declaring and justifying the reasoning (for instance garbage is a resource not a waste) behind the proposed solutions contributes to social acceptability (De Coninck et al, 1999). This cultivates environmentally responsible behaviour among the public. There is the need to move away from the traditional waste management system where experts and decision makers adopt a management system and try to convince the public to accept the system. The people, especially those in the vicinity of the waste treatment facility must be convinced that the facility is profitable economically, environmentally friendly and in their interest rather than a receptacle of waste.

The involvement of the private sector in both the collection and recycling and treatment will be important to run an efficient waste management. Dijkema et al (2000) observe that the similarity between the waste management sector and the other infrastructures is that this sector is also in transition as it is changing from a completely publicly owned sector to a public-private sector where privately owned companies carry out increasingly larger parts. Hamman and Houghton (2001) observed that facilitating community and private entrepreneur in the waste collection has the advantages of job creation, elimination of illegal dumping and non-payment of service fees due to regular and efficient service by the people from the community.

It is therefore important that the AMA provides the private sector with information on updates of waste generation rate; type and composition; type of infrastructure required (in collection and recycling); recommended technology; Quality of Service; Capital Investment and Financial Performance (Noll et al 1997). This kind of information provides the private sector the opportunity to be able to identify viable markets and opportunities to upgrade and run the waste collection, recycling and treatment business. This is because controlling operations and maintenance costs, while providing appropriate levels of service to customers is an important part of achieving an efficient waste management in the competitive market place (Noll et al 1997). This is an everyday management function of a private firm as it strives to stay in business. Also for the private sector to perform, they must be monitored so that their services are not overridden by profit concerns. At the same time legislation on waste disposal must be used to prevent indiscriminate waste disposal as well as evading waste tariffs, which will support the private sector to deliver efficient waste services.

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5.3 Lessons

The implementation of waste management and other environmental improvement regulations in developed countries has been argued on the basis of these regions' high income levels having gone through periods of economic development and environmental degradation (Grossman and Kruger 1994; Panayotou 1995). This then supports the existence of the Environmental Kuznets Curve, EKC[7] (Appendix 5). The Ghana

[7]The EKC hypothesizes the existence of an inverted U-shaped relationship between indicators of environmental degradation and economic growth–that as countries develop, environmental quality first

Government (2003) in its report stated that, with economic growth the financial situation in the landfill project towns is expected to improve to the extent that they can finance the operation and monitoring of the landfills eventually on their own. Assuming this is true then this is also expected to follow the EKC.

It is true that “standards such as those in Europe and America are simply unattainable in the short term in developing countries” (Röhrs et al 1999). However some technological innovations such as the anaerobic waste treatment can be made available and suitable to the conditions in the developing countries. This could make the way to ‘tunnel’ through the EKC to achieve better environmental quality through innovative and cost-effective waste management systems in the short run. For it is worth noting that some environmental problems are irreversible with future turning point coming too late. “It requires many years of accelerated irreversible, environment destruction before improvements would come about” (WWF-International 1998a). “According to Agenda 21, approximately 5.2 million people die each year of waste related diseases” (Fricke et al 2001). The worsening problems and growing environmental consciousness are fostering the demand for cost-effective, environmentally sound and uncomplicated technology for waste disposal. Therefore the “developing countries could learn important lessons from the experiences of the industrialized nations, and devise development strategies that can `tunnel' through any potential EKC—thereby avoiding going through the same stages of growth that involve relatively high (and even irreversible) levels of damage to the environment” (Munasinghe 1999).

The difficulty of cost recovery poses a great deal of problem in effective waste financial management in the Accra metropolis and the country as a whole. An important step towards the health improvement objectives of the metropolis is to satisfy the basic sanitation needs of the people. However, a lot of the people still have inadequate sanitation services provided them as a result of the inability to create waste management programs that make room for recurrent sanitation funds, with social and political deliberations causing difficulties and competition for scarce developmental resources and operational subsidies. It is difficult to ensure full cost recovery through waste user charges alone especially in the poor urban areas. There is therefore a critical need for managerial and financial improvement to meet budgetary constraints and to optimize solid waste management services. It is therefore essential to improve the allocation, size, and timing of the application of sanitation investment funds to contain most if not all costs and to diversify and increase the sources of recurrent income (Grossman and Kruger 1994; Nilsson-Djerf and McDougall 2000; Tanskanen 2000). Organizing to construct, operate and maintain solid waste management facilities and to derive maximum environmental and social benefits from these facilities while ensuring cost recovery is what the AMA should seriously consider. This is where the conversion of the Kwabenya landfill to a biological waste treatment facility should be given consideration over the conventional land filling.

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deteriorates and then eventually improves with income levels. This was based on the hypothesis proposed by Kuznets in 1955 that the distribution of income might become more unequal at first, but improve thereafter, as per capita incomes rose during the economic development process.

5.4 Conclusions

Waste collection and disposal has been the responsibility of the WMD of AMA which contracts waste collectors on franchise and contract basis. The franchise collection constitutes about 20% while the contract collection constitutes 80% with the AMA bearing the cost of collection. The solid waste disposal depends on dumping on land and landfilling in abandoned stone quarries. The public also burns, buries their garbage and throws the garbage into drainages and water bodies. Recycling of waste occurs but is very minimal. Current waste management practices are unable to keep pace with the waste generation rate. The failure is a result of complete dependence on government subsidy and external funding both for the establishment and operational maintenance of waste management facilities, with virtually no arrangements for internal revenue generation for operational maintenance purposes. The new sanitary landfill under construction at Kwabenya in Accra may suffer the fate of reverting to a dump if measures are not put in place for revenue generation. The anaerobic digestion offers benefits of large scale improvement in the cost effectiveness. It allows revenues from sales from landfill gas and energy crop from leachate and tipping fees to fund the operation of the landfill. The high biodegradable and water contents of the solid waste and the advantages of bioreactor landfilling over the conventional landfilling make the anaerobic waste suitable for Accra's waste. Integrating anaerobic treatment, collection, recycling and composting of solid waste is necessary for an effective waste management system that takes care of social, environmental and economic aspects of a sustainable waste management. In the process of integration: collection of materials for recycling and composting must be linked with the available markets for these materials; waste collection and handling must also be integrated with anaerobic treatment, processing and disposal activities; the biological treatment facility, collection, recycling and composting programs must be brought in close co-operation with the management authorities, the public and private investors.

5.5 Recommendations

It is recommended here that the AMA adapts the ISWM approach outlined here in solving the waste management problem. It is important that resources for running the waste management program are properly harnessed. Financial resources, legal institutional framework and human resources are the fundamental components on which the waste management can be run.

5.5.1 Financial resources

In addition to external sources of funds that help to establish waste management programs, these programs must be planned to internally generate funds to support operational maintenance. If the current uneconomic and or no tariffs on waste collection continue then there will be no progress in waste management. It is therefore recommended that;

- Direct cost recovery from users should be applied where it is possible to charge a full commercial price covering all operating and capital costs (Paying back of capital, operating cost, indirect cost and hidden cost) for solid waste collection services.

- Assemblies are to encourage private sector service providers to participate in the setting of tariffs for services which are to be provided on cost recovery basis.

- In considering the level of waste collection tariffs, a reasonable level of fees could be charged per household per month and this fee must be subject to gradual upward review to achieve a cost recovery rate.

- Anaerobic waste treatment is an important source of obtaining operational revenue and it is recommended here that the new landfill be reviewed to operate on this technology. Income from landfill gas and biomass from leachate circulation in vegetation as well as tipping fees are sources of operational funds that must be harnessed. The leachate is good for energy forest such as for bamboo cultivation. Bamboo is a fast growing plant which is used extensively in Ghana for constructional works to support structures as well as in the furniture industry. In this regard experimental cultivation of such forest could be carried out on different plant species with the leachate to determine the most suitable forest crop that can withstand the nutrient level of the leachate.

5.5.2 Legal institutional framework

To facilitate the ISWM concept, the current centralized approach to waste management planning need to be reviewed. The institutional and organizational aspects of the planning process should delegate responsibilities to prepare and implement the plan. The role of the AMA in this process would be to; set service standards, the enabling laws and regulations, monitoring and evaluation; initiate the necessary actions for the provision of an efficient waste management service; encourage private sector investment by a flexible approach to public-private partnership by ensuring fair competition between private sector service providers and between the public and private sectors. The best approach would be to incorporate other integrative and participatory modes involving citizens and other stakeholders. The aspect of source separation of waste management planning for instance could be decentralized to the community level where each individual becomes responsible.

5.5.3 Human Resources

To overcome the problem of lack of professional manpower human resource requirements can be tracked by; ensuring that appropriate training courses are available; collaborating with training institutions on suitable curriculum development; training arrangements through exchange programs with other international institutions. Corporate bodies can also be encouraged to provide sponsorship for training personnel abroad. These arrangements will ensure a constant supply of qualified staff. In addition to professionals and decision makers, the general public's involvement is of importance. The public must be involved in an informed consensus building by educating them on the socio-economic and environmental impacts of improper waste handling and be informed on the values of the waste if properly handled. By so doing, their active participation in effective waste management process is ensured.

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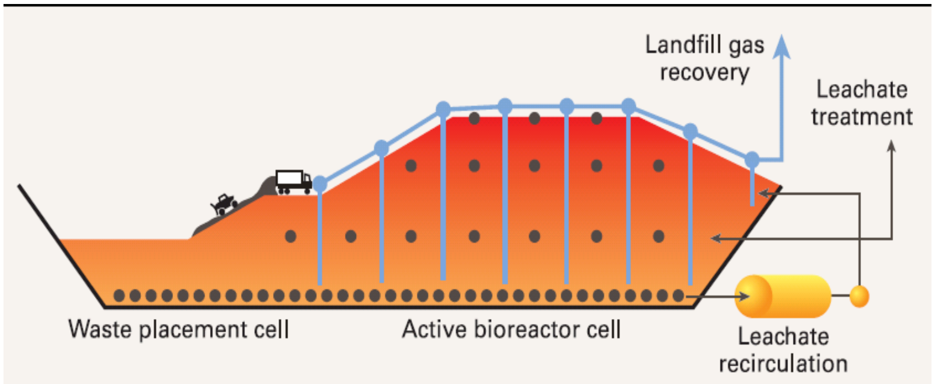
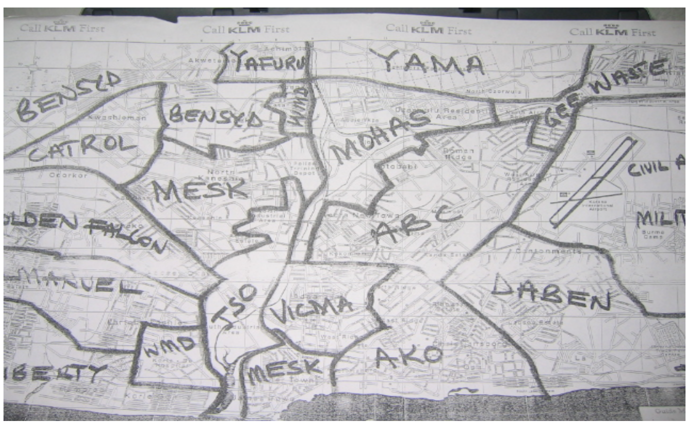
APPENDIX

Appendix 1: Bioreactor landfill with accessories for gas and leachate recovery



Source: Walsh and O'Leary (2002)

Appendix 2: Waste collection districts in Accra



Source: WMD, Accra

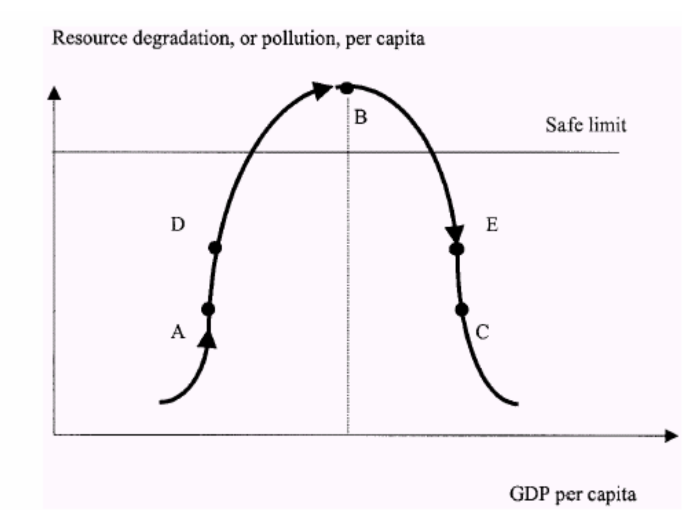
Appendix 3 Solid Waste composting site at Teshie almost turned into a dump

Source: By Author

Appendix 4 Leachate from the foot of a dump entering water course in Accra Ghana

Source: By Author

Appendix 5 Environmental Kutnetz Curve



Source: Seppällä et al. 2001