FINANCIAL ANALYSIS OF BUILDING AND OPERATING COMPOSTING FACILITIES IN THE ACCRA-TEMA METROPOLITAN AREA

BY

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF A MASTER OF PHILOSOPHY DEGREE IN AGRICULTURAL ADMINISTRATION

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DECLARATION

It is my sincerest declaration that, with the exception of the references made to other peoples' work that have been duly cited, the work done on **"FINANCIAL ANALYSIS OF BUILDING AND OPERATING COMPOSTING FACILITIES IN THE ACCRA-TEMA METROPOLITAN AREA"**, that is presented as an MPHIL thesis, is my original work. It is further declared that this thesis has never been presented either in whole or part for any other degree of the University or elsewhere.

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DEDICATION

This work is dedicated to the Honour and Glory of the Almighty God, and to my immediate relations; particularly: *Zakari Agyeruug Ayambillah, Mariama Zakari, Elizabeth Abanga-Zakari, Adisah Zakari-Adakudugu, Awudu Zakari, Sulemana Awini Zakari, Moro Salam Zakari, and Alifa Mbawini Zakari.*

It is also dedicated to *ANIA-ARE AGOUGGI* Family of the *ZAWSE CLAN* in BAWKU, UPPER EAST REGION OF GHANA.

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ABSTRACT

As the quantity of waste streams increases and grows in complexity in the Accra-Tema Metropolitan Area (ATMA), waste management has become a major environmental management problem in the area. This study examines the possibility of establishing municipal solid waste (MSW) composting facilities in the ATMA through the lens of economics. Using the review of literature, data analysis and economic reasoning, the study endeavours to: perform a comparative cost analysis of waste treatment methods in ATMA; determine the most economically feasible levels of MSW composting in the ATMA, determine the profitability and financial viability of compost projects in the ATMA; and investigate the constraints that are likely to militate against the establishment of composting facilities in the ATMA.

The results of the comparative cost analysis show that incineration is the most expensive method in ATMA, followed by landfilling and then by composting. The analysis further shows that the overall cost of building and operating composting facilities in the area at the base year (2001) is 76% and 3.5% of the overall costs of landfilling and incineration respectively. Using the German Agency for Technical Co-operation (GTZ) computer programme, all the options considered at the base year are found to record negative profits. From the investment analysis viewpoint, composting projects are not financially viable at the current interest rate of 45%. The study financial analyses of project A (i.e. 75% of the total waste generated in the ATMA) and Project B (i.e. 25% of the total waste generated in the ATMA). The projects (A and B) analysed shows negative Net Present Values (NPVs) at the discount rate of 45%. The internal rates of return of the projects analysed are found to be 41%

and 43% respectively, indicating that the former has a greater revenue earning capacity than the latter. On the sensitivity of the projects, the study reveals that the projects are not very sensitive to changes in the cost variables analysed such as initial capital cost overrun, and increases in fuel prices, labour costs and input costs. The projects are, however, sensitive to decreases in the sales prices of compost. The study also reveals that the primary cause of under-development of the composting industry in the study area is as a result of a web of endogenous and exogenous factors such as high interest rate; lack of appropriate technologies, research and development, land, and policy framework; ignorance on the part of waste producers and compost consumers; and preference of chemical fertilizers to compost products. It seems likely that, idealistic strategies for promoting the compost industry notwithstanding, government traditional roles and limitations in the compost industry will necessarily remain. Subsidisation, reduction in interest rates and provision of loan guarantees to compost entrepreneurs may be needed to sustain the compost industry in the area. The study recommends that future research programs should focus on aspects of societal well being (welfare economics), interrelationships between outputs and inputs, modelling of cost-effective transportation routes, and design and construction of composting facilities within the ATMA using available local resources.

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ACRONYMS

AMA	Accra Metropolitan Area
ATMA	Accra-Tema Metropolitan Area
C/NR	Carbon Nitrogen Ratio
DOS	Degradable Organic Substance
DR	Discount Rate
EPA	Environmental Protection Agency
ERP	Economic Recovery Programme
FASCOM	Farmers Services Company
GDA	Ga District Assembly
GTZ	German Agency for Technical Co-operation
IRR	Internal Rate of Return
MOFA	Ministry of Food and Agriculture
MSW	Municipal Solid Waste
NPV(s)	Net Present Value(s)
pH	Hydrogen Potential
SEEDS	Selected Environmental Educational Systems
TMA	Tema Municipal assembly
TPD	Tons Per Day
US EPA	United States Environmental Protection Agency
WMD	Waste Management Department
WTE	Waste Treatment Engineering

CHAPTER ONE

INTRODUCTION

1.1 Background

This Chapter discusses waste management trends and problems in the Accra-Tema Metropolitan Area (ATMA) and the opportunities that exist for municipal organic waste recycling and urban and peri-urban agricultural production in the Area. The discussions lead to problem formulation and derivation of the objectives to be addressed in this study.

1.1.1 Problems of Waste Management in Cities

Since time immemorial, Ghanaians learned to manage the wastes they generated in a number of ways including disposal outside settlements, incineration and traditional conversion into soil amendments. Many residents of towns collected their wastes into small containers and hauled them away into open dumps and/or established pits to escape the nuisance of vermin, odour and wild animals. Farmers in the countryside gathered their household organic wastes and turned them into farmyard manure through heap and pit composting. With time, waste management has become a critical issue amongst municipal authorities in the country as urban populations continue to grow. In 2000, the Accra Metropolitan Assembly alone spent as much as 40 billion cedis to manage its waste, which is far beyond the Assembly's annual budget (AMA, 2000). Asomani-Boateng et al (1996) estimated that the waste generation per person per day for the ATMA in 1995 was 0.51 kilogrammes. The researchers further stated that for low income, high-density areas such as Agbogbloshie, the generation per capita could be as high as 0.94 kg. Data available at the Waste Management Department of the Accra Metropolitan Assembly indicates that in 1985, the total amount of waste generated in Accra-Tema area was about 0.334 million metric tons (Waste Management Departments' Reports, 1985).

Also, a study conducted on waste generation in the same area by the Environmental Protection Agency in 1995 estimated the volume of urban waste (household, industrial and commercial) generated during that year to be 0.524 million metric ton (Environmental Protection Agency, 1995). The waste survey attributed the phenomenal increase in the amount of waste generated to many factors including population explosion; increase in production and consumption of consumer-goods; increase in urban and peri-urban agricultural production; and the increasing demand for development activities in all sectors of Ghana's economy. In addition, the survey revealed that large quantities of human waste (excrement) are being generated each day in Ghanaian municipalities, which has become problematic to manage with the given scanty resources.

The production and consumption of goods from extraction industry, agriculture, fishing and service sectors are significant in waste generation because by-products, supplements and negative externalities are generated in addition to the product itself (Aryes and Kneese, 1968). In recent years, the consumption of goods in private homes has kept pace with increasing population and prosperity (Boon, 2000). The buying of non-essential goods and the desire to use throw-away packaging in Ghana are playing, increasingly, important roles and have become part of the reasons for rising volumes of solid waste in the Accra-Tema Metropolitan Area (Essuman, 2000).

The provisional results of the 2000 census show that the population of the Accra-Tema Metropolitan Area was 2.730 million (Ghana Statistical Service, 2000) as compared to the population of 1.63 million in 1984 (Ghana Statistical Service, 1984). With the current population growth rate of 4.7% for ATMA, a population of about 4.00 million for the area is projected for the year 2010 (Ghana Statistical Service, 2000). It has also been estimated by waste management experts that by the year 2025, the ATMA will generate a total of 1.630 million metric tons of urban waste. With an estimated population of 5.0 million, the per capita waste generation will amount to 0.89 kilograms per day for the area as compared to the world's figure of 0.67 kilogram's per day (Beede and Bloom, 1995). Despite the fact that urban waste attracts a great deal of attention and concern, waste management authorities appear to be completely overwhelmed by the mounting waste streams in towns and cities. Indeed, over the past two decades or so, there has been the failure on the part of Accra Metropolitan and Tema Municipal Assemblies to create sufficient disposal capacities to handle the voluminous waste generated in these sprawling metropolitan areas (Armah and Kraemer, 1993). The waste crisis in the ATMA is becoming more and more acute and is putting increasing pressure on land, air, and water quality, and posing threats to human health. This pressure is expected to rise due to projected increases in human population and the resultant increases in total waste generation.

Waste management approaches in Ghana lay emphasis on waste minimization, material reuse, material recycling, energy recovery, and waste disposal. Although much of the municipal solid waste is collected and disposed of through burial in sanitary landfills and open dumps, and to a lesser extent through incineration and recycling, a good deal of the waste continues to be burned in the open, or haphazardly dumped in unauthorised places. In Ghana, about 60% of the urban waste, made of biodegradable and non-biodegradable components, is disposed of by burying (landfilling); 10% is burnt (incinerated); 5% is recycled; and 5% is aerobically composted (Waste Management Department of Accra Metropolitan Assembly, 1995). The limited capacities of local government authorities to deal with the huge waste burden could be attributed to lack of (or inadequate) waste management facilities, basic infrastructure, technical skills, viable technologies, political commitment, financial support and sound investment portfolios. In Ghana, investments in the solid waste sector have been contemplated only most recently. Under the World Bank-supported "Urban Environment Sanitation Project", which started in 1995,Ghana has planned to build its first properly designed, constructed and sited landfills in three major cities – Accra, Kumasi and Sekondi-Takoradi. It is anticipated that the landfills that will be constructed under this project will help to improve waste disposal practices in the three cities.

1.1.2 *Opportunities in Urban and Peri-Urban Agriculture for Organic Waste Recycling*

Projections made by Ghana Statistical Service estimate that within the next thirty years, the population of Accra-Tema Metropolitan Area would be about 5.0 million. The increase in the urban population calls for estate development needed to provide shelter, requiring horticultural practices such as landscaping and ornamental flowering. Increased population will also result in challenges for the need to organize food to feed the increasing number of people on sustainable basis and at low production and transport costs. These challenges were partly responsible for increasing amount of land in the urban and peri-urban areas put under agricultural use in the latter part of 1970s (Benneh et al, 1977). Generally, a wide spectrum of production systems can be found in the urban and peri-urban areas of Accra-Tema area, ranging from household subsistence to commercial farming. These systems include the production of perishable and high-yielding crops such as vegetables, root crops, cereals, livestock, and fishing. In the sub-humid tropics such as the Accra-Tema area, however, the management of soils for continuous and sustainable food production with acceptable and economic input levels constitutes a major problem.

The low fertility of the soils may be largely responsible for this problem (Omueti et al, 2000). Generally, in Ghana, chemical fertilizers are either not available to the farmers in adequate quantities or are expensive to buy in the open market because they are imported from abroad without subsidies. Accra-Tema soils are further known for their low organic contents and low activity clay, which make their water and nutrient holding capacities low (Nye and Stephens, 1962). In addition, environmental factors such as extreme heat and torrential rains oxidize the available organic matter, erode the soils and leach the essential nutrients that could have otherwise been utilized for crop growth (Acquaye and Kang, 1987).

Maintaining a good level of organic matter through fallowing, green manuring, mulching and intercropping have been practiced over the years to prevent deterioration of soil structure, improve water and nutrients retention, and lower soil erosion. These palliative measures are not enough to restore deteriorated soils to their formative qualities (Acquaye, 1986). Plant nutrients from external sources must be supplied to replenish the fertility of the soils. Meanwhile, abundant quantities of waste are being generated from various activities, viz: domestic, agricultural, livestock and industrial. Rather than throwing away most of the organically rich materials being generated, it makes sense for local government authorities to promote their conversion into useful nutrients for crop production. The process of decomposing organic matter by a mixed microbial population in warm, moist aerobic environment is known as composting. The organic matter is decomposed by the successive action of bacteria, fungi and actinomycetes in the presence of oxygen. For a developing country such as Ghana where municipal waste problems are huge and annual chemical inputs bills for farmers are high and increasing progressively with time, composting could be a cornerstone for agricultural development.

A number of opportunities that make composting in the Accra-Tema area very much feasible exist, and these opportunities could as well motivate compost entrepreneurs and managers to apply this integrated method of waste management. The first motivation for composting in the Accra-Tema area is that the raw material is in abundance and has high organic content. Solid waste generated in the Accra-Tema Area has about a 67% component organic matter (Environmental Protection Agency, 1995). This result corroborated the results of a stratified survey conducted by the Waste Management Department of Accra Metropolitan Assembly earlier in 1993. The survey examined the composition of waste generated by low-income, middle-income and high-income earners in the Accra metropolis. Table 1.1 below shows a summary of the outcomes of the survey conducted by the Assembly. The study showed that the waste composition in the Accra metropolitan area had a good potential for composting due to the high percentage of organic material in it. The study also indicated that the medium- and high-income areas produced larger proportions of organic material than low-income areas. The average percentage of organic material was found to be 64.9%. The remaining 35.1% represented the non-compostable component, which was made up of non-biodegradable plastics, metals, glass and other assorted inert wastes.

The second motivation for composting in the Accra-Tema municipality is that compost produced in the area is of relatively good quality. Etuah-Jackson et al (2000), after analysing compost samples obtained from the Teshie-Nungua compost plant corroborated the conclusions of earlier researchers. Data available from their analyses shows that, due to the higher fertilizer content in organic waste, the Ghanaian compost is comparable to compost produced in the United Kingdom.

Table 1.1: Solid Waste Composition in Percentages for Accra-Tema Area, 1993.

No.	Waste composition	Low-Income Areas	Medium-Income Areas	High-Income Areas	General
1	Organic Material	49.1	73.0	72.6	64.9
2	Inert Material	41.2	12.1	8.9	20.7
3	Paper	3.5	6.0	7.2	5.7
4	Plastics	2.7	3.0	4.0	3.2
5	Textiles	2.1	2.4	1.5	2.0
6	Metal	0.7	1.7	2.8	1.7
7	Glass	0.4	1.2	2.0	1.2
8	Others	0.3	0.6	0.9	0.6
9	**Total**	**100**	**100**	**100**	**100**

SOURCE: *Data obtained from Waste Management Department of AMA, 1993.* Cited in Etuah-Jackson et al (1999)

In terms of hydrogen potential (pH), electrical conductivity, concentrations of primary nutrients and levels of salmonella presence, the Teshie-Nungua compost was slightly better than compost products sampled from 33 sources in the United Kingdom. The concentrations of heavy metals and the presence of Escharechia coliform (faecal pollution) in the Teshie-Nungua compost were, however, a bit higher than the sampled compost from United Kingdom (Etuah-Jackson et al, 2000). The third motivation is that there is an unlimited market potential for good quality compost for urban and peri-urban agricultural production and landscaping in the Accra-Tema Metropolitan Area. The production of organic manures close to the consumption markets reduces the need for transportation of the product to long distances, and therefore reduces production costs to both the farmer and compost producer. The final motivation is that labour for compost production is abundant and cheap. Composting could therefore be undertaken with labour-intensive technologies at relatively lower costs.

1.2 Problem Statement

Proposals have been made by succeeding Ghanaian governments to adopt agricultural policies as a strategy for the development of the agricultural sector in order to meet the ever-increasing demand for food by urban populations. However, it should be noted that agriculture couldn't develop by itself with the current high costs of agricultural inputs including those of chemical fertilizers. The development of crop nutrients of non-chemical nature is therefore crucial for Ghana's agriculture production. The extent to which low cost organic soil ameliorants can be produced in a given municipal area depends upon the amount of biowaste available. Biowastes are organic substances that are biodegradable and may include green wastes, cuttings, pruning, crop residues, and garden wastes. A research conducted by Ahenkora et al. (1988) showed that Ghana has a great potential to meet a large part of domestic potash fertilizer requirements from cocoa pod husk. The researchers estimated that 0.794 kilogram of dry cocoa beans is equivalent to one kilogram dry husk, which produces 0.081 kilogram of ash containing 38% of potassium. Gerner et al. (1995) also report that oil palm bunch is another source of potassium and other macronutrients. They reveal that ash obtained from the incineration of an empty bunch of palm is very hygroscopic and has a pH of 10.6, potassium content of 26% (K_2O, 31%), calcium content of 6.8%; magnesium of 5.8%, phosphorus content of 4.0%, and moisture content of 32%. Though the cost of production of potash fertilizer from cocoa pod husks and oil palm bunches is not assessed, the overall impact of such a venture on Ghanaian agriculture could be very dramatic. Policy makers and agricultural scientists must be certain that raw organic materials can be processed into forms that are acceptable to local farmers. One way to convert biowastes into effective soil ameliorant is composting. As a prelude to composting, however, the economics of processing these resources into useable products, their qualities and agronomic responses need to be investigated. The principal aim of the investigation is to produce marketable organic soil conditioners locally in order to reduce the use of high-cost, imported chemical fertilizers in the country.

Secondly, while the demand for plant nutrients increases with population, the fertility of urban soils is being constantly depleted through soil fertility mining and various forms of erosion. Stoorvogel and Smaling (1990) estimated that, generally, Ghanaian soils are depleted annually of 57 kilograms of fertilizer nutrients per hectare. They further stated that nitrogen accounted for more than 50% of the depletion; phosphorus loss was only 7 kilograms (12.3%) in the form of phosphorus oxide, and the rest of the depletion was consigned to other important nutrients. Though the conclusions of their research were on the overall Ghanaian soil conditions, the specific situation for coastal soils is not significantly different from the rest of the country. In addition, Henao et al (1992), in a soil fertility management research conducted in Ghana in 1980, compared fertilizer use with nutrient uptake by plants. They estimated that the total nutrient depletion in 1990 for the country was 153,900 metric tons of fertilizer nutrients; representing 169,700 metric tons of nitrogen (N), 30,300 metric tons of phosphorus oxide (P_20_5) and 53,900 metric tones of potassium oxide (K_2O). The researchers further estimated fertilizer consumption that year to be between 10,000 and 15,000 metric tones of nutrients only. These findings meant that the plant nutrient requirements far outstripped the ability of the country to supply the degraded soils with those nutrients. Consequently, the shortfall must be met with organic soil conditioners, if agricultural production is to be enhanced in the country. One advantage is that organic materials have the ability to improve the soil characteristics and its water retention capacity. Certainly, chemical fertilizers have contributed significantly in adding nutrients to the soils in the urban and peri-urban areas. It is obvious that their continued use is essential if the urban burgeoning population is to be fed. However, the use of chemical fertilizers cannot be sustained forever because of rising fertilizer prices and declining value-cost responses. The astronomical increases in the prices of chemical fertilizers in Ghana since the mid-eighties have been largely attributed to high procurement costs, high interest rates, and exchange rate depreciation (Bumb et al, 1994). Also, Gerner et al (1995) discovered that the removal of subsidies on chemical fertilizers during the mid-eighties, which was not accompanied by corresponding increases in producer prices of crops, led to lower profitability of the input. Farmers, in effect, continued to bear the cost of the 1993 policy reforms through higher fertilizer prices purchased. These important conclusions about increasing chemical fertilizers' prices and falling profitability of chemical fertilizer use are still as relevant today as they were made several years ago. This is because chemical fertilizer prices are continuously increasing with years, while no policies have been put in place by the relevant authorities to shift the rate of these price increases, at least, in tandem with those of the producer prices of crops. However, economic theory suggests that farmers will be motivated to use chemical fertilizers as soil amendments if the expected benefits far exceed the cost of fertilizers, in order to compensate for the extra work involved in production, risk-taking and opportunity costs. It is therefore justifiable under this spate of increasing fertilizer prices for farmers and policy makers to look for cheaper, alternative crop nutrient supply. This is where recycling of municipal solid waste comes into the crop nutrient supply equation.

Given the importance of societal organic waste (municipal bio-waste and sewage sludge) in enhancing urban and peri-urban agriculture and their role in creating environmental and public health problems, it appears somewhat astonishing that municipal authorities, national governments and international agencies have given no priority to the question of composting.

The question, however, is whether composting is an economically viable alternative to the present waste management systems. District, Municipal and Metropolitan Assemblies will be motivated to undertake composting ventures if there are, among others, (1) adequate levels of raw materials, (2) available profitable technological options for compost production, (3) marketing potentials for the compost produced, and (4) sufficient information on the viability of compost production, and on the constraints that affect compost investment, production and marketing. The questions that arise from this background are: How does the cost of composting compare with that of landfilling or incineration in the Accra-Tema Metropolitan Area? What composting alternatives are most suitable for the Accra-Tema Metropolitan Area? Are new compost projects in the Accra-Tema Metropolitan Area financially viable? What are the major potential constraints facing investment in compost projects?

1.3 Objectives of Study

1.3.1 Primary Objective

The study aims primarily at assessing the prospects of constructing and operating viable alternative compost facilities in the Accra-Tema Metropolitan Area.

1.3.2 Specific Objectives

The specific objectives of the present study are:

1. To undertake a comparative cost analysis of lanfilling, incineration and composting of municipal solid waste (MSW) in the Accra-Tema Metropolitan Area.
2. To determine the most economically feasible levels of MSW composting in the Accra-Tema Metropolitan Area.
3. To assess the financial viability of establishing (MSW) facilities in the Accra-Tema Metropolitan Area.
4. To identify the major constraints facing investment in compost projects in the Accra-Tema Metropolitan Area.

1.4 Relevance of Study

Research into the financial aspects of compost production in Ghana remains largely an unchartered territory. Studies conducted by Hesse (1984), Obeng and Wright (1987), Asomani-Boateng et al, (1996) and Etuah-Jackson et al, (1999), focused on the possibilities of composting domestic solid waste and sewage sludge into organic manures as an integrated waste management strategy. The scope of the studies did not extend into the examination of the economic aspects municipal composting into detail. Much of the data needed for the economic assessment of compost programs is unavailable in current literature and/or is not comparable. This represents a major research need. The absence of research in the economics of municipal composting prompted the setting up of a composting pilot project in 1996 in a low income, high- density residential neighbourhood of Agbogbloshie in Ghana's capital city, Accra. The focus of the study was to demonstrate to residents how composting is done as a waste management practice. The current study is an attempt to fill-in the gap between theory and actual economic facts on compost production. It is an attempt to contribute to knowledge about the economic viability of compost projects, by examining alternative composting options through the use of cost-benefit analysis. A knowledge of investing in composting is not only necessary, but also a sufficient condition for predicting policy changes which may affect the utilisation of rural-urban nutrient cycles, urban and peri-urban agricultural production, extension services and municipal solid waste management. The study will guide choices among the range of options available for each component of composting. Comparison of possible alternatives will also reflect a variety of technical parameters that define the physical characteristics of specific organic waste streams and local geography, such as climate, sub-urbanization and transport infrastructure (Bloom and Boom, 1995). The study will also assess the performance of compost projects in terms of profitability and resource usage efficiencies. An assessment of some key economic parameters such as relative prices of labour, plant and equipment, materials, energy and land, will give waste management practitioners the opportunity to determine the feasibility, or otherwise, of composting in the Accra-Tema metropolis. Knowledge that relates factors of production to the quantity of compost produced can provide useful framework for adjustment of production, and the employment of cost effective factor-combinations that will yield optimal returns. Niemeyer et al. (1999) report that many compost projects face problems because analysts, managers and producers either lack information on the economics of building and operating compost facilities, or that available information is not processed and packaged properly. Information is normally missing on aspects related to possible technical alternatives and corresponding costs and benefits of the individual stages involved in the use of organic waste. If the production costs for compost are not known, the contribution margin cannot be calculated, and therefore the profitability of compost enterprises cannot be known; nor can the alternatives chosen be justified as the most attractive options from the economic point of view. Furthermore, if the composition of costs is not known, the partial composting processes, which incur most of the costs, cannot be identified and therefore it is not possible to save costs by initiating the relevant changes. Hence, the study ensures that all aspects, which are important for the economic viability of compost projects in urban areas, like the Accra-Tema Area, are not over looked.

1.5 Scope and Limitations of Study.

The preset study is designed to examine the financial implications of building and operating MSW composting facilities in the Accra-Tema metropolitan Area. The focus is on determining composting facility requirements and the least costly options for converting the area's abundant MSW streams into plant nutrients for urban and peri-urban agricultural production. The study is part of a broader research project designed to determine the possibility of capturing and recycling the enormous rural-urban nutrient fluxes in Ghana. The scope of the study covers profitability, investment and comparative cost analyses, as well as qualitative research methods. The study therefore requires detailed physical and financial data from a host of departments and agencies in Ghana, and comparative data from other countries such as Togo, Benin and Nigeria, which are along the West African coastline and have similar geographical conditions to Ghana. Lack of consistent and reliable data on capital requirements and operating expenses for an evolving industry like commercial composting, served as a major limitation to the study. Some of the relevant financial data had to be estimated or intuitively interpolated using market prices of the base year -2000. Official bureaucracies contributed largely to the delay in releasing whatever scanty data was available at departments and agencies for the author to analyse.

1.6 Organisation of Study

The present study is structured into six chapters. Chapter One discusses the background that leads to policy formulation and the development of objectives. Chapter Two makes a brief overview of the profile of the Accra-Tema Metropolitan Area, and how the characteristics of the area can facilitate (or otherwise) the establishment of MSW composting facilities. Chapter Three reviews relevant literature relating to the subject, particularly on the mechanics, dynamics, merits and economics of composting organic solid waste in a metropolitan environment. There is also a selective review of recent efforts of composting in the West African sub-region. Chapter Four discusses the methodology employed for the study, which covers theoretical foundations and concepts, analytical methods, data requirements and sources, and the methods of collecting and analysing the data. Chapter Five presents summaries of outcomes on the investigations on comparative cost analysis, composting profitability analysis using a GTZ model, and investment analysis. The summary, conclusions and policy recommendations are distilled in Chapter Six.

CHAPTER TWO

THE ACCRA-TEMA METREPOLITAN AREA - AN OVERVIEW

2.1 Introduction

This Chapter briefly describes the profile of Accra-Tema Metropolitan Area with particular reference to the characteristics that are relevant to the present study. The profile is necessary in order to assess the organic material supply, market potentials of compost, available means of transport to cart organic materials and compost, types and quantities of plant nutrients needed in the area, and farming systems being practiced in the urban and peri-urban areas. The profile is discussed under six broad topics: Geo-Physical Characteristics of the Study Area; Socio-Economic Activities; Agro-Climatic and Soil Conditions; Transportation Infrastructure; Waste Management Practices in the Area; and Legal Framework for Waste Management in the Area.

2.2 Geo-Physical Characteristics of the Area

The study covers the Accra-Tema Metropolitan Area, which forms part of the Greater Accra Region of Ghana. The Accra-Tema Metropolitan Area is geographically located between latitudes 5^0 30' N and 5^0 52' N of the Equator, and longitudes 0^0 05' E and 0^0 25' W of the Greenwich Meridian. It is bounded to the north by the southern part of Eastern Region, the south by the Gulf of Guinea, to the east by the Dangbe West and Dangbe East Districts, and to the west by the Central Region. This cosmopolitan area is often regarded together as the commercial and administrative capital of Ghana, with typical urban and peri-urban settlements surrounding the capital towns of Accra, Tema and Amansaman. The elaborate sub-urbanisation of the area makes it necessary for the creation of sub-metropolitan

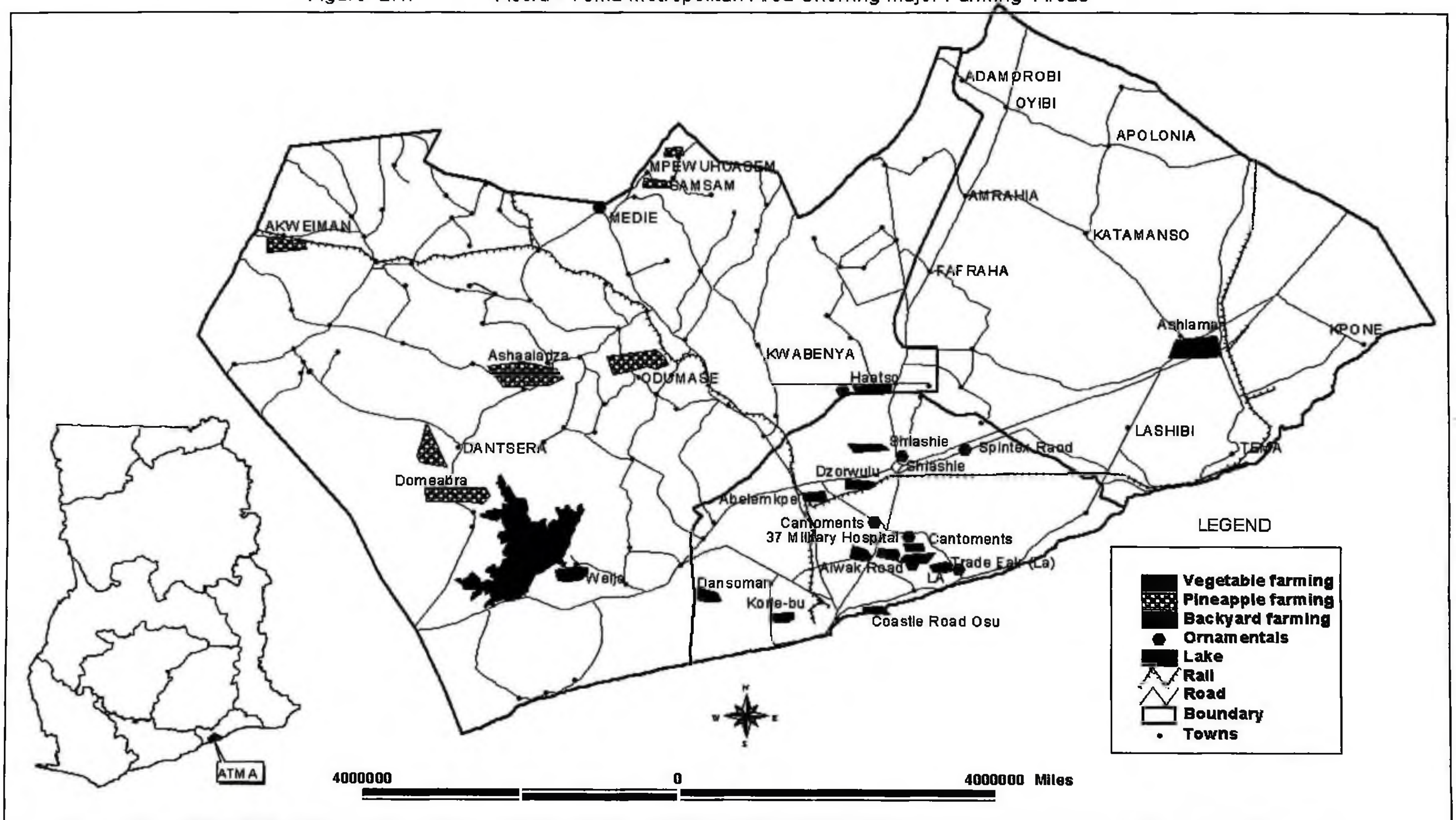
Assemblies, which assist in the local government administration of the combined city. These sub-metropolitan Assemblies are Ablekuma, Okai Kwei, Ashiedu Keteke, Ayawaso, Osu Clortey, Madina, Adenta, Kpeshie, Ashiaman, Kpone, Tema Township, Sakumuno, Amasaman and Weija.

According to the 2000 Population and Housing census, the total population of the area under study is estimated to be 2.7 million, representing about 94% of the total population of the Greater Accra Region and about 14.8% of the national figure. In 1984, the population of the area was 1.60 million (Ghana Statistical Service, 2000). With an estimated land area of about 1,079 km^2, the 2000 population density of the area amounted to 2,500 persons per square kilometre. The national population density in the same year was 77 persons per square kilometre. This means that there is extreme pressure on the land in the area. This accounts for the huge volumes of municipal solid waste generated in the area, which currently stands at about 539,000 metric tons per year (Accra Metropolitan Assembly, 2000).

2.3 Socio-Economic Activities

Agricultural production forms part of the local economy of the Accra-Tema area, and is mainly dictated by the climate, soil type and fertility status of the area. The farming population in the area was, as at 1998, estimated to be 3,350 by the Regional Directorate of Ministry of Food and Agriculture (Sackey, 1998). The major form of agricultural land use is the intensive cultivation of annual food crops such as maize and cassava, as well as vegetables such as okro, onions, tomatoes, pepper and garden eggs.

Figure 2.1: Accra - Tema Metropolitan Area Showing Major Farming Areas



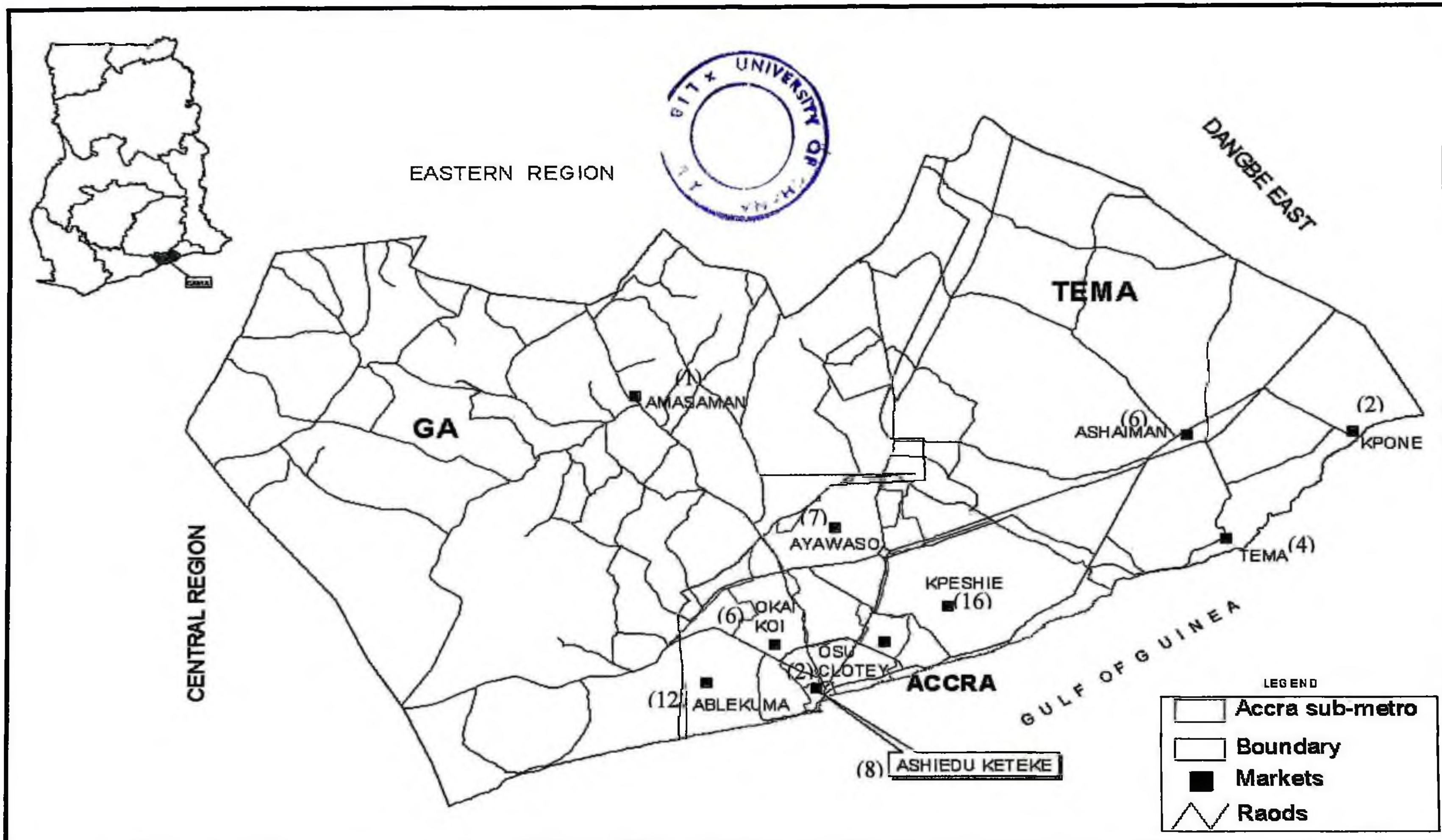
Source: Survey Department
Prepared by Remote Sensing & GIS Laboratory, Teaching & Research, Department of Geography & Resource Dev., University of Ghana, Legon

Figure 2.1 in page 18 above is a map detailing areas where vegetables are grown. Large-scale mechanised farming of pineapple and pawpaw on permanent basis is also now gaining attention by commercial farmers who are in export crop business. Livestock production (poultry, small ruminants, pigs and cattle) in the area has also been commercialised in the peri-urban agro-environments.

In the Accra-Tema area, there are 63 markets where vegetables are also sold. These markets are as follows: Ablekuma (12), Osu Clortey (2), Okai Kwei (6), Ayawaso (7), Kpeshie (16) Shiedu Keteke (8), Ashiaman (6), Tema (4), and Kpone (2). Figure 2.2 in page 20 below shows the market distributions in the area. With the present distribution of markets, there appears to be no problem with marketing of vegetables produced in the area.

Since Ghana's independence in 1957, the Accra-Tema area has been the centre of the country's industrial activity. Biney (1982) estimates that about 55% of Ghana's industries are located in the Accra-Tema area. The area has the highest number of financial institutions in the country, in addition to informal institutions such as co-operative bodies, private moneylenders, non-governmental organizations and credit unions. The availability of formal and informal funding promotes commercial activities in the area. In 1994, commercial activities were responsible for the generation of about 33% of the total municipal solid waste streams generated that year in the Accra-Tema area (Waste Management Department (WMD) of Accra Metropolitan Assembly, 1994). The rapid industrial expansion experienced in the area over the years brought in its trail increased municipal solid waste streams.

Fig. 2.2: Accra-Tema Metropolitan Area Showing Major Markets



Source: Survey Department and Field Work, 2001

Prepared by Remote Sensing & GIS Laboratory, Teaching & Research, Dept. of Geo. & Res. Dev. Uni. Of Ghana, Legon

The Waste Management Department of Accra Metropolitan Assembly estimated that in 1994 solid waste generation attributable to industry was about 0.050 million metric tons. This represented about 9.5% of the total solid waste generated in the area that year. Based on the average industrial growth rate of 2.5% per annum for Ghana, the solid waste generation by industry for the year 2000 was projected by WMD to be 0.75 million metric tons, or 13.6% of the total waste generated in ATMA during the year.

2.4 Agro-Climatic, Ecological and Soil Conditions

The climate in the Accra-Tema area is tropical and characterised by low amounts of rainfall, high levels of insolation temperatures, and high humidity values. The area has a bimodal rainfall pattern. The major rainy season starts from April and lasts till mid-July; and that season is followed by a short dry spell lasting until the end of August. Rain during the major season usually falls in intensive short storms. The minor rainy season starts from September and ends in mid-November. The mean rainfall ranges from 800 to 1100 mm, with a crop-growing period of 100 to 110 days during the major season. The humidity of the coastal savannah is generally high and can reach a mean of 70%. The humid period for the major rainy season ranges from 50 to 60 days, whereas the mean annual sunshine duration is 54 days. The mean maximum temperature for the Accra-Tema Area is 31°C, while the mean minimum temperature is 23°C per annum.

The characteristics of climate described above are of great importance in the production of all the food crops and livestock. The warm tropical climate and high humidity that prevail during the rainy season are favourable for the production of cassava, maize, plantain, pineapple and some vegetables, and of ruminants, pigs and poultry. According to officials of Ministry of Food and Agriculture (MOFA), most of the crops require about 900-1500 mm of rainfall per annum during the growing period. But the generally torrential nature of the rainfall during the major season makes soil erosion, nutrient leaching and laterisation ever-present hazards to agricultural production. During the minor season, the requirements for crop production are higher than the average rainfall within the study area, and as such it is normal to provide supplementary irrigation facilities to supply water to croplands, especially those used for vegetables. Another aspect of climate is that the combination of high temperature and humidity tend to create environmental conditions suitable for several disease-carrying insects as well as for a number of highly dangerous pathogens. The presence of diseases and pathogens presents a serious constraint to crop and livestock production in the area.

The study area is in the coastal savannah ecological zone, which covers about 0.50% of the total land area of Ghana. The topography of the area is generally undulating with high hills (400-600m) occurring in areas bordering the Eastern Region. The area is also characterized by thicket and tall-to-medium vegetation. Apart from the variety of trees, shrubs and herbs, the savannah re-growth is characterised by dominant grasses like *Panicum maximum* (elephant grass) and *Imperata cylindrica* (spear grass). Due to the nature of the coastal savannah vegetation, Accra-Tema area is vulnerable to bush burning. Burning causes sulphur to chemically combine with oxygen to form sulphur dioxide, which escapes into the atmosphere. Continuous annual bush burning, therefore, reduces the content of sulphur in coastal savannah soils that can be made available for crop production.

Soil characteristics and fertility status of an area are looked at from the viewpoint of the availability of macronutrients and micronutrients in the soil for agricultural production (Gerner et al, 1995). Macronutrients are those nutrient elements, which plants need in large quantities for growth and reproduction, whereas micronutients are those required by plants in minute amounts, but are nevertheless very important in crop production. Micronutrients such as iron, manganese, copper, molybdenum, zinc, boron, chlorine and iodine are available in the Accra-Tema soils in desired quantities, and therefore need no replacement from external sources (Gerner et al, 1995). Acquaye (1973) reports that Ghanaian coastal savannah soils are generally well buffered and possess better total potassium ion exchange (0.23 meq) than forest soils (0.16 meq). Also, he concludes that calcium concentrations and magnesium saturation of the complex soils in the coastal savannah are in sufficient quantities, and are generally satisfactory because of their high potential to support normal plant growth in the Accra-Tema Area.

Coarse-textured sands (regosols) occur along the coast as dunes and are very low in inherent fertility. Regosols by nature are usually not suitable for annual crop production, but may be suitable for permanent tree crops such as coconut (Kerbyson and Schandorf, 1996). In addition, Nye and Stephen (1962), Acquaye (1986) and Acquaye and Kang (1987) reveal that coastal savannah soils have widespread deficiency in nitrogen, phosphorus and sulphur. For example, the requirement for most annual crops in the coastal area is 152kg/N/ha, whereas the soils can supply only 67kg/N/ha (Gerner et al, 1995). This means that farmers in the coastal areas of Accra-Tema must always apply nitrogen-rich fertilizers to their soils on sustainable basis. Furthermore, organic phosphorus in the Accra-Tema soils, which can only be released through mineralisation of organic matter, is merely 66 parts per millimeter (ppm) as compared to forest soils of 129 ppm (Acquaye, 1986). The soils are therefore responsive to phosphate fertilizers or any organic soil amendments that are rich in phosphorus content. Generally, the rate of release of sulphur for savannah soils amounts only to about 3.36kg/ha annually (Nye and Stephen, 1962). Coastal savannah soils have low sulphur content, because savannah vegetation is incapable of recycling the sulphur nutrient from the sub-soil horizons (Acquaye and Kang, 1987). Sulphur is often supplied to the soils for crop production through the application of either chemical fertilizers or organic manures, including compost.

2.5 Transport Infrastructure

Transportation is important to the area's economy because it enhances the speedy movement of people, goods, logistics and ideas. The Accra-Tema Area has fairly good private transport system and intra-city road network. The railway transport system is however not good. The main streets are asphalted; however, some of the roads linking the suburbs to the main streets are not tarred or asphalted. Private buses, cars, taxis, and other vehicles carry out movement of people and goods in the metropolis. Local government authorities and private waste collectors own most of the vehicles used to carry people and goods in the municipality.

Waste haulage vehicles are mostly rickety and very often do not have covering materials to prevent the waste from spilling on the streets. Currently, road space is highly congested during rush and peak hours. The transport congestion and poor urban planning pose as serious constraints against locating compost facilities in the Accra-Tema area, especially those for decentralised large-scale compost projects with several transfer stations. Transport costs may be so high as not to justify the investment in such projects.

2.6 Waste Management Practices

Disposal of waste is mostly by open dumping in both controlled and uncontrolled sites. The management of wastes in the Accra-Tema areas revolves around public authorities:

Ministry of Environment and Science, Ministry of Health, Ministry of Local Government and Rural Development, Accra Metropolitan, Tema Municipal and Ga District Assemblies, and Environmental Health Division of the Ministry of Health. Specifically, the Waste Management Departments of the Assemblies are responsible for municipal waste collection, transportation and disposal within their areas of jurisdiction. The Environmental Protection Agency plays a complementary role by regulating and setting standards for waste-related emissions and monitoring of waste treatment and final disposal sites.

Waste generated in the area is made up of the organic fraction, biomedical materials, and non-biodegradable substances, such as plastics, metal, glass, and inert materials. Unfortunately, hospital and biomedical wastes, which are potentially more harmful to the public than any form of waste, are often treated the same way as other wastes. They are not separated from the main waste stream, but dumped in as much the same way as the other forms of waste. The infective agents in the waste therefore serve as potential health dangers to residents.

All but four of the twenty-two waste treatment plants in Accra-Tema area have broken down as a result of lack of funds to maintain them. For example, the Korle Bu Hospital had a treatment plant but this has been broken down for ten years because of financial difficulties, and what is available now at the site is offensive faecal matter choked up in the channels of the plant (Kwarteng, 2001). Other healthcare centres, households, companies and institutions in the metropolis channel their sewage sludge into septic tanks that are emptied periodically by the Waste Management Departments of the three Assemblies on a fee payment basis. The Assemblies carry out disposal of wastes at official disposal points in the area at the Mallam Landfill site and Teshie-Nungua Compost Plant. Under the Accra Waste Project and Metro-Environmental Health Initiative, a large, modern landfill will be constructed at Kwabenya to take care of most of the waste generated in the Accra Metropolitan Area.

Due to inadequate funds and other logistics, waste in the Accra-Tema area is not often properly managed, giving rise to associated socio-economic costs, environmental problems and health hazards. Being unable to manage the waste generated, some Assemblies have partly privatised waste collection. The Accra Metropolitan Assembly, for example, contracted waste collection in 1997 to a private company known as City and Country Waste Limited. To improve the collection system, the company was empowered to engage private collectors as sublet-contractors to collect waste from high-and medium-income and low-density areas. The house-to-house garbage collection service has been popular in these areas. There are various kinds of haulage vehicles and tractors used for collecting and transporting municipal solid waste to disposal points. Compaction vehicles, for example, are used to transport waste for moderate fees paid by waste generators. Special fee-free dispensation has been given to low-income and high-density areas, where households cannot afford to purchase their individual waste collection containers. Municipal authorities place central waste containers at vantage points for controlled dumping. These containers are monitored and supervised by various sub-metropolitan offices, which also ensure that these containers are emptied when they become full. Multi-lift hydraulically powered trucks are used to convey the central containers to official disposal sites where they are emptied. No fee is charged for dumping waste into these containers. Etuah-Jackson et al. (2000) estimate that about 45% of the total waste collection in the Accra-Tema area is done by this system.

Special waste collection practices have also been employed in the municipality covering commercial houses, private companies, markets, car parks, government institutions and diplomatic missions. Waste from these areas are either collected by the Assemblies or contracted to sub-contractors for fees, which are determined by the collector. Some non-governmental and community based organisations are collecting wastes generated in the market centres and turning them into marketable composts. Scavengers play important roles in collecting certain special wastes from waste dumps for reuse and recycling. Currently, there are five small-scale plastic recycling facilities in Accra and one paper recycling facility in Tema that arrange for special services from private contractors and scavengers.

2.7 Legal Framework for Waste Management

Environmental and economic instruments and regulations are necessary to guide waste management practitioners towards responsible municipal solid waste management and according to acceptable sanitation standards. Significant legislative acts have been enacted over the past four decades that have relevance to sustainable waste management in Ghana. The relevant ones are: the Criminal Code of 1960 (Act 29), the Local Government Act of 1993 (Act 462), the Environmental Protection Act of 1990 (Act 490) and the Environmental Impact Assessment Regulations of 1999 (Legislative Instrument 1652).

The Criminal Code of 1960 (Act 29) empowers metropolitan, municipal districts assemblies to develop their own by-laws to tackle waste generated in municipal areas. Sections 296 and 300 of the Code (Act 29 of 1960) deal specifically with the generation and dumping of waste by private businesses and individuals, but do not categorically state the sanctions that should be imposed on local government authorities if they fail to manage municipal wastes responsibly. Also, the penalties prescribed in the Act (29) are minor and non-deterrent, as well as not reflecting on the current social and legal demands of municipal waste management (Sarpong, 1999). Finally, the by-laws that are passed by the Assemblies do not emphasise on the economic use of the abundant organic waste component. Act 29 of the Criminal Code (1960) consigns the utilization of organic wastes for agricultural production to the exclusive discretion of individuals and organizations. Notwithstanding its deficiencies, Act 29 is relevant to composting because it limits the degree of indiscriminate waste dumping in and around cities, thus concentrating waste at designated places for easy collection. In this way, the costs of organic waste collection and transportation are reduced.

The Local Government Act of 1993 (Act 462) was enacted as an adjunct to the decentralization policy of the local government administration and machinery. The Act (462) spells out responsibilities of metropolitan, municipal and district assemblies towards waste management, even though it does not specifically prescribe the best options for treatment to be adopted. Nonetheless, it does make the general public and local governments squarely accountable for infractions in waste management practices. Under Act 462, the scope of the Assembly by-laws on Environmental Sanitation has been amply widened and reinforced. It recognizes the significance of recycling municipal wastes into organic manures for urban and peri-urban agricultural production.

The Environmental Protection Act, 1994 (Act 490) established the Environmental Protection Agency and also conferred on it certain legislative powers to deal with environmental abuses through the application of enforcement and compliance procedures. The provisions of the Environmental Protection Act (Act 490) deal generally with environmental protection in the country. With wide discretionary powers engendered in a number of omnibus clauses, the Agency develops, and occasionally upgrades, quality standards for entrepreneurs who want to invest their risky assets into productive ventures such as composting. The financial burden associated with achieving the best quality standards affects the costs of compost production considerably.

The Environmental Impact Assessment Regulation (Legislative Instrument 1652) was promulgated in 1999 by Ghana's Legislature. The Regulation (L.I. 1652) makes it obligatory for all new development projects to go through the environmental impact assessment procedures that will identify and mitigate environmental problems before commencing to execute the undertakings. The management of solid waste is one of such mitigation measures. A new compost project will have to be subjected to an environmental impact assessment at a cost to the entrepreneur. Once in operation, the entrepreneur will have to be regulated by the environmental management plan of compost facility. These two requirements will thus increase costs involved in establishing and running compost facilities in a given area.

In addition to these laws, Ghana, in 1999, adopted the National Environmental Sanitation Policy to provide the framework for developing and maintaining clean, safe and pleasant physical environment in all human settlements. Principal components of environmental sanitation such as collection and disposal of all types of waste, environmental education, inspection of disposal sites, monitoring and observance of environmental standards and enforcement of regulations are given prominence in the Policy. Out of the Policy, regulations on utilisation of organic and/or green waste for compost production and quality standards have been developed for the nation by the Environmental Protection Agency. The quality standards make it obligatory for compost producers to produce their products with minimal leachate, gaseous emissions, contaminants and pathogens. In the bid to meet these quality standards and to undertake environmentally safe operations, capital and operating costs of composting MSW are likely to increase for every facility. In spite of the existence of the National Environmental Sanitation Policy, waste management practices in ATMA leaves much to be desired. According to the Waste Management Department of Accra Metropolitan Assembly, less than 50% of urban dwellers were served with solid waste collection in the year 2000, and less than 30% of them were served with acceptable toilet facilities in the same year. The chaotic sanitation situation manifests itself through the lack of formally constituted environmental sub-sector in the local government system; lack of technical capacity in the Ministry of Local Government and Rural Development to orient and support the Metropolitan, Municipal, and District Assemblies in the provision of environmental sanitation services; weak, outmoded and poorly enforced environmental sanitation legislations; inadequate allocation of resources for environmental sanitation services; and inadequate manpower including engineers, planners and administrators for planning, management, policy formulation and research on waste management.

CHAPTER THREE

LITERATURE REVIEW

3.1 Introduction

The selection of composting facilities commensurate with the local economy, and the formulation of sustainable policies for composting municipal organic waste depends on clear-cut knowledge of what is involved in the art of composting. Knowledge about the dynamics and economics of composting will help political authorities, compost producers and users, agricultural scientists, and economic analysts in making decision on the level of composting. This Chapter reviews literature on (1) the main waste management methods (2) the dynamics of composting and (3) overview of the economics of compost investment in a municipality. The limitations of these bodies of work help to identify needed improvements on previous research efforts in the field of composting, as well as accomplishing the overall objectives of the research.

3.2 Municipal Solid Waste Management

Waste management in Ghana currently comprises three elements: waste collection, recycling and waste disposal. This section discusses some terminologies used in waste management, conventional waste treatment options practiced in the Accra-Tema area, disadvantages of each of the management options other than composting, and how composting will overcome these disadvantages.

3.2.1 Definition of Terminologies

The term "waste" is defined in the German Waste Act of 1993 and translated in English as a collection of portable objects that have been abandoned by the owner (Bilitewski et al, 1994). According to German Agency for Technical Co-operation (GTZ) handbook on composting, "waste" is defined as "movable objects, which the owner wants to dispose of, or the proper disposal of which is required to ensure the well-being of the general public, particularly for the reason of environmental protection". Harris et al (1993) state that mobile objects that are left by the owner to the institution responsible for disposal or a third party commissioned with the disposal are regarded as waste throughout the utilisation process until the materials or energy produced become available. Municipal solid waste therefore comprises disposable materials generated by households, commercial establishments, businesses, the service sector, industries, public institutions, open markets, and municipal sewage. Household waste is predominantly from private households, associated with municipal or private collection, regular pick-up, and disposal services. Utilisation of organic waste involves delivery, treatment and spreading of organic waste and mixtures on the land with the help of treatment facilities. The term "organic waste" is applied to materials that consist primarily of organic substances. These substances may include even contaminating materials that are biodegradable in nature. Biodegradable materials can be converted through microbial activity either into compost or methane that can be captured and used as fuel. In specialist literature, organic waste is used to describe waste that can be decomposed biologically through either aerobic or anaerobic processes. Aerobic processes are those decomposition methods that take place in the presence of oxygen, whereas anaerobic processes take place in the absence of oxygen (Waite, 1996). Solid waste, in particular bulking materials that can be easily ventilated, is suitable for aerobic treatment methods. Liquid waste and other waste with high water content and/or with weak structure are especially suitable for anaerobic treatment.

3.2.2 Waste Treatment Options

The available options for municipal waste treatment are landfilling, recycling, incineration and composting. Large landfills, incinerators and waste recovery plants are typical of developed countries. For developing countries like Ghana, however, the usual municipal waste management practices are landfilling, illegal dumping, limited recycling, incineration and composting. The degree to which the conventional methods are practiced depends upon the available technological acumen and financial resources available to the country involved.

3.2.2.1 Landfilling

The predominant method of waste disposal in this country has been and remains lanfilling. In landfilling, waste disposal sites are divided into a series of cells, which are filled one at time as part of the construction and control of the site. As the waste is deposited each day, it is covered with a landfill cover usually made of a layer of soil or other inert material such as construction waste, in order to minimise nuisance from windblown litter, odours and vermin. The heavy bulldozer-like compactor vehicles then compact the covered waste. For a modern landfill, lining, leachate treatment and gas control measures are absolutely necessary in order to meet environmental requirements and standards. Landfills are advantageous as a sole waste disposal method because the technology is rather simple. Furthermore, their low, short-term operational costs are also important when one is considering landfilling as an option for waste management. By 1990, five landfills had been constructed at the suburbs of Korle Bu, Teshie, Mallam and Amansaman in the Accra-Tema area. Currently, a modern landfill is planned to be constructed at Kwabenya, also a suburb in the area. Environmental regulations on leachate management and gaseous emissions, and increasing scarcity of land result in high landfill costs. Presently, only about 60% of the municipal solid waste is landfilled (AMA, 2000). The daily per capita cost of waste management in the ATMA was about ¢68.00 in the year 2000, which translated to about ¢67 billion in absolute terms for the year (AMA, 2000). With increasing population, changes in production and consumption patterns, demand for better environmental quality and stringent regulations imposed by the state and environmental control bodies, it is likely that per capita cost of waste management will increase in the nearest future, and thus straining the administrative capacities of local government authorities.

3.2.2.2 Incineration

The second method of waste disposal is that of waste incineration. Waste incinerators use the process of combustion to convert many of the materials within the municipal waste into their primary components of water, carbon dioxide and carbon. The purpose of incineration, therefore, is to thermally treat non-recyclable and non-reusable materials that results, *inter alia*, in: making hazardous wastes inert; destruction of contaminants; reduction in waste volume; energy recovery; and the production of marketable secondary materials (Bilitweski, 1994). Since not all the materials can be combusted, such as metal and glass, solid waste residue will always be disposed of at a landfill. Incineration is therefore a method of reducing the amount of waste to be disposed of by the landfill. Germany has the highest number of the state-of-the-art incinerators in the world, which treat only 30% of all disposable wastes in the country. In the rest of the European Union, only 13% of disposal waste is incinerated (Bilitweski et al, 1994). In most developing countries, the use of properly engineered incinerators for waste treatment has been limited. This is so because the method requires high treatment technologies, which are not readily available in the developing countries (Bilitweski et al, 1994). In Ghana, for example, there are no state-of-the-art incinerators established to recover energy, scrap and slag from organic waste. There are, however, a few improvised concrete incinerators being operated by some government institutions in the area. AMA estimates that about 10% of municipal solid waste in the area is burnt.

3.2.2.3 Recycling

The method of recycling describes the recovery and reuse, from the main waste stream, non-biodegradable and useful materials such as plastics, textiles, oil, metals, and glass. The 1980s saw a renewed interest in recycling in some developing countries including Ghana. This was prompted in part by a new environmental awareness of the general public as well as decreasing landfill space and increased disposal costs (Boon, 2000). However, the scale of recycling in developing countries has been extremely small, averaging about 5% per annum of the total waste streams generated (Harris et al, 1998). In the Accra-Tema area, the materials most frequently collected for recycling are glass, paper, plastics and metal cans. There are no officially organised collection schemes in the area. Scavengers, who sell their wares to small-scale recovery plants, do most of the collection and sorting of the recyclable materials.

3.2.2.4 Composting

Another process of waste treatment is composting. Composting is a biochemical process that breaks down organic substances into a stabilized residue called compost. According to Bilitweski et al (1994), organic wastes invariably carry a variety of benign, beneficial, microbes (mainly bacteria and fungi) fully capable of initiating and carrying through to completion a composting cycle. The compost so produced can either be used as a soil ameliorant in agricultural production or as a landfill cover. By 1981, one composting plant had been established at the suburb of Teshie-Nungua in the Accra-Tema Metropolitan Area. The facility has a designed capacity of processing 38,000 metric tons of raw MSW into about 21,000 metric tons of compost. The compost plant is currently being under-utilised due to technical and financial problems. Together with individual "composters", only 5% of the waste generated in the Accra-Tema area is composted annually.

3.2.3 Disadvantages of Waste Treatment Methods other than Composting

This sub-section discusses the disadvantages of landfilling, incineration and recycling of municipal solid waste as compared to composting.

Landfilling: In spite of the relative advantages of landfilling, several disadvantages and constraints are associated with it as a municipal waste management method. Rushbrook (1982) found out that the construction of properly engineered landfills is characterised by large initial capital outlays. For example, the overall cost of construction and management of landfills could be as much as 65% of annual municipal budget (Bilitweski et al, 1994). The costs of closing and recapping used landfills, and the expenses involved in managing leachate produced by closed landfills are equally high. In most developing countries, the ability of government authorities to construct new landfills has been constrained by lack of funds ((Johnnesssen, 1999). Consequently, most active landfills operating in developing countries have been constructed using funds obtained from multilateral and bilateral financiers with conditionality to the funds. Also, no matter how a landfill is engineered, it will always pollute land and water bodies with some amount of leachate. Gases such as carbon dioxide, methane and other constituents are released into the atmosphere that contributes to global warming and stratospheric ozone depletion (Johnnesssen, 1999). Landfill gaseous emissions account for nearly half of the world's total anthropogenic sources of methane, which when released into the atmosphere can contribute to about 2-4% of global release of greenhouse gases (Johnnesssen, 1999). Methane, which is often released from landfills, has about 21 times the global warming impact of carbon dioxide, and thus a powerful global warning agent (Johnnesssen, 1999).

Incineration: Incineration has several disadvantages that make it an infamous waste treatment method in most countries. The percentage of energy generated by the incineration of waste using locally designed technologies is relatively minor, and does not justify investment in this method of waste treatment (Bilitweski et al, 1994). Besides, the need for equipment for particulate collection, flue gas scrubbers and equipment for desulphurisation makes incineration investment and running costs extremely high. In addition, other disadvantages arise from the difficulty of minimising harmful gaseous emissions that are released into the atmosphere; high safety requirements; large and specialised spatial requirements; and the requirement of strict enforcement and compliance legal instruments, which are cost related.

Recycling: Recycling has the disadvantage of taking out only a small, select amount of the waste stream, and therefore fails to deal substantially with waste management problems in the cities. Also, there is lack of viable markets in the current developing economies at the moment to make this goal economically feasible. Boon (2000) argues that the average cost per ton of recyclables is also high, particularly in Ghana, due to costly recycling technologies, and expensive waste-to-energy facilities required for the incineration of non-recyclables. In addition, the art of recycling requires financial support and costly training programs for scavengers to enable them judiciously sort out the recyclable materials. Recycling of waste, like landfilling and incineration, also releases gases into the atmosphere causing indeterminable environmental pollution (Bilitweski et al, 1994). Finally, recycling is only achievable if there are well laid out legislations that hold both producers and distributors responsible for taking back packaging materials for the purposes of reusing or recovering it outside the municipal waste stream. The collection of recyclables must also be controlled by certain standards of recovery rates and sorting quotas as set by law.

3.2.4 Comparative Advantages of Composting Municipal Solid Waste

In general, clean and healthy living conditions in cities, towns and villages cannot be achieved without reliable and regular waste collection and disposal. In the past years, local government authorities throughout the world, in the bid to improve urban collection services, expended much effort in that direction including privatisation of waste management. As much as 65-80% of waste stream in middle and lower income countries are compostable (Hoornweg et al, 1999). Therefore, if this fraction of municipal solid waste is removed for composting, the process will improve the overall waste diversion volume from disposal sites, and provide an excellent opportunity to improve upon a municipality's waste collection and transportation programmes, thereby reducing nuisances such as pests, vermin and noxious odour and, of course, the cost of waste transportation to landfills and recovery centres. In comparison to other waste treatment methods, composting has only minor negative effects on the environment. It is an ecologically sound method of waste treatment because the organic component is returned to the natural cycle. Composting is one of the simplest ways of reducing emission of methane and other anthropogenic gases because the organic fraction, which constitutes about 70% of the waste stream in developing countries, is diverted from the main waste stream. The emission of landfill gas produced by the decomposition of organic material in a compost facility is lesser than for landfilling, incineration or recycling facilities of comparative sizes. The quantity of leachate produced from composting that is capable of causing pollution damage to the environment is considerably reduced. The practice of collection and re-circulation of leachate into active compost piles during composting mitigates any environmental impacts while at the same time enhances the composting process. Moreover, composting helps to minimize environmental pollution by reducing the concentrations of biochemical oxygen demand (BOD) and phenols produced as by-products from the decomposition of leaves and metals mobilized by the formation of carbonic acid from the matrix (Hoornweg et al, 1999). The costs of construction and management of leachate facilities and environmental damage caused during compost production are, therefore, considerably reduced.

Composting of waste reduces the ill-health effects associated with municipal solid waste. Available literature, such as those written by Caincross and Fachem, (1993), Rushbrook (1998) and Lopez-Real (2000), shows that the promotion of malaria, dengue fever, filarasis and similar waste-and water-related diseases has been attributed to improper waste management in tropical countries. Rushbrook (1998) further states that the ill-health effects of improper landfilling and incineration may include physical damage to human beings and animals arising from waste-related accidents, asphyxiation, musculo-skeletal injuries, fire and explosions, and other mishaps. Microbial contamination with bacteriological, protozoan pathogens and similar ineffective agents, resulting from lack of or improper waste management, can also cause ill health and deaths. Other ill health effects arise from radioactive, chemical and microbiological contamination that affect target organs, reproductive systems, and regulatory/control functions within the body. The chemical inducement of cancers is also a theoretical possibility. Composting thus reduces the possible contamination of pathogens and other infective agents and their subsequent transmission to a host, and minimizes diseases, deaths, stillbirths, low birth weights or specific birth effects and nervous disorders. It therefore reduces national health bills arising from significant health impacts of accumulated organic matter.

In addition, composting is more flexible to implement at different levels than other methods of disposal; it can be implemented from household efforts to large-scale decentralized facilities. Hoornweg et al (1999) state, from the point of view of economics, that composting can be started with very little capital and operating costs. The biological processes of a compost enterprise can be predicted, and is indeed well understood by scientists. The interactions among the key process factors can be variously manipulated to serve different circumstances. The flexibility of the composting process may account for the potential for low capital and operating costs.

Compost is a source of plant nutrients and energy for the soil ecosystem, with soil microbes subsequently making the nutrients available to plants in balanced proportions and distributed throughout the season. It also stimulates the complex of predatory microbes, which will help keep potential pests and pathogens under control (Lampkin, 1990). Gottschal et al (1987) also argue strongly that the humus effect of compost is associated with increased microbial activity, reduced aggressiveness and infestation of pathogens, increased viral resistance and reduced soil "tiredness" or toxicity. A research conducted by Schüller et al (1989) in Germany further established that the increase in pythium infection of beetroot, peas and beans was reduced from 80% to 20% through the application of compost. Finally, compost allows for the direct uptake by plants of specific chemicals such as phenols, which are needed for the development of immune systems of plants (Huber and Watson, 1987). Compost, used as a soil amendment material, has other conditioning advantages including improving the soil characteristic such as structure, texture and air pore space, and thereby increasing the water retention capacity and nutrient intake ability of plants (Langouche, 1993). Soil acidification associated with the excessive use of chemical fertilizers, especially those from nitrogenous sources, may be reduced with the use of compost. The compost keeps the soils as basic as possible and thus promotes the growth of a large variety of crops (Rynk, 1992). The cost of fertilizing a piece of land over a period of time with compost is less than fertilising the same land with chemical fertilizers over the period, since compost application has a long-term effect on the soil (Lampkin, 1990).

3.3 Dynamics of Composting

The focus of this section is on the technical aspects of composting and on how the various biodegradable processes affect the construction and operation of compost facilities in the Accra-Tema area. It also examines past experiences of compost production in some West African countries and the factors that affect the location of compost facilities. In the main, the aims of these discussions are to assess the technological and methodological gaps that exist in the processes of composting, and to generate additional information on technical issues that must be addressed by the current research.

3.3.1 Mechanics and Compost Production Processes

Composting is simply the enhancement of the natural biological degradation of organic matter in the presence of oxygen, moisture and microorganisms. Nutrients supplied by the organic material at suitable hydrogen potentials (pHs) are also necessary for the biological process. The process of composting, therefore, involves correctly controlling these three elements of water, oxygen and heat. Indeed, a ready supply of oxygen is essential for the decomposition process. The desired moisture content and temperature ranges for the decomposition process are 50-60% and 55^0C-65^0C respectively (Lardinois and van der Klundert, 1993; Hoornweg et al, 1999). For the survival of microorganisms that are responsible for the microbial activity, the preferred pH range is usually between 0 and 6 (Hoornweg et al, 1999). The quality of compost is determined by the level of impurities and heavy metals contamination, and by the carbon-to-nitrogen ratio (C/N ratio), (i.e. the amount of carbon relative to nitrogen). The optimum C/N ratio of good quality compost is usually within the range 20/1 and 35/1 (Hoornweg et al, 1999 & Bilitewski et al, 1994). The organic material that is to be composted must be put in a condition that makes the decomposition process efficient and less costly. Therefore, other key characteristics affecting collection and composting of municipal solid waste include density and surface area of the material, biodegradable content, and energy content of the material (Beede and Bloom, 1995). The optimum particle size depends upon the type of raw material to be composted, although a smaller particle size will increase the rate of aerobic decomposition since the available surface area is increased. Obeng and Wright (1987), in a technical presentation, discuss the co-composting of societal solid waste and human excrement and suggest that typical sizes should be approximately one centimetre for forced-aerated composting, and five centimetres for passive aeration windrow composting.

The technical requirements stated above have direct implications on the technologies available for composting, and on investment and operational costs. For example, high moisture content tends to clog windrow aeration machines, reducing the efficiency of the equipment and increasing the cost of repairs. Maintaining moisture content at a level that reduces composting time may make composting costly in arid regions, and in areas contaminated by salts, heavy metals, and other non-biodegradable pollutants

(Tchobanoglous et al, 1993). Secondly, if the technical requirements are to be adequately met, some mechanical facilities and equipment will be needed to manipulate the processes in order to achieve desired parametric levels. Costs are incurred to purchase and install capital items, and to run the facilities during the life of compost projects. Retrofit activities and improvement of facilities and processes are fairly costly ventures and if not properly analysed during project design, could throw the composting scheme overboard. Finally, the composition and physical characteristics of organic waste affect the economies of collecting and processing it, and the disposal of residual waste arising from the processing (Hardy et al, 1976).

The problem with conclusions drawn by on the technical parameters is how to quantify and categorise costs for each of these parameters when conducting investment analysis of compost projects. Earlier researches on the cost of composting municipal waste by Hovseius and Johansson (undated), Hart (1968) and Stone and Willes (1975) failed to develop models that assign specific costs to the partial processes of compost production. It is instructive to note, however, that though their conclusions did not establish functional relationships between the technical parameters on one hand, and investment and operational costs on the other, they nevertheless called for circumspection in conducting compost investment analysis. However, the difficulty can be overcome by taking average costs associated with each sub-process of existing and previous compost projects and compounding them to obtain present values (Hovsenius and Johansson, undated).

3.3.2 Existing Technological Options for Compost Production

Composting of municipal solid waste (MSW) consists of a series of stages and support systems, with each compost system having its own technical constraints and alternatives.

The availability of land, rate of composting and spatial distances between transfer stations and the compost plant are the key determinants of the choice of composting options and facilities for a municipality (Beede and Boon, 1995). The choice of a composting option is based on how its procedures will effectively reduce waste quantities that are available for collection, thereby improving efficiency and reducing operating costs of the waste management system. For MSW composting, the windrowing system is often preferred to other systems such as in-vessel composting (which occurs in containers or vessels that are equipped with mechanical devices designed to facilitate the aeration and minimise odours and process time), vermi-composting, or vermin-culture (which involves the break down of organic material through the natural digestion by red worms and earthworms), anaerobic digestion (that is, a process involving the decomposition of organic material in the absence of oxygen), and sewage sludge composting. Windrow composting is the oldest, simplest and most versatile method where the organic matter is built into piles for the biodegradation to occur. A windrow can either be a conical or a trapezoid collection or a heap of the material being composted. Control of the decomposition process in the windrow, through turning and watering, is necessary. The compost mass must be maintained at 65^0C for 2-3 consecutive days, and must be allowed to mature and then become biologically stable to prevent pathogens re-growth (Rynk, 1992 & Bilitewski et al, 1994). The degradation time required until the compost is finished is 9 to 12 weeks with regular turning; 12 to 16 weeks without turning but with forced aeration; and 20 to 25 weeks without turning and without forced aeration (Bilitewski et al, 1994).

The options available for municipal solid waste composting include: household composting, decentralised community composting and large-scale centralized composting, or a combination of the last two options. Household composting option is chosen when it is desired to manage residential kitchen and garden wastes. Backyard composting is an example of household composting, but this is usually practiced where land for the compost facility is available. Due to extreme caution required in avoiding vermin, rodents, scavenging animals and malodour, this composting option has not been popular with developing countries where resources for minimising such environmental nuisances are very much limited.

Decentralized community composting is suitable for households, commercial establishments and institutions where the organic waste generated is between five and fifty tons per day (Hoornweg et al, 1999). When this option is chosen, low capital, labour-intensive composting facilities may be required. Labour-intensive composting facilities are suitable for and common with developing countries, where the volumes of waste generated are of high organic content. In a large metropolitan area, such as Accra-Tema, several decentralised compost plants may be established at various strategic locations, with each plant treating the waste generated within its immediate vicinity. Under such circumstances, a few transfer stations may be required for the municipal waste prior to conveyance to the compost plant.

Centralized composting requires a medium to large initial capital outlay to be able to meet volumes of organic waste generated ranging from 10 to more than 500 tones per day (Hoornweg et al, 1999). To undertake a centralised composting, a large facility is established at a suitable place in the municipality where the waste is conveyed from a number of transfer stations to the compost plant for processing. Due to the requirement for large capital outlay, the centralised option has only been limited to industrialised countries such as The United Kingdom, United States of America and Germany. Centralised composting has been made possible by the availability of skilled labour, machinery and equipment, and financial resources in these countries (Bilitweski et al, 1995). Experience has shown that most centralised composting plants with several transfer stations established in the 1980s with foreign aid in municipalities of developing countries failed miserably because the operatives were not able to sustain their financing after the sponsors had withdrawn (Asomani-Boateng et al, 1996).

The technological options available can also be viewed in the light of source separation and mixed MSW composting. Composting of source separated MSW refers to the processing of only organic materials suitable for composting that have been separated at the point of generation. Mixed MSW composting involves the processing of the entire MSW stream without separation at the point of generation. That is, rather than separating the organics at the source, the separation is undertaken at the composting facility with the help of additional equipment or human labour. The choice between these options is often based on careful consideration and analysis of collection and processing costs and equipment needs, quality, marketability, and total diversion rates from disposal facilities, and the public perception towards recycling and composting (US EPA, 1992; Dillon and CalRecovery, 1989). Though waste collection costs for source separated composting has been found in most literature to be higher than for mixed MSW composting, the former has more advantages than the latter. Source separated composting has lower capital and processing costs, contaminants, physical capital depreciation, and public education needs than mixed MSW composting (Kashmanian and Spencer, 1993). In spite of these advantages, source separation composting has not been significantly practiced in most countries, including even developed countries. The trend in Europe, however, is to move away from mixed MSW composting towards source separation composting (Segall, 1992). The main problems associated with source separation in developing countries are ignorance on the part of waste generators and lack of funds to conduct intensive public education on the need to undertake source separation (Contreau-Levine, 1997). The key problem with developed countries in this respect is that households have not fully become amendable to new ideas of waste management (Bilitweski et al, 1995).

Whether labour-intensive or capital-intensive technologies are employed to these options, technical guidance is necessary. Most guidance materials on composting are based on explanation of techniques and technologies suited to the conditions and regulations in high-income countries. They are often based on extremely high automated, capital-intensive technologies and models, incorporating a wide range of aesthetic issues, low gaseous emissions and high qualities of leachate treatment. Consequently, such guidance materials are not necessarily relevant to the requirements and capabilities of municipalities in middle or lower-income countries. Entrepreneurs in developing countries will readily invest in compost facilities if technical guidance will show clearly that the risk involved in undertaking composting is minimal.

3.3.3 Overview of Compost Production in West Africa

The value of urban waste to peri-urban agriculture in West Africa is, in principle, well known. In general, community-generated refuse, crop residues, green wastes, stable manure, poultry droppings and household sweepings in these communities were either incinerated for potash, or mixed with night soil and composted (Harley and Greenwood, 1933). However, these traditional methods of organic fertilizer development were followed more empirically and less scientifically (Shridhar 1992, 1993 & 1995). Available literature reveals that, due to increases in urban population and chemical fertilizers' prices, many West African countries adopted more scientific methods of converting the huge urban waste into compost. Asomani-Boateng et al (1996) report that by the middle of 1990s, compost plants of various capacities were designed and installed in the West African sub-region. The purpose of this section is to discuss the experiences of some projects in the sub- West African region. Table 3.1 below summarises compost production experiences in Ghana, Togo, Burkina Faso, Nigeria and Benin. The selective review of composting efforts in the sub-region shows that despite the relative simplicity of composting, its suitability for developing countries and its compelling economic and environmental benefits, the history of composting in the region has not been healthy. All the projects reviewed in this study are currently operating below designed capacity. Apart from the Hevie (Benin) and Tevie (Togo) projects, most of the projects reviewed showed signs of traumatic failures due to technical, organizational, financial and institutional problems.

The Teshie-Nungua plant in Ghana, for example, has seen a wide variation of fortunes since its establishment in 1980. It produced nearly 11,000 metric tons (mt) of compost in 1980 and 21,000 mt in 1987, but by 1999 production had declined to an average of 1,800 metric tons per annum. The gradual collapse of the Teshie-Nungua compost facility is manifested by a large downtime and the fact that the site has virtually become a dumping ground for all sorts of waste generated by residents in the neighbourhood of the plant. Also, a developed Teshie-Nungua community now encapsulates the compost plant, which at the time of installation had no settlements in the vicinity. At present, the plant has become a centre of loud and furious protestations from nearby residents because of malodour and ill health concerns.

Table 3.1 **Compost Production Experiences in Some West Africa Countries**

Name and Location of Compost Facility	Teshie-Nungua, Accra, Ghana	Zogbo and Houeyiho Pilot Projects, Cotonou, Benin	Hevie Waste Separation and Compost Plant, Benin	Bodija Organo-Mineral Fertilizer Plant, Ibadan, Nigeria	Lome and Tsevie Compost Production Projects for Phytosanitary Purposes, Togo	Wogodogo Compost Plant, Ouagadougou, Burkina-Faso
Year of Establishment	1980	1994	1998	1985	1998	1998
Capacity of Compost Facility (Tons of Raw MSW per Annum)	38,000	550 (each)	5,000	9,000	3,600	5,000
Actual Production Capacity (2001) (Tons of Raw MSW per Annum)	11,000	360	3,000	3,600	1,700	3,000
Access to Sources of Organic Material	Easy Access to Organic Waste	No easy Access to MSW	Easy Access to MSW	Easy Access to Bodija Market Waste, and Slaughterhouse Waste.	Easy Access to MSW	Easy Access to MSW
Method of Waste Collection	House-to-house Collection system Communal Containers	House-to-house Collection System	Curbside collection System	Curbside Collection System (Communal Containers)	House-to-house Source-separated Waste collection System and Communal Containers.	House-to-house Collection system and Curbside System.
Technology Employed	Capital-intensive Mixed MSW Composting	Labour-intensive, Waste-separated before Composting	Labour-intensive, Manually-separated Waste Composting	Labour-intensive, Manually-separated Composting	Labour-intensive, Source-separated Composting	Labour-intensive, Manually-separated Composting
Viability of Compost Facility	Not Economically Viable	Not viable	Viable	Not viable, but Socially Desirable	Not Viable	Not Viable, But Socially Desirable

Source: Author's Own Results

Table 3.1 Con'd

Name and Location of Compost Faculty	Teshie-Nungua, Accra, Ghana	Zogbo and Houeyiho Pilot Projects, Cotonou, Benin	Hevie Waste Separation and Compost Plant, Benin	Bodija Organo-Mineral Fertilizer Plant, Ibadan, Nigeria	Lome and Tsevie Compost Production Projects, for Phytosanitary Purposes Togo	Wogodogo Compost plant, Ouagadougou, Burkina-Faso
Problems facing Compost Facility	-Lack of Spare parts, Water, Training and Public Education Programs, and reliable Energy. -Poor funding No clearly defined Marketing Strategies -Persistent Public Complaints about Malodour. -No Collaboration and Networking amongst Stakeholders	-Poor Quality of Compost. -Low priced Competing Products such as Poultry droppings, "Black soil", Animal Manure, Raw Waste etc. -Lower Market Prices of Compost than Production Cost. -Lack of Training Programmes for Operators. -Difficulty in Accepting the Value of Compost.	-Complaints about Malodour. -Cheaper priced Competing products such as black soil, poultry droppings, animal manure, raw waste etc. -Poor marketing strategies. -Far away from Farmers and other Compost Users.	-Political bickering over Ownership of Compost Facility -In adequate Working capital. -Poor quality of compost. -Lack of Skilled Personnel to Manage the Plant.	-Problem of Replicating Technology elsewhere in Togo. -Inadequate Funding. -Poor Marketing Strategies. -Poor quality of Compost. -Higher Prices of Compost Products.	-Cheaper priced Competing Products. -Lack of Public Education on the Benefits of Compost and Source Separation -Poor Marketing Strategies.

In Benin, peri-urban and urban agricultural farmers directly plough large volumes of organic wastes into the soil. With the direct utilisation of the organic waste by farmers, coupled with the low level of waste collection organisation, the availability of organic waste in Cotonou for the operation of the composting facilities became a hindrance. The two projects at Zogbo and Houeyiho, which were established as pilot projects, collapsed. Apart from the raw waste constraint, the technical skill needed to manage the compost plants was lacking. Farmers who had no skills in managing the compost plants abandoned the projects to concentrate on their personal vegetable farms. However, the much-improved version at Hevie has proved to be potentially viable.

The Bodija compost plant (in Ibadan, Nigeria) was developed in 1985 to turn the voluminous waste generated by the Bodija market into organic fertilizers. In spite of its high economic potential of the project, it has been a subject of political bickering since its establishment in 1985. There has not been a clearly defined ownership of the project as management of the plant keeps changing from one organization to another. Also, inadequate working capital, lack of skilled personnel and clearly defined roles, low compost prices, and heightened ethnic tensions in the area are problems that have hindered the management of this otherwise socially desirable compost plant.

Generally, compost quality and marketability problems have also featured prominently in the sub-region. Quality demands by compost users are high; therefore, municipal compost produced compete with other organic products and composts "for a share of the organic fertilizer market" in the sub-region. For example, production at the Zogbo and Houeyiho pilot projects at Cotonou, Benin, subsequently failed because of doubts about the value of compost, resulting in low real demand even though the product was found to be of high quality. Also, the market price of compost in Togo (i.e. CFA 4,000 francs/ton in 1995) could not cover production costs (CFA 19,000 francs/ton in 1995) of the compost produced. In Ouagadougou, Burkina Faso, whereas the sale price of the compost was calculated based on production costs at 15,000 F. CFA per ton, farmers could obtain other soil ameliorants such as "blacksoil" (earth screened at a waste landfill), animal manure, poultry droppings and brewery waste between 5,500 and 9,000 F. CFA per ton (Quoted in 1998 prices).

In conclusion, therefore, the history of compost projects in the sub-region has been checkered. While some projects are operating below designed capacities, others have been closed down because of financial and technical problems confronting them. If a composting facility's history is checkered, retrofit improvements to the program may not be easy to finance, given the increased financial risk of the project. This is because retrofit activities are not known at the start of the project and is unlikely to have been considered when the composting program was designed. Indeed, this has been the bane of the compost projects in the West African sub-region. The establishment of any future compost projects should therefore address the factors that militate against their sustainable operations.

3.3.4 Locating Compost Facilities and Municipal Solid Waste Transportation

In order to make the composting business in a metropolitan environment successful, all costs involved in the process must be kept as minimal as possible. Huie (1976) argues that a substantial proportion of the total cost of any waste management system (like composting) is incurred during the collection process. Uncovered collection trucks sometimes spill some of their loads on the streets, requiring extra costs to tidy them.

Contreau-Levine (1994) postulates that in developing countries, the cost per metric ton of cleaning off the streets could be between two and three times the cost of collection; and so covered trucks or more costly equipment must be used to reduce spillage to the barest minimum. Hardy et al (1976) further argue that for every waste management system there should be developed a location model that will determine the best locations for specified composting sites and transfer stations. The location for the compost facility should be chosen such that the distances of procurement markets (waste producers locations) and the sales market (compost purchasers location) to the compost facility are as short as possible, so that the cost of transportation becomes minimal. Locating transfer stations near municipal solid waste generators and major transportation routes helps to lower hauling costs per ton of waste (Contreau- Levine, 1994). Also, nearness to the consumption markets reduces the need for transportation of compost to farms. Exacerbating the cost of long distance transport of the MSW is "its relatively low economic value and its low bulk density" (CalRecovery, 1989).

3.4 Financial Aspects of Compost Project Appraisal

The purpose of this section is to discuss the financial ramifications of investing in MSW composting. Specifically, the discussion deals with the factors that affect cost-benefit comparisons, the determination of costs and benefits associated with compost production, and the scope and criteria for appraisal of compost projects.

3.4.1 Factors that Affect Cost-Benefit Comparisons in Composting

The traditional analytical tools for evaluating the production of goods and services have been cost-benefit analysis. Some factors generally influence cost-benefit comparisons in municipal compost production. These factors include: the relative cost of labour, capital and inputs; the efficient scales of operation; the interest rate on capital; and the geographical and infrastructure orientation of the municipality chosen for the compost project. Although capital-intensive composting techniques may be economically efficient in industrial countries, they may not be so in developing countries (Beede and Bloom, 1995). In developing countries, skilled labour and physical capital are scarce, and infrastructure is very much limited. Consequently, the costs of unskilled labour relative to skilled labour, land, and capital are generally lower for developing countries (Beede and Bloom, 1995). This explains why labour-intensive collection and processing of organic waste are commonly found in developing countries throughout the world (Bartone et al 1991). Cointreau-Levine (1994), Etuah-Jackson et al (2000) and Bennett et al (1993) respectively reveal how capital-intensive projects in Lagos (Nigeria), Teshie-Nungua (Ghana) and Jakarta (Indonesia) collapsed because of inappropriate technologies applied in compost production under various local conditions. These researchers were unanimous that labour-intensive, aerobic composting facilities may be more appropriate in developing countries than highly automated aerobic and anaerobic facilities that are typical of industrial countries, where national economies are strong enough to support large-scale compost facilities, machines and equipment. There is also the availability of skilled personnel in developed countries who very much understand the technology being applied.

Average composting cost per ton of organic waste may decline as the scale of operations increases for several reasons. First, because of fixed costs, composting alternatives that are intensive in unskilled labour will tend to achieve their minimum average costs at lower levels of capacity than alternatives that are intensive in physical and human capital (Beede and Bloom, 1995). Secondly, average cost of composting may decline as the amount of organic waste handled rises and more specialized machines or workers are used. Investment in new compost facilities is characterised by fairly large capital requirements, low start-up throughputs and meagre financial inflows. There is therefore the need for compost entrepreneurs to embark on short-term and long-term capital borrowing to supplement self-mobilised equity. But borrowed capital is secured at a cost that is equivalent to the interest rate charged by the lender. Investment in composting facilities will only take place as long as the real interest rate does not exceed the real rate of return on the investment. If the rate of return is smaller than the interest rate, it that means that, it will not be financially advisable to invest in compost projects.

Sub-urbanisation can raise the costs per ton of collection and transportation of organic waste and finished compost product (Contreau-Levine, 1994). This is because the cost of land for establishing new compost plants in the fringes is always rising, and the increased average travel distance that collection vehicles may cover between points will increase transportation costs. Although urbanisation raises the concentration per square metre of municipal solid waste, which may lower the cost of collection, urbanisation may also increase the cost of composting because low-income areas in cities often have narrow or congested streets that cannot support large collection trucks (Cointreau-Levine, 1994). Therefore, when urbanisation outpaces transport infrastructure, the average cost of composting will tend to rise.

In conclusion, before the cost-benefit analysis of compost projects is done, the analyst must examine the factors that influence costs and benefits in order to prepare cash flow projections for the project. These factors may include the cost of land, capital and inputs; the efficient scale of operation; the infrastructure orientation; and the cost of capital (or interest rate).

3.4.2 Determining Costs and Benefits in Compost Production

The valuation of a compost venture involves identifying and classifying some clear-cut costs and benefits of the composting options. According to German Technical Co-operation bulletin (1999), the tangible costs that can be incorporated into cost-benefit analysis of composting operations are:

1. Personnel costs comprising wages, salaries and other emoluments of workers;
2. Material and other non-personnel costs such as those for electricity, water, fuel, lubricants, additives etc;
3. Service costs covering consultancies, private waste collection charges and hiring of transport to convey finished product;
4. Cost of financing such as interest payable due to loans, overdrafts, and other services that are of financial nature;
5. Semi-variable costs for maintenance of buildings, machinery and environmental abatement facilities; for transporting municipal solid wastes or sorted organic waste to compost facilities; and for administrative overheads;
6. Costs of waste disposal, including costs of disposing residuals at landfills, leachate management, and wastewater collection and recycling;
7. Depreciation due to loss in values of capital equipment arising from wear and tear.

In conducting cost-benefit comparisons, the analysts usually classify these costs into "variable costs" (or "direct costs"), and "fixed costs". "Variable costs" represent expenses that are tied directly to the volume of product produced and/or sold in a given period. There may be "other direct costs" that normally include services tied directly to production levels, such as wages and benefits of plant labourers who are called in to work only when there is the need to process the product, or collect and/or sort organic waste outside normal working rates. "Fixed costs", record expenses that are incurred regardless of the volume of production and sales. Financial analysts and economists call them "fixed costs" because they are not chargeable in the short-term regardless of product volume. In composting, fixed costs may refer to capital costs of acquiring buildings and other facilities, vehicles, equipment, land, site plans and environmental permits. Typical variable expenses included in this category are management and office salaries, general utilities, insurance, interest, and depreciation of compost facilities and other resources. There are certain hidden costs of composting that cannot be quantified in monetary terms. These may include the cost of environmental damage caused as a result of gaseous emissions and leachate pollution, opportunity cost of using capital and the costs associated with employing risky assets in the business.

Economically, the sale of compost for a given accounting period must achieve cost coverage either in full or to some large extent. If the earnings from compost sales cannot cover overall costs then evacuation fees chargeable on waste generators must offset the cost of collection, or other compensatory payments made by the local authority because of savings from disposal costs avoided by the composting technologies. In sum, benefits for composting are derived from the sales of the compost product, waste evacuation fees, savings made in landfill costs and contributions from other sources such as subsidies from local government authorities (Bartone et al, 1990). Similarly, there are a number of benefits that cannot be easily quantified such as reduction in soil erosion, increased environmental quality, and reduced health hazards.

3.4.3 Investment Analysis of Compost Projects

Once the costs and benefits of the compost project are determined, it is appropriate to analyse the intended project to see if it is worth undertaking, and to identify the size and technology that appear promising for adoption. The method of assessing the profitability and feasibility of an investment is known as investment analysis. The purpose of investment analysis is to determine the project's capital requirements and structure, and how to allocate the available capital into profitable alternative ventures (Lee et al, 1980). Investment analysis is the basis upon which investment decisions are made. Beede and Bloom (1995) state that for investment in compost production to be successful and sustainable, the project must reveal from the onset that it will be financially viable. In his book titled "Agro-industrial Investment", Brown (1994) states that there are two dimensions to the financial viability concept in agro-industry projects including compost production. These are financial profitability and solvency of existing projects, and the viability of new projects yet to be established. Studies by Bartone (1991) show that only few continuing compost projects in Latin America are able to generate enough revenue to meet all financial obligations on timely basis, and to command adequate working capital for continued operations. Therefore, before the establishment of new projects, the analyst must ensure that they earn reasonable rates of return on capital employed in the business. Moreover, prospective investors and lenders will need to know the economic and financial environment in which the compost enterprise is to function, and the experience of other enterprises in the sector. There is scanty literature available on investment analysis of compost projects in both developed and developing countries. Many studies reviewed showed that the relative inexperience in investment analysis in compost production has undoubtedly reflected in the closure of many compost facilities worldwide. Studies conducted in Mexico City (SEEDS, 1984), United States (Kashmanian and Spencer, 1993), India (Selvan, 1996), Indonesia (Perla, 1997), Ghana (Etuah-Jackson et al, 1999; Kraemer, 1994)) and Brazil (Hoornweg et al, 1999) revealed that composting facilities in these countries had chronic financial problems, and most of them collapsed as soon as they were established. In a bid to achieve a large measure of municipal composting, funds were wrongly channelled to entrepreneurs whose technical and financial assumptions later proved to be woefully inappropriate and disastrous. Input and overhead costs were under-estimated, whereas revenues were over-estimated. In effect, they attributed the main reason for the compost "plague" to improper investment analyses of the projects in these countries, resulting in wrong choice of equipment and technologies, high production costs and financial losses, and non-marketability of compost products. The researchers further attributed the lack of investment analysis in these countries to low priority given to composting as an integrated waste management method. They concluded that if the successes of future compost ventures were to be guaranteed, then it was important to ensure that the miscalculations of costs and benefits that contributed to the demise of these compost projects were not repeated. The only way to guarantee the success of future municipal compost facilities is to appropriately evaluate and choose the most economically and technically attractive compost projects for cities (Kashmanian and Spencer, 1993). This means that the future success of compost facilities in municipalities will depend on how analysts can comprehensively appraise compost projects using the appropriate methods and sensitivity analyses on key financial variables in composting. On the contrary, the literature reviewed has shown that a few composting projects that initially received limited financial appraisal later proved to be successful during the implementation stage. For example, Kessler and Helbig (1999) report that following a careful socio-economic survey conducted in Lome and Tsevie in the Republic of Togo, the pilot composting schemes established in these areas achieved a measurable success in their desired objectives of organic waste utilisation and phytosanitary purposes. Also, an investment analysis conducted by an agro-chemical manufacturing company in India, Excel Industries Limited, resulted in the successful establishment in 1990 of semi-mechanical municipal composting facilities in various cities including Bombay, Ahmdabad, Gwalior, Bhopal and Vijayadad. The compost produced by the company resulted in the reduction of 25% chemical fertilizer use among farmers in the five cities (Selvan, 1996). Constanczak et al (1999) describe how compost projects in Katowice (Poland) and many cities in Germany are currently performing well after they had been independently appraised. Furthermore, the municipality of Sao Paulo in Brazil has successfully managed a 30-million US dollar, large-scale compost scheme since 1990 following a project evaluation (Hoornweg et al, 1999). From the financial point of view, the Net Present Value (NPV) and Internal Rate of Return (IRR) for the twenty-five year Sao Paulo project were US $3.22 million and 32.2% respectively (World Bank, 1997b). The NPV calculations indicated that investment was worth undertaking. Also, the 32.2% rate of return meant that the project would just break even at that discount rate, that is, the project would earn back all the capital and operating costs expended on it, and at the same time pay for the cost of capital invested. Since the project's IRR was greater than the average interest rate (25%) in Brazil at the time, the decision to establish the project was a right one.

The literature reviewed above on investment analysis shows that most compost projects have not been subjected to thorough investment appraisal before their establishment. This unfortunate phenomenon has resulted in several projects collapsing earlier than their designed life spans. Secondly, there has not been adequate information on sensitivity analysis of compost projects. Sensitivity analysis helps to determine how changes in each of the key financial variables, such as internal rate of return, initial capital outlay, sales volumes, product prices, input prices and cost overruns could flag serious risk factors in a compost project.

3.5 Lessons Learnt from Literature Review

The literature reviewed above has revealed a number of significant lessons concerning composting processes, technologies and facilities. These lessons are distilled in this section as follows:

1. The technological options employed in and the facilities required for composting MSW depend upon a number of technical parameters, composting processes and the composition and characteristics of the organic waste to be processed. In order to adequately meet the technical requirements of composting, some mechanical facilities and equipment will be needed to regulate the parameters to their desired levels. Costs are incurred in a bid to purchase and install capital items, and to run the facilities during the life of compost projects. Retrofit activities and improvement of facilities and processes of composting are fairly costly ventures and should be properly analysed during project design. Finally, the composition and characteristics of the organic waste affect the economics of collecting and processing it, and the disposal of residual wastes.

2. In spite of the economic significance of the dynamics and mechanics of composting, there is no detailed literature on the selection, construction and operation of composting facilities for MSW. Previous attempts at considering the economics of composting resulted in under-estimation of costs and over-estimation of benefits. Underestimation of costs or over-estimation of benefits implies the need to develop a framework that

accurately identifies all the costs points and all benefit streams. Also, there is the need to identify methods for appropriate valuation of costs and benefits. The current study will quantify and categorise all costs of initial capital, operation, and processing technologies that will produce consistent and marketable compost, through the application of the German Agency for Technical Co-operation's computerised software.

3. The establishment of MSW compost facilities depends on the cash flow projections made of the compost projects. The preparation of cash flow proforma is then followed by project appraisal that guides the analyst to make choices among a range of options available for each sub-process of composting. The conclusion is that every investment analysis should be comprehensive and thus include all the traditional and discounted criteria as well as an assessment of all the factors that make up the unique circumstances of the proposed compost project. The current study seeks to fill the gap between empirical guesswork and proper investment analysis in compost production.

CHAPTER FOUR

METHODOLOGY

4.1 Introduction

This Chapter examines the theoretical concepts in the economics of compost production and investment analysis, and develops a framework for analysing the tasks that must be tackled in order to accomplish the study objectives. The analytical tools adopted for this study are both qualitative and quantitative. The Chapter also discusses the data required for the analysis, the sources of the data collected, and the methods employed to analyse the data set collected.

4.2. Comparative Cost Analysis for Waste Processing Facilities

4.2.1 Theoretical, Empirical and Analytical Frameworks

The first specific objective of the study is to conduct a comparative cost analysis of the waste processing methods commonly practiced in the Accra-Tema Metropolitan Area i.e. landfilling, incineration and composting. This section presents theoretical, empirical and analytical frameworks for achieving this objective. The central components that constitute the framework discussions include investment capital requirements, operating costs and the overall costs of these waste-processing methods for a start-up year (2001).

4.2.1.1 Investment Capital Requirements for Waste-Processing Facilities

The acquisition of land, machinery and equipment, and the construction of waste processing facilities are based on specific design criteria and technical baseline data, as well as guidelines and rules established by individual countries or municipalities for waste management. The investment capital requirements for a MSW landfill are costs made on purchase of vehicles, equipment and land; construction of buildings, roads, liners, leachate and gaseous management facilities; site selection, survey, documentation and permitting; energy supply equipment; and final capping of the landfill and revegetation of the worked area.

A modern state of-the-art incinerator consists of the following functional areas: waste receiving; waste storage for pre-processing; charging and incineration unit; slag removal, residual treatment and storage unit; boiler and steam recovery unit; air control systems; and a stack for gaseous and particulate emissions. In addition to these facilities, purchase of land, vehicles and equipment, and the construction of buildings, bunkers and roads constitute major capital costs for a start-up incinerator.

The investment capital requirements for a MSW composting facility are: purchase of land vehicles, machinery and equipment; construction of buildings, bunkers, roads, leachate management and windrow watering facilities, and fencing; site selection, survey, documentation and permitting; energy supply mains, and testing and commissioning of the facility. The investment capital for a waste processing facility is the sum of all the capital cost items for the facility. Mathematically, the capital cost of a landfill, C_L, is given by:

$$C_L = \sum_{i=1}^{m} Cl_i \tag{4.1}$$

Where Cl_i represents the cost of *ith* landfill capital item in the range from 1 to m, and m is the number of cost items for a landfill.

Similarly, the capital cost, C_c, of a compost facility is given by:

$$C_c = \sum_{j=1}^{n} Cc_j \tag{4.2}$$

Where Cl_j represents the cost of *jth* compost capital item in the range from 1 to n, and m is the number of cost items for a compost facilitry. The typical technical criteria for determining the required investment capital for establishing a landfill and a composting facility are presented in appendices V and VI respectively. The investment capital cost for an incinerator is based on the throughput in tons per day. The standard technical equation commonly used by both economists and engineers for estimating the capital cost in local currency (C_{Ii}) of one incinerator is given by (Bilitweski et al, 1994):

$$C_{Ii} = C_l + 2.54 \times 10^6\, k\, X^{0.715} \qquad (4.3)$$

Where C_l = cost of land for the incinerator in the currency of the user-country; X = the throughput in tons per day; and k = the exchange rate of the user-country relative to US dollar in the calculation year. Thus, the capital cost of a modern incinerator in Ghana in the year 2001, when the exchange rate (k) was approximately ¢7,000 to one US dollar was: $C_{Ii} = C_l + 1.78\text{x}10^{10}\, X^{0.715}$ (4.4)

Thus, for *w* incinerators, the total capital cost in Ghana at the 2001 price levels is given by: $C_{Ti} = w(C_l + 1.78\text{x}10^{10}\, X^{0.715})$ (4.5)

4.2.1.2 Operating Costs of Waste Processing Methods

The total cost of operating a waste processing facility is the sum of all capital-dependent expenses and all running expenses. The capital-dependent expenses arise from all the costs involved in capital financing, taxation and insurance; whereas running expenses are those costs incurred on labour, repair and maintenance, water and sewerage, fuel, long-term care, administrative and sales activities, vector control, consumables and depreciation. In the case of incineration and composting, further expenses may be incurred in disposing of untreated and residual wastes in landfills. The operating cost (C_R) is the sum of all capital-dependent costs and all running costs of a facility and is given by:

$$C_R = \sum_{i=i}^{k} C_{de} + \sum_{j=i}^{w} C_{oe} \qquad (4.6)$$

Where C_{de} denotes capital-dependent expenses; C_{oe} denotes running expenses; and k and w represent the number of capital-dependent expenses and running cost items for ith capital-dependent cost and jth running cost of the facility respectively. The baseline data for computing operating costs for a landfill, incinerator and composting facility are presented in appendices II, III and IV respectively.

4.2.1.3 Total Costs of Waste Treatment

The total cost (C_T) of treating MSW using any waste treatment method or a combination of methods is the arithmetic sum of capital costs (Cc) and operating costs (C_R). Thus:

$$C_T = Cc + C_R \quad (4.7)$$

Equation (4.7) gives only the total cost incurred by one waste processing facility, which may just process a fraction of the waste stream. To compute the total costs of landfilling or composting all the waste generated in a municipality, the first step is to estimate the annual total waste volume (i.e. Q_t m^3/yr or tons/yr). The next step is to obtain the capacity of the landfill or compost facility ($y_{l,c}$) from technical specifications as contained in the operator's manual. The number of landfills (λ_l) or compost facilities (λ_c) needed to process all the MSW is then calculated as follows:

$$\lambda_{l,c} = Q_t/y_{l,c} \quad (4.8)$$

The total cost (C_{TL}) for λ_l landfills is therefore given as:

$$C_{TL} = \lambda_l(C_L + C_R) \quad (4.9)$$

Similarly, the total cost (C_{TC}) for λ_c compost facilities is given as:

$$C_{TC} = \lambda_c(C_L + C_R) \quad (4.10)$$

Substituting equations (4.1) and (4.6) in (4.9), we obtain a total cost of a landfill as:

$$C_{TL} = Q_t/y_l \left(\sum_{i=1}^{m} Cl_i + \sum_{i=i}^{k} C_{de} + \sum_{j=i}^{w} C_{oe}\right) \quad (4.11)$$

Also, substituting equations (4.2) and (4.6) in (4.10), we obtain a total cost of a compost facility as:

$$C_{TC} = Q_t/y_c \left(\sum_{j=1}^{n} Cc_j + \sum_{i=i}^{k} C_{de} + \sum_{j=i}^{w} C_{oe}\right) \quad (4.12)$$

For an incinerator, the total cost (C_{TI}) of treating the waste in Ghana is given by:

$$C_{TI} = C_I + 1.78 \times 10^{10} X^{0.715} + \sum_{i=i}^{k} C_{de} + \sum_{j=i}^{w} C_{oe} \quad (4.13)$$

The total cost (C_{TCI}) of using w incinerators to treat waste in Ghana during the start-up year is therefore: $C_{TCI} = w\left[C_I + 1.78 \times 10^{10} X^{0.715} + \sum_{i=i}^{k} C_{de} + \sum_{j=i}^{w} C_{oe}\right]$ (4.14)

For a volume of 550,000 metric tons of raw organic waste generated in the Accra-Tema Metropolitan Area in the year 2001, five-engineered landfills, each of capacity 110,000 metric tons per annum, will be required to treat it in accordance with international standards. Hence, from equation 4.11, the total cost of landfilling in the area is given by:

$$C_{TL} = 5\left(\sum_{i=1}^{m} Cl_i + \sum_{i=l}^{k} C_{de} + \sum_{j=l}^{w} C_{oe}\right) \qquad (4.15)$$

Similarly, 15 compost plants, each of capacity 37,000 metric tons of raw municipal solid waste per annum, are required for processing the total estimated waste generated. The total cost of composting the waste generated in the area, therefore, simplifies to:

$$C_{TC} = 15\left(\sum_{j=1}^{n} Cc_j + \sum_{i=i}^{k} C_{de} + \sum_{j=i}^{w} C_{oe}\right) \qquad (4.16)$$

Also, one incinerator of capacity 165,000 metric tons per annum is needed to deal with the waste generated in 2001, that is, 30% of the total waste generated in ATMA will be incinerated. Hence, equation 4.14 simplifies to:

$$C_{TCI} = \left[C_I + 1.78\text{x}10^{10}\, X^{0.715} + \sum_{i=i}^{k} C_{de} + \sum_{j=i}^{w} C_{oe}\right] \qquad (4.17)$$

4.2.2 Data Requirements and Sources

Cost considerations of waste processing facilities (landfills, incinerators and compost plant) require primary and secondary data on the capital and operating costs for all the three waste treatment methods outlined in section 4.2.1 above. Detailed data was collected from the offices of Municipal Waste Management Departments; the Kwabenya Landfill Project projections (Taywood Company Limited, Accra); composting projects in Ghana, Nigeria, Togo and Benin, and Architectural and Engineering Services Limited of Ghana through direct contacts with officials of these departments. The capital cost, and capital-dependent expenses and running costs were calculated for all the waste processing methods using the theoretical and the analytical frameworks analysis made in section 4.2.1 above. All costs were valued at market prices without taking into account macro-economic distortions. A comparative analysis was then made by comparing the totalcosts per ton of waste treated by the methods.

4.3 Profitability of Compost Projects

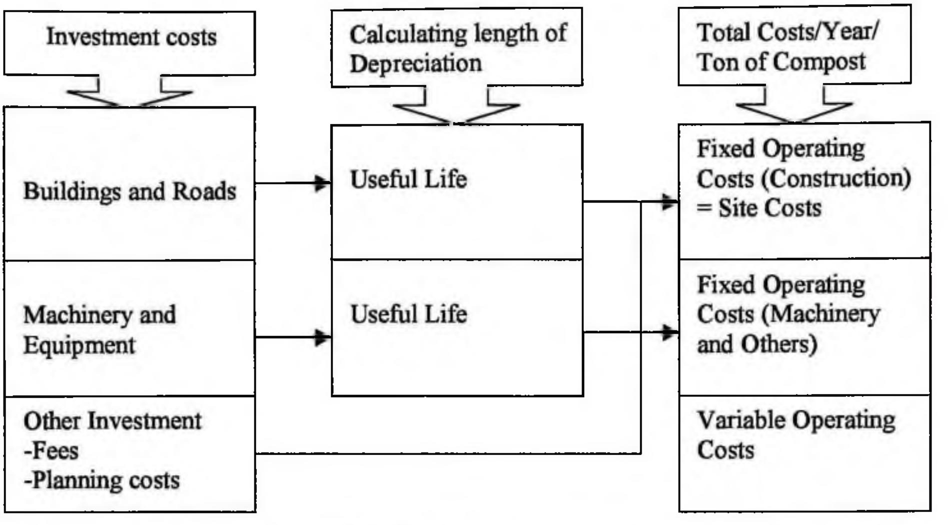
4.3.1 Theoretical Framework

The second specific objective of the study seeks to investigate the technical alternatives for the least cost composting in the Accra-Tema Metropolitan Area. This section examines the theoretical framework for achieving the tasks inherent in the objective. The main focus of discussion of the framework is on profit contribution margin analysis.

4.3.1.1 Profit Contribution Margin Analysis

The profit contribution margin is calculated as the difference between total earnings and total costs. The results of the contribution margin calculations show whether a profit or loss is expected from composting and how much the profit and loss will be per year or per ton. It is the difference between total revenues and total costs. Composting of organic waste in a municipality consists of four basic components: supply of raw material, processing of the organic waste, marketing of the compost product, and disposal of by-wastes or residuals. Each of these components and their interdependent relationships incur costs. These costs are: investment costs, the cost of collection and transportation, the cost of processing, and the cost of waste disposal. The various cost items are presented in Figure 4.1 below.

Figure 4.1: Framework for Calculating Costs of a Compost Facility



Source: Utilisation of Organic Waste in (Peri)-Urban Centres, (GTZ, 1998)

The investment costs show the level of capital outlay needed for investing in compost facilities, which cover the cost of constructing buildings, compost and maturation chambers and access roads; the cost of purchasing machinery and equipment; and fees for building plans, site surveys and environmental permits. The total costs on the other hand indicate the total expenditure incurred in the course of collecting, transporting and processing of the organic waste, and disposal of contraries and non-biodegradable wastes. Overall costs are, in fact, the sum of all fixed and variable costs. In practical terms, collection and transport costs are determined from two main sources: depreciation of capital items, and expenses incurred in collecting the organic material. Depreciation is calculated on the basis of capital expenditure, comprising the cost of land and buildings (e.g. for collection depots, compost facilities and drop-off sites); containers and other equipment associated with collection and transportation of the organic waste; and the promotion cost of establishing a new scheme. The straight-line method of depreciation is used in this study because of its simplicity. Tables 4.1 and 4.2 below give a summary of the capital expenditure and waste collection expenses statements respectively.

Table: 4.1

	Capital Expenditure for Waste Collection	**¢**
	Land (premises)	(a)
	Land (drop-off points/sites)	(b)
	Buildings	(c)
	Collection vehicles	(d)
	Collection container (banks)	(e)
	Equipment (collection)	(f)
	Equipment (Others)	(g)
	Consultancy/Promotion (on scheme establishment)	(h)
	Total Capital Expenditure (Total of (a) to (h))	(C)

Table: 4.2

Waste Collection Expenses			**¢**
Staff costs		Wages and overtime payments	(i)
	-	Other staff costs	(j)
Transport	-	Vehicle maintenance & repairs	(k)
	-	Road tax and insurance	(l)
		Fuel	(m)
	-	Vehicle higher	(n)
	-	Others	(o)
Site Expenses		rent and rates	(p)
		Heat, light and power	(q)
		Insurance	(r)
		Maintenance and repair	(s)
Other Expenses		Promotional information/ Preparation and distribution	(t)
	-	Consumables	(u)
	-	Office supplies and Professional services	(v)
		Telephone & postage	(w)
		Others	(x)
Total Collection Expenses (sum of (a) to (x))			(B)

The processing costs are calculated as the sum of capital depreciation and operational expenditure. The capital costs of processing involve the costs of land and buildings, equipment and facilities necessary for a compost plant. Processing expenses cover staff costs, fuel, maintenance and promotional fees. Tables 4.3 and 4.4 below summarise the costs involved in compost processing.

Table: 4.3 Capital Expenditure for Waste Processing

		(¢)
	Land	(a)
	Buildings	(b)
	Equipment (processing)	(c)
	Equipment (others)	(d)
Total Capital Expenditure (Total (a) – (d))		**(F)**

Table: 4.4 Waste Processing Expenses

Staff Costs	Wages & Overtime Payment	(e)
-	Other staff costs	(f)
Site Expenses	Rent and rates	(g)
	Heat, light and power	(h)
-	Insurance	(i)
	Maintenance & repairs	(j)
Process Costs	fuel	(k)
	Consumables	(l)
	Sorting & storage	(m)
-	Maintenance	(n)
	Waste disposal	(o)
Other Expenses-	Promotional information Preparation and distribution	(p)
	Office supplies and Professional services	(q)
	Telephone and postage	(r)
-	Other	(s)
Total Processing Expenses (sum of (e) to (s))		**(E)**

Waste disposal costs involves the expenditure incurred in collecting and transporting residuals and non-biodegradable materials from the compost site to landfills, and fees paid for dumping these contraries in the landfills. Table 4.5 below presents the income statement for compost production. It shows the overall costs and total sales income. [1]The total collection cost (D) of organic waste is the sum of the collection expenses (B) and the depreciation of the capital costs (C_d) of the collection and transportation of organic waste. Similarly, total processing cost (G) is the sum of the processing expenses (E) and the depreciation of the capital costs (F_d) of the processing the organic waste. To estimate the

[1] By the straight-line method of capital depreciation, which assumes that all capital assets decrease evenly in value over the period of their useful life, the cost of depreciation (C_d) associated with the collection of the organic waste for a compost facility with a life span of N years is given by: $C_d = C/N$ Similarly, the cost of depreciation of capital (F_d) associated with the processing of the organics in the facility is given by: $F_d = F/N$

total sales income (R) to a compost project, outputs and prices must be measured. Total output will depend on the amount of organic material available for processing (Q), and the rate or efficiency of production (η). The quantity of compost produced (q) in tons per year by a compost facility is therefore given by:

$$q = \eta Q \text{ (t/yr)} \tag{4.18}$$

Table 4.5 Annual Income Statements

Total material sales income		**R**
Total collection expense	(B)	
Add cost of collection depreciation (C/N)	(C_d)	
Therefore, total collection costs	(B)+(C_d)	= (D)
Total Processing Expense	(E)	
Add cost of processing depreciation (F/N)	(F_d)	
Therefore, total processing costs	(E)+(F_d)	= (G)
Total Composting Cost	**(D)+(G)**	**= (H)**
Therefore, Gross Revenue Equals		**R-H**

Prices of compost products are determined by considering production costs per unit measure of compost, or by assessing the ability and willingness of consumers to pay. Revenue (R) from compost is simply: $R = pq$ (4.19)

By substituting equation (4.18) into (4.19), we obtain: $R = \eta Qp$ (4.20)

Profit is estimated by subtracting the total cost of compost production from the total sales revenue generated thereof. Therefore, the gross financial profit π_g is calculated as:

$$\pi_g = R + W_c + S_c + S_d - H \tag{4.21}$$

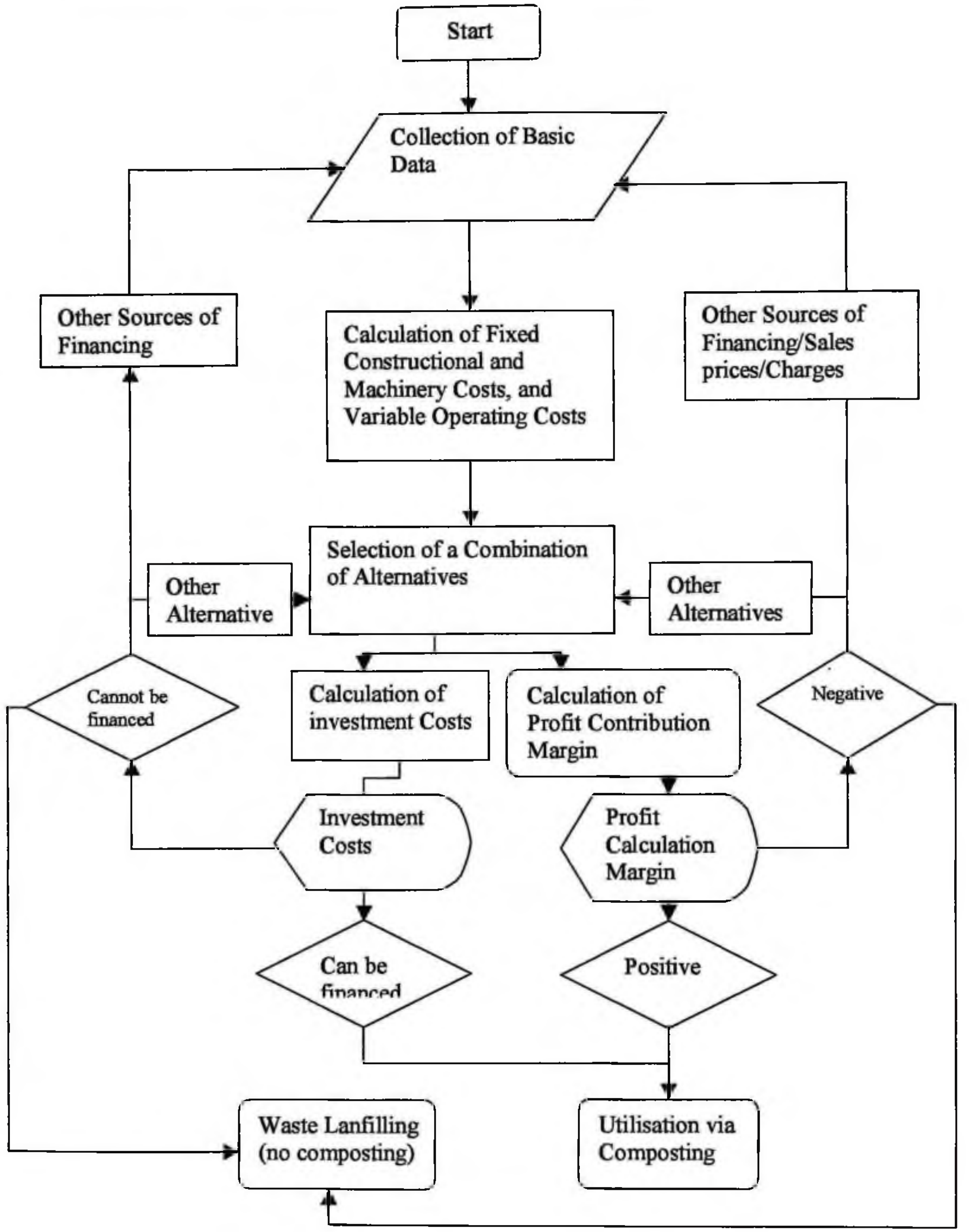
Where W_c, S_c and S_d are waste collection fees, saved cost from other waste treatment methods, and subsidisations respectively. Substituting the components of H in Table 4.5 into equation (4.21) above, and subtracting tax, T, and interest on capital, I, we obtain the net revenue (π_n) as:

$$\pi_n = (\eta Qp + W_c + S_c + S_d) - B - E - C_d - F_d - T - I \qquad (4.22)$$

4.3.2 Empirical and Analytical Frameworks

The most economically feasible levels of composting are determined using the German Agency for Technical Co-operation (GTZ) calculation model, which has been developed specifically for this purpose. The model uses a software guide that is based on iterative calculations. This computerised programme is an instrument that helps decision-makers to take well-founded decisions on composting in a given area and on the capital-labour mix. The software is equipped with sixty structured questions that are answered by the analyst who feeds in the data required for each question (See Appendix XIV for questions). Figure 4.2 below is a flow chart that shows the repeated calculation processes, which form the basis for determining the costs and benefits of composting facility and for ascertaining the best alternatives. The computer calculates by summing up all costs on one hand and all expenses on the other, and then takes the difference between the two results. In other words, the computer processes the data similar to the theoretical framework presented in sub-section 4.3.1 above. The computer displays three results -investment costs, total costs of production per unit of compost, and the Profit Contribution Margin after each calculation process.

Figure 4.2: Flow Diagram of the GTZ Calculation Process



Source: Adapted from Utilisation of Organic Waste in Urban Centres (GTZ, 1998)

The format for the calculation process is presented in Table 4.6 below. The gain/deficit (Contribution Margin, CM) is calculated as B minus A, thus:

$$CM = (m + n + o + p) - (a + b + c + d + e + f) \quad (4.23)$$

On yearly basis, the contribution margin, CM_y, is calculated as:

$$CM_y = (q + r + s + t) - (g + h + i + j + k + l) \quad (4.24)$$

Table 4.6: Investment Costs and Profit Contribution Margin

Type of Costs and Revenues	**US$/ton of Compost**	**(US$)/year**
INVESTMENT COSTS		
Personnel	a	g
Operational	b	h
Depreciation	c	i
Maintenance	d	j
Transport	e	k
Administration	f	l
OVERALL COSTS (A)	**(a+b+c+d+e+f)**	**(g+h+i+j+k+l)**
REVENUES		
Sales of Compost	m	q
Charges on Household	n	r
Saved Costs for Depositing Waste	o	s
Subsidisations	p	t
TOTAL REVENUES (B)	(m+n+o+p)	(q+ r+s+t)
GAIN/ DEFICIT (Contribution Margin)	**(B – A)**	**(B – A)**

The decision criterion for the model is that if the financing requirements ascertained do not exceed the financial resources available, or if the contribution margin is positive, the authorities can execute the project as planned - at least from the economic point of view. On the other hand if the financial requirements exceed available resources, or contribution margin is negative, the decision-maker may choose one of the following: not to introduce composting in the area assessed; or seek additional funding; or raise waste evacuation fees; or raise compost sales price; or choose less cost effective alternatives. The advantage of the GTZ calculation model is that the analyst can vary the physical and financial variables in the questionnaire until the most economically feasible option is obtained. In order words the various parameters have to be changed by selecting technical alternatives that will lower the total costs of composting.

4.3.3 Data Requirements and Sources

The data required for the calculation model include the composting capacity, output of composting facilities, sales volume, and number of transfer stations. Other data requirements are the number of households served, awareness creation costs, waste evacuation costs, waste accumulation volumes, subsidies and the rate of taxation on compost projects. The rest of the data requirements are waste collection costs, costs of machinery and equipment, waste containers, buildings, leachate treatment facilities, fuel, and workers' salaries and wages. The detailed data for the calculation process was obtained from Architectural and Engineering Services Limited, Ghana Water Company, Electricity Company of Ghana, Tractor and Equipment, Waste Management Departments of Ga District, Tema Municipal and Accra Metropolitan Assemblies, and from composting facilities at Teshie-Nunguah (Ghana), Bodija (Nigeria), Tsevie (Togo) and Hevie (Benin). The data on inputs, costs, and prices required for developing the multi-year composting enterprise budgets were generated in various ways, including structured and semi-structured interviews (See Q2 and Q3 in Appendices XIV and XV), and direct personal contacts with officials of the departments and agencies enumerated above. Single visit surveys to composting projects in Togo, Benin, Nigeria and Ghana, and multi-visits were made during the study period to local departments and agencies such as District, Municipal and Metropolitan authorities, Ministry of Food and Agriculture and

Environmental Health Division of Ministry of Health. Costs and benefits were valued at prices that composting entrepreneurs and users actually face, without deflating them by an index to take care of inflation. Land was valued on the basis of either as a rented capital expense or a purchased capital item and added to the cost of machinery and equipment. The data so collected was fed into a computer, which undertook the profit-loss calculation processes insitu. The results, which give the total cost and the calculation margin, were iterated several times until the most attractive compost options were obtained. The alternatives were checked to ensure that the costs per unit amount of compost are minimised. Also, by varying the key variables that influence composting in a municipality such as inputs and compost costs and interest rates, sensitivity analysis of the compost facility was conducted in the in-built calculating process.

4.4 Investment Appraisal

4.4.1 Theoretical Framework

The third objective of the study is aimed at assessing the financial viability of establishing a compost facility in the study area. The central concepts that constitute the framework of the objective include discounting of cash flows and application of annuities in discounting projects' worth.

4.4.1.1 Discounting Methods of Project Worth

Discounting methods are essentially techniques by which the future benefit and cost streams of an investment are reduced to their present value. Discounting methods do take account of the time value of money. Examples of discounted methods include benefit-cost ratio, net present value and internal rate of return. For the purpose of this study, the net present value and internal rate of return are considered in this discussion. The net present value is a discounted measure of a project worth at a given time. The internal rate of return is a discount rate that equates the net present value of a project to zero.

Project analyses are made by first identifying the technical inputs and outputs for a proposed investment, then valuing the inputs and outputs at market prices to construct financial accounts. This is essentially the process leading to the estimation of the future cash flows (inflows and outflows), which is the first and important step in project evaluation. Cash outflows (or costs) in the compost industry include expenditures on materials, labour, direct and indirect expenses for processing, selling and administration, inventory and taxes. Cash inflows include revenues obtained from the sales of compost products, collection fees, and cost savings paid by local government authorities as a result of composting the MSW.

Deciding on the discount rate to be used for calculating the present value of projects requires a special technique. To take care of the simultaneous effects of borrowed capital and owner equity in project financing, the conventional method often used by analysts to determine the appropriate discount rate is weighted averaging (Gittenger, 1982). In this study, it has been assumed that all the capital employed is owner equity. Therefore, the discount rate used in the net present value calculations is the bank-lending rate. Once the determination of the appropriate discount rate has been accomplished, the analyst proceeds to compute the present values for each corresponding year. The mathematical expression for this discounting process is given by:

$$NPV = (B_1 - C_1)(1+r)^{-1} + (B_2 - C_2)(1+r)^{-2} + (B_3 - C_3)(1+r)^{-3} - - - - - - - - + (B_n - C_n)(1+r)^{-n} - C_0 \quad (4.25)$$

Where NPV = net present value; B_t = benefit stream (cash inflows) at year t; C_t = cost stream (cash outflows) at year t; r = discount rate; C_o = initial capital outlay; n = life of project and t = 1,2,3,4…n

By simplifying equation (4.25), we obtain the value of the net present value, NPV, as:

$$NPV = \sum_{t=1}^{n} \{B_t - C_t)(1 + r)^{-t}\} - C_o \quad (4.26)$$

The standard mathematical expression for deriving the internal rate of return (IRR) is given by:

$$NPV = \sum_{t=1}^{n} \{B_t - C_t)(1 + IRR)^{-t}\} - C_o = 0 \quad (4.27)$$

When the above equation (4.27) is re-arranged by making C_o the subject, we obtain:

$$C_o = \sum_{t=1}^{n} \{B_t - C_t)(1 + IRR)^{-t}\} \quad (4.28)$$

In investment analysis, the calculated or determined IRR value is compared with a minimum acceptable rate of return, which is usually the opportunity cost of capital. Projects with internal rates of return equal to or greater than the minimum are accepted; whereas those with lower rates of return are rejected

4.4.1.2 The Annuity Concept

The concept of annuity is an important special case in investment analysis that deals with a series of equal cash flows expected every year over a period of years. In this case, the net present value is determined by multiplying the annuity discount factor by the cash flow. Annuity calculations are necessary especially for a project with a long life span when returns appear to dwindle and become uniform at the latter parts of the years. It is also possible to determine the terminal value of a project with useful end-assets through the use of the annuity concept. The conventional annuity calculations are based on the following derivations: Let C = the value of annual cash flow and r = the discount rate. Then the future or terminal value C_{an} is calculated as follows:

$$C_{an} = C(1+r)^{n-1} + C(1+r)^{n-2} + C(1+r)^{n-3} + \ldots + C(1+r) + C \quad (4.29)$$

By taking the common factor, C, out of the brackets on the right hand side, we obtain:

$$C_{an} = C\,[(1+r)^{n-1} + (1+r)^{n-2} + (1+r)^{n-3} + \ldots\ldots\ldots\ldots + (1+r) + 1] \quad (4.30)$$

By multiplying both sides of equation (4.47) by [(1+r)-1] and simplifying, we obtain:

$$C_{an} = C[(1+r)^{n}-1]/r \quad (4.31)$$

Consequently, the annuity discount factor, A_f, is:

$$A_f = [(1+r)^{n}-1]r^{-1} \quad (4.32)$$

The present study uses the annuity method as part of the calculations of the net present values and internal rate of return in the financial analysis.

4.4.2 Empirical and Analytical Framework

Measurement of financial viability in this study is determined using the two discounting methods discussed in 4.3.2 above. The cash inflows and cash outflows for each feasible option are obtained from the results of the iterative processes in the GTZ calculation model. In computing the net incremental benefits for each project, the cash outflows are subtracted from the cash inflows. The present values of future net cash flows for the years are obtained by discounting them at the prevailing cost of capital (40%). In discounting, the initial capital outlay, C_o, is discounted at a discount factor of one. The conventional equation for calculating the present value (PV) of a cash flow at a time, t, is given by:

$$PV = C(1+r)^{-t} \quad (4.33)$$

The present values (both negatives and positives) are then summed up to obtain the net present values. The decision criterion is that a firm should make investment in a project with zero or positive net present value. Those with negative NPVs are rejected.

To determine the internal rate of return of an investment, trial-and-error methods may be used. However, this procedure has been found to be both cumbersome and time-consuming (Lucey, 1988). Modern methods that eliminate the tiresome procedures are in use. Direct computer simulations and mathematical formulae are available for determining internal rates of return (Gittinger, 1982). The mathematical method used in this study to estimate the internal rates of return is arithmetic interpolation. The procedure involves the discounting all future cash flows using intuitive discount factors until a rate is found that gives a net present value nearly equal to zero. The next discount rate will then give a negative NPV closest to zero. The nearest discount rate that makes the net present value "infinitesimally" positive and the rate that makes the net present value "infinitesimally" negative are noted together with their respective net present values. By applying a mathematical formula of interpolation, the appropriate internal rate of return may be calculated as follows:

$$IRR = L + (H - L) \times NPV^{+}/(|NPV^{+}| + |NPV^{-}|) \qquad (4.34)$$

Where IRR = internal ate of return; L = discount rate before NPV takes a negative value; H = discount rate after the NPV takes a negative value; NPV^{-} = Negative net present value; NPV^{+} = positive net present value; and the symbol | |: means the absolute value of the quantity inside it. The values of discount factors and annuity discount factors for 30% and 35% discount rates used in this study (corresponding to the lower and upper limits) were obtained from tables.

4.4.3 Data Requirements and Sources

Calculating the net present value involves deciding what cash flow data to use, and then estimating the selected data. The quantitative data required to carry out calculations of the net present value, internal rate of return and sensitivity analysis are: the initial capital outlay (C_o) needed to establish the facility, the cost of supplying the capital or minimum rate of return acceptable (i.e. discount rate), the value of future net cash flows, ($B_t - C_t$), in each period and the life of the project (n). The net cash flows were obtained from iterations made of the most feasible options selected using the GTZ calculation model (i.e. 75% and 25% composting of all wastes generated in the study area). The costs and benefits obtained from calculation processes were converted using the exchange rate prevalent in 2001 (i.e.7000 Ghanaian cedis to one US dollar). In all, twenty iterations were made, allowing for 25% inflationary rate on the prices of inputs and 10% increases in the prices of compost products (as has been suggested in literature by Bennet et al, 1992). The average of the fifteenth to twentieth iteration was taken as the annuity value for the rest of the 20-year period. The discounting procedures as described in subsection 4.3.1 were applied to determine the net present values and internal rates of returns using equations 4.31 and 4.32 respectively. By assuming an initial capital cost overrun of 30% and reducing compost prices by 10%, their various sensitivities in the form of changes in the financial rates of return were calculated.

4.5 Determining the Constraints Facing MSW Composting

4.5.1 Sampling Method and Data Sources

A combination of factors accounts for why only a few urban areas have been able to successfully construct and operate composting plants. Baseline studies are necessary to determine the extent of the problem so that the factors that militate against the establishment of MSW composting facilities are mitigated. The fourth objective of the study is meant to examine the constraints likely to militate against the establishment of compost facilities in the Accra-Tema Metropolitan Area. The procedure for determining the constraints requires the use of qualitative methods. The process may be done through the application of semi-structured interviews, direct contacts or the administration of questionnaires. In this study, all these methods were applied. A questionnaire was designed and pre-tested in the study area (See Appendix XIII for the questionnaire, Q3). Using the revised questionnaire, information was collected from the offices of the three Assemblies and 15 sub-metropolitan councils within the study area.

In addition to the administration of the questionnaires, one-on-one discussions and semi-structured interviews were held with 15 people who are already in the compost industry in Ghana, Togo, Benin and Nigeria. In order to facilitate the interpretation of the results, the militating factors were then categorised and summarised into twelve areas, namely political will and commitment; accessibility to institutional credit; interest rate on capital; availability of machinery; equipment and spare parts; technical skills and manpower development; knowledge about composting industry; land acquisition; policy framework; research and development; farmers' preferences to soil ameliorants; and the bulkiness of the compost product. The results of the responses were then tabulated.

CHAPTER FIVE

DISCUSSION OF RESULTS

5.1 Introduction

This Chapter presents discussions of the results of the study. The results are discussed in four main sections in accordance with the specific objectives of the study. The first section presents the outcomes of the comparative cost analysis of waste processing facilities in the Accra-Tema Metropolitan Area. The second section discusses the results of the GTZ computer programme used to analyse the profitability of various composting alternatives. The third section evaluates the financial results of composting alternatives in the area; whereas the constraints that militate against building and operating composting facilities in the area are discussed in section four.

5.2 Comparative Cost Analysis of Waste Processing Facilities in the Accra-Tema Metropolitan Area

The primary concern of selecting a solid waste management system is cost. There is no justification in applying a particular system if the initial total investment is extremely high, or if that municipality cannot secure enough funds to successfully run the system on sustainable basis. Table 5.1 presents a summary of cost estimates of landfilling, incineration and composting of MSW during a start-up year (2001). In this analysis, each waste processing facility was assumed to have a lifespan of 20 years. The results show that the capital requirements for a modern engineered sanitary landfill with a filling capacity of 110,000 tons per year at the base year is ¢16.587 billion. For a total volume of 550,000 tons of MSW generated in the Accra-Tema Metropolitan Area, 5 landfills will be required to dispose of such a waste burden. Therefore, the capital requirements for the 5 landfills sums up to be ¢82.935 billion at the 2001 price levels. Also, the estimated total operating cost (i.e. the sum of capital-dependent and running expenses) for the landfills is approximately ¢22.880 billion. The total cost (capital costs plus operating costs) for establishing the 5 landfills and for running them in the metropolitan area during the start-up year (2001) is ¢105.815 billion (See Appendices VI and VII for detailed calculations).

Table 5.1: Summary of Cost Estimates for Waste Processing Facilities in the Accra-Tema Metropolitan Area for the Start-up Year (2001 price levels)

PARAMETER	LANDFILLING	INCINERATION	COMPOSTING
Volume of Waste (t/year)	550,000 (100%)	165,000 (30%)	357,500 (65%)
Capacity of One Facility (t)	110,000	450t/day	24,000
Number of Facilities Required	5	1	15
Life of One Facility (in Years)	20	20	20
Total Capital Costs (in Million Cedis, ¢)	82,935	1,425,100	27,748
Total Operating Costs (in Million Cedis)	22,880	767,867	22,500
Cost of Landfilling Residual Waste (in Million Cedis)	0	84,652	30,159
Total Costs (in Million Cedis)	105,815	2,277,619	80,409
Total Costs (¢)/t of MSW Handled	192,400	4,141,126	146,198
Savings Made as a Result of Composting (in Million Cedis)	-25,406	-2,197,210	0
Savings made in ¢/ton (MSW)	-46,193	-3,994,927	0

Source: Author's Own Computations

Practically, the total public and private refuse collection and disposal bills for 60% of the MSW in the Accra Metropolitan Area alone (i.e. 205,800 mt) was ¢40.000 billion in the year 2001. Assuming that the total cost of collection and disposal is directly proportional to the percentage of waste landfilled, it would have required nearly ¢67.000 billion to landfill all the waste generated (343,000 metric tons) in Accra alone. However, the waste generated in Accra is 63% of the total waste stream in the Accra-Tema Metropolitan Area. Consequently, at the 2001 price levels, the overall cost of landfilling 550,00 metric tons of MSW in the area works out to be ¢107.435 billion. This figure compares favourably with the conservative cost estimates made by the landfilling method analysed in this study with an error margin of less than 2%.

Practical experience drawn from past initiatives has shown that no country can incinerate efficiently all the MSW generated; not even the developed countries that are endowed with sound economies can incinerate all manner of wastes. The part of the MSW stream, which contains metals, glass and inert materials, cannot be combusted with an incinerator. According to Bilitweski et al (1994) a modern state-of-the-art incinerator in Germany is capable of incinerating nearly 82% of the total MSW mass. The remaining 18% of the waste mass that cannot be incinerated by the thermal process is therefore landfilled as contraries. This study assumes that the municipal authorities in the study area have the resources to collectively incinerate 30% (165,000 mt) of the total waste generated per annum. Out of this, 82% of that volume contains materials that can be incinerated in the combustor, while the contraries, which constitutes 18%, is disposed of in a landfill, as it is the case in Germany. To incinerate 30% of the 550,000 metric tons generated in the Accra-Tema Metropolitan Area (i.e. 165,000 mt), one centralised incinerator with an overall cost requirement of ¢2,277.619 billion are needed. This overall cost comprises ¢1,425.100 billion capital costs, ¢867.867 billion operating costs (See Appendix VIII for computations), and ¢84.652 billion landfilling costs for the residual waste as a result of incineration. The costs of the properly engineered incineration analysed in this study are prohibitive and should not be considered unless, of course, the following measures have been considered: concerns that the combined capacity of landfills and compost facilities are inadequate; economic regulations requiring utilities to purchase electricity from incinerators at premium rates; investment tax credits covering the construction of incinerators; and inexpensive government-backed financing for the construction of incinerators. These measures appear to be beyond the capabilities of developing countries with poor economies. Even in the U.S.A, the federal states are finding it too expensive to maintain these incentives. By 1990 the number of incinerators in that country were either reduced or discontinued, which resulted in incineration fees roughly doubling that of the corresponding landfill fees (Beede and Bloom, 1994). Since then, growth in incineration in the U.S.A has moderated. Besides, the energy produced is so small (about 0.46% of energy potential of municipal waste) that its contribution to any national energy grid cannot justify the huge capital requirements for incineration in a developing country (Bilitweski et al, 1994).

Waste analysis has shown that 65% of municipal waste generated in the study area is compostable (WMD of AMA). With a composting capacity of 24,000 tons per year (or 67 tons per day), 15 composting plants will be required to convert the organic waste stream of 357,500 metric tons per annum into compost. From the analysis, the total capital requirements for establishing 15 compost facilities in the study area during the base year is ¢27.748 billion (See Appendices IX and X for the analysis). A total of ¢22.500 billion will be required to run the facilities in order to process all the organic waste in the area. In addition, it will require an amount of ¢30.159 billion to dispose of 200,000 metric tons of non-biodegradable waste in two landfills. In sum, an overall amount of ¢ 80.409 billion will be needed to establish and run 15 composting facilities in the area at 2001 price levels.

Generally, the analysis shows that the total cost of building and operating composting facilities in the Accra-Tema Metropolitan Area at the base year (2001) is 76% of the total landfill cost and only 3.5% of the total cost of incineration. Comparatively, the total cost of landfilling 550,000 metric tons of waste is 4.6% of the total costs of incinerating 30% of the MSW during the same base year. In addition, composting of MSW in the area saves ¢25.400 billion of landfill costs and ¢2,197.210 billion of incineration costs. The average investment costs per ton for landfilling, incinerating and composting MSW in the area for the start-up year are ¢192,400, ¢4,141,126 and ¢146,198 respectively. Also, the average operating costs per ton of waste handled by landfilling, incinerating and composting facilities in the area are ¢41,600, ¢1,396,200 and ¢40,900 respectively. It must, therefore, be stated that landfilling and incineration facilities are costly waste treatment methods in the study area. For example, it is difficult for any municipal authority in Ghana to incinerate about 30% of the total waste generated in the municipality, and still have enough funds to meet other pressing urban needs. Even in the developed economies, it is only Germany that can thermally treat about 30% of her waste disposed of annually, followed by the United Kingdom and United States of America each with incineration fractions close to 20% of their total waste burden (Bilitweski et al, 1994). With Ghana's per capita income of US$390 (Ministry of Finance, 2001 Annual Budget), it would appear unadvisable to commit nearly three trillion Cedis (almost 430 million US dollars) to incinerate MSW in one city only to reap meagre returns from energy recovery, scrap and recyclable materials, and slag. Also, these methods are highly capital-intensive, and would therefore contribute little to labour absorption in the area. Despite the small impact on employment, the analysis shows that landfilling and incineration will require very sizeable overall investments during the star-up year (2001). From rough estimates, it will require 2,040 workers (2000 waste collectors, 25 unskilled facility labour and 15 skilled management staff) each for landfilling and incineration; whereas 30,195 will be needed for all the composting facilities analysed in this study. The capital-labour ratios for landfilling, incineration and composting during the base year (2001) are therefore calculated to be ¢40.654 million, ¢67.000 million and ¢981,960 per worker respectively. Whereas landfilling and incineration will employ 4 workers per 1000 tons of waste handled, composting facilities will employ 50 workers per 1000 tons of waste handled. In addition to lower capital intensity, composting processes are flexible as opposed to the two other waste treatment methods. Composting activities such as windrow turning and watering can be manipulated by reducing the amount of capital equipment employed whilst increasing the amount of labour force so as to further lower the capital-labour ratio. Mainly land-use systems, environmental quality concerns, health standards and the level of public consciousness towards waste management issues dictate the nature and magnitude of the costs of waste treatment in a municipality. The waste methods analysed in this study permits the operations of the facilities in a manner that avoids nuisances such as, odours and fires to adjoining residents, and prevents environmental damage from leachate and gaseous emissions. The unavailability of land for establishing properly engineered landfills, incinerators, and their transfer stations, and the requirements for meeting environmental quality standards are the major causes of the high capital cost of landfilling and incineration.

The analysis made in this study has not been without blemish, part of which appear intrinsically difficult to control. First, the data set for the analysis was collected from a wide range of technical sources. This discrete data from many sources could be one source of computational error. Second, the formula used to compute the capital requirements for the incinerator (See Equation 4.5 in Chapter 4) was adopted from standard technical specifications provided in German architectural literature, which was scientifically developed for temperate countries after a structural study conducted in 1990. While acknowledging that scientific formulae may be applied worldwide to solve real problems, the waste characteristics of temperate countries are slightly different from those of a tropical, underdeveloped country like Ghana. Wastes in developing countries have higher organic components than those in developed countries. Energy and thermal requirements for incineration are also different for temperate and tropical countries. Consequently, the formula used in the analysis to determine the capital requirements for a modern incinerator may be subject to theoretical criticisms. Third, the costs of capital items and inputs were valued at prices that waste practitioners face in the market, without an attempt to adjust for economic distortions. In a country with an unstable inflationary environment, it will be expedient to deflate all market prices by a price index to reflect such economic distortions. Finally, in calculating the operating costs of the waste processing facilities, it was assumed that all capital items would depreciate completely. The assumption of zero salvage value at the end of their useful lives may not necessarily hold. This is because some of the capital items will still have commercial values after decommissioning. Land used for landfilling, for example, may still have a value after its closure and revegetation.

The conclusion drawn from the analysis is that composting, as an integrated waste management method, attracts lower costs in the Accra-Tema Metropolitan Area as compared to landfilling and incineration. It must be noted, however, that even though composting emerged as the least costly processing method, the totall capital investment during the start-up year is still high for a developing municipality like Accra-Tema, whose financial commitments are largely met from the central government coffers. But considering the hidden social and environmental benefits the composting scheme generates such as improvement of soil fertility and structure, reduction in health wage bills, and reduction in the cost of waste disposal, the establishment of composting facilities in the area should be encouraged while the selection of the facilities should be based on labour-intensive technologies. This minimizes the capital expenditure required, which forms about 35% of the total cost of composting during the base year. In view of the comparatively low cost involved in the building and operation of composting facilities and the potential to generate employment in labour-surplus economy, the State needs to play a pivotal role in promoting composting of MSW throughout the country. It may be more efficient for the municipality to contract the composting of MSW to private entrepreneurs instead of undertaking the venture by itself. Profit-seeking firms generally have greater flexibility and incentives than government bureaucracies in redeploying workers and physical capital quickly in response to changing circumstances, and to design and implement cost cutting innovations. For a low income country like Ghana, one option may be to remove sanctions on the informal sector waste collection and recycling enterprises, integrate them with commercial composting, and employ means that these enterprises can economically divert MSW from incinerators and landfills. Government regulations and regular monitoring of waste collection schemes may support the privatisation of MSW composting. Empirical evidence from experiences gained in Canada, United Kingdom, Germany and United States of America have generally shown that non-competitive collection services are less efficient than competitive private firms (Beede and Bloom, 1995). In Benin and the Republic of Togo, efficient waste collection practices have been achieved through active private participation. The comparative analysis done for waste processing facilities in the TMA is an attempt to determine the least costly waste processing facilities for the area. However, more detailed information is needed on waste characteristics in order to plan efficient solid waste management systems within the urban environment.

5.3 Profitability Analysis of Composting Projects Using the GTZ Calculation Model

To determine the profitability of composting facilities in the Accra-Tema Metropolitan Area, the GTZ Computer Programme (Calculation Model) was applied to various degrees of composting in the area. Fifteen decentralised composting facilities with transfer stations for each possible alternative were identified, based on the available potential sites for composting in the study area. From literature, the organic fraction of the municipal solid waste generated in the Accra-Tema Metropolitan Area is about 65%. Calculations based on the 15 composting facilities and 65% organic fraction resulted in the choice of 6,500, 13,000, 18,000 and 24,000 metric tons (mt) composting capacities per facility for each option for the year 2001. These volumes represent 25%, 50%, 75% and 100% respectively of the organic waste generated in the area in the year 2001 (i.e. 65% of 550,000 mt)). In order to have a fair idea and comparative knowledge about composting in the West African sub-region the calculation process was extended to cover existing composting projects in Nigeria, Togo and Benin. The results of calculations provided a practical foundation for taking decisions on whether or not the facilities to be established and the methods employed are economically feasible for a given municipality. Appendices XI, XII, XIII and XIV show examples of the results of the calculation processes obtained from the GTZ computer programme. The summarised results presented in Table 5.2 show that the so-called "best of worst scenarios" and "worst scenarios", which correspond to medium and highly automated alternatives respectively, produced unimaginably high deficits for the hypothetical projects in the Accra-Tema area. This could only be explained by the fact that highly automated compost plants need higher investment capital per ton of compost than small-scale plants with low level of automation.

Due to the large deficits, medium-to-high capital-intensive options cannot be contemplated in the area. For example, it will be economically unwise to lose as much as $37,115,949 in the star-up year (2001) only to compost 25% of the organic waste generated in the ATMA. The following discussion is therefore limited to the results of the labour-intensive alternatives, in which it is assumed that the operations are subsidized by the local government authorities. The results in Table 5.2 also show that the contribution margins for facilities with annual capacities of 24,000, 18000, 13,000 and 6,500 metric tons (mt) of raw MSW composted in 2001are: -$91, -$90, -$67 and -$32 respectively, at 2001 constant prices. These figures work out to be: -$1,281,791, -$897,455, -$433,619 and -$105,244 respectively. The annual ratios of deficits to tons of raw waste used are, therefore, $53.40, $49.86, $33.36 and $16.19 respectively.

Table 5.2: Summary of Cost-Benefit Analysis of Composting Schemes in the Accra-Tema Metropolitan Area (Ghana) Using the GTZ Calculation Model (At 2001 Constant Prices)

SCENARIO	COSTS/ BENEFITS	GHANA (100%) (24,000t)[a] (13,000t)[b]		GHANA (75%) (18,000t)[a] (10,000t)[b]		GHANA (50%) (13,000t)[a] (6,500t)[b]		GHANA (25%) (6,500t)[a] (3,300t)[b]	
		US $/t COMPOST	US $/yr	US $/t COMPOST	US $/yr	US $/t COMPOST	US $/yr	US $/t COMPOST	US $/yr
"BEST SCENARIO"[c]	COSTS	271	3,623,041	270	2,698,695	247	1,603,619	212	699,994
	BENEFITS	180	2,341,250	180	1,801,250	180	1,170,000	180	594,750
	DEFICIT (-)/ PROFIT (+)	-91	-1,281,791	-90	-897,455	-67	-433,619	-32	-105,244
"BEST OF WORST SCENARIOS"[d]	COSTS	15,126	196,641,988	12,965	129,647,288	13,968	91,491,437	11,263	37,166,466
	BENEFITS	135	1,757,000	135	1,351,250	134	878,750	134	594,750
	DEFICIT (-)/ PROFIT (+)	-14,991	-194,884,988	-12,830	-128,296,038	-13,834	-91,403,567	-11,083	-36,571,696
"WORST SCENARIO"[e]	COSTS	21,819	283,640,798	15,082	150,818,366	15,407	100,916,214	-11,381	-37,558,149
	BENEFITS	134	1,757,000	134	1,757,000	134	878,750	134	442,200
	DEFICIT (-)/ PROFIT (+)	-21,685	-281,883,798	-14,948	-149,061,366	-15,273	-100,037,464	-11,247	-37,115,949

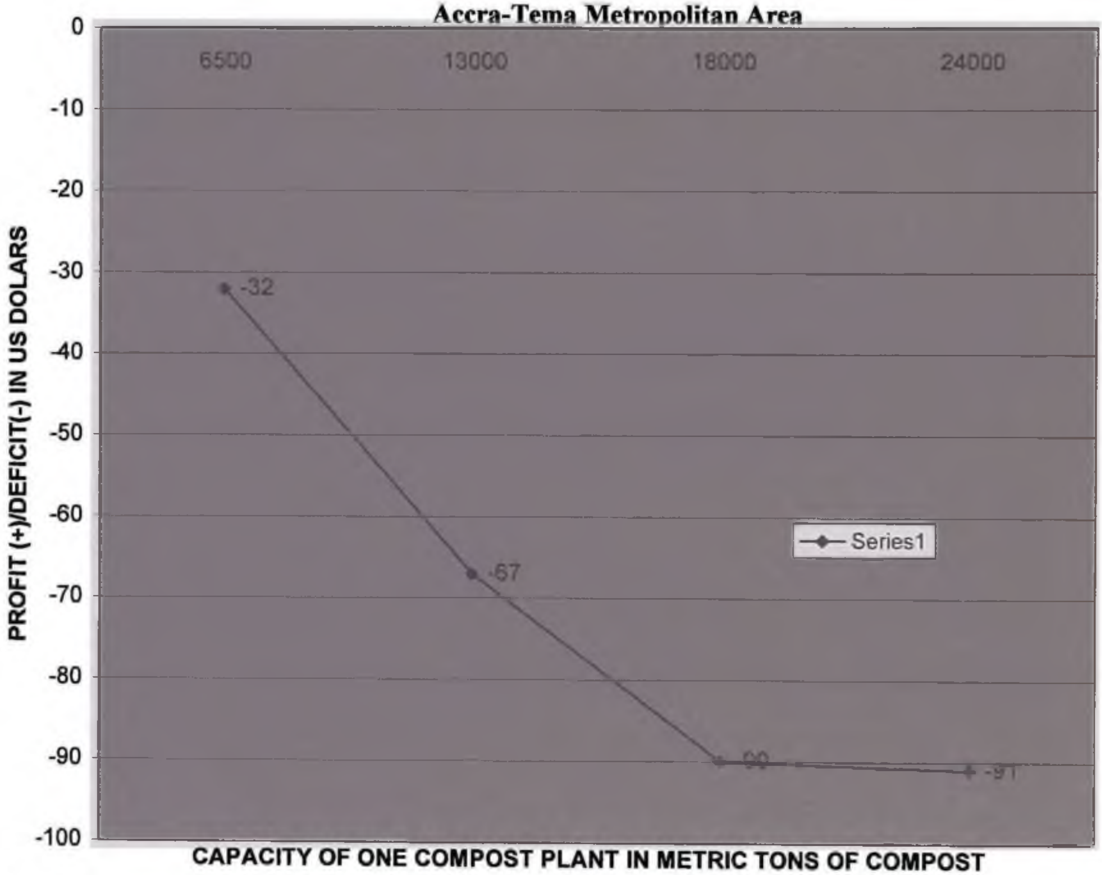
Source: *Author's Own Analysis*

a: Volume of raw Municipal Solid Waste
b: Volume of finished Compost Product
c: Labour-intensive Technology
d: Medium Capital-intensive Technology without Subsidies
e: Capital-intensive Technology without Subsidies

Two reasons account for the deficits in the operations of the compost facilities with their various capacities considered in the analysis. First, the total benefits generated from sales of compost ($429,000/year), "subsidies"(i.e. other waste management costs saved) ($165,000/year) and chargeable fees on households ($750/year) were extremely small, and remained fairly constant for all the possible alternatives considered. ($165,000/year) and chargeable fees on households ($750/year) were extremely small, and remained fairly constant for all the possible alternatives considered. Second, the total costs of production for all the projects were very high. The capital items of the MSW composting facilities are found to be expensive, resulting in extremely high depreciation expenses for all the options considered in the calculation process. Once the accepted prices of compost products are relatively low, transport and treatment costs were the decisive factors in determining the profitability of the projects. Unfortunately, maintenance and transportation costs for all the projects were also high relative to the scale of operations undertaken by the projects (See appendices XI, XII, XIII and XIV for examples).

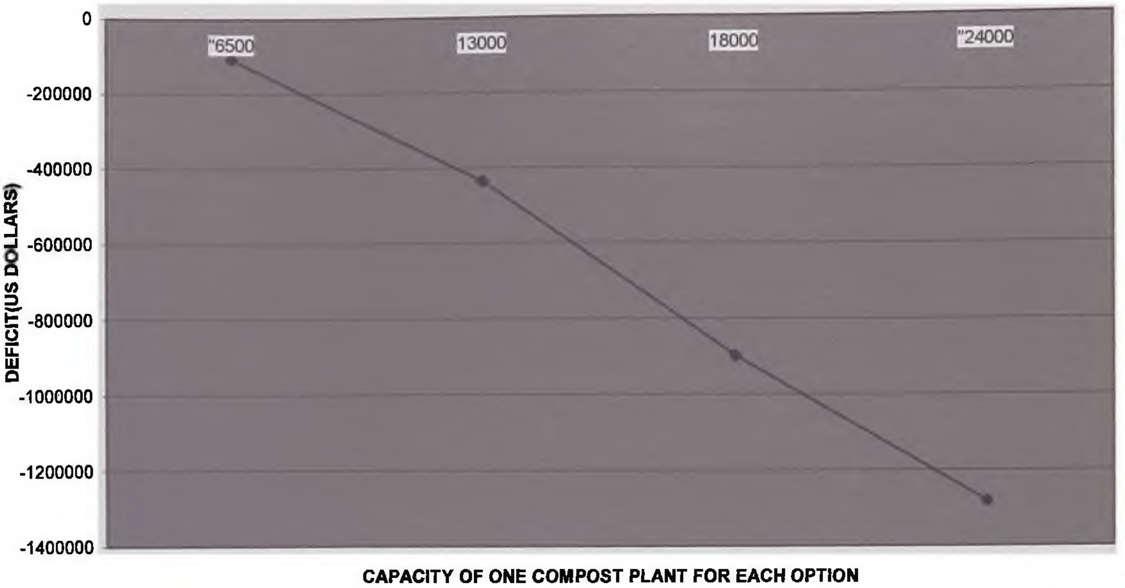
From the analysis, it appears that profitability per ton of compost produced does not follow any form of mathematical progression. However, the deficits per annum follow a fairly linear progression. According to the results, the preference of fractional composting of organic waste generated in the ATMA in 2001 is 25%, 50%, 75%, and 100%, in that order. The deficit increases sharply from the 25% mark ($32 per ton of compost) to 50% mark (with a deficit of $67 per ton of compost). Thereafter, the contribution margin falls to - $90 per ton of compost at the 75% mark, and gradually to -$99 at the 100% mark. Figures 5.1 and 5.2 below graphically show how the deficits for the various options behave. Though it is difficult to explain the erratic phenomenon exhibited by the calculation process, nevertheless, the following deduction may be made of the results. Labour-intensive composting of the organic waste in the ATMA is not economically feasible during the start-up year (2001). For example, if a compost producer decides to compost all (100%) the organic waste generated in the ATMA at 2001 price levels using labour-intensive technologies, he/she will lose more than one million dollars that year. Also, due to the fairly large negative contribution margin shown by a facility that is composting 18,000 metric tons (i.e. 75% of 2001 volume) of raw organic materials (i.e.: -$90 per of compost), labour-intensive composting at that fractional rate is equally not viable from the economic point of view.

Figure 5.1: Profit Contribution Margins for Various Levels of Composting in the Accra-Tema Metropolitan Area



Source: *Author's Own Analysis*

Figure 5.2: Deficits for Various Levels of Composting in the Accra-Tema Metropolitan Area (in the Year 2001)



Source: *Author's Own Analysis*

Furthermore, composting 6,500 mt (25%) and 13,000 mt (50%) at the 2001 price levels produces fairly low deficits per ton of compost produced (i.e. -$32 and -$67 respectively); but the fractions of organic to be removed appear to be small, from the environmental point of view. The question is: at what volumes per facility should composting be recommended for the Accra-Tema Metropolitan Area? The viability of the compost business is a key-determining factor. However, the ability of the compost business to meet the supply and demand for the product is also the basis for assessing early survival of the business. A decision to compost 24,000mt (100%) will be unwise since the ratio of deficits to tonnage of organic waste composted (i.e. $53.41/t) is fairly large. Also, to treat 13,000mt (50%) means only half of the organic waste generated in 2001 would have been composted, while the remaining waste volume (23,667mt) is landfilled at the cost of $650,465 per facility, as can be seen in Table 5.3 below, which is a presentation of the costs for composting various fractions and landfilling the rest of the municipal solid waste not composted. The net costs (deficits) are total costs of composting minus total benefits derived from composting.

Table 5.3: Total Costs of the Various Levels of Composting and Landfilling the Remaining Municipal Solid Waste in the Accra-Tema Metropolitan Area at 2001 Price Levels

METHOD	Volume (mt)	Net Cost (US$)	Volume (mt)	Net Cost (US$)	Volume (mt)	Net Cost (US$)	Volume (mt)	Net Cost (US$)
Composting	6,500	105,244	13,000	433,619	18,000	899,455	24,000	1,281,791
Landfilling Remaining Waste	30,167	829,204	23,667	650,465	18,667	513,052	12,667	348,145
Totals (one Compost Facility)	36,667	1,034,448	36,667	1,084,084	36,667	1,310,507	36,667	1,629936
Totals for 15 Compost Facilities	550,000	15,516,720	550,000	16,261,260	550,000	19,657,605	550,000	24,449,09 0

Source: Author's Own Computations

The costs of landfilling the remaining wastes after composting are calculated from the results contained in Table 5.1 (page 85) above by assuming that the cost of landfilling waste is directly proportional to the volume being landfilled. The total net costs for each facility composting 6,500, 13,000, 18,000 and 24,000 mt of organic waste and landfilling the remaining 30,167, 23,667, 18,667 and 12,667mt of waste respectively are $1,034,448, $1,084,084, $1,310,507 and $1,629,936. For 15 compost facilities (for each of the options), the respective costs are $15,516,720, $16,261,260, $19,657,605 and $24,449,090. From both economic and environmental points of view, 13,000 and 24,000 mt may be ruled out of consideration. Consequently, the 6,500 mt (25%)and 18,000 mt (75%) options may be considered for the Accra-Tema area, though both fractions are not viable at the start up year (2001). The smaller scale shows a better profitability prospect per ton of compost produced, but if the total compost market potential is to be fulfilled for peri-urban and urban agriculture in the area, 45 small compost plants each with capacities of 3,300 metric tons of compost, will be needed to deal with same organic waste burden as the 15 plants for the 75% composting. Due to these market factors, and the need to drastically reduce the volume of MSW that goes to landfills, the 75% composting is more favoured.

The selection of the technical alternatives depends considerably on the expected planned capacity of the compost production. All the processes involved in the utilisation of compost facilities can be carried out in highly mechanised systems or with a minimum of technical aids. Manual processes are suited for small throughput levels, where as a large throughput will require a high degree of automation. This is so because the high depreciation costs involved in the use of machinery and equipment can only be covered if a certain volume of compost is produced. Because of the higher degree of automation, the quality control of compost products will be better for the 75% composting than for the 25% composting in the area. Lower technology that may be employed for the 25% will result in lower quality of compost that can pose serious marketing problems. Also, the large volume associated with the 75% composting will create a "large mass" in the compost market without adding to the cost of a coordinating unit needed for the 45 plants of the same capacity. Furthermore, in the wake of scarcity of suitable lands for establishing compost facilities in the ATMA, it can only be better to select an alternative that requires lower land space and costs, as it is the case of 75% composting alternative.

In the process of determining the above results, it has been assumed that land for the composting facilities and transfer stations is owned by the municipal authority employing the GTZ computer programme and, therefore, land is not valued and incorporated into the calculation processes. However, the cost of land in the West African sub-region constitutes a significant investment cost and is the most important case of the need for estimating the net value of production foregone. To take care of this problem, the value of land is considered in the calculation processes by two convenient scenarios. First, it is assumed that land for a compost facility is purchased outright. Its value is added to the cost of machinery as provided in the GTZ model. Secondly, land is leased over the life of each compost project. Its leased value is divided by the life of the project – 20 years – and then added to the cost of machinery before the computerisation is done for the various options. The results of factoring in the cost of land purchased or rented in the computer programme are shown in Table 5.4 below. The analysis shows that when the value of land purchased is factored into the calculation process, the deficits for the various options (24,000, 18,000, 13,000 and 6,500 mt of organic waste) will increase from \$91, \$90, \$67 and \$32 per ton of compost to \$99, \$91, \$68 and \$34 per ton of compost respectively. In terms of annual deficits, the values of the increases are \$8,369, \$6,941, \$6,500, and \$6,083 respectively. These annual deficits are quite substantial for a municipal authority in a developing country like Ghana with meagre resources.

It is instructive to not that when the GTZ computer programme is applied in the ATMA, the total investment costs for composting all the organic waste generated in 2001 using 15 composting plants (without considering land as a capital cost) is \$54,345,615 (i.e. 15 x \$3,623,041in table 5.2). However, from the manual calculations done in section 5.2 above, the total investment costs for composting the entire organic component is 80.409 billion cedis at 2001 price levels (See Table 5.1; last column, row 8). At an exchange rate of 7,000 cedis per one US dollar, this value works out to be \$11,487,000 making it about one-fifth the value obtained from the GTZ simulation. This disparity arises because the manual calculations were based purely on labour-intensive technology, while the GTZ simulation method was based on moderate capital-intensive technology.

Table 5.4 Summary of Cost-Benefit Analysis of Labour-Intensive Composting Schemes in the Accra-Tema Metropolitan Area with the Cost of Land Factored in the GTZ Calculation Process

SCENARIO	COSTS/ BENEFITS	24,000 mt (100%)		18,000 mt (75%)		13,000 mt (50%)		6,500 mt (25%)	
		US$/t OF COMPOST	US$/yr	US$/t OF COMPOST	US$/yr	US$/t OF COMPOST	US$/yr	US$/t OF COMPOST	US$/yr
OUTRIGHT PURCHASE OF LAND	Total Costs	279	3,631,410	271	2,706,646	248	1,611,119	214	706,077
	Total Benefits	180	2,341,250	180	1,801,250	180	1,171,000	180	594,750
	Deficit (-) /Profit (+)	-99	-1,290,160	-91	-905,396	-68	-440,119	-34	-111,327
LAND IS RENTED OVER THE LIFE OF PROJECTS	Total Costs	279	3,625,274	271	2,700,822	248	1,605,309	213	701,362
	Total Benefits	180	2,341,250	180	1,801,250	180	1,171,000	180	594,750
	Deficit (-) /Profit	-99	-1,284,024	-91	-899,572	-68	-434,309	-33	-106,712

Source: Author's Own Computation

If the shared value of the rented land is added to the cost of machinery before computerisation, the deficits per tonnage are approximately $8, $1, $1 and $3 higher than when land is not considered for the respective capacities of organic waste composted. The annual increases in deficit are $2,833, $2,117, $1,468 and $690 respectively. As compared to outright purchase of land, the deficits for rented land are lowered by $6,136, $5,824, $5,810 and $4,515 respectively, which are quite favourable and substantial for any municipal authority in Accra-Tema area.

To conclude, land is an important capital item in undertaking composting schemes in the Accra-Tema Metropolitan Area, especially when municipal authorities have no land of their own and have to purchase it from landowners in the area. The cost of land (whether rented or purchased) must therefore be factored in any financial analysis of compost projects; otherwise results obtained will not reflect the true situation on the ground.

The results for the calculation processes for the compost projects in Nigeria, Togo and Benin are presented in Table 5.5 below. For all the countries, it is assumed that land is purchased and its value factored into the calculation processes. The results of Table 5.5 show that, at the 2001 price levels, the compost projects at Bodija (Nigeria), Tsevie (Togo) and Hevie (Benin) are being run at losses, whether the technologies applied were capital-intensive, labour-intensive or a mixture of the two. For the labour-intensive alternatives that are presented in the Table (5.5) as "best scenarios", the negative contribution margins (or deficits per ton of compost) are $175, $264 and $77 for the Bodija, Tsevie and Hevie projects respectively. These figures correspond to annual deficits of $876,346, $237,870 and $228,382 respectively. The results also show that if the projects are highly capital-intensive, composting will result in the "worst scenarios", with negative margins of $13,090, $8,600 and $15,568 per ton respectively. The corresponding losses for the year will therefore be $65,454,641, $7,740,570 and $46,702,053 respectively. Finally, the analysis also shows that if composting is done with the view to deriving the best out of the worse scenarios, by applying medium capital-intensities, the deficits will be $12,381, $1,091 and $14,039 per ton for Bodija, Tsevie and Hevie projects respectively. In terms of annual deficits, the corresponding values will be $61,908,110, $981,980 and $42,115,800 respectively. From the results quoted above, the Hevie project in Benin proves to have the least deficit for the "best scenarios" (labour-intensive alternatives) as compared to the Bodija (Nigeria) and Tsevie (Togo) projects. However, as the intensity of capital employed is increased, the fortunes of all the projects dwindle and become worse of, with the Tsevie project showing better resilience than the Bodija and the Hevie projects. It can be concluded therefore that the operations of the Bodija, Tsevie and Hevie projects at the 2001 levels had no economic merits. Their operations are justified purely on the basis of environmental and health benefits. The various local government authorities, at "ostrich" positions, maintain subsidies for the operations of the compost facilities. That is, the authorities are not acknowledging that they are, indeed, losing from operations of the compost facilities. The results confirm what has been widely held in literature – that, high capital-intensive compost projects are not cost-effective for developing countries. While benefits were found to be low, costs of depreciation, transportation and maintenance were rather extremely high. For all the countries (Togo, Nigeria and Benin), prices of compost products, household waste service fees and local government subsidies payable to compost producers were all found to be meagre. Verbal discussions held with key players of these projects revealed that because prices of closed substitutes such as "black soils", animal manure and poultry droppings were cheaper in all the countries during the study year (2001), compost producers were compelled to sell their products at prices far below the costs of production.

Table 5.5: Summary of Cost - Benefit Analysis of Compost Projects in Nigeria, Togo and Benin Using the GTZ Calculation Model, at 2001 Constant Prices

SCENARIO	COSTS/ BENEFITS	NIGERIA (Bodija) (9,000t)[a] (5,000t)[b]		TOGO (Tsevie) (1,700t)[a] (900t)[b]		BENIN (Hevie) (5,50t)[a] (3,00t)[b]	
		US$/t COMPOST	US $/yr	US$/t COMPOST	US $/yr	US $/t COMPOST	US $/yr
"BEST SCENARIO"[c]	COSTS	324	1,619,046	392	352,665	244	730,862
	BENEFITS	149	742,700	128	114,795	167	502,480
	DEFICIT (-)/ PROFIT (+)	-175	-876,346	-264	-237,870	-77	-228,382
"BEST OF WORST SCENARIOS"[d]	COSTS	12,530	62,650,810	1,219	1,096,775	-14,206	42,618,280
	BENEFITS	149	742,700	128	114,795	167	502,480
	DEFICIT (-)/ PROFIT (+)	-12,381	-61,908,110	-1,091	-981,980	-14,039	-42,115,800
"WORST SCENARIO"[e]	COSTS	13,239	66,197,341	8,728	7,855,365	15,735	47,204,533
	BENEFITS	149	742,700	128	114,795	167	502,480
	DEFICIT (-)/ PROFIT (+)	-13,090	-65,454,641	-8,600	-7,740,570	-15,568	-46,702,053

Source: Author's Own Calculations

a: Volume of raw Municipal Solid Waste
b: Volume of finished Compost Product
c: Labour-intensive Technology
d: Medium Capital-intensive Technology without Subsidies
e: Capital-intensive Technology without Subsidies

Besides, chemical fertilizers were heavily subsidised in all the countries, which made the prices of the latter comparable to those of compost products. The prices of compost in Nigeria, Togo and Benin, at the time of the survey, were $108, $120 and $150 per ton respectively, whereas the costs of production of the respective projects were $145, $150 and $160 per ton respectively. The average prices per ton of organic substitutes (black soil, animal manure and poultry waste) were $65, $40 and $45 for in Nigeria, Togo and Benin respectively. Finally, the average prices of chemical fertilizers per ton were $280, $305 and $310 respectively for the countries studied.

There appears to be two substantial problems arising from the framework of the GTZ programme for analysing the profitability of compost facilities. Firstly, human errors are inevitable because too much value judgment was required for both the voluminous data collection and the rigorous analysis. Secondly, the dynamic and year-specific programme has a number of defects, particularly when applied to a developing country. First, the programme was developed in Germany, which has completely different waste characteristics and investment environment from the countries for which programme was applied in this study. Therefore, the accuracy of the results obtained by the calculation processes may appear questionable within critical minds. Second, the programme does not make provisions for adding value to the compost production, by incorporating into the calculation processes additives that will improve the quality of compost products.

5.4 Investment Analysis of Compost Projects in Accra-Tema Metropolitan Area

The two previous sections (i.e. 5.2 and 5.3) looked only at costs of composting at the start-up year (2001) in the ATMA. In addition to the costs, Section 5.3 also looked at benefits at the start-up year. However, it is not a sufficient condition for determining the future viability of the compost facilities by just looking at the start-up year of a project. This section analyses the financial viability of compost projects using discounted methods. Costs and benefits have to be projected into the future and discounted to determine their present worth. By applying two conventional discounted cash flow methods (NPV and IRR) at 45% discount rate, the worth of the projects are estimated over their entire life spans. The GTZ Calculation Model was modified and applied to determine costs and benefits of the most attractive options (i.e. 75% and 25% composting), which formed the basis for calculating the incremental net benefits. To reflect progressive increases in input prices resulting from inflationary impacts in Ghana, all costs are inflated by the 2001-inflation rate of 40%. Due to changes in exchange rate, depreciation of equipment and other factors, all costs are projected by a compound rate of 40% over the 20-year period. The average values of all the costs over the 20-year period were taken for both projects and then used as representative costs throughout the years. The average values of the 75% and 25% compost pants were ¢17,988 and ¢5,784 respectively (See Table 5.6). Benefits are projected by a 25% rate, which were compounded over the lives of the projects. The 25% compound rate used in the analysis was an average of the rate of increases in prices of organic soil ameliorants such as compost, "blacksoil", and poultry manure over the last five years (1997-2001). For ease of discussions, the projects taken from the 75% (18,000 mt) and 25% (6,500 mt) composting alternatives have been designated as "Project A and "Project B" respectively. Tables 5.6 and 5.7 below illustrate how the net present values (NPVs) and (financial) internal rates of return (IRR) respectively are computed using the costs and benefits adjusted for inflationary impacts.

From the analysis in Table 5.6 below, NPVs for projects A (75% composting) and B (25% composting) discounted at 45% are -¢1.663 billion and -¢0.451 billion respectively. For both projects, the NPVs are substantially negative, with Project A having an NPV less than that of Project B. This shows that the higher the scale of operations, the smaller the NPVs, calculated at the same discount rate.

Table 5.6: Analysis of Compost Projects Illustrating the Computation of Net Present Values

Year	PROJECT A (1 COMPOST FACILITY COMPOSTING 18,000 MT RAW MSW (i.e. 75% OF 2001 VOLUME)					PROJECT B (1 COMPOST FACILITY COMPOSTING 6,500 MT OF RAW MSW WASTE i.e. 25% OF 2001 VOLUME)				
	Incremental Costs (¢'10^6)	Incremental Benefits (¢'10^6)	Incremental Net Benefits (¢'10^6)	Discount Factor (45%)	Present Values (¢'10^6)	Incremental Costs (¢'10^6)	Incremental Benefits (¢'10^6)	Incremental Net Benefits (¢'10^6)	Discount Factor (45%)	Present Values (40%; '¢10^6)
0	1,388	0	-1,388	1.000	-1,388	463	0	-463	1.000	-463
1	17,988	12,608	-5,380	0.690	-3,712	5,784	4,163	-1,621	0.690	-1,118
2	17,988	14,327	-3,661	0.476	-1,743	5,784	4,731	-1,053	0.476	-501
3	17,988	16,281	-1,707	0.328	-560	5,984	5,376	-608	0.328	-199
4	17,988	18,502	514	.0226	116	5,784	6,109	325	0.226	73
5	17,988	21,021	3,033	0.156	473	5,784	6,943	1,159	0.156	181
6	17,988	23,894	5,906	0.108	638	5,784	7,890	2,106	0.108	227
7	17,988	27,153	9,165	0.074	678	5,784	8,960	3,182	0.074	238
8	17,988	30,857	12,869	0.051	656	5,784	10,189	4,405	0.051	225
9	17,988	35,066	17,078	0.035	598	5,784	11,579	5,795	0.035	203
10	17,988	39,849	21,861	0.024	525	5,784	13,158	7,374	0.024	177
11	17,988	45,284	27,296	0.017	464	5,784	14,953	9,169	0.017	156
12	17,988	51,461	33,473	0.012	402	5,784	16,992	11,208	0.012	134
13	17,988	58,480	40,492	0.008	324	5,784	19,310	13,526	0.008	108
14	17,988	66,457	48,469	0.006	292	5,784	21,944	16,160	0.006	97
15-20	17,988	75,521	57,533	0.010	574	5,784	24,937	19,153	0.010	192
TOTAL	271,208	536,761	265,553	3.221	-1,663	87,223	177,239	89,816	3.221	-451

Source: Author's Own Calculations a. NPV (75%) ≈ **-¢1.663 billion** b. NPV (25%) ≈- **¢0.451billion**

Table 5.7: Analysis of Compost Projects Illustrating Interpolation to Estimate Internal Rates of Return

Year	PROJECT A (1 COMPOST FACILITY COMPOSTING 18,000 MT RAW MSW (i.e. 75% OF 2001 VOLUME)					PROJECT B (COMPOSTING 1 COMPOST FACILITY 6,500 MT OF RAW MSW (i.e. 25% OF 2001 VOLUME)				
	Incremental Net Benefits (¢'10⁶)	Discount Factors (40%)	Present Value (40%; ¢'10⁶)	Discount Factor (45%)	Present Values (45%;¢'10⁶)	Incremental Net Benefits (¢'10⁶)	Discount Factors (40%)	Present Values (45%; ¢'10⁶)	Discount Factor (45%)	Present Value (50%; ¢'10⁶)
0	-1,388	1.000	-1,388	1.000	-1,388	-463	1,000	-463	1.000	-463
1	-5,380	0.714	-3,841	0.690	-3,712	-1,621	0.714	-1,157	0.690	-1,118
2	-3,661	0.510	-1,332	0.476	-1,743	-1,053	0.510	-537	0.476	-501
3	-1,707	0.364	-621	0.328	-560	-608	0.364	-221	0.328	-199
4	514	0.260	134	.0226	116	325	0.260	85	0.226	73
5	3,033	0.186	564	0.156	473	1,159	0.186	216	0.156	181
6	5,906	0.133	785	0.108	638	2,106	0.133	280	0.108	227
7	9,165	0.095	870	0.074	678	3,182	0.095	302	0.074	238
8	12,869	0.068	875	0.051	656	4,405	0.068	300	0.051	225
9	17,078	0.046	786	0.035	598	5,795	0.046	267	0.035	203
10	21,861	0.035	758	0.024	525	7,374	0.035	258	0.024	177
11	27,296	0.025	682	0.017	464	9,169	0.025	229	0.017	156
12	33,473	0.018	602	0.012	402	11,208	0.018	202	0.012	134
13	40,492	0.013	526	0.008	324	13,526	0.013	176	0.008	108
14	48,469	0.009	436	0.006	292	16,160	0.009	145	0.006	97
15-20	57,533	0.019	1,093	0.010	574	19,153	0.019	364	0.010	192
TOTAL	265,553	3.495	403	3.221	-1,663	89,816	3.495	444	3.221	-451

Source: Author's Own Calculations   a. IRR = 40 + 5(403)/2066 ≈ **41%**   b. IRR = 40 + 5(444)/895 ≈ **43%**

As the scale of operation increases, it is expected that more capital equipment will be employed to deal with the larger volume of waste for the 75% option, particularly during the maturation stage. The higher capital-intensive alternatives required for project A are responsible for the higher investment costs, which in turn makes the NPV smaller. For the 25% composting, labour-intensive technologies may be applied to the compost processing right from beginning to the main maturation stage. In a labour-surplus economy like that of Ghana, labour costs are low; hence, the comparatively smaller NPV for project B. The payback periods for the two projects may be computed, using the incremental net benefits obtained from Table 5.6 above, as follows:

Table 5.8: Payback Period For Project A

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
-1,388 -5,380 -6,768	-10,429	-12,136	-11,622	-8,589	-2,583	+6,482
-3,661	-1,707	+514	+3,033	+5,905	+9,165	-
-10,429	-12,136	-11,622	-8,589	-2,583	+6,482	

Source: Author's Own Computation

Payback Period = 6 years + (2583/9165 x 12) months
= 6 years 3.52 months
≈ **6 years 4 months**

Table 5.9: Payback Period For Project B

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
- 463 -1.621 -2,083	-3,137	-3,745	-3,420	-2,261	-155	+3,027
-1,053	-608	+325	+1,159	+2,106	+3,182	-
-3,137	-3,745	-3.420	-2,261	-155	+3,027	-

Source: Author's Own Computation

Payback Period = 6 years + (155/3182 x 12) months
= 6 years 0.58 months
≈ **6 years 1 month**

By examining the two projects, it is clear that project B has a smaller payback period (6 years 1 month) than project A, whose payback period is 6 years 4 months (See Tables 5.8 & 5.9). This means that project B will pay for itself 3 months earlier than Project A does so. The analysis also shows that the internal rates of return (IRRs) for Projects A and B, evaluated at 2001 price levels, are 41% and 43% respectively (See Table 5.7 above). These are the rates that drive the net present values of the projects to zero. In order words, at the discount rates of 41% and 43%, projects A and B will earn back all the capital and operating costs expended and pay the compost entrepreneurs 41% and 43% respectively for the use of funds to establish and operate the composting facilities. The rates obtained in this study are below the average rate of borrowed capital (45%) in Ghana during the year 2001, but well above the conventional range used by the World Bank (i.e. 8-15%) to estimate opportunity costs of capital for developing countries. This means that these compost projects are not be financially viable using domestic capital borrowed in Ghana. They will, however, be viable in terms of World Bank calculations. The analysis further shows that a decrease by 10% (i.e. from 45%-35%) in the cost of capital will increase the NPVs of Projects A and B from -¢1.663 billion to ¢3.776 billion, and from -¢0.451 billion to ¢1.605 billion respectively. The increases are 327% and 456% respectively. Compost projects are, therefore, very sensitive to marginal changes in the capital invested in the projects.

The following sensitivity analyses were further conducted to assess the resilience, or other wise, of the projects to various financial changes: (1) 30% initial capital cost overrun; (2) 10% fall in the sales price of compost; (3) 10% increase in labour costs; (4) 10% increase in fuel prices; and (5) 10% increase in material (input) costs. Tables 5.10 and 5.11 below give the procedures and the results of the sensitivity analyses conducted on the 30% initial capital cost overrun and 10% decrease in the sales price of compost.

Table 5.10: Sensitivity Analysis of Compost Production Illustrating 30% Initial Capital Cost Overrun

PROJECT A (1 COMPOST FACILITY COMPOSTING 18,000 MT RAW MSW (i.e. 75% OF 2001 VOLUME)						PROJECT B (1 COMPOST FACILITY COMPOSTING 6,500 MT OF RAW MSW (i.e. 25% OF 2001 VOLUME)				
Year	Incremental Net Benefits (¢'10⁶)	Discount Factor (35%)	Present Value (35%; '10⁶)	Discount Factor (40%)	Present Values (40%; ¢'10⁶)	Incremental Net Benefits (¢'10⁶)	Discount Factors (40%)	Present Values (40%;¢'10⁶)	Discount Factor (45%)	Present Values (45%); ¢'10⁶)
0	-1,804	1.000	-1,804	1.000	-1,804	-602	1.000	-602	1.000	-602
1	-5,380	0.741	-3,787	0.714	-3,841	-1,621	0.714	-1,157	0.690	-1,118
2	-3,661	0.549	-2,010	0.510	-1,867	-1,053	0.510	-537	0.476	-501
3	-1,707	0.406	-693	0.364	-621	-608	0.364	-221	0.328	-199
4	514	0.301	155	0.260	134	325	0.260	85	0.226	73
5	3,033	0.223	676	0.186	564	1,159	0.186	216	0.156	181
6	5,906	0.165	974	0.133	785	2,106	0.133	280	0.108	227
7	9,165	0.122	1,118	0.095	870	3,182	0.095	302	0.074	238
8	12,869	0.091	1,171	0.068	875	4,405	0.068	300	0.051	225
9	17,078	0.067	1,141	0.046	786	5,795	0.046	267	0.035	203
10	21,861	0.050	1,093	0.035	758	7,374	0.035	258	0.024	177
11	27,296	0.037	1,010	0.025	682	9,169	0.025	229	0.017	156
12	33,473	0.027	904	0.018	602	11,208	0.018	202	0.012	134
13	40,492	0.020	810	0.013	526	13,526	0.013	176	0.008	108
14	48,469	0.015	727	0.009	436	16,160	0.009	145	0.006	97
15-20	57,533	0.036	2071	0.019	1,093	19,153	0.019	364	0.010	192
TOTAL	265,137	3.850	3,360	3.495	-22	89,678	3.495	305	3.221	-412

Source: Author's Own Calculations a. **IRR = 35 +5(3360)/3382 ≈ 40%** b. **IRR = 40 + 5(305)/7171 ≈ 42%**

Table 5.11: Sensitivity Analysis Illustrating 10% Fall in Compost Prices

PROJECT A (1 COMPOST FACILITY COMPOSTING 18,000 MT RAW MSW (i.e. 75% OF 2001 VOLUME)						PROJECT B (1 COMPOST FACILITY COMPOSTING 6,500 MT OF RAW MSW (i.e. 25% OF 2001 VOLUME)				
Year	Incremental Net Benefits (¢'10⁶)	Discount Factors (35%)	Present Value (20%; ¢'10⁶)	Discount Factor (40%)	Present Values (25%; ¢'10⁶)	Incremental Net Benefits (¢'10⁶)	Discount Factors (35%)	Present Values (35%; ¢'10⁶)	Discount Factor (40%)	Present Values (40%; ¢'10⁶)
0	-1,388	1.000	-1,388	1.000	-1,388	-463	1.000	-463	1.000	-463
1	-6,641	0.741	-4,921	0.714	-4,742	-2,016	0.741	-1,510	0.714	-1,455
2	-5,094	0.549	-2,797	0.510	-2,598	-1,663	0.549	-838	0.510	-778
3	-3,335	0.406	-1,354	0.364	-1,214	-1,251	0.406	-465	0.364	-417
4	931	0.301	280	0.260	242	- 797	0.301	-86	0.260	-74
5	3,517	0.223	784	0.186	654	- 298	0.223	104	0.186	86
6	6,450	0.165	1,064	0.133	858	251	0.165	217	0.133	175
7	9,783	0.122	1,194	0.095	929	854	0.122	279	0.095	217
8	13,571	0.091	1,235	0.068	923	1,518	0.091	308	0.068	230
9	17,876	0.067	1,198	0.046	822	2,247	0.067	311	0.046	213
10	22,768	0.050	1,138	0.035	797	3,050	0.050	303	0.035	212
11	28,327	0.037	1,048	0.025	708	3,933	0.037	284	0.025	192
12	34,644	0.027	935	0.018	624	4,904	0.027	257	0.018	171
13	34,644	0.020	693	0.013	450	5,975	0.020	232	0.013	151
14	41,823	0.015	627	0.009	376	7,151	0.015	209	0.009	126
15-20	49,981	0.036	1,799	0.019	950	12,513	0.036	1,996	0.019	1,053
TOTAL	211,877	3.850	1,537	3.495	-1,608	35,408	3.850	1,138	3.495	-361

Source: **Author's Own Calculation** **a. IRR = 35 + 5(1537)/3145 ≈ 38%** **b. IRR = 35 + 5 (1138)/1499 ≈ 39%**

The results on the sensitivity tests conducted on increases in fuel price, labour costs and input costs are obtained using similar computational procedures as those undertaken and presented in Tables 5.10 and 5.11. Only a summary of the results of the sensitivity analyses is presented in Table 5.12 below.

Table 5.12: Summary of Sensitivity Analyses Conducted on the Compost Projects.

NO	DESCRIPTION OF ANALYSIS CONDUCTED	PERCENTAGE CHANGE (%)	INTERNAL RATE OF RETURN	
			PROJECT A (%)	PROJECT B (%)
1	Initial Capital Cost Overrun	30	40	42
2	Fall in Compost Sales Price	10	38	39
3	Increase in Labour Costs	30	39	43
4	Increase in Fuel Costs	10	41	43
5	Increase in Input Costs	10	41	41
(OWN) INTERNAL RATE OF RETURN OF PROJECTS		-	***41***	***43***

Source: Authors Own Computations

The results of Tables 5.10, 5.11 and 5.12 show that the compost projects do not respond significantly to most of the financial variables tested for their sensitivity. The IRRs of Projects A and B will both be reduced by 1% at the 30% initial cost overrun considered in the analysis. This is because the initial capital costs of the projects are far smaller than the operating costs. Therefore, any marginal change in the initial capital does not significantly affect the fortunes of the projects. Also, if the prices of compost products fall by 10%, the IRRs of Projects A and B will fall by about 3% and 4% respectively. This is so because the higher the price, the lower the demand, resulting in lower sales revenues and lower incremental net benefits. The cost of labour, which represents one of the important elements of composting MSW in a developing country situation, does not appear to affect significantly the IRRs by the 30% increase in salaries and wages in Ghana, as has been the case in the country for the past ten years. The results show that the IRR for Project A will change slightly from 41% to 39% as a result of the 30% increase in labour cost in the country. However, the IRR of Project B will remain effectively at 43%, suggesting that Project B is not sensitive to a 30% increase in labour costs. Labour prices in Ghana are extremely low; thus an increase in the cost of labour by a 30% will not seriously affect the financial fortunes of the projects. For 10% increases in fuel prices and input costs, Project A proves to be more resilient than project B. For Project A, the IRRs resulting from the 10% increases in theses two financial variables remain at 41%, which is the same as the "own" IRR of the Project (A). For Project B, only the increase in the cost of inputs will inexplicably cause a slight change in the IRR by 2%; the IRR for Project B is not affected by the 10% increase in fuel prices. Once the projects are labour-intensive, changes in costs of fuel do not seriously affect the incremental net benefits, and consequently the IRRs of the projects.

A number of important conclusions can be drawn from the results of the financial analysis. First, the choice of the proposed area for establishing MSW composting facilities does not appear to merit project approval from the standpoint of the NPV criterion. Due to the fact that the average cost of financing domestic capital in Ghana is high (i.e. 45% in 2001), the net present worth for both projects takes negative values. To the extent that the local government authorities or private entrepreneurs have at their disposal proposals for other projects yielding a return of 41% or 43% but having greater employment prospects than composting, consideration might be given to these other projects. In this case, the logical approach is to choose those projects with higher positive margins first, and to approve the compost projects only if investment funds remained unexhausted after the allocation to the preferred projects. Second, Project B has a greater potential to earn revenue than Project A, since the internal rate of return of the former is slightly higher than that of the latter. Third, on the average, Project A is more sensitive than Project B to changes in the compost sales price and labour costs considered in the project appraisal. Finally, Project B pays for its investment 3 months earlier than Project A does. From the financial analysis point of view, therefore, Project B should be preferred to Project A. However, as discussed earlier in section 5.3 above, the 25% composting of organic waste will not meet the desired aim of considerably reducing the amount of waste that reaches the landfills. If waste treatment in the study area is considered holistically, composting 25% of organic waste and landfilling the remaining 75% will obviously not be socially cost-effective option than vice versa. The composting alternative chosen should be selected on the basis of the combination with landfill methods that incur relatively lower economic costs. Besides, compost projects have the potential to offer major solutions to unemployment, poverty, health and general environmental problems in the area, and the higher the volume, the better. If compost entrepreneurs cannot capture sufficient benefits to meet their costs of production, the government should subsidise the production of compost to close the gap between costs and benefits. However, subsidisation of the compost industry should be monitored to ensure that such publicly funded projects do not become "white elephants" like the Teshie-Nungua Compost Project, the State Farms established during the first Republic, and the Gyankobaah Ginger Factory at Nkawie built during the Supreme Military Council (I) Regime. Investment in composting facilities in Ghana appears less attractive not only because borrowed domestic funds are costly, but also because the liberalised financial sector renders the base rates highly volatile. Loans for compost projects should have a fixed rate, and compost producers should be protected from upward movements of interest rates and is able to take advantage of downturns in the compost industry. Moneylenders should not shift interest risks back to borrowers by offering adjustable-rate loans, because it will increase financial risks and thus the likelihood of loan default. In addition to subsidies, government may intervene by seeking cheaper finance from abroad to supplement locally mobilised resources.

5.5 Constraints Facing the Establishment of MSW Composting Facilities

Twenty-five copies of a questionnaire developed to investigate the constraints facing the establishment of MSW composting facilities were administered to Ghanaian respondents; one each to Compost Project Managements at Bodija (Nigeria), Tsévié (Togo), and Hevie (Benin). The results of the investigations were collated and are summarised in Table 5.10 below.

The results show that the establishment of MSW composting facilities is constrained by twelve major problems. About 75% or more respondents ranked the first eight constraints as major ones confronting composting. These constraints are high interest rates on borrowed capital; lack of policy framework for composting; difficulty in securing land in municipalities; lack of research in the compost industry; lack of technical personnel and skilled manpower to man the compost facility; lack of political will and commitment; lack of machinery, equipment and spare parts; and farmers' preference of imported chemical fertilizers to compost products.

Fifty percent or less stated that ignorance about waste separation at source, difficulty in accessing institutional credit, ignorance about compost benefits, and the bulkiness of the compost product constituted major constraints to the development and establishment of MSW composting facilities. Interestingly, the entire four compost projects (i.e. Teshie-Nungua, Bodija, Tsevie and Hevie), which responded to the questionnaire, were amongst the latter category of respondents. On the basis of the practical experience gained by these existing projects, it may not be correct to rank these constraints at the lowest end of the hierarchy, as has been discovered in the investigation. A large number of respondents (75%) were not compost producers, and possibly were not exposed to these practical problems, which could have accounted for the so-called low ranking of these constraints.

Table 5.13: Summary of Constraints Facing Composting Industry in Accra-Tema Area

No.	Constraints	Number of Respondents	Percentage of Total (%)	Rank
1	High Interest Rates on Loanable Funds	28	100	1
2	Lack of Policy Framework on MSW Composting	27	96	2
3	Difficulty in Securing Land for Composting Facilities and Urban Agricultural Production	26	93	3
4	Lack of Research and Development in the Compost Industry	26	93	3
5	Lack of Technical Personnel and/or Skilled Manpower to man Composting Facilities	25	89	5
6	Lack of Machinery, Equipment and Spare Parts to Collect, Transport and Process the MSW	23	82	6
7	Lack of Political Will and Commitment to Promote and Invest in Composting Facilities	23	82	6
8	Farmers' Preference of Imported Chemical Fertilizers to Compost	21	75	8
9	Ignorance on the Part of Compost Users about the Benefits of Composting	14	50	9
10	Inaccessible Institutional Credit for Compost Entrepreneurs	13	46	10
11	Ignorance on the Part of Waste Generators about Source Separation of Waste	13	46	10
12	Bulkiness of the Compost Product	10	31	12

Source: Authors' Own Computations.

Municipal authorities consider composting as high-risk, low-yielding business venture. This is because market for compost is often not assured, which can result in the investment capital being locked up in the compost business. In addition, the prices of substitutes such as "backsoil", poultry manure, and animal dung are often far lower than for most compost products. Hence, farmers are willing to purchase these less costly substitutes to fertilise their farms. In other words, it is perceived that the compost business does not "roll" as smartly as other businesses with similar portfolios. To make it roll, municipal authorities will be compelled to reduce compost sales prices far below production costs. In the process, benefits become lower than costs of production. Consequently, there is a general lack of political will and commitment towards the composting industry, which results in meagre funds being allocated for research and development of MSW composting facilities in developing countries. Most respondents assert that it is the responsibility of government to provide the best waste management services, including composting, to residents. However, they admit that this is often not the case because local government authorities do not feel threatened of being replaced in office, at least within the democratic framework, by others who can provide the services better. Many respondents cited the current practice of nominating municipal mayors by the country's President, rather than they being elected, as the main reason for low priority given to waste management by local political authorities.

Some respondents acknowledged that institutional credit is available in the financial sector; however, interest rates for loanable funds, cumbersome loan acquisition procedures and lack of government guarantees make borrowed capital inaccessible to compost entrepreneurs. Few respondents stated that due to low levels of savings in the economy and high rates of currency depreciation, the level of financing compost production is extremely low. Machines, equipment and spare parts are generally lacking in developing countries. Lack of spare parts in particular results in frequent breakdowns, or in completely inoperable facilities. Most respondents noted that because developing countries do not have the appropriate skills to design and fabricate capital items, they have to import them from developed countries with foreign currency, much to the disadvantage of other municipal development activities.

Special skills are needed by compost managers and operators to produce a high quality product for the market. Unfortunately, however, respondents believed that composting is severely constrained by lack of technical personnel or skilled manpower to develop, manage and operate MSW composting facilities. They intimated that the absence of skilled personnel has been responsible for the massive transfer of technologies from developed countries without considering local factors such as waste characteristics, seasonal variations, technical education and training needs, cultural attitudes towards solid waste management, and status of waste management in the body-politic of the recipient country. The preference of highly capital-intensive to labour-intensive technologies resulted in the collapse of compost facilities in many African countries during the 1970s and 1980s (Asomani-Boateng, et al, 1996). Only a few mechanised composting plants are currently operating at designed capacities, many are running below planned capacities and a substantial number have been shut down.

Some respondents stated that there is enormous ignorance on the part of waste generators about source separation of waste. Households are not easily amenable to source separation of waste, because they have become so used to mixed collection that they find it difficult to easily give up the practice. Other respondents cited ignorance on the part of compost users and local authorities on the benefits of MSW composting as a major constraint to composting. According to them, this has resulted in some farmers preferring imported chemical fertilizers to compost products.

About 93% of the respondents cited land as a major constraint to the establishment of composting facilities in a municipality. As the population of the municipality increases, land becomes scarce and, therefore, is not available for peri-urban and urban agricultural production, which is the main user of compost products. Location of compost facilities will only be feasible in an area where there is enough land and where resentments concerning odour and vermin from local residents are minimal.

Research into compost industry must include a comparison between public resource investment and social benefits streams, among others. If the social benefits are more than costs, it will be a sensible sufficient condition for investment in the industry. Research is also needed to determine the least costly method of organic waste collection, transportation and processing. According to most respondents, however, research on compost industry in the country has virtually been lacking. The respondents explained that lack of scientific research in the industry has resulted in the application of less appropriate composting technologies, high costs of waste collection, transportation and processing, and in the utilisation of low quality and mediocre compost products by farmers.

Quite a sizeable number of the respondents (96%) also said that, lack of policy framework for composting constitutes a major problem. They identified public investment, quality standards, institutional credit, research, education and extension services as areas where polices are needed.

A few respondents (40%) said the bulkiness of the product brings about high transportation costs to both producers and users, which is within apriori expectations. Most of the compost users (who were some of the respondents) are within the peri-urban and urban areas, and therefore transporting the compost to these areas will not be too costly. However, if the compost is to be transported to long distances before use, the bulkiness of the compost will be a serious constraint, as transportation costs will be high.

CHAPTER SIX

SUMMARY, POLICY IMPLICATIONS AND RECOMMENDATIONS

6.1 Summary of Results

This study aims at examining the municipal solid waste (MSW) trends and problems, and then selecting the most cost-attractive alternatives that will satisfy the technical, financial, managerial, marketing and socio-economic requirements for compost production in the Accra-Tema Metropolitan Area. The study endeavours to perform a comparative cost analysis of waste treatment methods in ATMA; to determine the most economically feasible levels of MSW composting in the ATMA, to determine the profitability and financial viability of compost projects in the ATMA; and to investigate the constraints that are likely to militate against the establishment of composting facilities in the ATMA.

The study has found out that waste management has become a major environmental management problem in the Accra-Tema Metropolitan Area (ATMA), as the quantity of waste streams increases and grows in complexity with population growth. In 1985, the MSW generated in ATMA was about 334,000 metric tons. By 1995, the volume of the waste generated in the area was about 524,000 metric tons, increasing to about 550,000 metric tons in the year 2000. On the average, therefore, each person in the ATMA produced 0.54 kilograms (kg) of MSW daily in 2000, up from 0.45 kg daily per person in 1985, or up from 0.51 kg per person per day in 1995. Daily per capita waste generation has been projected to be 0.89 kilograms per day by the year 2025 as compared to the world's estimated figure of 0.67 kilogram's per day. In fact, waste management authorities in the area appear to be completely overwhelmed by the rising waste streams. Indeed, such increasing waste streams continue to pose technical and financial difficulties to municipalities in their attempts to manage the large waste volumes generated in the area. Yet, there is the compelling need to promptly and properly manage these waste volumes in order to avoid any intolerable and catastrophic consequences on environmental quality and public health. Government and local authorities will be compelled to devote substantial resources towards municipal waste management, using the least costly technologies.

Also, the study reveals that there is the need to produce sufficient food to feed the increasing population of the metropolitan area. However, soil fertility levels of coastal agricultural lands such as those found in the Accra-Tema areas are extremely low because of continuous mining, leaching and erosion, whereas the prices of chemical fertilizers are increasing with years. Therefore, the need to replenish coastal soils with cheaper organic fertilizers such as compost cannot be overemphasized.

The comparative analysis of waste processing facilities in the ATMA, based on 2001 constant prices, has shown that the total cost of building and operating composting facilities in the Accra-Tema Metropolitan Area at the base year (2001) is 76% of the total landfill cost and only 3.5% of the total cost of incineration. Based on the results of this study, it can be concluded that composting is the least costly method for waste treatment in the area. Therefore, composting should take priority over the other methods of waste treatment in the study area, though landfilling of residuals during composting is unavoidable. Though the cursory study was hampered by unreliable data, it can be fairly demonstrated that incineration should be the last option to be considered as a waste management method in Ghana. The study further reveals that as a result of regulatory requirements associated with new technological standards, the overall scope and construction of landfills and incinerators have become much more demanding and costly. Modern landfills require impermeable seals, leachate collection and treatment, and methane gas collection for flaring or for use. Excluding water completely from landfills is impossible, and some decomposition will always occur in them anyway. Consequently, monitoring of leachate and gas must take place for many years, even after the landfill has been closed, capped and revegetated. Monitoring and environmental management costs represent a large portion of landfill operating costs. The initial capital outlay for a modern incinerator is huge, in addition to the high operating costs needed for the facility.

The profitability analysis was carried out with the help of a GTZ computer programme, which was specifically developed for that purpose. By varying the technical parameters involved in composting, four important results come out distinctively. These results are:

1. For each of the four options considered (i.e. composting 25%, 50%, 75% and 100% of the waste generated in the year 2001) for the ATMA, 15 composting plants will be required to convert the various fractions of organic waste into compost. Figure 6.1 presents suggested locations for 15 compost plants in the ATMA.

2. Medium- to capital-intensive technologies are not economically suitable for the ATMA, because they are extremely costly in the short-run, and are therefore far beyond the financial capabilities of the municipal authorities in the area.
3. The iterative processes show that profitability of composting does not only depend on the prices of compost products and cost of inputs used, but also on the volume of organic waste processed by the composting facilities. The most economically feasible option is to compost 25% (6,500 metric tons of raw MSW) of the available waste in the area, followed by 50% (13,000mt), then 75% (18,000mt), and then by 100% (24,000 mt. If the 25% of compost is adopted, the 75% left will be landfilled at a cost. Similarly, if 50% and 75% were adopted, then 50% and 25% of the total waste volume respectively will have to be landfilled at various costs.
4. The main causes of the low or negative profitability of the options considered in the calculations processes are low prices of compost products, and high costs of transportation, depreciation and operations.

The corresponding profit contribution margins (i.e. profit or loss per ton of compost) for each facility that employs labour-intensive composting technologies (when the cost of land is not considered in the analysis) for the 100%, 75%, 50% and 25% options are found to be: -$91, -$90, -$67 and -$32 respectively, at 2001 constant prices. These figures work out to be: - $1,281,791, -$897,455, -$433,619 and -$105,244 respectively for the year 2001. The total deficits for 15 composting plants for the respective options are $19,226,865, $13,461,825, $650,538 and $228,660 for the year 2001. When the costs of landfilling the remaining fractions of waste for each option are considered together with the results of the calculation, the total net costs for each facility composting 6,500, 13,000, 18,000 and 24,000 mt of organic waste and landfilling the remaining 30,167, 23,667, 18,667 and 12,667mt of waste respectively for the options are $1,034,448, $1,084,084, $1,310,507 and $1,629,936. For 15 compost facilities (for each of the options), the respective costs are $15,516,720, $16,261,260, $19,657,605 and $24,449,090. Also, when land for the compost facilities is purchased and its value factored into the calculation process, the deficits for the various options (24,000 (100%), 18,000 (75%), 13,000 (50%) and 6,500 (25%) mt of organic waste generated in 2001) will increase from $91, $90, $67 and $32 per ton of compost produced to $99, $91, $68 and $34 per ton of compost produced respectively. In terms of annual deficits, the values of the increases are $8,369, $6,941, $6,500, and $6,083 respectively per each facility.

Three conclusions can be drawn from the profitability analysis. First, for a private company that is only interested in profit maximisation, the 25% composting using 15 plants is the most feasible option for the area. Second, if the need to avoid large volumes of MSW reaching the landfill, and /or if hidden costs and benefits are to be considered, municipal authorities should choose the 75% (i.e. 18,000 metric tons per facility per year) composting option (with 15 composting plants) for more detailed investigations of the economic feasibility in which shadow prices are used. Finally, land, as a capital item, significantly affects the profitability of compost projects in the ATMA. Its value must, therefore, be factored in any financial or economic analysis of compost projects in the area.

The GTZ calculation processes formed the basis for forecasting the cash flows for the investment analysis. At a discount rate of 45%, the net present values of the projects considered (i.e. one composting facility drawn from 75% and 25% composting options each) are estimated to be -¢1.663 billion and -¢0.451 billion respectively. From the stream of cash flows, it will take project A (75% composting) 6years 4 months to pay for itself, and 6years 1 month to pay for project B (25% composting). The results of the analysis also show that the internal rates of return for projects A and B are 41% and 43% respectively. The results of the sensitivity analyses show that a decrease in the cost of capital from by 10% will increase the NPVs of the projects from negative to positive values, and by 327% and 456% respectively for projects A and B. An initial cost overrun of 30%, 10% increases in labour costs and 10% increases in input costs have no significant effects on the internal rates of return for Project A. Also, an initial cost overrun of 30%, 10% increases in fuel prices and 10% increases in labour costs have no significant effects on the internal rates of return for Project B. However, a fall of 10% in the price of compost will result in the internal rates of projects A and B to decline by as much as 3% and 4% respectively. While Project A is slightly sensitive to 10% increases in labour costs by 2% decrease in internal rate of return, Project B is slightly sensitive to 10% increases in input costs by the same margin. On the basis of financial analysis, therefore, project B is preferred to A.

Though composting is the more preferred waste management option for the area, the industry is constrained by major and interdependent problems. The study establishes that the major constraints facing the industry are high interest rates on loanable funds; lack of policy framework for composting; lack of appropriate technologies and lack of research and development in the industry; wide gaps in the quality and quantity of skilled manpower; and preference of chemical fertilizers to compost products. Ignorance about the composting industry, difficulty in accessing institutional credit, lack of properly developed marketing systems for compost products, and lack of co-ordination amongst stakeholders are also common limitations that can possibly militate against composting operations in the study area. Finally, municipal authorities generally give solid waste management a low priority in terms of financial and institutional support.

6.2 Policy Implications

Given the prevalence of high interest rate on borrowed capital, non-commitment to public spending on waste management and little private sector participation in waste management in developing countries, composting has not received considerable policy attention. Well-meaning government actions on compost production have been inferior and consigned to the policy of standing back and letting individual local retroactive responses and market mechanisms for agricultural inputs to work. Also, well-intentioned government policies that influence prices may have unintended and undesirable consequences on the quality and scope of MSW management in general. In India, Indonesia, Nigeria, Togo, Benin and other developing countries, governments subsidise the production or importation of chemical fertilizers, thereby stifling the development of agricultural markets of compost. If composting is considered a means of improving agricultural production, waste management and social welfare, public support of composting may need to take the form of subsidies or payments to waste generators to separate their wastes at source. Of course, society has the prerogative of using subsidies to augment private economic incentives to countervail perceived external diseconomies of importing chemical fertilizers. However, external diseconomies of compost production also require attention by analysts. Present and future increases in chemical fertilizers prices and current improvements in compost production techniques could well justify future investments in composting facilities without direct government subsidies. Rather than biasing waste utilisation by providing tax exemptions or subsidies for composting, the government could, on the contrary, facilitate research in composting and bear a portion of the risk through loan guarantees. Market expansion, through greater public support on education and training may help to promote the judicious use of composting facilities in a municipality.

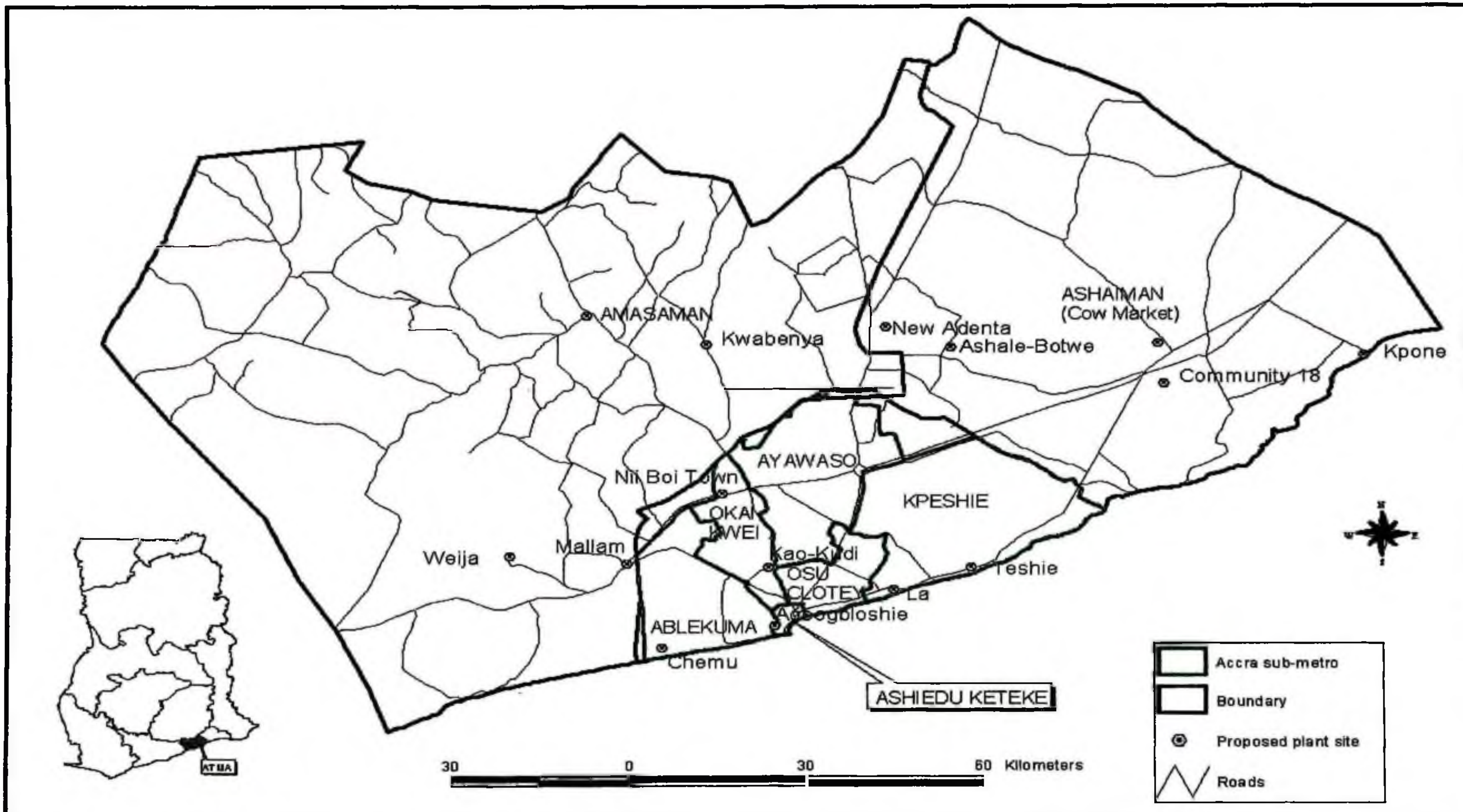
There has been considerable thought about policy reforms necessary to promote the establishment of composting facilities in Ghanaian municipalities to process the huge waste volumes into organic fertilizers for agricultural production. There is virtue to such a thought. However, the current study reveals that the cost and benefit relativity of composting does not make composting viable either by the state or private sector. In general, the issues that are relevant to policy considerations towards the promotion of MSW composting in the country include waste separation, institutional and technological developments, quality standards, interest rates, compost pricing and subsidisation, organisational arrangements, and education and training. The principal policy implications to be drawn from the discussions is that positive actions should be undertaken to ensure that composting barriers do not become critical and that economic losses are minimised. These positive actions may include subsidising compost as an organic input, releasing government lands for compost stations and waste transfer stations, insisting that municipal authorities undertake only labour-intensive technologies in compost production and establishing compost stations very close to waste dumps to reduce transport costs. To achieve a sustainable development of the composting industry, adequate institutional arrangements should be made in order to bring down capital and operational costs and raise benefits substantially. Drawing from international best practices and experiences, the government may consider the following areas:

1. There is the need to develop composting equipment and spare parts within the municipality using locally available artisans for their fabrication. This will stem down the cost of capital items usually associated with the imported ones. The technology can then be replicated all over the country. Well-thought-out and specific training programs for managers, engineers, artisans, compost users and labourers are also needed to close the knowledge gap that exists in the industry.
2. Source separation is necessary to ensure a uniformly high quality and an economically acceptable utilisation of organic waste. Non-separation of waste means transport or later separation costs which may be too high as to justify the establishment of MSW composting facilities. To achieve a reasonable measure of source separation of waste, it is necessary to select pilot areas for demonstration purposes, with the hope of replicating successes throughout the municipalities.

3. There should be the need to develop research into composting and pass on findings to compost producers and users for adoption. The focus of the research should be on the least costly methods of waste collection and transport routing within the municipality. The research could be re-enforced by adopting imported technologies from other countries with considerable experience. For example, experience gained by the Bodija Compost Project in Ibadan, Nigeria, has shown that it is possible to produce compost products in pellets form, which will reduce its bulkiness in order to be transported to the farms for application. This will require extensive studies on the material that can firmly bind the compost product together, and yet dissolve quickly when applied on the farms.

In addition, it is crucial to gain strong political support in advance before attempting to install composting facilities for compost production. This political will should manifest itself as the sustained allocation of additional finance and materials, possible legislative changes to help compost producers, and subsidies to compost producers to make up for the high cost of waste transportation, collection and processing. Also, there should be the need to have a national strategy for composting of MSW. Such a national strategy should contain diffusion programs in ways that would mobilise the demand for compost products. The promotion and sale of compost could be done through pilot demonstration programs in the municipality. Piloting could be carried out in the areas outlined in Figure 6.1 below, the choice of which is based on the availability of suitable sites, nearness to the raw organic waste, and the proximity of compost users to planned facilities.

Figure 6.1: Accra -Tema Metropolitan Area Showing Suggested Locations of 15 Compost Plants



Source: Survey Department
Prepared by Remote Sensing & GIS Laboratory, Teaching & Reserach Unit. Department of Geography & Resource Dev. Uni. of Ghana, Legon

The pilot projects should serve as a testing ground for solutions to the problems of costs, odour, flies, vermin, aesthetics, and community relations, all of which must be addressed before the program could be expanded. When piloting proves that high-quality compost can be produced at relatively low cost, an expansion or replication scheme can then be implemented throughout the country. As a start, the traditional backyard composting facilities that already exist should be improved upon, through the development of such demonstration programs.

The adoption of compost will depend on the quality of the compost products, costs of compost and other soil enhancers, and the willingness and ability for compost users to pay for compost products. The government can intervene by establishing and enforcing strict quality standards for compost products from the onset. Also, in order to sustain the continued use of composting facilities and, at the same time, maintain the demand for compost products, a happy compromise between production costs and consumers' ability to pay should be sought. The equation to this paradox can only be solved through extensive research on waste collection and transportation, and compost-pricing policy backed by subsidies put in place by the appropriate political authorities in Ghana. When compost producers are sure these structures are in place and will be sustained, the impetus to put their risky assets in the compost industry will be enhanced or guaranteed. Finally, the study has shown that little information is available on composting industry in Ghana. For the production of compost to receive positive action, it must be linked to real-life actors in the industry who are well conscientised. When the general public is not well informed about the industry and research findings, waste separation at source and other cost-saving strategies may be ignored in the scheme of composting. Secondly, farmers are likely to continue to patronise imported chemical fertilizers if they are not aware of the availability and positive effects of compost on their farms. The effect of education, through public campaigns, manpower training, seminars, public discussions, extension services, and inclusion of composting as a subject in the curricula of schools, will help reduce significantly ignorance about the composting industry.

6.3 Suggestions for Future Research

Though conceptually simple, the GTZ programme is difficult to implement in situations where the market value of many inputs are not well defined in the real world, social demands are high, and the problems of operational definition and measurement arise with respect to the financial variables. For example, when valuing compost production, other less obvious costs such as opportunity cost of assets, risk-taking costs, hidden costs arising from decrease in quality of air, water and land, and intangible costs such as gaseous emissions, pathogenic infections and leachate pollution must be accounted for. Also, to discover the most profitable lines of compost production, benefits of improvements in public health, employment, and soil characteristics and conditions must also be accounted for. Attaching monetary values to these non-pecuniary costs and benefits has become a classic economic problem. Traditional accounting approaches used by some municipal authorities for determining the profitability of compost projects have resulted in the closure of several composting operations established in the past. The World Bank is currently using contingent valuation and other techniques to assess some of these social costs and benefits. Unfortunately, such techniques do not take account of preferences of future generations; nor do they consider the opinions of individuals outside the local community who have interest in these issues. Moreover, reliable values for the productivity, amenities and externalities associated with production are not available for most developing countries. However, it has become necessary for analysts to begin to apply some of the tested and appropriate techniques for calculating the monetary values of the impacts of environmental protection and management methods. To summarise, because of the problem of excluding so many variables associated with the GTZ programme, there is too much value judgment needed in the process of determining the profitability of compost projects. There is the need to introduce improvements in the programme by making a more competent integration of these variables through the use of more appropriate (but less exotic) software adapted for local situations, but obviously solutions will not come easy.

Also, there are difficulties and problems associated with the project appraisal discussed in this study. These setbacks may be summarised as follows: Firstly, as already discussed above, the intangible costs and benefits, which did not lend themselves well to monetary valuations in the calculation processes, were not also considered in the analysis. The present value of the opportunity cost of land was not also considered. Secondly, cost estimates for the investment period of the projects were generally prepared on the assumption that no disasters such as geological tremors, floods, landslides, windstorms and unusually bad weather will occur. Clearly, it would be unrealistic to make project costs estimates based simply on these assumptions of perfect knowledge of future happenings. Any sound project planning requires that provisions be made in advance by including contingency allowances as part of the project estimates. In the present analysis, allowances were made for a five-year routine repair and maintenance scheme. No reinvestments for machines and equipment with shorter life spans than those for the two projects were considered, the consideration of which would have greatly influenced the cash outflows, and thus the net incremental benefits. Additionally, the capital assets were assumed to have zero salvage values. Consequently, the total cost of investment was underestimated. Thirdly, the assumption that all the composts produced will be promptly marketed should be viewed with cautious optimism. Experience has shown that a backlog of huge volumes of compost products have been found in many countries, especially when compost users are doubtful about the quality of the products. In America, for example, there was an excessive supply of the compost in the early 1990s that forced compost prices to downslide considerably (Kashmanian and Spencer, 1993). Fourthly, prices of inputs were valued at 2001 price levels, which were inflated by an aggregate rate of 40% in anticipation that future input prices will rise constantly by that much over the twenty-year period. In a developing country situation like Ghana, inflation rates fluctuate so widely that that assumption might not hold. Finally, it was also assumed that domestic inflation is different from that of the world inflation, and that inflation will affect costs differently from benefits. However, inflation will have different impacts on some prices than others, which the analysis did not account for.

Certainly, the current study is a pioneering attempt to analyse the economics of MSW composting. Unfortunately, however, judging from the above discussions, the analysis of composting facilities has not been holistically done in this study. Clearly, conducting financial analysis alone is not very useful in determining the viability of composting industry in Ghana. The project appraisal in this study only looked at the financial aspects of investment analysis in which the present worth of income accruing to the compost projects being analysed was determined for each project using market prices. However, the economy in which the compost investment is to take place will experience costs and benefits that will not appear directly in the accounts of the enterprise, (as those stated above. Moreover, local government authorities are interested to know the present worth of incremental national income generated by the compost investment for society's benefit and the economic rate of return of the investment. If it is accepted that composting is a quasi-development activity with social bias, the "social cost-benefit analysis" should be undertaken as has been advocated by economists such as Little and Mirrless (1969), Squire and van der Tak (1975), Dasgupta et al (1977) and Devarajan et al, 1997. Such a comprehensive analysis will thus include an assessment of social, political, environmental and management factors that make up the unique circumstances of any proposed compost project for an area. "Social cost-benefit analysis" will also remove the numerous assumptions inherent in the financial analysis discussed in this study, and therefore reduce any stochastic errors in the calculations. The value of future studies for project planners, practitioners of waste management, and policy-makers would be enhanced by such more precise economic assessment of compost projects, using "shadow prices" and social interest rates. The fundamental belief is that by accounting for the social benefits of the composting projects, and comparing these benefits with social costs, one necessarily would determine whether the project could be welfare-increasing, and whether any set of projects could be ranked in order of social desirability.

Examination of existing composting techniques within the framework of municipal waste planning requires models that describe waste generation, spatial location of waste, and waste collection, transfer and disposal processes. A cost model, for example, may be expected to assist in the selection of the most efficient mix of equipment and employees; the optimal location of waste pick-up, routes, transfer stations and disposal sites; most desirable frequency of collection; and the ultimate type of disposal. The model should also serve to establish the rate of schedules appropriate to different users of waste service and compost products. Programming optimum location of composting plants and transfer stations would provide pay-offs in determining the least costly system for each municipality.

The estimation of functional relationships between outputs and inputs is fundamental to studies concerned with various aspects of production cost and efficiency of a composting facility (firm). Thus, future studies on the composting industry should include the estimation of production functions for the industry. Conventionally, a comprehensive production function should be able to address the empirical relations between outputs, and technical and non-technical input variables in the general array of factors including labour, land, capital, technology, utility services, compost prices and prices of compost substitutes.

Finally, Ghanaian engineers should be commissioned to research into the most appropriate technologies for compost production in municipalities. This will include the design and fabrication of facilities using local materials so as to minimise the number of costly capital items imported into the country from outside. The engineers should also extend the scope of research to cover machines and facilities that can conveniently pelletise the compost products for easy handling, application, and absorption.

To conclude, potential profitability may be the key incentives in a private entrepreneur's decision to invest in composting, but the resources available to them and the constraints they face will determine the viability of the options for a particular municipality. The profitability of composting depends upon a number of factors such as scarcity of chemical fertilisers; level and composition of compost demand, return to alternative uses of land, labour and capital resources, and cost of production relative to cost of available substitutes for compost products. There is a long way to travel in the compost industry in Ghana. It is only comprehensive researches in the industry that can link these factors together, and possibly solve the motley of problems that face the industry.

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APPENDICES

APPENDIX I

REQUIREMENTS FOR INVESTMENT CAPITAL FOR LANDFILLING

The typical technical criteria for determining the required capital for constructing a landfill are found in the table below.

Criteria	Units	Requirements
Throughput	m^3/y	$1x10^5$
Power Output	kW	50
Enclosed Building Space	m^3	$1x10^3$
Landfill Area	m^2	$2x10^5$
Construction Time	Year	1½

APPENDIX II

BASELINE DATA FOR DETERMINING CAPITAL-DEPENDENT EXPENSES OF A LANDFILL OR A COMPOST PLANT

I. Capital-Dependent Expenses:	Requirements
Annuities	
Capital financing (%)	45
Construction, Real Estate (%)	10
Operations and Maintenance (%)	25
Taxes and Insurance (%)	28

APPENDIX III

BASELINE DATA FOR DETERMINING OPERATING EXPENSES OF A LANDFILL OR A COMPOST PLANT

Operating Expenses	Requirements
Repair and Maintenance:	
Construction (%)	1.00
Operations and Maintenance (%)	5.00
Labour Costs-skilled (¢' 000/employee)	$3x10^6$
Labour Costs-unskilled (¢' 000/employee)	$2.5x10^3$
Water and Sewerage (¢/m³)	$7x10^3$
Diesel Fuel (¢/tons)	$2.8x10^6$
Operation, Auxiliary Material Vector Control & Landfill Roads (¢/ton of Waste)	$1x10^3$
Long-term Care (¢/ton of Waste)	$1x10^3$
Capacity of yearly Filling (tons of Waste/year)	$1.1x10^5$
Cover Material (¢/tons of Material)	$1.3x10^3$

APPENDIX IV

BASELINE DATA FOR CALCULATING RUNNING COSTS FOR AN INCINERATOR

Criteria	Units	Requirements
Capital-dependent Expenses:		
Cost of Financing	% of Capital Costs	45
Construction of Real Estate	% of Capital Costs	10
Taxes and Insurance	% of Capital Costs	2.8
Operating Expenses:		
Repair and maintenance:		
1. Buildings	% of Capital Costs	1
2. Operations and Maintenance (Machinery)	% of Capital Costs	25
Labour Cost per Annum:		
1. Skilled Labour	¢/Employee	$3x10^7$
2. Unskilled Labour	¢/Employee	$2.5x10^6$
Administrative Costs	% of Capital Costs	5
Water and Sewerage	¢/m3	$7x10^3$
Neutralisation	¢/ton	$7.8x10^5$
Heating Oil	¢/ton	$3.6x10^5$
Landfill	¢/ton	$1.4x10^6$

APPENDIX V

TECHNICAL CRITERIA FOR DETERMINING THE CAPITAL REQUIREMENTS FOR BUILDING A COMPOST FACILITY

Criteria	Units	Requirements
Throughput	tons/year	13,000
Power Output	kWh	100
Enclosed Building Space	m^3	1,000
Construction Time	year	1
Compost Facility Life	year	20
Office Equipment	% of Building Costs	15
Decommissioning	% of Construction Costs	2
Capital Financing	% of Total Costs	10

APPENDIX VI

INVESTMENT CAPITAL FOR A LANDFILL WITH A YEARLY FILLING OF 110,000 m³, AND EXPECTED LIFE OF 20 YEARS (PRICE LEVEL: JULY, 2001)

FEATURE	CAPITAL REQUIREMENT ('000 CEDIS)
Vehicles and Equipment (6 sets)	¢776,000
Land Purchase (20 plots)	540,000
Site Selection, Survey & Permitting	204,000
Development costs	195,000
Buildings/Structures	332,000
Base Liner	1,824,000
Leachate Collection	1,316,000
Gas Collection	290,000
Final Capping	3,230,000
Revegetation	245.000
A) Total Construction Costs	14,682,000
Operations and Maintenance (O & M)	
Vehicles, Equipment and Scale	318,000
Energy Needs	648.000
B) Total Operations and Maintenance costs	966,000
Financing (6% of (A + B)	939,000
TOTAL CAPITAL REQUIREMENTS	16,587,000

APPENDIX VII

CALCULATION OF LANDFILL RUNNING COSTS (PRICE LEVELS: JULY, 2001)

I. Capital-Dependent Expenses:	(¢'000)	(¢'000)
1. Annuities:		
- Capital financing (45%)	397,000	
- Construction, Real Estate (10%)	1,428,000	
- Operations and Maintenance (25%)	240.000	
- Sum of Annuities		2,065,000
2. Taxes and Insurance (28%)		64.000
Sum of Capital-Dependent Expenses		2.529.000

II. Operating Expenses		
1. Labour Costs		
- Skilled Labour (3)	90,000	
- Unskilled Labour (6)	16.000	
Total Labour Costs		106,000
2. Repairs and Maintenance:		
-Operations & Maintenance (Machinery)	48,000	
- Buildings	147.000	
Total Repairs and Maintenance Expenses		195,000
3. Water & Sewerage Charges (50,000m³ of Leachate)		350,000
4. Fuel (100 tons)		280,000
5. Cover Material (18,000 tons)		24,000

6. Operating and auxiliary Materials, Vector Control and Landfill Roads		110,000
7. Reserves for Long-term Care		110,000
8. Administrative and Sales Expenses:		
- 5% of Labour costs	5,000	
- 5% of items (2 - 6)	38,000	
Sum of Administrative and Sales Expenses		43,000
9. Depreciation		829,000
II. Sum of Operating Expenses		2,047,000
III. TOTAL EXPENSES [Sum of (I & II)]		4,576,000
For 5 landfills, the Total Expenses		2.880 billion

APPENDIX VIII

RUNNING COSTS OF INCINERATION FOR A START-UP YEAR

Capital - Dependent Expenses

Annuities:	($\times 10^6$ Cedis)	
1. Cost of capital financing (45%)	34,020	
2. Construction of real estate (10%)	7,560	
3. Taxes and insurance (2.8%)	2,117	
Sub-total of Capital-dependent Costs ($\sum_k C'_{de}$)		43,697
Operating Expenses		
4. Repair and maintenance (R & M)		
Building (1%)	1,512	
Operations and Maintenance (25%)	529,214	
Sum for R&M		530,726
5. Labour costs		
- Skilled Labour (5)	150	
- Unskilled Labour (8)	20	
Sum of Labour costs		170
6. Administrative Costs (5%)		75,602
7. Water and sewerage (50,000 m³/yr)		350
8. Neutralization (150,000t/yr)		116,960
9. Heating oil (100t/yr)		362
10. Landfill (400,000t/yr)		60,318
Sum of Operating Expenses		828,185
Total running cost		= ¢$4.3697 \times 10^{10} + 1.20412 \times 10^{12}$
		= ¢1.247817×10^{10}

APPENDIX IX

INVESTMENT CAPITAL REQUIREMENT FOR A COMPOSTING FACILITY IN THE ACCRA-TEMA AREA OF CAPACITY 24,000 TONS OF ORGANIC WASTE AND EXPECTED LIFE OF 20 YEARS (PRICE LEVEL: JULY, 2001).

FACILITY FEATURES	CAPITAL REQUIREMENT ('000 Cedis)	('000 Cedis)
1. Purchase of Land:		
- For Compost Facility	¢72,000	
- For Transfer Stations	54,000	
Sum of Cost of Land		126,000
2. Buildings:		
- Compost Facility, Transfer Stations & Building Installations	98,000	
- Construction Planning and Supervision	54,000	
Sum of Buildings		107,000
3. Machinery and Equipment:		
- Vehicles (6)	750,000	
- Equipment (6)	49,000	
Total Costs of Machinery & Equipment		824,000
4. Leachate Management Facilities:		
- Leachate Seals Construction	39,000	
- Leachate Collection	68,000	
- Leachate Treatment	72,000	
Total Costs of Leachate Management		179,000
5. Window Watering Facilities:		
- Irrigation Equipment	3,000	
- Water Supply	5,000	
Total Costs of Windrow Watering Facilities		8,000
6. Site Selection, Survey and Permitting		305,000
7. Consultancy and Promotional Fees		85,000
8. Electrical Equipment		5,000
9. Fencing and Security		4,000
10. Testing and Commissioning		5,000
11. Decommissioning		23,000
12. Operations and Maintenance:		
- Vehicles, Equipment and Scales	8,000	
- Energy Needs	3,000	
Total Operation and Maintenance		11,000
13. Financing Costs (10%)		168,000
14. Required Capital Investment for One Facility		1,850,000
15. Therefore, 15 compost Facilities		27,750,000
16. Landfilling of Wastes and Contraries		30,159,000
17. Therefore, the Total Capital Required for Composting (35,7500t) and Landfilling (200,000t) of MSW		57,909,000

APPENDIX X

DETERMINATION OF THE RUNNING COSTS FOR A COMPOST FACILITY OF CAPACITY 24,000 METRIC TONS ORGANIC WASTE (¢, ROUNDED TO 2001 COSTS)

I. Capital Dependent Costs		
	(¢'000)	(¢'000)
1. Annuities:		
- Financing (45%)	49,000	
- Construction & Estate (10%)	140,000	
- Machinery & Equipment (20%)	160.000	
Sum of Annuities		349,000
2. Taxes and Insurance (28%)		320,000
3. Operating Capital (5% of Investment capital)		72.000
Sum of Capital - Dependent Expenses		741,000
II. Operating Expenses		
4. Labour Costs:		
- Skilled labour (3)	90,000	
- Unskilled labour (12)	31.000	
Sum of labour Costs		21,000
5. Repairs and Maintenance:		
Buildings (0.05%)	1,000	
- Vehicles (0.02%)	2,000	
- Equipment (0.23%)	2.000	
Sum of Repair and Maintenance Costs		5,000
6. Operating and Auxiliary Materials		4,000
7. Fuel (150 tons)		417,000
8. Power: - Basic Service Charge ¢121,400/kWh	14,000	
- Consumed Power	18.000	
Sum of Energy Costs		32,000
9. Disposal of Non-biodegradable Waste and Residuals		24,000
10. Administrative and Sales Expenses:		
- 5% of Labour Costs	6,000	
- 4% of items (2-6)	33.000	
Sum of Administrative and Sales Expenses		39,000
11. Reserves for Long-Term Care		24,000
12. Depreciation		93.000
Sum of Operating Expenses		759,000
TOTAL EXPENSES [SUM OF (I + II)]		1,500,000
For 15 compost facilities, the Total Running costs are:		22,500,000

Source: Author's Own Data Computed By GTZ Software

APENDIX XI (SAMPLE RESULTS OF GTZ CALCULATION PROCESSES)

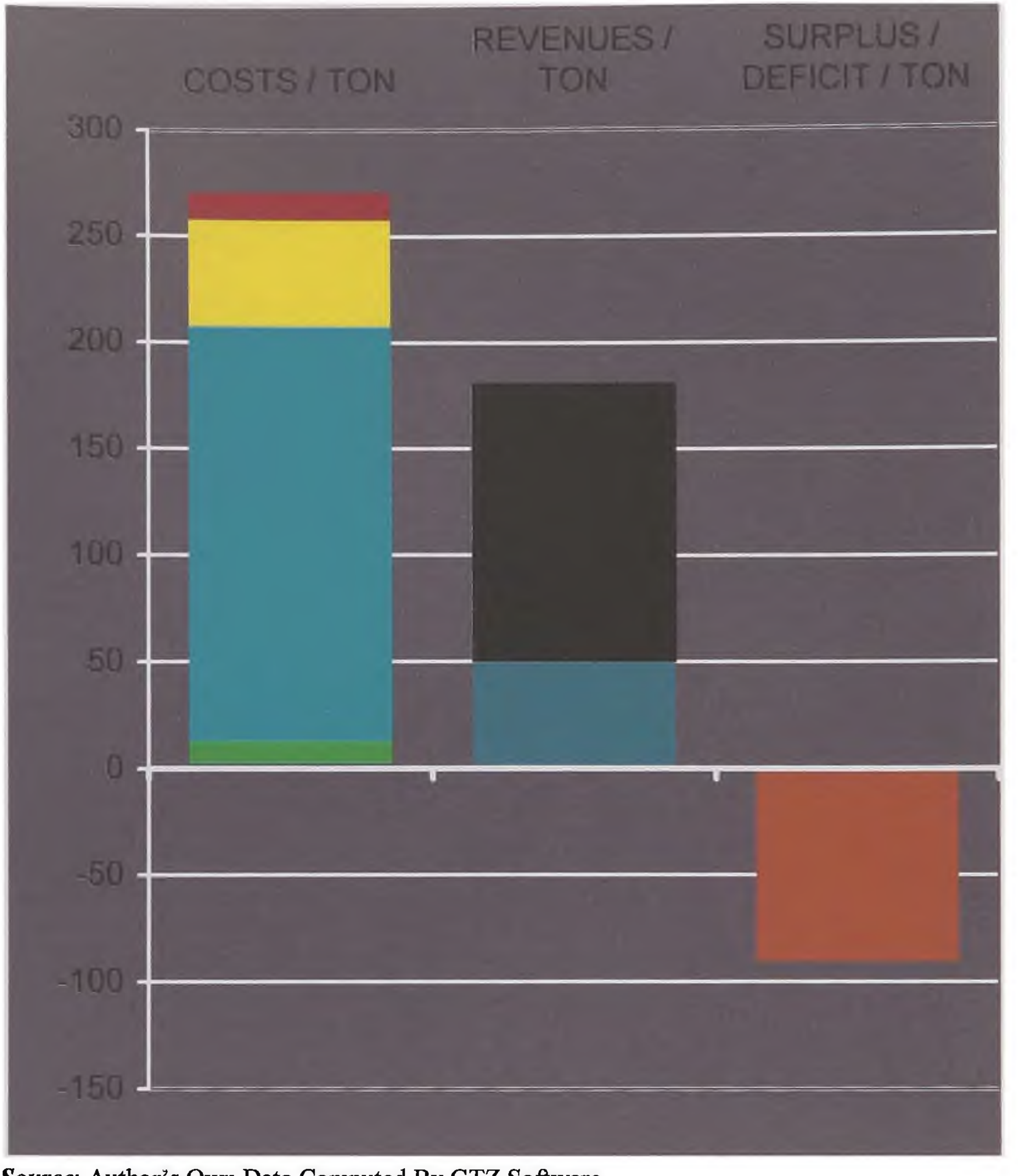
Graphics of Contribution Margin for Composting 6,500 Metric Tons of Organic Waste Generated in Accra-Tema Metropolitan Area – Land assumed to be owned by Implementing Municipal Authority; therefore, Cost of Land is not considered in the Analysis.

APPENDIX XII (SAMPLE RESULTS OF GTZ CALCULATION PROCESSES)

Type of Costs / Revenues	(US$)/ton Comp.	(US$)/year
COSTS		
PERSONNEL	13	43,104
OPERATIONAL	50	165,660
DEPRECIATION	129	426,214
MAINTENANCE	17	56,323
TRANSPORT	1	4,312
ADMINISTRATION	0	431
OTHERS	1	3,949
TOTAL COSTS	212	699,994
REVENUES		
SALES	130	429,000
CHARGES	0	750
SAVED COSTS FOR DEPOSITING	0	0
SUBSIDATIONS	50	165,000
TOTAL REVENUES	180	594,750
SURPLUS	-32	-105,244

Source: Author's Own Data Computed By GTZ Software

Investment Costs, Total Costs and Profit Contribution Margin for Composting 6,500 Metric Tons of Organic Waste Generated in Accra-Tema Metropolitan Area – Land assumed to be owned by Implementing Municipal Authority; therefore, Cost of Land is not considered in the Analysis.



Source: Author's Own Data Computed By GTZ Software

APENDIX XIII (SAMPLE RESULTS OF GTZ CALCULATION PROCESSES)

Graphics of Composting 18,000 metric tons (75%) of Organic Waste Generated in Accra-Tema Metropolitan Area in 2001 – Cost of Land Purchased is added to Cost of Machinery and Equipment Before Analysis.

APENDIX XIV (SAMPLE RESULTS OF GTZ CALCULATION PROCESSES)

Type of Costs /Revenues	(US$)/ton Comp.	(US$)/year
PERSONNEL	13	130,619
OPERATIONAL	50	502,000
DEPRECIATION	195	1,948,913
MAINTENANCE	10	103,163
TRANSPORT	1	13,067
ADMINISTRATION	0	1,306
OTHERS	1	7,578
TOTAL COSTS	271	2,706,646
REVENUES		(US$)
SALES	130	1,300,000
CHADGES	0	1,250
SAVED COSTS FOR DEPOSITING	0	0
SUBSIDATIONS	50	500,000
TOTAL REVENUES	180	1,801,250
SURPLUS	-91	-905,396

Source: Author's Own Data Computed By GTZ Software

Investment Costs, Total Costs and Profit Contribution Margin for Composting 18,000 metric tons of Organic Waste Generated in Accra-Tema Metropolitan Area in 2001 – Cost of Land Purchased is added to Cost of Machinery and Equipment Before Analysis.

APPENDIX XV

THE GTZ CALCULATION MODEL QUESTIONS

1. In which country will composting be introduced?
2. What is the total planned composting capacity (input)? (Ton of organic waste per year)
3. How high is the planned production of mature compost (output)? (Ton of compost per year)
4. How much mature compost can be sold each year? (Ton of compost per year)
5. What is the selling price per ton ex-compost plant when sold unbagged? (US$ per ton)
6. What is the selling price per ton of ex-compost plant when sold in sacks? (US$ per ton)
7. Are transfer stations planned and if so, how many? (Number)
8. How much households are to be included in the composting project? (Number)
9. How much waste is accumulated annually from these households? (Kg/year/household).
10. What annual financial contribution is required to increase awareness among the population of the need for waste separation? (US $/household).
11. What is the average distance from individual households to the transfer station/composting plant? (Km)
12. What is the average distance from the transfer station to the composting plant? (Km)
13. Is composting subsidised? If so, what is the actual figure per ton of compost? (US$/ton/yr)
14. What charges will be made per household for waste removal? (US$/household/year)
15. What percentage of waste removal charges for community will be used for collection and transport of organic waste? (%)
16. Are state subsidies/funding available to cover the cost of investment, if yes by how much? (US$)
17. Is it possible to utilise state subsidised loans to cover the cost of investment and if so how high is the rate of interest? (%)

18. What is the annually rate of taxation or state charges incurred when operating a compost plant? (%)
19. How high is the rate of interest when raising capital? (%)
20. What is the cost per m^2 to seal the ground and collect seepage water? (US$/ m^2)
21. What is the cost per m of fencing and gate(s) for a composting plant? (US$/m)
22. What is the cost of providing mains electricity to the installation? (Total cost in US$)
23. What is the cost of providing electricity installations in the composting plant? (Total cost in US$)
24. What is the cost per m^2 of roofing over windrows and/or temporary storage? (US$/$m^2$)
26. What is the cost of providing and distributing dustbins to all households? (US$/bin)
27. What is the purchase price for a truck with 3-5 tons loading capacity? (US$/container)
28. What is the purchase price for a truck with 5-10 tonnes loading capacity? (US$)
29. What is the purchase price for motorised collection vehicles? (US$)
30. What is the purchase price for a truck weighbridge? (US$)
31. What is the purchase price of a wheel loader? (US$)
32. What is the purchase price for an automatic turning machine? (US$)
33. What is the purchase price of a shredder? (US$)
34. What is the purchase price of a cutter? (US$)
35. What is the purchase price of a conveyor belt? (US$)
36. What is the purchase price of a conveyor belt with a magnetic separator? (US$)
37. What is the purchase price for a cylindrical sieve? (US$)
38. What is the purchase price for an air separator? (US$)
39. What is the purchase price for a bagging unit? (US$)
40 What is the average service life for the structural units? (Years)
41 What is the technical service life for mobile machinery? (Years)
42. What is the average service life for stationary machinery? (Years)
43. What is the cost of electricity? (US$ per kWh)
44. What is the cost of drinking water? (US$ per m^3)

45. What is the cost of non-drinkable water, for industrial purposes? (US$ per m^3)

46. What is the cost of diesel oil? (US$ per litre)

47. What is the cost of a plastic sack for bagging mature compost? (US$ per unit)

48. What are the average wage costs for a manual worker per day? (US$/day)

49. What are the average wage costs for a machine operator/driver per day? (US$/day)

50. What are the average wage costs for a machine operator/driver per day? (US$/day)

51. How long is the average working day for a manual worker/machine operator/driver? (Hours per day)

52. What is the cost, if applicable, of depositing solid waste at a landfill? (US$/ton)

53. How for is the distance between the compost plant and the landfill? (Km)

54. How for is the distance between the waste producers compost and the landfill? (Km)

55. Is there a fee payable to the municipal authorities for siting collection containers throughout the city? (US$/container)

56. What percentage of bulky waste (e.g. tree or bush punnings) will have to be added, on estimate? (%)

57. What is the cost of bulky material (tree/bush prunnings) if needed as an additive? (US$ per ton)

58. What is the percentage of remaining inorganic impurities in organic waste material, if waste separation is carried out? (%)

59. What quantities of organic waste could those informal groups collect annually? (T per year)

60. What fees would the informal groups have to be paid? (US$ per ton)

APPENDIX XVI

QUESTIONNAIRE (Q_1)

(Administered to District, Municipal, Metropolitan & Sub-Metro Assemblies)

1. Name of Organization: ....
....
2. Name of Officer filling-in the Questionnaire ....
....
3. Rank of Officer filling-in the Questionnaire ....
....
4. What volumes of waste were collected within your area of jurisdiction during the following years?
   (a) 1980 ....(b) 1985....................................
   (c) 1990 ....(d) 1995 ....
   (e) 2000 ....
5. What fractions of the waste, stated in (4) above, was collected by outsiders or waste contractors?
   (a) 1980 ....(b) 1985 ....
   (c) 1990 ....(d) 1995 ....
   (e) 2000 ....
6. State the amount of money spent by your organization on outside waste collection.
   (a) 1980 ....(b) 1985 ....
   (c) 1990 ....(d) 1995.....................................
   (e) 2000 ....
7. State the amount of money spent on landfilling for each of the year mentioned in the table (Q1.7) below.

YEAR	AMOUNT
1980	
1985	
1990	
1995	
2000	

8. What amounts of money were spent on other methods of waste treatment for the same years? Fill-in-Table (Q1.8) below

YEAR	AMOUNT
1980	
1985	
1990	
1995	
2000	

9. What amount of investments or costs did your organization expend on waste management for each of the years stated in Table (Q1.9) below.

YEAR	AMOUNT EXPANDED
1980	
1985	
1990	
1995	
2000	

10. Does your organization benefit directly and financially from waste management practices? (Please tick one).
Yes: [ ] / No: [ ]

If yes, state the amount and source of the financial benefit for the years mentioned in table (Q.1) below:

YEAR	AMOUNT BENEFITED	SOURCE (S)
1980		
1985		
1990		
1995		
2000		

11. In your opinion, what are the constraints militating against waste management in your area of jurisdiction? Please rank 1st, 2nd, 3rd, 4th - etc.

1st: ....

2nd: ....

3rd: ....

4th: ....

5th: ....

etc. ....

12. In your opinion, what are the constraints likely to face the establishment of compost plants in your area of jurisdiction? Please rank 1st, 2nd, 3rd, etc.

1st: ....
2nd: ....
3rd: ....
4th: ....
5th: ....
etc. ....

13. State where waste dumps are (whether official or unofficial) in your area under your jurisdiction.

(1 ....
(2)..
(3) ....
(4)..
(5)..
(6)..
etc. ....

14. In your opinion, where would you like a compost plant to be sited/ established your area? Please rank 1st, 2nd, 3rd ,etc.

1st..
2nd..
3rd..
4th: ....
5 th ....
6 th..
etc. ....

15. Please, assign reasons to your choices in (14) above

(a) ....
(b)..
(c) ....
(d)..
(e)..
(f)..
etc. ....

16. In your opinion, would you prefer a single large-scale compost facility with many waste depot stations, or many small-scale composting plants serving your area of jurisdiction? Give reasons for your preference in a ranked form.

Large-scale Plant? ..... Or Small-scale Pants?................(Please tick one)

Reasons: 1st: ....
2nd: ....
3rd:..
4th..
5th: ....
etc. ....

APPENDIX XVII

QUESTIONNAIRE (Q2)-COMPOST PROJECTS

1.0 Background of Project

1.1 Name of Compost Project: ....
....

1.2 Name of Officer filling-in the Questionnaire ....
....

1.3 Rank of Officer ....
....

1.4 When was the compost facility of establishment? ....
....

1.5 What is the production capacity of compost plant?
(a) Weight of raw organic waste ....
....
(b) Weight of finished compost product ....
....

1.6 What is the type of ownership of the compost plant? (Please tick one)
(a) Public ☐
(b) Private ☐
(c) Both ☐

1.7 What is the source of capital employed? (Please tick one):
(a) Own capital ☐
(b) Borrowed capital ☐
(c) Own-borrowed capital Mix ☐

1.8 If the capital employed is of type (1.7) above, what are the respective fractions?
(a) Own capital...
(b) Borrowed capital ....

1.9 Is the production of compost subsidized by local government? (Please, tick one)
(a) Yes ☐
(b) No ☐

1.10 If yes, by what percentage is it subsidized?
(a) 1995 .... (b) 1996 ....(c) 1997....................
(d) 1998 ....(e) 1999 ....(f) 2000 ....

1.11 State the economic life of your project ....

1.12 State the economic life of the following:
(a) Machines and Equipment: ....
(b) Buildings and fittings: ....
(c) Roads ....
(d) Purification facilities: ....
(d) Leachate sealing: ....

2.0 Fundamental Data
2.1 Input-Output Data

What weight (volume) of input (raw organic waste) was processed during 1995, 1996, 1997, 1998, 1999 and 2000? And, what weight (volume) of output (end product of compost) was produced during 1995, 1996, 1997, 1998, 1999 and 2000?Fill-in the table (Q 2.1) below

YEAR	INPUT (tons or m^3)	OUTPUT (tons or m^3)
1995		
1996		
1997		
1998		
1999		
2000		

2.2 Estimate the volume of compost market your project dealt with between 1980 and 2000. Fill in the table (Q.2.2) below

YEAR	VOLUME OF COMPOST MARKET
1980	
1985	
1990	
1995	
2000	

2.3 How is the organic waste procured? (Please tick one)

(a) Self ☐

(b) Waste collectors ☐

(c) Both (self and waste collectors) ☐

2.4 What percentage of organic waste constitutes the main waste stream?

....

....

2.5 What is the amount of waste collected by outsiders? How many waste collectors are involved? What is the rate of fees payable to the collectors? And what amount of waste is collected? Fill-in the table (Q2.5) below:

YEAR	Amount Collected by Outsiders	Number of Waste Collectors	Fees Payable to Collectors	Amount Collected by Project

2.6 Sales Volumes

What amount of compost produced was sold, and at what prices, between 1995 and 200? Fill-in table (Q 2.6) below

YEAR	AMOUNT OF COMPOST PRODUCED	SALE PRICE PER TON
1995		
1996		
1997		
1998		
1999		
2000		

2.7 Annual Taxation

What level of taxation that did your projects paid between 1995 and 2000? Fill-in table (Q2.7)

YEAR	PERCENTAGE TAX	AMOUNT PAID AS TAX
1995		
1996		
1997		
1998		
1999		
2000		

3.0 Estimation of Investment Cost

3.1 What is the initial investment cost for each of the items listed below? Fill-in the table (Q.3.1) below:

Capital Item	Unit	Number	Unit Price	Total Price
Land (Premise)	m^2			
Land (drop-off sites)	m^2			
Buildings and fittings	m^3			
Collection Vehicles	pcs			
Collection containers	pcs			
Equipment	pcs			
Purification facilities	pcs			
Leachate sealing	m^2			
Consultancy/Promotional Fees	m^2			
Environmental and site permits	n°			
Planning and Mobilization	n°			
Monitoring & Evaluation	n°			
Fencing & Security	m^2			
Publicity & Awareness creation	n°			
Testing and commissioning	n°			
Office Equipment	pcs			
Watering facilities	m^3			
Electrical equipment	pcs			

4.0 Estimation of Fixed Construction Costs

4.1 What amount of money was expended on financing depreciation and maintenance? Fill-in table (Q4.1) below

YEAR	DEPRECIATION	COST OF FINANCING	COST OF MAINTENANCE
1995			
1996			
1997			
1998			
1999			
2000			

5.0 Variable Operating Costs

5.1 What are the costs involved in processing raw organic material into compost? (Costs may result from waste separation, public awareness, waste collection, and transport from producer).

Cost item	1995	1996	1997	1998	1999	2000
Material/Non-personnel costs						
Cost of disposal						
Transport costs						
Total						

6.0 Machinery and Other Fixed Operating Costs

6.1 What are the costs involved in machinery operations and other facilities? (The costs may result from waste separation, public awareness, waste collection, and transport of compost from the production centres to consumers). Fill in the table (Q.5.1) below.

Cost Item	**Amount/Year**					
	1995	1996	1997	1998	1999	2000
Personnel Cost						
Outside Sources						
Depreciation						
Cost of Financing						
Maintenance cost						
Administrative Cost						
Total						

7.0 In your opinion, what are the constraints facing, compost investment, production and marketing in the Accra-Tema Area?

1st: ....

2nd: ....

3rd: ....

4th: ....

5 th...

etc. ....

8.0 Suggest ways of mitigating these constraints

1st: ....

2nd:..

3rd: ....

4th: ....

5th: ....

etc. ....

APPENDIX XVIII

German Technical Co-Operation (GTZ) Calculation Model-Data For Four West African Coastal Countries (Labour-Intensive Composting)

Q. NO.	BODIJA, IBADAN	HÉVIE, LOME	HÉVIE, COTONOU	GHANA (100%)	GHANA (75%)	GHANA (50%)	GHANA (25%)
1	Nigeria	Togo	Benin	Ghana	Ghana	Ghana	Ghana
2	8,000t/yr	3,000t/yr	5,000t/yr	24,000t/yr	18,000t/yr	13,000t/yr	6,500t/yr
3	5,000t/yr	900t/yr	3,000t/yr	13,000t/yr	10,000t/yr	6,550t/yr	3,300t/yr
4	5,000t/yr	900t/yr	3,000t/yr	13,000t/yr	10,000t/yr	6,550t/yr	3,300t/yr
5	16,900N/t	84,000CFA/t	105,000CFA/t	¢840,000/t	¢840,000/t	¢840,000/t	¢840,000/t
6	17,550N/t	91,000CFA/t	112,000CFA/t	¢910,000/t	¢910,000/t	¢910,000/t	¢910,000/t
7	1	1	5	3	3	2	1
8	300hds	275hds	400hds	300hds	500hds	400hds	300hds
9	1,300kg/yr	1,300kg/yr	1,800kg/yr	1,900kg/yr	1,500kg/yr	1,500kg/yr	1,500kg/yr
10	1,300N/hd	7,000CFA/hd	7,000CFA/hd	¢70,000/hd	¢70,000/hd	¢70,000/hd	¢70,000/hd
11	1km	1km	1km	2km	1km	1km	1km
12	1km	22km	21km	5km	1km	1km	1km
13	5,200N/t	14,000CFA/t	42,000CFA/t	¢350,000/t	¢350,000/t	¢350,000/t	¢350,000/t
14	2,000N/yr	14,000CFA/yr	9,000CFA/yr	¢ 70,000/yr	¢ 70,000/yr	¢ 70,000/yr	¢ 70,000/yr
15	90%	90%	80%	60%	25%	25%	25%
16	780,000N	3,500,000CFA	28,000,000CFA	¢105,000,000	¢105,000,000	¢105,000,000	¢105,000,000
17	25%	10%	10%	20%	20%	20%	20%
18	2%	0	0	28%	28	28%	28%
19	25%	25%	25%	45%	45%	45%	45%
20	26,000N/m²	2,100CFA/m²	120,000CFA/m²	¢1,400,000/m²	¢1,400,000/m²	¢1,400,000/m²	¢1,400,000/m²
21	3,900N/m	10,500CFA/m	3,500CFA/m	¢140,000/m	¢140,000/m	¢140,000/m	¢140,000/m
22	200,000N	1,050,000CFA	120,000CFA	¢560,000	¢280,000	¢ 280,000	¢280,000
23	500,000N	2,800,000CFA	300,000CFA	¢3,500,000	¢3,500,000	¢3,500,000	¢3,500,000
24	4,900N/m²	2,100CFA/m²	2,000CFA/m²	¢140,000/m²	¢140,000/m²	¢140,000/m²	¢140,000/m²
25	650N/bin	17,500CFA/bin	4,200CFA/bin	¢35,000/bin	¢35,000/bin	¢35,000/bin	¢35,000/bin
26	6,500N/C	120,400CFA/C	100,000CFA/C	¢350,000/C	¢280,000/C	¢280,000/C	¢280,000/C
27	2,340,000N	0	0	0	0	0	0
28	0	28,000,000CFA	24,000,000CFA	¢140,000,000 (¢252,000,000)	¢140,000,000 (¢252,000,000)	¢140,000,000 (¢252,000,000)	¢140,000,000 (¢252,000,000)
29	0	0	0	0	0	0	0
30	0	0	0	2,000	2,000	2,000	2,000

28[1] In Ghana, when land is not considered, the cost of machinery is ¢140,000,000; the value (¢252,000,000) is cost of land plus cost of machinery

Cont'd

Q. NO.	BODIJA, IBADAN	HÉVIE, LOME	HEVIE, COTONOU	GHANA (100%)	GHANA (75%)	GHANA (50%)	GHA NA (25%)
	Nigeria	Togo	Benin	Ghana	Ghana	Ghana	Ghana
31	65,000N	196,000CFA	200,000 CFA	¢10,500,000	¢10,500,000	¢10,500,000	¢4,900,000
32	0	0	0	0	0	0	0
33	0	0	0	¢14,000,000	¢14,000,000	¢10,500,000	¢10,500,000
34	0	0	0	¢7,000,000	¢7,000,000	¢7,000,000	¢7,000,000
35	0	0	0	¢10,500,000	¢7,000,000	¢7,000,000	¢7,000,000
36	78,000N	280,000CFA	300,000CFA	0	0	0	0
37	65,000N	28,000CFA	250,000CFA	¢10,500,000	¢7,000,000	¢7,000,000	¢7,000,000
38	0	0	0	0	0	0	0
39	0	0	0	¢10,500,000	¢7,000,000	¢7,000,000	¢7,000,000
40	20yrs	25yrs	20yrs	20 yrs	20 yrs	20 yrs	20 yrs
41	10yrs	10yrs	10yrs	10 yrs	10 yrs	10 yrs	10 yrs
42	8yrs	10yrs	10yrs	8 yrs	8 yrs	8 yrs	8 yrs
43	,080N/kwh	700CFA/kwh	10,500CFA/t	¢112,000/kwh	¢112,000/kwh	¢112,000/kwh	¢112,000/kwh
44	140/m³	500CFA/m³	7,400CFA/m³	¢ 7,700/m³	¢ 7,700/m³	¢ 7,700/m³	¢ 7,700/m³
45	130/l	500CFA/m³	700CFA/m³	¢7,000/m³	¢7,000/m³	¢7,000/m³	¢7,000/m³
46	135/l	600CFA/l	600CFA/l	¢2,300/l	¢2,300/l	¢2,300/l	¢2,300/l
47	125/sack	650CFA/sack	700CFA/sack	¢4,500/sack	¢4,500/sack	¢4,500/sack	¢4,500/sack
48	*	*	*	*	*	*	*
49	650N/day	670CFA/day	1,000CFA/day	¢7,000/day	¢7,000/day	¢7,000/day	¢7,000/day
50	700N/day	840CFA/day	1,200CFA/day	¢9,000/day	¢9,000/day	¢9,000/day	¢9,000/day
51	8hr/day	8hr/day	8hr/day	8hr/day	8hr/day	8hr/day	8hr/day
52	250N/t	1,400CFA/t	1,500CFA/t	¢14,000/t	¢14,000/t	¢14,000/t	¢14,000/t
53	1km	3km	0	10km	20km	10km	10km
54	15km	3km	22km	20km	22km	20km	10km
55	2/container	0	0	0	0	0	0
56	5%	5%	10%	5%	5%	5%	5%
57	500N/t	490CFA/t	1,000CFA/t	¢ 140,000/t	¢140,000/t	¢140,000/t	¢140,000/t
58	10%	5%	5%	10%	5%	5%	5%
59	100t/yr	1000t/yr	2,000t/yr	4,000t/yr	3,000t/yr	3,000t/yr	2,000t/yr
60	500N/t	3,500CFA/t	4,200CFA/t	¢70,000/t	¢70,000/t	¢70,000/t	¢70,000/t

Appendix XIX

German Technical Co-Operation (GTZ) Calculation Model-Data For West African Coastal Situations (Capital-Intensive Composting)

Q. NO.	BODIJA, IBADAN	HEVIE, LOME	HEVIE, COTONOU	GHANA (100%)	GHANA (75%)	GHANA (50%)	GHANA (25%)
1	Nigeria	Togo	Benin	Ghana	Ghana	Ghana	Ghana
2	8,000t/yr	3,000t/yr	5,000t/yr	24,000t/yr	18,000t/yr	13,000t/yr	6,500t/yr
3	5,000t/yr	900t/yr	3,000t/yr	13,000t/yr	10,000t/yr	6,550t/yr	3,300t/yr
4	5,000t/yr	900t/yr	3,000t/yr	13,000t/yr	10,000t/yr	6,550t/yr	3,300t/yr
5	16,900N/t	84,000CFA/t	105,000CFA/t	¢840,000/t	¢840,000/t	¢840,000/t	¢840,000/t
6	17,550N/t	91,000CFA/t	112,000CFA/t	¢910,000/t	¢910,000/t	¢910,000/t	¢910,000/t
7	1	1	5	3	2	2	1
8	300hds	275hds	400hds	500hds	500hds	400hds	300hds
9	1,300kg/yr	1,300kg/yr	1,800kg/yr	1,900kg/yr	1,500kg/yr	1,500kg/yr	1,500kg/yr
10	1,300/hd	7,000CFA/hd	7,000CFA/hd	¢70,000/hd	¢70,000/hd	¢70,000/hd	¢70,000/hd
11	1km	1km	1km	2km	1km	1km	1km
12	1km	22km	21km	5km	1km	1km	1km
13	5,200/t	14,000CFA/t	42,000CFA/t	¢350,000/t	¢350,000/t	¢350,000/t	¢350,000/t
14	2,000/yr	14,000CFA/yr	9,800CFA/yr	¢70,000/yr	¢70,000/yr	¢70,000/yr	¢70,000/yr
15	90%	90%	80%	60%	25%	25%	25%
16	780,000N	3,500,000CFA	28,000,000CFA	¢105,000,000	¢105,000,000	¢105,000,000	¢105,000,000
17	25%	10%	10%	20%	20%	20%	20%
18	2%	0%	5%	28%	28%	28%	28%
19	25%	25%	25%	45%	45%	45%	45%
20	26,000N/m²	2,100CFA/m²	120,000CFA/m²	¢1,400,000/m²	¢1,400,000/m²	¢1,400,000/m²	¢1,400,000/m²
21	3,900N/m	10,500CFA/m	3,500CFA/m	¢140,000/m	¢140,000/m	¢140,000/m	¢140,000/m
22	200,000N	1,050,000CFA	120,000CFA	¢560,000	¢420,000	¢280,000	¢280,000
23	500,000N	2,800,000CFA	300,000CFA	¢10,500,000	¢10,500,000	¢7,000,000	¢7,000,000
24	4,000N/m²	2,100CFA/m²	2,000CFA/m²	¢140,000/m²	¢140,000/m²	¢140,000/m²	¢140,000/m²
25	650N/bin	17,500CFA/bin	4,200CFA/bin	¢35,000/bin	¢35,000/bin	¢35,000/bin	¢35,000/bin
26	6,500N/C[6]	120,400CFA/C[6]	100,000CFA/C[6]	¢350,000/C	¢280,000/C	¢280,000/C	¢280,000/C
27	2,340,000N	24,000,000CFA	12,600,000CFA	¢126,000,000	¢126,000,000	¢126,000,000	¢126,000,000
28[1]	2,964,000N	28,000,000CFA	24,000,000CFA	¢140,000,000 (¢252,000,000)	¢140,000,000 (¢252,000,000)	¢140,000,000 (¢252,000,000)	¢140,000,000 (¢252,000,000)
29	3,900,000N	31,000,000CFA	28,000,000CFA	¢240,000,000	¢240,000,000	¢240,000,000	¢240,000,000
30	56,000N	200,000CFA	250,000CFA	¢3,000,000	¢3,000,000	¢3,000,000	¢3,000,000

28[1] In Ghana, when land is not considered, the cost of machinery is ¢140,000,000; the value (¢252,000,000) is cost of land plus cost of machinery

Cont'd

Q. NO.	BODIJA, IBADAN Nigeria	TSEVE, LOME Togo	HEVIE, COTONOU Benin	GHANA (100%) Ghana	GHANA (75%) Ghana	GHANA (50%) Ghana	GHANA (25%) Ghana
31	65,000N	196,000CFA	200,000CFA	¢10,50,000	¢10,50,000	¢7,000,000	¢7,000,000
32	65,000N	250,000CFA	180,000CFA	¢3,500,000	¢3,500,000	¢3,500,000	¢3,500,000
33	65,000N	240,000CFA	240,000CFA	¢14,000,000	¢14,000,000	¢10,500,000	¢10,500,000
34	39,000N	280,000CFA	200,000CFA	¢7,000,000	¢7,000,000	¢7,000,000	¢7,000,000
35	65,000N	210,000CFA	200,000CFA	¢10,500,000	¢3,500,000	¢3,500,000	¢3,500,000
36	78,000N	280,000CFA	300,000CFA	¢7,500,000	¢7,000,000	¢7,000,000	¢7,000,000
37	65,000N	280,000CFA	250,000CFA	¢7,500,000	¢7,000,000	¢5,000,000	¢3,500,000
38	52,000N	280,000CFA	270,000CFA	¢10,000,000	¢7,000,000	¢5,000,000	¢3,000,000
39	71,500N	400,000CFA	400,000CFA	¢7,000,000	¢7,000,000	¢5,000,000	¢4,000,000
40	20yrs	25yrs	20yrs	20yrs	20yrs	20yrs	20yrs
41	10yrs	10yrs	10yrs	10yrs	10yrs	10yrs	10yrs
42	8yrs	10yrs	10yrs	8yrs	8yrs	8yrs	8yrs
43	2,080N/kwh	700CFA/kwh	10,500CFA/t	¢112,000/kwh	¢112,000/kwh	¢112,000/kwh	¢112,000/kwh
44	140N/m³	500CFA/m³	7,400CFA/m³	¢ 7,700/m³	¢ 7,700/m³	¢ 7,700/m³	¢ 7,700/m³
45	130N/l	500CFA/m³	700CFA/m³	¢7,000/m³	¢7,000/m³	¢7,000/m³	¢7,000/m³
46	135N/l	600CFA/l	600CFA/l	¢2,300/l	¢2,300/l	¢2,300/l	¢2,300/l
47	125N/sack	650CFA/sack	700CFA/sack	¢4,500/sack	¢4,500/sack	¢4,500/sack	¢4,500/sack
48	*	*	*	*	*	*	*
49	650N/day	670CFA/day	1,000CFA/day	¢7,000/day	¢7,000/day	¢7,000/day	¢7,000/day
50	700N/day	840CFA/day	1,200CFA/day	¢9,000/day	¢9,000/day	¢9,000/day	¢9,000/day
51	8hr/day	8hr	8hr/day	8hr/day	8hr/day	8hr/day	8hr/day
52	250N/t	1,400CFA/t	1,500CFA/t	¢14,000/t	¢14,000/t	¢14,000/t	¢14,000/t
53	1km	3km	0	10km	20km	10km	10km
54	15km	3km	22km	20km	22km	20km	10km
55	2N/container	0	0	0	0	0	0
56	5%	5%	10%	5%	5%	5%	5%
57	500N/t	490CFA/t	1,000CFA/t	¢ 140,000/t	¢140,000/t	¢140,000/t	¢140,000/t
58	10%	5%	5%	10%	5%	5%	5%
59	100t/yr	1,000t/yr	2,000t/yr	4,000t/yr	3,000t/yr	3,000t/yr	2,000t/yr
60	500N/t	3,500CFA/t	4,200CFA/t	¢70,000/t	¢70,000/t	¢70,000/t	¢70,000/t