ECONOMIC VIABILITY OF FAECAL SLUDGE-TO-FORTIFER COMPOSTING PROJECT IN THE NORTHERN SECTOR OF GHANA

BY

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A THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL ECONOMICS, AGRIBUSINESS AND EXTENSION IN THE SCHOOL OF GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, GHANA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF

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DECLARATION

I hereby declare that this submission is my own work towards the award of Master of Philosophy in Agricultural Economics. That, to the best of my knowledge, it contains no material previously published by another person or material which has been accepted for the award of any other degree in any University, except where due acknowledgement has been made in the text:

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DEDICATION

This work is dedicated to my supportive and sweet wife, Barbara Opoku Nyame and my sweet and wonderful children: Nana Poku K. Opoku-Nyame and Abena Osaah Opoku-Nyame for their love and concern.

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The heights so attained by men, are mostly not achieved by their own efforts alone, but theirs in combination with direct or indirect efforts by others- PK Otabil. This echoes with Chinua Achebe axiom that; “he who pays respect to the great one pave way to his own greatness”. I could not have come thus far without the help of the Almighty God who connected me to the right persons in life with all the accompanying opportunities and assistances they offered me.

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ABSTRACT

Recently, the application of excreta-based fertilizers has attracted attention due to the strongly increasing prices of chemically produced fertilizers and poor soil fertility problem of the agricultural land. Meanwhile, faecal sludge from on-site sanitation systems is rich in nutrients and organic matter constituents, which contribute to replenishing the humus layer and soil nutrient reservoir and to improving soil structure and water-holding capacity. Hence, it represents an important resource for enhancing soil productivity on a sustainable basis. However, there is little in the scientific literature about the performance of treatment technology allowing recovery of nutrient resources from human waste. Meanwhile, waste management is seen as a financial burden for most developing countries. Hence, there is a general call for private sector participation in the sanitation sector. In Ghana, the most predominant way of managing waste is by disposal in designated and illegal places. In an attempt to find a sustainable way of managing faecal sludge and solid organic waste, the fortifer business model which falls within the broad resource reuse and recovery project was started by the International Water Management Institute on a pilot scale. This led to the production of fortified excreta pellets, the so called "fortifer".The feasibility of faecal sludge and or market waste composting into fortifer in the Northern Ghana was studied from an economic perspective. Two models using the 'fortifer' were evaluated under this study. The decentralized composting plant situated at the Tamale metropolis is being operated by both community and entrepreneur (M1), and the second one involves operation by the entrepreneur alone (M2). The results reveal that the fortifer business model is economically viable for the two ownership scenarios. From the results, it was noted that, the facilities being operated by both community and entrepreneur (M1), is the best alternative which generates the highest cost-benefit ratio and net present benefit. On the other hand, the second alternative (M2) had the highest capital costs. A sensitivity analysis was also conducted. M1 was always better than the other alternative regardless of the changes in the key uncertain parameters.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATION

B/C : Benefit cost ratio

cu.m : cubic metre

EIRR : Economic Internal Rate of Return

DF : Discount factor

FS : Faecal sludge

GHGs : Greenhouse gases

GHS : Ghana Cedis

IWMI : International Water Management Institutes

MSW : Municipal Solid Waste

NPV : Net Present Value

O&M : Operation and Maintenance

US$: United States Dollar

t : Tonne

WHO : World Health Organization

Yr. : Year

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Human excreta use in agriculture has been practised for centuries, particularly in Far East countries like China (WHO, 2006). According to Wolgast (1993), the nutritional composition in the annual amount of human excreta generated by one person is equivalent to the amount of fertilizer required to produce 250kg of cereal. Drangert (1998) reported that the fertilization equivalent of human excreta, which is, in theory at least, nearly sufficient for a person to grow his own food. Although the use of faecal sludge has many benefits, it is associated with significant health risks that tend to erode its benefits if not undertaken in a safe manner.

Health risks often associated with human excreta application in agriculture are helminthiasis and other gastro-enteric infections (Blumenthal & Peasey, 2002).In settings where the agricultural application of the excreta is practised, disease transmission is mainly the consequence of several risk factors including those related to direct contact with excreta during application in the field (Blumenthal & Peasey, 2002; WHO, 2006).

In other cases, faecal sludge collected from on-site sanitation installations is sometimes transported to treatment ponds but is more often dumped in depressions, streams or the ocean, discharged in lakes or fish ponds or disposed off within the household compound. Assuming a per capita faecal sludge production of 1 litre/day

(Strauss *et al.*, 1997), a truck-load of 5m^3 dumped indiscriminately is equivalent to

5000 open defecations (Kones *et al*., 2007). In Ghana, this situation is common and puts a lot of pressure on government's budget (Cofie *et al*., 2005), although waste management is not effective. As a result of the financial burden, the government of Ghana is strategically seeking private participation in the waste management sector (MLGRD and EHSD, 2010).

However, if we could harness the energy value from faecal sludge and market waste by composting, we can prevent death from poor sanitation, clean up the environment and even protect the skies and the air by reducing greenhouse gases emissions. When wastes are reused, some benefits achieved especially in low-income countries include reduction of indiscriminate dumping; creation of jobs and addressing sanitation funding shortfall (Nkansah, 2009); and reduction in the need for expensive artificial fertilizers to increase food production (Cofie *et al.,* 2005; Strauss *et al*., 1997). Moreover, it has been estimated that, worldwide, the global fertilizer industry produces some 170 million tons of fertilizer nutrients annually (International Fertilizer Industry Association, 2009); while at the same time 50 million tons of fertilizer equivalents are dumped into water bodies via sewered sanitation systems (Werner, 2007).

The fortifer project which falls within the broader resource recovery and reuse business model is seen as a sustainable way of tackling the waste problem and at the same time as a cheap source of nutrient supply for farmers (Esrye, 2000 and World Health Organization, 2006). Studies conducted in Ghana by Drechsel *et al*. (2004), Cofie *et al*. (2005), Mariwah and Drangert (2011), and Murray *et al*. (2011) on the reuse of human excreta have been geared towards the technical aspect of improving the nutritional composition. These studies have led to the development of fortified excreta pellets, the so called 'Fortifer' by the International Water Management Institute (IWMI) in Ghana. This is viewed as environmental-friendly, nutritionally enriched and economically accessible to farmers; and a product free from pathogenic organism and safe for use in agriculture.

Before this product is rolled out on a commercial phase, a comprehensive investigation into the economic aspect of running such a project in Ghana is looked at, by undertaken a comprehensive evaluation of its impacts on health and other potential cost saving aspects to ascertain its social acceptability. Therefore, information about the viability of the project would be one of the crucial decision tools to attract both public and private investments.

1.2 Problem Statement:

Faecal sludge are rich in nutrients and organic matter constituents which contribute to replenishing the humus layer and soil nutrient reservoir and to improving soil structure and water-holding capacity (Kones, 2004). However, over the years, its use in agriculture has become less popular in developed countries because of the health related issues associated with the practice. By contrast, in developing countries, such as Ghana, the practice is gaining popularity among some farmers in some part of the country since they use the untreated raw faecal sludge extensively for the improvement of their agricultural land. Cofie *et al*., (2005) and Adamptey *et al*, (2009), reported that, some farmers in Tamale and Bolgatanga claim to have used human excreta to cultivate cereals (their major staple) around the cities for up to 30 years.

Though, the use of untreated faecal sludge shows significant response to crop yield as opined by Adamptey *et al*, (2009), yet, these practices represent a significant risk to public health and have a high disease impact on farmers and their families, the households living in the immediate area and on vulnerable populations (Cifuentes *et al*., 2000; WHO, 2006).

In most urban areas of Ghana, faecal sludge (FS) management remains largely unregulated and chaotic; hence it causes contamination of soils and water bodies and endangers human health. Metropolitan decision-makers are well aware, though, that developing and applying sound recycling strategies would greatly contribute to alleviating the management problems. However, little action has been taken to recycle FS on a sustainable basis.

Although, treatment of faecal sludge (FS) has not yet received adequate attention in this country, as a result, farmers continue to use the risk associated product for crop production neglecting its negative consequences, nevertheless, recovery of organic matter and nutrients from human waste as biosolids is an economic necessity and an urgently needed environmental protection strategy. As a consequence, strategies and low-cost technological options for excreta treatment have been developed which allow the cost-effective and affordable recycling of organic matter and nutrients especially for urban and peri-urban agriculture.

This study attempts to estimate the economic costs and effects of the processing of faecal sludge to fortifer for agricultural purposes, to ascertain how viable economically the project will be to the benefits of the country.

Under this study two models of decentralized composting of fortifer were investigated.

1.3 Research Questions

The study sought to answer the following questions,

1. What are the direct costs and benefits associated with the Fortifer Project?
2. What are the potential costs saved with the Fortifer Project in terms of infectious diarrhoeal cases and landfilling disposals?
3. Are the two alternatives of the Fortifer Project viable based on costbenefit outputs?
4. Are the two alternatives of the Fortifer Projects still viable when certain key parameters are altered?

1.4 Objectives of the study

The main objective of the study was to analyze the economic viability of faecal sludge-to- fortifer (compost) project in the Northern and the Ashanti Regions of Ghana. The specific objectives examined included;

1. To estimate the direct costs and benefits associated with the fortifer project.
2. To estimate potential cost saved by embarking on the fortifer project in terms of infectious diarrhoea cases and landfilling disposal avoided.
3. To evaluate the economic viability of two alternative business models for undertaking the Fortifer Project.
4. To examine how sensitive the viability indicators are to changes in economic variables.

1.5 Justification of the study.

Government spends millions of foreign exchange importing fertilizer for farmers on a subsidized basis. Meanwhile raw faecal sludge used by farmers elsewhere in the country contain appreciable amount of plant nutrients, which when harnessed could reduce the heavy financial burden involved in obtaining fertilizers for Ghanaian farmers.

In spite of the fertilizer subsidy programme run in the country, agricultural productivity reduction resulting from deterioration of soil fertility is common in the study area. Despite the high soil fertility problem the utilization of faecal compost as best substitute or complement for chemical fertilizer and for increasing crop production is given little attention and it is not well known by most communities.

Furthermore, frequent hikes in prices of imported chemical fertilizer have serious economic threat to rural and urban agriculture. As a result farmers in their bid to increase production resort to various and cheaper ways of improving the fertility of the soil in a way which could be detrimental to their health and the environment, as farmers are not aware of the various risks associated with the use of untreated faecal sludge.

This study therefore, seeks to carry out economic viability on a proposed project involving the production of compost by using cheap available local resources, like faecal sludge and agricultural waste as soil ameliorate, to inform policy makers of an alternative product which is environmentally friendly and proposed to be economically viable.

Again, information provided by this study will help the existing firms/private entities in their decision-making to go into the production of the compost or move into partnership with the public in the composting business. More so, this study seeks to make a meaningful contribution to existing knowledge since there are scanty information on the economic viability of the project in the country, support future research and policy formulation in this context.

1.6 Organization of the Study

This study is organized into five chapters. Chapter One presents an introduction to the study. Chapter Two presents a review of relevant information on the topic. Chapter Three discusses the methodology employed for the study. Chapter Four presents results and discussions for the various objectives the study set out to achieve. Chapter Five summarizes the findings, and makes recommendations for research and development.

CHAPTER TWO

2.0 LITERATURE REVIEW

This section looks at the technical and financial aspects of co – composting schemes in relation to the fortifer project. The weaknesses and gaps in theoretical and empirical knowledge are identified and discussed. Topics on work done, work-inprogress and what can be done are the centers of discussion. In light of these, the section looks at Excreta and sludge use in agriculture, benefit of composting FS with health benefit as the locus, the value chain, the technical aspects of the production of the product, the potential bottlenecks along the value chain of the product., studies done on financial parameters of co-composting and the knowledge gap in these aspects. Published literatures on the issues are the bases for discussion.

2.1 Excreta and Faecal Sludge use in agriculture:

According to Cofie *et al.* (2005), untreated excreta contain organic matter, plant nutrients, trace elements and micronutrients as well as pathogens such as bacteria, viruses and helminthes. When this is not well managed it serves as source of disease and environmental problems. On the other hand, proper management contributes positively to local resources. Human excreta, like animal manure, are a good soil conditioner and a renewable source of plant nutrients, such as nitrogen, phosphorus and potassium. Shrestha *et al*. (2003), estimated that N: P: K content in the bio-slurry is 2.7:1.9:2.2. It was again, estimated that the use of bio-slurry annually saves 39 kg of nitrogen, 19 kg phosphorus and 39 kg potash per household (Shrestha et al, 2003).The nutrient content of human waste excreted each year is approximately equal to that consumed and to that required for corresponding biomass production.

Table 2. 1: Fertilization equivalent of human excreta

Nutrient in kg / cap year

Nutrient	In urine (500 l/year)	In faeces (50 l/year)	Total	Required for 250 kg of cereals
Nitrogen (as N)	4.0	0.5	4.5	5.6
Phosphorus (as P)	0.4	0.2	0.6	0.7
Potassium (as K)	0.9	0.3	1.2	1.2
Carbon (as C)	2.9	8.8	11.7	

Source: Adapted from cofie et al (2005)

Cofie *et al* (2005) again, opined that the benefits of using faecal biosolids in agriculture are similar to those for compost. This acclamation was supported by the US Composting Council (2000) to include: improvement in soil structure, porosity and density, thus creating a better plant root environment; increase in infiltration and permeability of heavy soils, thus reducing erosion and runoff; improvement in waterholding capacity, thus reducing water loss and leaching in sandy soils.

However if care and right procedures are not adopted excreta use could become a source of disease transmission.

2.2 Benefits of Composting

Composting is a biological decomposition process in a controlled aerobic or anaerobic environment (Kwon, 2005). Besides oxygen, there are four other key factors to control during the process: carbon to nitrogen (C/N) ratio, moisture, pH, and temperature. Through the composting process, organic raw waste is converted into humic substances, which are compost.

Composting can provide several economic benefits (Otten, 2001; Hoornweg, *et al*, 1999), although it sometimes also has negative environmental impacts such as odour and leachate, and financial problems. The benefits that composting bring into communities are as follow.

- extension of landfill life-time
- cost savings from reduced waste transportation to landfill
- cost savings from avoided waste disposal at landfill
- Cost savings from reduced infectious diarrhoeal cases
- creation of new jobs

- revenue from the sale of compost

In addition, there can be environmental benefits, such as reduced methane generation at landfill sites

2.3 Technical, financial and economic parameters of faecal sludge compost

The technical aspect of producing co-compost from faecal sludge centers on the design and operation. The technical and economic parameters of schemes which reuse faecal sludge as co-compost in Ghana and two schemes which uses solid organic waste in India and Bangladesh are shown in table 2.2 These schemes are different in their sizes and the raw materials used. The scheme in Bangladesh and India use organic community waste while, both schemes in Ghana use faecal sludge.

Table 2.2 Technical and financial and economic parameters of co-composting schemes in three countries

	Mirpur-Dhaka Composting Scheme in Bangladesh	Buobai cocomposting in Kumasi, Ghana	Anamol Krishi Udyog composting business in India	Fortifer pilot project in Accra , Ghana
Reference	Zurbrugga et al, 2005	Steiner et al,2002	Harper, 2004	Nikiema et al 2013
Capacity	1095 tons of collected waste per yr. [a]	500 m3 faecal sludge per yr.	1000 tons per yr.	36 tons per yr. [b]

Method of composting	Indonesian windrow technique aerobic and thermophite composting method	Windrowing composting method	Windrowing composting method	Windrowing composting method
Raw materials	Organic waste mixed with cow dung, saw dust and urea	Faecal sludge and organic solid waste	70% solid organic waste and 30% community waste	Faecal sludge, organic solid waste enriched with ammonium sulphate
Labour	10 workers on full time base	2 full time workers and outsourced labour	12 daily wage workers and 1 full time supervisor	2 full time workers. 6 daily wage workers and contracted labour for dewatering and sorting
Revenue	Compost sales of $9728 per yr. Collection fees of $6087 per yr.	Compost sales is $5 per ton	Selling price of compost product is $ 40 per ton	Selling price based on WTP is $495 – 990 per ton [c]
Operation cost	Collection of waste is $3119 per yr. Composting [d] is $7511 per yr.	$1800 per yr. [e]	Production cost [f] = $34.20 per ton	Production cost = $200 per ton [f]
Amortization period	10yrs	15yrs		_

Interest rate	15%	5%	12%	_

a. Based on an assumption that operation is throughout the year. Original capacity stated in study is 3 tons of collected waste per day
b. 3 drying beds produce 6 tons in 2 weeks; co-compost takes 60 days to mature. Yearly estimation is based on assumed continuous operation throughout the year
c. Exchange rate of $1 = 2.02 Ghana cedis. WTP is 1- 2 Ghana cedis per 0.5 kg
d. Cost items comprise salaries, and expenses for electricity, water and additional feed stocks (sawdust, urea, cow dung)
e. include waste sorting, sludge removal, sand refilling, waste sorting, compost, screening and bagging, salaries
f. include biological agent (3kg/ton), packaging, marketing expenses, overheads

According to Cofie *et al*, (2009), operation of co-composting plant of 37ton/year capacity showed that the plant is economically viable, though financially it is not. However, the projects has numerous external benefits (such as reducing waste volume, transport costs, increasing the agronomic value of compost and improving public health) but were not evaluated.

Again, Renkow *et al* (1998), opined, that operation of public-private and privately owned-privately operated waste composting were economically viable with positives net present value at 5% interest rate with 14years amortization period. The study failed to evaluate the monetary value of some project externalities. Moreover, a study conducted by Aborah (2013), indicated that production of fortifer is viable with positive net present value (GHS 2,000) at 5% discount rate with 20years lifespan for Publicly owned-Privately Operated composting Plant. This study also failed to consider the evaluation of the project external benefits or costs.

A report by CM consulting (2007) indicated that, the net economic benefit of composting organics instead of landfill represents a net economic benefit of between $1.4 million to $5.8 million per annum. This study evaluated environmental benefit or cost, which is the sum of the monetized value of various pollutants, like greenhouse gas emissions (eCO_2); human health toxics (eToluene); human health carcinogens (eBenzene); Eutrophication (eN); Acidification (eSO_2). The environmental benefit also includes the monetized value of avoided pollutants as a result of finished compost replacing pesticides and synthetic fertilizers.

This study therefore, considered the monetary value of three externalities on: health effects in terms of reduced diarrhea infections, cost saved through fewer disposals and increase in crop yield as a result of undertaking the faecal sludge composting Project.

2.5 Health effects of Excreta and Faecal sludge use in agriculture

Faecal sludge is the general term for the undigested or partially digested slurry or solid that results from the storage or treatment of blackwater in so-called on-site sanitation systems such as septic tanks, latrines, toilet pits, dry toilets, unsewered public toilets and aqua privies on the other hand, biosolids are treated sludge or the treated by-products of domestic and commercial sewage, wastewater and faecal sludge treatment that can be beneficially utilized as soil amendment and fertilizer. These residuals are treated to reduce their organic matter content, volume and/or mass, the pathogens and the vector attraction potential (Raschid-Sally and Jayakody, (2008)).

Faecal sludges are rich in nutrients and organic matter – constituents which contribute to replenishing the humus layer and soil nutrient reservoir and to improving soil structure and water-holding capacity. Hence, they represent an important resource for enhancing soil productivity on a sustainable basis (Kones, 2004). Unfortunately, in most urban areas of developing countries, FS management remains largely unregulated and chaotic; hence it causes contamination of soils and water bodies and endangers human health.

The use of excreta and FS have reduced the depletion of soil nutrients by providing organically rich nutrients resulting in increased crop yield and hence reduced the pressure to expand cropland, the principal cause of deforestation in Northern Ghana. A study conducted by Cofie *et al*, (2005) indicated soil infertility was one of the major problems and that the use of FS was a cost effective way for improving farm productivity.

According to Carr, (2001), human excreta contain many types of pathogens. When these pathogens are introduced into the environment some can remain infectious for long periods of time and, under certain conditions, they may be able to replicate in the environment. The presence of pathogens presents a potential threat to human health.

However, for an actual risk of disease an infectious dose of the excreted pathogen must reach a human host. This occurs when untreated or inadequately treated wastewater or excreta (faecal sludge) are applied to soil and crops. The persons at risk are the farmers, farm workers and their families as well as consumers of crops produced in such a way.

Table 2.3 provide information on selected faecal-oral pathogens and selected transmission routes.

Pathogen survival(time in days unless otherwise indicated)		
Organism	Soil	Crops
Viruses	6-180	0.4-25
Salmonellae	15-100	5-50
Cholera	<20	<5
Faecal coliforms	<100	<50

Protozoan cysts	+75	ND
Ascaris eggs	1-2yrs	<60
Tapeworm eggs	7months	<60

Source: Carr, (2001) ND-no data

The use of inadequately treated faecal sludge in soil amendment and fertilization is especially associated with elevated prevalence of intestinal helminthes infection. For example, untreated or partially treated FS was directly responsible for 80% of all Ascaris infections and 30% of diarrhoeal disease in farm workers and their families revealed by Cifuentes *et al*. (2000).

Trematode infections are caused by parasitic flatworms (also known as flukes) that infect humans and animals. Infected individuals transmit trematode larvae in their faeces. Infections with trematode parasites can cause mild symptoms such as diarrhoea and abdominal pain or, more rarely, debilitating cerebral lesions, splenomegaly and death, depending on the parasite load.

2.6 The fortifer value chain and Key actors

The fortifer project is a pilot project being carried out by the International Water Management Institute in Accra. It falls under the broad resource recovery and reuse business model. This project seeks to serve as a sustainable way of dealing with waste (faecal sludge and solid organic waste) disposal by producing a good quality soil nutrient supplement out of the organic solid waste and faecal sludge (Nikiema *et al*., 2013).

According to Drechsel and Kunze (2001), the value chain of a business model which reuses waste and faecal sludge depicts a closed loop of the nutrient cycle. In this chain faecal sludge generated in households and public toilets are combined with organic solid wastes, processed and applied back as soil nutrient supplement.

In a description of the processes chain of fortifer production, Aborah, (2013) mentions that the chain starts with the sourcing and sorting of organic solid wastes to the suction of stored faecal sludge of domestic households and public toilets and then the conveyance of the faecal sludge to a disposal site. He iterated that the suction or emptying of the domestic septic tanks and public toilets is carried out by either the municipal assembly or private companies, who are charged a disposal fee for dumping the faecal sludge on the drying beds at the treatment station. Nikiema *et al*. (2013) describe the processes and ingredients used in the production of fortifer. They came up with different formulations for the final product. These formulations include: (i) compost, which is made up of matured faecal sludge only (ii) co-compost, which consists of a mixture of dried faecal sludge and organic waste like market waste or saw dust (iii) fortified pellets, which is the premium product consisting of a mixture of co-compost and ammonium sulphates. However, they argued that the fortified pellets are favoured over the other formulations because they facilitate broadcasting and

PHASE 1 Drying step	Emptying of faecal sludge from public latrines and domestic septic tanks in the drying bed to get solid faecal sludge (main raw material). 3 Drying beds of 240 m^2 each can produce 2tonnes of solid faecal sludge each in 2 weeks	Municipality: Managing the disposal of faecal sludge treatment area. Truck drivers:

application methods of fertilizing the soil, steadily release soil nutrients and are effective in decreasing soil nutrients losses.

In the preliminary market survey on the fortifer products, Ankrah and Owusu (2012) found out that the potential end users for the fortifer product are small scale farmers and few cash crop cultivators on a large scale. Table 2.3 shows the technical processes involved in producing the fortifer.

Table 2.4: Processes in producing fortifer, the potential actors and their respective role

Processes	Description of process	Actors / roles

		Transporting faecal
1st Sorting	Initial sorting is carried out off - site at the refuse dumps (markets) to remove plastics and other non-degradable materials	Contracted labour fo sorting and truck drivers
2nd Sorting / Shredding	Final sorting is carried on - site on the sorting platform. Big organic market waste are cut into pieces using the shredder	Takes place in the composting facility, which is owned and managed by a privat investor
Co- composting	Adding the organic market waste to the solid faecal sludge in the ratio 3:1, turning, adding water and monitoring the temperature (50 -55ºC required). Drying the matured compost. 60 days to produce a matured compost. A 150 m^2 platform carries 3 tons of co-compost	" idea as in 2nd sorting
Grinding	Matured compost are grinded into fine particles using the grinder	" idea as in 2n sorting
PHASE 2 Enrichment	Mixing starch (binder), ammonium sulphate and water to the grinded compost using the mixer. 3% starch (binder), 7% ammonium sulphate and 26% water	"
Pelletizing	The mixer from the enrichment stage is put into the pelletizer to form pellets. Evenly sized pellets required. Thus more pelletizer of the same size is required in the upscale project	"
Drying	The pelletized compost are sun dried on a platform. Drying of the matured compost for 2-3 days	"
Packaging	The dried pelletized composts are sieved,	"
		sludge and transporting solid faecal sludge to composting plant

weighted and packaged in size
of 300 – 500 g

Source: Nikiema *et al,*2013

2.7 Ownership structure for decentralized composting

Financing is a paramount factor for the commencement and sustenance of any business operations. Governments in developing countries spend large portion of their annual budget towards managing waste. Gradually, these governments are decreasing subsidies for services such as faecal sludge emptying, transport and disposal (Mehta and Knapp, 2004). In Ghana, the private sector has been actively involved in the sanitation sector. They have been successful without financial support in faecal sludge collection and conveyance, but not in treatment plant construction and operation (Evans, 1996; Murray *et al*., 2011a). These studies which support the success stories of the private sector do not state if private sector will be able to function successfully if waste is reused instead of being disposed. The government of Ghana envisions a complete privatization of the value chain of the sanitation sector by 2015 (MLGRD and EHSD, 2010). This expectation does not state whether the government will be relieved of its responsibility as key stakeholders in the sanitation sector. Hall and Lobina (2008) argue that the challenge is how to attract private investment in a sector which has historically been run by the public sector. They buttress this point by comparing the contribution of private sector in sanitation infrastructure in both developing and developed countries. In their book 'Decentralized composting for cities of low-and middle –income countries', (Rottenberger *et al*. 2006) provide different business partnerships and management models available for a co-compost production and the role played by the government or public sector (see table 2.5).

Table 2.5: Management models for a decentralized composting.

Options	Characteristics	Role of city or Government
Model 1 – Municipally owned- Municipally operated	Integrated into the existing municipal Solid waste management system and focused on reducing waste	Introduces recycling and composting into the Solid waste management (SWM) policy
Model 2 – Municipally owned- Community operated	Benefiting community is involved in the management of primary waste collection and composting. Non-profit seeking model	Introduces recycling and composting into SWM policy. Supports communities to develop proper system of waste collection and disposal. Provides support funds for constructing plants and the setting up of a primary waste collection
Model 3- Municipally owned – Privately operated	Benefiting community is partly involved. Profit seeking model is possible. At least full cost recovery (from fees and compost sales)	Introduce and implement recycling and composting policy. Investment (selects composting sites and construct plants). Contracts out the operation and maintenance. Monitors performance of contractors
Model 4 – Privately owned – privately operated	Profit seeking enterprise based on ideal compost market conditions. Income is generated through compost sale and collection fees	Introduces recycling and composting into the SWM policy. Transparent regulations. For public – private partnerships. Cooperates in supplying raw waste and disposal of residues

Source: Rottenberger *et al*., 2006

According to Murray et al. (2011b), the 'municipally owned – community operated' model has been effectively practiced in a decentralized module in China with waste water reuse. In Bamako, Mali, a partnership between Peace Corp volunteers and the local community was established to manage the faecal sludge through co-composting. However, the municipality was expected to play a key role in this project (Steiner *et al*., 2002). Among the models outlined in Table 2.4, studies conducted in some developing countries report that the most promising and relevant model for a low- income country is a partnership between the municipality and the private sector. Some of the projects that have been undertaken with this model are in Nam Dinh in Vietnam

(Klingel *et al*., 2001); Buobai treatment plant in Ghana (Steiner *et al*., 2002) and Mirpur, Dhaka in Bangladesh (Zurbrugga *et al*., 2005). The need for collaboration between private and public sector was emphasized by Cofie and Kones (2009). They noted in their study on co-composting faecal sludge and organic solid waste in Ghana that combining the process of faecal sludge drying and co-composting is costly for private companies.

Moss (2008) gives a different picture about the public private partnership model. He stressed on a privately owned and managed sanitation sector. He pins down the attractiveness of investment in the sanitation by the private sector to secured revenue stream, manageable risk profile, confidence and certainty in terms of engagement. Based on the difficulty of public and private operators in recovering the costs of operating wastewater treatment plants in China, he deduced that the sanitation sector in lower – income countries could not readily generate revenue streams to recover investments.

2.8 Potential bottlenecks of the fortifer business model

Continuity of operation is key, for the success of the business model. Identifying potential bottlenecks which might impede the continuity of operation is a critical subject to study. Therefore, this section delves into the bottlenecks related to the value chain of faecal sludge co-composting schemes. The discussion hinges on the following potential bottlenecks: availability of raw materials, scale of operation and the perception of the co-compost produced.

2.8.1 Availability of raw materials

The faecal sludge and organic solid waste are integral raw materials used in the production of the fortifer, hence their supply and availability is vital for successful running of production. In a study by Murray *et al*. (2011b) on evolving policies of public and private stakeholders in faecal sludge management in Ghana, the situational analysis of the level of faecal sludge treatment in Ghana were looked at. They pointed out that most of faecal sludge generated in Ghana is dumped off without treatment. They also observed that there is no accurate quantitative assessment of total volume of faecal sludge treatment in Ghana. An attempt to quantify sewage in Cameroon by Mougoue *et al*. (2012) looked at a combination of two methods to quantify sewage. These include counting trucks at the entrance of emptying sites and their classification according to the volume of the tanker and household demand for sewage services. The same method was used by Drechsel *et al*. (2004b) which used the logbooks of truck drivers who collect and dispose the faecal sludge. They opined that in adopting a business model which involves a partnership between the public and private sector, the implication will be that policy on the disposal of faecal sludge will be in the domain of the municipal assembly.

The aspect of interest to the private sector is the disposal of the raw faecal sludge to generate solid faecal sludge from the dewatering process. One issue of faecal sludge disposal which are not captured in most literature has to do with open defecation. Additionally, the availability of organic solid waste, which forms the majority part of the mixture in the co-compost, is vital. In Ghana, separation of waste is not popular.

Thus, there is limited or no literature concerning waste separation. According to Rottenberger *et al*. (2006), initial sorting of organic solid waste is required. They also stated in their study that the sorting process requires a lot of time. They concluded that although there will be substantial faecal sludge and organic solid wastes generated, quantification and availability of waste will be quite challenging. Nikiema *et al*. (2013) mentioned availability of raw material as a factor to consider when up scaling. They recommended in their study that considerations should be given to the needs of the market and the availability of raw materials in the area where project will be sited. Because, the quantity of faecal sludge readily assessed at dumping site and the amount of organic solid waste affect the continuity of operation.

2.8.2 Scale of Operation

According to Steiner *et al*. (2002), investment, operation and maintenance costs of faecal sludge management are influenced by their respective local conditions. Hence, they argue that these must be estimated based on each independent case. For the execution of the estimation of up scaling and comparison of treatment options, Steiner *et al*. (2002) considered that labour such as waste sorting and compost turning are manual. Niemeyer *et al*. (2001), in their paper 'The economic viability of organic waste composting' attributed the decision to mechanize the maturation phase of composting to the following:

- planned capacity of the plant
- available space and price of land
- available funds for the investment
- level of personnel costs
- level of funding to cover running costs
- existence of legal regulations governing emission values

Thus, Niemeyer *et al*. (2001) and Steiner *et al*. (2002) in their studies acknowledged that a mix of manual activities like sorting, turning and mechanized operations like grinding, mixing and pelletizing are suitable for an upscale project. Opting for a mechanized operation requires other investments in equipment such as an electricity generator for continuity of operation and skilled labour to run and operate the machines. This concern is emphasized by Harper (2004) who studied the "Anamol Krishi Udyog" composting business in India. Another critical process which could be mechanized during the up scaling exercise is the drying of the pelletized fortifer. In the pilot project of the fortifer business model, sunshine is used for drying. This requires a large platform for the drying process. Dependence on sunshine restricts operation during raining seasons in a year, thereby, affecting the scale of operation.

2.8.3 End users' perception of fortifer

A first step towards attracting private investors in the business model of using human excreta as co – compost is to find out whether the product will appeal to the prospective end users. In Ghana, the faecal sludge has been perceived as a cheap and effective source of soil nutrients. A study conducted by Danso *et al*. (2006) was focused on the end users' perception of the co-compost. This study looked at farmers' perception of co – compost from municipal solid waste and the potential cost of the co-compost in three selected cities in Ghana. Results from the study showed that most of the farmers perceived the cost of co-compost to be expensive, but majority of the farmers in these cities had a positive perception about the use of co-compost. Hence, low-cost but good quality co-compost is required. In a similar study conducted in the Effutu district, a predominant farming community of the Cape Coast Metropolitan Assembly, the results showed that majority of farmers are willing to use fertilizer from human excreta, although, some raised concerns about the safety of usage. This study concluded that collection and reuse of human excreta will help improve crop yield (Mariwah and Drangert, 2011). In addition to these perception studies on the use of fertilizer produced from faecal sludge, IWMI conducted a preliminary survey on end users' perception of upgraded co-compost produced from faecal sludge and

fortified with inorganic nutrients (Fortifer). The survey reports that farmers in four major regions in Ghana were willing to use the product. They also highlighted the possibility of enrolling fortifer as one of the fertilizers used by the government in the subsidized fertilizer programme.

CHAPTER THREE

METHODOLOGY

3.1 Study Area.

The study was conducted in the Tamale Metropolitan Assembly (TMA) and Kumasi Metropolitan Assembly (KMA) in the Northern sector of Ghana.

TMA has a population of 293,900 with a growth rate of 2.5% p.a and KMA has a population of 2,035,064 with 5.4% p.a growth rate. For several decades, some farmers in the larger Metropolitan area have used faecal sludge from on-site sanitation installations as their preferred soil ameliorant for crop production. Crop cultivated in the sludge fields include cereals, legumes and to a lesser vegetables (excluding all kinds of leafy vegetables eaten or uncooked). A detailed description of the sludge application practices is presented elsewhere (Cofie *et al.*, 2005; Seidu & Steinstrom, 2012).

3.1.1 Waste management system in Tamale

The waste collection system in Tamale is based on containers, which are distributed over the city and emptied as soon as they are filled up. Special contractors examine the container every morning and report to the Waste Management Department about the need of emptying. A sanitary landfill site is operational at Gbalahi, a peri-urban location 11 km northwest of the city Centre. It includes a sludge treatment system and is supposed to have a composting facility.

3.1.2 Waste management system in Kumasi

The solid waste collection in Kumasi is done by the Waste Management Department, which operates 124 waste transfer stations. These stations are enclosed spaces, sometimes equipped with a container, which are emptied regularly (once a week to twice a month). They are distributed throughout the city, but do not cover the city sufficiently so that the inhabitants additionally dump their waste on illegal dumping sites within the city. Moreover, the transfer sites are often insufficiently maintained and emptied so people dump their waste in surrounding areas. The Waste Management Department has several trucks which collect the waste from the transfer sites. Private companies cart the waste to the Dompoase landfill site.

3.1.3 Night soil in Tamale

Calculating with a daily production of 0.15 kg per person, about 16,400m^3 of sludge is produced every year in Tamale. The liquid waste collection in Tamale is done by private contractors and the Waste Management Department with trucks, one collection is GHS 15. A landfill at Gbalahi is in operation. The collected sludge is 90% discharged into depression around the city and often used in peri-urban agriculture sites (Asare *et al*., 2003). The latter is done in the dry season between October and April/May. During the rainy season in June to September the contents of septic tanks are only dumped at different places in the outskirts of the city.

Farmers prefer the contents of public toilet septic tanks to private household tanks as these generally have a much higher water content which makes application difficult. According to logbooks of the truck drivers, about 14,900 m^3 per year of sludge are collected from households and public toilets. Out of this, over the whole year about 4,200 m^3 are dumped into nature including streams and would be available for composting, with a monthly amount of 160m^3 in the dry season (October to April) and 740 m^3 during the rainy season (June to September). This is a minimum amount.

3.1.4 Night soil in Kumasi

An amount of 183,000 m^3 of night soil is collected via various on-site systems (WC, latrines, VIP, etc.) with 36% being public toilets (Mensah, 2004). Until very recently, nightsoil was discharged at Buobai and Kaase which exceeded both design capacities on daily base and overall capacity after a short period of several months. A new and larger treatment site with a design capacity of 500 m^3/day is operational in Dompoase. So far, Buobai and Dompoase have not been desludged and the actual amount of settled sludge per year is not known. For the first pond at Buobai an annual sludge volume of

4000 m^3 (wet) has been estimated which corresponds with a similar wet weight or a dry weight of approximately 600 t, which would be available for composting if the appropriate logistics for transport are in place. The new Dompoase site can accept about 2.5 times the intake of Buobai, thus will provide at least a similar amount of sludge per year.

3.2 Data collection

The information needs, of the study were addressed using different sources of data. Secondary data were extensively collected, evaluating national and municipal reports and statistics as well as research studies and consultancy reports. These sources were especially useful in the assessment of household and market waste as well as night soil (human excreta).

In-depth interviews were conducted with staff of Waste Management Departments, municipal administrations, waste truck drivers, fellow researchers and experts working in NGOs and donor agencies in order to update, verify and enhance data obtained from secondary sources. This was essential as the coverage of these reports was very limited, and data sources and reliability often unclear. Secondary information were also obtained from Ministry of Health (MoH) on diarrhoeal cases in the metropolis, MoFA on the output of maize in the metropolis using chemical

fertilizers,

Additionally, primary data collection was done in peri-urban villages around Kumasi and Tamale on diarrhoea infectious cases. The study was conducted using 50 faecal sludge applying agricultural households in the TMA and KMA. The household were drawn from five peri-urban areas of the Metropolis where faecal sludge application in agricultural fields has been practiced for decades. Focus group discussion was also used to capture information on the costs of using the sludge in crop production.

Financial costs and benefits of the proposed project were also obtained from IWMI.

3.3 Conceptual Framework for Economic Analysis

Financial analysis looks at the viability of the fortifer project given the market prices of inputs and outputs. Economic analysis on the other hand provides a measure of the impact of the project from the viewpoint of the whole economy. That is, whether the proposed composting project would contribute to the overall welfare of the economy in terms of national income. This was achieved by valuing inputs and outputs to reflect their scarcity values. In the process, the financial accounts were converted to economic accounts by converting market prices to shadow prices so as to reflect their opportunity cost or the scarcity value. In doing so, the approach of Gittinger (1982) was used extensively.

Potential externalities related to the project were also valued using conventional valuation approach of Mburu, (2002). It looks at the impacts of sanitation degradation on human health, and the effects this has on individual's and society's productive potential. It establishes a direct cause and effect relationship between FS and infection of diarrhoeal diseases.

According to Kwon, (2005), a project should be assessed for economic feasibility along with technical specifications because a project is of little value if it cannot benefit either a project proponent or a community. For this reason, it is necessary to identify all of the costs and the benefits of a project. There are two techniques commonly adopted in economic analysis: financial analysis and cost-benefit analysis (CBA). But social CBA was employed in the study since it quantifies all possible costs and benefits in terms of social gains and losses. The framework below (fig 3.1) was used in conducting the economic analysis for the proposed project.

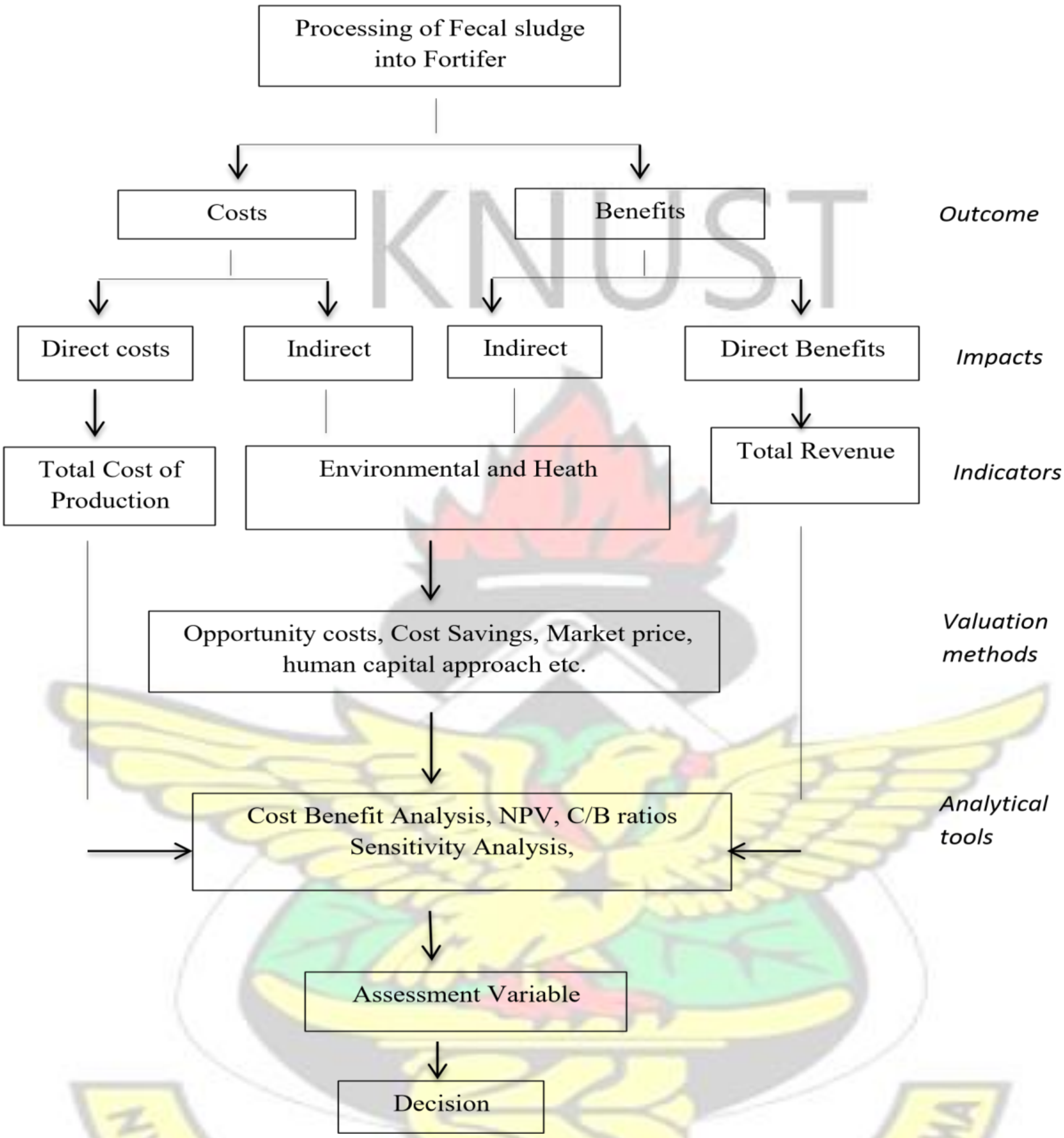

Figure 3.1: Framework for economic analysis of Fortifer Project.

3.4. Identification of alternatives

In this project, two models composting facilities were identified for the faecal sludge and market waste composting. Models/ Alternatives 3 and 4 are decentralized facilities sited near and within the metropolis. The alternatives are described in more detail in section in 2.6

3.4.1 Identification of components of costs and benefits

There are three basic types of costs and benefits: capital cost, operation and maintenance costs and benefits. Capital costs are initial investment costs in order to establish a project. They are generally one of the largest items in project expenditure.

Each item under capital costs can have a different lifetime (Curry and Weiss, 1993, Kwon, 2005). For instance, land preparation will be permanent, and does not need to be repeated, while machinery has a limited lifetime. In this case, machinery requires replacement, which incurs replacement costs. Operating and maintenance funds are necessary to operate and maintain an item until the end of the life of the project. Operating cost is measured on an annual basis, but maintenance costs can be assessed on an as-needed basis. Machinery either has a regular annual maintenance schedule or is repaired when necessary. Benefits are from the output of the project, or from cost savings. There can be revenue from the sale of a product and indirect benefits either outside or inside of organizations. For example, organic waste disposal at landfill would be avoided by composting, bringing reduced disposal cost to communities and infectious diarrhoeal cases would also reduce.

Based on the three types above, in this study, components of costs and benefits related to composting activity were identified and estimated, based on the data from on-site interviews, local market surveys and literature.

Capital costs involve land preparation, facility construction, utility installation, and equipment and vehicle acquisition. Operation and maintenance costs include labor, utilities, tools and supplies, fuel, vehicle maintenance, transportation cost, land leases and so on. Last, as benefits, fortifer sale, avoided landfill costs and reduced infectious diarrhoeal cases were considered. (Appendix A gives more details of each component). Other costs and benefits, such as environmental impacts due to emission of greenhouse

gases (GHGs), increases in property value, eutrophication and increased crop yield were also described. The monetary value of the items in the table
2.6 were quantified and aggregated to estimate the total costs and benefits.

3.5 Shadow Price of Labour and Land

The opportunity cost of unskilled labour was valued at the going market wage and further reduced by a standard conversion factor of 0.28. The conversion factor used here is calculated from the official exchange rate. The opportunity cost of labour was calculated by estimating the total man days required for the project in the peak season and multiplying that by the wage rate in the area for the peak season and reduced further by the conversion factor. The peak season is the season when everybody can find work to do. At that period, the opportunity cost of labour could be equal to the marginal productivity of labour. But it is not clear as to how many days of work would be available in the peak season. In Tamale and Kumasi, farmers who are not going into production could readily find casual work in the building industry which fetches them GHS 35 per man day or can work on a neighbour's farm for GHS 30 per man days. This assumption was also made by Otabil, (2013) and Gittinger (1984). For the skilled labour the minimum wage rate of GHS 6.0 and a fringe benefit of 15% on salary per month were used to reflect the scarcity value of a skilled labour. This assumption was also used by Hutton *et al.,* (2004).

The opportunity cost of land was valued using agricultural use of land in farming maize crop in the study area, where the use of one acre of land pays for 1bag of maize at harvest which gave an average price of GHS80.Other inputs costs and utilities were all taken as a true economic costs and so no adjustment of cost was required.

3.6 The choice of the Social discount rate.

The actual value of the discount rate is important, as it has a potentially large impact on the results. Values used in the literature vary between 0% and 10%, and arguments can be found to support this wide range (WHO, 2006). The sources generally argued to best reflect social time preference are the market interest rate or the government discount rate .But it should be recognized that the latter is often based on the former. A competitive market interest rate reflects the average preference for future over present consumption. However, this can be strongly influenced by the level of economic development of a society. For example, in a developing country such as Ghana, the amount of savings people can put aside means that there is limited capital available for entrepreneurs or households to borrow. Hence, interest rates may be higher than in developed countries. Furthermore, the gross market interest rate does not reflect the return on investment to private investors, who have to pay tax on the income they earn from interest payments. Also, private investment decisions do not (fully) reflect the interests of future generations. Hence, a lower discount rate would give future generations greater weight in the analysis, both on the cost and impact side. For consistency with previous guidelines, discount rate of 9% was used and this is also in conformity with the IMF interest rate on loans to Ghana.

3.7 The choice of Time period/horizon

Traditionally, CBA evaluates investment projects, where intervention costs are frontloaded (i.e. principally incurred at or near the beginning of the project) and benefits tend to be delayed and spread over a longer period (WHO, 2006). CBA with a short time horizon would tend to reduce the benefit–cost ratio of the intervention. On the other hand, when the discount rate is relatively high (e.g. more than 5%), the costs and impacts occurring in the distant future are relatively small compared to the current. An additional problem with extending the time horizon of the analysis to the long-term, e.g. beyond 20 years, is that costs and impacts become increasingly uncertain. Hence, a time horizon of 20years was used in this analysis. Also cost– benefit analyses traditionally measure intervention effects for a maximum of 15–20 years (WHO, 2006).

3.8 Projected Cost and Benefit Stream

The following assumptions were made in computing the projection for the costs and benefits streams for the fortifer project for the two scenarios.

- The benefits and costs were projected over 20 year period.
- Approximately 4tonnes of fortifer produced in a day and1152tonnes of fortifer produced per year.
- Depreciation was calculated using straight line and reducing balance for building and machinery with 3% and 10% respectively.
- 9% social discount rate was used to reflect societal preference for future consumption to present consumption.
- The cost of input (inorganic minerals) was increased by 14% from the eight year to the twentieth year.
- Cost of water, electricity, fuel and telephone were increase by 10% annually.
- Labour costs (wages and salaries) increase by 10% from the seventh to the twentieth year.

Two currencies, the Ghana Cedis, and the US dollar, are commonly used in Ghana. All the costs and benefits in this study were converted to US dollars. Exchange rates applied in this study are as follows.

- 1 US dollar = 3.60 Ghana Cedis

In this study, cost-benefit analysis was conducted to estimate the externalities- the indirect costs and benefits of the project. This CBA requires a general framework which identifies and assesses impacts- positives and negatives of the project and the procedure is outlined below.

1. Identifying Project Impacts
2. Identifying Impacts that are of Economic Relevance
3. Physical Quantification of Relevant Impacts
4. Monetary Valuation of Relevance Effects
5. Discounting of Costs and Benefits Flows
6. Applying the Net Present Value Test
7. Conduct sensitivity analysis

3.9 Identifying Project Impacts.

These impacts indicators in Table 2.6 are associated with the project, both benefits and costs.

Table 2.6: Indicators for indirect costs and benefits associated with Fortifer business model

	Benefits	Costs
Social		
	Increase in yield/productivity	
	Increase in property value	
Health		
	Health care costs savings	Increased health risks due to possible pathogen survival
	Productivity gains due to improved health Time savings	

Environmental	Estimated GHG emissions reduction	Estimated GHG emission from process
	Area of landfill saved and cost saving of land used for dumping sites.	Observed eutrophication

Source: IWMI, 2013

3.10 Identification of Impacts that are of economic relevance

Due to problems in measurement and valuation of some of the economic benefits arising from fortifer project, the aim of this present study was not to include all the potential economic benefits that may arise from the project, but to capture the most tangible and measurable benefits. Some less tangible or less important benefits were left out for three main reasons: the lack of relevant economic data available (Hutton 2007); the difficulty of measuring and valuing in economic terms some types of economic benefit (Hanley & Spash 1993; North & Griffin 1993; Field 1997); and the context-specific nature of some economic benefits which would reduce their relevance for cost-benefit analysis study. Instead they would be described.

Under this study six (6) impacts indicators were considered. Health impact was looked at on the basis of infectious diarrhoeal cases in the project area: health care saving, Productivity gains due to improved health, time saving, and Environmental; cost saving of dumping sites and increase in crop yield.

This approach was adopted not only because of the difficulties of measuring some types of economic benefit due to environmental changes (Hanley *et al*,1993;Fied,1997), but also because the selected benefits were those most likely to occur in all settings. The other benefits and costs tabulated in the Table 2.6 were not included in the cost-benefit analysis. They would be described briefly, with a justification for leaving them out.

3.11 Physical Quantification and Valuation of Relevant Impacts

After identifying all the relevant impacts (based on input from a multidisciplinary team of experts), the next step was to quantify them in physical terms where possible.

Here the application of “with and without” principle is relevant.

The impacts of fortifer production can be measured as the differences between the scenarios; with fortifer production and without fortifer production—the actual change in impacts. The aim here should be to separate out only the impacts that are clearly associated with fortifer production and not include those impacts or changes that would have occurred even without fortifer production. With and without is a useful tool in quantifying impacts of any intervention or policy (Hassain *et al* 2001). It is important to note that only incremental net impacts were associated with the fortifer production situation. For this study the scenarios used were the project scenario; compost (fortifer) production and no-project (base or current) scenario; landfill/wild dumping or raw fecal sludge use in agriculture.

Figure 3.2. Represents the framework for valuing the various impact associated with the fortifer project. This framework is similar to others applied in Pakistan by IWMI in valuing the impacts of wastewater irrigation (Hussain, *et al.* 2001).

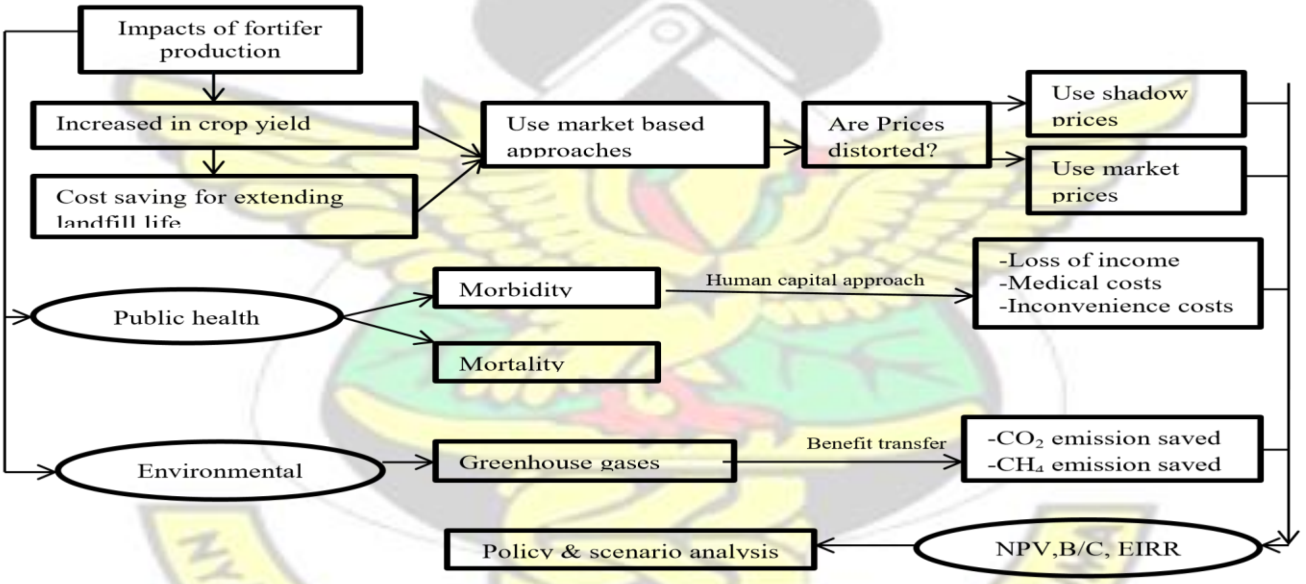

Figure 3. 1: The framework for valuing the various impacts associated with the fortifer project.

3.12.1 Estimating Health Benefits

Health benefits of the project were valued using conventional economic methods of valuation. To be specific human capital approach and market price (Hanley *et al.,* 1993; Curry *et al.,* 1993)

The analysis has been restricted to infectious diarrhoea as it accounts for the main disease burden associated with poor water, sanitation and hygiene (Prüss *et al*., 2002). The following outcomes are taken as being associated with diarrhoeal disease:

- Reduction in incidence rates (cases reduced per year).
- Reduction in the number of deaths (deaths averted per year)

A risk reduction of 37% of diarrhoeal cases avoided based on the current water treatment at the point of use (Haller *et al*. (2007), was used to estimate the cost saved from diarrhoeal diseases due to the project.

Table 2.7: shows the components looked at in estimating the health benefits and the beneficiary.

Beneficiary	Direct economic benefits of avoiding diarrhoeal disease	Indirect economic benefits related to health improvement
Health sector/Patients(adults)	Less expenditure on treatment of diarrhoeal disease and less related costs	Value of avoided days lost at work or at school
	Less expenditure on transport in seeking treatment	
	Less time lost due to treatment seeking	

3.13 Mathematic Model for Valuing Impacts

3.13.1 Health benefits

As mentioned earlier, there could be potential risk of disease (s) or mortality (extreme case) with faecal sludge use or its exposure to the environment. Illnesses caused by faecal-oral pathogens may result in:

- loss of potential earnings;
- medical costs;

Loss of potential earnings or labor productivity was evaluated using opportunity cost principle. These losses are quantified in economic terms by using the information on prevalence of disease (on number of sick days, both full-time and part-time, and offwork, generally called restricted activity days in literature), daily wage rate and incidence of disease.

The loss of potential earnings in the case of employed population, due to morbidity caused by infectious diarrhoeal was estimated in the following manner.

A Labour productivity loss due to diarrhoea diseases was valued using this approach.

$$PL = \sum\{(SD_i * WR_i * ID_{fc}) \qquad (1)$$

Where:

SD is the number of sick days attributed to faeco-oral pathogens per person per year

WR is the average wage rate

IDfc is the incidence of diseases or percent of population affected

Medical or healthcare costs may be added to obtain total costs of health related illnesses. The medical costs include the cost of medical consultation, cost of medication, transport cost. The WHO regional cost data was used as proxy (opportunity cost) for medical costs as public healthcare is highly subsidized in most developing countries like Ghana (WHO, 2007; Hassain *et al,* 2001).

Medical costs MC may be calculated as follows:

$$MC = \sum \{(CC + MC + TC + OC)\ i\ (ID_{fc}) \qquad (2)$$

Where

CC is the cost of medical consultation

MC is the cost of medicine

TC is the transport cost

OC are the other health sector assumptions

ID_{fc} is the incidence of diseases or percent of population affected

3.13.2 Cost saved due to reduced diarrhoeal cases

For ease of comprehension and interpretation of findings, the benefits of the fortifer project (sanitation improvements) were classified into two main types: (1) direct economic benefits of avoiding diarrhoeal disease; (2) indirect economic benefits related to health improvement.

3.13.3 Direct economic benefits of avoiding diarrhoeal diseases

The direct economic benefits of the project consist partly of costs averted due to the prevention or early treatment of disease, and thus lower rates of morbidity. “Direct” includes the value of all goods, services and other resources that are consumed in the provision of the intervention or in dealing with the side effects or other current and future consequences linked to it (Gold et al. 1996). The savings associated with other sanitation-based diseases are excluded as only infectious diarrhoeal disease was included in this study. Costs saved due to less cases of diarrhoeal may accrue to the health service (if there is no cost recovery), the patient (if cost recovery). In economic evaluation, what is most important is not who pays, but what are the overall use of resources, and their value. Therefore, in the current analysis, the health service direct cost of outpatient visits and inpatient days are assumed to equal the economic value of these services.

For the treatment of diarrhoea, unit costs included the full health care cost (consultation and treatment), which is GHS 36.22.The total cost savings were calculated by multiplying the health service unit cost by the number of cases averted, using assumptions about health service use per case. The analysis assumes that 8.2% of diarrhoea cases seeking outpatient care are hospitalized (World Health Organization, 2007), with an average length of stay of 5 days each. Other forms of treatment seeking are excluded due to lack of information on health seeking behaviour for informal care or self-treatment and the associated costs.

Non-health sector direct costs are mainly those that fall on the patient, costs usually related to the visit to the health facility, such as transport costs to health services, other visit expenses (e.g. food and drink) and the opportunity costs of time. The most tangible patient cost included was the transport cost, although there is a lack of data reported on average transport costs. In the base case it was assumed that (70%) of diarrhoea cases seeking formal health care take some form of transport, excluding other direct costs associated with the journey. Other costs associated with a visit to the health facility were also assumed such as food and drinks, and added to transport costs making GHS10.

The assumption that improved water and sanitation (composting, proper disposal site for faecal sludge) reduces diarrhoea cases by 37% was used for this estimation. This assumption was also used by (Haller, 2007).Time costs avoided of treatment seeking are assumed to be included in the time gains related to health improvement.

3.13.4 Indirect economic benefits related to health improvement

A second type of benefit looked at in this study is the productivity effect of improved health (Gold et al. 1996). These are traditionally split into two main types: gains related to lower morbidity and gains related to fewer deaths. But for this study, gain related to fewer deaths was not tackled since data was not obtained.

In terms of the valuation of changes in time use for cost-benefit analysis, the convention is to value the time which would be spent ill at some rate that reflects the opportunity cost of time. It is argued that whatever is actually done with the time, whether spent in leisure, household production, or income-earning activities, the true opportunity cost of time is the monetary amount which the person would earn if they were working (Curry & Weiss 1993).

However, given that many of the averted diarrhoeal cases will not be of working age, the population is divided into three separate groups and their time valued differently: infants and non-school age children (children, 5 years); school age children until 15; and adults (age 15 and over).This study only focused on the time value of adult cases since they fall within the working age group.

For those of working age, the number of work days gained per case of diarrhoea averted is assumed to be 2 days per case. The value of time is taken as the minimum wage rate in the year 2014 which is GHS 6.0, as it reflects the average economic value of a member of society. Also, from an equity perspective, it is appropriate to assign to all adults the same economic value of time, so that high income earners are not favoured over low or non-income earning workers or men over women.

3.14 Non-health benefits

There are many and diverse potential benefits associated with improved sanitation through the composting of faecal sludge to fortifer, ranging from the easily identifiable and quantifiable to the intangible and difficult to measure (Hutton, 2001).Two potential benefits estimated under this section are; increase in crop yield and cost saved due to fewer landfill disposals. A social cost-benefit analysis should include all the important socio-economic benefits of the project, which includes both cost savings as well as additional economic benefits resulting from the project, compared with a do-nothing scenario (that is, maintaining current conditions) (Curry & Weiss 1993; Drummond *et al*., 1997).

As a general rule, these benefits were valued in monetary terms – in Ghana Cedis & United States Dollars (US$) in the year August, 2014 – using conventional methods for economic valuation (Curry & Weiss 1993; Hanley & Spash 1993; Field 1997). Details concerning the specific valuation approaches are described for each benefit below.

3.14.1 Cost Saving from fewer landfill disposals

The potential cost savings were incorporated into the estimation of benefits. Cocomposting reduces the need for landfill disposal by diverting organic waste to a composting facility. As a result, the landfill tipping fee, GHS 2.50/tonne, is saved.

Below is the equation to estimate the amount of money saved from fewer disposals.

Cost saving from landfilling = GHS 2.50/tonne × total waste diverted to a composting plant (tonne/year) (3)

3.14.2 Increased in crop yield

Information obtained from (IWMI), Adamptey *et al* (2009) involving the use of faecal sludge, Co-compost(fortifer) and chemical fertilizer on the performance of maize crop was used in the quantification and valuation of the impact of the project on agricultural output.

$$\text{Benefit or value of Co-compost (fortifer)} = NVO_{w} - NVO_{wo} \quad (4)$$

$$\text{and } NVO_{w} = GVO_{w} - C_{w}$$

$$NVO_{wo} = GVO_{wo} - C_{wo}$$

Where NVO is the net value of output, GVO is the gross value of output; C is the total cost of production, subscripts *w* and *wo* represent with and without Co-compost (fortifer).

The costs of production for the various scenarios to be treated under this study are the same except for the prices of the fertilizers and the quantities used.

Therefore the cost of production for the various scenarios would be:

The Price of X, Y, Z multiply by the Quantities of X, Y, and Z

Where, X, Y, Z represent Co-compost (faecal sludge and MSW), Chemical fertilizers and Untreated faecal sludge used in crop production respectively.

3.15. Estimation and discounting of costs and benefits

This step is a demanding task to gain a clear picture of the true costs and benefits of a project. Desirability of a project is usually expressed in terms of money. Not only are costs and benefits expressed in monetary value, but also they should be expressed in terms of the time value of money, that is dollars at a particular time. Generally, resources used or generated in earlier years are weighed higher than those in later years. This weight, called discounting factor, over a certain period can be mathematically expressed as follows (Watkins, 2004; Szonyi, *et al.*, 2000; Nas, 1996; Curry and Weiss, 1993).

$$\text{Discounting factor} = \frac{1}{(1+r)^n} \qquad (5)$$

Where, r = compounded discount or interest rate (in decimals)

n = number of years in the future

There are assumptions in this equation that the discount rate is constant year to year, and the same rate is applied to both costs and benefits. Given the discounting factor, the following equation shows the relationship between the present value (P) and the future value (F) of an amount of money.

$$P\text{- } F \times \frac{1}{(1+r)^n} \text{– } F\ (P \mid F\ r, n) \qquad (6)$$

-where, r = social discount rate (in decimals) n

= number of years in the future

3.16 Selection of a project alternative by Applying NPV, B/C ratio test.

The main purpose of CBA is to help select projects which are efficient in terms of their use of resources. Therefore, after carrying out a CBA the criterion of Net Present Value (NPV) is used. This criterion simply asks whether the sum of discounted gains exceeds the sum of discounted losses. If the sum of discounted gains exceeds the sum of discounted losses, then the project is said to represent an efficient shift in resource allocation. The NPV of a project is calculated as follows

$$\text{NPV} = \sum B_t \ (1+i)^{-t} \quad - \sum C_t \ (1+i)^{-t} \qquad (7)$$

The summation run from t =0 (the first year of the project) to t =T (the last year of the Project, i=social interest rate .The criterion for project acceptance is; accept if and only if NPV>0. Given two project with positive NPV the one with a higher NPV should be selected.

The C/B ratio approach was also applied together with EIRR in this study.

$$\text{B/C} = \sum \frac{B_t \ (1+i)^{-t}}{C_t(1+i)^{-t}} \qquad (8)$$

Economic internal rate of return (EIRR)

$$\text{EIRR} = \text{LDR} + (\text{HDR-LDR})^* \left[\frac{(NPV@LDR)}{(NPV@LDR - NPV@HDR)}\right] \qquad (9)$$

Where: LDR=Lower Discount Rate

HDR=Higher Discount Rate

From these equations, the probability of making a loss can be estimated as when EIRR < i (discount rate) for equation 9 and when B/C < 1 for equation 8.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Presentation of results

This analysis generated a huge quantity of data. Selected results are presented for the two alternatives/scenarios. Cost-benefit ratios are presented for all costs and benefits together. The sensitivity analysis presented reflects the high cost assumption and low benefit assumptions, to give the most conservative cost-benefit ratios. Other cost and benefit outputs like the NPV and EIRR were also calculated for.

In brief, the calculation of the total societal economic benefit is the sum of:

- Health sector benefit due to avoided illness
- Patient expenses avoided due to avoided illness
- Value of productive days gained of those with avoided illness
- Landfill cost saved due to fewer disposals
- Direct project benefits and costs, detailed in (appendices A &B)

Values on the impact of the fortifer on increase in crop yield was also calculated for, but not included in the CBA.

4.2. Treatment costs saved due to less diarrhoea cases

The potential annual health sector costs saved in the regions due to reduced infectious diarrhoea cases avoided was estimated to the tune of GHS 461,592 million per year and patients non-health sector amounted to GHS 55,873 per year. The two figures amounted to a total cost saved due to reduced diarrhoea treatment cost of about GHS 517,500 to the regional economy. Table 4.1 shows a summary of the direct costs incurred for the treatment of diarrhoeal diseases in the health sector.

Table 4. 1 : Treatment costs saved due to less diarrhoea cases

Total diarrhoea cases for adult/year	6864			
Total diarrhoea cases to be averted by the fortifer project (37%)	2540			

Patients	Unit treatment cost/visit/day (GHS)	Visit/day/case	% of patients to be treated	Total treatment avoided/year(GHS)
Outpatients	36.22	1	8.2	84444.26
In-patients	36.22	5	91.8	377147.56
Subtotal				**461591.82**
Other treatment costs savings				
T&T and Food				25396.80
Income gained due to days lost work avoided/yr				30,476.16
Total cost		**517,465 saved**		

Source: Author

4.3 Estimating Cost saving from fewer landfilling disposal

Here, the analysis reveals that GHS 25,000 worth of waste is saved from reaching the landfill site per year as result of diverting 10,000tonnes of waste to the compost site, thereby extending the life span of the land fill site. The calculation was based on the 2013 average waste deposition, which is 284120tonne for the reference year.

Table 4. 2: Cost saved from landfilling

Total waste deposited at the landfill site/tonne/year.	284,120
Unit cost/tonne(GHS)	2.5
Total waste diverted to the project site/tonne/year.	10,000
Total cost saved from land filling as a result of the project(GHS)	25,000

Source: Author

4.4 Estimation of co-compost (Fortifer) effect on the yield of maize

Table 4.3 below compares the effects of co-compost, untreated faecal sludge and inorganic fertilizer on the yield performance of maize crop base on the nitrogen content and requirement as recommended by the FAO and Grain and Legume development board-Ghana. According to Cofie *et al* (2009), maize requires a minimum of 91 kg N /ha and a maximum of 210 kg N/ha for successful growth and development in Ghana.

Table 4. 3 Effect of FS and Co-compost on the yield of Maize

Fertilizer	Application rate	Yield (kg/ha)
Soil+ Faecal Co-compost	14 t /ha	5071.35
Soil + Faecal (S+FS)	7.3 t/ ha	6180.48
S + NPK + $(NH_4)_2SO_4$	450 kg NPK + 399 $(NH_4)_2SO_4$	5630.56

Source: Adamptey *el al* (2009) 100kg of maize = GHS80 (April, 2013) From the table, it reveals that maize responded favourably well to untreated FS than any of the other fertilizers. The average annual maize yield for raw faecal sludge was 6180.48kg/ha/yr and that for faecal co-compost (fortifer) was 5071.35kg/ha/yr whiles, Inorganic fertilizer gave 5630.56kg/ha/yr .The maize yield for inorganic fertilizer was 5.2 percent higher than co-compost.

Whiles the maize yield for raw faecal sludge was 9.9 percent higher than co-compost.

This gave negative yield effects of 11.09bags of maize to co-compost and 5.5bags to inorganic fertilizer, yielding negative effects of GHS 887.30. The result is not surprising since untreated FS contain urine which by itself contains appreciable amount of nitrogen and water which also complement yield.

4.5 Other Impacts (Benefits and Costs) Described.

The other benefits and costs tabulated in Table 2.5 were not included in the cost-benefit analysis. These benefits were described briefly below, with a justification for leaving them out.

Indirect effects on vector-borne disease transmission resulting from faecal sludge (FS) composting depend on many local factors and are therefore difficult to estimate in monetary terms.

GHGs emission reduction due to the project was not factored in this analysis because trucks transporting waste to the project site emits gases, at same time FS and its composting process produce more GHGs which makes it difficult to quantify the quantities of GHGs emission from the process. Again in Ghana, Clean Development Mechanism (CDM) is not yet fully operationalized therefore data problem is paramount.

Eutrophication of water bodies due to discharged of leachate from faecal sludge was also left out from this analysis because nutrient such as phosphates and sulphates which could cause weeds to grow in water bodies could also come from other source such as inorganic fertilizers as a results of farming along river banks. So it would be difficult outlining which eutrophication is caused by leachate from FS or the use of inorganic fertilizer for farming. Therefore its omission from the analysis.

In areas with improved sanitation, due to the project, property value is likely to increase, North, *et al* (1993). Such an increase is, however, indirect and difficult to evaluate without databases from the regions, and if entire areas receive the improvements the market may not be able to support price increases. Moreover, property value increases represent a transfer of resources and not a gain to society per se, hence its omission.

4.6 Cost Benefit Analysis

4.6.1 Costs and Benefits of the Decentralized Fortifer Composting Facilities.

4.6.2 Alternatives of Composting Facilities

This project examines the costs and benefits of two Fortifer composting alternatives, and evaluates the economic viability of each. Out of the four alternatives proposed by Rottenberger *et al*. (2006), two of them were analyzed; this is because only these two models have profit making as one of components:

- Model 1- Municipally owned – Privately operate.
- Model 2 – Privately owned – privately operated

4.6.2.1: Model 1-Municipally owned – Privately operate.

Model 1- community is partly involved. Profit seeking model is possible. At least full cost recovery (from fees and compost sales).

4.6.2.2 Total Capital Costs

Capital costs involve the facility construction, utility installations, and the equipment and truck purchase. There is no land cost because the site would be donated by the community in this case near its landfill site. Since land was donated by community its opportunity cost as in it being employed in agriculture production was used in valuing the land. This gave land cost to be GHS 3,000 as compared to GHS80, 000 for model

2. Therefore, total capital costs amounted to GHS345714. The Table 4.4 represents the summary of the capital costs and figure 4.1 showing the proportion of capital cost in percentages. For detailed about the capital expenditure see appendix E.

Table 4.4 Total capital costs

Item	Amount(GHS)
Machinery, equipment and Plant cost	17,633
Installation	33,647
Building	159,424
Trucks	132,010
Total Cost	345,714
20year annual amortization cost	19,687

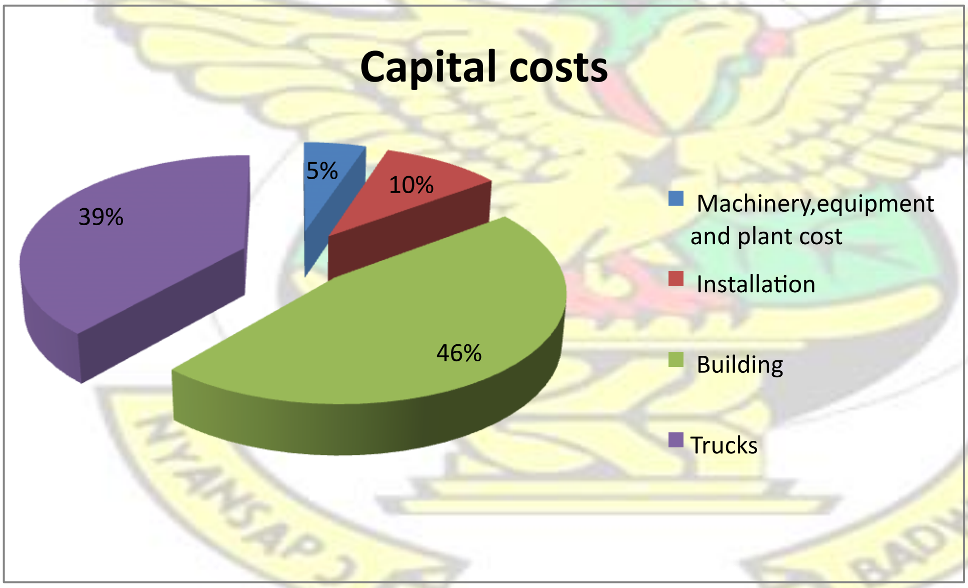

Figure 4. 1 Proportion of capital costs expended.

Depreciation of capital cost is equivalent to GHS19, 687 when the total cost is amortized over 20 years with a 13% interest.

4.6.2.3 Operational and Maintenance Costs

Table 4.5 Operation and maintenance costs.

Expenses	Annual cost(GHS)
Raw material costs	165,024
Wages and salaries	107,352
Utilities, tools and supplies & Maintenance	42,377
Transportation	12,000
Advertisement	90,900
TOTAL	417,653

Source: Author

Total operation and maintenance costs amount to GHS417, 653/year. The largest portion of O&M costs is raw materials, which comes to GHS165, 024/year. This is so because of the inorganic soil amendment which is used to fortify the compost. Wages and salaries also take the second largest portion of O&M. The required number of people is 18, involving 12 operators, one truck driver, 3 security men, one supervisor and one office clerk. Figure 4.2 below shows the proportion of the various O&M costs components

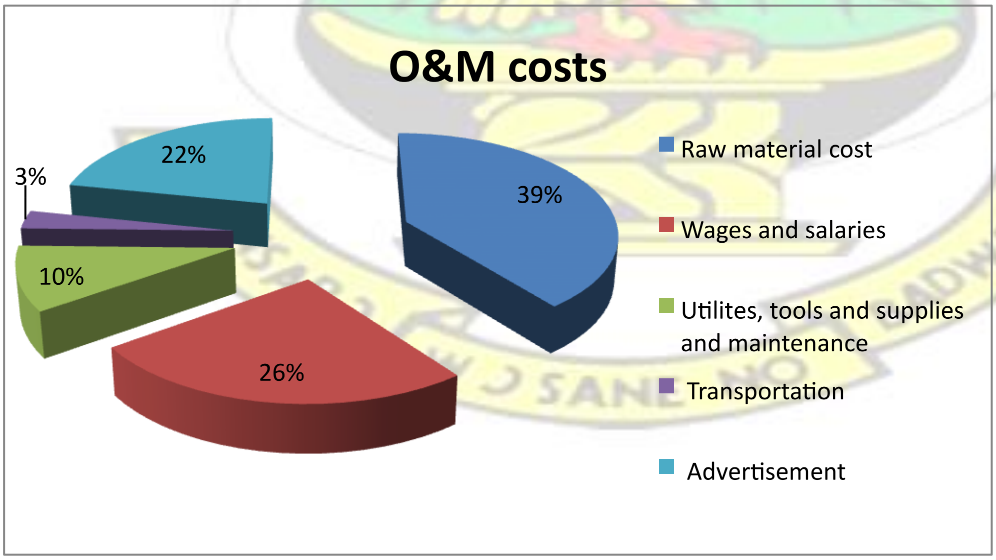

Figure 4. 2: The various components of O&M costs in their respective percentages

Detailed picture of all the O&M costs is in the appendix F.

4.6.2.4 Benefits

The composting plant creates around GHS 1,187,600 of benefit every year as represented in table 4.6

Table 4.6: Summary of benefits of the Project.

Components	Unit	Unit value	No. of unit/year	Total(GHS/year
Benefits				
Sales of co-compost	GHS/50kg	28	23,040	645,120
Cost savings				
Landfill disposal avoided	GHS/tonne	2.5	10,000	25,000
Diarrhoea treatment cases avoided				517,465
TOTAL				1,187,585

The calculation of total benefits is quite straightforward. The revenue generated from the sale of compost comes to GHS645, 120/year. There is also benefit from the cost savings. First, the cost avoided from landfill disposal reaches GHS 25,000/year when 10,000 tonne/year of waste were diverted, with the landfill tipping fee of GHS 2.5/tonne. In addition, the composting facility is likely to save to the sum of about GHS 517,465 of infectious diarrhea treatment cost.

4.6.3. Model 2 – Privately owned – privately operated

Model 4 is a profit seeking enterprise based on ideal compost market conditions. Income is generated through compost sale and collection fees.

4.6.3.1 Capital costs

In model 2, the capital costs is almost the same as for model 1, amounting to about GHS422, 714. The difference between these two alternatives is because in this site the land was purchased outright whiles in the other alternative it was donated. Other costs are all the same in both alternatives. The amortized annual cost is GHS19, 687 over 20 years with a 10% and 3% depreciation rate on equipment and building respectively. Land was not depreciated that is how come we have the same amortization cost for both alternatives Table 3.4 summarizes the components of capital costs and the estimated costs of components.

Table 4.7 Total capital costs

Item	Amount(GHS)
Machinery, equipment and Plant cost	17,633
Installation	33,647
Land and Building	239,424
Trucks	132,010
Total Cost	422,714
20year annual amortization cost	19,687

Source: Author

4.6.3.2 Operational and Maintenance Costs

In this alternative, the operation and maintenance costs amount to GHS417, 653/year in total. The salary paid, in total, is GHS107, 352/year, which is the same amount as in the first option. Other costs are also the same. The details of operation and maintenance costs in the model 2 are represented in table 3.5.

Table 4.8 Operation and maintenance costs.

Expenses	Annual cost(GHS)
Raw material costs	165,024
Wages and salaries	107,352
Utilities, tools and supplies & Maintenance	42,377
Transportation	12,000
Advertisement	90,900
Total	417,653

Source: Author

4.6.3.3 Benefits

Benefits are exactly the same as the first model 1, because the same amount of compost is produced, and the same amount of waste is diverted. The revenue generates GHS 645,120 of the facility income, and also the facility saves GHS542, 465 from the diarrhoeal treatment cases avoided and landfill disposal. This brings total benefits due to the project to GHS 1,187,585.

Table 4.9: Summary of benefits of the Project.

Components	Unit	Unit value	No. of unit/year	Total(GHS/year
Benefits				
Sales of co-compost	GHS/50kg	28	23,040	645,120
Cost savings				
Landfill disposal	GHS/tonne	2.5	10,000	25,000
Diarrhoea cases avoided				517,465
Total				1,187,585

Source: Author

4.7 Comparison of alternatives.

The total costs and benefits of the two alternatives are compared in table 4.10. The alternatives are annotated as M1 and M2 in the table. M0 indicates the existing waste landfilling system as the reference. Since there is no composting facility in the existing system, it has a net benefit of zero. This figure is compared with the NPV, B/C ratio and EIRR for the various alternatives.

Table 4.10 Comparison of the alternatives (20 year amortization, 9% social rate)

Indicators/Component	M0	M1	M2
Capital cost(GHS)		345,714	422,714
Annual capital cost(GHS/yr		19,687	19,687
O&M cost(GHS/yr)		417,653	417,653
Benefits(GHS/yr)		1,187,585	1,187,585
NPV @ 9%	0	5,248,046.69	5,171,046.69
B/C ratio	0	1.94	1.91
EIRR	0	100.25%	21%

Source: Author

M0 = existing system, M1 = municipally owned-privately operated

M2 = privately owned- privately operated.

NPV = net present value, B/C = benefit cost ratio, EIRR = economic internal rate of return.

Benefit cost ratios of 1.94 and 1.91 were realized for both M1 and M2 alternatives respectively. Therefore ratio of 1.94 means that when a resource worth GHS1.00 is invested in fortifer business an amount worth GHS1 and 94 pesewas would be realized, this means the project is worth expending on. Again, EIRR figures of 21% for M2 and a little above 100% for M1. $EIRR_{m2}$ of 21% means that the project, earns back all capital and operating cost expended on it and pay us 21% for the use of our money and the same thing goes $EIRR_{m1}$ of 100.29% for M1. These indicate that the two alternatives are highly economically viable especially alternative M1. This so because in alternative M1, land cost which takes a larger chunk of the capital cost was omitted.

4.8 Sensitivity Analysis.

The calculations of physical quantification of impacts are carried out with varying level of uncertainty. Therefore, it becomes necessary to conduct a sensitivity analysis to capture the different likely future scenarios. According to Mburu (2002), in all ex ante cases of CBA the analyst must make predictions concerning future physical flows (outputs) and future relative values. None of these predictions can be made with perfect foresight.

Therefore, NPV, EIRR and BCR values must be recalculated when certain key parameters are changed. Such parameters include: O&M Costs, Benefits, Social discount rate, Project life span.

Table 4.11 shows the "base case" results from section 4.10. The estimates in this table are the basic figures to compare with the results from the changes in the uncertain parameters. The sensitivity analyses in this chapter will make the economic analysis viable.

Table 4.11 Comparison of the alternatives (20 year amortization, 9% social rate)

Indicators/Component	M0	M1	M2
Capital cost(GHS)		345,714	422,714
Annual capital cost(GHS/yr		19,687	19,687
O&M cost(GHS/yr)		417,653	417,653
Benefits(GHS/yr)		1,187,585	1,187,585
NPV @ 9%	0	5,248,046.69	5,171,046.69
B/C ratio	0	1.94	1.91
EIRR	0	100.25%	21%

Source: Author

M0 = existing system, M1 = municipally owned-privately operated

M2 = privately owned- privately operated.

NPV = net present value, B/C = benefit cost ratio, EIRR = economic internal rate of return.

Based on the results of the sensitivity analysis, the project is insensitive to the changes in the parameters in both scenarios, since the analysis showed a positive NPV's in all the likely change of 10% in the cost of production, benefit reduction and cost and benefits combined. NPV of GHS 4,646,330.574 and 4,723,331.574 were recorded in both private and public-private partnership respectively, when cost of production was increased by 10%, this represented a decrease in the 10% of the based NPV. A percentage increase of 29 was realized when benefits were also reduced by 10%, given NPV of GHS 6,693,939.009 and 6,770,939.009 whiles a 31% decrease was witnessed when a combination of cost (increased) and benefits (reduced) by that same percentage.

In both scenarios the EIRR's were above the base EIRR of 21% and BCR's were all above unity. The table below depicts the results of the sensitivity analysis.

Table 4.12 Summary of sensitivity analysis for Public – Privately owned (M1)

Scenario/Indicators	NPV	EIRR	BCR
Cost of production increases by 10%	4,723,331.574	61%	1.77
Reduction in benefits by 10%	6,770,939.009	23%	1.74
Increase in cost of production and reduction in benefits by 10% each	363,928.388	145%	1.59

Source: Author

Table 4.13: Summary of sensitivity analysis for Privately-owned (M2)

Scenario/Indicators	NPV	EIRR	BCR
Cost of production increases by 10%	4,646,330.574	53%	1.75
Reduction in benefits by 10%	6,693,939.009	50%	1.72

Increase in cost of production and reduction in benefits by 10% each	3,562,238.388	64%	1.58

Source: Author

4.8.1 Changes in Social discount rate

Since the annual interest rate in Ghana fluctuates, social rates, from a low of 3% to a high of 18%, were applied to analyze the effects of using different social rates. The amortization period remains as 20 years. The results are provided in tables 6 and 7. As the social rate increases, the net present value proportionally decreases in the two alternatives even though they still remain positive. However, the differences between two alternatives are affected only a little by social rate changes.

Table 4.14: Costs and benefits with a 3% social rate and a 20year lifespan.

Components	Private (M2)	Public-Private (M1)
Capital cost(GHS)	422,714	345,714
Annual capital cost	11,295.22	11,295.22
O&M cost (GHS)	712,993.65	712,993.65
Benefits (GHS)	1,187,585	1,187,585
NPV @ 3%	7,433,243.71	7,510,243.71
BCR	2.08	2.14

Source: Author

Table 4.15: Cost and benefit with an 18% social discount rate a 20year lifespan

Components	Private (M2)	Public-Private (M1)

Capital cost(GHS)	422,714	345,714
Annual capital cost	11,295.22	11,295.22
O&M cost(GHS)	712,993.65	712,993.65
Benefit(GHS)	1,187,585	1,187,585
NPV@18%	3,314,419.85	3,391,419.85
BCR	1.72	1.74

Source: Author

4.8.2 Changes in Project Lifespan

The amortization period affects annual capital costs. A 20 year amortization period for the facility was assumed in the previous basic analysis. In this section, amortization periods of 10 to 30 years were analyzed. However, the equipment and truck have a shorter lifetime than the facility site, and they needed replacement due to obsolescence. Therefore, it was assumed to use a higher depreciation rate of 10%.The net present values and BCR with 10 year and 30 year amortization are provided in table 4.6 and table 4.7 along with the costs and benefits of each alternative. The social rate is 9% in all cases.

Table 4.16: Cost and benefit with a10 year amortization and 9% social discount rate.

Components	Private (M2)	Public-Private (M1)
Capital cost(GHS)	422714	345714
Annual capital cost	14469.29	14469.29
O&M cost(GHS)	444369.12	444369.12
Benefit(GHS)	1,187,585	1,187,585
NPV@9%	4436837.36	4513837.357
BCR	2.39	2.45

Source: Author

Table 4.17: Cost and benefit with a 30year amortization and 9%social discount

Components	Private (M2)	Public-Private (M1)
Capital cost(GHS)	422714	345714
Annual capital cost	9778.20	9778.20
O&M cost(GHS)	1452214.59	1452214.59
Benefit(GHS)	1,187,585	1,187,585
NPV@ 9%	3440312.57	3517312.57
BCR	1.39	1.41

Source: Author

4.8.3 Changes in social discount rate and amortization

In this section, both social rates and amortization period (lifespan) were changed to examine the combined effects. The tabulation of NPVs and BCRs with various combinations is given in table 4.8. The results show little change in the ranking of the alternatives. However, the changes in both factors are more effective in changing the net present value than the individual variation of the factors. All the cases produce benefits, except with 3% social rate and amortization period of 30years which was highly sensitive as benefit-cost ratio went down below unity for both alternatives. As expected, both alternatives have the highest net present benefit with a 3% social rate and 20 year amortization.

Table 4.18: Changes in combinations of social rate and amortization period

Combination		NPV (M2)	BCR	NPV Public- Private (M1)	B/C Private
10years	3%	5960095.14	2.45	6037095.135	2.48
	9%	4436837.36	2.39	4513837.36	2.45
	18%	3027821.35	2.31	3104821.35	2.39
20years	3%	7411820.15	1.52	7488820.15	2.14
	9%	5171046.69	1.91	5248046.69	1.94
	18%	3306711.90	2.08	3383712.90	1.74
30years	3%	-436929.15	0.52	-359959.15	0.68
	9%	3440312.57	1.39	3517312.57	1.41
	18%	3090357.77	1.89	3167357.77	1.94

Source: Author

4.9 Summary and Discussion

This study was conducted to evaluate whether composting faecal sludge and, or market waste is viable from the economic perspective. This section summarizes the result of the economic analysis in section 4.1 and 4.8.3

4.10 Summary of the Economic Analysis

Costs and benefits of around 4.5tonnes per day composting facility were analyzed with two alternatives: a municipally operated-privately owned (M1) and a privately operated-privately owned (M2). Sensitivity analysis was also carried out.

4.10.1 Cost-benefit estimates

Costs and benefits quantified for each alternative are summarized in Tables 4.4, 4.5, 4.6, 4.7, 4.8 and 4.9 together with the externalities - health impacts and landfill cost saved. The annual capital costs were calculated based on 20 year amortization (facility lifetime) and 9% social rate.

The capital costs involve facility construction, utility installation, equipment and a truck purchase. The costs are almost the same in all alternatives just that in M1, the land cost was not added since it was donated by the community. For instance, in a study on various composting schemes, Steiner *et al*. (2002) considered the provision of land as one of the major public sector involvement. For that matter its alternative use in crop production (maize) was used to estimate for its opportunity cost. This situation reduces the construction cost, which mostly contributes to the capital cost.

On the contrary, operation and maintenance costs are the same for all alternatives examined. The main piece of O&M costs is raw material, and M2 is the most expensive because of the cost of land. The second largest portion of the O&M costs is wages and salaries.

The benefits are mainly created from the sale of compost, which was assumed to be sold at GHS28 per 50kg. There are benefits of cost savings accruing from composting as well. More money is saved from the reduced treatment of diarrhoeal cases avoided than the avoided waste disposal fee at a landfill. As a result, overall, M1 appears to be the economically best decentralized composting option in the northern sector of Ghana. This alternative has the highest BC ratio and net present value, even though option M2 is also viable, better than the existing landfilling system. The results reverberates with the conclusion drawn by Harper (2004) that individuals and municipalities seeking to venture into the composting business could cover their operating costs and earn some surplus for a production capacity of 1000 tonnes a year. Renkow *et al.* (1998), stated, that operation of public-private and privately ownedprivately operated waste composting were economically viable with positives net present value at 5% interest rate with 14years amortization period. All the alternatives have positive NPVs, above unity B/C ratios and EIRR above the discount rate. This means that all the alternatives are economically viable than the existing system. However, the NPV difference between M1 and M2 is, GHS77000/year is much higher compared with a case of community based decentralized composting plant in Loas, Vientiane (Kwon, 2005). Differences of the Loas study from this study involve the following: lower construction cost, probably due to different construction materials or design specifications, exclusion of land cost, and much cheaper labour cost. Again, this study estimated potential health benefits as one of its cost savings.

4.10.2 Sensitivity analysis

As the results reveal a high benefit per cost investment and net present value, it is important to test the conclusions of the base case analysis by recalculating the costbenefit ratios and NPV under different assumptions. For example, does the costbenefit ratio remain above unity (1.0) or NPV still positive when all the cost input data are given their upper bound and combining these with the lowest input values for all the benefit variables?

The effects of uncertainties in the following factors were examined: social discount rate, amortization period, total operation and maintenance costs and total benefits. Table 4.19, shows the summary of the analyses, and the detailed results are provided in sections 4.8 through 4.8.3

All the factors analyzed in this study resulted to changes in the BCR and net present benefit of the two alternatives. Social rate and amortization period changes had an influence upon the costs, changing the BCR and net present value (benefit). The BCR and net present value decreases as the social rate decreases with increasing amortization period. In the combinations of social interest and amortization period changes, the combination of the lowest social rate and the longest amortization period gives the worse value. Social rate is a more effective factor than amortization period if the period is longer than 10 years.

The operation and maintenance costs and the benefits are less affected by uncertain factors, since they all posed a positive NPV and above unity BCR in all alternatives even though alternative M1 is more viable to be selected compared to alternative M2. It was noted that M1 was, at all times, the best alternative no matter what parameter was changed.

Table 4.19: Summary of the results of sensitivity analyses

Assumed values*	Cost benefit outputs					
	NPV_{m1}	B/C_{m1}	$EIRR_{m1}$	NPV_{m2}	B/C_{m2}	$EIRR_{m2}$
Base case[1)]	5248046.7	1.94	100.25%	5171046.69	1.91	21%
10% increase in O&M costs	4723331.6	1.77	61%	4646330.57	1.75	53%
10% reduction in benefits	6770939.1	1.74	23%	6693936.01	1.72	50%
10% reduction in benefits and 10% increase in O&M costs	363928.4	1.59	145%	3562238.39	1,58	64%
$r^{2)}$=3%, n=30years	-359959.15	0.68	-	-436929.15	0.52	-

r=18%, n=10	3104821.35	-	-	3027821.35	-	-

Source: Author
* Other values not given in each column are the same as the base case
1) 9% social rate, 20 year amortization,

2) Social rate

3) Amortization period.

4.10.3 Omission of variables

The omission of other health impacts, other than infectious diarrhoeal diseases underestimated the cost-benefit ratios presented in this study. Also, some potential economic and noneconomic benefits were left out of the analysis, as presented in Table 2.6. These benefits were left out for various reasons: (a) lack of research studies presenting the likely range of benefits per project or per person, (b) lack of valuation methods for estimating the monetary equivalent value of some benefits, such as, for example, increase in property value, and (c) some benefits were likely to be small in relation to others.

On the other hand, some potential negative impacts of faecal sludge to fortifer technologies were also omitted, thus leading to the underestimate of costs. For example, a partial treated leachate from dewatered FS may be discharged into streams and rivers, providing a habitat for vectors to breed, and the possibility of re-infection is likely to occur. Clearly all these omitted benefits and costs should be included for a comprehensive analysis, and a more accurate cost-benefit ratio and NPV, and future cost-benefit analyses should try and quantify their effects.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

This chapter provides conclusions derived from the analysis including recommendations. This information may be useful for other areas, which are in a similar socio-economic situation as Ghana.

5.1 Conclusions

This study has shown that there is a strong economic case for investing into the composting of faecal sludge (fortifer) business model, when the expected cost of the two different alternatives of fortifer business model were compared with the expected economic benefits. Under base case assumptions the cost-benefit ratio is at least GHS2 in economic benefit per GHS1 invested, and even under pessimistic data assumptions in the one-way sensitivity analysis, the benefits per Cedis invested remained above the threshold of GHS1 in all alternatives of the fortifer models studied. Again, when all potential benefits that were omitted from the analysis are included, the economic case for investment in fortifer business becomes stronger, depending on the context.

While these findings make a strong case for investment into fortifer production, it should be recognized that many of the benefits included in this analysis may not give actual financial benefits. For example the time gains calculated do not necessarily lead to more income-generation activities. Furthermore, the assumptions about the value of time may overestimate the actual economic value, due to the presence of unemployment, underemployment or seasonal labour, which all determines the income earned when more time is available for work (Hutton, *et al.,* 2007).

Even with these shortfalls, conclusion could still be drawn that, processing of faecal sludge to fortifer is economically viable. The results from study attested to the fact that; both Public-Private Partnership and Private scenarios of the fortifer business ownership were economically viable from the cost benefit outputs indicators. However, the Public-Private scenario had higher chances of being economically viable than the Private scenario since that has the higher BC ratio and NPV.

Therefore, up scaling the fortifer business model is economically viable; however the public sector involvement increases the chances of its feasibility.

5.2 Recommendation

- From the conclusions, it is recommended that the policies on waste management should be geared at reusing waste in a more sustainable way such composting, to help food production, biogas and fuel extraction for improving livelihood.
- The public sector should not relegate the management of the waste entirely to the private sector. Instead, they should be actively involved in cost recovery schemes in collaboration with private investors.
- Then again, to achieve effective and sustained health protection for these exposed urban populations, future latrine provision programmes must develop an approach that links on-site sanitation infrastructure to the transport system and safe reuse or disposal/treatment of the emptied faecal sludge (solids, liquid, or a mixture of both).

- Finally, the government should introduce the Fortifer products to farmers by including them in the fertilizer subsidy program runs in the country to promote its usage.

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APPENDICES

A. Table 1.Components of costs and benefits for faecal sludge composting into fortifer.

Capital costs

Land	
Facility construction	site preparation pad and roof of process area water pond fence office building, machinery room storage access road drainage system water supply
Utility installation	electricity, water, telephone
Equipment	shredder, water pump office furniture computer/printer air conditioner telephone
Vehicle	truck
Operation and maintenance costs	
Salaries	supervisor office worker operators, truck driver
Utilities	electricity, water, telephone
Tools and supplies	shovels, rakes, hoses, bags, sieves, hand carts, uniforms, gloves, boots etc.
Truck O&M	fuel, repair and other maintenance
Land rent	rental payment
Transportation	compost organic or inorganic waste rejected
Amendments	Starch, saw dusts, inorganic elements

Benefits	
Revenue	sale of compost

Cost savings	landfill disposal infectious diarrhoeal cases

B: Data source to estimate cost-benefit components of the fortifer facility.

Components		Sources
Capital costs		
Land		Traditional authorities and real estate agents
Facility construction	Site preparation, pad and roof of process area, facultative ponds office building machinery room access road, fence drainage system water supply	
Utility installation	Electricity/water/telephone	Local supplies(V R A, Ghana water co.& Ghana telecom)
Equipment	Shredder, water pump, office furniture, computer/printer air conditioner telephone	Hardware shops, local computer shops and furniture shops all in Kumasi.
Vehicles	Trucks	Used trucks dealers and Japan Motors in Adum-Kumasi
O&M costs		
Salaries	Supervisor office worker operators security men opportunity cost of labour	Minimum wage rate, fringe benefits and in building industry.
Utilities	Electricity/water/telephone	Local supplies
Tools and supplies		Hardware shops

Truck O&M	Fuel Repairs and maintenance	Goil fuel station Truck drivers and owners
Advertisement		FM and TV stations
Land lease		Traditional leaders and opportunity cost of land for agricultural production of maize
Disposal of FS&MSW		Landfill manager Waste collection companies
Amendments	Inorganic elements sawdust and starch	Alibaba.com, Ayensu starch factory, local sawmill operators
Benefits		
Revenue	Compost price	Local compost manufacturers
Cost savings	Landfill disposal fee Diarrhoeal cases averted	Landfill manager MoH-Tamale metropolis

C: Input parameters used in the estimation of the fortifer production

Ratio of faecal sludge to solid organic waste	1:3	Nikiema et al., 2013
0.1 m³ per m³ fresh FS (biosolids)		SuSanA, 2009
Assumed organic fraction in household waste:	50%	SuSanA, 2009
Density of matured compost	0.5 t/m³	SuSanA, 2009
Annual dewatered faecal sludge produced from six 240m² drying beds	288 tons	Steiner et al., 2002
Annual volume of organic waste produced	864 tons	Author
Annual volume of fortifier produced (Capacity of composting facility)	1152 tons	Author

Volume of ammonium sulphate (Amendment)	7%
Volume of Starch (binder)	3%

E: Summary of Capital costs for Model 1-Privately operated-privately owned

Components	Units	Quantity	Unit cost (GH¢)	Total cost (GH¢)
Cost of land	GH¢/m^2	8	10000	80000
Facility construction				
Site preparation	GH¢/m^2	8	250	2000
Processing area	GH¢/m^2			129110
Fencing	GH¢/m^2			15040
Subtotal				**26150**
Equipment				

Installation	GH¢/yr			500
Grinder	GH¢/yr	1	2000	2000
Mixer	GH¢/yr	1	4300	4300
Pelletizer	GH¢/yr	1	2000	2000
Shredder	GH¢/yr	1	2000	2000
Weighing scale	GH¢/kg	1	1000	1000
Sowing machine	GH¢/yr	1	500	500
Computer	GH¢/set	1	1649	1649
Printer	GH¢/set	1	289	289
Air conditioner	GH¢/set	1	1395	1395
Furniture	GH¢/set	1	2000	2000
Subtotal **17633**				
Pond & drainage				
Pond digging	GH¢/m^2	4	2000	8000
Drainage (Plumbing works)	GH¢/m			4024
Subtotal				**12,024**
Utility installation				
Electricity	GH¢/unit			28478
Water	GH¢/unit			6250
Telephone	GH¢/unit			99
Internet	GH¢/unit			70
Subtotal		**34897 Vehicles**		
Truck	GH¢/tonne			69075
Pick up	GH¢			62935
Subtotal **132010**				

TOTAL (M2) **422714**
(M1)

345714

M1- land was donated; therefore opportunity cost (OC) of land for crop production was used instead of the market price.

F: Summary of Operating and Maintenance cost (O&M) Model 1 & Model 2

Components	Unit	Quantity	Unit cost/mth	Total/year
Salaries				
Supervisor	GH¢/mth	1	1656	19872
Office worker	GH¢/mth	1	1440	17280
Driver	GH¢/mth	1	1440	17280
Laborers’	GH¢/mth	12	294	42336
Security men	GH¢/mth	3	294	10584
Subtotal				**107,352 Utility bills**
Electricity	GH¢/KWh	12	500	6000
Water	GH¢/m^3	12	50	600
Telephone	GH¢/min	12	60	720
Internet	GH¢/min	12	50	600
Subtotal Supplies				**7920 Tools and**
Shovel, uniforms, Rakes, wheelbarrow Bags, Nose mask etc	GH¢/yr			
Subtotal				**13061 Vehicles O &M**
Fuel	GH¢/Km			16896
Maintenance	GH¢/Km			4500
Subtotal				**21396 Inputs**
Amendments	GH¢/tonne			102816
Starch binder	GH¢/tonne			62208
Organic waste	GH¢/tone			12000

	Variable	Data source	Data value	
1.Patients				
Direct expenditures avoided, due to less illness from diarrhoeal diseases.	Unit Cost per treatment	WHO regional unit cost data(WHO,2007)	US$4.0-US$16.0 per visit/day	14.4-57.60 Average cost (GHS36.0)
	% of patient use transport&food	Assumptions	70% of patient use transport	GHS10.00

	Number of Cases	Ghana Health Service (2013)	
Subtotal Advertisement			**177024**
Radio adverts (6 months)	GH¢/mins		10800
TV adverts (3 months)	GH¢/mins		80100
Subtotal			**90900 Total**
Production Cost		**17,653**	

G: Data and source for the estimation of diarrhoeal diseases burden averted by the proposed project.

	Visits/days per case	Expert opinion	1 outpatient visit per case (0.5-1.5) 5 days for (3 - 7) hospitalized cases
	Hospitalization rate(Inpatients)		8.2% of cases hospitalized
Income gained due to days lost from work avoided	Days off work/episode	Expert opinion	2days (1-4)
	Number of people of working age	MoH-Tamale metropolis(2013)	6864
	Opportunity cost of time	Ghana data minimum wage	GHS 6.0
Percentage of reduced diarrhoea cases due to improved sanitation(composting of faecal sludge)	37%	Hutton,(2007)	

H: Tamale Metro Health Annual Reports, 2010-2013 (infectious diarrhoea cases in the tamale metropolis)

Age	Female Cases	Male Cases	Total cases
(1-11mths)	976	853	1829
(1-4)	2050	2109	4159
(5-9)	446	458	904
(10-14)	219	264	483
(15-17)	144	266	410
(18-19)	156	355	511
(20-34)	1048	2864	3912
(35-49)	519	989	1508
(50-59)	194	329	523
(60-69)	200	196	396
(70+)	215	516	731
Total annual cases			15366

I: Detailed calculation of health benefits in terms of infectious diarrhoeal cases avoided.

Total Adult diarrhoea cases	6864	GHS
% of adult diarrhoea case averted due to the project (37%)	2540	
Outpatient treatment cost avoided	36.22*(0.918*2540)	84444.26
Inpatient treatment cost avoided	36.22.*5*(0.82*2540)	377147.56
Income gained from time lost	2*6*2540	30,476.16
T&T avoided	2540*10	25396.80
TOTAL COST AVOIDED		517,465

J: Summary of the projected costs and benefits stream for 20 year period for Privately-owned (M2).

Year	Cost stream	Benefit stream	Net Benefit	D F (9%)	Discounted Cost stream	Discounted Benefit Stream	Discounted Stream
0	422714	0	-422714	1	422714	0	-422714
1	437340.02 688297.94	1,187,585	688297.94	0.9174	401229.38	1089527.32	
2	348267.02 706436.96	1,187,585	706436.97	0.8417	293129.38	999566.35	

N

3	364942.82	1,187,585	635230.53	0.7722	281802.85	917033.35	635230.53
4	384103.07	1,187,585	569206.70	0.7084	272108.29	841314.99	569206.69
5	406049.05	1,187,585	507944.59	0.6499	263904.02	771848.62	507944.59
6	431126.11	1,187,585	451051.59	0.5963	257066.41	708118.00	451051.58
7	459729.39	1,187,585	398161.82	0.5470	251487.72	649649.54	398161.82
15	889579.65	1,187,585	81813.75	0.2745	244223.45	326037.19	81813.74
16	980021.83	1,187,585	52278.83	0.2519	246837.86	299116.69	52278.83
17	1082697.56	1,187,585	24236.62	0.2311	250182.36	274418.99	24236.62
18	1199264.86	1,187,585	-2476.10	0.2119	254236.64	251760.54	-2476.10
19	1331610.13	1,187,585	-28011.44	0.1945	258984.42	230972.97	-28011.44
20	1481879.72	1,187,585	-52511.30	0.1784	264413.11	211901.81	-52511.31
	NPV @ 9%	5171046.69					
	BCR	1.91					
	EIRR	21%					
8	503045.58	1,187,585	343547.14	0.5019	252461.61	596008.75	343547.14
9	533466.76	1,187,585	301174.10	0.4604	245622.92	546797.022	301174.11
10	575621.36	1,187,585	258499.96	0.4224	243148.68	501648.64	258499.96
11	623526.23	1,187,585	218591.21	0.3875	241636.89	460228.11	218591.22
12	677944.19	1,187,585	181194.93	0.3555	241032.70	422227.63	181194.93
13	739743.81	1,187,585	146076.16	0.3262	241288.63	387364.79	146076.16

14 809913.85 1,187,585 113016.70 0.2992 242363.86 355380.54

113016.69 K: Summary of the projected costs and benefits stream for 20 year period fo

Year	Cost stream	Benefit stream	Net Benefit	D F (9%)	Discounted Cost stream	Discounted Benefit Stream	Discounted Net Stream
0	345714	0	-345714	1	345714	0	-345714
1	437340.02	1,187,585	688297.94	0.9174	401229.38	1089527.32	688297.94
2	348267.02	1,187,585	706436.97	0.8417	293129.38	999566.35	706436.96
3	364942.82	1,187,585	635230.53	0.7722	281802.85	917033.35	635230.53
4	384103.07	1,187,585	569206.70	0.7084	272108.29	841314.99	569206.69
5	406049.05	1,187,585	507944.59	0.6499	263904.02	771848.62	507944.59
6	431126.11	1,187,585	451051.59	0.5963	257066.41	708118.00	451051.58
7	459729.39	1,187,585	398161.82	0.5470	251487.72	649649.54	398161.82
8	503045.58	1,187,585	343547.14	0.5019	252461.61	596008.75	343547.14
9	533466.76	1,187,585	301174.10	0.4604	245622.92	546797.022	301174.11
10	575621.36	1,187,585	258499.96	0.4224	243148.68	501648.64	258499.96
11	623526.23	1,187,585	218591.21	0.3875	241636.89	460228.11	218591.22
12	677944.19	1,187,585	181194.93	0.3555	241032.70	422227.63	181194.93
13	739743.81	1,187,585	146076.16	0.3262	241288.63	387364.79	146076.16
14	809913.85	1,187,585	113016.70	0.2992	242363.86	355380.54	113016.69
15	889579.65	1,187,585	81813.75	0.2745	244223.45	326037.19	81813.74
16	980021.83	1,187,585	52278.83	0.2519	246837.86	299116.69	52278.83
17	1082697.56	1,187,585	24236.62	0.2311	250182.36	274418.99	24236.62
18	1199264.86	1,187,585	-2476.10	0.2119	254236.64	251760.54	-2476.10
19	1331610.13	1,187,585	-28011.44	0.1945	258984.42	230972.97	-28011.44
20	1481879.72	1,187,585	-52511.30	0.1784	264413.11	211901.81	-52511.31

NPV @ 9%	5248046.69
BCR	1.94
EIRR	100.25%

PublicPrivately owned (M1).

L: Sensitivity analysis for Public-Privately owned

YR	REDUCTION IN REVENUE BY 10%						
YR	COST STRM	BENEFIT STR	REDUCED BENEFIT STRM	DF 9%	DISC NET STR	DISC COST S	RDISC BENEFIT TRM
0	345714	0	0	1	-345714	345714	0
1	437340.02	1187584.778	1068826.3	0.91743119	631486.2802	401229.3761	980574.5873
2	348267.02	1187584.778	1068826.3	0.84167999	720559.2802	293129.383	899609.7132
3	364942.8179	1187584.778	1068826.3	0.77218348	703883.4823	281802.8151	825330.0121
4	384103.0716	1187584.778	1068826.3	0.70842521	684723.2286	272108.2996	757183.4973
5	406049.0513	1187584.778	1068826.3	0.64993139	662777.2489	263904.0228	694663.759
6	431126.1072	1187584.778	1068826.3	0.59626733	637700.193	257066.4115	637306.2009
7	459729.3876	1187584.778	1068826.3	0.54703424	609096.9126	251487.7184	584684.588
8	503045.5767	1187584.778	1068826.3	0.50186628	565780.7235	252461.6121	536407.8789
9	533466.7621	1187584.778	1068826.3	0.46042778	535359.5381	245622.9167	492117.3201
10	575621.3591	1187584.778	1068826.3	0.42241081	493204.9411	243148.6827	451483.7799
11	623526.2337	1187584.778	1068826.3	0.38753285	445300.0665	241636.8986	414205.3027
12	677944.1905	1187584.778	1068826.3	0.35553473	390882.1097	241032.7014	380004.8648

13	739743.8095	1187584.778	1068826.3	0.32617865	329082.4907	241288.6348	348628.3164
14	809913.848	1187584.778	1068826.3	0.29924647	258912.4522	242363.856	319842.4921
15	889579.6477	1187584.778	1068826.3	0.27453804	179246.6525	244223.4541	293433.479
16	980021.8259	1187584.778	1068826.3	0.25186976	88804.47431	246837.8647	269205.0266
17	1082697.565	1187584.778	1068826.3	0.23107318	-13871.26486	250182.3658	246977.0886
18	1199264.861	1187584.778	1068826.3	0.21199374	-130438.5607	254236.6433	226584.485
19	1331610.138	1187584.778	1068826.3	0.19448967	-262783.838	258984.4162	207875.6743
20	1481879.702	1187584.778	1068826.3	0.17843089	-413053.4018	264413.1138	190711.6278
						5592875.187	9756829.694
NPV					6770939.009		
BCR					1.744510537		

INCREASE COST OF PRODUCTION BY 10%

YR	COST STRE	ACOST @1	STREAM BENEFIT STREA	NET BENEFIT STR @	DISC FACTOR	NET DISC STR	DISC COST STR	ADISC BENEFIT TREA
0	345714	345714	0	-345714	1	-345714	345714	
1	437340.02	481074.022	1187584.778	706510.7558	0.917431193	648175.0053	441352.3138	1089527.
2	348267.02	383093.722	1187584.778	804491.0558	0.841679993	677124.0264	322442.3214	999566.3
3	364942.818	401437.0997	1187584.778	786147.6781	0.77218348	607050.2499	309983.0967	917033.3
4	384103.072	422513.3788	1187584.778	765071.399	0.708425211	541995.8673	299319.1296	841314.9
5	406049.051	446653.9564	1187584.778	740930.8213	0.649931386	481554.1959	290294.4251	771848.
6	431126.107	474238.7179	1187584.778	713346.0599	0.596267327	425344.9483	282773.0526	708118.0
7	459729.388	505702.3263	1187584.778	681882.4514	0.547034245	373013.0519	276636.4902	649649.5
8	503045.577	553350.1343	1187584.778	634234.6434	0.50186628	318300.9809	277707.7733	596008.7
9	533466.762	586813.4383	1187584.778	600771.3395	0.46042778	276611.8138	270185.2084	546797.0
10	575621.359	633183.495	1187584.778	554401.2828	0.422410807	234185.0932	267463.551	501648.6
11	623526.234	685878.8571	1187584.778	501705.9207	0.38753285	194427.5255	265800.5885	460228.
12	677944.19	745738.6095	1187584.778	441846.1682	0.355534725	157091.656	265135.9715	422227.6
13	739743.81	813718.1905	1187584.778	373866.5873	0.326178647	121947.2976	265417.4983	387364.7
14	809913.848	890905.2328	1187584.778	296679.545	0.299246465	88780.30508	266600.2416	355380.5
15	889579.648	978537.6125	1187584.778	209047.1653	0.274538041	57391.39931	268645.7995	326037.1
16	980021.826	1078024.008	1187584.778	109560.7693	0.251869763	27595.04496	271521.6512	299116.6
17	1082697.57	1190967.322	1187584.778	-3382.543789	0.231073177	-781.6151389	275200.6024	274418.9
18	1199264.86	1319191.347	1187584.778	-131606.5692	0.21199374	-27899.76883	279660.3076	251760.5
19	1331610.14	1464771.152	1187584.778	-277186.3742	0.19448967	-53909.88641	284882.8578	230972.9
20	1481879.7	1630067.672	1187584.778	-442482.8944	0.17843089	-78952.61657	290854.4252	211901.8
							6117591.305	1084092
	NPV					**5414758.574**		
	BCR					**1.772089919**		

YR	INCREASE IN COST OF PRODUCTION BY 10% AND REDUCTION IN REVENUE BY 10%						
	COST @10%	REDUCED BENEF	IDF 9%	NET TREAM	DISC.COST STRM	DISC.BENEFI	TDISC. NET ST
0	345714	0	1	-345714	345714	0	-345714
1	481074.022	1068826.3	0.91743	587752.2782	441352.3138	980574.5873	539222.274
2	383093.722	1068826.3	0.84168	685732.5782	322442.3214	899609.7132	577167.392
3	401437.0997	1068826.3	0.77218	667389.2005	309983.0967	825330.0121	515346.915
4	422513.3788	1068826.3	0.70843	646312.9214	299319.1296	757183.4973	457864.368
5	446653.9564	1068826.3	0.64993	622172.3438	290294.4251	694663.759	404369.334
6	474238.7179	1068826.3	0.59627	594587.5823	282773.0526	637306.2009	354533.148
7	505702.3263	1068826.3	0.54703	563123.9739	276636.4902	584684.588	308048.098
8	553350.1343	1068826.3	0.50187	515476.1659	277707.7733	536407.8789	258700.106
9	586813.4383	1068826.3	0.46043	482012.8619	270185.2084	492117.3201	221932.112
10	633183.495	1068826.3	0.42241	435642.8052	267463.551	451483.7799	184020.229
11	685878.8571	1068826.3	0.38753	382947.4431	265800.5885	414205.3027	148404.714
12	745738.6095	1068826.3	0.35553	323087.6907	265135.9715	380004.8648	114868.893
13	813718.1905	1068826.3	0.32618	255108.1097	265417.4983	348628.3164	83210.818
14	890905.2328	1068826.3	0.29925	177921.0674	266600.2416	319842.4921	53242.2505
15	978537.6125	1068826.3	0.27454	90288.68774	268645.7995	293433.479	24787.6795
16	1078024.008	1068826.3	0.25187	-9197.708281	271521.6512	269205.0266	-2316.6246
17	1190967.322	1068826.3	0.23107	-122141.0214	275200.6024	246977.0886	-28223.514
18	1319191.347	1068826.3	0.21199	-250365.0467	279660.3076	226584.485	-53075.823
19	1464771.152	1068826.3	0.19449	-395944.8518	284882.8578	207875.6743	-77007.184
20	1630067.672	1068826.3	0.17843	-561241.372	290854.4252	190711.6278	-100142.8
					6117591.305	9756829.694	
NPV							**3639238.39**
BCR							**1.59488093**

L: Sensitivity analysis for Privately-owned

Increase in production cost by 10%

NPV and BCR

INCREASE COST OF PRODUCTION BY 10%						
COST STREAM	COST STREAM @10%	BENEFIT STREAM	NET STREAM	NET STREAM FLOW @10%	DISCOUNT FACTOR 9%	NET STREAM@10%
422714	422714	0		-422714	1	-422714
437340.02	481074.022	1187584.778	750244.7578	706510.7558	0.917431193	648175.0053
348267.02	383093.722	1187584.778	839317.7578	804491.0558	0.841679993	677124.0264
364942.8179	401437.0997	1187584.778	822641.9599	786147.6781	0.77218348	607050.2499
384103.0716	422513.3788	1187584.778	803481.7061	765071.399	0.708425211	541995.8673
406049.0513	446653.9564	1187584.778	781535.7265	740930.8213	0.649931386	481554.1959
431126.1072	474238.7179	1187584.778	756458.6706	713346.0599	0.596267327	425344.9483
459729.3876	505702.3263	1187584.778	727855.3902	681882.4514	0.547034245	373013.0519
503045.5767	553350.1343	1187584.778	684539.2011	634234.6434	0.50186628	318300.9809
533466.7621	586813.4383	1187584.778	654118.0157	600771.3395	0.46042778	276611.8138
575621.3591	633183.495	1187584.778	611963.4187	554401.2828	0.422410807	234185.0932
623526.2337	685878.8571	1187584.778	564058.544	501705.9207	0.38753285	194427.5255
677944.1905	745738.6095	1187584.778	509640.5873	441846.1682	0.355534725	157091.656
739743.8095	813718.1905	1187584.778	447840.9683	373866.5873	0.326178647	121947.2976
809913.848	890905.2328	1187584.778	377670.9298	296679.545	0.299246465	88780.30508
889579.6477	978537.6125	1187584.778	298005.1301	209047.1653	0.274538041	57391.39931
980021.8259	1078024.008	1187584.778	207562.9519	109560.7693	0.251869763	27595.04496
1082697.565	1190967.322	1187584.778	104887.2127	-3382.543789	0.231073177	-781.6151389
1199264.861	1319191.347	1187584.778	-11680.08308	-131606.5692	0.21199374	-27899.76883
1331610.138	1464771.152	1187584.778	-144025.3604	-277186.3742	0.19448967	-53909.88641
1481879.702	1630067.672	1187584.778	-294294.9242	-442482.8944	0.17843089	-78952.61657
NPV						4646330.574

COST STREAM @ 10%	BENEFIT STREAM	DISC FACTOR 9%	DISC COST STREAM	DISC BENEFIT STREAM
422714	0	1	422714	0
481074.022	1187584.778	0.917431193	441352.3138	1089527.319
383093.722	1187584.778	0.841679993	322442.3214	999566.3478

401437.0997	1187584.778	0.77218348	309983.0967	917033.3466
422513.3788	1187584.778	0.708425211	299319.1296	841314.9969
446653.9564	1187584.778	0.649931386	290294.4251	771848.621
474238.7179	1187584.778	0.596267327	282773.0526	708118.0009
505702.3263	1187584.778	0.547034245	276636.4902	649649.5421
553350.1343	1187584.778	0.50186628	277707.7733	596008.7542
586813.4383	1187584.778	0.46042778	270185.2084	546797.0222
633183.495	1187584.778	0.422410807	267463.551	501648.6442
685878.8571	1187584.778	0.38753285	265800.5885	460228.114
745738.6095	1187584.778	0.355534725	265135.9715	422227.6275
813718.1905	1187584.778	0.326178647	265417.4983	387364.7959
890905.2328	1187584.778	0.299246465	266600.2416	355380.5467
978537.6125	1187584.778	0.274538041	268645.7995	326037.1988
1078024.008	1187584.778	0.251869763	271521.6512	299116.6961
1190967.322	1187584.778	0.231073177	275200.6024	274418.9873
1319191.347	1187584.778	0.21199374	279660.3076	251760.5388
1464771.152	1187584.778	0.19448967	284882.8578	230972.9714
1630067.672	1187584.778	0.17843089	290854.4252	211901.8086
			6194591.305	10840921.88
BCR			1.750062489	

Reduction in benefits @ 10%

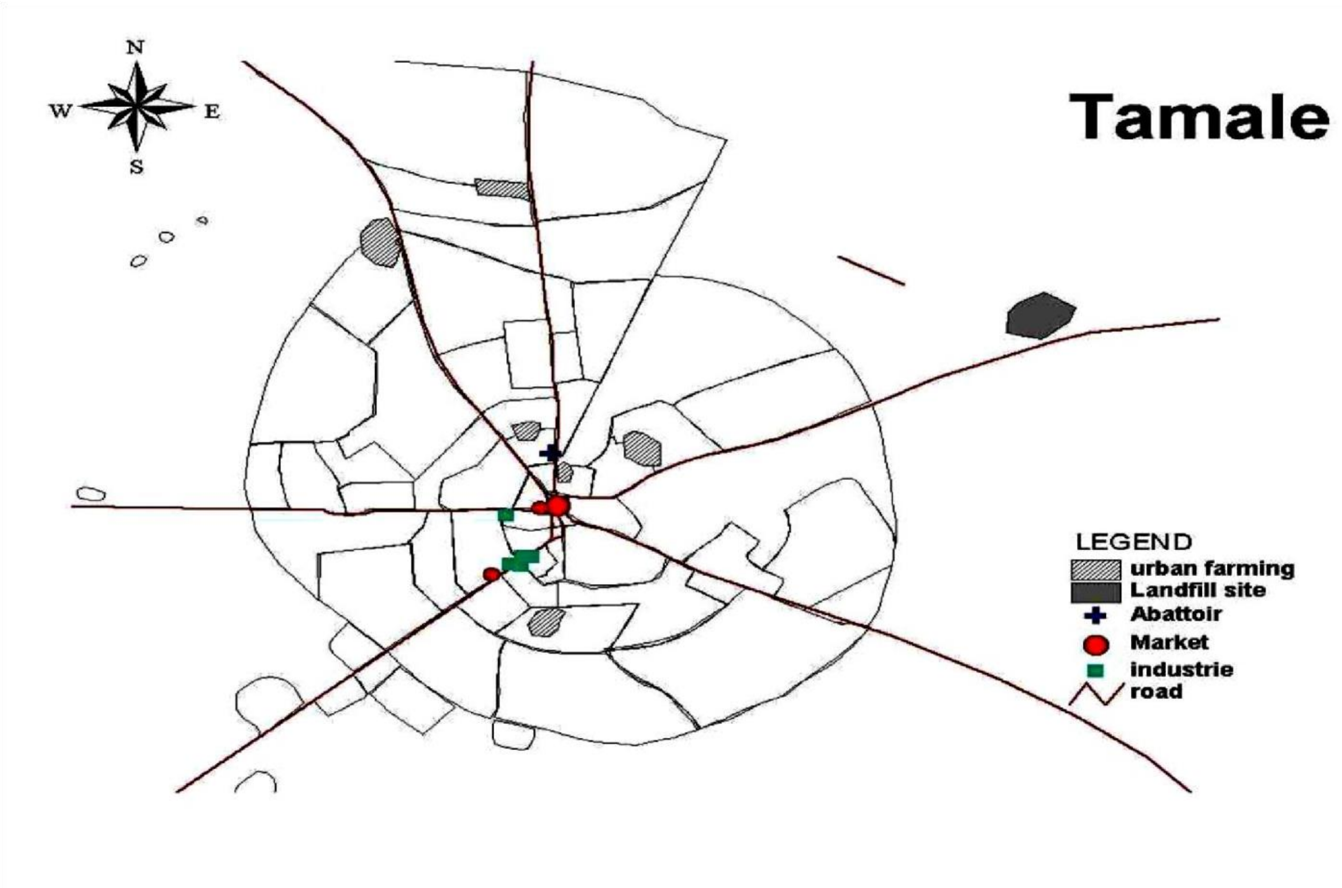
NPV and BCR Calculations

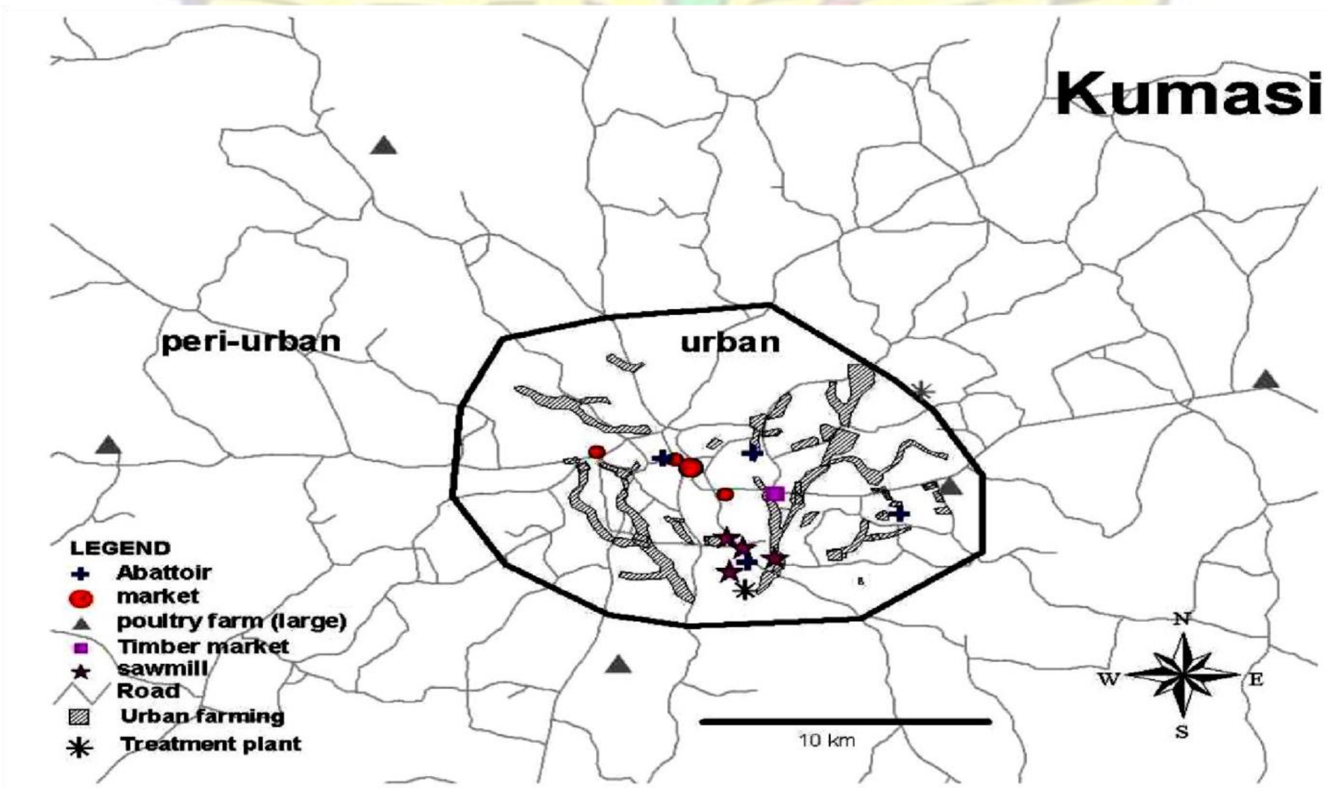
	COST STREA	BENEFIT STREA	REDUCED BENEFIT BY 10	DF 9%	NET STREAM	DISC COST STRM	DISC BENEFIT STRM
0	422714	0	0	1	-422714	422714	0
1	437340.02	1187584.778	1068826.3	0.917431193	631486.2802	401229.3761	980574.5873

2	348267.02	1187584.778	1068826.3	0.841679993	720559.2802	293129.383	899609.7132
3	364942.818	1187584.778	1068826.3	0.77218348	703883.4823	281802.8151	825330.0121
4	384103.072	1187584.778	1068826.3	0.708425211	684723.2286	272108.2996	757183.4973
5	406049.051	1187584.778	1068826.3	0.649931386	662777.2489	263904.0228	694663.759
6	431126.107	1187584.778	1068826.3	0.596267327	637700.193	257066.4115	637306.2009
7	459729.388	1187584.778	1068826.3	0.547034245	609096.9126	251487.7184	584684.588
8	503045.577	1187584.778	1068826.3	0.50186628	565780.7235	252461.6121	536407.8789
9	533466.762	1187584.778	1068826.3	0.46042778	535359.5381	245622.9167	492117.3201
10	575621.359	1187584.778	1068826.3	0.422410807	493204.9411	243148.6827	451483.7799
11	623526.234	1187584.778	1068826.3	0.38753285	445300.0665	241636.8986	414205.3027
12	677944.19	1187584.778	1068826.3	0.355534725	390882.1097	241032.7014	380004.8648
13	739743.81	1187584.778	1068826.3	0.326178647	329082.4907	241288.6348	348628.3164
14	809913.848	1187584.778	1068826.3	0.299246465	258912.4522	242363.856	319842.4921
15	889579.648	1187584.778	1068826.3	0.274538041	179246.6525	244223.4541	293433.479
16	980021.826	1187584.778	1068826.3	0.251869763	88804.47431	246837.8647	269205.0266
17	1082697.57	1187584.778	1068826.3	0.231073177	-13871.26486	250182.3658	246977.0886
18	1199264.86	1187584.778	1068826.3	0.21199374	-130438.5607	254236.6433	226584.485
19	1331610.14	1187584.778	1068826.3	0.19448967	-262783.838	258984.4162	207875.6743
20	1481879.7	1187584.778	1068826.3	0.17843089	-413053.4018	264413.1138	190711.6278
					6693939.009	**5669875.187**	**9756829.694**
NPV					**6693939.009**		
BCR						**1.720819131**	

	INCREASE IN COST OF PRODUCTION BY 10% AND REDUCTION IN REVENUE BY 10%						
	COST @10%	REDUCED BENEFIT BY 10	DISC FACTOR 9%	NETBENET/COST	DISC COST STRM	DISC BENEFIT STRM	NET STREAM
0	422714	0	1	-422714	422714	0	-422714
1	481074.022	1068826.3	0.917431193	587752.2782	441352.3138	980574.5873	539222.2736

2	383093.722	1068826.3	0.841679993	685732.5782	322442.3214	899609.7132	577167.3918
3	401437.0997	1068826.3	0.77218348	667389.2005	309983.0967	825330.0121	515346.9154
4	422513.3788	1068826.3	0.708425211	646312.9214	299319.1296	757183.4973	457864.3677
5	446653.9564	1068826.3	0.649931386	622172.3438	290294.4251	694663.759	404369.3339
6	474238.7179	1068826.3	0.596267327	594587.5823	282773.0526	637306.2009	354533.1483
7	505702.3263	1068826.3	0.547034245	563123.9739	276636.4902	584684.588	308048.0978
8	553350.1343	1068826.3	0.50186628	515476.1659	277707.7733	536407.8789	258700.1056
9	586813.4383	1068826.3	0.46042778	482012.8619	270185.2084	492117.3201	221932.1117
10	633183.495	1068826.3	0.422410807	435642.8052	267463.551	451483.7799	184020.2289
11	685878.8571	1068826.3	0.38753285	382947.4431	265800.5885	414205.3027	148404.7142
12	745738.6095	1068826.3	0.355534725	323087.6907	265135.9715	380004.8648	114868.8933
13	813718.1905	1068826.3	0.326178647	255108.1097	265417.4983	348628.3164	83210.81804
14	890905.2328	1068826.3	0.299246465	177921.0674	266600.2416	319842.4921	53242.25048
15	978537.6125	1068826.3	0.274538041	90288.68774	268645.7995	293433.479	24787.67948
16	1078024.008	1068826.3	0.251869763	-9197.708281	271521.6512	269205.0266	-2316.624602
17	1190967.322	1068826.3	0.231073177	-122141.0214	275200.6024	246977.0886	-28223.51382
18	1319191.347	1068826.3	0.21199374	-250365.0467	279660.3076	226584.485	-53075.82266
19	1464771.152	1068826.3	0.19448967	-395944.8518	284882.8578	207875.6743	-77007.18351
20	1630067.672	1068826.3	0.17843089	-561241.372	290854.4252	190711.6278	-100142.7974
					6194591.305	9756829.694	
NPV							**3562238.388**
BCR							**1.575056241**





M: Compostable waste supply points in Tamale and Kumasi Metropolis.

Source: IWMI