Municipal Solid Waste Disposal in Developing Countries: A Case Study of Wa Municipality, Ghana

By

Patrick Aaniamenga Bowan

A Doctoral Thesis Submitted in Partial Fulfilment of the Requirements for the Award of the Doctor of Philosophy of Loughborough University, United Kingdom

NOVEMBER 2018

Supervised By

Dr Sam Kayaga, Dr Andrew Cotton and Dr Julie Fisher

DEDICATION

This thesis is dedicated to my parents, my wife (Oli), and my children (Kyelle and Liere).

ACKNOWLEDGEMENT

I first wish to express my heartfelt gratitude to my supervisors: Dr Sam Kayaga, Dr Andrew Cotton and Dr Julie Fisher, for their patience and directions that guided me in undertaking this research. Their scholarly guidance, constructive comments and critical revision of the drafts made it possible for me to complete this thesis. I am also in a debt of gratitude to my internal assessor, Professor M. Sohail, for his constructive feedbacks that helped shaped this research project. I also thank my cousin Dr Martin Tuuli and his family for welcoming and accommodating me when I started the programme.

I am grateful to Research Triangle Institute (RTI) International for providing the Municipal Solid Waste Decision Support Tool used in the scenarios analysis in this study, especially Keith Weitz for his guidance and suggestions on the effective use of the tool.

I equally want to thank the Government of Ghana and Ghana Education Trust Fund (GETFund) for sponsoring this research, especially Madam Florence of GETFund for facilitating the release of my fees and stipends. I thank Mr Peter Aluze-ele, Dr Aaron Aavuur and my colleagues, especially Derick Monsuur, for their friendship that helped to reduce stress and boredom during my research period.

My appreciation also goes to all my research participants, especially the staffs of the Wa Municipal Assembly, Environmental Health Unit, Environmental Protection Agency, and Zoomlion Ghana Limited whose cooperation and support made my fieldwork a success.

ABSTRACT

Municipal solid waste management (MSWM) is a global challenge and the situation is worse in urban areas of developing countries due to ineffective disposal systems. In many industrialised countries, waste minimisation and recycling/reuse policies have been introduced to reduce the amount of waste generated, and increasingly, alternative waste management practices to waste disposal on land have been implemented to reduce the environmental impacts of MSWM. Nevertheless, research and MSWM in most developing countries have largely concentrated on waste collection.

This doctoral study investigates how planning and decision-making for MSW disposal in developing countries with similar circumstances and MSW problems to Ghana can be improved, using the Wa Municipality as a case study. It established the baseline scenario of MSW disposal and examined MSW disposal management and operational performances. The methodology and research design for the study was a descriptive and interpretive case study that was analysed through both qualitative and quantitative research methods.

The key research findings indicate that the current state of MSW disposal management performance in Ghana does not present an enabling environment for effective MSW disposal. Also, the present MSW disposal practices in the case study area and Ghana in general consist of some waste collection, transportation and open dumping, where the entire amount of waste is open dumped without pre-treatment.

Evaluation of MSW disposal operational performance through modelling and scenario analysis showed that open dumping/landfilling of waste creates copious health effects (0.0001519 lbs/year on average), whereas, MSW disposal in an integrated solid waste management (ISWM) system optimises the minimisation of health effects (-0.0005812 lbs/year on average). The study developed and validated a framework for the improvement of planning and decision-making for MSW disposal, which can easily be applied in the context of developing countries. Also, the developed framework provides a theoretical standpoint for the concept of MSW disposal in ISWM. Appropriate MSW disposal treatment technologies based on the developed framework could be applied to ameliorate the impacts of MSW disposal in Ghana and other developing countries.

Key Words: municipal solid waste; waste disposal; management performance; operational performance; environmental performance; Ghana.

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USED ACRONYMS / ABBREVIATIONS

ACARP	Accra Compost and Recycling Plant
ACT	Australian Capital Territory
AD	Anaerobic Digestion
CBA	Cost Benefit Analysis
AFR	Africa Region
Defra	Department of Environment Food and Rural Affairs
EAP	East Asia and Pacific
ECA	Europe and Central Asia
EPA	Environmental Protection Agency
EU	European Union
FAO	Food and Agricultural Organisation
FRM	Frith Resources Management
GHG	Greenhouse Gas
GDP	Gross Domestic Product
GSS	Ghana Statistical Service
LCA	Life Cycle Assessment
LCR	Latin America and the Caribbean Region
MCA	Multi - Criteria Analysis
MDGs	Millennium Development Goals
MENA	Middle East and North Africa
MMDAs	Metropolitan, Municipal and District Assemblies
MLGRD	Ministry of Local Government and Rural Development
MSW	Municipal Solid Waste

MSW DST	Municipal Solid Waste Decision Support Tool
MSWM	Municipal Solid Waste Management
OECD	Organisation of Economic Cooperation and Development
RTI	Research Triangle Institute
SAR	South Asia Region
SD	Sustainable Development
SDGs	Sustainable Development Goals
SW	Solid Waste
SWC	Solid Waste Collection
SWM	Solid Waste Management
UN	United Nations
UNEP	United Nations Environment Programme
UN-HABITAT	United Nations Human Settlements Programme
WMA	Wa Municipal Assembly
WMD	Waste Management Department
WTE	Waste to Energy
ZGL	Zoomlion Ghana Limited
ZW	Zero Waste

CHAPTER ONE – INTRODUCTION

Chapter Overview

This chapter is the introduction to the entire thesis and presents the context of the research. It covers the background to the study, the statement of the research problem, the aim and objectives of the study, the justification for undertaking this research, the scope of the study, an outline of the methodology and research design, and the structure of this thesis.

1.0 Background to the Study

The growing world population, economic growth, rapid urbanisation, and the rise in human living standards, especially in developing countries, are resulting in high resource use in response to changing lifestyles. The accompanying increase in consumption is rising waste generation far beyond the management ability of most municipal authorities in developing countries (Tudor et al., 2011). As a result, waste disposal is an immediate and critical issue for many developing countries now, as ineffective or irresponsible disposal of solid waste (SW) pollutes the environment and poses health risks to the public (Desa et al, 2011).

Ejaz et al (2012) report in a study on the problems of solid waste management (SWM) in developing countries that, 90 per cent of municipal solid waste (MSW) collected ends up in open dumps, and a fraction of the remaining 10 per cent receive proper disposal. The current state of municipal solid waste management (MSWM) in Ghana, for instance, leaves much to be desired. Less than 40% of urban residents are served with solid waste collection (SWC) services (Obirih-Opareh and Post, 2002; Awortwi, 2006; Mariwah, 2012). The traditionally applied methods of dealing with waste have been unsuccessful, and the resulting contamination of water and land has led to growing concern over waste management environmental performance in the country (Badgie, et al, 2012; Lawson and Lawson, 2016).

Although MSWM is usually considered as a local problem, it has national and even global implications (Spiegelman and Sheehan, 2005), as the adverse impacts of improper MSW disposal have no bounds and are currently felt globally. For instance, a recent study found that the amount of plastic waste entering the oceans from land each year exceeds 4.8 million tons, and may rise to as high as 250 million tons by 2025 (Marine Litter Solutions, 2017). Once in the ocean, plastic waste affects the safety of sea transport, fisheries, tourism, and recreation (Sheavly and Register, 2007; Kershaw *et al.*, 2011). When broken up into tiny pieces, plastic attracts toxic chemicals released over decades from industry and agriculture, the concentration of which increases as they move up the food chain (Plastic Oceans Foundation, 2017).

Waste disposal challenges have made MSW disposal a topical issue currently. Consequently, to tackle the menace of MSW, the global community through the United Nations (UN) General Assembly, included MSWM in the 2030 Agenda for Sustainable Development (SD). This agenda has 17 Sustainable Development Goals (SDGs) with 169 targets, with the overall objective of achieving SD in its three dimensions (economic, social, and environmental) in a balanced and integrated manner by 2030 (UN, 2015).

The specific goal which focuses on MSWM is SDG 11:

‘*Make cities and human settlements inclusive, safe, resilient and sustaina*ble’, and properly delineated in target 11.6:

> *‘By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management’* (UN, 2015).

It is worth noting that, the three dimensions of SD (economic, social, and environmental) are also the three evaluative assessment dimensions for SWM. Therefore, MSWM has the potential of contributing to the attainment of target 11.6 and some of the other SDGs through the improvement of MSW disposal in developing countries.

However, the trajectory of research in SWM, especially in developing countries, has largely focused on cost minimisation of waste management systems (economic aspects) and the social aspects of waste management (Morrissey and Browne, 2004; Al-Rawi and Al-Tayyar, 2013; Zurbrügg *et al.*, 2014; Vaccari, Tudor and Perteghella, 2018), with less research concentrating on the environmental aspects of SWM, especially the health impact category of SWM environmental impacts, in developing countries. Thus, this doctoral research is focused on the environmental aspects of MSW disposal in developing countries, using the Wa Municipality in Ghana as a case study.

1.1 Research Problem, Aim and Objectives

The problem that this study addressed is the ineffective MSW disposal systems in Ghana and many other developing countries. The primary research question for this study was:

How can MSW disposal be improved in developing countries with similar circumstances and MSW problems to Ghana?

MSWM is a global challenge and the situation is worse in urban areas of developing countries (Asante-Darko, et al., 2017). Many researchers indicate that between 33% and 50% of solid waste (SW) generated within most cities in low and middle-income countries is not collected, but illegally dumped on streets and open spaces (UN-HABITAT, 2010; Guerrero, Maas and Hogland, 2013; Srivastava *et al.*, 2015). This affects local community sustainability, as they lead to public environmental problems, including the release of toxic chemicals, emissions of pollutants and odour, and leachate contamination of ground and surface waters (Domingo and Nadal, 2009; Cao and Wang, 2017; Olapiriyakul, 2017). The effects of such environmental problems are long-term, and in some cases, irreversible.

Various pollutions (air, soil, water, and landscape) due to improper waste disposal would not only affect the natural environment but also exposed the community to various diseases. An example is the contamination of surface and groundwater supplies from indiscriminate dumping of wastes in most developing countries (Vasanthi and Kaliappan, 2008; Odukoya and Abimbola, 2010; Alam and Ahmade, 2013). This occurs through leachate from MSW disposal sites and run-off that carry MSW into water bodies.

The pollution of watercourses leads to rising levels of Biochemical Oxygen Demand (BOD) and the presence of microbial contaminants in drinking water sources (Henry, et al., 2006). It takes only a small amount of leachate to contaminate a large volume of groundwater, which in turn can contaminate and affect biodiversity and enter the food chains (Bakare *et al.*, 2007; Garaj-Vrhovac, et al., 2009; Mukherjee and Mukhopadhyay, 2015).

Open dumps, which are prominent in most developing countries, also attract vermin and scavenging animals and provide food and habitat for disease vectors such as rats and mosquitoes. Gastro-intestinal infections such as typhoid fever, poliovirus infection, hepatitis E infection, and cholera are often transmitted through contaminated food or water (Boadi and Kuitunen, 2005; Cabral, 2010) by these disease vectors. Clogging of storm drains and creation of stagnant water due to the choked drains (as illustrated in Plate 1.1) are other problems of improper MSW disposal in urban areas in most developing countries and are the prime cause of flooding in the rainy season in cities in Ghana.

Choked drains equally act as breeding grounds for insects such as mosquitoes and tsetse flies (Olukanni, et al., 2014; Gogate, et al., 2017). These insects spread water-borne and communicable diseases such as malaria, trachoma and diarrhoeal diseases. Malaria is the most important disease with the greatest economic impact in tropical countries, and the number one killer of children under five years in sub-Saharan Africa (Black et al., 2003; Guyatt and Snow, 2004; Longdoh Njunda *et al.*, 2017).

Plate 1.1: A choked drain in Accra, Ghana, after a rain (1:100cm scale)

In addition, uncontrolled burning of MSW, which is widespread in most developing countries, contributes significantly to urban air pollution. MSW contains considerable hazardous components and the open MSW burning in urban areas causes direct exposure of hazardous materials to citizens (Wang *et al.*, 2017). Globally, efforts are being made to control greenhouse gases (GHG) emissions from various sources, and the waste sector is one of them (Kumar *et al.*, 2004).

MSW contributes 13.9% of national emissions and constituents 1.5 % of CO_2 emissions in Ghana (IPCC, 2015). GHG do not only contribute to climate change but also cause respiratory infections such as asthma, cardiopulmonary diseases, and lung cancer (Bruce and Perez-Padilla, 2002; Ayres *et al.*, 2009).

Notwithstanding these, the goals of modern SWM in general, and particularly MSW disposal are to protect human health and the environment, conserve resources, treat waste before disposal, and to create employment, especially for the teeming unemployed youth in sub-Saharan Africa (Song, et al., 2015; Abiti, et al., 2017; Barr, 2017; Rodic and Wilson, 2017). These goals cannot be attained in Ghana and other developing countries with the current scenario of MSW disposal practices. Thus, something needs to be done to make the process of disposing of MSW in developing countries systematic and efficient to prevent the continuous pollution of the environment, and to enable MSW disposal to contribute to the attainment of the goals of SWM.

Therefore, the aim of this doctoral research is to:

> **improve planning and decision-making for MSW disposal in developing countries with similar circumstances and MSW problems as Ghana.**

The specific objectives that guided the study using the case study were to:

1. Investigate MSW generation and characteristics reported in literature and official documents
2. Examine MSW disposal management performance
3. Establish a baseline scenario of MSW disposal
4. Evaluate MSW disposal operational performance
5. Develop a planning framework for MSW disposal decision-making in developing countries

1.2 Justification for the Research

Due to increasing MSW generation and their significant impacts on human health, environmental assessment of MSWM, especially disposal methods are becoming more and more important (Limoodehi *et al.*, 2017). As a result, increased environmental concerns and the emphasis on safe disposal technologies are changing the orientation of MSW disposal and planning. These concerns are due to limited suitable land area and resources, growing public opposition, and the deterioration of environmental conditions, especially in developing countries, because of ineffective MSW disposal systems.

Initially, MSW disposal was focused on removing potentially harmful substances or materials away from human settlements (Ludwig, et al., 2012; Hilburn, 2015). However, as the environmental, social and economic implications of unsustainable consumption leading to growing waste generation became apparent, MSW disposal began to shift from a mere pollution prevention and control exercise, towards more holistic approaches that regard waste as a resource. This is because it has been realised that the prosperity and environmental sustainability of cities are intimately linked (Yigitcanlar, et al., 2015).

Thus, appropriate waste management has been recognised as an essential prerequisite for SD (UNEP, 2013; Papargyropoulou *et al.*, 2014). Consequently, in many industrialised countries, waste management has changed much over the last decade. Waste minimisation and recycling/reuse policies have been introduced to reduce the amount of waste generated, and increasingly, alternative waste management practices to SW disposal on land have been implemented to reduce the environmental impacts of waste management (Coburn *et al.*, 2006; Kuenen and Hjelgaard, 2016).

On the contrary, research and management of MSW in developing countries such as Ghana have largely concentrated on collection (Coad, 2011; Work Bank, 2012; Guerrero, et al., 2013; Fakoya, 2014), primarily due to public complaints about uncollected waste in homes, on the streets, and at communal collection points. Very few studies have analysed waste disposal problems in detail in most developing countries (Khajuria, et al., 2010; Remigios, 2010; Khatib, 2011; Tian *et al.*, 2013; Akhtar, 2014; Fei-Baffoe, et al., 2014; Lohri, et al., 2014; Proietti, et al., 2014; Mudhoo, et al., 2015; Papargyropoulou *et al.*, 2015).

As a result, the environmental damage caused by improper disposal of SW is poorly understood in most developing countries (Appasamy and Nelliyat, 2007). However, understanding the environmental burdens of MSW disposal is important to enable waste management stakeholders to take decisions that will ameliorate the burdens of MSW disposal.

Accordingly, application of optimisation techniques has been introduced due to the growing concern about the environmental impact of waste management, with much research carried out to assess waste management performance and optimise its processes towards efficiency (Wilson, 2002). Yet to date, the study on the overall environmental performance of MSW disposal, especially in developing countries, has not been done. The optimisation in MSWM is largely focused on the economic optimisation with cost minimisation being the sole objective disregarding potential environmental impact in most developing countries.

However, for sustainable waste management solutions, proper strategies are required for the optimisation of both socioeconomic and environmental considerations. This will lead to the identification of adaptive and mitigative measures to combat the risks pose by improper MSW disposal practices. In this respect, there is the need for research on MSW disposal environmental performance to optimise the minimisation of MSW disposal environmental burdens in developing countries, which is the focus of this research.

Thus, Wa municipality of Ghana was selected as the study area for this doctoral research. The choice of Ghana is because Ghana is a typical developing country, which has similar economic and climatic conditions as well as MSWM challenges as most developing countries, particularly, sub-Saharan African countries and for the reason that, the Government of Ghana was the sponsor of this research and Ghana is the researcher's home country, which made the field work for the study easier. Also, the choice of Wa municipality in the Upper West Region of Northern Ghana as the case study area is because most researches on SWM in Ghana and other developing countries have largely been concentrated in the bigger cities, to the neglect of smaller cities and towns, thus, the choice of the Wa municipality.

1.3 Scope of the Research

This study was limited to MSW disposal in developing countries with a focus on the health impact category of environmental impacts of MSW disposal. The study also acknowledges that there are variations in the SWM systems especially when SW generation and characteristics are superimposed on governance setups, as the governance issues that create the enabling environment for effective waste management may be significantly different in various developing countries.

MSW disposal for this study covers the activities to minimise the quantity of produced MSW, to decrease or eliminate hazardous components in waste, the activities to contain waste in a location or facilities which meet environmental protection standards. Other wastes such as medical and electronic wastes are sometimes found in the MSW stream in most developing countries (Chandrappa and Das, 2012; Zainu and Songip, 2017), however, this study was limited to household waste, street sweepings, and non-hazardous institutional and commercial waste.

1.4 Outline of Methodology and Research Design

This study adopted the realist paradigm in terms of research philosophies in order to achieve the aim of the study. The realist paradigm is born from a frustration that positivism was over-deterministic and that interpretivism was so totally relativist (Flowers, 2009). Thus, realism takes aspects of both positivist and interpretivist positions. It holds that real structures exist independent of human consciousness, but that knowledge is socially created, with Saunders et al., (2009) arguing that our knowledge of reality is a result of social conditioning.

Therefore, the researcher adopted the realist position for this research because the researcher wanted to observe and describe the reality of MSW disposal in the case study area and other developing countries from an objective viewpoint and to understand the differences between various roles of stakeholders (as social actors) in SWM.

Furthermore, the inductive approach was the research approach employed for this study. The inductive approach focuses on a specific area in a larger field for the specific to affect the larger. In this approach, data is collected concerning specific phenomena and then the data examined for patterns between various variables (Jensen, 2002). Thus, the researcher adopted the inductive approach for this study, since the study was focused on MSW disposal (specific) with the aim of improving MSWM (general) through the development of a planning framework for MSW disposal decision-making in developing countries.

Also, the research strategy used in this study was the case study strategy. Yin (2003:p13) defines a case study as:

> "*an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident*".

A research strategy like the experiment was less applicable to this study as the researcher did not have control over the phenomenon to be studied. This is because the experimental studies attempt to manipulate independent variables to observe the behaviour of the dependent variables (Collis and Hussey, 2013), which was not possible to achieve in this research.

Similarly, a survey strategy is usually associated with the deductive approach (Saunders et al., 2009), and positivist philosophical positioning (Collis and Hussey, 2013), however, this research is inclined towards realism with a more inductive approach. Hence, survey strategy was also deemed inapplicable to this research.

A case study was more suitable since the research question sought to explain the present situation and the possible improvement of MSW disposal in the case study area and other developing countries. Therefore, the research design for this study was a descriptive and interpretive case study that was analysed through both qualitative and quantitative research methods.

1.5 Thesis Structure

This thesis is organised into eight chapters and a series of supporting appendices, the details are outlined as follows and shown in figure 1.1:

- Chapter One – Introduction: This is the introduction to the entire thesis and presents the context of the research.
- Chapter Two – Literature Review: This chapter presents literature relating to the background and context of the study.
- Chapter Three – Methodology and Research Design: This section outlines a range of research methodologies adopted to address the research objectives and the justification for their selection.
- Chapter Four – Results: MSW Generation and Characteristics, Management Performance, and Baseline Scenario - This chapter presents the research results and analysis of the first three research objectives.
- Chapter Five – MSW Disposal Operational Performance: This section presents the results and analysis of the operational performance of MSW disposal in the case study area based on the modelling of five scenarios.
- Chapter Six – Discussion of the Research Results: this chapter discusses the key research findings.
- Chapter Seven – MSW Disposal Planning and Decision-Making Framework: Chapter 7 presents the developed and validated framework for planning and decision-making for MSW disposal.
- Chapter Eight – The Research Conclusion and Implications: This chapter concludes this doctoral research with highlights on each objective together with the research limitations and implications.

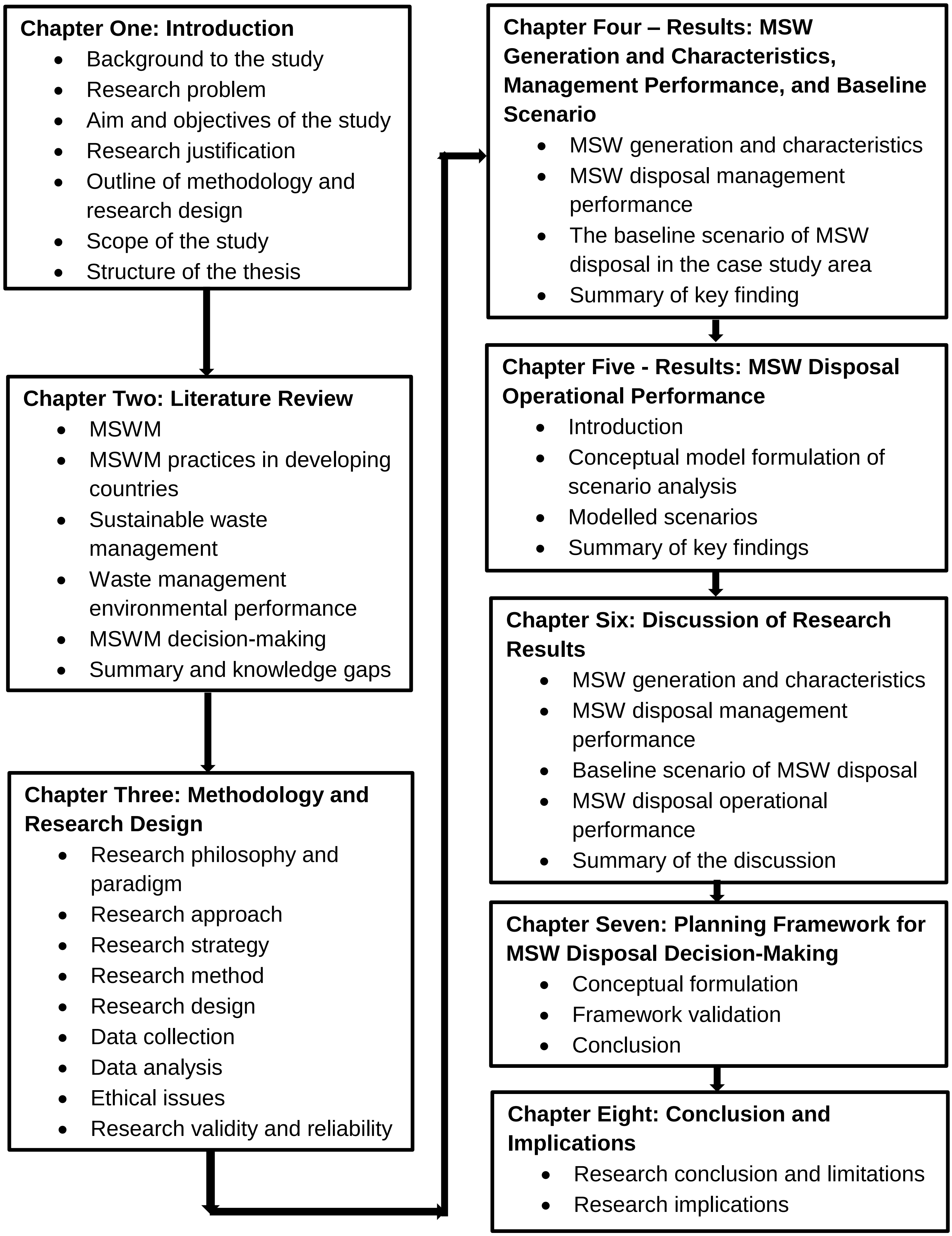

Figure 1.1: Thesis structure

Chapter two, the next chapter of this thesis, presents the reviewed literature relating to the general background and context of the study.

CHAPTER TWO – LITERATURE REVIEW

2.0 Introduction

This chapter presents literature relating to the background and context of the study. The first section focuses on the first objective of the study - *to investigate MSW generation and characteristics reported in literature and official documents* – and discusses the concept of MSWM in terms of MSW definition, generation and characteristics; the second and third sections concentrate on the third objective of this research - *to establish a baseline scenario of MSW disposal* – and reviews literature on MSWM practices in developing countries and sustainable waste management respectively.

Section four of this chapter focusses on waste management environmental performance, and addresses the literature relating to research objectives two and four - *to examine MSW disposal management performance, and to evaluate MSW disposal operational performance* respectively; and lastly, section five presents literature on MSWM decision-making in relation to some aspects of research objective four (scenario analysis) and research objective five - *to develop a planning framework for MSW disposal decision-making in developing countries*.

2.1 Municipal Solid Waste Management

MSWM may be defined as the discipline associated with controlling the generation, storage, collection, transfer and transport, processing/treatment, and disposal of SW in a manner that is in accordance with the best principles of health, economics, engineering, conservation, aesthetics, and other environmental considerations, and that is also responsive to public attitudes (Schübeler, et al., 1996; Khatib, 2011; Oteng-Ababio, et al., 2013). In its scope, MSWM includes all administrative, financial, legal, planning, and engineering functions involved in the solutions to all problems of SW in urban areas.

2.1.1 Defining Municipal Solid Waste

MSW is generally defined as SW collected by municipalities or other local authorities (Pipatti, et al., 2006; Dahlén and Lagerkvist, 2010; Edjabou et al., 2015; Aleluia and Ferrão, 2016). Typically, MSW includes household waste; garden (yard) and park wastes; streets sweepings; and non-hazardous commercial/institutional waste (Kalyani and Pandey, 2014; Rajaeifar *et al.*, 2015; Ripa *et al.*, 2017).

Similarly, Beneroso *et al.*, (2014b) posit that MSW consists mainly of waste from households (60–90%), though similar wastes from other sources such as commerce or public institutions are also included. Medical waste, which needs special handling and management is regarded as MSW in some locations, whilst municipal construction and demolition wastes are mostly excluded from MSW.

Accordingly, other researchers and institutions describe MSW as a term usually applied to a heterogeneous collection of wastes produced in urban areas, the nature of which varies from region to region (Diaz et al., 2005; UNEP., 2005; Breeze, 2012; Work Bank, 2012; OECD, 2013). The variants in wastes between regions or within the same region are because the characteristics, quantity and quality of SW generated in a region are not only a function of the living standard and lifestyle of the region's inhabitants, but also of the abundance and type of the region's natural resources.

From the preceding definitions of MSW, it can be deduced that the definition of MSW is based on either the source or composition of waste or both. Therefore, this study defines MSW as SW arising from streets, domestic, commercial and institutional activities, in an urban area that enter and/or leave the municipal waste stream.

Municipal authorities or other government authorities in developing countries are solely responsible for the management of MSW (Rugemalila and Gibbs, 2015). Because of this, MSW should include only waste that does not need special handling. Other waste such as clinical and construction/demolition wastes when included in MSW will further exacerbate the MSWM problem confronting many developing countries.

2.1.2 MSW Generation and Characteristics

MSW generation refers to the generation of any solid, non-hazardous substance or object within an urban area, excluding wastewater sludge (dos Muchangos, et al., 2017). The main constituents of MSW generated in general are similar throughout the world, but the quantity generated, the density and the proportion of streams vary widely from country to country depending largely on the level of income and lifestyle, culture and tradition, geographic location and dominant weather conditions (Johari *et al.*, 2012; Marshall and Farahbakhsh, 2013; Al-Khatib *et al.*, 2015; Kamali *et al.*, 2016).

Sound waste management and optimisation of resource recovery from waste require reliable data on the generation rates and characteristics of waste (White et al., 2012;

Williams, 2013; Edjabou *et al.*, 2015), because the accurate prediction of MSW generation and knowledge of the waste characteristics provide the basic data on which a waste management system is planned, designed, and operated (Chen and Chang, 2000; Sharholy *et al.*, 2008; Miezah *et al.*, 2015; Abbasi and Hanandeh, 2016; Asante-Darko, Adabor and Amponsah, 2017).

However, reliable data on MSW generation and characteristics that will inform effective planning on waste management in most developing countries is absent (Miezah *et al.*, 2015). This is partly because MSW generation trends differ due to variations in consumption patterns in various locations. Many other factors play significant roles in MSW generation, including urban population, economic development, consumption rate, geographic location, and administrative systems (Wang and Nie, 2001; Dyson and Chang, 2005). Among these factors, urban population and economic conditions seem to be the two most crucial factors contributing to the quantity of MSW.

Achieving the anticipated prediction accuracy with regard to the generation trends particularly in the rapidly growing cities and towns of developing countries is quite challenging, since reliable data on waste generation and characteristics determinants such as population and economic indicators are not readily available (Asante-Darko, et al., 2017). As a result, the proper planning and operation of SWM systems are intensively affected by poor MSW streams analysis and inaccurate predictions of SW quantities (Abbasi *et al.*, 2012; Abbasi and Hanandeh, 2016).

Nevertheless, the global MSW generation rates are rising exponentially. The World Bank (2012) indicates that the current global MSW generation levels are roughly 1.3 billion tonnes per year and are expected to increase to approximately 2.2 billion tons per year by 2025 (see Tables 2.1 and 2.2). This would signify a major increase in per capita waste generation rates, from 1.2 to 1.42 kg per person per day in the next eight years. Waste management problems in most developing countries are likely to worsen if appropriate plans are not put in place to effectively deal with this galloping generation rate.

Table 2.1: Waste generation per capita by regions (World Bank, 2012)

Region	Waste Generation Per Capita (kg/capita/day)		
	Lower Boundary	Upper Boundary	Average
Africa Region (AFR)	0.09	3.0	0.65
East Asia and Pacific region (EAP)	0.44	4.3	0.95
Europe and Central Asia region (ECA)	0.29	2.1	1.1
Latin America and the Caribbean region (LCR)	0.11	5.5	1.1
The Middle East and North Africa region (MENA)	0.16	5.7	1.1
Organisation for Economic Co-operation and Development (OECD)	1.10	3.7	2.2
South Asia region (SAR)	0.12	5.1	0.45

Table 2.2: Waste generation projections for 2025 by regions (World Bank, 2012)

Region	Current Available data			Projection for 2025			
	Total Urban Population (millions)	Urban Waste Generation		Projected Population		Projected Urban Waste	
		Per Capita (kg/capita/day)	Total (tons/day)	Total Population (millions)	Urban Population (millions)	Per Capita (kg/capita/day)	Total (tons/day)
AFR	260	0.65	169,119	1,152	518	0.85	441,840
EAP	777	0.95	738958	2124	1229	1.5	1,865,379
ECA	227	1.1	254,389	339	239	1.5	354.810
LCR	399	1.1	437,545	681	466	1.6	728,392
MENA	162	1.1	173,545	379	257	1.43	369,320
OECD	729	2.2	1,566,286	1,031	842	2.1	1,742,417
SAR	426	0.45	192,410	1,938	734	0.77	567,545
Total	2,980	1.2	3,532,252	7,644	4,285	1.4	6,069,703

Furthermore, Eiselt and Marianov (2015) note that the per capita waste generation rates in many developing countries have now crossed the one kilogram per day mark, which is a worrying trend because most municipal authorities do not have the capacity to effectively manage this waste. The waste generation in sub-Saharan Africa is nearly 62 million tons per year; although per capita waste generation is generally low in the region, the generation spans a wide range, from 0.09 to 3.0 kg per person per day with an average of 0.65 kg/capita/day (Hoornweg, Bhada-Tata and Kennedy, 2013; Miezah *et al.*, 2015).

Also, the average waste generation per capita per day in OECD countries is 2.2 kilograms and the SW generation rate is increasing at an estimated rate of about 0.5 – 0.7 per cent per year (World Bank, 2012). Similarly, the waste generation for the Middle East and North Africa (MENA) is in tune with the rest of the world, as the SW generation in MENA is 63 million tons per year and the per capita waste generation is ranging between 0.16 and 5.7 kg per person per day and has an average of 1.1 kg/capita/day (World Bank, 2012).

The exponential increase in the waste generation across the world, comes with its management challenges, especially for developing countries where there are competing interests on the municipal budget. However, with the majority of the world's population now urbanized, MSW generation rates are likely to increase further, particularly in developing countries, where more and more people are migrating from rural areas to cities (Hoornweg and Bhada‐Tata, 2015; Adam, et al., 2016).

Currently, high-income countries produce the most waste per capita, while low-income countries produce the least SW per capita (Gaeta-Bernardi and Parente, 2016). This is not only because in low-income countries, there are less commercial and industrial activities, resulting in lower waste generation rates, but also because there is an overall correlation between the generation of MSW and wealth (Gross Domestic Product) (Wiedmann *et al.*, 2015), as illustrated in Table 2.3.

Table 2.3: Waste generation per capita by income levels (World Bank, 2012)

Income level	**Waste Generation Per Capita (Kg/capita/day)**		
	Lower Boundary	**Upper Boundary**	**Average**
High	0.70	14	2.1
Upper Middle	0.11	5.5	1.2
Lower Middle	0.16	5.3	0.79
Lower	0.09	4.3	0.60

Therefore, effectively decoupling waste generation from economic growth is a concept worth considering for sustainable waste management. In Europe, there has been a decline in MSW generation in some countries such as Bulgaria, Romania, Slovenia, and Norway ranging from 3 to 40% between 1995 and 2015 as shown in Table 2.4, which is attributable to the application of Directive 2008/98/CE on MSW. Although some countries in Europe such as Latvia, Greece, Malta, and Denmark have had a drastic increase in MSW generation over the same period, there is some evidence of the possibility of decoupling waste generation from economic growth.

According to the European Environement Agency (EEA), (2007), within the OECD region, the increase in municipal waste generation was about 58% (2.5%/year) from 1980 to 2000, and 4.6% (0.9%/year) between 2000 and 2005. These data suggest a strong relative decoupling of municipal waste generation from economic growth. The generation of municipal waste was projected to increase from 2005 to 2030 within the OECD region by 38% (1.3%/year), which was less than the projections that were made in 2001, reflecting the recent downturn in the municipal waste generation in countries such as Sweden (EEA, 2007).

In contrast, rapid industrialization is happening in most developing countries that have not yet developed the appropriate systems to effectively deal with waste (Singh *et al.*, 2014; Srivastava, et al., 2015). This calls for waste management systems that will integrate concerns for SD in developing countries (Alexis Laurent *et al.*, 2014; Rodríguez *et al.*, 2015).

Table 2.4: Municipal waste generated by some European countries in selected years (European Commission, 2017)

EU Country	Year (kg per capita)					
	1995	2000	2005	2010	2015	Change (%) 1995 - 2015
Belgium	455	471	482	456	418	-8
Bulgaria	694	612	588	554	419	-40
Denmark	521	664	736		789	52
Estonia	371	453	433	305	359	-3
Greece	303	412	442	532	485	60
Hungary	460	446	461	403	377	-18
Latvia	264	271	320	324	404	53
Malta	387	533	623	601	624	61
Netherlands	539	598	599	571	523	-3
Norway	624	613	426	469	421	-33
Romania	342	355	383	313	247	-28
Spain	505	653	588	510	434	-14
Slovenia	596	513	494	490	449	-25
Turkey	441	465	458	407	400	-9
United Kingdom	498	577	581	509	485	-3

2.1.2.1 MSW Composition

Waste composition indicates the components of the waste stream given as a percentage of the total mass (Arena and Gregorio, 2014; Pressley *et al.*, 2015). Like MSW generation, MSW composition is equally influenced by many factors, such as level of economic development, cultural norms, geographical location, energy sources, and climate (Slagstad and Brattebø, 2013; Zorpas *et al.*, 2015). Oteng-Ababio (2014) supports this in his assertion that, as a country urbanises, and populations become wealthier, consumption of inorganic materials (such as plastics, paper, and aluminium) increases, while the relative organic fraction decreases. This is event in the high volumes of inorganic waste generated in developed countries and the high organic waste generated in developing countries.

Accordingly, MSW stream is broadly classified into organic and inorganic wastes (Hamid et al., 2015). In general, low-income countries have a high percentage (between 40 to 85%) of organic matter in the urban waste stream, while paper, plastic, glass, and metal fractions dominate the waste stream of high-income countries (Zhang, Tan and Gersberg, 2010; Zorpas, et al., 2017).

For instance, East Asia and the Pacific Region has the highest fraction of organic waste (62%) compared to OECD countries, which have the least (27%) (Breivik *et al.,* 2016). On the other hand, the amount of paper, glass, and metals found in the MSW stream are the highest in OECD countries (32%, 7%, and 6%, respectively) and lowest in the South Asia Region (4% for paper and 1% for both glass and metals) (Breivik *et al.,* 2016).

Similarly, sub Saharan Africa also has the highest fraction of MSW being organics (57%) (World Bank, 2012). This supports Miezah *et al.* (2015) in their characterisation and quantification of MSW in Ghana in which they found the MSW composition as 61% organics, 14% plastics, 6% inert, 5% miscellaneous, 5% paper, 3% metals, 3% glass, 1% leather and rubber, and 1% textiles. Table 2.5 indicates the MSW composition and generation rate in some selected cities in Africa. Only cities in Ghana have miscellaneous MSW fraction, probably due to the non-segregation of waste at the point of generation.

Table 2.5: MSW composition and generation rates in some selected cities in Africa

City	Country	Per capita GDP (US$) (The World Bank, 2016)	Population of city (million)	Generation rate kg/p/day	Organics (%)	Inorganic (%)	Inert (%)	Miscellaneous (%)	Source
Accra	Ghana	1,513.5	1.96	0.74	65.8	25.7	5.2	4.1	Miezah *et al.*, (2015)
Kumasi			1.47	0.75	48.4	33.2	10.7	7.8	
Tamale			0.36	0.33	58.6	23.7	4.5	3.4	
Lagos	Nigeria	2,178.0	9.00	0.5	53	39	8	-	Ojo and Bowen, (2014)
Freetown	Sierra Leone	496.0	0.80	0.56	59.2	10.2	19.9	-	Sankoh, et al., (2012)
Nairobi	Kenya	1,455.4	2.75	0.6	65	21	14	-	Okot-Okumu, (2012)
Cape Town	South Africa	5,273.6	3.43	0.7 – 1.3	47	32	21	-	Baloyi *et al.*, (2012)
Cairo	Egypt	3,514.5	7.73	1.3	56	34.7	9.4	-	Zaki *et al.*, (2013)

From the foregoing, there is a consensus among researcher that MSW stream in developing countries is more organic, whereas that of developed countries is made up of more inorganic waste. The organic fraction is an important component, not only because it constitutes a significant portion of the MSW stream in developing countries, but also because of its potentially adverse impact on public health and environmental quality if not properly treated and/or disposed.

A major adverse impact of organic waste is its attraction of rodents and vector insects for which it provides food and shelter (Fei-Baffoe, et al., 2014). The impact of organic MSW on environmental quality takes the form of foul odours, unsightliness and leachate from open dumps, especially after rainfall, and emission of harmful gases (Akhtar, 2014). These impacts are usually not limited only to the disposal site, they pervade the neighbouring area to the site and wherever the wastes are generated, spread, or accumulated. Unless an organic waste is appropriately treated and disposed of, its adverse impact will continue until it has fully decomposed or otherwise stabilised.

Therefore, accurate forecasting of MSW generation and composition are important for the planning, management and utilisation of MSW in a sustainable way (Intharathirat *et al.*, 2015), because the methods by which various waste streams are collected, recovered, processed, treated or disposed of depend largely on the generation rate and composition (Chen *et al.*, 2016; Bisinella *et al.*, 2017). However, the forecasting of MSW generation and composition is poor in many developing countries because the concentration in MSWM is largely on collection with little attention paid to waste reduction and other components of MSWM.

2.1.2.2 Moisture Content and Calorific Value of MSW

The moisture content of SW is expressed as the mass of moisture per unit mass of water or dry materials (Cai *et al.*, 2012; Beneroso *et al.*, 2014; Yermán, et al., 2017). It is a very important factor that influences decisions on MSW collection and transportation (Watkins and McKendry, 2015). Transfer of moisture takes place in garbage bins and collector trucks during storage and transportation of MSW, therefore, the moisture contents of various components change with time (Sukholthaman and Shirahada, 2015).

Moisture content equally plays a key role in the degradation and treatment of MSW. For example, in composting, moisture content affects the magnitude of heat generation, which can affect the quality of compost (Rada *et al.*, 2014; Ballardo *et al.*, 2016; Benavente, et al., 2017). In a landfill, leachate is formed when the refuse moisture content exceeds its field capacity (Iqbal *et al.*, 2015). Also, many researchers have observed that high moisture content is a major hindrance in the field of thermal conversion of waste-to-energy (WTE) technologies (Zhao *et al.*, 2014; Tom, et al., 2016) because the moisture content influences the calorific value of the waste to be incinerated.

The energy value of the waste depends on its calorific value, which is influenced by the moisture content and hydrogen content of the wastes (Tyagi and Lo, 2013; Roberts, 2015; Watkins and McKendry, 2015; Shi *et al.*, 2016). Accordingly, the ability of waste to sustain a combustion process without supplementary fuel depends on a number of physical and chemical parameters, of which the lower (inferior) calorific value is the most important (Shahir *et al.*, 2014; Brunner and Rechberger, 2015), though, the minimum required lower calorific value for a controlled incineration depends on the furnace design.

Knowledge of the calorific value of MSW is particularly necessary when MSW incineration and other WTE technologies are to be considered as options for energy recovery from MSW. The high organic waste component of the MSW stream in Ghana has resulted in high moisture content (above 50% on average) of the MSW, which conforms with the waste stream in other developing countries (Wilson *et al.*, 2012; Srivastava *et al.*, 2015; Thaiyalnayaki and Jayanthi, 2017).

2.2 MSWM Practices in Developing Countries

MSWM involves the collection, storage, transportation, recovery/recycling, processing, treatment, and final disposal of waste. The collection, transport, treatment, and disposal of SW, particularly waste generated in medium and large urban centres, have become a relatively difficult problem to solve for municipal authorities in developing countries who are solely responsible for SWM (Dukhan, et al., 2012; Hall, et al., 2013; Marshall and Farahbakhsh, 2013). The problem is getting acuter in these countries because financial, human, and other critical resources generally are scarce.

Also, the MSWM situation in some developing countries is getting worse, because research into SWM has often focused on industrialized nations (Alexis Laurent *et al.*, 2014; Chen *et al.*, 2016), with only a few studies focusing on providing information that is required in developing countries (Sthiannopkao and Wong, 2013). Subsequently, in some developing countries, there is a growing concern of inadequate management of waste, particularly in urban areas where the consumption patterns have changed and the generation rate has increased substantially (Marshall and Farahbakhsh, 2013; Gandy, 2014; Jambeck *et al.*, 2015).

The challenge of MSWM for the cities' authorities in developing countries are mainly due to the increasing generation of waste, the burden posed on the municipal budget because of the high costs associated with its management, the lack of understanding of a diversity of factors that affect the different stages of waste management, and linkages necessary to enable the entire handling system functioning (Guerrero et al., 2013). While systems analysis largely targeting well-defined, engineered systems have been used to help SWM agencies in industrialized countries since the 1960s, collection and removal dominate the SWM sector in developing countries (Guerrero, et al., 2013; Marshall and Farahbakhsh, 2013).

It is common for municipalities to spend 20 to 50 percent of their available recurrent budget on SWM, while 30 to 60 percent of all the urban SW remains uncollected and less than 50 percent of the population is served (Hird *et al.*, 2014). This compels municipal authorities to concentrate waste collection services in the high-income residential areas where the residents are more vocal in complaints about poor collection services to the detriment of poor and slum dwellers (Majale, Oosterveer and Mireri, 2013; Clark, Palfreman and Rhyn, 2015; Eduful and Shively, 2015). Like most environmental hazards, deficiencies in waste management unduly affect poorer communities as waste is often not collected or dumped in land near slums.

Nevertheless, Courtois (2012) argues that the management of MSW is not just a public service but also an important economic sector which can provide business and job opportunities. She contends that the sector is worth USD 390 billion in both OECD and emerging countries and provides up to 5% of urban jobs in low-income countries. Similarly, FAO (2012) indicates that there is a potential global market of almost a trillion dollars in food waste and food loss alone. The global MSW production is projected to double in the next five years (Dukhan, et al., 2012), while this increase in MSW production will result in management challenges in developing countries, it equally presents an opportunity for municipal authorities and private sector to harness for SD.

Therefore, the waste sector, with all its complexities in developing countries, has a lot of potentials to be organized in a way that is more economically, environmentally, and socially sustainable (Hultman and Corvellec, 2012). Improved waste management approaches can generate economic growth through the creation of new business and employment opportunities for the teeming unemployed youth in most developing countries. Also, proper waste management can facilitate the recovery and reuse of valuable resources and a corresponding reduction in the depletion of virgin materials (Gharfalkar *et al.*, 2015).

Despite the possible benefits of MSWM, many developing countries do not have the needed technological know-how to harness the opportunities that come with the high volumes of generated MSW (Osibanjo *et al.*, 2012). The focus of MSWM in developing countries has largely been limited to improving the environment, however, MSWM can provide direct health benefits, support economic productivity, and provide safe, dignified and secure employment opportunities.

2.2.1 MSW Collection

Waste collection is the gathering of SW from the point of production (residential, industrial, commercial, and institutional) to the point of treatment or disposal (Rozenberga, 2013). Waste collection is the main component of waste management that links waste generators to the waste management system (Gukhool, 2015 p37). Typically, the collection is the costliest and fuel intensive component in the SWM system (Levis, et al., 2015). It also defines the initial separation of materials which affect all downstream processes.

There are several ways of MSW collection, however, the common methods of waste collection are:

House-to-house: waste collectors visit each individual house to collect garbage. The user generally pays a fee for this service;

Communal collection: Users bring their garbage to community containers/bins that are placed at vantage points in a neighbourhood or locality. MSW is picked up by the municipality, or its designate, according to a set schedule;

Curb-side Pick-Up: Users leave their garbage directly outside their homes according to a garbage pick-up schedule set by the local authorities;

Self-Delivered: Generators deliver the waste directly to disposal sites or transfer stations, or hire third-party operators; and

Contracted or Delegated Service: Businesses hire firms (or municipality with municipal facilities) who arrange collection schedules and charges with customers. Municipalities often license private operators and may designate collection areas to encourage collection efficiencies.

(Coad, 2011; World Bank, 2012; Gukhool, 2015)

The effectiveness of these collection methods depends on other urban infrastructure such as well-planned settlements and good road network. However, due to the high infrastructure deficit in most developing countries, the communal collection is the most popular method of collection. For instance, in Ghana curb-side and house-to-house collections are limited to the high-income residential areas where there are goods roads and the residents can afford to pay for the service, while the middle and low-income areas rely on communal collection and improper waste disposal practices such as throwing waste into drains, bushes, and burning.

MSW collection is a public service that has important impacts on public health and the appearance of towns and cities (Coad, 2011), and forms about 85 percent of the total cost of waste management systems in most countries worldwide (Gukhool, 2015 p39). The failure of many authorities in developing countries to consider important parameters of each particular location in the purchase of MSW collection equipment has led to many failed collection systems and the wastage of huge sums of money (Coad, 2011; Is-haque and Huysman, 2013; Wiesmeth and Häckl, 2017). In many cases, collection vehicles and containers have been purchased in large numbers in some developing countries, but they have not been effective and have been operational for only short periods that are much less than their expected design lives (Guerrero et al., 2013).

The purchase of unsuitable equipment in some cases is attributed to corruption and the assumption that the same type of waste collection equipment will work effectively in any situation (Fakoya, 2014), without considering the specific contextual circumstances of the local situation and waste characteristics. Many other factors act against effective MSW collection in urban areas of developing countries, some of which are traditional values and religious beliefs (Wilson, et al., 2006; Wilson and Ing, 2013; Akhtar, 2014). For instance, it is widely believed in India that works requiring direct contact with SW is strictly for the lower classes (Akhtar, 2014).

In an effort to ensure effective waste collection, there has been a trend towards privatisation of MSW collection in many cities in developing countries since the 1980s (Dukhan, et al., 2012; Bowan, 2013; Is-haque and Huysman, 2013). There are cases in which the private sector has succeeded in providing a good SW collection service in cities where the public sector had previously failed, but it is more common to find that, where the public sector (local government) has failed, private enterprise also fails to deliver the required service (Coad, 2011), especially where the private sector enjoys monopoly in most developing countries, it becomes worse than the public sector.

However, the engagement of the private sector in the waste collection through competition, transparency, and accountable processes has drastically improved SW collection in some developing countries (Van de Klundert and Lardinois, 1995; Henry et al., 2006; Dukhan et al., 2012).

2.2.2 MSW Disposal

In the past, the disposal of wastes did not pose a significant problem because the population was small and the amount of land available for assimilation of waste was large (Ray, ND; Bolund and Hunhammar, 1999). However, the need for adequate treatment and disposal of waste by man arose as populations moved away from dispersing geographical areas to congregate together in communities (Williams, 2013).

Thus, safe disposal of waste is now a global norm, though, MSW treatment and disposal is still a neglected area in many developing countries. Improper disposal of MSW in developing countries are manifested in the dumping of MSW into water bodies and wetlands, and the burning of waste to reduce its volume (Khatib, 2011). These practices are known to have adverse environmental impacts ranging from polluting natural resources and the ecology to the creation of health problems, which might lead to long-term public health complications, causing a public nuisance, and degradation of the environment and aesthetics.

Nonetheless, inappropriate disposal of waste is not only peculiar to developing countries, as the practice has occurred in every country at a point in time. Rathje (2013) posits that in the past

> "*there were no ways of dealing with SW that have not been known for thousands of years. These ways are essentially four: dumping it, burning it,*

converting it into something that can be used again, and minimizing the volume of material goods – future garbage – that is produced in the first place".

Thus, every country at one point in time has been confronted with the challenge of improper waste disposal. For instances, there were reported cases of cholera outbreaks in the UK in the 1950s and 1960s due to poor sanitation, including SWM (Griffith, Kelly-Hope and Miller, 2006).

Presently, open dumping of waste is the norm in Ghana and other developing countries (Sharholy *et al.*, 2008; Ogwueleka, 2009; Papargyropoulou *et al.*, 2015). Open dumping is an illegal process, in which any type of the waste such as household trash, garbage, tires, demolition/construction waste, metal or any other material is dumped at any location such as along roadsides, any available space either public or private property other than a permitted landfill or facility (Khajuria, Yamamoto and Morioka, 2010; Badgie *et al.*, 2012; Ali *et al.*, 2014; Karim *et al.*, 2017).

Open dumps are simple open sites with no engineered measures and no consideration for leachate and landfill-gas controls. They have devastating effects on the environment with long-term impacts such as pollution of air, soil, surface and groundwater.

Accordingly, landfilling is the most recommended method for MSW treatment and disposal in developing countries (Brunner and Fellner, 2007; Yang *et al.*, 2014; Tozlu, et al., 2016; Zainu and Songip, 2017), because it is the simplest and normally cheapest method for disposing of waste (Aljaradin and Persson, 2012). Hitherto, the main considerations in the design, construction, operation and decommissioning of landfills, which are emissions control and groundwater pollution prevention (Townsend *et al.*, 2015a; Yusoff and Zamri, 2015), are often ignored due to the high capital cost and lack of technical skills needed for landfilling in some developing countries. Therefore, un-engineered landfilling, which is a disguised open dumping, is the practice in most developing countries.

Despite that a lot of significant efforts have been made in the last few decades in many developing countries, through technical and financial support from some developed countries and international organizations, substantial reforms in the disposal of MSW are still not attained (Tian *et al.*, 2013; Lohri, et al., 2014). This failure can be attributed to the absence of the enabling environment for MSWM such as waste management governance (policy, legal, institutional, and financing frameworks) and adequate technical capacity, which is a sustainability element needed to ensure sustainable waste management (Zurbrügg *et al.*, 2012).

2.2.3 MSWM in Ghana

SWM is one of the most challenging and contentious issues in Ghana, especially in urban areas (Alhassan *et al.*, 2010), and viewed by most residents in urban areas as the third-most important urban service, besides sanitation (including toilets) and drainage (Aglanu and Appiah, 2014). Rapid urbanisation and population growth together with inadequate detailed and accurate data on quantity and composition of waste have exacerbated the problem of MSWM in the country (Miezah *et al.*, 2015).

The commonly practiced MSWM option in Ghana, as in many other developing countries, basically involves the collection of mixed waste materials and subsequent dumping at designated dump sites (Ayuba *et al.*, 2013). It is not a practice to separate waste materials at the source or any point during its management. In Ghana, MSW stream generally consists of putrescible, plastics, paper, textile, metal, and glass; similar to the waste streams in sub-Saharan Africa (Ayuba *et al.*, 2013; Miezah *et al.*, 2015).

It is generally reported that the quantity of waste generated daily is increasing enormously across the country, with the high socioeconomic class areas usually generate the highest quantity of waste, however, these may not be the exact figures since proper records of collection and disposal are not kept by the authorities responsible.

The African Development Bank (2013) indicates that Ghana generates about 3.6 million tons of SW per year, made up of predominantly organic compostable, such as food, yard, and wood wastes. There are no operational transfer stations, although three have recently been constructed in Accra by Zoomlion Ghana Limited (ZGL), a private waste collection company, they are not in use. All collected MSW in Ghana is disposed of in designed dumps or un-engineered landfill sites (which are poorly managed), without any formal material recovery, though some informal material recovery is undertaken by scavengers at homes and at the various disposal sites.

Many researchers have attributed the poor management of MSW in Ghana to negligence on the part of authorities responsible and the citizenry to deal with waste as a priority issue in the country (Oduro-Kwarteng and Shaw, 2009; Anku., 2010; Aglanu and Appiah, 2014; Miezah *et al.*, 2015; Asante-Darko, et al., 2017).

Nevertheless, the challenges facing MSWM in Ghana are many and include lack of waste reduction strategies, unavailability of properly engineered sanitary landfills and waste processing/treatment plants, weak enforcement of environmental regulations - which allows local authorities to flout environmental regulations without any sanctions, and the lack of expertise and appropriate technical know-how to effectively manage MSW (Adu and Lohmueller, 2012; Oteng-Ababio, 2012; Oteng-Ababio et al., 2013; Aglanu and Appiah, 2014; Miezah *et al.*, 2015).

Consequently, the UN-HABITAT (2010), observes that managing SW well and affordably is one of the key challenges of the 21st century and one of the key responsibilities of a city government;

> "*it may not be the biggest vote-winner, but it has the capacity to become a full-scale crisis, and a definite vote-loser, if things go wrong"*.

MWSM was initially meant to protect public health but has been modified over the years in pursuit of public policy objectives of pollution control, resource conservation and, most recently, SD (Spiegelman and Sheehan, 2005). Despite these, the MSWM system in Ghana continues to bury or burn most of the wastes that enter the system. The focus of MSW disposal in the country is on getting rid of the trash by collecting and open dumping waste at designated sites.

To ensure sustainable waste management, the activities associated with SW disposal from the generation point to final disposal normally include, generation analysis, waste reduction, reuse, recycling, handling, collection, transfer and transport, transformation (e.g., recovery and treatment), and disposal (Arafat et al., 2015; Arushanyan *et al.*, 2017). Therefore, a sound waste management program that combines some of the necessary activities into an integrated solid waste management (ISWM) system is vital in achieving sustainable solutions in Ghana.

2.3 Sustainable Waste Management

Waste is no more treated as the useless garbage with no intrinsic value, rather waste is considered as a resource in the present time (Zaman, 2010, 2015; Zaman and Lehmann, 2013). Resource recovery is presently the important focus in the design of most waste management systems. Consequently, waste reduction and waste separation are the two important components of resource recovery from waste and sustainable SWM (Permana *et al.*, 2015). These actions are apparently impossible to implement without high consciousness within the communities as well as a strong commitment and support from waste management authorities.

For several reasons, resource recovery is a major element in SWM in most developing countries (Badgie et al., 2012; Thaiyalnayaki and Jayanthi, 2017). Reclaimable inorganic components (metals, glass, plastic, textiles, and others) traditionally have been recovered mostly by way of unregulated manual scavenging by private individuals (informal sector) (Srivastava et al., 2015; Leal Filho *et al.*, 2016; Stoeva and Alriksson, 2017), however, waste reduction and waste separation are rarely practiced by households and waste management authorities' due to poor waste management governance, which is militating against sustainable waste management in most developing countries.

Most developing countries in an attempt to accelerate the pace of their industrial development have failed to pay adequate attention to sustainable waste management (Mathieu and Williams-Jones, 2015). This has led to severe penalties in the form of resources needlessly lost and a staggering adverse impact on the environment and on public health and safety (Othieno and Awange, 2016).

Thus, every country needs to adopt appropriate waste management systems that meet their needs at every level of development in order not to pass on waste management challenges for future generations to solve. Appropriate planning is key to SD in the waste sector through the development of sustainable waste management infrastructure and systems (Topić, et al., 2013; Sanford *et al.*, 2016).

Accordingly, planning is the first step in designing or improving a SWM system (Khalili and Duecker, 2013), however, in most developing countries, planning is ignored and ad-hoc measures are used to only get waste out of sight. Nevertheless, planning is required to balance the social, economic, political, governance, environmental and technical considerations for waste management (Marshall and Farahbakhsh, 2013; Rodríguez *et al.*, 2015), because MSWM planners are faced with a system that involves a variety of these factors. Therefore, in making decisions, the trade-offs among these factors are a central concern.

As indicated in section 2.1.2 above, the cornerstone for planning for SWM is reliable baseline information of the waste generation and characteristics. For instance, the baseline information of the waste generation and characteristics will assist in the formulation of targets for waste reduction and material recovery (Alqader and Hamad, 2012).

However, unfortunately, MSW planners in most developing countries do not have the resources and the expertise needed to analyse all the information that is relevant to a proposed waste management policy (McKay, et al., 2015). In most cases, only the financial cost borne by the municipality is considered (Rogge and Jaeger, 2013; Lohri, et al., 2014), effects on air and water, and environmental equity are only considered when a crisis with the public develops, or when regulations are imposed (Percival, 2015; Asomani-Boateng, 2016).

The key role of waste management planning is to establish which combination of waste management strategies and methods will ensure sustainable waste management. Therefore, in planning for waste management, the objectives must be sustainable and realistic, consistent with the environmental policies and regulations and measurable so that progressive achievements are verifiable (Zaccariello et al., 2015).

Accordingly, sustainable waste management has been achieved through various concepts/strategies for MSWM in many parts of the world (particularly in developed countries). These strategies are based on waste reduction strategies and/or a combination of various waste management technologies. The following subsections discuss some of the applicable concepts/strategies for the achievement of sustainable waste management.

2.3.1 Concepts/Strategies for MSWM

The continuously increasing waste generation worldwide calls for innovative strategies that integrate concerns for SD in MSWM (Koroneos and Nanaki, 2012; Laurent *et al.*, 2014). Accordingly, UNEP (2013) indicates that every nation needs to develop a strategy for waste management and that the objective of any strategy for MSWM should be to improve upon the approach to waste management, which in most developing countries is disorganised, haphazard and under-resourced.

Waste management is a complex sector with varied interest groups (Golden, 1998; Hamilton, et al., 2015), who are expressing increasing concerns about the appropriateness of various strategies and technologies in managing MSW globally. With high public awareness about the problems posed by inadequate MSWM and the negative effects of some MSWM technologies, broad consultation and involvement of all stakeholders are needed in the development of a workable MSWM strategy.

Therefore, any strategy should compose of a systematic assembly of policy choices made at a given point in time, within the national context, that builds upon and addresses the fundamental elements and situation and gap analysis while giving particular emphasis to priority issues (UNEP, 2013). Hence, to develop effective waste management strategies, developing countries which are engulfed with waste management challenges need to consider their present waste situation and embed their strategies in their national development plans.

Presently, raw materials are becoming scarcer and energy more expensive, and all around the world, soil, air and water pollution pose a risk to SD (Leardini and Serventi, 2016). Waste management is closely associated with these problems, as waste disposal issues are exacerbated by changing patterns of consumption, industrial development and urbanisation. This means that the traditional systems for SW disposal and recycling are no longer appropriate (Mmereki *et al.*, 2016).

Consequently, in Europe and other parts of the globe, waste is increasingly being used to produce both materials and energy, and recycling now saves more greenhouses gases than it generates (Bhada-Tata and Hoornweg, 2016). For instance, the focus of the European policy on environmental protection has shifted to a more encompassing aim of protection and mitigation, with subsequent policy and legislation setting out a more general framework for the handling, storage, treatment and disposal of all waste streams.

The European policy on environmental protection is reflected by the principles that are included in the Fifth European Commission (EC) Environmental Action Programme - '*Towards Sustainability*', which is the foundation of waste management legislation in Europe (European Investment Bank, 2002) (Table 2.6 indicates the principles of EU Waste Management Policy).

However, many developing countries, especially sub-Saharan African countries, are still faced with the major challenge of improving their inadequate and unsustainable waste management systems (Makoni et al., 2016), to cope with the rising population, urbanisation and economic growth, which are leading to increasing MSW generation rates.

Table 2.6: The principles of EU waste management policy (European Investment Bank, 2002)

Principle	Description
Waste Management Hierarchy	A ranking of waste management options, from the most to the least desirable: reduction, reuse, recycling, recovery and optimum final disposal as well as improved monitoring.
Proximity	Waste should be disposed of as close as possible to its point of origin, to reduce waste movements
Self-Sufficiency	A network of integrated waste disposal facilities should exist throughout the Member States in the Community, with co-operation between countries ensuring that waste generated within the Community is only disposed of within the Community.
Best Available Techniques Not Entailing Excessive Cost (BATNEEC)	Processes should be optimised and associated emissions from installations should be minimised, while still being economically efficient.

2.3.1.1 The Waste Management Hierarchy

The waste management hierarchy is the most popular concept globally. It was first adopted in the 1970s when disposal-based waste management was criticised by the environmental movement and environmental advocacy groups that arose out of the movement because the method appeared to be unsustainable (Shamshiry *et al.*, 2015). Members of the movement argue that instead of considering SW as a consistent mess, it must be seen as being composed of a variety of constituents that need to be treated using different and appropriate methods.

Hence, the waste hierarchy comprises a set of options for attending to waste, preferentially ranked in terms of their perceived environmental benefits (Gregson *et al.*, 2013; Herva and Roca, 2013; Antonopoulos *et al.*, 2014; Eriksson et al., 2015; Soltani *et al.*, 2015). The proponents of the waste hierarchy contend that when waste is created the priority is how it can be reduced, reused, recycled, recovered before final disposal.

Thus, disposal (effectively landfill) and recovery (as energy) are at the bottom of the hierarchy, recycling or materials recovery is in the middle, and (preparation for) reuse or reduction and prevention at the apex (Gregson *et al.*, 2013), as shown in Figure 2.1. The overarching aim of the waste hierarchy is to extract the maximum practical benefits from products while generating the minimum amount of waste (Hultman and Corvellec, 2012; Efraimsson *et al.*, 2014).

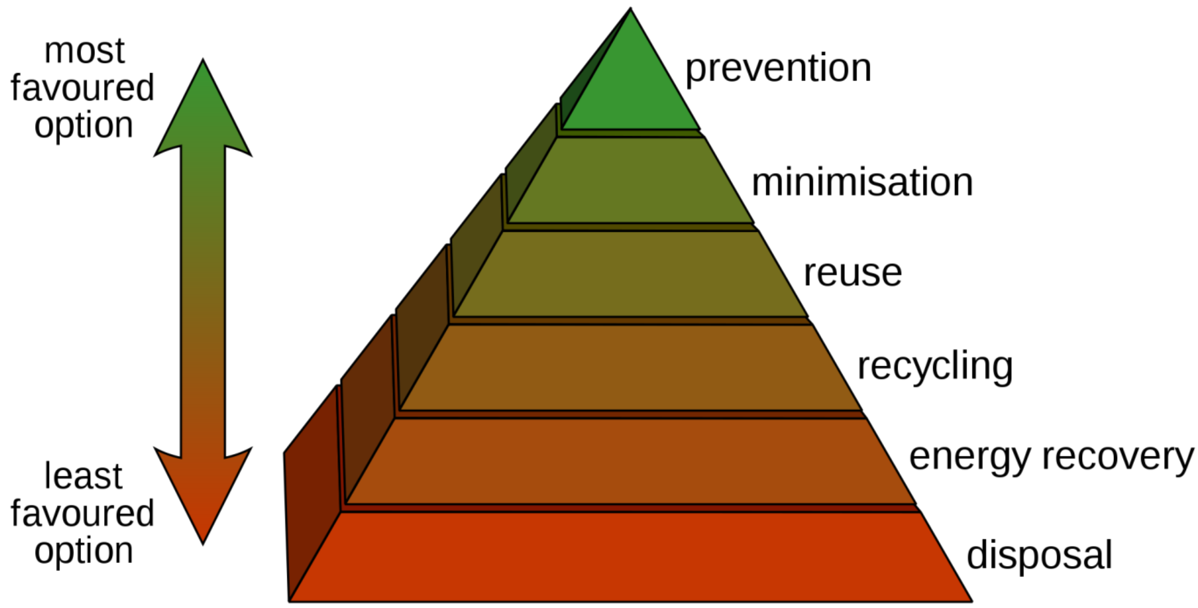

Figure 2.1: Waste management hierarchy (Hyman *et al.*, 2013)

Therefore, the waste management hierarchy classifies waste management strategies according to their order of importance and is the cornerstone of most waste minimisation strategies (ACT, 2011; Stegmann, 2017). Accordingly, the waste hierarchy approach is a strategy finalised to avoid, eliminate and prevent the causes of waste environmental problems (Cucchiella, et al. 2014), and hence is comparable to the popular saying in human health and medicine that: '*prevention is better than cure'*.

Consequently, many modern environmental legislations include principles of minimising impacts on the environment and conserving natural resources (Hultman and Corvellec, 2012; Efraimsson *et al.*, 2014). These legislations follow the waste hierarchy concept, which among other things, gives preference to recycling or reuse of material over waste disposal (EU Waste Directive, 2008).

However, the waste hierarchy seems to be more prominent in Europe than elsewhere. Accordingly, some researchers observe that the waste hierarchy has become more entrenched in EU legislation than the US legislation, though the idea of the waste hierarchy was formulated in the US. This is probably because many critics of the waste hierarchy are of the view that it is inflexible and suggest that where clearly a better environmental outcome can be shown, the hierarchy strategy should be avoided (Dukhan, Bourbon-Séclet and Yannic, 2012; Ewijk and Stegemann, 2016).

Also, the implementation of the waste hierarchy has emphasised the less desirable alternatives to landfill (Ewijk and Stegemann, 2016; Fazeli *et al.*, 2016), nonetheless, due to high changing patterns in consumption, landfilling will always be necessary for the disposal of residue from other waste processing/treatment methods. Moreover, waste that is technically suitable for recovery does not automatically become a raw material if there is no market for it, or its use is not commercially effective and, hence, should be disposed of (Thierry, et al., 1995; Twardowska and Szczepanska, 2002).

Again, the waste hierarchy requires adequate legislation for its implementation and may not be applicable in all locations, especially in some developing countries, where there are inadequate legislation and poor institutional framework for waste management. Therefore, many researchers are of the opinion that, treatment and processing of MSW should target minimising the volume of landfilled waste, whilst recovering as many resources out of it as possible (Arafat, et al., 2015; Wanka, et al., 2017).

Material recovery and recycling

Originally, managing waste was about protecting human health and maintaining environmental amenity (Makwara and Magudu, 2013; Srivastava *et al.*, 2015; Ziraba, et al., 2016), however, since the 1990s, SD came to prominence and waste recycling has become a priority (Gregson *et al.*, 2013; Wilson and Ing, 2013; Aydiner *et al.*, 2016).

Resource recovery has been a major element in SWM, especially in developing nations, through the informal sector (Guerrero, et al., 2013; Laurent, Clavreul, *et al.*, 2014; Brunner and Rechberger, 2015), where scavenging for recoverable materials is a source of livelihood for many people. Thus, in most developing countries, a lot of recovery and recycling takes place informally in such a way that some materials do not enter the municipal waste stream (Ali and Bella, 2016).

Recycling or materials recovery is in the middle of the waste management hierarchy and is an applicable waste reduction method in both developed and developing countries. In the past, reclaimable inorganic components were recovered mostly by way of unregulated manual scavenging by private individuals (Brunner and Rechberger, 2015), however, in recent years, the trend has been formalised and mechanised scavenging is practiced through the establishment of material recovery facilities in some developing countries (Townsend *et al.*, 2015b).

Moreover, attention is now given to the recovery of organic waste in most developing countries since organic waste constitutes at least 50% of the waste stream (World Bank, 2012). Accordingly, the resource recovery aspect regarding the organic component is threefold: the component can be used in agriculture as a soil amendment through composting, its energy content can be recovered either biologically or thermally, and the organic content can be hydrolysed either chemically or enzymatically to produce sugar (UNEP, 2005).

For example, Accra Compost and Recycling Plant (ACARP), an integrated waste processing and recycling company established in Accra, Ghana in July 2012, is helping to solve the plastic waste menace in Accra and other parts of Ghana, through the recycling of plastic waste into high quality pelletized plastics as raw materials for other local industries for further production into various plastic items. ACARP also recovers materials such as textiles, packaging materials and other highly combustible materials which are also used for the manufacture of high calorific burning materials for specific industries.

Nevertheless, recycling process itself can lead to the introduction of pollutants in goods and reservoirs. For example, the recycling process can increase heavy metal contents in recycled plastics, or it can lead to accumulation of metals in the soil when sewage sludge is applied to agricultural fields (Brunner and Rechberger, 2004). Also, the challenge with material recovery and recycling in most developing countries is the processing of mixed waste to recover materials. The success of these will depend upon the degree of source separation of the waste, as well as the types of materials to be recovered.

Presently in most developing countries including Ghana, there is no separation of waste at the generation point. This hinders material recovery and recycling. Conversely, the initial cost of waste processing facilities for recycling is a deterrent to most developing countries which are still struggling to provide basic amenities such as potable water to their citizenry.

2.3.1.2 Zero Waste Approach

Zero waste (ZW) is one of the most visionary concepts for solving waste problems (Zaman and Lehmann, 2013) in a whole-system approach that aims to eliminate rather than manage waste. It encourages waste diversion from landfill and incineration because ZW has the philosophy of eliminating waste at source and at all points down the supply chain (Curran and Williams, 2012).

Thus, the Planning Group of Zero Waste International Alliance (ZWIA) adopted the following definition of ZW:

> "…..*ZW is a goal that is ethical, economical, efficient and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use. ZW means designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them. Implementing ZW will eliminate all discharges to land, water or air that are a threat to planetary, human, animal or plant health*."

(Liss and Loomis, 2013)

Subsequently, other organisations that wish to achieve holistic ZW goals have adapted and utilised this working definition. For instance, ZW in England is defined as:

> "*a simple way of encapsulating the aim to go as far as possible in reducing the environmental impact of waste; it is a visionary goal which seeks to prevent waste occurring, conserves resources and recovers all value from materials*" (Phillips *et al.*, 2011)

Lombardi (2011) contends that the pioneers of the ZW were very clear that ZW to landfill was not the same as ZW. He further argues that ZW is about making the best choice with natural resources – from extraction to production to consumption to disposal. The emphasis of ZW approach is on avoiding waste created by the constant evaluation of materials choices and a strong commitment to eliminating waste, not just treating waste. Therefore, ZW is completely opposed to waste disposal in landfill and WTE technologies.

Consequently, Zaman (2015) in a review of the development of ZW management between 1997 and 2014 observes that the concept has been embraced by policymakers because it stimulates sustainable production and consumption, optimum recycling and resource recovery. Thus, ZW's implementation is not limited to only waste management but is equally applicable to mining, manufacturing, and urban development.

ZW is seen as the best practice in ISWM because it is comprehensive, thorough, emphasises prevention first in the strategies employed, and fosters local value-added manufacturing opportunities for the collected materials (Gainer, 2013). Nevertheless, ZW is not a feasible concept of waste management presently in anywhere in the world due to its major economic and financial implications. It is inevitable to avoid waste generation in this era that more resources are needed to meet the developing needs of nations.

Also, ZW implementation requires adequate legislation, good institutional framework and efficient waste governance. These are lacking in most developing countries and as such, its application is not practicable in these countries. Waste reductions are the focus of most present waste management concepts and not outright avoidance of waste generation. The idea of completely eliminating waste is highly unrealistic currently, rather, the approach should be espoused for waste to be handled in such a manner that does not harm the environment while optimising the resource potentials of waste for SD.

2.3.1.3 Cradle-to-Cradle / Cradle-to-Grave

The phrase cradle-to-cradle was invented in the 1970s by Walter R. Stahel and popularised by William McDonough and Michael Braungart in their 2002 book of the same name: '*cradle-to-cradle'* (Sim, 2013). The cradle-to-cradle framework seeks to create production techniques that are not only efficient but are really waste free

(Dalmia, 2014; Bosch, 2015). Accordingly, UNEP (2013) underscores that the cradle-to-cradle concept focuses, first and foremost, on defining the intention behind the design of a product in terms of its positive impact with the objective of avoiding waste completely.

The cradle-to-cradle concept and the ZW approach have a similar objective of avoiding waste, however, the cradle-to-cradle concept is not opposed to material recovery from waste because all materials are inputs and outputs during production. Thus, for the cradle-to-cradle concept, rather than ultimately ending up as waste, the materials in a product at the end of its useful period begin a new life in a new cycle, at the same level of quality, time and again (UNEP, 2013). Thus, waste is always a resource and its generation is avoided completely.

In contrast, cradle-to-grave refers to a company taking responsibility for the disposal of goods it has produced, but not necessarily putting products' constituent components back into service (Wiel, et al., 2012; Vandermeersch *et al.*, 2014). El-Haggar (2016) simplifies the meaning of the cradle-to-grave concept in his explanation that '*cradle is where life starts, and the grave is where life ends*'.

No matter how a particular waste is reused, there comes a point that it must be disposed of. Therefore, cradle-to-grave is used in reference to a company's perspective on the environmental impact created by their products or activities from the beginning of its life cycle to its end or disposal (El-Haggar, 2016). This concept focuses on ameliorating the negative impacts of waste emanating from a product throughout its lifecycle.

In order to apply both cradle-to-cradle and cradle-to-grave concepts in MSWM, materials must have a known, well-defined chemical composition; materials must be either biological nutrients (i.e. safe to return into a natural biological cycle) or technological nutrients; and the products must be designed for easy disassembly (UNEP, 2013). These call for forms of interaction along the supply chain of products between producers and consumers which is unlikely because there is usually no direct link between producers and customers.

2.3.1.4 Integrated Solid Waste Management Concept

Integrated solid waste management (ISWM) is an evolving concept (Memon, 2010), which is the interlinked stages of a system to collect, process, treat, and dispose of waste. Initially, ISWM was developed to increase the efficiency of MSWM chain, through source separation, collection and transportation, transfer stations, treatment and final disposal (Tchobanoglous, 1993; Marshall and Farahbakhsh, 2013), but later became an umbrella management system to coordinate all waste types from all the waste sources (residential, commercial, industrial, healthcare, construction and demolition and agriculture) within a geographic or administrative boundary such as a city (Mwangi and Thuo, 2014)

ISWM refers to the strategic approach to sustainable management of SW covering all sources and all aspects, covering generation, segregation, transfer, treatment, recovery and disposal in an integrated manner, with an emphasis on maximizing resource use efficiency (Memon, 2009, 2010; Zurbrügg *et al.*, 2012; Haregu et al,. 2016, 2017), as shown in Figure 2.2. Waste management operations and strategies are incorporated in an integrated approach that includes a hierarchy of waste management alternatives, including waste avoidance, resource recovery, and environmentally sound treatment and disposal (UNEP, 2005) in the ISWM concept. Therefore, this concept can be described as the agglomeration of all SWM concepts/strategies.

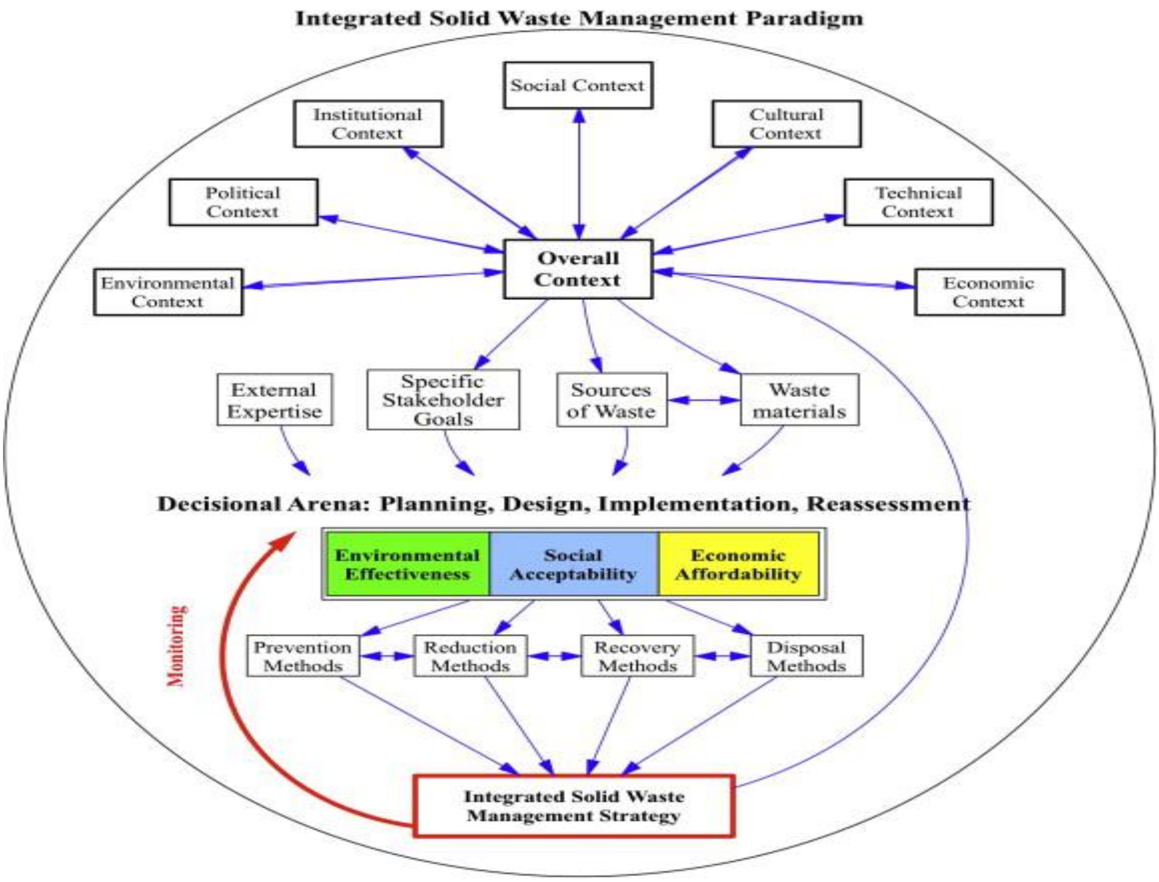

Figure 2.2: Integrated solid waste management framework (Marshall and Farahbakhsh, 2013)

The initial point of an ISWM system is the possibility of waste reduction, choosing the optimal ways of its treatment starting from its creation to its final handling and its transformation into something safe for the environment and the well-being of people (Ristić, 2005). This concept thrives on adequate data and information on waste characterisation and quantification (including future trends), and assessment of the current management system (the baseline scenario) (Ristić, 2005; Ionescu *et al.*, 2013). Accordingly, the SWM systems that operate successfully in various parts of the world indicate that a single option is not suitable to handle efficiently the full array of MSW (Marshall and Farahbakhsh, 2013; Badgie, Manaf and Samah, 2016).

There are many alternatives for the management of SW including recycling, biological treatment, thermal treatment, and landfill disposal, however, the selection and mix of these alternatives must be technically and economically sustainable based on local considerations. This is because ISWM requires making informed decisions to optimise SWM by minimising environmental releases, energy and resource use, and costs while maximising useful outputs. Therefore, good judgment is required to balance these factors for a given region (Ham *et al.*, 2002). As such, all realistic methods of SWM must be considered, including recycling, combustion, composting, and landfilling.

However, the use of several of these processes in a waste management system may be too expensive for most developing countries. Currently, waste management systems in most developing countries are contending with the barriers of socio-political, technological, regulatory, financial, and human resources constraints (Bufoni, et al., 2016). Nevertheless, combining several waste treatment options in an integrated manner is the way to solving MSWM problems as various streams of waste require different processing or treatment technologies. The ISWM concept is the adopted concept for this study. Thus, *the analysis of this research findings, and a developed and validated framework fit into the ISWM concept (see chapters 5 and & 7).*

2.3.2 MSW Processing and Treatment Technologies

Waste processing and treatment is the core means to reach the MSWM objectives in terms of protection of human health and environment, economic development, and fulfilment of social and regulatory requisites (Soltani *et al.*, 2015). Waste processing issues are addressed in diverse ways in different countries, regions, cities and towns because much depends on the local conditions, financial possibilities and other factors (Rumyantseva *et al.*, 2017).

The technology options available for processing and treatment of MSW are based on either bioconversion or thermal-conversion processes (Defra, 2014; Watkins and McKendry, 2015), as outlined in Table 2.7. The bioconversion process is applicable largely to the organic waste, to form compost or to generate biogas such as methane (Cesaro and Belgiorno, 2014; Kiran *et al.*, 2014), whereas the thermal conversion technologies are incineration with or without heat recovery, pyrolysis and gasification, plasma pyrolysis and palletisation or production of refuse-derived fuels (RDF) (Fodor and Klemeš, 2012; Evangelisti *et al.*, 2015; Ouda *et al.*, 2016; Nizami *et al.*, 2017). The thermal conversion technologies are generally not suitable for MSW of high organic content, because the calorific value of waste is influenced by its moisture content.

Table 2.7: Technology options available for processing and treatment of MSW

Bioconversion technologies	**Thermal Conversion Technologies**
Composting	Incineration
Anaerobic digestion	Pyrolysis
Fermentation	Gasification

Opinions differ on the effectiveness of these technologies for the processing and treatment of MSW (Environment Canada, 2013). This is because waste infrastructure has a long lifetime and care needs to be taken at the start to ensure systems can adapt to potential long-term changes (Dukhan, et al., 2012). Thus, the flexibility of a technology to future change is usually the key consideration in the choice of a technology. Nonetheless, the appropriate selection of a technology is equally dependent on many factors such as technological efficiency, economic benefit, and social and environmental acceptability (Zaman, 2013).

2.3.2.1 Bioconversion of MSW

Biochemical conversion of MSW uses biological agents (enzymes and microorganisms) to break down organics for biogas production and collection of value-added products (Pragya, et al., 2013; Ng *et al.*, 2014; Nizami *et al.*, 2016).These processes are able to convert not only MSW but other biomass waste such as sewage sludge, plastic, tires, agricultural residues and the like, as well as coal, to useful products such as hydrogen, ethanol and acetic acid (Nizami *et al.*, 2016). The end product of any bioconversion technology is either the production of clean energy in the form of biogas which can be converted to power and heat using a gas engine (Srirangan *et al.*, 2012; Zafar, 2016) or compost which can be used as a soil conditioner.

<u>Composting</u>

Composting is the aerobic decomposition of biodegradable organic matter in a warm, moist environment by the action of bacteria, yeasts, fungi and other organisms (Temgoua *et al.*, 2015; Muttalib, et al., 2016). Factors affecting the rate and completeness of decomposition are manipulated according to local needs and constraints to produce the desired decomposition (Ham *et al.*, 2002). These factors include waste selection or exclusion, particle size reduction, mixing, seeding, moisture addition, and aeration.

Composting produces a product that is biologically stable and free of viable pathogens and plant seeds and can be applied to agricultural lands to improve the soil nutrients. It conserves nutrients in waste (N,P,K) and increases soil carbon content and moisture holding capacity (Levis and Barlaz, 2015). Thus, composting is the most widely used process for treatment of organic SW, especially in developing countries where organic waste is the dominant component of the MSW stream (Hoornweg, et al., 2000; Levis and Barlaz, 2015).

More costly facilities (usually in developed countries) use mechanical methods to prepare the waste and to promote decomposition, whilst less costly facilities (in developing countries) emphasise natural processes, reducing mechanical needs (Ham *et al.*, 2002). In general, composting involves three basic steps: pre-processing which involves size reduction and nutrient addition; decomposition and stabilization of organic material; and post-processing which involve grinding and screening (Tiwary, *et al.,* 2015). These processes reduce the volume and weight of waste by approximately 50% and result in a stable product that can be applied in agriculture (Antonopoulos *et al.*, 2014; Temgoua *et al.*, 2015).

There are various technologies available for composting but the most common technologies are aerobic, anaerobic and vermicomposting (Gupta and Gupta, 2016). Vermicomposting is a recent technology for MSW and sludge management (Mohee and Soobhany, 2014). It is basically the breakdown of organic matter by some species of earthworms (Huang *et al.*, 2014; Mohee and Soobhany, 2014; Sequeira and Chandrashekar, 2015). The dropping of the worms together with the broken organic matter makes vermicomposting to be nutrient-rich than other compost and thus, can be used as a natural fertilizer and soil conditioner.

Many researchers observe that composting is the cornerstone of SD in the waste sector (Salim *et al.*, 2014; Lehmann and Joseph, 2015), and therefore, suggest that composting should be a more widespread practice in developing countries (Kane and Solutions, 2015), because it can be implemented at small and large scales (Levis and Barlaz, 2015). However, large and centralised composting plants are often not economical, due to high operational, maintenance and transportation cost in developing countries (Mudhoo, et al., 2015).

The viability of commercial composting is usually dependent on the availability of a ready market for the final compost product. Subsistence farming is still widely practiced in most developing countries, with farmers depending on their own animals' droppings for manure. The demand for compost may not be able to meet the production cost in most developing countries. For instance, Taiwo (2011) indicates that in Nigeria, composting of MSW has failed in various regions of the country due to lack of funds for maintenance because there were no ready markets for the compost produced.

On the other hand, Ghana in the same West African sub-region with Nigeria is reducing fertilizers import due to composting. Ghana used to spend over US$ 63 million annually on fertilizer subsidy to farmers (Banful, 2009), however, ACARP's compost fertilizer which is now utilised across the country has helped to reduce Ghana's over-dependence on imported fertilizers. Nonetheless, composting cannot be regarded as a panacea to today's waste management problems but should be an important component within an ISWM system in developing countries (Hoornweg et al., 2000).

On the environmental burdens of composting, Ham *et al.* (2002) in a report to the US EPA observe that although composting has a long history and has been the subject of much research and development, little is known about the extent of decomposition. Because of this, there is no information on the amount of gases produced during decomposition and only general information and theoretical projections of the gas composition are usually made.

Carbon dioxide (CO_2) and ammonia (NH_3) gases are the primary metabolic by-products of the composting process. CO_2 is a well-known greenhouse gas; however, little is known about the actual yields and production rates of CO_2 and NH_3 in composting (Ham *et al.,* 2002). Also, no significant amounts of leachate are produced in composting facilities, if the compost is covered and the moisture content is kept near optimal values (Cole, 1994; Rynk and Richard, 2001; Sanders et al., 2010). For this reason, leachate production within the composting facility is often assumed to be negligible.

Composting of MSW in developing countries has the potential of reducing GHG and leachate emissions from open dump sites, the quantity of waste that is landfilled, and the high import bill on fertilizers. Also, the resource potential of MSW through composting presents business and job opportunities that can assist in the fight against poverty and underdevelopment and ensure food security in many developing countries.

Anaerobic digestion

Anaerobic digestion (AD) is the natural biological process which stabilizes organic waste in the absence of air and transforms it into bio-fertilizer and biogas (Mohammed *et al.*, 2013; Poh *et al.*, 2015). AD is either a wet process used for materials with moisture contents more than 85% or a dry process used for materials with moisture contents less than 80% (FRM, 2013).

AD is rapidly developing as the main technology for wet household organics, manures and slurries, and is particularly suitable for food waste which is usually high in moisture content (Damgaard, 2015; Zafar, 2016). Through the AD process, it is possible for organic waste from various sources to be biochemically degraded in highly controlled, oxygen-free conditions to result in the production of biogas which can be used to produce both electricity and heat (Srirangan *et al.*, 2012).

In comparison with composting, AD processes require less energy input than aerobic composting and also creates much lower amounts of biologically produced heat, although additional heat may be required to maintain optimal temperatures in an AD process (FRM, 2013). AD technology has been implemented widely across the globe for many years.

While some AD implementations have been successful, others have failed woefully, particularly in some developing countries. According to Mudhoo et al. (2015), an AD project named '*TAKA'* (waste) has been successfully implemented in Tanzania. They indicate that this project is dealing with the growing problem of MSW and produces biogas for electricity production.

On the other hand, biogas plants that were installed in Ghana in the early 2000s all failed due to inadequate waste supply to the plants and lack of technical expertise in managing the plants (Müller, 2007), however, new biogas plants are currently under construction across the country, especially in senior high schools for faecal sludge management.

Fermentation

The fermentation process is used to manage waste and produce fuel (Pandey *et al.*, 2016). It is mostly used in industries that produce food and drink products in many countries. It is a metabolic process that converts sugar into acids, gases, and alcohol in the presence of yeast and bacteria (Vohra *et al.*, 2014; Pandey *et al.*, 2016; Sarris and Papanikolaou, 2016). Like in the AD, in the MSW fermentation process, the waste is acted upon by yeast and bacteria in the absence of oxygen to produce ethanol, acids, and trace of gases which are eco-friendly fuels (Hansen and Cheong, 2013).

Despite these, the use of fermentation as a waste treatment technology is limited to only breweries in most developing countries. Even in industrialised countries, there is no evidence of its application for general MSWM. Nonetheless, fermentation is an emerging technology worth considering for MSWM in developing countries.

2.3.2.2 Thermal Conversion of MSW

The three principal methods of thermal conversion are combustion in excess air, gasification in reduced air, and pyrolysis in the absence of air (Zafar, 2016). However, the most common technique for producing both heat and electrical energy from waste is incineration (Tozlu, et al., 2016). Thermal conversion technologies are commonly implemented in developed countries but scarcely used in developing countries due to the high construction, operation, and maintenance costs involved.

<u>Incineration</u>

Incineration is mainly the waste destruction in a furnace by controlling combustion at high temperatures to produce steam which in turn produces power through steam turbines (Bosmans *et al.*, 2013; Søndergaard *et al.*, 2016; Tozlu, et al., 2016; Zafar, 2016). By incinerating waste, approximately 70% of the total waste mass and 90% of total volume can be reduced (Bhada-Tata and Hoornweg, 2016; Tozlu, et al., 2016), which leaves a small residue of waste to be disposed of in a landfill and thereby reducing the pressure and demand for landfills.

Incineration is particularly appropriate for the treatment of certain hazardous waste (medical waste), where the high temperature will destroy disease causing pathogen and toxins (Tanigaki, et al., 2016, p71). Waste incineration is popular in countries such as Japan where there is the scarcity of land for landfilling, while Denmark and Sweden have been using the energy generated from incineration for many decades (Tan *et al.*, 2015).

However, a World Bank report on MSW incineration indicates that MSW incineration plants tend to be among the most expensive SWM options, and also require highly skilled personnel and careful maintenance (Rand, et al., 2000). The World Bank, thus, advises that incineration should be the desired choice only when other, simpler, and less expensive choices are not available. Consequently, incineration plants have been shut down in many cities around the world, including Buenos Aires, Mexico City, Sao Paolo and New Delhi, due to their high repair and maintenance costs (UNEP, 2005)

Nonetheless, incineration is widely practised in some industrialised countries (as shown in Table 2.8) and only used to burn medical waste in some developing countries such as Ghana, because there is a high failure rate of incineration implementation in African developing countries. For instance, a waste-to-energy (WTE) incinerator which was recently installed and commissioned in Tanzania, with the support of international experts has failed (Mudhoo, et al., 2015). The high maintenance and operation costs of the incinerator are the reasons for the failure of this project.

Additionally, related environmental problems such as air pollution are a major hindrance to incineration globally (Kumar and Gupta, 2016). There is usually widespread resistance to the setting up of incineration plants near human settlements because of the potential air pollution effects on residents near the plants. This would be especially precarious in most developing countries where there are weak legal regimes and poor environmental governance.

Accordingly, Kadir *et al.* (2013), report that the Malaysian government since the year 2000 has suggested the construction of a centralised and high-scale incineration system to assist in reducing the huge volume of MSW in urban areas, however, the proposal has faced unfavourable representation in the media and protest by local residents.

Table 2.8: The proportion of incineration of MSW in some developed countries (Rumyantseva *et al.*, 2017)

Country	Population (Million)	Municipal Solid Waste (million tons)	The Number of Waste Burning Plants	The share of Burning Waste (%)
Switzerland	7	2.9	29	79
Japan	123	44.5	1900	72
Denmark	5	2.6	32	65
Sweden	9	2.7	21	59
France	56	18.5	100	41
Holland	15	71	9	39
Germany	61	40.5	51	33
Italy	58	15.6	51	17
USA	248	180	168	16
Spain	38	11.8	21	6
England	57	35	7	5

Nevertheless, energy recovery from incineration of MSW has been practiced in many developed countries such as Japan for decades in an effort to promote SD initiatives (Kadir *et al.*, 2013). Incineration does not only reduce the quantities of MSW but can provide alternative sources of energy. Therefore, it is obvious that the adoption of incineration - be it small or large-scale - in some developing countries such as Ghana is inevitable soon, because energy from incineration can contribute to the reduction of the current high-power deficit which is affecting economic development in these countries.

For instance, for the past ten years, Ghana has not had a regular supply of power for both domestic and industrial purposes. The country has been depending largely on hydro for her energy needs, however, due to climate change, the water level in the hydro dams over the years has reduced substantially, resulting in the two hydro dams generating about half of their generation capacity. Thus, incineration of waste can produce an alternative source of energy for Ghana and other developing countries.

Pyrolysis and Gasification

Pyrolysis and gasification represent refined thermal treatment methods as alternatives to incineration and are characterised by the transformation of the waste into product gas as an energy carrier for later combustion in, for example, a boiler or a gas engine (Zafar, 2016). These methods exhibit several potential benefits over traditional incineration (Dong *et al.*, 2016). For instance, in terms of emissions pyrolysis/gasification-based WTE technique enables a decrease in dioxins and NOx emission (Noma *et al.*, 2012).

In the pyrolysis process, thermal decomposition takes place in which biomass is heated to a temperature from 400 °C to 550 °C in the absence of oxygen to produce char, non-condensable gases and vapours or aerosols (Ansah, et al., 2016). An external heat source is usually required to maintain this temperature (FRM, 2013). Pyrolysis of raw municipal waste typically would require some mechanical preparation and separation of glass, metals and inert materials prior to processing the remaining waste (FRM, 2013).

Also, in general, pyrolysis processes tend to prefer consistent feedstocks, and there is a very limited track record of commercial scale pyrolysis plant accepting municipal derived waste in the world (Woolf *et al.*, 2014; Guo, et al., 2015). Therefore, MSW is usually not appropriate for pyrolysis, though the process can be applied on MSW to produce fuels such as charcoal and coke produce gas.

On the other hand, gasification, also known as indirect combustion, is the conversion of SW to fuel or synthesis gases through gas forming reactions (Shareefdeen, Elkamel and Tse, 2015). It can be defined as a partial oxidation reaction of the MSW in the presence of an oxidant, thus creating the syngas instead of combustion gases as seen with incineration (Arena, 2012; Shareefdeen, et al., 2015). Gasification can be considered as a process of pyrolysis and combustion because it involves the partial oxidation of a substance.

The main product of gasification and pyrolysis is syngas which has a calorific value, and so can be used as a fuel to generate electricity or steam or as a basic chemical feedstock in petrochemical and refining industries (Shareefdeen, et al., 2015). The development of pyrolysis and gasification technologies for commercial and prepared municipal waste is becoming an established form of technology in the UK (FRM, 2013). However, for MSW treatment these technologies are confronted by challenges such as operational inexperience, high costs, lack of financing, and concerns about toxic emissions (Seltenrich, 2016).

Nevertheless, pyrolysis and gasification are promising alternative solutions for overcoming MSW treatment challenges and the increasing global energy demand (Sharma and Sheth, 2015). The demand of finding low carbon energy technologies for the future world calls for the adoption of gasification and pyrolysis technologies to reduce carbon footprints in MSW treatment, although, lack of financing and high operation and maintenance could deter most developing countries from exploring their feasibility.

2.3.3 Waste-to-Energy (WTE) Technologies

The utilisation of MSW for energy production has been implemented globally for many decades (Kalyani and Pandey, 2014; Zheng *et al.*, 2014; Yigitcanlar, et al., 2015). There are three fundamental types of WTE technologies: thermal conversion; biochemical conversion; and physio-chemical conversion (Tozlu, et al., 2016), as shown in Figure 2.3.

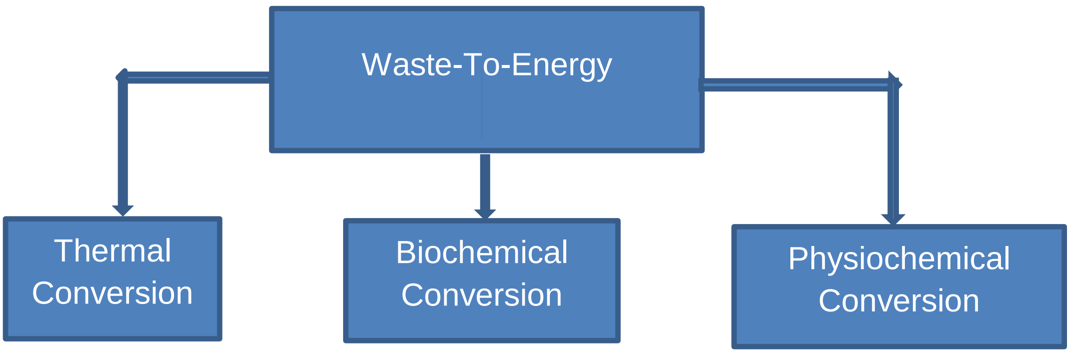

Figure 2.3: Schematic diagram of WTE technologies

MSW is a source of renewable energy due to its composition. Renewable energy has attracted a growing attention due to global warming and rapid depletion of natural resources (Larcher and Tarascon, 2015). The fraction of MSW typically treated in a WTE unit is the unsorted residual waste (URW), i.e. that residual from the operations of source separation and collection of dry recyclable and wet organic fractions (Arena, et al., 2015). These WTE technologies are the same as the bioconversion and thermal conversion processing and treatment methods already discussed in section 2.3.2 above except for the physiochemical conversion method.

2.3.3.1 Physiochemical Conversion

The physiochemical technology involves various processes to improve physical and chemical properties of MSW (Agbor *et al.*, 2014; Behera *et al.*, 2014). In this process, the combustible fraction of the waste is converted into high-energy fuel pellets which may be used in steam generation (Filippis *et al.*, 2014). Usually, the waste is first dried to bring down the high moisture levels, sand, grit, and other incombustible materials are mechanically separated before the waste is compacted and converted into pellets or refuse derived fuels (RDF) (Li *et al.*, 2013; Andreadou, 2016). Fuel pellets have several distinct advantages over coal and wood because it is cleaner, free from incombustible, has lower ash and moisture contents, is of uniform size, cost-effective, and eco-friendly (Loppinet-Serani *et al.*, 2012).

Most local communities in developing countries depend on wood and charcoal for cooking. For instance, the main sources of fuel for cooking for most households in the Wa Municipality in Ghana (the case study area for this research) are charcoal (55.2%) and wood (22.9%) (Ghana Statistical Service, 2014). A huge quantity of wood is also used in the brewing of a local beer '*pito'* in most parts of northern Ghana. The use of wood and charcoal for cooking and heating in some small-scale industries in Ghana is aggravating deforestation with its well-known climate change effects. Thus, physiochemical conversion of MSW can produce fuel pellets to replace firewood which is commonly used in cooking in Africa and other developing countries.

Notwithstanding that WTE technology is considered as one of the optimal methods for solving the MSWM problem in a sustainable way, it has a poor historical image in most countries (Defra, 2014). The reason for this is because many countries have depended on landfills for many years, and due to the fact that many of the earlier WTE technologies such as incineration were disposal-only plants, which simply burned waste to reduce its volume (Arushanyan *et al.*, 2017).

As a result, there is strong opposition to the continuous implementation of WTE technologies in some parts of the world. The zero waste movement (ZWM) in the US, for instance, argues that WTE technologies in the marketplace are actually waste of energy, money and natural resources (Lombardi, 2011), because of the high capital, operation and maintenance costs involved with these technologies.

Similarly, other critics are of the view that WTE technologies make no sense economically, environmentally and socially as it has the most GHG per fuel type, its emission produces dangerous air pollutants, it has the most expensive form of electricity, and it fails to create a fraction of the jobs created by recycling and composting (Fobil, Carboo and Armah, 2005; Lombardi, 2011; Arafat, Jijakli and Ahsan, 2015). However, the benefits of WTE technologies are overwhelming as energy is not only recovered from waste, but also the amount of MSW to be landfilled is reduced drastically. Table 2.9 illustrates the global application of WTE technologies.

Table 2.9: Globally application of WTE technologies (Transparency Market Research, 2017)

WTE Type	Application	Region
Incineration & Combustion	Only Heat	North America
Pyrolysis	Only Electricity	Europe
Gasification	Combined Heat & Power	Asia Pacific
Plasma Arc Gasification	Transport Fuels	Middle East & Africa
Anaerobic Digestion	Gas for Power	Latin America

2.3.4 Sanitary Landfilling

Landfilling is sometimes regarded as a WTE technology when energy recovery is incorporated in its design, construction and operation. Cointreau-Levine (2004) defines a sanitary landfill as:

> *"a contained and engineered bioreactor and attenuation structure, designed to encourage anaerobic biodegradation and consolidation of compacted refuse materials within confining layers of compacted soil*."

In general, sanitary landfill structures can be broadly separated into three categories: anaerobic, semi-aerobic, and aerobic, depending on the amount of air introduced into the waste layer (Kajiwara *et al.*, 2014). Among these, Manfredi and Christensen (2009) indicate that semi-aerobic landfill systems are widely used globally.

Sanitary landfilling is the most customary means of MSW disposal globally and is the most cost-effective system of SW disposal in developing countries, as 65 to 80% of collected MSW is disposed of in landfills in developing nations (Agamuthu, 2013). In an evaluation of different MSW disposal methods, Cointreau-Levine (2004) observes that composting of SW costs 2-3 times more than sanitary landfill, and incineration costs 5-10 times more. Therefore, landfilling is not the most preferred option only in developing countries but all over the world today due to its high energy production potentials (Tozlu, et al., 2016).

Despite this, the problem of leachate and gas (especially methane) emissions are difficult to mitigate during the operation and decommissioning stages of landfills. Although technology has improved to trap methane for useful purposes, leachate from MSW landfills is inevitable no matter the type of liner system used. Leachate contains various contaminants at concentration levels that may have environmental impacts on ground and surface water and can, therefore, be a threat to human health.

As a result, the role of landfilling has been rapidly diminishing in some developed countries waste management in recent years. For example, Cullen (2016) indicates that between 2006 and 2014, the number of operational landfill sites in the UK declined at an average rate of 6% per annum. This declining number of active landfills shows that there has been a monumental and broadly positive shift in the UK waste management in a relatively short space of time, with higher levels of recycling, and the rise of energy from waste moving material up the waste hierarchy (Cullen 2016). However, the reduction of operational landfills is not limited to the UK, but across Europe in compliance with the EU directive of diverting waste from landfills.

Nevertheless, sanitary engineered landfills are the best disposal option in most developing countries and are in operation in some African countries, including South Africa, Botswana and Zimbabwe (Mudhoo, et al., 2015), with environmental impacts properly mitigated, despite that, most landfills in other developing countries are not engineered and are mostly covering by refuse waste in the dump sites neither with proper technical input or with treatment of the emerging emission to water, air and soil (Khajuria, et al., 2010).

Developing countries, especially sub-Saharan African countries, need to convert their numerous open dumps into sanitary landfills and possibly incorporate energy recovery in the landfill designs to benefit from the energy potentials of landfilling to supplement their energy needs. Sub-Saharan African countries are currently facing energy crisis with many areas without access to electricity. For instance, only 16% of households use gas as their main source of fuel for cooking in the Wa municipality in Ghana (Ghana Statistical Service, 2014). Therefore, energy recovery (methane) from waste can play a role in minimising the impact of MSW on the environment, unemployment, and provide an alternative source of energy for economic development.

2.4 Waste Management Environmental Performance

The management issues relating to MSW all over the world are increasing daily due to rapid urbanization (Sanjeevi and Shahabudeen, 2015), and the challenges faced by MSWM decision makers go beyond simple quantification and characterization of waste (Teixeira and Neves, 2009). The challenges involve not only regulation and law-abidance but also global performance assessment by quantification of the system's efficiency. Therefore, in developing a sustainable system, properly selected sustainability performance indicators are required to be used in monitoring, controlling, and communicating with both internal and external stakeholders (Olapiriyakul, 2017).

Sustainability issues and SD are terms of relevance in recent years, particularly associated with debates of environmental responsibility (Fernandes *et al.*, 2017). The sustainability issues can be classified into economic, environmental, and social. The economic issues are generally related to either cost or profit, the environmental issues are usually expressed as the amount of pollutants released into the environment, and the social issues are about the social perceptions of various stakeholders (Olapiriyakul, 2017).

For the waste sector, environmental performance (EP) assessment is particularly required to improve the overall performance, to assess the sustainability of management systems, and to improve the quality of the service provided to service beneficiaries (Mendes *et al.*, 2013). Environmental performance integrates environmental and human health risks in the assessment process, consequently ensuring that new policies are adopted by decision makers under the concept of continuous improvement of waste management systems (Scipioni *et al.*, 2008).

Thus, environmental performance evaluation (EPE) covers not only operational aspects, such as the handling, transfer, transport, separation, processing, and disposal of waste, but also aspects on public perception, environmental, economic, and social issues (Shekdar, 2009; Agamuthu, 2012; Mendes *et al.*, 2013; Bing, et al., 2016). Because of these, there are strong motivations in the waste sector for EPE, which include, to: encourage the service's improvement, comply with regulations, specify verifiable strategic objectives, regulate technical and operational activity, and support the decision-making process (Schübeler, et al., 1996; Mendes *et al.*, 2013).

Consequently, EPE is usually based on key indicators and conditions, however, currently, there is no consensus on the best indicators for performing waste management EPE (Greene and Tonjes, 2014), probably because social indicators are involved but which are difficult to define due to the fact that social perception is subjective. As a result, the choice of indicators for EPE is driven by the availability of data and by the capacity to measure the performance (Zaccariello, et al., 2015), and are, therefore, selected based on area specificities.

Performance indicators (PIs) are simple measures, easy to interpret, accessible, and reliable for monitoring and controlling various types of systems including waste management services (United Nations, 2007; Olapiriyakul, 2017). Smeets and Weterings (1999) define an indicator as:

> "*an elementary datum or a simple combination of data capable of measuring an observed phenomenon"*.

PIs monitor the effect of policy measures for waste management. Thus, Ristić (2005) observes that if there is one environmental policy field where the need for indicators as tools for monitoring is particularly significant, that is the waste field, because possibly no other environmental issue has such a strong and relevant management side as waste and no other has the same impact on the everyday life of consumers and producers.

Accordingly, environmental performance (EP) for SWM is divided into two components: management performance (MP) and operational performance (OP) (Jasch, 2000; Wilson, 2002; Habib, Schmidt and Christensen, 2013). MP indicators are generally related to the sustainability aspects (social indicators), which are the governance features (institutional, political, and financial issues) and the various groups of stakeholders involved in waste management, whereas the OP indicators are usually concerned with the physical system and its technological components, with a focus on the environmental sustainability (environmental indicators) aspect of the system.

2.4.1 Waste Management Performance (MP)

MP is measured by chosen indicators defined to measure qualitatively and quantitatively the coherence of environmental policy with objectives, the rate of compliance with a regulation framework, and the effective integration of stakeholders through an effective communication strategy (Jasch, 2000; Haugh and Talwar, 2010; Turki, et al., 2017).

MP assessment enables waste management authorities to determine opportunities for improvement and to implement the necessary actions needed to achieve intended outcomes of environmental management. MP requirements can be described as development drivers that create the enabling environment - a pillar of sustainability necessary to bring about a sustained change – for sustainable waste management (Wilson, 2007; Zurbrügg *et al.*, 2012).

Consequently, the policy and legal, institutional and financial arrangements, as well as the technical capacity required for effective waste management, are often set as the MP key indicators for SWM (Smeets and Weterings, 1999; Nabegu and Mustapha, 2015; Srivastava, et al., 2015; Leal Filho *et al.*, 2016). These are essential in achieving the main priorities of waste management - the minimisation of environmental impacts of waste with the overall objective of reducing waste generation, and reduction of resource use and the related task of successful implementation of appropriate waste management policies, with complete or partial recovery or recycling of materials.

While a lot of research and evaluation of waste MP has been undertaken in most developed countries (Boldrin, et al., 2011; Stanisavljevic and Brunner, 2014; Zaccariello, et al., 2015; dos Muchangos, et al., 2017), research and evidence of the evaluation of waste MP in developing countries are lacking (Zurbrügg *et al.*, 2014). The reason for the lack of MP evaluation in developing countries can be attributed to the fact that traditionally, waste management is the responsibility of local governments, who are often challenged with inadequate funding and poor technical expertise for the daily waste management operations to the extent that, they tend not to pay attention to waste MP issues.

However, with the increasing rate of SW generation, and awareness and regulations (for recycling and recovery, management and source reduction by intervening at production and consumption level), various institutions have got involved into one or more aspects of SWM chain (Mariwah, 2012; Nabegu and Mustapha, 2015). There is the urgent need for waste MP evaluation in developing countries. MP can lead to the assessment of compliance with applicable laws and regulatory requirements together with the involvement of all waste management stakeholders.

Public participation is a wholly accepted crucial element for the success of any waste management programme including source reduction and recycling, as shown in Figure 2.4. The public must be made aware of the relationship between managing MSW and protection of human health, and the environment (UNEP, 2005). Thus, there is the need for the continuous evaluation of waste management systems to identify possible areas that require improvements.

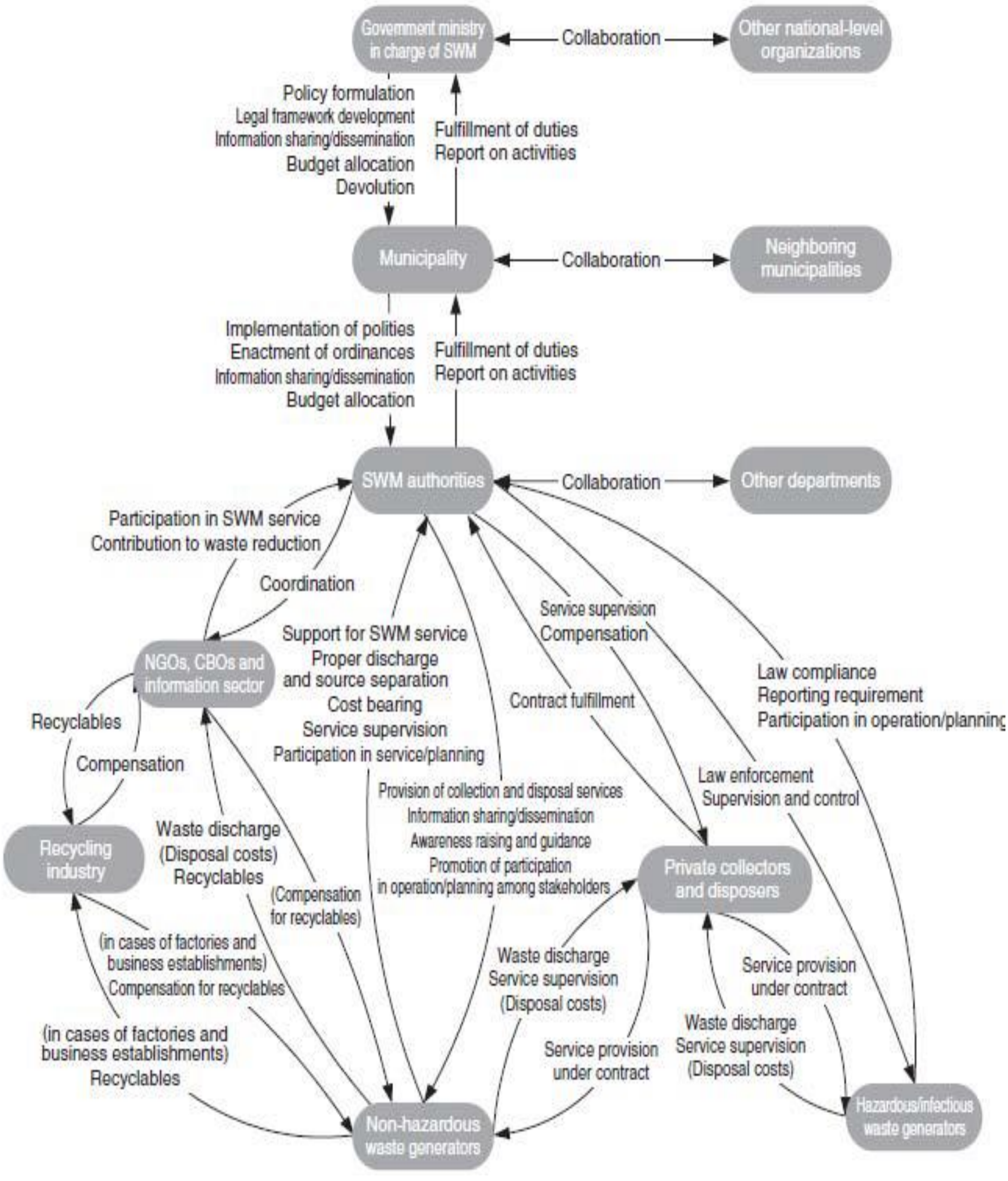

Figure 2.4: Relationships among different stakeholders in SWM (Japan International Cooperation Agency (JICA), 2009)

For instance, a study by Santibañez-Aguilar *et al.* (2013) addresses the social impact of SWM systems, with their interest in the reduction of the amount of SW that goes to landfills. Other researchers have focused on waste management financing (Busse, 2012; Woodruff, 2014; World Bank, 2014). Adequate budget sources and recurrent waste management financing are necessary for effective waste management.

However, poor national economic policies, coupled with extreme poverty in rural areas and high infrastructure deficits make financial considerations one of the most obvious constraints to developing appropriate waste management systems in most developing countries (Anku, 2010). Accordingly, there are four ways of financing local public goods in most developing countries including waste management: local taxes such as the property tax, user charges which are levied on various urban services, grants from higher levels of government, and loans from the capital market and Government/financial institutions or international agencies like the World Bank (Appasamy and Nelliyat, 2007).

On the other hand, in most developed countries, especially in Europe, the polluter pay principle, whereby the polluter bears the expenses of carrying out the measures decided by public authorities to ensure that the environment is in an acceptable state, has provided a secure funding source for waste management (Baldock, 1992).

Meanwhile, the central government and municipal authorities are solely the financiers of waste management in many developing countries. This has led to inadequate funding for waste management in most developing countries, resulting in SW being merely dumped in low-lying areas (euphemistically called a landfill), which creates several environmental problems.

2.4.2 Waste Management Operational Performance (OP)

Environmental pressures from the generation and management of SW include emissions into the air, water and soil, all with potential impacts on human health and nature (Misra and Pandey, 2005; Babayemi, Ogundiran and Osibanjo, 2016). Therefore, environmental policies and strategic measures are required to reduce waste emission and improve waste management (Moh and Manaf, 2014). The foundation of modern waste management is the combination of regulatory, design, construction, operational, maintenance, and monitoring features to create an inter-dependent, overlapping system for protection of human health and the environment.

Consequently, in order to mitigate any adverse effects of waste management operations, Dentch (2016:p53) observes that waste management authorities need to establish, implement, control, and maintain the processes mandatory to meet environmental management requirements by establishing operating criteria for the processes, and to control planned changes and review the consequences of intended changes in the waste management operations.

These can enable waste management authorities to establish appropriate controls to ensure that the environmental requirements are addressed in the design and life-cycle stages of waste management systems through operation performance assessment. Waste management OP indicators are usually expressed as the amount of pollutants released into the environment, calculated based on life cycle assessment (LCA) methodologies (Olapiriyakul, 2017).

2.4.2.1 Environmental Impacts of MSW Disposal

Management of MSW through the unit operations of collection, transfer, separation, processing/treatment, and final disposal form a complex interrelationship of mass flows with associated energy consumption, SW production, and airborne and waterborne emissions. These pose potential risks to the environment and health in the handling of MSW.

Direct health risks concern mainly the workers in the waste sector and residents near processing or disposal facilities. The public may be affected indirectly by waste management activities such as emissions and leachate emanating from waste processing and disposal. The decomposition of waste into constituent chemicals is a common source of local environmental pollution (Domingo and Nadal, 2009; Keith-Roach *et al.*, 2015).

Initially, pollution from waste was not a major issue when the human population was relatively small and nomadic, however, a number of serious and highly publicised pollution incidents associated with incorrect waste management practices, led to public concern about the lack of controls, inadequate legislation, environmental and human health impacts (Giusti, 2009). Consequently, waste management hierarchy based on the most environmentally sound criteria favours waste prevention/ minimisation, waste reuse, recycling, and composting (Ali *et al.*, 2014; Eriksson, Strid and Hansson, 2015; Fudala-Ksiazek *et al.*, 2016).

Nonetheless, in many developing countries, a large percentage of waste is presently not reused, recycled or composted and the main disposal methods are landfilling/open dumping and open burning (Cointreau-Levine, 2004; Agamuthu, 2013; Yusoff and Zamri, 2015). This problem is especially acute in developing nations such as Ghana. Very few existing landfills in the world's poorest countries would meet environmental standards accepted in industrialised nations, and with limited budgets, there are likely to be few sites rigorously evaluated prior to use in the future (Agamuthu, 2013; Yang *et al.*, 2014).

Nevertheless, this is not peculiar to only developing countries. In the past, the performance of many landfills and incinerators has been quite poor in some developed countries, including landfills that were built with a containment barrier (a clay liner or a synthetic membrane) (Giusti, 2009). Roche (1996) in a survey of 4000 landfill sites in England found out that there was a high failure of landfills resulting in surface and groundwater pollution even though about one-third of them had a clay liner. Such information usually heightens the fears of the public on the effects of waste disposal especially disposal sites near residential areas.

Accordingly, the major environmental concerns of SW disposal are gas and leachate release by decomposing waste (Jha *et al.*, 2008; Mukherjee and Mukhopadhyay, 2015). These cause all types of pollution - air, soil, water, and climate as shown in Table 2.10. The commonest gases emitted through MSWM operations are carbon dioxide (CO_2) and methane (CH_4). CO_2 emission is related more to SW transportation (collection vehicles) than directly from MSW final disposal, while methane is a by-product of the anaerobic respiration of bacteria, and these bacteria thrive in landfills with high amounts of moisture.

In accounting for emission from waste management, CO_2 is usually included in emission emanating from the use of energy during transportation, while CH_4 is counted as a direct waste management emission (Guendehou *et al.*, 2006). CH_4 forms 50 to 60% of the composition of landfill gas emissions (Kumar *et al.*, 2004; Johari *et al.*, 2012; Friedrich and Trois, 2013; Tozlu, Özahi and Abuşoğlu, 2016), depending on the stage of the landfill.

In many developing countries, urban SW generation is increasing enormously and most of the SW are disposed of by landfilling in low-lying areas, resulting in the generation of copious quantities of biogas. CH_4, the major constituent gas is known to cause global warming due to its GHG effect. CH_4 gas released from a landfill is a serious threat to our environment as its global warming potential is more than 20 times that of CO_2 (Friedrich and Trois, 2013; Bhada-Tata and Hoornweg, 2016). CH_4 emission from the landfill is estimated to account for 3 – 19% of the anthropogenic sources in the world (Pipatti et al., 2006), while CH_4 produced at SW dump sites contributes approximately 3 to 4 percent to the annual global anthropogenic GHG emissions (Bhada-Tata and Hoornweg, 2016).

Furthermore, leachate from MSW disposal sites affects groundwater quality regardless of an ideal site selection and a monitoring network design of the landfill. The danger of leachate infiltration in groundwater is great considering that even the best liner and leachate collection systems will ultimately fail due to natural deterioration (Lee and Jones-Lee, 2004; Palma and Mecozzi, 2010; Mukherjee and Mukhopadhyay, 2015).

It takes only a small amount of leachate to contaminate a large volume of groundwater, which in turn can contaminate and affect biodiversity and enter the food chains (Bakare *et al.*, 2007; Garaj-Vrhovac, et al., 2009; Mukherjee and Mukhopadhyay, 2015). However, determining the actual measurement is difficult because the quantity and quality of leachate generated are dependent on numerous factors (Wilson, 2002), including the SW composition.

Table 2.10: Main environmental impacts of MSW processing/disposal: modified from Giusti, (2009)

Activity	Water	Air	Soil	Landscape	Climate
Landfilling	Leachate (heavy metals, synthetic organic compounds)	CO_2, CH_4, odour, noise, VOCs	Heavy metals, synthetic organic compounds	Visual effect, vermin	Worst option for GHG Emission
Incineration	Fall-out of atmospheric pollutants	SO_2, NOx, N_2O, HCl, HF, CO, CO_2, dioxins, furans, PAHs, VOCs, odour, noise	Fly ash, slags	Visual effect	GHG
Composting	Leachate	CO_2, CH_4, VOCs, dust, odour, bioaerosols	Minor impact	Some visual effect	Small emissions of GHG
Open dumping	Bacteria, viruses, heavy metals	Bioaerosols, dust, odour	Bacteria, viruses, heavy metals, PAHs, PCBs	Vermin, insects	Small emissions of GHG
Recycling	Wastewater	Dust, noise	Landfilling of residues		Minor emissions
Waste Transportation	Spills	CO_2, SO_2, NO_x, dust, odour, noise	Spills		Significant contribution of CO_2

CO_2 = carbon dioxide; CH_4 = methane; VOCs = volatile organic compounds; SO_2 = sulphur dioxide; NO_x = nitrogen oxides; N_2O = nitrous oxide; HCl = hydrochloric acid; HF = hydrofluoric acid, CO = carbon monoxide; and PAHs = polycyclic aromatic hydrocarbons.

Health Issues from MSWM

Despite important technological advancements, improved legislation and regulatory systems in the field of waste management, and more sophisticated health surveillance, the public acceptance of the location of new waste disposal and treatment facilities is still very low due to concerns about adverse effects on the environment and human health (Giusti, 2009).

Health issues are associated with every step of the handling, treatment and disposal of waste, both directly (through recovery and recycling activities or other occupations in the waste management industry, by exposure to hazardous substances in the waste or to emissions from incinerators and landfill sites, vermin, odours and noise), or indirectly (e.g. by ingestion of contaminated water, soil and food) (Giusti, 2009; Daley *et al.*, 2015; Edmunds et al., 2016).

The impact of SW on health are varied and may depend on numerous factors including the nature of the waste, duration of exposure, the population exposed, and availability of prevention and mitigation interventions (Ziraba, et al., 2016). The impacts may range from mild psychological effects to severe morbidity, disability or death. Nevertheless, the literature on health impacts of SW remains weak and inconclusive as there is no clear evidence of adverse health outcomes for the general population from waste management (Giusti, 2009; Haregu, et al., 2016), however, landfill health concerns are widely acknowledged (Olapiriyakul, 2017).

The literature on landfill health effects shows that living near a waste site is the cause of various adverse health effects, ranging from allergies to cancer and birth defects (Vrijheid, 2000). Similarly, Giusti (2009) indicates that there is convincing evidence of a high risk of gastrointestinal problems associated with pathogens originating at waste treatment plants.

Consequently, Haregu et al. (2016) categorise the waste management impacts on health into four:

- infection transmission - this could be bacterial, viral and other disease-causing organisms;
- physical bodily injury - these may include cuts, drowning, blunt trauma, and chemical or radiation injury;
- noncommunicable diseases – long-term exposure may lead to cellular damage and development of cancer while other might result in bodily organ injury and damage; and
- emotional/psychological effects (strong smells, unsightly waste such as human body parts).

However, one type of SW may lead to more than one health outcome directly or through an intermediate mechanism, for example through vectors and other individual-level predisposing factors (Williams, 1990).

Despite these, some aspects of waste management can reduce health impacts and provide other benefits. For instance, composting allows organic materials to naturally degrade and be reused as fertilizer. This is a natural substitute for using chemical fertilizers, which either runoff during heavy rains or seep into groundwater and contaminates water supplies.

Also, composting provides a more environmentally friendly alternative to the dumping of yard or food waste. These two categories of waste are generally the ones responsible for leachate production due to their organic origins and composting them reduces leachate amounts as well as odours and other sources of nuisance (Hoornweg et al., 2000).

Again, improved waste management provides a cleaner environment including in poor and marginalised areas of cities and improves the quality of health of all residents. A cleaner city helps provide a more attractive environment for investment and tourism which, in turn, improves a city's economic competitiveness, creating jobs and new business opportunities for local entrepreneurs (Lombardi, 2011). SWM can also be linked to the development of new eco-friendly sources of energy, thereby, helping to tackle climate change. Thus, United Nations Environment Programme (UNEP) (2010), notes that:

> "*the waste sector is in a unique position to move from being a minor source to becoming a major saver of global emissions*".

2.5 MSWM Decision-Making

Several waste management technologies are available at the current time with different waste management capacities (Williams, 2013; Walter Leal Filho *et al.*, 2016). Cities in the developing world are besieged by private vendors selling technologies, most of which are inappropriate (Dedinec *et al.*, 2015), however, these cities usually have a limited technical capacity and analytical tools for assessing their claims and viability. Many times inappropriate systems have been built, only to close within months of costly start-up operations (Kamali *et al.*, 2016).

The variables affecting municipal authorities' decision-making on SW technology and management choices in developing countries have become more complicated, especially when consideration for GHG reduction and avoidance, landfill-minimisation, and land reclamation are involved (Soltani *et al.*, 2015; ThiKimOanh *et al.*, 2015). These have made the waste sector a specialised industry, with high technological standards, therefore engagement with the sector requires in-depth experience, thorough research and engineering know-how.

Many of the technologies applied in reprocessing and recycling waste, extracting energy and producing other products from the waste and gas captured from landfills, may have been tested in commercial use in industrialised countries, but the effort required to adopt these technologies to local conditions in developing countries is usually underestimated (Ouda *et al.*, 2016). For example, an old technology like landfill gas extraction does not work in a developing country such as Ghana in the same manner as it does in Germany (Busse, 2012). Therefore, knowledge of the local context and the appropriate adaption to local conditions are just as important as technological know-how.

The equipment used must match with the composition, quantities and qualities of waste delivered to the facilities, the local climatic conditions and the potential demand for products derived from the waste (Mutz *et al.*, 2017). However, many city authorities in developing countries are overwhelmed with the magnitude of the waste problem, and often tend to seek out environmentally friendly but costly win-win technologies via public-private partnerships with investors often from the North, regardless of the fact that these technologies may be inappropriate for their local conditions (Oteng-Ababio et al., 2013). The authorities' intentions may be out of goodwill, but the approach most often is born out of an empirical vacuum.

Decision-making in waste management is a complex issue and requires clear goals, appropriate methods, and reliable data of known uncertainty (Stanisavljevic and Brunner, 2014). The objectives of waste management are multidisciplinary: protection of humans and the environment, conservation of resources and no export of waste management problems into the future. These goals cover hygienic, environmental, engineering, socio-economic and ethical aspects. Hence, methods to support decision-making in waste management must be able to cope with all these topics.

2.5.1 Waste Management Systems Assessment

Waste management is one of the most crucial issues in environmental protection and natural resources conservation. Because of this, assessment methods have been developed to support decisions regarding waste management (Wilson *et al.*, 2012; Guerrero et al., 2013). Waste processing/treatment and disposal alternatives provide specific environmental, social and economic performances (Antonopoulos *et al.*, 2014). Therefore, there is the need to identify, estimate and thoroughly examined the crucial environmental, social and economic criteria to determine the most appropriate technology.

The methodologies commonly used in SWM assessment are generally based on three models: cost-benefit analysis (CBA), life cycle assessment (LCA) and multi-criteria analysis (MCA) (Ghinea and Gavrilescu, 2010; Kurka and Blackwood, 2013; Kadafa et al., 2014). The analysis of these methods is based on the cost, the environmental impacts of the system or both.

For the CBA, all aspects of the waste management system are estimated in monetary terms and the results presented in a clear manner, with all impacts summed up into one monetary figure (Morrissey and Browne, 2004). This enables decisions to be taken based on the most efficient use of limited available resources. However, some researchers observe that there is uncertainty involved in estimating the monetary value of several environmental and/or social impacts in monetary terms (Morrissey and Browne, 2004; Spash and Vatn, 2006). As such, the CBA does not present the actual cost of the system.

The MCA approaches are used to determine the most preferred option and/or rank of options by involving various waste management (WM) stakeholders in the decision-making process (Cheng et al., 2003; Pohekar and Ramachandran, 2004; Karagiannidis and Perkoulidis, 2009; Zhang et al., 2011). For this approach, multiple stakeholders are able to evaluate the often conflicting criteria, communicate their different preferences, and rank or prioritise WM strategies to finally agree on some elements of these strategies and make an applicable decision (Soltani *et al.*, 2015).

Thus, the choice of WM system is based on consensus among the various stakeholders as the MCA method offers a level of flexibility and inclusiveness that purely economic-based models tend to lack (Vučijak et al., 2016; Melaré *et al.*, 2017). Nevertheless, MCA techniques are very cumbersome and unwieldy as there is a need for personal judgment and experience in making the decisions (Morrissey and Browne, 2004). Therefore, a compromised decision can be reached to select a waste management system (WMS), which may not be appropriate.

On the other hand, LCA is the widely-used method for the evaluation of energy consumption and environmental burdens of WM systems (Dong *et al.*, 2014; Evangelisti *et al.*, 2014), because it is generally considered the best environmental management tool that can be used to obtain an objective quantification of all the environmental impacts related to different SWM scenarios (Arena, et al., 2003; Levis and Damgaard, 2015).

The LCA presents a good environmental performance evaluation so that the best decision is made. Nonetheless, most studies acknowledge that the LCA of waste management systems (WMS) suffers from malpractices in several aspects such as significant deficiencies in terms of their goal and scope definition as well as the unclear delimitation of the system boundaries (Rajaeifar *et al.*, 2015).

Laurent *et al.* (2014) report of malpractices in several aspects of the LCA with significant differences across studies in their critical review of 222 published LCA studies of SWM systems. Examples are a frequent neglect of the goal definition, a frequent lack of transparency and precision in the definition of the scope of the study, such as an unclear delimitation of the system boundaries, a truncated impact coverage, difficulties in capturing influential local specificities such as representative waste compositions into the inventory, and a frequent lack of essential sensitivity and uncertainty analysis (Laurent *et al.*, 2014).

Similarly, Cleary (2009) indicates that in most LCAs, lifecycle emissions from energy inputs or capital equipment are either not mentioned or included in the calculation of results, though the estimated emissions levels are essential in determining the global warming intensity and the amount of gas emission that emanate from some WM equipment

In general, there are difficulties in capturing influential local specificities such as representative waste compositions into the inventory, and a frequent lack of essential sensitivity and uncertainty analysis in all these waste management assessment techniques which often lead to inadequate or conflicting results (Lin et al., 2013). As a result, these tools may not produce the exact results needed in deciding on the appropriate WMS.

However, currently, many modelling tools have been developed based on these methods to support decision-making in WM. These modelling tools can assist practitioners and decision-makers to understand, select and apply the method which is most appropriate for their specific needs.

2.5.1.1 Waste Management Decision Support Tools

There are several management options for MSW, therefore, choosing the appropriate option(s) usually involves decisions on the technology and location specifics (Achillas *et al.*, 2013). Selecting a single WM approach or arrangement that satisfies the decision-makers' objectives is often challenging (Herva and Roca, 2013; Soltani *et al.*, 2015). As a result, several decision support tools or models have been developed for WM decision-making. These tools assist decision-makers to compare the MSWM options based on their level of performance in fulfilling defined criteria.

The need for credible and scientific-based information for making more informed WM decisions precipitated the development of decision support tools for municipal waste (Thorneloe et al., 2007). Decision support tools are used to identify weaknesses or strengths of existing and new systems in a structured way and thereby highlight factors of success and failure (Zurbrügg et al., 2014). The use of these tools is especially required in developing countries where decision-makers need to select sustainable actions for improving WM that will meet their local needs.

However, the use of decision support tools in WM decision-making in developing countries is very limited (Zurbrügg et al., 2014; Melaré *et al.*, 2017). Laurent *et al.* (2014) in a critical review of 222 published LCA studies of SWM systems found that the published studies have primarily been concentrated in Europe with little application in developing countries.

No specific reason has yet been given for the limited use of decision support tools in WM decision making in developing countries, however, this limited use can be attributed to the cumbersomeness in the use of most of the available decision support tools as their use requires personal judgement and experience (Morrissey and Browne, 2004).

In general, WM decision support tools are categorised into two: those that use optimising methods and those that use compromising methods (Morrissey and Browne, 2004; Ghinea and Gavrilescu, 2010), however, the optimising methods are widely utilised in WM decision-making than the compromising methods. Three elements are involved in these methods: decisions, constraints, and an objective (Ragsdale, 2015:p19). Similarly, Winston (2016) indicates that an optimisation model has three parts: the target cell, the changing cells, and the constraints.

The target cell represents the objective or goal to either minimise or maximise the quantity in the target cell, the changing cells are simple worksheet cells that can be changed or adjusted to optimise the target cell, and the constraint is a function of the decision variables that must be less than or equal to, greater than or equal to, or equal to some specific value (Ragsdale, 2015:p20; Winston, 2016:p269-270).

Consequently, several optimising models have been applied in WM decision-making, including:

- Integrated Waste Management 2nd edition (IWM2), UK (Procter & Gamble, 2005);
- Life Cycle Assessment tools for the development of Integrated Waste Management (LCA-IWM), EU (Boer et al., 2007);
- Organic Waste Research (ORWARE), Sweden (Björklund et al., 1999; Eriksson *et al.*, 2002; Assefa *et al.*, 2005);
- Waste Integrated Systems Assessment for Recovery and Disposal (WISARD), UK (McDougall and Hruska, 2000; Bovea et al., 2010; Pires et al., 2011);
- Waste Reduction Model (WARM) (Diaz and Warith, 2006; Lou and Nair, 2009);
- Environmental Assessment System for Environmental Technologies (EASETECH), developed by the Technical University of Denmark;
- OpenLCA developed from GreenDelta since 2006; and
- Municipal Solid Waste Decision Support Tool (MSW DST) created by Research Triangle Institute (RTI) International in conjunction with the US Environmental Protection Agency (EPA).

The performances of most of these models have been compared and reviewed by many researchers (Morrissey and Browne, 2004; Pohekar and Ramachandran, 2004; Aghajani Mir *et al.*, 2016). Whereas some models are limited to calculating the inventory of the system's environmental exchanges, other models support the further evaluation phases of the life cycle assessment in a limited manner (Bhander et al., 2010).

After a critical review of the application of the above-mentioned modelling tools in SWM decision-making, this study adopted the *Municipal Solid Waste Decision Support Tool* **(***MSW DST)* for this doctoral research. The researcher adopted the MSW DST for this study because this tool can evaluate various MSWM options and optimises their environmental burdens, it is applicable to both small and large WM systems, and the developers of the tool were charitable to release it free for use in this study.

The MSW DST is an outcome of a cooperative research agreement with the Research Triangle Institute (RTI) International (co-funded by the EPA and U.S. Department of Energy) which started in the mid-90s. RTI led a team that comprised of academic institutions and research firms through the complex task of building this tool that can weigh out the results of any SWM scenario thrown at it. While a prototype of the MSW DST was finished by the early 2000s, it did not become available for use until 2012 (Research Triangle Institute, 2012)

According to Rosengren (2016), the non-profit Delta Institute used the MSW DST for a 2014 study on the Chicago Metropolitan Region's WMS that mapped out various diversions rate scenarios for 2040. Using data derived from the tool, combined with other economic models, Delta found the potential for major job creation and economic growth with higher diversion rates. The overall focus of the DST is to support the evaluation of cost and life cycle environmental impacts associated with alternative strategies for ISWM in a community or region.

Accordingly, the MSW DST can provide SW planners with a standard approach to evaluating the cost and environmental aspects of waste management systems (RTI, 2000), because it is able to quickly analyse the baseline cost and environmental performance and analyse alternative management strategies for their ability to reduce cost and environmental impacts (RTI, 2012).

The tool can be used to simulate existing systems and/or analyse new strategies for managing MSW. It considers all activities required to manage the MSW from the time it is sent out for collection to its ultimate disposition, whether that is disposed of in a landfill, compost applied to the land, energy recovered from combustion or landfills, or materials recovered and remanufactured into new products (RTI, 2000, 2006).

In addition, The MSW DST is an educational tool that can help waste planners and decision-makers gain a better understanding of the cost and environmental trade-offs for alternative WM strategies and to identify key drivers for cost and environmental impacts. The MSW DST uses a cost methodology that is consistent with the principles of full-cost accounting and includes the capital, operating, and labour costs for different WM activities (RTI, 2012). Costs, as calculated, are representative of an engineering cost analysis. Cost results are presented as net costs, meaning that any revenues from the sale of recovered materials or energy products are netted out of the costs.

Also, energy consumption and environmental impacts are quantified using the principles and methods of life cycle assessment. The key features of a life cycle assessment include the view of WM as an integrated system, and also the energy and environmental considerations that account for upstream processes (such as impacts associated with fuels and electrical energy production) and downstream activities (such as the impacts reduced by virtue of materials or energy recovery) (RTI, 2012).

In contrast to some other models, GHG, energy consumption, and the potential release of pollutants can all be measured for a wide range of collection and disposal methods (system boundaries are defined) with the MSW DST but which are not measurable by other decision support tools. Thus, Rosengren (2016) remarks that:

> "*the MSW DST is meant to take the guesswork out of big decisions for state and local planners by providing a better picture of how their current waste management system is working and what effects changes could have"*.

Therefore, target users of the MSW DST include WM planners and consultants, decision-makers, policy-makers, waste industry researchers, Non-governmental organizations (NGOs), and academic or other research or advocacy organizations.

Nevertheless, the MST DST is embedded with only North American default data and assumptions. Though it can be customised to accept site-or region-specific conditions as shown in Table 2.11, there may be some challenges with its application in other regions, especially in some developing countries where site-specific data is rarely available. The following are some of the model limitations outlined by the developers:

- The DST is a planning and screening tool, and not a design tool. The model will identify a SWM solution that is optimal for a user-defined objective and user-defined constraints
- There is uncertainty associated with the model results, thus, model results should be interpreted in consideration of the fact that they are not 100% precise
- The DST is strictly a steady-state model. This means that only one value for each model input parameter can be entered and the model solution assumes that this parameter remains constant with time over the planning horizon
- The calculated value for each life cycle inventory (LCI) parameter represents the total for the entire SWM system
- The SWM system that is modelled begins at curb-side
- Construction related LCI effects are not included
- The model only allows for one of each type of facility

Table 2.11: MSW DST process model assumptions and allocation procedures: adapted from Thorneloe et al., (2007)

Component	Key assumptions and design properties	Allocation procedures
Collection	Location specific information (e.g., population, generation rate, capture rate) is model input.	Environmental releases are allocated based on mass. Cost is based on volume and mass.
Transfer station	The user selects between several default design options based on how the MSW is collected.	Same as collection
Materials recovery facility (MRF)	The design of the MRF depends on the collection type (mixed waste, commingled recyclables, etc.) and the recyclables mix. Eight different designs are available.	Same as the collection. Also, includes revenue from the sale of recyclables.
Combustion (with and without energy recovery)	The default design is a new facility assumed to meet the most recent US regulations governing combustion of MSW. Designs to model older facilities are also available.	Environmental releases are allocated based on mass and stoichiometry. Cost is based on mass and includes revenue from the sale of metal scrap and electricity
Refuse-derived fuel (RDF) and processed refuse fuel (PRF)	Traditional RDF and PRF design options are available. The facilities are designed to meet the US Clean Air Act regulations for MSW combustion.	Same as combustion.
Composting (both yard and mixed MSW)	A low and high quality mixed MSW and yard waste compost facilities are included. All use the aerated windrow composting process as the default design.	Same as MRFs. However, no revenue was assumed for sale of compost for this analysis.
Landfill (traditional, bioreactor, and ash)	The default design meets US federal requirements. Process model also includes design for wet/bioreactor landfills (with leachate recirculation) and ash	Cost and emissions for operations, closure, and post-closure are allocated equally over the mass of refuse buried. Landfill gas and leachate are allocated to MSW items.
Electrical energy	Regional electrical energy grids are used for waste management processes; the national grid for upstream processes.	Environmental releases are based on the fuel source used by regional or national electricity grids. Regional grids are used for waste management operations; National grid used for manufacturing operations. Cost is not considered.
Inter-unit process transportation	Distances between different unit operations are key input variables.	Environmental releases are based on mass. Cost is based on volume and mass and is considered only for transportation necessary for waste management.
Materials production	Primary (virgin) and secondary (recycled) closed-loop production processes are included.	Environmental releases are based on mass. Cost is not considered.

2.6 Summary and Knowledge Gaps

This literature review has demonstrated the complicated interactions that exist within the MSWM processes by providing an overview of relevant research that has been carried out primarily on MSWM operations (collection, storage, transportation, transfer, and treatment/disposal), sustainable waste management, waste management environmental performance, and MSWM decision-making. This has provided a general understanding of MSWM systems, particularly systems in developing countries and the challenges militating against the effective functioning of these systems, especially improper disposal of waste which causes various pollution (air, soil, water and landscape) and affects the health of inhabitants and the beauty of cities.

Consequently, the following areas of MSWM were identified as the knowledge gaps in MSWM in most developing countries, particularly in Ghana which this research intends to bridge:

(a) Insufficient data and analysis of MSW generation and characteristics
(b) Research and evidence of the evaluation of waste MP in developing countries are lacking
(c) Inadequate documented research on MSW reduction
(d) The baseline scenario of MSW disposal in most municipalities are not documented or understood
(e) Deficiency of detailed documented research on integrated MSWM environmental performance
(f) The application of waste management decision support tools in MSWM decision-making is very limited and not documented
(g) The environmental burdens of MSW disposal have not been adequately explored and are poorly understood
(h) Planning frameworks that relate key variables for MSWM decision-making are non-existence in most developing countries

Therefore, the aim of this research is to *improve planning and decision making for MSW disposal in developing countries with similar circumstances and MSW problems to Ghana*, through the following objectives:

1) Investigate MSW generation and characteristics reported in literature and official documents. This is intended to address research gap (a)

2) Examine MSW disposal management performance. This is intended to bridge research gap (b)
3) Establish a baseline scenario of MSW disposal. This is envisioned to address research gap (d)
4) Evaluate MSW disposal operational performance. This focuses on research gap (f) and (g)
5) Develop a planning framework for MSW disposal decision-making in developing countries. This objective is intended to bridge research gap (h)

The next chapter (chapter three) addresses the methodology and research design that the researcher adopted to achieve the research objectives.

CHAPTER THREE – METHODOLOGY AND RESEARCH DESIGN

3.0 Introduction

This section presents a range of research methodologies adopted to address the research objectives and the justification for their selection. These include discussions on the research philosophy and paradigm underpinning this research, the research approach, research strategy, research methods, research design, data collection, data analysis techniques, ethical issues pertaining to this research, and the validity and reliability of this research. A summary of the methodologies adopted for the achievement of the research objectives is presented in a research map as Appendix A.

3.1 Research Philosophy

The idea that there are different views of the world, and the processes that operate within it, is part of what is known as philosophy (Trochim and Donnelly, 2001). Philosophy is concerned with views about how the world works and as an academic subject, focuses primarily on reality, knowledge, and existence (Trochim and Donnelly, 2001; Johnson, et al., 2007). Therefore, all research is based on some underlying philosophical assumptions about what constitutes 'valid' research and which research method(s) is/are appropriate for the development of knowledge in a study (Mingers, 2001).

A research philosophy is therefore defined as a belief about the way in which data about a phenomenon should be gathered, analysed and used (Myers, 1997; Johnson et al., 2007; Wahyuni, 2012). Research philosophies can differ on the goals of the research and in the best way that might be used to achieve these goals (Goddard and Melville, 2004; Håkansson, 2013). These ways are not necessarily at odds with each other, but the choice of research philosophy is defined by the type of knowledge being investigated in the research project (May, 2011).

Accordingly, the research process has three major dimensions: ontology, epistemology, and methodology (Gough, 2002; Antwi and Hamza, 2015). Ontological and epistemological aspects concern what is commonly referred to as a person's worldview which has considerable influence on the perceived relative importance of the aspects of reality (Hirschheim, 1985; Cobern, 1991; Yolles, 2000), whereas methodology is the strategy or plan of action which lies behind the choice and use of particular methods (Scotland, 2012). However, there is a link between these three dimensions of research philosophy. Taylor and Edgar, (1999:27) summarise the links between the concepts of ontology, epistemology and methodology as:

> *'the belief about the nature of the world (ontology) adopted by an enquirer will affect their belief about the nature of knowledge in that world (epistemology) which in turn will influence the enquirer's belief as to how that knowledge can be uncovered (methodology*)'.

3.1.1 Research Paradigms

A research paradigm is an all-encompassing system of interrelated practice and thinking that define the nature of enquiry along the three dimensions of ontology, epistemology, and methodology (Solem, 2003; Morgan, 2007; Antwi and Hamza, 2015). Guba (1990) defines a paradigm as an interpretative framework, which is guided by:

> *"a set of beliefs and feelings about the world and how it should be understood and studied*".

There are three key research paradigms, namely: positivist, interpretivist/constructivist, and realist (Falconer and Mackay, 2000; Flowers, 2009). These paradigms are chosen because they effectively form the 'poles' from which other paradigms are developed or derived; often, different names are used to describe apparently similar paradigms (Flowers, 2009).

3.1.1.1 Positivism

Positivists believe that reality is stable and can be observed and described from an objective viewpoint without interfering with the phenomena being studied (Levin, 1991). According to Flowers (2009), the positivist position is derived from that of natural science and is characterised by the testing of hypothesis developed from existing theory through measurement of observable social realities.

This position presumes the social world exists objectively and externally, that knowledge is valid only if it is based on observations of this external reality and that universal or general laws exist or that theoretical models can be developed that are generalisable, can explain cause and effect relationships, and which lend themselves to predicting outcomes (Lomborg and Kirkevold, 2003; Goduka, 2012).

Furthermore, positivists contend that phenomena should be isolated and that observations should be repeatable. This often involves manipulation of reality with variations in only a single independent variable to identify regularities in and to form relationships between some of the constituent elements of the social world.

So, positivism is based upon values of reason, truth, and validity and there is a focus purely on facts, gathered through direct observation and experience and measured empirically using quantitative methods – surveys and experiments - and statistical analysis (Flowers, 2009; Saunders et al., 2009).

3.1.1.2 Interpretivism

Interpretivists contend that only through the subjective interpretation of an intervention can reality be fully understood (Angen, 2000; Plack, 2005). The study of phenomena in their natural environment is key to the interpretivist philosophy, together with the acknowledgement that scientists cannot avoid affecting those phenomena they study (Pouliot, 2007). They admit that there may be many interpretations of reality but maintain that these interpretations are in themselves a part of the scientific knowledge they are pursuing.

As a result, in the social world, it is argued that individuals and groups make sense of situations based on their individual experience, memories, and expectations. Meaning is therefore constructed and constantly re-constructed through experience resulting in many differing interpretations (Flowers, 2009). Because of this, Moksha (2013) observes that interpretivism has a tradition that is no less glorious than that of positivism, nor is it shorter.

3.1.1.3 Realism

Realism paradigm is born from a frustration that positivism was over-deterministic and that interpretivism was so totally relativist (Flowers, 2009). Thus, realism takes aspects of both positivist and interpretivist positions. It holds that real structures exist independent of human consciousness, but that knowledge is socially created, with Saunders et al., (2009) arguing that our knowledge of reality is a result of social conditioning.

Whilst realism is concerned with what kinds of things there are, and how these things behave, it accepts that reality may exist in spite of science or observation, and so there is validity in recognising realities that are simply claimed to exist or act, whether proven or not (Flowers, 2009).

In common with interpretivist positions, realism recognises that natural and social sciences are different and that social reality is pre-interpreted, however realists, in line with the positivist position also hold that science must be empirically-based, rational and objective and so it argues that social objects may be studied 'scientifically' as social objects, not simply through language and discourse (Jessop, 2005; Flowers, 2009; Dreher and López, 2015).

Whereas positivists hold that direct causal relationships exist, that these relationships apply universally (leading to prediction) and that the underlying mechanisms can be understood through observation, realists take the view that the underlying mechanisms are simply the powers or tendencies that things must act in a certain way, and that other factors may moderate these tendencies depending upon circumstances, and hence the focus is more on understanding and explanation than prediction (Mingers, 2004; Wilson and McCormack, 2006; Flowers, 2009; Easton, 2010; Goduka, 2012).

Therefore, the researcher adopted the realist position for this doctoral research because the researcher observed and described the reality of MSW disposal in the study area from an objective viewpoint and understood the differences between various roles of stakeholders (as social actors) in waste management.

3.2 Research Approach

The main division between forms of reasoning that is made in philosophy is between deductive reasoning and inductive reasoning (Burney, 2008). An inductive approach is defined as moving from the specific to the general, while deduction begins with the general and ends with the specific (Quadagno and Knapp, 1992; Calhoun, 1998).

Arguments based on experience or observation are best expressed inductively, while arguments based on laws, rules, or other widely accepted principles are best expressed deductively (Soiferman, 2010). In general, deductive research tends to proceed from theory to data (theory, method, data, findings), while an inductive research tends to proceed from data to theory (method, data, findings, theory) (Langley, 1999; Pathirage et al., 2007).

According to Trochim and Donnelly (2001), these two methods of reasoning have a very different "feel" to them when conducting a research. They posit that inductive reasoning, by its very nature, is more open-ended and exploratory, especially at the beginning, whereas deductive reasoning is narrower in nature and is concerned with testing or confirming hypotheses. Thus, the main difference between inductive and deductive approaches to research is that whilst a deductive approach is aimed at testing a theory, an inductive is concerned with the generation of new theory (Gabriel, 2013).

3.2.1 Deductive Approach

A deductive research method entails the development of a conceptual and theoretical structure prior to its testing through empirical observation (Gill and Johnson, 2010). The emphasis in this approach is the deduction of ideas or facts from the new theory in the hope that it provides a better or more coherent framework than the theories that preceded it (Remenyi and Williams, 1995; Pathirage et al., 2007). However, Gill and Johnson (2010) posit that what is important is the logic of deduction and the operationalisation process, and how this involves the consequent testing of the theory by its confrontation with the empirical world.

Accordingly, deduction is the dominant research approach in the natural sciences, where laws present the basis of explanation, allow the anticipation of phenomena, predict their occurrence and therefore permit them to be controlled (Norris et al., 2005; Pathirage et al., 2007; Collis and Hussey, 2013). Consequently, Robson (2002) proposes five sequential stages through which deductive research should progress:

- deducing a hypothesis from the theory;
- expressing the hypothesis in operational terms;
- testing the operational hypothesis;
- examining the specific outcome of the inquiry; and
- if necessary, modifying the theory.

The deductive approach thus might be considered particularly suited to the positivist approach, which permits the formulation of hypotheses and the statistical testing of expected results to an accepted level of probability (Snieder and Larner, 2009). However, a deductive approach may also be used with qualitative research techniques, though in such cases the expectations formed by pre-existing research would be formulated differently than through hypothesis testing (Elo and Kyngäs, 2008; Saunders et al., 2009).

3.2.2 Inductive Approach

Inductive approach is the reverse of the deductive process. In this approach, the observations are the starting point for the researcher, and patterns are looked for in the data (Zalaghi and Khazaei, 2016). Thus, Chen et al., (2012) observe that in the inductive approach there is no framework that initially informs the data collection and the research focus can thus be formed after the data has been collected. Although this may be the point at which new theories are generated, it is also true that as the data is analysed that it may be found to fit into an existing theory (Braun and Clarke, 2006).

This approach may also be used effectively within positivist methodologies, where the data is analysed first and significant patterns are used to inform the generation of results (Perry, 1998; Dana and Dana, 2005). Accordingly, this method is more commonly used in qualitative research, where the absence of a theory informing the research process may be of benefit by reducing the potential for researcher bias in the data collection stage (Tranfield et al., 2003; Johnson and Onwuegbuzie, 2004; Johnson et al., 2007).

This approach focuses on a specific area in a larger field for the specific to affect the larger. Data is collected concerning specific phenomena and then the data may be examined for patterns between various variables (Jensen, 2002). Thus, the researcher adopted the inductive approach for this study since the study was focused on MSW disposal (specific) with the aim of improving MSWM (general) through the development of a planning framework for MSW disposal decision-making in developing countries.

3.3 Research Strategy

The research strategy is how the researcher intends to carry out the work. Thus, a typical research strategy considers the research method(s), research designs, sampling strategies and data analysis techniques to be adopted in achieving the research objectives (Benbasat et al., 1987; Darke et al., 1998; Langley, 1999). Once a researcher has written the research question(s)/objective(s), the next step is to determine the appropriate research strategy necessary to study the question/objective.

Therefore, Saunders et al. (2009) mention that appropriate research strategy must be selected based on research questions and objectives, the extent of existing knowledge on the subject area to be researched, the amount of time and resources available, and the philosophical underpinnings of the researcher.

Both Yin (2013) and Saunders et al (2009) admit that although various research strategies exist, there are large overlaps among them and hence the important consideration would be to select the most advantageous strategy for a particular research study. However, it is possible to employ two or more strategies in a hybrid plan by combining aspects of different strategies in a single research (Kurttila *et al.*, 2000).

Accordingly, the research strategies commonly used are experiment, survey, case study, action research, grounded theory, ethnography, archival research, cross-sectional studies, longitudinal studies and participative enquiry (Easterbay-Smith, et al., 2008; Saunders, Lewis and Thornhill, 2009; Collis and Hussey, 2013). Consequently, Yin (2013) recommends that a particular research strategy has to be selected based on three (3) conditions:

- the type of research question or objective,
- the extent of control an investigator has over actual behavioural events, and
- the degree of focus on contemporary or historical events.

Table 3.1 provides an outline of the relative performance of each type of research strategy under each condition.

Table 3.1: Relevant situations for different research strategies: adapted from Yin, (2013)

Research Strategy	Form of research question	Requires control over behavioural events?	Focuses on contemporary events?
Experiment	how, why	Yes	yes
Survey	Who, what, where, how many, how much	No	yes
Archival analysis	Who, what, where, how many, how much	No	yes/no
History	how, why	No	no
Case study	how, why	No	yes

Based on an analysis of these research strategies and the aim of this research, the case study research strategy was adopted as the appropriate strategy for this study. The following section describes the case study strategy and justify its preference as opposed to the other strategies.

3.3.1 Case Studies Research

Yin (2003:p13) defines a case study as:

> "*an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident*".

He further indicates that the case study strategy deals with technically distinctive situation, relies on multiple sources of evidence, and benefits from prior development of theoretical prepositions to guide data collection and analysis, and is, therefore, a preferable research strategy when the phenomenon and the context are not readily distinguishable.

Similarly, Collis and Hussey (2013) describe a case study as:

> "*a methodology that is used to explore a single phenomenon in a natural setting using a variety of methods to obtain in-depth knowledge*".

Furthermore, using the number of cases involved, Hak (2008:p4) defines case study as:

> "*a study in which one case (single case study) or a small number of cases (comparative case study) in their real-life context are selected and scores obtained from these cases are analysed in a qualitative manner"*.

Thus, it can be seen that case study research strategy is capable of accommodating different research techniques and is normally used when it is required to obtain in-depth knowledge with regard to a particular phenomenon (Wedawatta et al., 2011).

Accordingly, Schell (1992) classifies case studies into three categories: the exploratory (traditional form), the descriptive, and the explanatory. However, Schell (1992) observes that there is no exclusivity between the three categories, as some of the best-case studies are either exploratory and descriptive or descriptive and explanatory. Hence, this doctoral research was an exploratory and descriptive case study.

3.3.1.1 Rationale for Selecting Case Study Research Strategy

The case study is considered by Yin (2013) and Benbasat et al., (1987) to be viable for the following reasons:

- it is necessary to study the phenomenon in its natural setting;
- one cannot manipulate the behaviour of those involved in the study;
- the focus of the study is to answer "how" and "why" questions, to understand the nature and complexity of the processes taking place;
- one may want to cover contextual conditions because you believe they are relevant to the phenomenon under study;
- research is being conducted in an area where few if any, previous studies have been undertaken; or
- the boundaries are not clear between the phenomenon and context.

Accordingly, the main research question for this doctoral study - *how can MSW disposal be improved in developing countries with similar circumstances and MSW problems to Ghana?* - satisfies the criteria for selecting a case study strategy as delineated above. This study answered questions of how MSW is collected, transported, and disposed of; why the environmental burdens of MSW disposal is poorly understood in most developing countries; how environmental burdens of MSW can be minimised; how decisions are made on waste disposal; and how material recovery from MSW can be maximised. These research questions predominantly consisted of how and why type of research questions, and therefore, favoured a case study research strategy.

The second condition Yin (2013) identifies for a case study research is the degree of control the researcher has over actual behavioural events. In this study, the researcher did not have control over the behaviour of the research participants (waste management stakeholders). The researcher was outside to the “case” by being an observer. Therefore, a case study allowed the researcher to retain the holistic characteristics of real-life events while investigating the empirical events (Schell, 1992; Easton, 2010).

A research strategy like experiment was less applicable to this study as the researcher did not have control over the phenomenon to be studied. This is because the experimental studies attempt to manipulate independent variables to observe behaviour of the dependent variables (Collis and Hussey, 2013), which was not possible to achieve in this research.

Similarly, a survey strategy is usually associated with the deductive approach (Saunders et al., 2009), and positivist philosophical positioning (Collis and Hussey, 2013), however, this research is inclined towards realism with a more inductive approach as discussed in sections 3.1.1.3 and 3.2.2 above. Hence, survey strategy was also deemed inapplicable to this research. A case study was more suitable since the research questions sought to explain the present situation and the possible improvement of MSW disposal in Ghana and other developing countries.

3.3.1.2 Validity and Reliability in Case Study Research

Case study research is subjected to criticism. The lack of a well-defined, formalised methodology of case study research is one of the key criticisms of this type of research (Schell, 1992; Hak, 2008). Again, case studies can be considered weak as they are typically restricted to a single organisation/area and it is difficult to generalise findings since it is hard to find similar cases with similar data that can be analysed in a statistically meaningful way (Benbasat et al., 1987; Easterby-Smith, 1997; Meredith, 1998).

Additionally, some critics claim that the process of preparing case studies takes too long and result in massive, unreadable documents or report only the researchers conclusions, the analysis and presentation of case study data requires more skill, hence more highly qualified (and scarce) researchers, and is subject to more risk of researcher bias (different researchers may have different interpretations of the same data) than other research strategies (Venkatraman, 1989; Schell, 1992; Voss et al., 2002).

Because of these criticisms, it is important that validity and reliability of a case study research are established, by following four tests: construct validity, internal validity, external validity, and conclusion validity or reliability (Schell, 1992; Trochim and Donnelly, 2001; Wedawatta et al., 2011; Yin, 2013). Table 3.2 highlights the different tactics that were used in this research to satisfy the tests, and thereby ensured the validity and reliability of the case study research strategy used in this study.

Table 3.2: Case study tactics used for the four design tests (Trochim and Donnelly, 2001; Wedawatta et al., 2011; Yin, 2013)

Test	Case study tactic used in the research
Construct validity	• Use of multiple sources of evidence • Review of draft case study reports by key informants
Internal validity	• Pattern-matching • Explanation building
External validity	• Use of replication logic
Conclusion validity/reliability	• Use case study protocol • Develop case study database

3.3.1.3 Selection of the Case Study Area and Units of Analysis

Case studies research may either focus on a single case or use several cases. A single case may form the basis of research on typical, critical or deviant cases, while multiple cases may be used to achieve replication of a single type of incident in different settings, or to compare and contrast different cases (Schell, 1992; Perry, 1998). This research was a single case study with mixed research methods. Though it is better, i.e. more valid and generalisable, to include multiple cases, there are instances where a single case is instructive (Stewart, 2012; Fouché, et al., 2016).

Accordingly, Orum et al. (1991) indicate that a single case study is an appropriate strategy when an in-depth holistic investigation is required because it offers the opportunity to obtain information from multiple sources of data. Therefore, an in-depth holistic investigation was needed to answer the main research question of this study - "*how can MSW disposal be improved in developing countries with similar circumstances and MSW problems to Ghana*"? - so, the adoption of a single case study strategy in this research.

Furthermore, on the use of a single case study together with mixed research methods, Yin (2013) observes that the mixed research methods provide the opportunity for greater insights into the underpinning principles as opposed to sampling size dependent statistics. Hence, a detailed single case study strategy was more appropriate for this doctoral research where the goal was to bridge a theoretical knowledge gap.

Therefore, Wa municipality of Ghana was the sole case study area. The choice of the case study from Ghana was because Ghana has similar economic and climatic conditions as well as MSWM challenges as most developing countries in sub-Saharan Africa and because Ghana is the researcher's home country which made the field work for the study easier. Also, the choice of Wa municipality in the Upper West Region of Northern Ghana as the single case study area was because most researches on SWM in Ghana have largely been concentrated in the southern parts of Ghana and the larger metropolitan areas such as *Accra*, *Kumasi*, *Takoradi,* and *Tamale*.

The unit of analysis is the major entity that is analysed in a study (Yin, 2003; Cronin, 2014; Samraj, 2016). So, for this study, the Wa municipality's MSW disposal system was the case and the study was focused on the MSW generation and characteristics, the baseline scenario of MSW disposal, and the management and operational performances of the disposal system.

3.3.1.4 Theoretical Framework for the Case Study Generalisation

Generalisation is a logical argument for extending one's claims beyond the data, positing a connection between events that were studied and those that were not (Maxwell, 1992; Ruddin, 2006). There is a misconception that a case study strategy provides little basis for scientific generalisation (Dubois and Gadde, 2002; Herold, 2017). However, case studies, like experiments, are generalisable to theoretical propositions and not to populations or universes (Schell, 1992; Flyvbjerg, 2006; Herold, 2017).

Accordingly, Flyvbjerg (2006) identified five common misunderstandings for case studies strategy as:

- theoretical knowledge is more valuable than practical knowledge
- one cannot generalise from a single case
- the case study is most useful for generating hypotheses
- the case study contains a bias towards verification
- it is often difficult to summarise different case studies

Notwithstanding these misunderstandings, a single case study strategy offers a valid approach to researching MSWM in developing countries as the MSW generation, characteristics, and management challenges are similar in most municipalities in developing countries as discussed in section 2.1.2 of the literature review chapter. Thus, the scientific generalisation of the findings of this study within Ghana and other developing countries with similar MSWM problems to Ghana would be possible.

The theoretical framework for this study is the integrated solid waste management (ISWM) framework discussed in section 2.3.1.4 of the literature review. The theoretical basis of this study evolved over time in response to both the researcher's deepened understanding gained through the collection of the field data and the changing ideas concerning the appropriate theory for this study.

Thus, this case study showed why implementation of an ISWM framework is the solution to improving MSW disposal in developing countries, as the findings of this research have relevant policy, practical and theoretical implications for improving MSWM on the ground in many developing countries (see chapters five, six, seven, and eight of this thesis).

3.4 Research Method

The determination of an appropriate research method is considered as an essential element in a research study, especially in a doctoral research study (Wedawatta et al., 2011). Saunders et al. (2009) in a research onion outlined the research methods as the mono method, the mixed method, and the multi-method. Similarly, Creswell, (2014:p32) states that there are basically three research methods: qualitative, quantitative, and mixed methods, however, the three approaches are not as discrete as they appear.

As such, qualitative and quantitative approaches should not be viewed as rigid, distinct categories, polar opposites, or dichotomies (Creswell, 2014). Instead, they represent different ends of a continuum (Newman and Benz, 1998). A research tends to be more qualitative than quantitative or vice versa and mixed method resides in the middle of this continuum because it incorporates elements of both qualitative and quantitative approaches (Creswell 2014). Table 3.3 highlights the difference between the three research methods.

Table 3.3: Differences between the three research methods: adapted from Teddlie and Tashakkori, (2009); Creswell, (2014)

Category	**Qualitative Method**	**Quantitative Method**	**Mixed Method**
Research questions/objectives	Qualitative research questions/objectives	Quantitative research questions/objectives, research hypotheses	Mixed method research questions/objectives (quantitative & qualitative)
Form of data	Narrative	Numeric	Narrative & numeric
Purpose of research	Exploratory and confirmatory	Confirmatory and exploratory	Both Confirmatory and exploratory
Data analysis	Thematic: categorical and contextualising	Statistical: descriptive and inferential	Integration of thematic and statistical to converge
Validity/trustworthiness issues	Trustworthiness, Credibility and transferability	Internal and external validities	Inference qualities and transferability

3.4.1 Quantitative Research Methods

Quantitative research methods explain phenomena by collecting numerical data that are analysed using mathematically based methods (Muijs, 2010). This method predominately deals with figures to produce data that can help establish correlations between given variables and outcomes (Maxwell, 2010). Quantitative research methods are more structured and have well-defined characteristics that allow researchers to plan much of the research process before it starts (Etikan et al., 2016).

Accordingly, Hulme (2000) observes that quantitative research method is especially useful when carrying out a large scale needs assessment or baseline survey. This is because, the results are independent of the researcher and one should get comparable results no matter who carries out the research (Trochim and Donnelly, 2001). Thus, the researcher employed quantitative research method to assess the baseline MSW disposal scenario and operational management performance for the case study area of this research.

The quantitative data collection methods applied in this study were documentary view, questionnaires, and scenarios modelling. Content analysis, statistical programme for social sciences (SPSS), uncertainty and sensitivity analysis were used for the quantitative data analysis.

3.4.2 Qualitative Research Methods

Qualitative research methods tend to be more evolutionary in nature when compared with quantitative research designs (Sukma et al., 2016). Mack *et al.* (2005) indicate that qualitative research seeks to understand a given research problem or topic from the perspectives of the local population it involves. They further note that it is especially effective in obtaining culturally specific information about the values, opinions, behaviours, and social contexts of populations.

MSWM is affected by behavioural tendencies and has social, economic and environmental implications. Therefore, qualitative research methods enabled the researcher to understand waste management stakeholders' perception of MSW and its management in the study area. The qualitative data collection methods applied in this study included: interviews, questionnaires, observation, memory-work and documentary view. The data obtained were analysed in themes.

3.4.3 Mixed Research Methods

Mixed methods involve integrating quantitative and qualitative approaches to generating new knowledge and can involve either concurrent or sequential use of these two classes of methods to follow a line of inquiry (Brannen, 2005; Bulsara, 2015). Consequently, Symonds and Gorard (2008) postulate that the classification of all numerical research as quantitative and all other research techniques as qualitative necessitated the construction of a third category – that of mixed methods - to describe studies which use both types of techniques.

However, Bulsara (2015) posits that employing the mixed research method usually mean working with different set of data which may involve different indicators. For this reason, mixed research method is often seen as a multi-strategy research method (Brannen, 2008; Östlund *et al.*, 2011; Hussein, 2015), implying the application of a number of different research strategies related to a complex range of research questions/objectives and a complex research design (Brannen, 2005).

Thus, Sukma et al. (2016) observe that this method may put a greater burden on a researcher by slowing down the research process, especially if there is the need to conduct a qualitative research phase (e.g., interviews) before settling on the appropriate type of quantitative research phase (e.g., experimental or non-experimental).

Notwithstanding these, the researcher adopted a mixed research method for this doctoral study. Mixed method was appropriate for this study because it drew from the strengths of both qualitative and quantitative research approaches while minimising the limitations of both approaches (Creswell, 2014). Thus, the study adopted a concurrent mixed method to collect and analyse the data as shown in Figure 3.1.

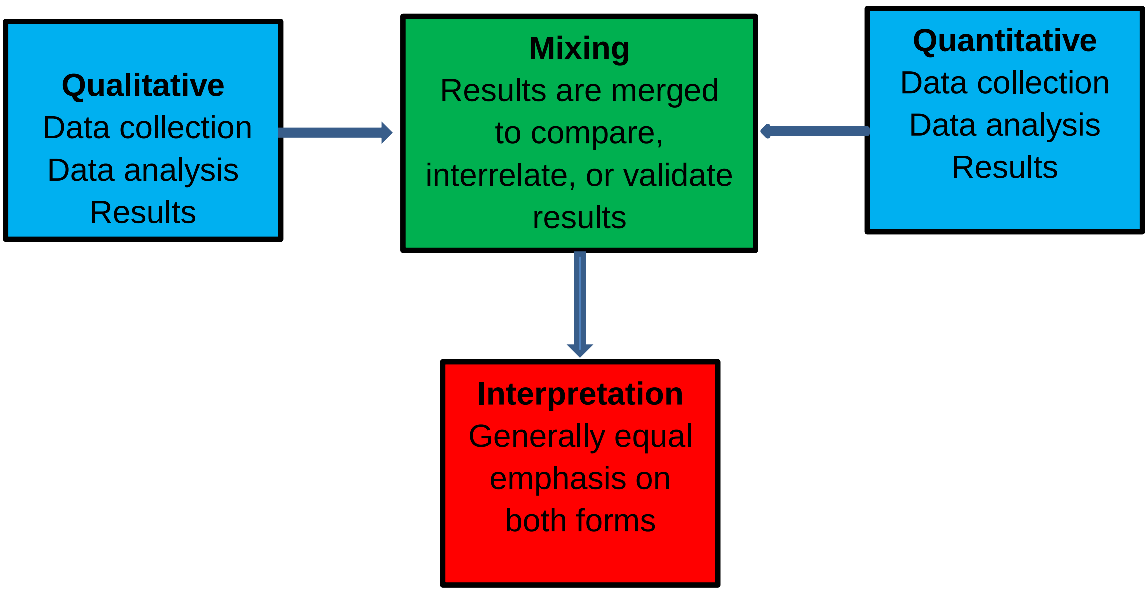

Figure 3.1: Concurrent mixed methods design: adapted from Clark *et al.* (2008)

3.5 The Research Design

Research design is the overall plan for connecting the conceptual research problems to the pertinent empirical research (van Wyk, 2012). It can be thought of as the logic or master plan of a research that throws light on how the study is to be conducted. Thus, a research design articulates what data is required, what methods are going to be used to collect and analyse this data, and how the research question will be answered (Charmaz and Smith, 2003; Johnson et al., 2007).

Hence, Trochim and Donnelly (2001) note that research design provides the glue that holds the research project together as a design is used to structure the research, to show how all of the major parts of the research project work together to try to answer the central research questions. The type of research question/objective will typically dictate the methodology that will be employed, and the reliability and validity of the results depends on the proper selection of the research approach and design (Barriball and While, 1994).

Therefore, the research design for this study was a descriptive and interpretive case study that was analysed through both qualitative and quantitative methods. Figure 3.2 below summarises the research design for this study.

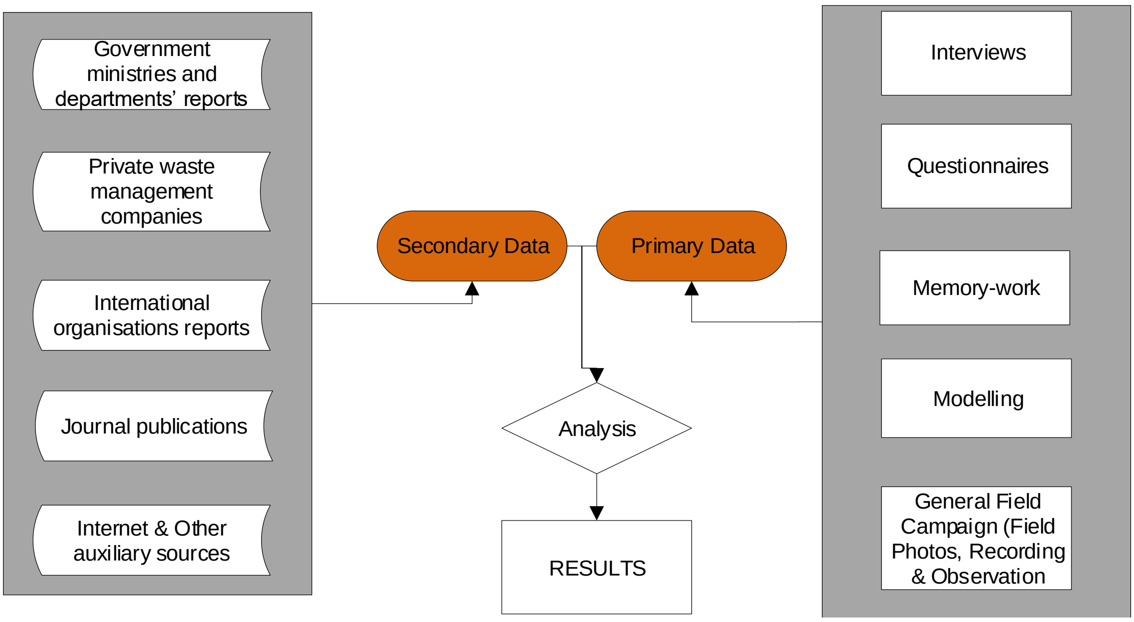

Figure 3.2: Summarised data collection and general approach to the research work

3.5.1 The Study Setting – Wa Municipality, Ghana

Urbanisation has been one of the most significant processes in transforming all societies, particularly since the early twentieth century. Everywhere, cities are synonymous with modernization, economic development, social progress and cultural innovation. However, the nature of urban development, particularly in sub-Saharan Africa, including Ghana, seriously constrains the productivity of cities and hence reduces the extent to which they can effectively perform their role in national development (Yankson and Bertrand, 2012). Lack of adequate infrastructure and services provision, poverty, pollution, overcrowding, congestion and shortage of affordable housing are undermining the traditional civilizing influence of cities (Bardos *et al.*, 2016).

Nevertheless, Ghana continues to experience rapid urbanisation, which has led to many sustainable development challenges, particularly regarding sanitation and transportation infrastructure. The proportion of the country's population living in towns, as officially defined (any settlement with at least 5,000 people), has increased rapidly over the years as shown Table 3.4. The percentage of urban dwellers before independence in 1955 was 19.1%, it rose drastically to 40.1% by the end of the 19th century. However, in recent decades, the country has experienced steady urbanisation with the current urban population being 52.7%.

Table 3.4: Urban population percentages between 1955 and 2018 in Ghana (Worldometers, 2018)

Year	Total Population	Urban population (%)
2018	29,463,643	52.7
2017	28,656,723	54.2
2016	28,033,375	53.7
2015	27,409,893	53.2
2010	24,317,734	50.6
2005	21,389,514	47.3
2000	18,824,994	43.9
1995	16,760,991	40.1
1990	14,628,260	36.4
1985	12,716,238	32.9
1980	10,802,025	31.2
1975	9,831,409	30
1970	8,596,977	29
1965	7,710,547	26.1
1960	6,652,285	23.3
1955	5,680,406	19.1

The increasing rate of urbanisation in Ghana, as in many countries in Africa, is the result of a combination of high rates of natural increase of the national populations and net in-migration to the urban areas (Yankson and Bertrand, 2012). The two major processes reinforce each other, although their relative importance has varied over the years. Initially there was migration from rural to urban areas, particularly in the cities but lately, the migration is from small towns to the cities. This is largely a function of the differences in the level of development between urban and rural areas, given the urban bias in development.

This urban bias theory has led to demoralising and insidious problems and challenges in many urban areas in Ghana, including the Wa Municipality (Yankson and Bertrand, 2012). Sanitation including SWM has become a major issue of concern to urban residents because most urban areas are engulfed with filth which leads to outbreaks of communicable diseases such as cholera. There is a general high infrastructure deficit in the country which has resulted in major development problems in areas such as education, health, water and sanitation, and transportation in many urban areas.

The Wa municipality is a middle-sized town with a large rural component. It is one of the eleven District/Municipal Assemblies that make up the Upper West Region (UWR) of Ghana. It was initially named the Wa District and was upgraded to Wa Municipal in 2004 with Legislative Instrument (LI) 1800 in pursuant to the policy of decentralization which started in 1988. Under section 10 of the Local Government Act 1993 (Act 426), the Assembly exercises deliberative, legislative and executive functions in the Municipality. The Wa Municipal shares administrative boundaries with *Nadowli- Kaleo* District to the north, Wa East District to the east and to the west, and Wa West District to the south. It lies within latitudes 1º40'N to 2º45'N and longitudes 9º32'W to 10º20'W.

The population of Wa Municipal, according to the 2010 Population and Housing Census, is 107,214 representing 15.3 percent of the region’s total population. Males constitute 49.7% and females represent 50.6%; and about 34% of the population reside in rural localities (Ghana Statistical Service, 2012). The Municipality has a household population of 102,264 with a total of 9,592 houses. The average household size in the municipality is 5 persons per household, children constitute the largest proportion of the household structure accounting for 42% of the household population, spouses form about 9.7%, and nuclear households (head, spouse(s) and children) constitute only 9.5% (Ghana Statistical Service, 2012).

The Wa Municipality has its capital as Wa (as indicated in Figure 3.3), which also serves as the regional capital of the Upper West Region (UWR). It has a land area of approximately 579.86 km^2, which is about 6.4% of the region. All assemblies in Ghana, including the Wa Municipal Assembly are empowered as the highest political and administrative bodies charged with the responsibility of facilitating the implementation of national policies and waste management.

According the Ghana Statistical Service (2014), the solid waste final disposal method in the Wa Municipality is open dumping in an un-engineered landfill site; 44.6% of the households in the Wa Municipality are provided with communal container for the disposal of their solid waste, but 24% of households’ actual resort to the communal containers for their solid waste disposal; as high as a proportion of 17.6% of households dump their solid waste indiscriminately; 4.3% of households rely on house-to-house waste collection service; and for liquid waste disposal, throwing waste onto the street (53.5%) and onto the compound (17.7%) are the two most common methods used by households in the Wa Municipality.

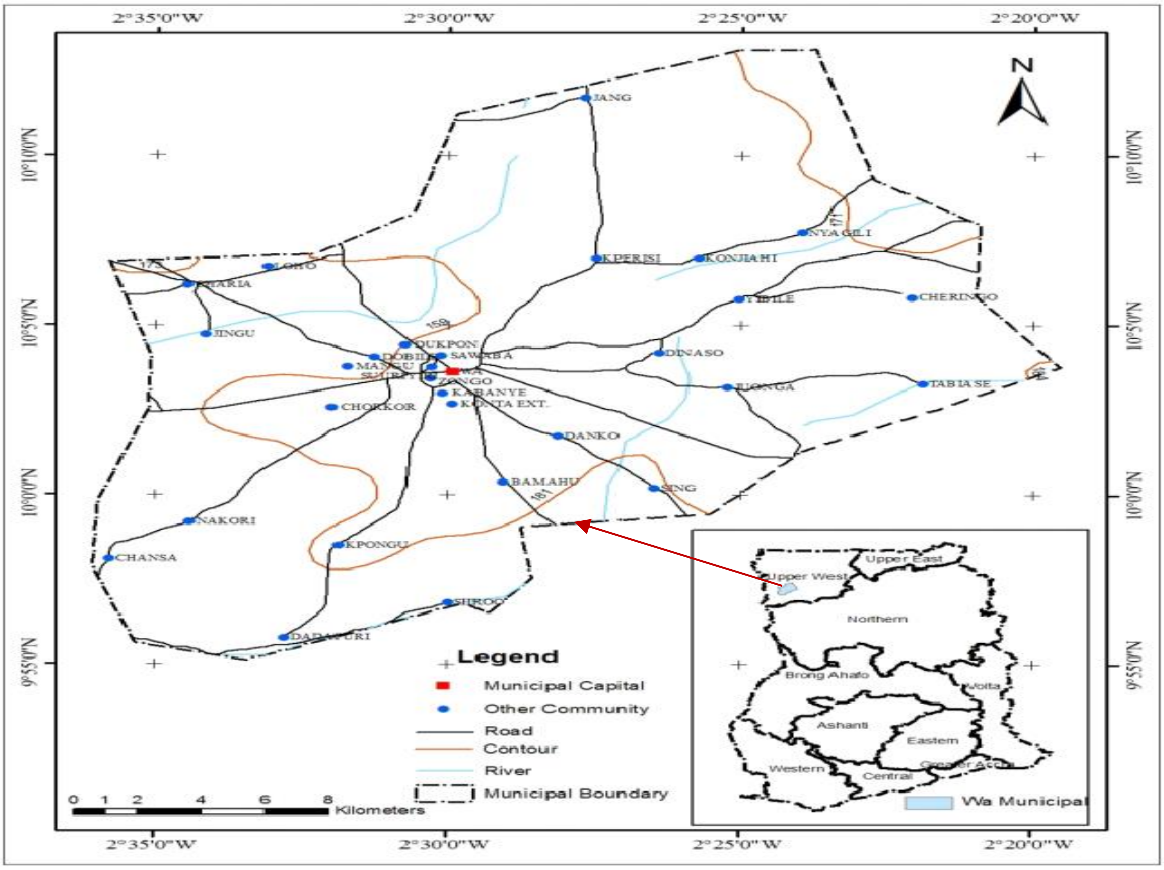

Figure 3.3: Wa municipality's map: modified from (Aduah and Aabeyir, 2012)

3.5.2 The Research Population and Sample Size

MSW is usually generated in commercial centres/businesses, institutions, on streets and households. Therefore, all waste generating sectors in the Wa Municipality were part of the study population for this study. Also, key stakeholders and interest groups in MSWM such as waste generators, regulators, service providers, recyclers, waste pickers and the community were included in the research population.

3.5.2.1 Sampling Technique

Sampling is the process of selecting units (e.g., people, organisations) from a population of interest with the aim to draw conclusions for the entire population after conducting a study on a sample taken from the same population (Arber, 2001; Trochim and Donnelly, 2001; Forza, 2002; Hargittai, 2015).

Accordingly, there are two main types of sampling: probability and non-probability sampling (Kitchenham and Pfleeger, 2002; Baker *et al.*, 2013). The difference between the two types is whether the sampling selection involves randomisation (Lepetit and Fua, 2006). Randomisation occurs when all members of the sampling frame have an equal opportunity of being selected for a study (Herek, 2014; Banerjee *et al.*, 2015).

This research was focused largely on the key waste management stakeholders, therefore, purposive sampling (a non-probability sampling technique) was used to obtain the data from the key stakeholders in the case study area. Table 3.5 indicates the key waste management stakeholders sampled for this study. Purposive sampling technique was suitable for this study because the researcher had experience and knowledge of the groups sampled (Gentles *et al.*, 2015; Roy *et al.*, 2015).

Table 3.5: Key waste management stakeholders sampled for the study

Type of stakeholders	Research participants
Waste disposal service providers	• Wa Municipal Assembly • Zoomlion Ghana Limited (Private waste collection company) • Informal waste collectors/waste pickers/Scavengers
Government institutions with some functions over SWM	• Environmental Protection Agency • Town & Country Planning Department • Lands Commission • Water Resources Commission • Department for Urban Roads
Waste disposal service beneficiaries	• Households • Businesses • Institutions

Also, the researcher employed stratified random sampling (a probability sampling technique) to gather data from waste generators (households) for this study. The stratified random sampling technique first divides the population into strata, such that the sampling units are homogeneous with respect to the characteristic under study within the subpopulation. The sample is then randomly selected from each stratum.

Therefore, the households in the case study area were grouped into three strata according to their residential typology/income levels (single-units dwelling/high-income, semi-detached dwelling/middle-income, and compound-house dwelling/ low-income) and then households in each stratum were randomly selected to be sampled for the study.

Notwithstanding that with stratified random sampling, the researcher must identify every member of the population being studied and classify each of them into one and only one subpopulation (Fife-Schaw, 2000; Meyer and Wilson, 2009), it was suitable for this study (household survey) because it reduced selection bias and ensured that the sample accurately reflected the population being studied in terms of the criteria used for the stratification (residential typology and income level) (Waksberg, 1978; Winship and Mare, 1992; Tongco, 2007; Acharya *et al.*, 2013).

3.5.2.2 Sample Size

After a researcher has decided what and whom to study and the design to be used, how many 'subjects' to be sampled must be decided (Maxwell, 2000; Halpern et al., 2002; Maxwell et al., 2008). Thus, Zodpey (2004) observes that even the most rigorously executed study may fail to answer its research question if the sample size is too small, and if the sample size is too large, the study will be more difficult and costly than necessary.

Therefore, the key stakeholders (waste generators, service providers, managers and regulators) in MSWM in the case study area were sampled for the study. Waste generators sampled for the study were the households, staff of ministries departments, and traders and shop owners in the Wa central market in the case study area. Fifty (50) households each in compound-house, semi-detached, and single-unit dwellings (totalling 150) formed the households sample size. The researcher applied systematic sampling in selecting the 50 uniform households in the various residential dwellings, as a systematic sample is obtained by selecting items at uniform intervals. Though this households sample size was small, as the Wa municipality's household population was 102,264 (Ghana Statistical Service, 2014), because of a limited budget and time constraints, it was "big enough" to be of scientific and statistical significance (Lenth, 2001; Zodpey, 2004; Ahmad *et al.*, 2012).

3.6 Data Collection

Data collection techniques allow a researcher to systematically collect information about the objectives of a study (people, objects, phenomena) and about the settings in which they occur (Chaleunvong, 2013). Therefore, a researcher needs to be diligent in the collection of data. If data are collected haphazardly it will be difficult to answer the research questions in a conclusive way (Chaleunvong, 2013). Consequently, Anderson *et al.* (2006) indicate that there are mainly two types of data collection techniques, namely, primary and secondary data collection techniques.

Primary data are gathered by a researcher/team and usually done by survey research (data is original, unedited and 'first-hand'), whilst secondary data are the data that have been already collected and recorded by someone else and readily available from other sources (data is 'second-hand', edited and interpreted material) (Pope et al., 2000; Barlett et al., 2001; Yee, 2010). The researcher applied both primary and secondary data collection techniques to gather the data for this study.

The data collection was in two phases, with a pilot study included in the first phase. The pilot study enabled the researcher to familiarise himself with the research environment, identified key stakeholders in the waste sector and pre-tested the research instruments (questionnaires and interview guides). Subsequently, questionnaires were administered, and interviews held with some key waste management stakeholders (staff of the Wa Municipal Assembly, the Environmental Protection Agency (EPA), and informal waste pickers). The first phase of data collection was undertaken in the case study area (Wa Municipality) over a fourteen-week period between February and April 2017.

The second fieldwork was carried out in the study area from the last week of November 2017 to the end of March 2018. Under this phase, questionnaires were administered to households and ZGL (the only private waste collection company in the case study area), and interviews held with some key waste management stakeholders (retired waste management practitioners, municipal authorities, some household heads, and informal waste pickers), together with observation of waste management practices in the study area.

3.6.1 Primary data collection

Primary data are those which are collected for the first time and are always given in the form of raw materials and are original in character (Marcus et al., 1993; Cowie and Lehnert, 1996). These types of data usually need the application of statistical methods to ease the analysis and interpretation processes.

Currie, (2005) indicates that there are three main methods that can be used to collect primary data: *the survey method, the interview method and the observational method*. Usually, the method adopted for a research depends largely on the type of data required to answer the research questions. The researcher applied all the three primary data collection methods in this study together with memory-work, an emerging method of collecting qualitative data.

3.6.1.1 Questionnaire Survey

The application of questionnaire method in this study made the quantification of information possible. The reason for the use of a questionnaire is that the opinions of respondents can be obtained in a structured manner (Linsky, 1975; Silke, 2001). Thus, questionnaires were used to obtained information on waste management practices, and institutional arrangements for waste management in the study area. The use of a questionnaire was cheaper and quicker because some sample for the study (households) were widely dispersed and not readily available.

A total of two hundred and eleven (211) households residing in compound-house (low-income), semi-detached (middle-income), and single-unit (high-income) dwellings in the Wa municipality responded to the questionnaires with the support of two research assistants engaged by the researcher. This number exceeded the initial planned household sample size of 150 since there was a good response to the households' questionnaire. Table 3.6 shows the sampled residential areas based on the residential typology/income level in the case study area. A sample of the households' questionnaire is attached as Appendix B of this thesis.

Table 3.6: Household respondents

Residential Typology/Income Level	Name of Residential Area	Number of Questionnaires Administered	Average Household Size (Ghana Statistical Service, 2014)
Compound-house dwelling (low-income)	• Dondoli • Kambale • Kpaguri • Konta	104	6.4
Semi-detached Dwelling (middle-income)	• Dobile Quarters • SSNIT Flats • Degu Quarters • Kpaguri Estates	64	5
Single-unit dwelling (high-income)	• Jdzedayiri – Tampalepani Residential Area • Xavier Residential Area • Xavier Extension • Airport Residential Area	43	5.4
Total		**211**	**5.6**

Furthermore, the questionnaire method of data collection was especially helpful in obtaining information from Zoomlion Ghana Limited (ZGL) officials (the only private waste collection company operating in the case study area) and some staff of the Wa Municipal Assembly (WMA) who did not agree to be interviewed, because there was an on-going investigation into some SWM contracts due to allegations of the use corrupt practices by ZGL in securing waste management contracts in Ghana. Samples of the questionnaires administered to ZGL and the WMA are attached as Appendices C and D respectively of this thesis.

Also, a questionnaire was used to validate a developed framework for MSW disposal decision-making, through a focused group discussion made of municipal waste engineers in Wa, Lawra, Jirapa, and Sissala East Municipal Assemblies, and senior staff of EPA in the Upper West Region, Ghana. The researcher chose the municipal waste engineers and senior staff of EPA as the validators of the developed framework, because the municipal assemblies and EPA are the SWM service providers and regulators in Ghana respectively. The framework validation questionnaire is attached as Appendix VII of this thesis.

The questionnaire survey was valid and reliable for this research because a pilot study with research participants refined the questionnaires to suit the research objectives, with the questions in the questionnaires covering the full range of the research problem; all the questions in the various questionnaires were aligned to the research objectives and each question had a logical link to one or more research objective(s); and the questionnaire survey was the appropriate research instrument for the research sample and population as households and other waste management stakeholders were involved (Hinkin, 1998; Boynton and Greenhalgh, 2004; Chaudhuri *et al.*, 2006; Amann and Anderson, 2014; Sudore *et al.*, 2014).

3.6.1.2 Interview Method

Valenzuela and Shrivastava (2002) define an interview as the verbal conversation between two people with the objective of collecting relevant information for research. According to McNamara (1999), interviews are particularly useful for getting the story behind a participant's experiences, the interviewer can pursue in-depth information around the topic, and interviews may be used as follow-up to certain respondents. The types of interviews used in research include: personal (face-to-face) interview, telephone interview, focus group interview, depth interview and projective techniques (Fontana and Frey, 1994; Cooper, Schindler and Sun, 2003; Berg, 2004).

Among these types, Opdenakker (2006) posits that personal interview is the dominant interview technique. Many researchers prefer personal interviews because the interviewer is able to capture the verbal and non-verbal cues such as body language, which can indicate the level of discomfort with the questions, thereby indicating the level of interest for the topic being discussed (Price, 2004). Thus, the researcher used personal interviews in this study to investigate the present MSW disposal situation in the study area by interviewing key SWM stakeholders.

The Wa Municipal (WMA) is mainly responsible for waste management in the case study area (the Wa municipality), thus, the researcher arranged and held formal and informal interviews with senior officials of the assembly, including and not limited to, the director for the Municipal Waste Department (MWM), municipal engineers (two number), environmental health officers (five number), and budget officers (one number), to obtain information on the current management performance in the study area. Also, two senior staffs of Ghana's Environmental Protection Ghana (EPA) (the regulator of Ghana's environment, including waste management), some workers of ZGL (three drivers and ten cleaners), informal waste pickers/collectors (three metal waste merchants), and scavengers at the waste disposal site (one boy and three women) were also interviewed.

Additionally, the researcher arranged and held formal interviews with a senior staff each of government institutions with some functions over SWM to solicit their views on how their functions could help improve SWM and vice versa. These institutions included the Town and Country Planning Department, Lands Commission, Water Resources Commission, and the Department for Urban Roads.

All the interviews with the formal sector (government institutions) were pre-arranged with the research participants before the date of the interview, whereas, for the informal sector (metal waste merchants and scavengers), the researcher visited their operations sites and requested to hold informal interviews with them. Additionally, follow-up informal interviews were held with some households' respondents to seek clarification on some answers given in the households' questionnaires.

The interview method was valid and reliable for this research because of the following:

- a pilot interview was conducted, and the subsequent interviews flowed naturally and were rich in detail;
- the researcher took detailed notes, and in some cases, audio recorded the interviews and the proceedings transcribed later;
- interviewees were giving the chance to sum up and clarify the points they had made; and
- the results were coded and analysed in themes.

3.6.1.3 Observational Method

Observation method is the most commonly used method of data collection, especially in studies relating to behavioural science (Jick, 1979). It is a process of observing the behaviour patterns of people, objects, and occurrences without questioning or communicating with them (Barley, 1986; Colella, 2000). Thus, Caldwell and Atwal (2005) note that observation allows the researcher to study people in their 'natural setting' without their behaviour being influenced by the presence of a researcher.

Accordingly, Spradley (2016) suggests that observation is probably the most common and the simplest method of data collection because it does not require much technical knowledge. Because of this, it is the widely method used for getting information about recurring activities such as waste management (Hargittai, 2001).

The data obtained by observation method usually consists of detailed information about particular groups or situations which can provide a deeper, richer, understanding than survey work which tends to produce less detailed information about a larger number of people (Adler and Adler, 1994; Kitzinger, 1995). However, observation method as a data collection technique is too subjective (Adler and Adler, 1994), and was used in this research to supplement or verify information gathered by other methods such as questionnaires and interviews.

Therefore, the use of observation in this study was limited to waste handling practices in the study area such as households waste storage and disposal methods, communal collection containers, street sweeping, waste collection vehicles routing, waste transportation, various open dump sites, and activities at the main waste disposal site located at *Siiriyir* in the Wa West District. The researcher observed these activities mostly through passive observations, usually in the mornings between the hours of 5:00 am and 10:00 am, but in a few instances, through pre-arranged participant observations. Thus, waste collection vehicles routing, and waste transportation activities were observed through participant observation and the period for the researcher’s participant observation depended on the collection vehicles drivers’ schedule for the pre-arranged observation dates (usually between 8:00 am and 4:00 pm).

3.6.1.4 Memory-Work

Memory-work is a research method that was developed in Germany to bridge the gap between theory and experience (Onyx and Small, 2001). It is not only experience but works with the experience, which is useful as a research method (Haug, 1997). Memory is relevant in the design and improvement of waste management systems because without a memory of the past we cannot operate in the present or think about the future (McLeod, 2007).

The use of this method in this study was targeted at experienced and/or retired waste management practitioners to solicit written accounts of their work and experiences in the waste management sector in the study area. A retired director of the Wa Municipal Waste Department (MWD) with over thirty years' experience in waste management gave a written account of his experiences in MSWM in the Wa Municipality and Ghana in general. This enabled the researcher to obtain information on the past MSW disposal system to assist the researcher compare the historical system with the present system in the case study area.

3.6.2 Secondary Data Collection

Secondary data are those which have already been collected to answer a research question other than the question(s) for which the data were initially collected (Marcus et al., 1993; Vartanian, 2010). This contrasts with primary data in which the same individual/team of researchers collects the data. Secondary data is mostly collected through documentary view and literature studies (Yee, 2010), from many sources but largely government departments, university/college records, journal publications, authors' websites and self-reports (Koziol and Arthur, 2011). Documentary view and literature studies were employed to collect the secondary data for this study.

The purpose of a literature review is to establish what is already known in a subject area (Walsh and Downe, 2005). Thus, the researcher reviewed literature to provide information relating to the general background and context of this study. The literature review (chapter two of this thesis) focused on the concept of MSWM including MSW definition, generation and its characteristics; MSWM practices in developing countries; sustainable waste management; waste management environmental performance; and MSWM decision-making. The literature review was largely conducted from academic journals and published official reports through documentary view and content analysis of the materials viewed.

The researcher depended on the secondary data because the data was available and thus, saved time and money which otherwise would have been used to collect primary data as less field trips and surveys were involved (Champ 2003). The secondary data obtained for the study is deemed valid, reliable, and accurate since the research design and methodology, and data analysis of the documents viewed followed research protocols; the information was relevant and appropriate to the research question and objectives for this study; the information was directly associated with the concepts under scrutiny in this study; and because there was consistency in the data in the documents viewed (Patton, 1999; Golafshani, 2003; Noble and Smith, 2015).

3.7 Data Analysis

Data analysis is the process of systematically applying statistical and/or logical techniques to describe and illustrate, condense and recap, and evaluate data (Gong and Richman, 1995; Savenye and Robinson, 1996; Bello *et al.*, 2015). Data integrity is essential to the accurateness and appropriateness of the analysis process (Gersten *et al.*, 2005). In this respect, Gog *et al.* (2008) give the rule of thumb concerning data analysis as:

> "*do not attempt to analyse all possible kinds of collected data"*.

For this reason, the data analysis for this research was strictly based on the research objectives. The primary research question for this study was:

> "*how can MSW disposal be improved in developing countries with similar circumstances and MSW problems to Ghana*"?

And was translated into the main aim of the study as:

> "*to improve planning and decision making for MSW disposal in developing countries with similar circumstances and MSW problems to Ghana"*.

Table 3.7 below indicates the alignment of the research objectives with the research methods and data analysis techniques.

Table 3.7: Objectives aligned with research methods

Research Objective	Data Sources	Research Method(s)	Analysis Techniques
1. To investigate MSW generation and characteristics reported in literature and official documents	Journal publications and official reports	Literature/ Documentary review	Documentary analysis and content analysis
2. To examine MSW disposal management performance	Government departments, SWM regulators and service providers, journal publications and official reports	literature review, questionnaires, interviews, and memory-work	Documentary analysis, thematic analysis, and situational analysis
3. To establish the baseline scenario of MSW disposal	SWM stakeholders (regulators, service providers and service beneficiaries)	Questionnaire survey, interviews, observation, and memory-work	Statistical analysis, thematic analysis, pictorial evidence, and situational analysis
4. To evaluate MSW disposal operational performance	Journal publications and official reports, SWM stakeholders (regulators and service providers), databases, and MSW DST default data	Literature review, questionnaire, and interviews surveys	Documentary analysis, content analysis, thematic analysis, inventory analysis, sensitivity analysis, and uncertainty analysis
5. To develop a planning framework for MSW disposal decision-making in developing countries	The results of the other four objectives of this research, Journal publications and official reports, and SWM regulators and service providers	Literature review and questionnaire	Documentary analysis and thematic analysis

3.7.1 MSW Generation and Characteristics

The baseline data on waste generation and characteristics form the basis for the planning of waste management systems. Data on MSW generation rates and characteristics for the study area such as composition, moisture content and calorific value were obtained through documentary view of official reports and journal publications. The focus of the documentary view was on the content analysis of the quantitative data on MSW generation rates and characteristics in the documents viewed. The content analysis enabled the researcher to sift through large volumes of data with relative ease in a systematic manner (Wilhelmsen and Dixon, 2016).

3.7.2 MSW Disposal Management Performance

The examination of MSW disposal management performance in the case study area was carried out through documentary analysis and thematic analysis. As indicated in the literature review, there is no consensus on the best indicators for performing waste management performance evaluation. Therefore, four sustainability elements (governance issues) required to provide the enabling environment for sustainable waste management, namely, technical capacity, financial sustainability, institutional arrangements, and policy and legal frameworks for waste management, were set as the MSW disposal management performance examination indicators for this study.

The data was collected from in-depth reviews of published and unpublished literature, and reports on waste management in Ghana and the Wa Municipality, through questionnaires and interviews with waste management stakeholders in the case study area (waste experts, waste managers, waste management regulators, waste management service providers, and waste management beneficiaries), and by observations during fieldwork conducted in the case study area. The data obtained was largely qualitative and was analysed in themes through content and critical analysis of articles, documents, questionnaires, interviews, and things observed.

3.7.3 Baseline Scenario of MSW Disposal

The analysis of baseline scenario in the case study area was theoretically based on empirical observation and an exploratory design. Exploring the current scenario of MSW disposal in the study area enabled the researcher to identify environmental impacts which allowed some predictive planning and optimisation for interventions. Therefore, the assessment of the baseline scenario of MSW disposal in the study area was carried out through material flow analysis (MFA) and by investigating MSW handling practices.

MFA is an analytical method that describes systems of any complexity based on two fundamental scientific principles: the mass conservation, and systems analysis (dos Muchangos, et al., 2017). Accordingly, for waste management, MFA focuses on bulk flows of MSW and highlighting recyclables, emissions and residues in the MSWM system (Wilson *et al.*, 2012; Stanisavljevic and Brunner, 2014). Thus, MFA in this study provided the scientific support to the decision-making process for MSW disposal and ensured that the technical inputs to this process were transparent and rigorous, and assisted in formulating strategies that optimised the overall performance of the waste management system in the case study area (Tang and Brunner, 2014; Zaccariello, et al., 2015; dos Muchangos, et al., 2017).

The methodological principle adopted for the analysis was based on primary sources of data that was collected through field survey. Questionnaires and interviews were used to obtain information on MSW handling practices and attitudes towards MSW disposal of various waste management stakeholders (households, institutions, Wa central market, and waste collection service providers and regulators). The data was organised, classified and analysed in themes as well as visual presentation in the form of charts.

3.7.4 MSW Disposal Operational Performance

The evaluation of MSW disposal operational performance was based on the formulation, building, optimisation and scenarios analysis of five modelled MSW disposal options through the combination of material flow analysis (MFA) and substance flow analysis (SFA) with the aim of optimising the minimisation of MSW disposal environmental burdens, using the municipal solid waste decision support tool (MSW DST).

The MSW DST and other decision support tools have been discussed extensively in section 2.5.1.1 in the literature review chapter of this thesis. Situational analysis, inventory analysis, sensitivity analysis and uncertainty analysis were employed in the modelling and analysis of the five MSW disposal scenarios. Details of the analysis of the MSW disposal operational performance examination are presented in chapter five of this thesis.

3.7.5 Planning Framework for MSW Disposal Decision-Making

The development of a planning framework for MSW disposal decision-making was founded on the results of MSW generation and characteristics, the established baseline scenario of MSW disposal, the MSW disposal performance management, and the operational performance of MSW disposal in the study area. The developed and validated framework is aimed to aid MSWM decision-makers to improve upon MSW disposal and lead to the minimisation of MSW disposal environmental burdens. The developed framework was validated by MSWM stakeholders in the Wa, Lawra, Jirapa, and Sissala East Municipalities for the possible generalisation of this study.

3.8 Ethical Issues

Ethics is used in research to judge the activities of the researcher and the significance of the research (Hoepfl, 1997; Creswell, 2014). The purpose of ethics is to guide individuals to make decisions when there is a moral question of whether an action is right or wrong (Hunt and Vitell, 1986; Trevino, 1986). Therefore, research ethics refer to the responsibility of the researcher to make sure that the participants and the researcher are not harmed by the research (Williamson and Prosser, 2002; Guillemin and Gillam, 2004; Mackenzie et al., 2007).

Accordingly, the researcher read and understood the "*Guidance for Completion of Ethical Clearance Checklist*" of the Loughborough University and got ethical approval for this research before involving the research participants and followed ethical considerations in dealing with human participants during the data collection. The ethical clearance process for this research involved the approval of a school-level risk assessment (Risk Assessment Number for this study was DT_6776) together with an ethical checklist. The school-level risk assessment was based on the potential risk that this research could pose to the research participants and the researcher.

Consequently, during the data collection for this research, a participant information sheet was presented to and/or explained to all the research participants of this study. Some of the research participants sought for clarification on some aspects of the research after reading and/or explanation of the human research participants sheet. The researcher gave clarity to all grey areas of the research to the satisfaction of the research participants, before an informed consent form was provided to all the research participants to agree to participate in the research, by initialling and signing the informed consent form. The adult participants information sheet and the informed consent form are attached as Appendices E and F respectively.

3.9 Validity and Reliability of the Research

Reliability refers to the repeatability of findings whereas validity symbolises the credibility or believability of the research (Golafshani, 2003; Noble and Smith, 2015). There is an intrinsic relationship between research validity and reliability because if data are valid, they must be reliable (Patton, 1999). There are two important aspects of validity: internal validity - the instruments or procedures used in the research measured what they were supposed to measure – and external validity - the results can be generalised beyond the immediate study (Angen, 2000; Johnson et al., 2007).

This research was valid and reliable as the appropriate methodology and research design was chosen (a case study research strategy as discussed in section 3.3.1 and 3.5), taking into account the characteristics of the study (Tranfield et al., 2003); the most suitable sampling and data analysis techniques were selected for the study (Hernandez *et al.*, 2006; Silver *et al.*, 2006) – purposive and stratified random sampling methods and various data analysis techniques – as discussed in sections 3.5.1 and 3.7 respectively; the research participants were not pressured in any ways to give specific answers (Waters, 1990; Boxall *et al.*, 1996), as the researcher strictly followed research ethics and protocols in the collection of the data as discussed in section 3.8; and the results and conclusions of this study are valid for the context of this research.

The next chapter, chapter four, presents the results and analysis of the first three objectives of the study: MSW generation and characteristics reported in literature and official documents (objective 1), MSW disposal management performance (objective 2), and the baseline scenario of MSW disposal (objective 3). The results and analysis of research objectives 4 (evaluation of MSW operational performance) and 5 (development of a planning framework for MSW disposal) are presented as standalone chapters, as chapters 5 and 7 of this thesis respectively.

CHAPTER FOUR – RESULTS: MSW GENERATION AND CHARACTERSITICS, MANAGEMENT PERFORMANCE, AND BASELINE SCENARIO

4.0 Introduction

This chapter presents the research results and analysis of the first three research objectives. The research activities were carried as described in the methodology and research design chapter (chapter three) of this thesis. The results and analysis of the research objectives presented in this chapter are:

- Objective 1: investigation on MSW generation and characteristics reported in literature and official documents.
- Objective 2: examination of MSW disposal management performance, and
- Objective 3: assessment of the baseline scenario of MSW disposal.

The results and analysis of objective 4 (evaluation of MSW disposal operational performance) and objective 5 (development of a planning framework for MSW disposal decision-making in developing countries) are presented in standalone chapters, as chapters 5 and 7 of this thesis respectively.

4.1 MSW Generation and Characteristics

The accurate prediction of MSW generation and knowledge of the waste characteristics provide the basic data on which a waste management system is planned, designed, and operated (Chen and Chang, 2000; Sharholy *et al.*, 2008; Miezah *et al.*, 2015; Abbasi and Hanandeh, 2016; Asante-Darko, Adabor and Amponsah, 2017). The global MSW generation is rising exponentially, with the MSW generation rates across Ghana, irrespective of the socioeconomic considerations, ranging between 0.2 and 0.9 kg per person per day, and more organic MSW (over 60%) being generated (Miezah *et al.*, 2015), as indicated in Tables 4.1 and 4.2 respectively.

The MSW composition in Ghana is heterogeneous and mixed (non-degradable materials and degradable components) with different chemical properties. Particularly for the case study area (the Wa Municipality), organic waste forms 52% of the households MSW composition, whiles 47% forms the organic portion of the commercial (Wa Central Market) waste stream (Municipal Waste Department, 2010; Bowan and Tierobaar, 2014), as indicated in Figure 4.1 and Table 4.3 respectively.

Table 4.1: Household waste generation in the regional capitals of Ghana: modified from Miezah *et al.* (2015)

Regional capital	2017 Population (based on 2010 Census)	High-class income areas (kg/p/day)	Middle - class income area (kg/p/day)	Low - class income areas (kg/p/day)	Average generation rate (kg/p/day)	Total generation (population/ tons)
Accra	2237933	0.86	0.73	0.62	0.74	1656
Bolgatanga	147836	0.31	0.20	0.20	0.21	31
Cape Coast	205674	0.74	0.69	0.58	0.67	138
Ho	321544	0.34	0.33	0.27	0.31	100
Koforidua	213915	0.80	0.54	0.48	0.61	130
Kumasi	2425639	0.63	0.73	0.86	0.75	1819
Sunyani	144599	0.52	0.49	0.47	0.49	71
Tamale	446080	0.38	0.27	0.36	0.33	147
Takoradi	648940	0.76	0.68	0.65	0.70	454
Wa	128873	0.30	0.23	0.21	0.25	32
Average	691605	0.56	0.49	0.47	0.51	458

The increasing MSW generation in the case study area (Wa) can to be attributed to the presence of the University for Development Studies (UDS), Wa campus and the Wa Polytechnic, which have led to an influx of students into the town, because the amount of SW generated in any society relates strongly to its population dynamics.

The Wa Municipality of Ghana is a small town with a 2017 projected population of 128873. The average household waste generation rate is 0.25 kg/p/day, which results in a total waste generation rate of 32 tons/day, with the composition being heterogeneous and mixed (non-degradable materials and degradable components), with different chemical properties.

Table 4.2: Household waste composition and generation in Ghana modified from Miezah *et al.* (2015)

Component	High class income areas (%)	Middle class income areas (%)	Low class income areas (%)	Average (%)
Yard waste (leaves)	17.334	7.562	8.915	11.270
Animal dropping/manure (Grass)	0.176	0.379	0.291	0.282
Wood (Branches)	1.301	1.346	1.282	1.310
Newspaper	0.674	0.388	0.414	0.492
Cardboard	3.223	3.215	2.233	2.890
Office paper	0.605	0.445	0.541	0.530
Tissue paper	1.148	1.520	1.677	1.448
HDPE - Translucent	3.075	2.751	3.418	3.081
HDPE - Pigmented	2.071	3.628	5.358	3.686
PET	3.315	3.297	2.104	2.905
PP rigid	1.554	1.521	1.126	1.400
PS	0.606	0.538	0.583	0.576
PVC	0.554	0.618	0.247	0.473
Other plastics	2.402	1.983	2.153	2.179
Ferrous Can	1.721	1.319	2.108	1.716
Ferrous metals	1.060	1.575	0.530	1.055
Plain glass	0.846	1.072	0.588	0.835
Coloured glass	2.864	1.991	0.00	1.618
Leather & Rubber	1.012	1.171	1.035	1.073
Food waste	44.201	50.595	49.358	48.051
Textiles	0.528	1.149	1.799	1.159
Miscellaneous	9.73	11.937	14.24	11.969
total	100	100	100	100

HDPE = High-density polyethylene, PET = polyethylene terephthalate, PP = Polypropylene, PS = Polystyrene, PVC = Polyvinyl chloride.

The high proportion of miscellaneous MSW (12 % on average, as indicated in Table 4.2) calls for the separation of waste at the generation point since there is no segregation of waste before disposal or collection in Ghana

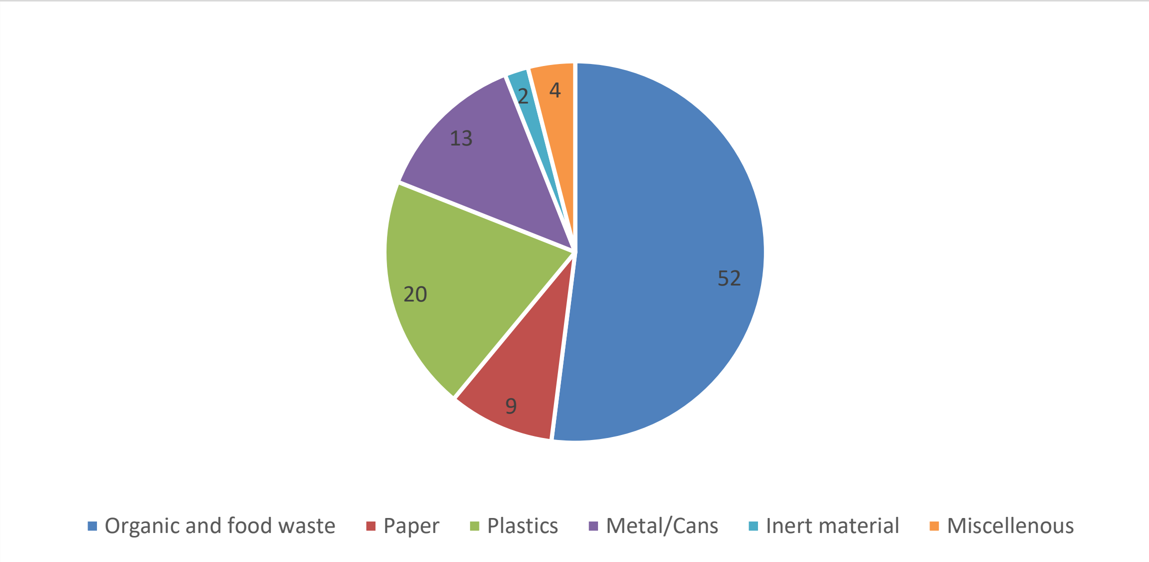

Figure 4.1: Wa municipality's households MSW composition (Municipal Waste Department, 2010)

Table 4.3: Wa Market waste composition (Bowan and Tierobaar, 2014)

Composition	Percentage (%)
Organics	46.6
Cardboard	13.1
PET	4.9
Ferrous cans	2.6
Textiles	3.4
Other	29.4
Total	100

The high organic waste component of the MSW stream in Ghana has resulted in high moisture content (above 50% on average) of the MSW, as indicated in Table 4.4, which conforms with the waste stream in other developing countries (Wilson *et al.*, 2012; Srivastava *et al.*, 2015; Thaiyalnayaki and Jayanthi, 2017).

Table 4.4: Chemical composition of household wastes in Ghana

Property	Kuleape, et al. (2014)	Fobil, et al. (2005)	Adu & Lohmueller (2012)
Calorific value (kJ/kg)	$1.39 \times 10^4 – 2.99 \times 10^4$	$1.4 \times 10^4 – 2.0 \times 10^4$	1.69×10^4
Moisture Content (%)	25 - 76	40 - 60	50
Ash Content (%)	2.2 - 19	nd	nd
Volatile Solids (%)	31 - 88	nd	nd
Density (kg/m^3)	nd	$5.3 \times 10^2 – 5.4 \times 10^2$	nd

*nd = not determined

The MSW stream in Ghana is more organic. The organic fraction is an important component, not only because it constitutes a significant portion of the MSW stream in Ghana and other developing countries, but also because of its potentially adverse impact on public health and environmental quality if not properly treated and/or disposed of.

A major adverse impact of organic waste is its attraction of rodents and vector insects for which it provides food and shelter (Fei-Baffoe, et al., 2014). Also, the impact of organic MSW on environmental quality takes the form of foul odours, unsightliness and leachate from open dumps, especially after rainfall, and emission of harmful gases (Akhtar, 2014). These impacts are usually not limited only to the disposal site, they pervade the neighbouring area to the site and wherever the wastes are generated, spread, or accumulated. Unless an organic waste is appropriately treated and disposed of, its adverse impact will continue until it has fully decomposed or otherwise stabilised.

4.1.1 Summary of Key Findings on MSW Generation and Characteristics

Reliable data on MSW generation and characteristics are not readily available in Ghana and other developing countries, however, the global MSW generation rates are rising exponentially. The MSW generation rates in Ghana and other sub-Saharan African countries are lower (less than 0.65 kg/capita/day) compared to other developing countries such as countries in Asia (1.1 kg/capita/day) (World Bank, 2012). The waste generation rates across Ghana, irrespective of the socioeconomic considerations ranges between 0.2 and 0.9 kg per person per day (Miezah *et al.*, 2015). Organic waste forms the highest fraction of the MSW stream (over 50%) in Ghana and other developing countries (Wilson *et al.*, 2012; Miezah *et al.*, 2015; Srivastava *et al.*, 2015; Thaiyalnayaki and Jayanthi, 2017).

4.2 MSW Disposal Management Performance

The examination of MSW disposal management performance in the case study area was carried out through documentary and thematic analysis. As indicated in the literature review (see section 2.4), there is no consensus on the indicators for performing waste management performance evaluation. Thus, four sustainability elements (governance issues) required to deliver a well-functioning MSWM system: policy and legal framework, institutional arrangement, financing arrangement, and technical capacity, were set as the MSW disposal management performance examination indicators for this study. The following sections present the findings and analysis of these indicators.

4.2.1 Legal and Policy Framework for MSWM

Ghana has a long history of attempting to safeguard the environment from being abused by enacting and including environmental protection in appropriate legislation. The best result from these attempts is the establishment of an organisation solely responsible for the environment – the Environmental Protection Agency (EPA) in 1994 by an Act of Parliament (Act 490) with powers to regulate activities within the environment, including SWM.

Also, various other legislation specifically targeting some aspects of waste management have been enacted either before or after the EPA ACT 490. Additionally, due to the changing problems posed by waste, and to complement the legislation enacted to govern waste management, the Ministry of Environment, Science and Technology; Ministry of Local Government and Rural Development; and the Ministry of Health have prepared guidelines and standards for waste management in the country. A total of 18 documents (table 4.5) that guide various aspects of SWM at national and district levels were retrieved and viewed. Notwithstanding these policy and legal arrangements for waste management in Ghana, the fieldwork for this study revealed that enforcement of the laws in the Wa Municipality and other Assemblies in Ghana was a challenge.

Three themes were identified during the analysis of the interviews and questionnaires administered to waste management stakeholders, namely: adequacy of SWM laws and policies, compliance with these laws and policies, and enforcement of SWM laws and policies. The stakeholders' assessment of the adequacy, compliance with, and enforcement of SWM laws and policies in the case study area is presented in Table 4.6.

Table 4.5: Waste management laws and policies in Ghana

Waste Management Laws	**Waste Management Policies and Guidelines**
• Land Planning and Soil Conservation Act, 1953 (No. 32) • Criminal Code, 1960 (Act 29) • Abandoned Property Disposal Act, 1974 (N.R.C.D.308) • Control and Prevention of Bushfires Act, 1990 (P.N.D.C.L. 229) • Local Government Act, 1990 (Act 462) • Environmental Assessment Regulations, 1999 (LI 1652) • EPA Act, 1998 (Act 490) • Water Resources Commission Act, 1996 (Act 522) • Pesticides Control and Management Act, 1996 (Act 528) • National Building Regulations, 1996 (LI 1630), and • Public Health Act, 2012 (Act 851).	• National Environmental Quality Guidelines (1998) • Environmental Sanitation Policy (1999) • Ghana Landfill Guidelines (2002) • Manual for the preparation of district waste management plans in Ghana (2002) • Guidelines for the management of healthcare and veterinary waste in Ghana (2002) • National Implementation Plan of the Stockholm Convention on Persistent Organic Pollutants (2007) • Handbook for the preparation of District Level Environmental Sanitation Strategies and Action Plans (DESSAPs).

Table 4.6: Stakeholders' thematic assessment of the legal and policy framework for MSWM

Stakeholder	Adequacy	Compliance	Enforcement
WMA	Very adequate	No	Not effective
EPA	Quite adequate	No	Not effective
ZGL	Adequate	No	Not effective
Informal waste collectors	Not sure	No	effective
Households	Not sure	No	Not effective

Whereas most of the waste management stakeholders agreed that the SWM policies and laws were adequate, all the stakeholders admitted that there was no compliance with these policies. On the enforcement of SWM policies and laws, only the informal waste collectors claimed that the enforcement was effective because their operations, usually at the main disposal site, was not allowed by the municipal authorities. However, the rest of the stakeholders agreed that the enforcement of SWM policies and laws was not effective. A senior official of the Wa Municipal Assembly (WMA) affirmed this, stating that:

> "*the authorities are relaxed in enforcing the laws, as the people also do not obey the laws*".

However, a retired director of the Wa MWD, through memory work, observed that:

> "*in the past, laws governing waste management were properly enforced as waste management laws offenders were prosecuted and heavy fines imposed on them to serve as a deterrent to others, but presently offenders are not prosecuted or penalised in any way"*.

Additionally, some environmental health officers in an interview with this researcher recounted that they had been beaten and banned from visiting some parts of the Wa Municipality in their attempt to enforce waste management laws. An environmental officer narrated that:

> "*in an instance, when we were beaten and chased out of the community, we reported to the police and the offender was arrested but released on the same*

> *day without any charge proffered against the offender due to pressure from above*".

According to the environmental health officers interviewed, the 'pressure from above' is usually intervention by highly placed government officials, chiefs, and other community leaders for the release and determination of sanction for SWM law offenders.

Similarly, a municipal engineer revealed that summons to individuals who disposed of their SW indiscreetly were not obeyed because chiefs, assembly members, and prominent politicians intervene and demand the termination of sanctions. Nevertheless, a retired senior official of the WMD recounted how stringent enforcement of waste management laws in the past in the Wa municipality and most parts of Ghana led to compliance:

> "*in the past, there was no or little education to the general public on good sanitation including SWM practices. The law of force was the order of the day. Sanitary offenders feared the environmental health officer because of summons and prosecution in court. The moment a health inspector (called in the local parlance 'Tangas' or 'Samasama') was sited approaching a house, people screamed and run helter-skelter to remove all unwanted materials from their homes. The presence of the yesteryear inspector was felt always. Today the situation is not the same*".

The researcher's checks with the judicial service (two courts) in the case study area revealed that there have not been any successful prosecutions of SWM offenses in the Wa Municipality for the past ten years. A court clerk revealed that:

> "*A number of waste management related cases have been brought here but none has been allowed to go through its full length since I started working in this court for the past 15 years; usually the individual or department that brings the case to court at a point in time ask for out-of-court settlement*".

The lack of political will to enforce waste management laws and the attitude of waste generators of non-compliance to the laws governing waste management are the present bane of MSWM in the Wa municipality and Ghana in general

4.2.2 Institutional Arrangements for MSWM

Ghana is divided into ten administrative regions with each region, in turn, divided into district assemblies. The assemblies are second-level administrative subdivisions of Ghana (there are currently 254 districts). However, depending on their population size, the assemblies are classified as metropolitan (more than 250,000 people), municipal assembly (population of over 95,000 people) or district assembly (population 75,000 people and over). These Metropolitan, Municipal and District Assemblies (MMDAs) under the decentralised local government system are supervised by the Ministry of Local Government and Rural Development (MLGRD). The MLGRD has the mission:

> "*to promote the establishment and development of a vibrant and well-resourced decentralized system of local government for the people of Ghana to ensure good governance and balanced rural-based development*".

According to the Ministry, this will be achieved by:

- Formulating, implementing, monitoring, evaluating and coordinating reform policies and programmes to democratise governance and decentralise the machinery of government,
- Reforming and energising local governments to serve effectively as institutions for mobilizing and harnessing local resources for local national administration and development,
- Facilitating the development of all human settlements through community and popular participation,
- Facilitating the promotion of a clean and healthy environment,
- Facilitating horticultural development,
- Improving the demographic database for development planning and management, and
- Promoting orderly human settlement development

Consequently, the Local Government Act (Act 462 of 1993, which was repealed and re-enacted as Act 936 of 2016) mandates various decentralised MMDAs, through the MLGRD with the responsibility of SWM, however, the regulation of the environment including SWM is vested in the Environmental Protection Agency (EPA), which is under the Ministry of Environment and Science. The Assemblies are supposed to enact by-laws to govern the environment based on their local conditions and to form local unit committees in their communities to effectively protect and manage their respective environments.

Additionally, the Waste Management Department (WMD) was established in 1985 in the assemblies to specifically manage environmental sanitation services, including SWM. Figure 4.2 illustrates the decentralised government system and SWM arrangements in Ghana.

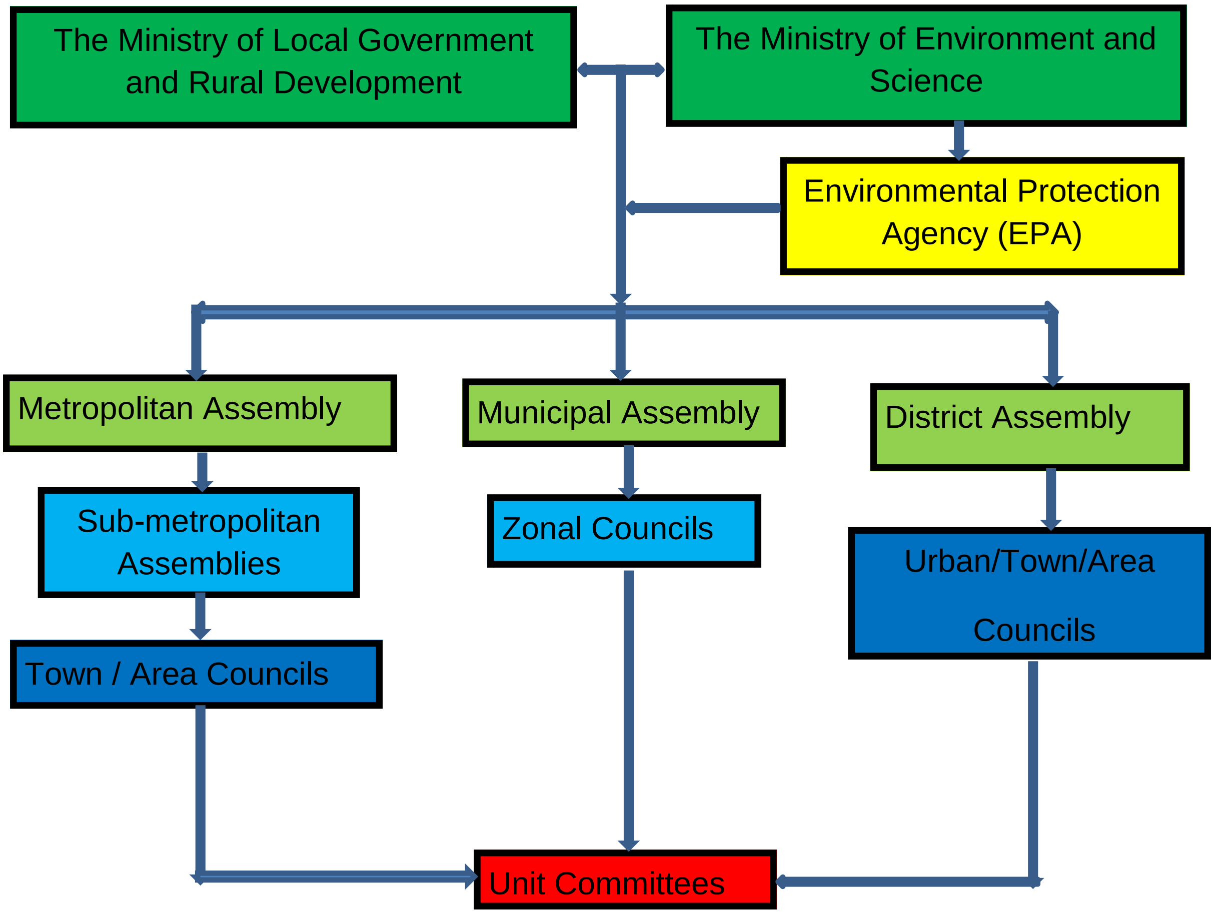

Figure 4.2: Decentralised local government system and SWM arrangements in Ghana: modified from Oteng-Ababio (2012)

4.2.2.1 Stakeholders in MSWM

There are several stakeholders and interest groups in MSWM. These include waste generators, regulators, service providers, recyclers/waste pickers and the community (Memon, 2009). The ability to locate stakeholders is crucial to identify and incorporate social impacts into waste management system planning (Olapiriyakul, 2017), as every stakeholder needs to be involved in the attainment of waste management goals. For instance, the public (waste generators) must be made aware of the relationship between managing SW and protection of human health, and the environment (UNEP, 2005). The Relationship between stakeholders in MSWM in Ghana is shown in Figure 4.3. The thematic assessment of the effectiveness of the relationship between stakeholders in SWM and their satisfaction with the role is presented in Table 4.7.

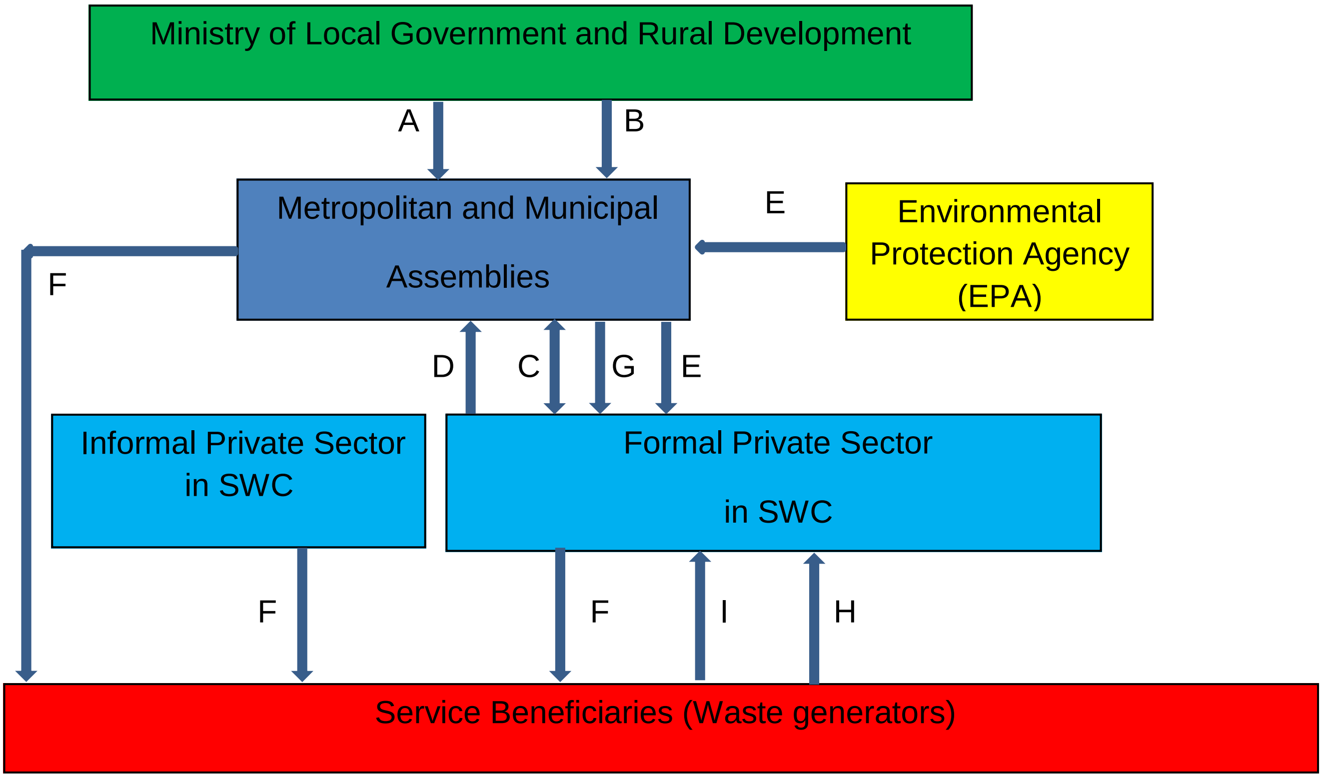

Figure 4.3: Relationship between stakeholders in SWM in Ghana: modified from Oduro-Kwarteng and Shaw (2009)

A – Sanitation and SW policies formulated for the Assemblies to implement

B – Provision of funds for solid waste collection (SWC) activities

C – Submission of reports by private companies and access to data from Assemblies

D – Payment of charges to the Assemblies by private companies

E – Supervision and monitoring of activities of service providers

F – Rendering of services to beneficiaries by the Assemblies or private companies

G – Release of funds to private companies for services rendered

H – Payment of user charges to private companies by service beneficiaries

I – Complaints about service quality by beneficiaries

Table 4.7: Stakeholders' thematic assessment of the effectiveness of the relationship between stakeholders in SWM and their satisfaction with the role

Stakeholder	Effectiveness	Satisfaction
WMA	Not effective because of inadequate resources and inability to supervise private sector	Not satisfied
EPA	Not effective because of inadequate resources	Not satisfied because of inability to regulate SWM
ZGL	Very effective	Very satisfied
Informal waste collectors	Effective	Not satisfied because their operations at dumping site are not permitted
Households	Not effective because of inadequate waste collection bins and lack of education on their role	Not satisfied

The MLGRD is by legislation responsible for SWM in Ghana. Therefore, the MLGRD formulate sanitation, including SWM, policies and provide oversight responsibility for the Assemblies (A), and disburses funds (B) for SWC services in the Assemblies. The EPA is mandated by Act 490 to regulate the environment. Therefore, EPA, as mandated by law, is supposed to monitor the activities of the Assemblies to ensure that SW is properly collected and disposed of. However, currently, the EPA is under-resourced and is not able to effectively supervise SW disposal in the Assembles.

A senior official of EPA in an interview lamented about the inability of EPA to monitor waste management in the Assemblies:

> "*EPA per the act of parliament (ACT 490) is supposed to have operational offices in all MMDAs, but this is not the case. EPA only has operational offices in all the regional capitals and a few offices in some MMDAs*. *Even where EPA*

has operational offices, it is so preoccupied with other environmental problems, such as illegal gold mining and siting of petroleum products filling stations to the neglect of SWM".

Currently, in the Wa municipality, the EPA does not regulate MSW disposal, as communal containers and open dumps are sited without the notice or permission of EPA.

The Assemblies also contract private companies to collect waste in certain locations within their jurisdictions (E). The assemblies pay the private companies for their services (G); however, the private companies recover some of the cost through payment of user charges (H) by some service beneficiaries, mostly house-to-house collection service beneficiaries.

Officials of the WMA confirmed to this researcher that the private sector involvement in SW collection has drastically improved waste collection in the municipality, although, in the opinion of the official, the private sector lacks the technical expertise required for effective waste management. The official attributed the improvement of waste collection to the resourcefulness of the private sector and observed that, Zoomlion Ghana Limited (ZGL) (the only private waste collection company operating in the Wa Municipality):

"*has the requisite equipment for SWM but lacks the technical expertise*".

Additionally, the Wa Municipal Authorities bemoaned their inability to monitor and supervise the operations of ZGL. In an answer on the arrangements for the supervision of the private sector's operations, a municipal engineer revealed that:

"*the MWD is supposed to monitor and supervise the operations of the private sector but, it is not happening* because p*ayment for the private sector's operations is made by central government, through the MLGRD without recourse to the Municipal Assembly. Most often, the company is ineffective in waste collection and yet is fully paid for waste collection services*".

Presently, ZGL is the only private company engaged to collect waste in all 216 MMDAs (38 additional MMDAs which were created in February 2018 are yet to be operational) by the MLGRD. The condition(s) of the contract between the MLGRD and ZGL, since 2006 has been shredded in secrecy (this the reason for ZGL's claim of effectiveness and satisfaction with their role, as indicated in table 4.3). This lacks the elements of private sector involvement in waste management - competition, transparency, and accountability (Cointreau-Levine, 1994; Van de Klundert and Lardinois, 1995).

However, ZGL indicated that the contractual agreement between them and the local assembly was through a "*public-private-partnership*" (PPP), nevertheless, the content of the agreement or partnership is unknown to the municipal authorities. Meanwhile, in 2013 the World Bank debarred Zoomlion Ghana and Zoomlion Liberia (subsidiaries of Zoomlion Company Limited) for two years because Zoomlion Company Limited was accused of fraud and paying bribes to secure waste management contracts sponsored by the World Bank in Liberia (The World Bank, 2013).

Notwithstanding this, the evidence on the ground showed that ZGL has improved SWC in the Wa Municipality and other Assemblies in Ghana. A municipal public health engineer in the MWD admitted this in an interview with this researcher, but observed that:

> "*if the MWD was given half of the money paid for the services of ZGL, the MWD would have performed far better, because the MWD has the technical expertise but lacks the resources, whereas ZGL has the resources, but lacks the technical expertise*".

However, research shows that the private sector performs better, especially in the waste collection because it can overcome bureaucracies and source funds to purchase the requisite equipment for SWM activities through loans (Busse, 2012; Courtois, 2012; Is-haque and Huysman, 2013).

4.2.3 MSWM Financing

Poor national economic policies coupled with extreme poverty and high infrastructure deficits make financial considerations one of the most obvious constraints to developing appropriate waste management systems for Ghana and other developing countries (Anku, 2010). Accordingly in most developing countries, there are four ways of financing local public goods, including SWM: local taxes such as the property tax, user charges which are levied on various urban services, grants from higher levels of government, and loans from the capital market from governments/financial institutions or international agencies like the World Bank (Appasamy and Nelliyat, 2007).

MSWM requires substantial investment, while the continuous maintenance and use of waste management infrastructure and equipment entail costs incident on individuals, households, communities, and government. Households usually like their wastes to be collected and taken away to a disposal site and would be willing to pay for this service either through a conservancy tax or as a user charge because they do not like the waste to accumulate either inside or outside the house since it would be a health hazard. However, the household may not be paying the full cost of SWM which includes the ultimate disposal of the waste.

In Ghana, urban spiralling has exhausted the capacity of existing traditional disposal sites to the extent that wastes must be transported greater distances to sites outside many urban areas. The WMA's disposal site is located at *Siriyiri* in the Wa West District, about 5km away from Wa. This leads to the irregular collection of waste in poor residential areas who mostly rely on communal containers for their waste collection. A municipal engineer admitted that there was no schedule for the lifting, transporting and emptying of communal containers under the management of the MWD by saying that:

> "*it depends on the availability of fuel, it can be one week, two weeks, three weeks, one month and sometimes two months for the Assembly to lift communal containers in various parts of the municipality*".

As a result, most middle and low-income household dwellers often complain of unsatisfactory or unreliable waste management services. For this reason, they often resist paying any charges for waste management and instead resort to illegal dumping and burning of their waste. Only high-income households, who mostly reside in the beautiful parts of the municipality pay for waste collection through the house-to-house collection service operated by ZGL.

MSWM is in Ghana is solely financed by the central government. Initially, the various district assemblies were mainly responsible for waste management within their jurisdictions, however, since the early 1990s, the private sector has been involved in waste collection, especially in the bigger cities such as Accra, Kumasi, and Takoradi.

The government pays the private company for the collection services from monies deducted from the various Assemblies Common Fund. However, the bigger metropolitan assemblies (Accra, Kumasi, and Takoradi), who generate high volumes of waste above the collection capacity of a single private SWC company, engage additional private companies for waste collection and pays for the collection from funds internally generated from sources such as property rates and market user levies, among others.

In the Wa Municipality, there is no alternative or funding structure for SWM, except the funding from central government. A budget officer at the WMA in an interview with this researcher confirmed that there was no allocation or budgeting for the recurrent cost for MSWM but acknowledged that,

> "*for the first time, we were asked to make provisions for solid and liquid waste management in the 2018 budget, however, without a specific budget source. So, I'm wondering where the money will come from for waste management"*.

Similarly, a municipal engineer in an answer to how recurrent MSW disposal is financed in the assembly said that:

> "*There is no proper financing arrangement for MSW disposal in the assembly. Finances are provided when the need arises, for instance, when there is a cholera outbreak*".

Thus, the current and future projected cost for MSWM is unknown to the municipal authorities. Meanwhile, the provision of SW services is an expensive undertaking, and resources are required to purchase the appropriate equipment and infrastructure, fund the maintenance and daily operation of vehicles and equipment and train or upskill personnel. The scarcity of resources (financial and logistical) is a major hindrance to effective SW disposal practices in the Wa Municipality and Ghana in general.

4.2.4 Technical Capacity for Waste Management

Technical skills (human resource) and the requisite equipment disposition are essential for effective waste management, especially the daily operations of waste management. In this regard, the capacities of the WMA and ZGL (the only private company involved in waste collection in the Wa Municipality) were examined. The results showed that, in terms of the technical skills the WMA had more skilled waste management personnel than ZGL, whereas, in terms of waste management equipment disposition, ZGL was more equipped than the WMA. The technical skills and equipment disposition of the WMA and ZGL are presented in Tables 4.8 and 4.9 respectively.

Essential waste management personnel such as landfill and plant managers were absent in both the WMA and ZGL. Also, the researcher during the fieldwork observed wastes spillage around the communal containers because of overflowing due to the irregular emptying of the containers (see Plate 4.1). The spilt wastes were usually not collected because of the lack of requisite waste management equipment such as front-end loaders, bulldozers, and landfill compactors. However, the use of motorised tricycles and manual tricycles in SWC by ZGL enabled access for SW collection in poorly planned and crowded parts of the municipality, where there were no good or access roads.

Table 4.8: A comparison of the technical skills between the WMA and ZGL

Technical Skill	**Qualification**		**Number**	
	WMA	**ZGL**	**WMA**	**ZGL**
Public Health Engineer	BSc., Public health engineering	BSc., Environmental science	3	1
Environmental Health officer	Certificate in environmental health and hygiene	-	10	-
Civil Engineer	BSc., Civil Engineering	-	1	-
Account officer	BSc., Accounting	BSc., Accounting	3	1
Administrative Assistant	BSc. Administration	Higher National Diploma	2	1

Table 4.9: A comparison of the equipment disposition between the WMA and ZGL

Equipment	Number Operational		Number Ideal		Number Broken Down	
	WMA	ZGL	WMA	ZGL	WMA	ZGL
Compactor truck	1	4	1	3	-	1
Skip truck	1	4	1	4	-	-
Tipper truck	-	1	-	1	-	-
Tractor	-	2	-	1	-	1
Motorised tricycle	-	12	-	5	-	-
Manual tricycle	-	10	-	15	-	-
Communal containers	15	22	-	-	10	5

4.2.4 Summary of Key Findings on MSW Disposal Management Performance

The current scenario of waste management performance in the Wa Municipality needs improvement as there is non-enforcement of, and non-compliance with laws governing waste management, there is dissatisfaction with the private sector engagement in waste collection due to the inability or refusal of the municipal authorities to supervise and monitor ZGL's operations, waste management financing is woefully inadequate because of the over-reliance on central government, and the technical capacity of both the Wa Municipal Assembly and ZGL is not adequate for effective MSW disposal.

Consequently, a municipal engineer described the future direction for MSW disposal in the Wa Municipality as bleak and concluded that:

> "*if things are not put in proper perspective, in a few years' time, the MWD in the WMA will collapse, as no resources are allocated for waste management, and so the entire MSWM system is broken*".

4.3 Baseline Scenario of MSW Disposal

MSW disposal covers the activities to minimise the quantity of produced MSW, to decrease or eliminate hazardous components in waste, and the activities to contain waste in a location or facilities which meet environmental protection standards. Understanding the baseline scenario of waste disposal is essential to improving waste management in a location. Thus, the third objective of this study was to establish a baseline scenario of MSW disposal through material flow analysis and understanding of MSW handling practices in the case study area. The baseline scenario of MSW disposal was carried out with a focus on the MSW handling practices and material flow in households, institutions, the Wa central market, and streets in the Wa Municipality.

4.3.1 Households MSW Handling Practices and Disposal

There is a minimal provision of SWM facilities, such as communal collection containers, open dump sites, and house-to-house collection of waste across urban Ghana, including the Wa Municipality. Usually, the generators of SW are responsible for their storage and disposal. There is no segregation of waste at any point of its management, as waste is not sorted at the generation point, despite the dominance of recyclable materials in the waste composition, which comprised of hazardous and non-hazardous waste.

In the Wa Municipality, the fieldwork showed that majority of the households' respondents (40.8%) store their mixed unsorted waste in closed containers, such as bins, whereas, 8.1% resort to other storage methods such as storing the waste in a pit and subsequently burning to reduce the volume of the waste. The MSW storage methods are shown in Figure 4.4.

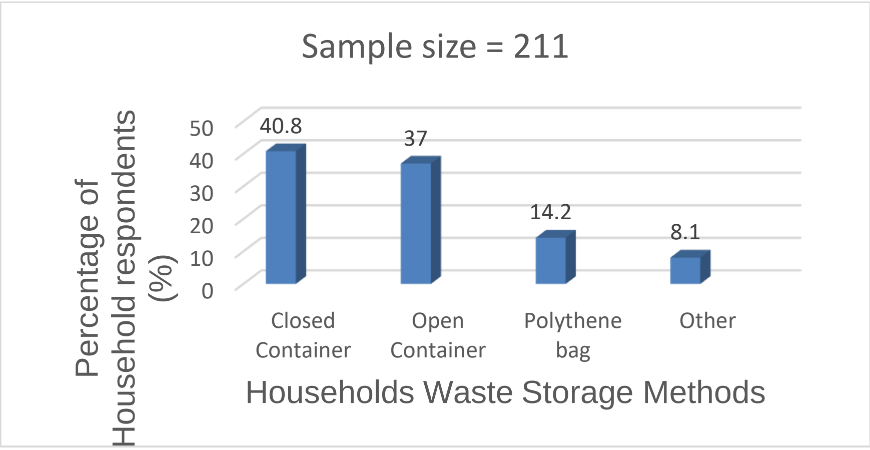

Figure 4.4: Households MSW storage methods

The fieldwork for this study also indicated that the most widely used method of SW disposal in the Wa Municipality was by burning, with 32.2% households resorting to this option; 30.8% of households depended on communal collection which constitutes the second widely used method of SW disposal; and only 16.6% of households relied on house-to-house waste collection service for their waste disposal, as shown in Figure 4.5.

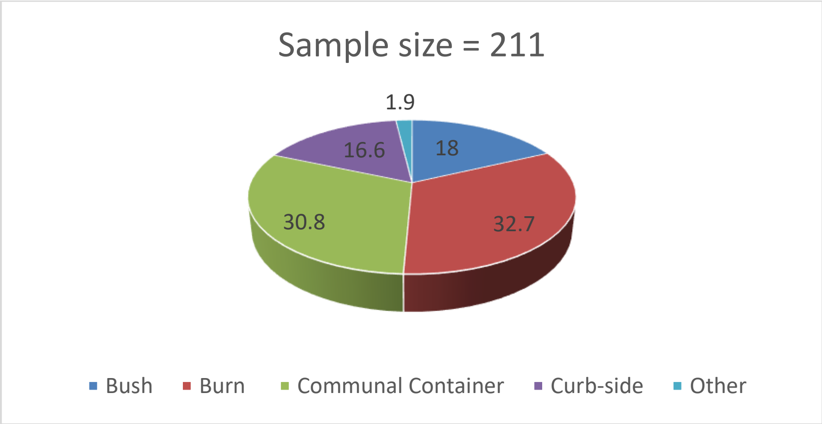

Figure 4.5: Households waste disposal methods in the Wa Municipality

These MSW disposal methods show an improvement in MSW disposal methods in the Wa Municipality from the 2010 population and housing census, which indicated that 44.6% of the households in the Wa Municipality were provided with communal container for the disposal of their solid waste, but 24% of households' actual resorted to the communal containers for their solid waste disposal; as high as a proportion of 17.6% of households dumped their solid waste indiscriminately; 4.3% of households relied on house-to-house waste collection service (Ghana Statistical Service, 2014).

The most common system of waste collection is the central container collection system, whereby households are responsible for transporting their waste to refuse containers located within the communities. Both middle and low-income residential areas are serviced in this way, representing 30.8% of the household respondents of this study. Although the central containers are to be sited at a maximum of 150 meters from residences, this researcher in his fieldwork observed that in the Wa Municipality, containers were commonly located further distances than the maximum, sometimes up to 450 to 600 meters in some communities. Also, emptying of the containers was not consistent, and in most instances, were left to overflow (as shown in Plate 4.1).

Plate 4.1: Container overflowing with waste in Wa (1:100cm scale)

There were 37 communal containers positioned at various location within the Wa municipality. 22 of these containers were managed by ZGL and the remaining 15 containers were managed by the local assembly. Whereas ZGL claimed that they emptied the communal containers under their jurisdiction daily, which contradicted the households' responses to the collection schedule, the local authority did not have any scheduled collection period, as a supervisor of the communal containers at the WMA told this researcher that:

> "*it depends on the availability of fuel; the emptying of the communal containers can be within one week, two weeks, three weeks, one month, and sometimes two months*".

This statement of the communal containers supervisor was confirmed by 68 household respondents of this study who depended on the communal collection service, as the household respondents gave varied emptying periods of the communal containers in their localities, with majority (45.6%) of the respondents indicating that the communal containers were emptied once every month as illustrated in Figure 4.6.

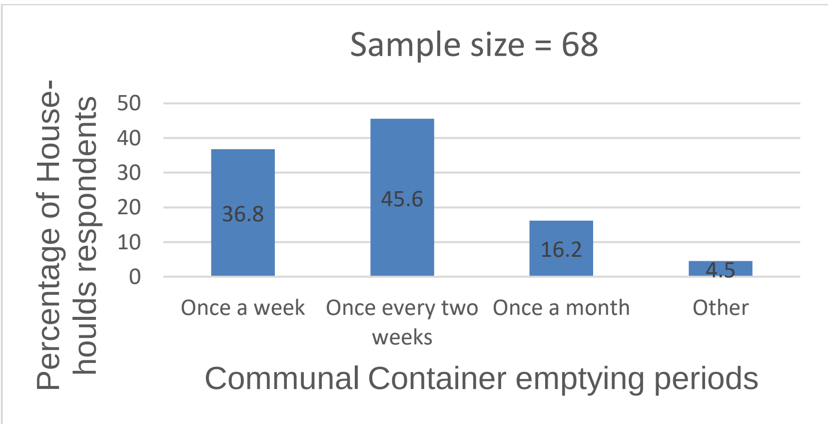

Figure 4.6: Communal containers emptying periods according to households

The irregular emptying of the communal containers discouraged patronage of the service by residents, who then resorted to illegal disposal practices such as throwing of waste into drains, bushes, and burning. These often lead to the spread of communicable diseases such as cholera, and health hazards ranging from stench emanating from uncollected and decaying garbage to choked drains.

However, in some parts of the Wa municipality (accessible and high-income residential areas), ZGL operated house-to-house collection service. 16.6% of the household respondents of this study, depended on the house-to-house collection service in the Wa Municipality. Unlike the communal collection service dependants who had irregular emptying of the containers, a majority (76.9%) of the house-to-house collection beneficiaries, confirmed in this study that their bins were emptied regularly (once a week). Since the house-to-house collection beneficiaries paid a monthly collection charge of 15 Ghana cedis (approximately $4) directly to ZGL, the private company seemed to over-concentrate its operations on this service, to the detriment of the majority who depended on the communal collection service.

The study also found out that majority (43.8%) of the households in the Wa Municipality depended on the local authority for the collection of their waste, 10.5% of households depended on the private waste collection company (ZGL), 34.3% of households relied on both the local authority and ZGL for their waste collection, whiles 11.4% of the households were not covered by any waste collection service. All the collected MSW is disposed of into a disposal site located at *Siriyiri* outside the Wa Municipality in the Wa West District.

4.3.1.1 Households' Knowledge, Attitudes, and Practices towards MSW Disposal

Household waste contributes significantly to MSW generation rates globally. For instance, household waste constitutes over 50% of MSW in Ghana (Miezah *et al.*, 2015). Thus, this study evaluated households' knowledge, attitudes, and practices (KAP) towards source separation, waste disposal practices, and willingness to pay for solid waste collection (SWC) services. Also, the study analysed the relationship between demographic variables (age, gender, and education) and KAP toward MSW disposal. 211 households were sampled for this study. The age, gender and educational level of the households' respondents are shown in Figures 4.7, 4.8, and 4.9 respectively.

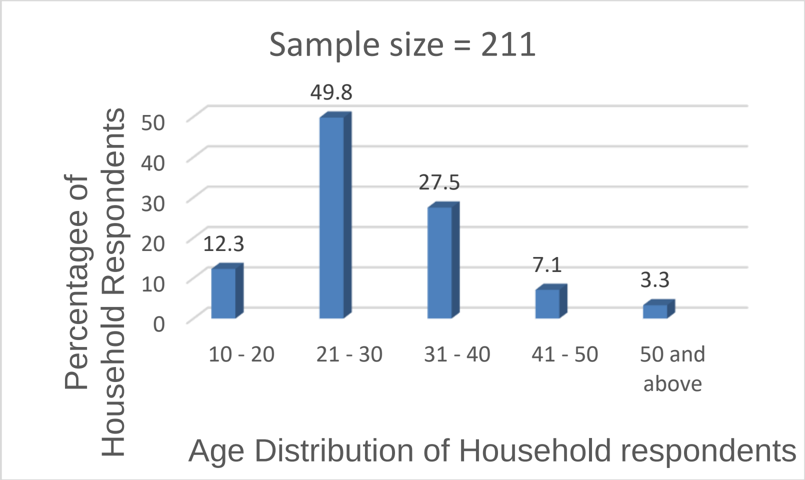

Figure 4.7: Age Distribution of households' respondents

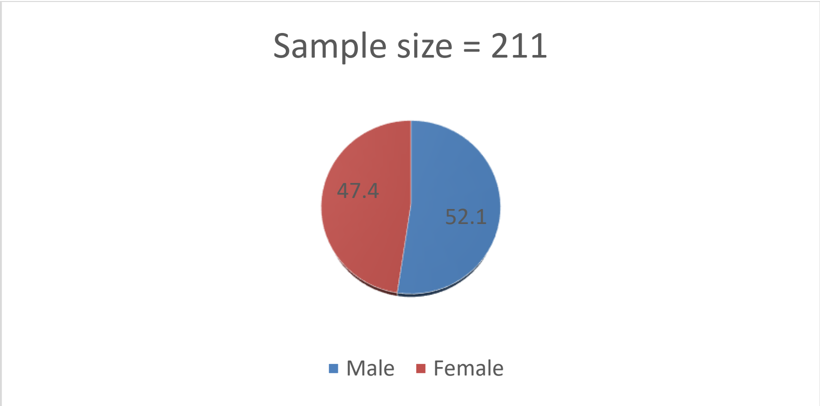

Figure 4.8: Gender of households' respondents

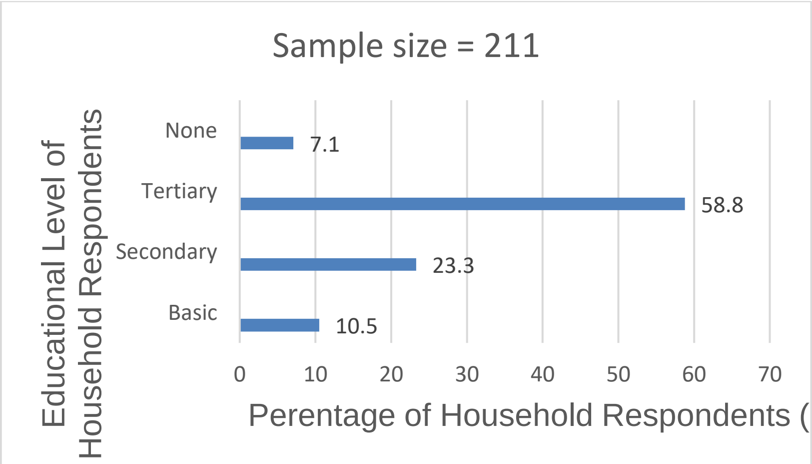

Figure 4.9: Educational level of households' respondents

The results from this study showed that there was low knowledge of households towards waste reduction and source separation, though these are essential for sustainable waste management. 83.9% of the household respondents did not sort their waste for collection and did not practice waste reduction. These respondents stated varied reasons for their lack of interest in separation and waste reduction, including in no order: inadequate storage bins, lack of education on waste separation and reduction, no organised recycling and composting programmes, and non-enforcement of and non-compliance with policies and laws on waste reduction/separation. Only 16.1% of the respondents did sort their waste for disposal, however, not because of their knowledge of waste separation or reduction, but because they separated dry waste from wet waste for easy burning.

Nevertheless, 45.8% of the household respondents who did not sort their waste were willing to sort their waste if they were provided with multiple bins. Presently, in the Wa Municipality and Ghana in general, only house-to-house collection service beneficiaries are provided with a single closed container for waste storage (see Plate 4.2), while those who cannot afford to pay for the house-to-house collection service (mostly, low-income and compound-house dwellers) or are not covered by this service, provide their own waste storage containers, usually open containers, as shown in Plates 4.3 (a) and (b). On the contrary, 54.2% of the household participants who did not sort their wastes, were still not willing to sort their wastes and practice waste reduction.

Plate 4.2: Closed containers for waste storage by house-to-house service beneficiaries

(a) (b)

Plate 4.3: Waste storage containers by low-income residential dwellers

On willingness to pay for waste collection, 60.3% of the respondents who did not pay for waste collection were willing to pay for effective waste collection, whereas, 39.7% were still not willing to pay for the collection of their waste. Their unwillingness to pay for waste collection can be attributed to their satisfaction level as the majority of the respondents (40.4%) were unsatisfied with SW collection in their localities. Only 5.3% of the respondents were very satisfied with SW collection (most of whom were the house-to-house collection service beneficiaries). Figure 4.10 illustrates the households' satisfaction levels with waste collection service provision in their localities.

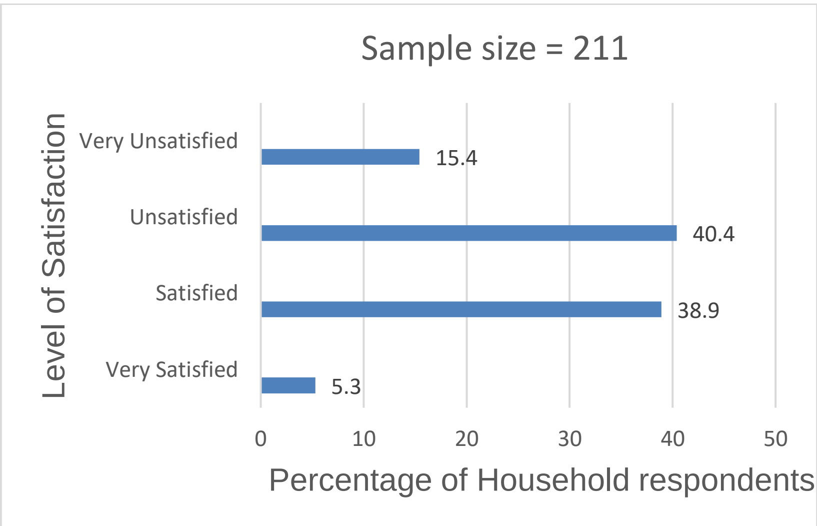

Figure 4.10: Households satisfaction level with waste collection services

By conducting investigations under some demographic characteristics, this study found a very weak correlation between demographic variables (age, sex, and education) and KAP in households as shown in Table 4.10. Age, sex, and education had very weak negative correlations with household's waste storage type, despite that sex had a highly significant relation with the SW storage method, as $p = 0.042 < 0.05$.

For the relationship between MSW disposal method and age, sex, and education; age and sex had very weak positive correlations with MSW disposal method, whereas, education had a very weak negative correlation with MSW disposal method, however, age had a moderate significance on MSW disposal method: $p = 0.046 < 0.05$, sex had a low significance on MSW disposal method with $p = 0.056 > 0.05$, and Education had no significance on MSW disposal method, as $p = 0.914 > 0.05$.

Similarly, age, sex, and education correlated poorly with source separation of waste, yet age strongly influence household sorting of waste, as $p = 0.008 < 0.05$; sex and education did not influence household sorting of waste significantly, as $p = 0.151 > 0.05$ and $p = 0.699 > 0.05$ respectively. On household's willingness to pay for MSW collection services, age correlated poorly negatively, whereas, sex and education correlated poorly positively with households' willingness to pay for MSW collection services. Correspondingly, age, sex, and education did have any influence on willingness to pay for waste collection as their p-values were all greater than 0.05.

Also, this study found out that age, sex, and education of households correlated poorly negatively with their satisfaction level with waste collection and did not also have any significance on their level of satisfaction with waste collection activities (age, sex, and education had $p = 0.664$, $p = 0.779$, and $p = 0.479$ respectively, all of which are greater than 0.05).

The impact of demographic variables on KAP of SWM is well known (Ristić, 2005; Babaei *et al.*, 2015), however, the dependency of demographic variables on KAP has not been established. Thus, this study supports other researchers, who indicated that demographic variables correlate poorly with KAP (Ristić, 2005; Babaei *et al.*, 2015).

Table 4.10: Correlation of demographic characteristics and KAP

Question	Demographic Variable	Correlation coefficient (r)	p-value
Q_7 (MSW storage)	Age	-0.047	0.495
	Sex	-0.140	0.042
	Education	-0.069	0.318
Q_8 (MSW disposal method)	Age	0.137	0.046
	Sex	0.132	0.056
	Education	-0.008	0.914
Q_{11} (Source separation)	Age	0.184	0.008
	Sex	0.099	0.151
	Education	-0.027	0.699
Q_{18} (Willingness to pay for MSW collection)	Age	-0.013	0.118
	Sex	0.145	0.080
	Education	0.001	0.993
Q_{19} (Satisfaction with MSW collection)	Age	-0.030	0.664
	Sex	-0.020	0.779
	Education	-0.049	0.479

4.3.2 Institutional, Commercial, and Street MSW Handling Practices

The institutions covered in this study were mainly government departments/offices and the commercial area that this study considered was the Wa central market. Like household waste handling practices, there was no sorting of waste at the point of generation in the institutions and the Wa market.

The researcher observed that the institutional waste was mainly paper, which was usually stored in smaller bins and disposed of by open burning. The institutions were not covered by any waste collection service. In an interaction with some staff in some institutions in the Wa municipality, the staff did not want to be covered by any collection service as one staff indicated that:

> "*the waste we generate here is small and mainly paper, which we easily burn. So, why should we pay for someone to dispose of our waste which we can easily dispose of? Besides, no allocation is made for waste disposal in our*

institution. Do you expect me to pay for my office waste disposal from my pocket? Our cleaners empty the bins every morning and burn the waste".

Additionally, a head of a government department justified the institutions burning of waste paper and not subscribing to a collection service with the explanation that:

> "*Most of the waste paper we disposed of are confidential documents, but we don't have paper shredders to shred them before disposal. The best way to keep confidential documents waste paper from the public eye is to burn them*".

Also, the Wa market waste was mainly generated by traders and shop owners in the Wa market. Organic waste dominates the Wa market waste stream. Bowan and Tierobaar (2014) in their characterisation of Ghanaian markets waste found the Wa market waste to be 46.6% organic, 13.1% paper/cardboard, 4.9% plastic, 3.4% textiles, 2.6% metal, and 29% miscellaneous waste. Communal containers were placed at vantage points for the collection of waste in the Wa market.

During the fieldwork, the researcher held informal interviews with some of the market traders and shop owners. These research participants complained about the irregular emptying of the communal containers as they claimed that the communal containers were usually allowed to overflow for many days. However, during the fieldwork, the researcher did not come across an overflowing communal container in the Wa market. The researcher, though observed that little children were open defecating by the communal containers.

Street cleaning in the Wa municipality is carried out by ZGL, a local private waste collection company. There is no provision of street bins in the Wa municipality and most parts of Ghana. Thus, street littering is a common practice in the Wa municipality. The street litter is mostly made of plastics bags (sachet waste bags) and leaves. ZGL had 200 street cleaners in the Wa municipality, who usually work between 5:00 am and 8:00 am daily. The researcher observed that majority of the street sweepers were women and illiterate. The few male street sweepers were provided with manual and motorised tricycles to enable them access clustered parts of the municipality to collect SW.

An observation of the street sweepers activities revealed that there was an inadequate provision of protective working gear for the street cleaners. The researcher observed that some of the street sweepers were collecting waste with their bare hands and wearing flip-flops. Through informal interviews, some of the street sweepers told this researcher that their hand gloves had won-out, while others complained of discomfort with the use of the hand gloves. The collected street waste is disposed of into nearby bushes or burnt. Plates 4.4 (a) and (b) illustrate the burning of street waste on a street and in a nearby bush in the Wa municipality respectively.

(a) (b)

Plate 4.4: Burning of street waste in the Wa Municipality

4.3.3 Material Recovery from MSW

There is no formal material recovery from the waste in the Wa municipality. However, materials are recovered by informal metal waste merchants (scrap dealers) and scavengers. The informal metal waste merchants usually have working gangs called '*Zabarma'* who move from house-to-house in search of unwanted metals. The '*Zabarma'* weighs the unwanted metal with a scale and bargains with the owner to arrive at a compromised price.

The price of 1kg of metal waste was between fifty pesewas and one Ghana cedi (the equivalent of $0.11 and $0.22). The recovered metals are transferred in pusher carts (see Plate 4.5 (a)) to various open dumps sites (see plate 4.5 (b)), usually near the residence of the metal waste merchant and stored until the quantity is substantial (20 to 30 tonnes), before the metals are loaded and transported to the Southern part of Ghana, *Tema* (an industrial city) in trucks (see plate 4.6 (a)), where the metals are recycled into product, such as iron rods usually used as reinforcement in construction, as shown Plate 4.6 (b).

(a) (b)

Plate 4.5: Pusher card (a) and metal waste open dump (b)

(a) (b)

Plate 4.6: Truck loading metal waste (a) and rods from recycled metal waste (b)

The researcher during a visit to a metal waste merchant's resident realised that their operations had created a job opportunity for some women in the Wa municipality. The researcher observed that women between the ages of 25 and 55 were employed to load the truck that transported the metal waste from Wa to Tema (see Plate 4.7). The women in an interaction with this researcher confirmed that the scrap dealers' operations had provided them with an alternative source of livelihood, especially during the dry season when they could not engage in farming.

However, the women were not quite happy with their daily wage. Some of the women told this researcher that because of the lack of employment opportunities, they were not able to negotiate on their daily wage and were paid either 15 Ghana cedis or 20 Ghana cedis per day (equivalent of $3.74 or $5), depending on how exhausted they were after a day’s work, based on the metal merchant’s assessment.

Plate 4.7: Women loading a metal waste truck

Another type of material recovered from waste in the Wa Municipality was plastic (rubber) waste (see Plate 4.8) at open dumping sites and the main disposal site by mostly women and children scavengers (see Plate 4.9). There are over 10,000 scavengers in Ghana (Madrigal, 2011).

Scavenging at the main disposal site located in *Siriyiri* is prohibited by the municipal authorities, however, to outwit the managers of the disposal site, children scavengers between the ages of 7 and 16, usual visit the disposal site early in the morning (between 4am and 6am) to recover materials in the dumped waste before the arrival of managers of the disposal site and waste disposal trucks. Like the metal waste, all the recovered plastic/rubber waste is bought and transported to the southern part of Ghana (*Tema* and *Kumasi*), where the plastics waste is recycled into useful products.

In an interviewer with a 12-years old scavenger at the disposal site, who was bare-footed and without protective clothes, he lamented about the posture of the municipal authorities towards their operations. He told this researcher that:

> “*we recover ferrous cans and rubber and sell them to support our schooling needs, such as buying of pencils, pens, and exercise books because our parents cannot afford them; so why can’t they allow us*”.

When the researcher pointed out to him some possible dangers (infections and injuries) of scavenging for waste at the disposal site, He retorted that:

> "*I started scavenging for waste at this site when I was six years old together with my elder brothers and sisters but none of us has ever been infected or injured on the site*".

(a) (b)

Plate 4.8: Scavenged materials at the Wa disposal site

Plate 4.9: Scavengers at the WMA's disposal site

4.3.4 MSW Flow in the Wa Municipality

The commonly practiced MSW disposal option in the Wa Municipality and the whole of Ghana (as in many other developing countries) basically involves the collection of mixed waste materials and subsequent dumping at designated dump sites. Thus, in the Wa municipality, all the collected SW from residential areas, commercial areas, institutions and streets are carried to a lone dumping ground (as indicated in Plate

4.10) at *Siriyiri. Siriyiri* is in a different district - the Wa West District. The *Siriyiri* disposal site was created in 2001 and has been poorly managed - without any formal material recovery, though some informal material recovery is undertaken by scavengers.

(a) (b)

Plate 4.10: Opening dumping of waste at the WMA's disposal site (1:100 scale)

The MSW flow in the Wa municipality begins at the waste generation sources (households, commercial areas, institutions, and streets). As stated earlier, waste segregation, the technique by which SW is divided into its components (mainly organic & inorganic), is not undertaken at the generation point and throughout the waste management chain. As result, the municipal authorities did not have a good knowledge of the MSW generation and characteristics in the municipality.

Therefore, some MSW generators dispose of their waste inappropriately into bushes, by burning, and by burring in pits. MSW that was disposed of by these methods immediately after generation, did not enter the MSW stream and were not managed by the municipal authorities, who are solely responsible for MSWM. However, other waste generators store their waste in various ways (as discussed in section 4.3.1 of this chapter) for collection and subsequent disposal.

MSW collection was undertaken by both the formal (municipal authorities and ZGL) and the informal (waste merchants) sectors. The informal waste collectors transported all the collected waste to designated dumping sites, usually near the waste merchant's residence, for onward transportation to the southern part of Ghana for sale as discussed in section 4.3.3 above, whereas, the formal sector transported all the mixed collected waste to the main disposal site (un-engineered open dumping site) at Siriyiri for final disposal. Figure 4.11 illustrates the MSW flow in the Wa Municipality.

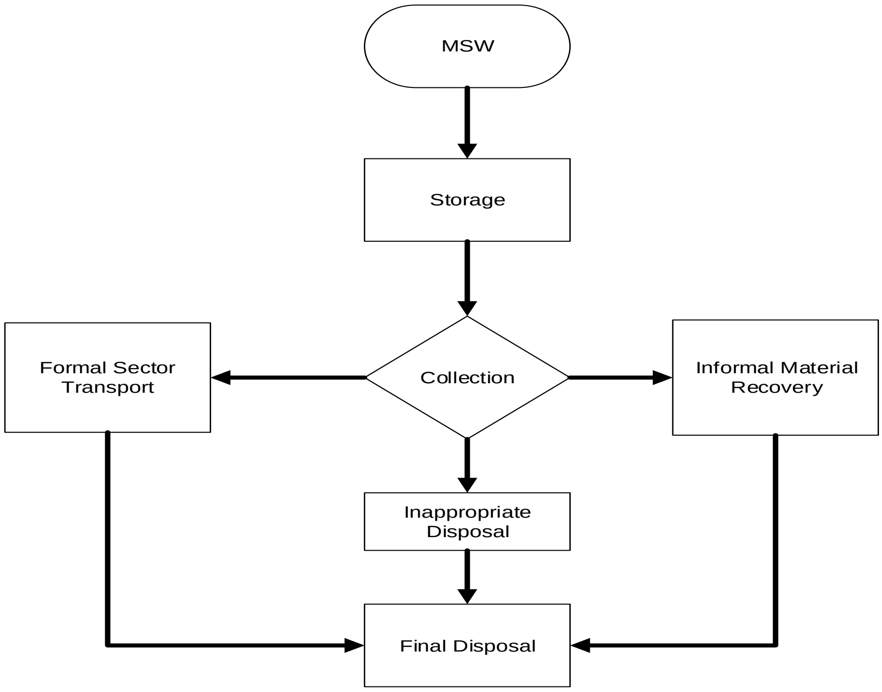

Figure 4.11: MSW flow in the Wa Municipality

The researcher during a visit to the *Siriyiri* disposal site observed that, most part of the disposal site is in a low-lying area (see Plate 4.11) and a borehole is located 300m away from the disposal site without any precautionary measures, however, both liquid (human excreta) and solid wastes are disposed of in the same dumping site. The researcher did not test the borehole water to ascertain its quality, however, there is the great potential of the contamination of the borehole water by leachate from the disposal site. The manager of the disposal site, in an interaction with the researcher, said that the *Siriyiri* community has protested the location of the disposal site on several occasions but to no avail; which is a breach of environmental justice.

(a) (b)

Plate 4.11: Waste disposed in low-lying areas at the WMA's disposal site (1:100cm scale)

However, the researcher observed that the Wa Municipal dumping site is quite large (1000m^2), and thus, can easily be converted into a sanitary landfill. This can be achieved by partitioning the disposal site, such that the open dumping will continue near the area where the sanitary landfill cells development will begin. The disposal site already has a properly constructed office (see Plate 4.12), though without services such as electricity and water supply. These services will be needed to facilitate the conversion of the disposal site into a sanitary landfill.

Plate 4.12: WMA's waste disposal site office (1:100cm scale)

4.3.3 Summary of the Findings on Baseline Scenario of MSW Disposal

The current MSW disposal in the Wa Municipality consists of waste collection, transportation and open dumping, where the entire amount of waste is open dumped without pre-treatment. This study identified the shortcomings of the Wa municipality's MSW disposal system as:

- not all the population is connected to the waste collection system;
- there is non-segregation of waste at source;
- no waste reduction programmes;
- municipal authorities have no knowledge of waste generation rates and characteristics;
- no transfer stations;
- no formal material recovery from waste;
- no amount of waste is formally recycled;
- no material recovery facilities
- opening dumping of waste is the final disposal option
- opening dumping of biodegradable waste results in large and long-term emissions (gas and leachate) and ineffective use of landfill space;
- no ISWM

Because of these, sustainable waste management has remained elusive in the municipality and Ghana in general, due to poor management performance as discussed in section 4.2. Therefore, to overcome these shortcomings, five MSW disposal scenarios were modelled. The modelling was according to their potential to improve the shortcomings listed above, to minimise and stabilise MSW before final disposal. The scenarios were developed aiming at the minimisation of MSW disposal environmental burdens through the evaluation of the operational performance of each scenario.

Chapter five, which is the next chapter, presents the operational performances of the modelled scenarios.

CHAPTER FIVE – RESULTS: MSW DISPOSAL OPERATIONAL PERFORMANCE

5.0 Introduction

The analysis of the baseline scenario of MSW disposal in the case study area (research objective 3) showed a precarious MSW disposal situation. In order to overcome the shortcomings of the baseline scenario, the fourth objective of this doctoral research was:

“*to evaluate MSW disposal operational performance*”.

The evaluation of the operational performance of the Wa Municipality’s MSW disposal system was carried out through the formulation, building, optimisation and scenario analysis of various MSW disposal operations including, waste generation, source separation, collection, transportation, processing/treatment, and final disposal.

The focused of the operational performance evaluation was on the combination of the material flow analysis (MFA) and substance flow analysis (SFA) with the aim of optimising the minimisation of MSW disposal environmental burdens (human health impact category), using the municipal solid waste decision support tool (MSW DST). Five (5) MSW disposal scenarios, reflecting different MSW disposal systems, were compared.

Since the scenarios were assumed not to influence MSW generation, the same amounts and composition of MSW were disposed of in all 5 scenarios and acid gases (nitrogen oxide (NOx) and sulphur oxide (SO_X)) and particulate matter that have direct impacts on human health, were chosen as the objective functions for all the five scenarios.

NO_X plays a major role in several environmental and health effects. Breathing air with a high concentration of NOx can irritate airways in the human respiratory system, such exposures over even short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty in breathing) (US, EPA 2017).

Similarly, exposure to SO_X in the ambient air has been associated with reduced lung function, increased incidence of respiratory symptoms and diseases, irritation of the eyes, nose, and throat, and premature mortality (World Bank, 1998). Particulate matter equally causes health problems. Small particles less than 10 micrometers in diameter pose the greatest problems because they can get deep into human lungs, and some may even get into the bloodstream (US, EPA 2017b).

For the substance flow analysis (SFA): lead, cadmium, arsenic, mercury, copper, chromium and zinc were chosen as indicators (pollutants) for all the five scenarios. The health impacts were categorised as cancer air, cancer water, noncancer air, and noncancer water. The scenarios were modelled using the municipal solid waste decision support tool (MSW DST). The MSW DST has been discussed extensively in section 2.5.1.1 of the literature review chapter of this thesis.

5.1 Conceptual Model Formulation of Scenarios Analysis

The MSW DST was used to conduct the scenario analysis of the five MSW disposal options. The tool is designed to analyse the management of MSW of a given quantity and composition. It considers all activities required to manage the MSW from the time it is sent out for collection to its ultimate disposition, whether disposal in a landfill, compost applied to land, energy recovered from combustion or landfills, or materials recovered and remanufactured into new products.

The MSW disposal system modelled was the Wa Municipality's MSW disposal system. The processes that were modelled included waste generation, collection, transfer, separation (material recovery), composting, combustion, refuse-derived fuels (RDF), and disposal in a landfill. Five MSW disposal scenarios were formulated, built and analysed based on uncertainty and sensitivity analysis with the objective of optimising the minimisation of environmental burdens.

The MSW DST modelling process consists of four basic components:

- process models,
- waste flow model,
- optimisation model, and
- a graphic user interface (GUI).

The process models consist of a set of spreadsheets developed in Microsoft Excel. These spreadsheets use a combination of default and user-supplied data to calculate the cost and life cycle inventory (LCI) coefficients on a per unit mass basis for the MSW components being modelled for each SWM unit process (collection, transfer, treatment, and disposal). There are eight overall steps, but six steps are required to complete modelling a scenario. These steps are presented in Table 5.1.

Table 5.1: Steps in the MSW DST

Step	Description
Define generation*	Define generation sectors to include in the model scenario analysis. The parameters for residential sectors to be defined include the population, generation rate (kg/person/day) and the household population density (people/house), and the parameter for commercial sectors include the number of commercial units and generation rate
Select Processes*	Select processes to include in the model and scenario analysis (waste collection, transfer, MRF, treatment, and landfill disposal methods)
Select Report Options*	Select objective function
Specify process input	Input site-specific information for the process
Build model*	This creates the life cycle inventory
Set process constraints	Specify constraints (if any)
Set diversion targets	Define which processes to divert waste to (recycling and composting) and the target of diversion in percentages
Solve and view report*	Three four reports can be created: impact assessment, cost and inventory analysis, recycling, and mass flow reports

* a step required to complete modelling a scenario

The site-specific data used in the modelling were the Wa municipality and Ghana MSW generation and characteristics data obtained from secondary sources as discussed in section 3.7.1 of the methodology and research design chapter of this thesis and presented in section 4.1 of chapter four of this thesis (see Tables 4.1, 4.2, 4.3 and 4.4), and some MSW DST default data

Five scenarios were modelled and analysed, including analysis of environmental and economic aspects, along with sensitivity and uncertainty analysis to enable the study to propose the most suitable scenario for MSW disposal for the case study area.

5.1.1 Goal and Scope Definition

The optimisation module of the MSW DST is implemented using CPLEX linear programming solver. The model is constrained by mass flow equations that are based on the quantity and composition of waste entering each unit process, and that intricately link the different unit processes in the waste management system (i.e., collection, recycling, treatment, and disposal options).

The optimisation module uses linear programming techniques to determine the optimum solution consistent with the specified objective and mass flow and specified constraints. Thus, **the main objective function of the modelling and optimisation in this study was to minimise the health impacts category of MSW disposal**.

The categories of MSW environmental impacts include human health, greenhouse effect (global warming), acidification, eutrophication, and photochemical ozone synthesis. However, this study was limited to only the human health impact category of MSW and aimed to optimise the minimisation of the environmental burdens of acid gases (NOx and SO_X) and particulate matter that have direct impact on human health. Additionally, the following (seven) substances were chosen as indicators for the substance flow analysis (SFA): lead, cadmium, arsenic, mercury, copper, chromium and zinc.

Lead, copper, zinc, arsenic and chromium in landfills and leachates determine aftercare in a long-term perspective (Hjelmar, 1996; Stanisavljevic and Brunner, 2014). These compounds are equally relevant for air quality as well as surface and groundwater qualities (Kubin, 1998; Suddick *et al.*, 2013; Shonkoff, et al., 2014), as some can cause mild mental retardation and cardiovascular diseases (Prüss-Üstün and Corvalán, 2006). Cadmium, mercury, and lead are also indicators for toxic atmospheric metals (Stanisavljevic and Brunner, 2014).

Five scenarios were conducted to determine the optimal MSW disposal system based on the least engineering cost and optimal minimal environmental burdens. The aim of the modelling and optimisation using the MSW DST is to increase the level of decision-makers' awareness by the results of this research and possibly lead to the reduction of the future undesirable environmental effects of MSW disposal. Therefore, the results were analysed on an inventory of stressors by the health impact category of the modelled scenarios.

5.1.2 Functional Unit

The International Organisation for Standardisation (ISO) 14040 standard defines the functional unit as:

> ''*the quantified performance of a product or system for use as a reference unit in a life cycle assessment stud*y'' (ISO, 2006).

The functional unit for a SWM system should reflect the period of time for which the environmental impacts and waste generation are considered, based on the amount of waste and their composition (Limoodehi *et al.*, 2017). Therefore, for this study, the functional unit was chosen as the average amount of municipal generated waste in the Wa municipality per day in the residential sectors based on the residential typology/income level (compound-house, semi-detached, and single-unit residential dwellings) and one commercial generation sector (Wa market).

The daily waste generation of Wa (average daily generation of 0.25 kg/capita/day and 32 ton/day based on 2017 population projection of 12,8873) and household MSW composition in Ghana was considered as the input of the residential sector (the household MSW composition in Ghana is presented in table 4.2 in chapter 4 of this thesis), and Wa market waste average daily generation of 0.23 kg/day and MSW composition shown in Table 4.3 was also considered as the input of the commercial sector. Thus, the modelled systems were made of inputs from the residential and one commercial sector.

5.1.3 System Boundaries and Limitations of the Modelling

The system is the actual object of the MFA and SFA (Brunner and Rechberger, 2004), and the subsequent optimisation of the minimisation of MSW disposal environmental burdens. A system is defined by a group of elements, their interaction and the boundaries between these elements in space and time (Guendehou *et al.*, 2006; Ardolino, et al., 2017; Limoodehi *et al.*, 2017).

The system requires a temporal and spatial boundary (Laurent, *et al.*, 2014; Nizami *et al.*, 2017), together with a material boundary in order to specify which type of environmental burdens will be accounted for (Cleary, 2009; Ardolino, et al., 2017). Thus, the system for this study was the Wa Municipality MSW disposal system.

In modelling the MSW disposal system for the Wa municipality, the study used some assumptions and generalisations. The MSW DST itself has limitations in its methodology and applicability to various locations around the world. The researcher acknowledges the following key assumptions and limitations of the analysis:

- Studies to characterise the quantity and composition of MSW are often cited as a key factor in selecting waste management processes (Burnley, 2007; Pandey *et al.*, 2016). The study applied Ghana and Wa municipality waste characterisation data available in literature in the modelling and analysis but could not determine the data quality.
- The modelling relied on some default data in the model because of the non-availability of some site-specific data from Ghana and the Wa municipality.
- The MSW DST does not include models for all possible waste disposal technologies. Therefore, anaerobic digestion and new or emerging technologies, such as waste gasification and pyrolysis were not considered.
- The study did not place a limit on the amount of waste that any process can accept. In practice, facilities are designed to handle a certain minimum or maximum capacity of waste and, therefore, would be limited in the amount of waste they could process.
- The study was focused on only the health impact category of MSW disposal, though there are other impact categories such as greenhouse effect (global warming), acidification, eutrophication, and photochemical ozone synthesis.

5.2 Modelled Scenarios

The five MSW disposal scenarios that were modelled based on their ability to overcome the shortcomings of the baseline scenario of MSW disposal in the case study area as discussed in section 4.3.3 of the results presentation and analysis chapter were:

- Scenario 1 - Landfill disposal only
- Scenario 2 - composting and landfill disposal
- Scenario 3 - composting, combustion, RDF, and landfill disposal
- Scenario 4 – source separation, composting, combustion, RDF, and landfill disposal

- Scenario 5 - source separation, transfer stations, MRF, composting, combustion, RDF, and Landfill disposal

5.2.1 Scenario 1: Landfill Disposal Only

Sanitary landfilling is the most recommended MSW disposal option for most developing countries and is the desired disposal option in the case study area. For this scenario, all mixed MSW was collected and disposed of in a sanitary landfill and the human impact categories evaluated to determine the environmental impacts of this disposal scenario.

The optimal solutions found for NO_X, SO_X, and TPM as the optimising objectives for scenario 1 were 5970, 1890, and 358 lbs/year respectively, and the engineering cost for the landfill disposal only was 1,210,000 $/year for the entire system. There was no change in the mass flow for all the three optimising objectives as a total mass flow of 5250 tons/year was disposed of in the landfill. Figure 5.1 shows the mass flow of waste for scenario 1.

The values of the chosen pollutants (lead, cadmium, arsenic, mercury, copper, chromium and zinc) and their impact categories are presented in Table 5.2. The highest pollutant for all the three optimising objectives in this scenario was cadmium (9.00E-08 lbs/year) under cancer water impact category, followed by lead which was 8.4E-05 lbs/year under noncancer air for both NO_X and SO_X as optimising objectives, and 9.4E-05 lbs/year also under noncancer air for optimising objective TPM. On the other hand, copper under noncancer water was the least pollutant (1.28E-09 lbs/year) for all the three optimising objectives.

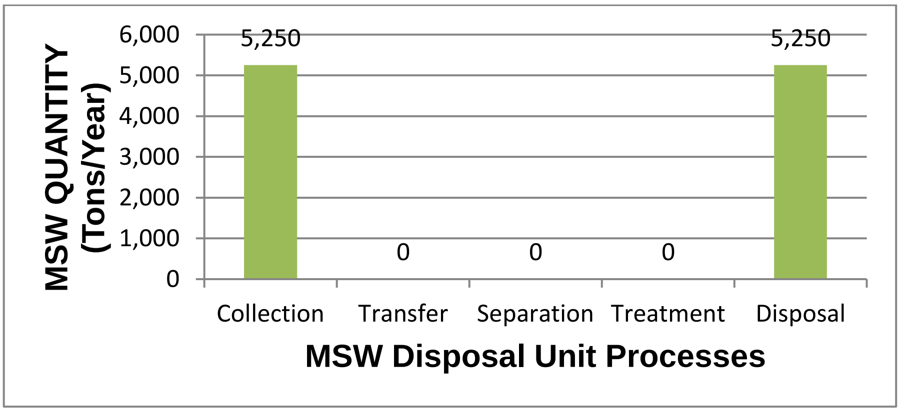

Figure 5.1: MSW mass flow in scenario 1

Table 5.2: Inventory of human health impact categories for scenario 1

Impact Categories	Pollutant Name	Objective Function		
		NO_X = 5,970 lbs/yr	**SO_X = 1,890 lbs/yr**	**TPM = 358 lbs/yr**
		Value (lbs/year)		
Cancer Air	Lead	2.39E-07	2.39E-07	2.39E-07
Cancer Water	Cadmium	9.38E-08	9.12E-08	9.12E-08
	Arsenic	2.38E-05	2.38E-05	2.38E-05
	Mercury	3.33E-07	3.33E-07	3.33E-07
	Lead	4.62E-08	4.62E-08	4.62E-08
Noncancer Air	Lead	8.40E-05	8.40E-05	9.40E-05
Noncancer Water	Copper	1.28E-09	1.28E-09	1.28E-09
	Cadmium	2.45E-05	2.45E-05	2.45E-05
	Arsenic	1.77E-03	1.77E-03	1.77E-03
	Mercury	3.94E-05	3.94E-05	3.94E-05
	Chromium	1.56E-09	1.56E-09	1.56E-09
	Lead	1.62E-05	1.62E-05	1.62E-05
	Zinc	1.57E-05	1.57E-05	1.57E-05
Average		**1.519E-04**	**1.519E-04**	**1.519E-04**
Average of the 3 objective functions		**1.519E-04**		

5.2.2 Scenario 2: Composting and Landfill Disposal

Composting and sanitary landfilling are the two most recommended waste management options for highly organic waste fraction, especially in developing countries. For Scenario 2, all the collect mixed MSW (5,250 ton/year) was first sent to a separation plant and the mixed waste sorted into organic and inorganic components. The organic component of 4,500 tons/year was processed through composting, 386 ton/year of inorganic MSW and 436 ton/year of non-compostable organic MSW were disposed of in a landfill. The mass flow of the waste is presented in Figure 5.2.

The optimal solutions for NO_X, SO_X, and TPM as the optimising objectives were 85.7, -3,490, and -2,630 lbs/year respectively. The total engineering cost for scenario 2 was 1,340,000 $/year. The pollutants (lead, cadmium, arsenic, mercury, copper, chromium and zinc) values and their impact categories are presented in Table 5.3. Lead under cancer air impact category was the lowest pollutant (-3.83E-08 lbs/year) for NO_x as the optimising objective, optimising objective SO_X also had lead under cancer air impact category being the least pollutant (-4.25E-08 lbs/year), whereas, optimising objective TPM produced cadmium under noncancer water impact category as the least pollutant (1.02E-04 lbs/year).

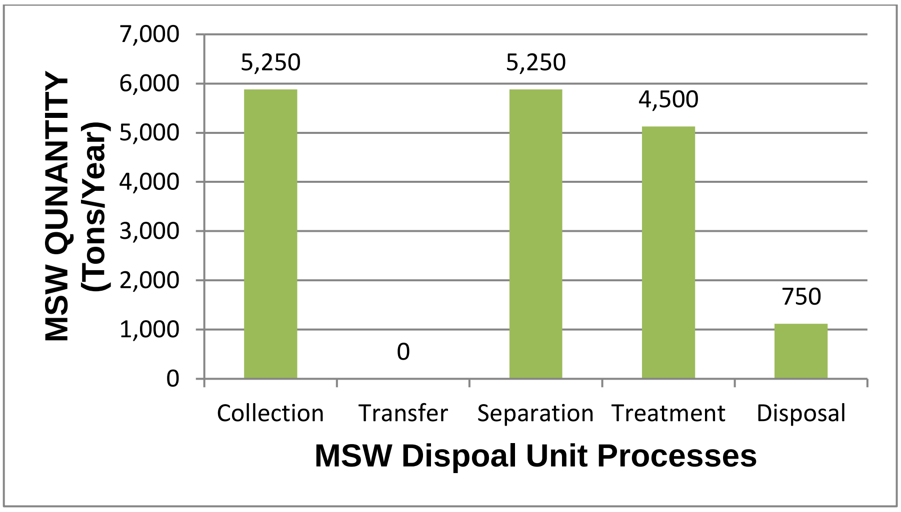

Figure 5.2: MSW mass flow in scenario 2

Table 5.3: Inventory of human health impact categories for scenario 2

Impact Categories	Pollutant Name	Objective Function		
		NO_X = 85.7 lbs/yr	**SO_X = - 3,490 lbs/yr**	**TPM = - 2,630 lbs/yr**
		Value (lbs/year)		
Cancer Air	Lead	-3.83E-08	-4.25E-08	3.08E-09
Cancer Water	Cadmium	3.69E-07	3.68E-07	3.78E-07
	Arsenic	4.30E-06	4.28E-06	4.44E-06
	Mercury	3.17E-08	2.60E-08	7.17E-08
	Lead	1.34E-07	1.33E-07	1.41E-07
Noncancer Air	Lead	-1.34E-05	-1.49E-05	1.08E-06
Noncancer Water	Copper	7.66E-08	7.66E-08	7.65E-08
	Cadmium	9.90E-05	9.88E-05	1.02E-04
	Arsenic	3.19E-04	3.17E-04	3.29E-04
	Mercury	3.75E-06	3.07E-06	8.49E-06
	Chromium	2.99E-10	2.67E-10	5.10E-10
	Lead	4.69E-05	4.67E-05	4.95E-05
	Zinc	7.46E-04	7.46E-04	7.47E-04
Average		**9.278E-05**	**9.242E-05**	**9.555E-05**
Average of the 3 objective functions		**9.358E-05**		

5.2.3 Scenario 3: Composting, Combustion, RDF, and Landfill Disposal

In scenario 3, MSW was collected and transported to a sorting plant for separation and subsequently taken to various processing/treatment plants. Compostable organic MSW was sent to a composting facility, inorganic MSW was sent to combustion and RDF facilities. Non-compostable and non-combustible MSW together with the residues of the composting, combustion and RDF processes were disposed of in a landfill.

For this scenario, the mass flow for NO_X and SO_X as optimising objectives was the same as all 5250 tons/year of MSW was sent to RDF facility, which resulted in 1210 tons/year of residue (ash) disposed of in a landfill. However, for TPM as optimising objective, 5250 tons/year of MSW was sent to a mixed combustion treatment plant, which resulted in 889 tons/year of residue (ash) disposed of in a landfill. The mass flow of waste for scenario 3 is illustrated in Figure 5.3.

Scenario 3 had negative values of -5250, -45700, and -4710 lbs/year as the optimal solutions for NO_X, SO_X, and TPM as the objective functions for the optimisation respectively. The engineering cost for scenario 3 system was 1,200,000 \$/year, which is slightly lower than the engineering cost for scenario 1 system by 10,000 \$/year.

The health impact categories and their pollutants values are shown in Table 5.4. This scenario had arsenic pollutant under cancer water impact category being the least pollutant for NO_X and SO_X optimising objectives (-9.35E-06 lbs/year), while mercury under the cancer water impact category of -9.51E-09 lbs/year was the least pollutant for TPM as the optimising objective.

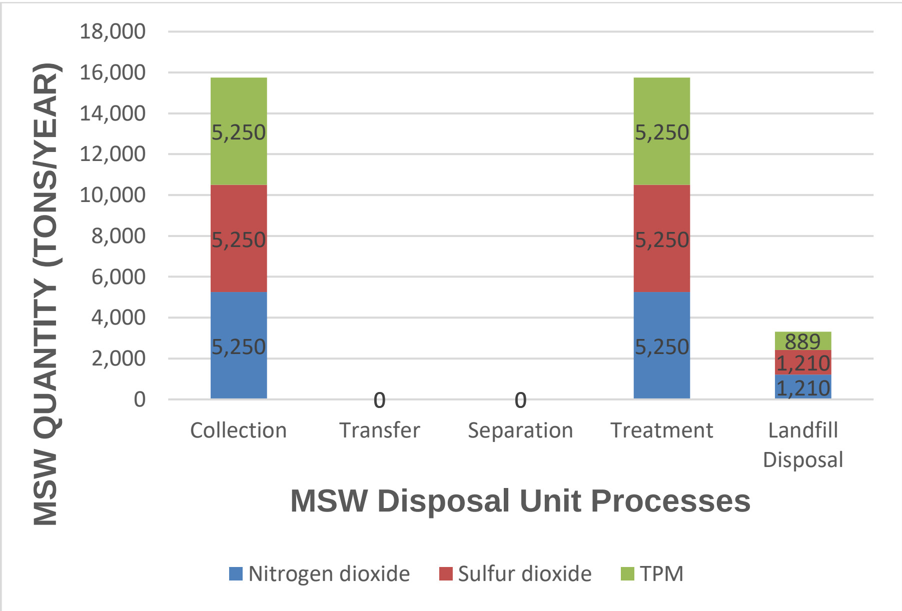

Figure 5.3: MSW mass flow in scenario 3

Table 5.4: Inventory of human health impact categories of scenario 3

Impact Categories	Pollutant Name	Objective Function		
		NO_X = -5,250 lbs/yr	SO_X = -45,700	TPM = -4,710
		Value (lbs/year)		
Cancer Air	Lead	-5.50E-06	-5.50E-06	-1.62E-06
Cancer Water	Cadmium	1.56E-08	1.56E-08	1.89E-08
	Arsenic	-9.35E-06	-9.35E-06	-6.08E-06
	Mercury	-1.46E-08	-1.46E-08	-9.51E-09
	Lead	-1.57E-08	-1.57E-08	-1.02E-08
Noncancer Air	Lead	-1.93E-03	1.93E-03	-5.7E-04
Noncancer Water	Copper	-5.65E-08	-5.65E-08	-3.67E-08
	Cadmium	4.19E-06	4.19E-06	5.07E-06
	Arsenic	-6.92E-04	-6.92E-04	-4.51E-04
	Mercury	-1.73E-06	-1.73E-06	-1.13E-06
	Chromium	-4.13E-10	-4.13E-10	-2.53E-10
	Lead	-5.49E-06	-5.49E-06	-3.58E-06
	Zinc	-2.68E-04	-2.68E-04	-1.72E-04
Average		**-2.237E-04**	**-2.237E-04**	**-9.234E-05**
Average of the 3 objective functions		**-5.530E-04**		

5.2.4 Scenario 4: Source Separation, Composting, Combustion, RDF, and Landfill Disposal

Scenario 4 was similar to scenario 3 except that, for scenario 4, there was segregation of MSW into organic and inorganic MSW at the point of generation for collection. The organic MSW was transported to a composting plant for treatment/processing, whereas the inorganic MSW was transported to combustion and RDF facilities for treatment/processing.

There were different mass flows for all the three optimising objectives. For NO_X as an optimising objective, the entire 5250 tons/year of MSW was first sent to a front end mixed separation point. After the separation, 4580 tons/year of organic MSW was sent to a composting facility for processing/treatment, whereas 434 tons/year of MSW was disposed of directly in a sanitary landfill. The composting process generated 568 tons residue, which was disposed of in a landfill.

Similarly, setting SO_X as the optimising objective, 558 tons/year of pre-sorted recyclables were taken to a recycling plant and 4,700 tons/year of MSW was sent to a RDF facility to produce pellets. The RDF process produced a residue of 1080 ton of ashes, which was disposed of in a landfill. For the TPM as an optimising objective, 890 tons/year of recyclables were sorted from the 5250 tons/year of MSW and 4360 tons/year of MSW was taken to a mixed combustion facility for WTE conversion. The combustion process produced 716 tons/year of ashes which was disposed of in a landfill. The mass flows of the waste for scenario 4 are shown in Figure 5.4.

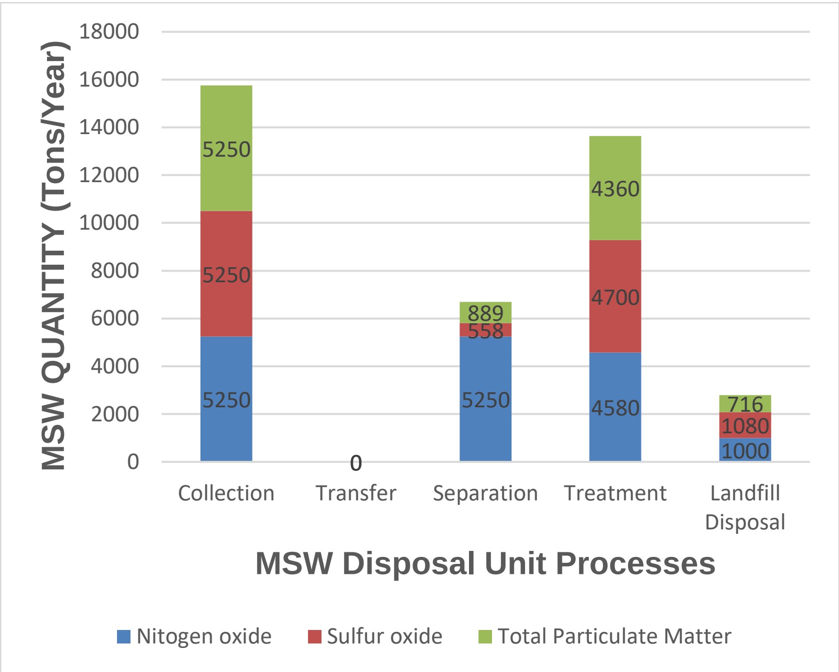

Figure 5.4: MSW mass flow in scenario 4

The optimal engineering cost for scenario 4 was 1,150,000 $/year, which is lower than the engineering cost for scenarios 1, 2, and 3. Optimising objectives SO_X and TPM had negative optimal solutions, -19800 and -4520 lbs/year respectively, whilst objective function NO_X had a positive lower optimal solution of 71.7 lbs/year, which is far lower than the NO_X optimal solution for scenario 1 (5970 lbs/year). Table 5.5 presents the health impacts and their corresponding pollutants values.

This scenario produced varied pollutants values for all the three optimising objectives. Optimising objective NO_X had the least and highest pollutants being lead (-9.64E-06 lbs/year) under noncancer air impact category and cadmium (8.85E-05 lbs/year) under noncancer air impact category respectively. Similarly, SO_X as the optimising objective had chromium (-8.51E-09 lbs/year) and lead (-1.03E-04 lbs/year) being the least and highest pollutants under noncancer air impact category respectively. For TPM as the optimising objective, zinc (-8.48E-04 lbs/year) under noncancer water was the least pollutant and lead (3.08E-07 lbs/year) cancer air category was the highest pollutants.

Table 5.5: Inventory of human health impact categories of scenario 4

Impact Categories	**Pollutant Name**	**Objective Function**		
		NO_X= 71.7 lbs/yr	**SO_X = -19,800**	**TPM = -4,520**
		Value (lbs/year)		
Cancer Air	Lead	-2.75E-08	-1.59E-06	3.08E-07
Cancer Water	Cadmium	3.3E-07	-6.8E-08	1.36E-08
	Arsenic	3.85E-06	-1.78E-04	-7.42E-05
	Mercury	2.83E-08	-1.31E-07	-5.44E-08
	Lead	1.2E-07	-2.95E-07	-1.23E-07
Noncancer Air	Lead	-9.64E-06	-5.56E-04	1.08E-04
Noncancer Water	Copper	6.84E-08	-3.62E-07	-1.5E-07
	Cadmium	8.85E-05	-1.83E-05	3.66E-06
	Arsenic	2.85E-04	-1.31E-02	-5.5E-03
	Mercury	3.35E-06	-1.55E-05	-6.44E-06
	Chromium	2.67E-10	-8.51E-09	-3.49E-09
	Lead	4.2E-05	-1.03E-04	-4.32E-05
	Zinc	6.66E-04	-2.63E-03	-8.48E-04
Average		**8.304E-05**	**-1.277E-03**	**-4.892E-04**
Average of the 3 objective functions		**-5.611E-04**		

5.2.5 Scenario 5: Source Separation, Transfer Stations, MRF, Composting, Combustion, RDF, and Landfill Disposal

The MSW is separated at source, transported to transfer stations and subsequently transferred to a material recovery facility (MRF) before finally sent for treatment/processing in composting, combustion, and RDF facilities in scenario 5. Some MSW and residue of the processing were disposed of in a sanitary landfill. Like scenario 3, scenario 5 has all three optimising objectives having negative optimal solutions: -3820, -19900, and -4,520 lbs/year for NO_X, SO_X, and TPM respectively.

The engineering optimal cost for scenario five was 1,150,000 $/year, which is the same as the cost for scenario 4 disposal system. The human health impact categories and their pollutants values are presented in Table 5.6. NO_X optimising objective produced lead cancer air impact category of -7.13E-07 lbs/year as the least pollutant and mercury noncancer water impact category of 9.35E-06 as the highest pollutant. Optimising objective SO_X had chromium noncancer water impact category of -8.52E-09 lbs/year as the least pollutant and -1.03E-04 lbs/year of lead noncancer water impact category as the highest pollutant. For TPM as an optimising objective, zinc (-8.48E-04 lbs/year) was the least pollutant and 3.66E-06 lbs/year cadmium being the highest, both under noncancer water impact category.

Scenario 5 equally produced different mass flows for the three optimising objectives. The mass flows of scenario 5 are shown in Figure 5.5. Optimising objective NO_X had 4,370 tons/year of MSW out of the total 5250 tons/year of MSW disposed of in landfill with the possibility of methane capture; SO_X, as the optimising objective had 559 tons/year of commingled recyclables taken out of the 5250 tons/year of MSW for recycling and 4,700 tons/year of mixed MSW, was sent for WTE conversion in a combustion facility.

The WTE conversion resulted in 1,080 tons/year of ashes, which was disposed of in a landfill. Also, for TPM as the optimising objective, 889 tons/year of recyclables were recovered for recycling and 4,360 tons/year of MSW was sent for WTE conversion in a combustion facility. The combustion produces 716 tons/year of ashes which was equally disposed of in a landfill.

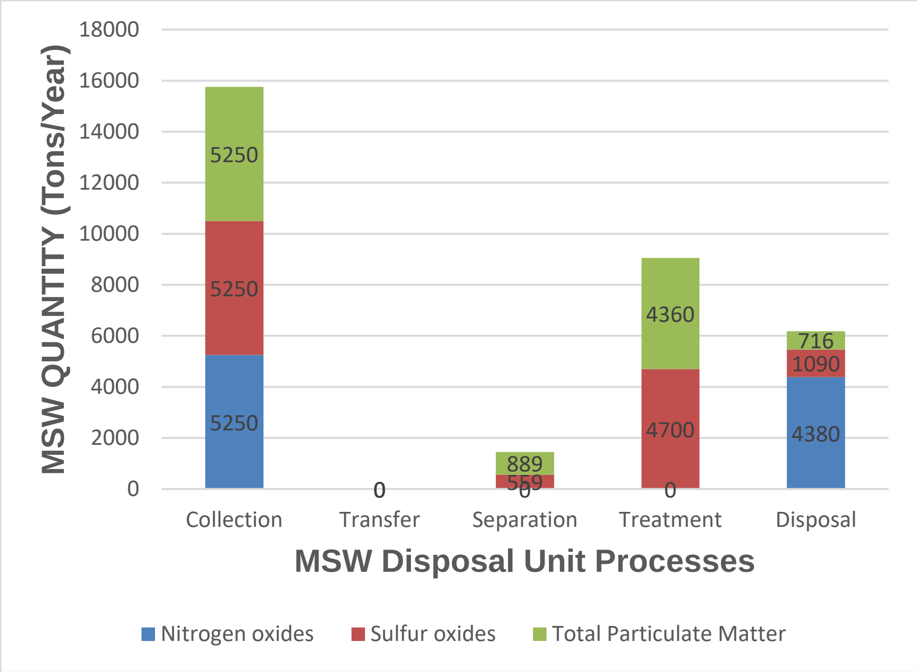

Figure 5.5: MSW mass flow in scenario 5

Table 5.6: Inventory of human health impact categories of scenario 5

Impact Categories	Pollutant Name	Objective Function		
		NO_X = -3,820 lbs/yr	SO_X = -19,900 lbs/yr	TPM = -4,520 lbs/yr
		Value (lbs/year)		
Cancer Air	Lead	-7.13E-07	-1.58E-06	3.08E-07
Cancer Water	Cadmium	4.75E-08	-7.54E-08	1.36E-08
	Arsenic	1.23E-06	-1.77E-04	-7.42E-05
	Mercury	7.9E-08	-1.31E-07	-5.44E-08
	Lead	9.28E-09	-2.95E-07	-1.23E-07
Noncancer Air	Lead	-2.5E-04	-5.53E-07	1.08E-04
Noncancer Water	Copper	4.57E-09	-3.61E-07	-1.5E-07
	Cadmium	1.28E-05	-2.03E-05	3.66E-06
	Arsenic	9.09E-05	-1.31E-02	-5.5E-03
	Mercury	9.35E-06	-1.55E-05	-6.44E-06
	Chromium	3.4E-10	-8.52E-09	-3.53E-09
	Lead	3.25E-04	-1.03E-04	-4.32E-05
	Zinc	4.25E-04	-2.63E-03	-8.48E-04
Average		**2.246E-05**	**-1.277E-03**	**-4.892E-04**
Average of the 3 objective functions		**-5.812E-04**		

5.3 Summary of the Findings on the Five Modelled Scenarios

Management of MSW through the unit operations of collection, transfer, separation, processing/treatment, and final disposal form a complex interrelationship of mass flows with associated energy consumption, SW production, and airborne and waterborne emissions. These pose potential risks to the environment and health in the handling of MSW. Direct health risks concern mainly the workers in the waste sector and residents near processing or disposal facilities.

The public may be affected indirectly by waste management activities such as emissions and leachate emanating from waste processing and disposal. Thus, the five scenarios were modelled, analysed and compared to determine which scenario was efficacious in generating the least health impacts and engineering cost.

In terms of the engineering cost, scenarios 4 and 5 produced the least engineering cost of 1,150,000 $/year for the entire MSW disposal system, whereas scenario 2 produced the highest cost of 1,340, 000 $/year as indicated in Figure 5.6. Also, in terms of the health effects, scenario 5 again produced the least average health impacts of -5.812E-04 lbs/year, whiles scenario 2, which generated the highest engineering cost, equally produced the highest average health impact of 9.358E-05 lbs/year. Scenarios 5 and 4, which had WTE conversion included the disposal system in an ISWM system format, produced the lowest average health impacts (-5.812E-04 lbs/year and -5.611E-04 lbs/year respectively) and the lowest engineering cost as illustrated in Figure 5.7.

However, on the objective functions optimisation, scenario 3 produced the best minimising optimisation (optimal solution) for all the three objective functions (NO_X, SO_X, and TPM), with the lowest negative net optimal solution as indicated in Figure 5.8, whereas, scenario 1 generated worst minimising optimisation for the three objective functions with the highest net optimal solution. On the other hand, scenario 5 (source separation, transfer stations, composting, combustion, RDF, and landfill disposal system) produced the least engineering cost and optimised the minimisation of health effects than the other four scenarios.

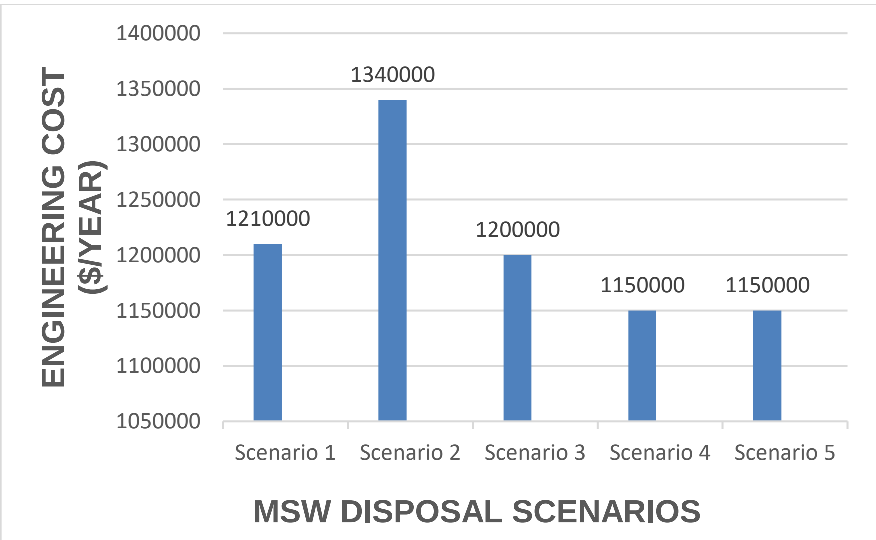

Figure 5.6: Engineering cost of the five scenarios

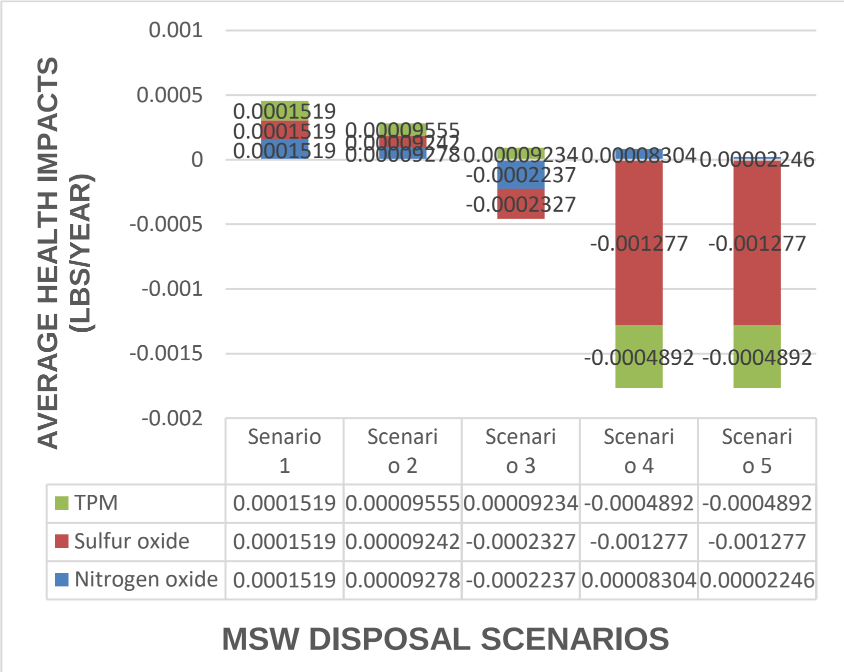

Figure 5.7: Comparison of the health impacts of the five scenarios

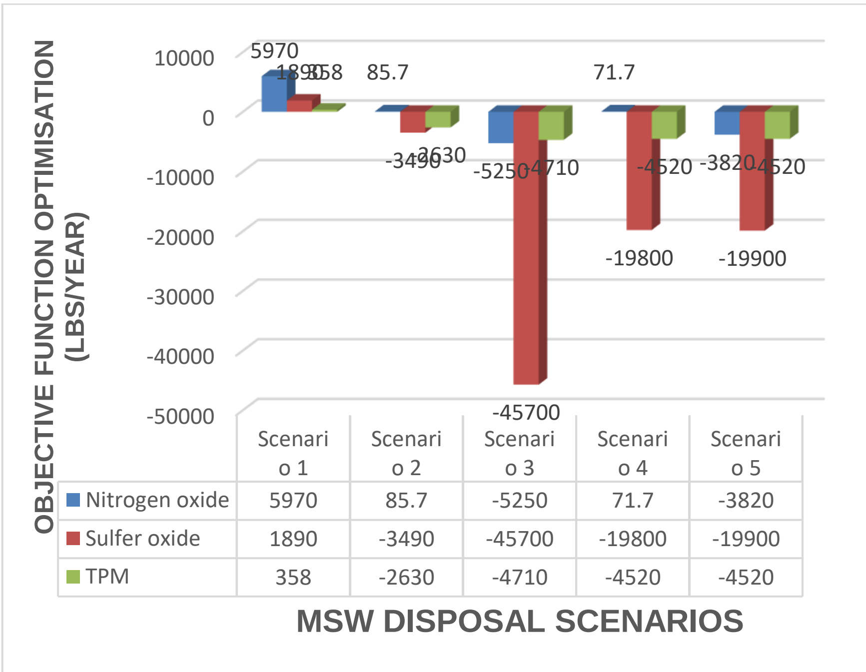

Figure 5.8: Objective functions optimisations of the five scenarios

The next chapter (chapter six) presents a discussion of the key findings of each research objective of this study.

CHAPTER SIX – DISCUSSION OF THE RESEARCH RESULTS

6.0 Introduction

This chapter discusses the key findings of the research objectives which led to the achievement of the main aim of the research. The discussion in this chapter is based on the research results presented in chapter 4 and chapter 5 of this thesis. The aim of this doctoral research is:

> "*to improve planning and decision making for MSW disposal in developing countries with similar circumstances and MSW problems to Ghana*".

The objectives that guided the study were, to:

1. Investigate MSW generation and characteristics reported in literature and official documents
2. Examine MSW disposal management performance
3. Establish a baseline scenario of MSW disposal
4. Evaluate MSW disposal operational performance
5. Develop a planning framework for MSW disposal decision-making in developing countries

Discussions on the first four research objectives are presented in the following sections in this chapter. The discussion on the last research objective (objective 5) is presented in a separate chapter (chapter five of this thesis).

6.1 MSW Generation and Characteristics

The accurate prediction of MSW generation and knowledge of the waste characteristics provide the basic data for sustainable waste management. Therefore, the first objective of this doctoral study was to examine the MSW generation and characteristics reported in literature and official documents. The results as presented in sections 2.1.2 and 4.1 of the literature review chapter and chapter 4 respectively, indicate that the global MSW generation rates are rising exponentially due to the increasing global population and improvement in living standards.

The increasing waste generation rates is further exacerbating the problems of MSWM in developing countries such as Ghana, which are currently struggling with ineffective MSWM systems due to the lack of the enabling environment for effective waste management. Though the MSW generation rates in the case study area (Wa municipality, Ghana) and other sub-Saharan African countries are lower (0.25

kg/capita/day on average) compared to other developing countries such as countries in Asia (1.1 kg/capita/day) (World Bank, 2012), this still poses a burden on the municipal budget because of the high costs associated with its management (Guerrero et al., 2013).

The research results also indicate that MSW streams in developing countries such as Ghana are more organic (over 60%), while those in the developed countries is made up of more inorganic waste. The organic fraction is an important component, not only because it constitutes a significant portion of the MSW stream in Ghana and other developing countries, but also because of its potentially adverse impact on public health and environmental quality if not properly treated and/or disposed of. A major adverse impact is its attraction of rodents and vector insects for which it provides food and shelter (Fei-Baffoe, et al., 2014).

The impact of organic MSW on environmental quality takes the form of foul odours, unsightliness and leachate from open dumps, especially after rainfall, and emission of harmful gases (Akhtar, 2014). These impacts are usually not limited only to the disposal site, they pervade the neighbouring area to the site and wherever the wastes are generated, spread, or accumulated. Unless an organic waste is appropriately treated and disposed of, its adverse impact will continue until it has fully decomposed or otherwise stabilised.

In addition, the high organic content in Ghana's MSW stream has resulted in high moisture content (above 50% on average) of the MSW, which conforms with the waste streams in other developing countries (Wilson *et al.*, 2012; Srivastava *et al.*, 2015; Thaiyalnayaki and Jayanthi, 2017). The moisture content of MSW is a very important factor that influences decisions on MSW collection, transportation, treatment/processing and final disposal (Watkins and McKendry, 2015).

For example, in composting, moisture content affects the magnitude of heat generation, which can affect the quality of compost (Rada *et al.*, 2014; Ballardo *et al.*, 2016; Benavente, et al., 2017), and in a landfill, leachate is formed when the refuse moisture content exceeds its field capacity (Iqbal *et al.*, 2015). Also, many researchers have indicated that high moisture content is a major hindrance in the field of thermal conversion of waste-to-energy (WTE) technologies (Zhao *et al.*, 2014; Tom, et al., 2016) because moisture content influences the calorific value of the waste to be incinerated.

Thus, the high organic composition of the MSW stream in developing countries, including Ghana and the Wa municipality, beckon the adoption of appropriate management technologies to ameliorate the negative impacts of MSW.

6.2 MSW Disposal Management Performance

The second objective of this doctoral research was to examine MSW disposal management performance in the case study area. As stated in section 2.4 of the literature review chapter of this thesis, there is no consensus on the key indicators for waste management performance examination, however, based on the waste management challenges in the case study area and the researcher's experience, the policy, legal, and institutional arrangements; the financial arrangements; and technical capacity required for the effective functioning of a waste disposal system were set as the key indicators for the MSW disposal management performance examination in this doctoral study. The following sections discuss the key findings on these indicators in detail.

6.2.1 Legal and Policy Framework for MSWM

From the results presented in section 4.2.1 of chapter four of this thesis, Ghana has sufficient and robust legislation, existing bylaws, policies and programmes regarding SWM. However, the challenge is the non-enforcement of, and non-compliance with the laws and regulations governing SWM. The poor enforcement of waste management policies and laws have significantly contributed to the inefficient MSW disposal in the Wa Municipality and the entire country.

Baabereyir (2009) observes that a municipality's inability to implement existing bylaws on waste disposal results in a 'throw-it-where-you-like' attitude and general disregard of waste disposal regulations. Consequently, many individuals, households, traders and businesses have resorted to indiscriminate waste dumping in open spaces, streams, drains and drainage channels in the case study area. This creates unsanitary living conditions, blocks existing drainage channels and creates a breeding ground for mosquitos and rodents (Ejaz *et al.*, 2010; Alam and Ahmade, 2013; Srivastava *et al.*, 2015).

6.2.2 Institutional Arrangements for MSWM

The research results indicate that Ghana has a good institutional arrangement for SWM. However, there is too much institutional fragmentation for SWM in Ghana because many institutions are involved in the sector. As a result, many at times an institution reneges on its responsibility on a SWM problem thinking that another institution will tackle the problem because there is confusion (in practice) about who is responsible (Mariwah, 2012; Nabegu and Mustapha, 2015). Coupled with this, are weak institutional capacity, and lack of resources (both human and capital), as difficulties the authorities faced in ensuring that all the SW generated in the municipality is collected and properly disposed of.

6.2.2.1 Stakeholders in MSWM

The relationship between stakeholders in MSWM in Ghana shows (as indicated in figure 4.2 and presented in section 4.2.2.1 of chapter four of this thesis) that the emphasis on stakeholders' involvement in SWM is focused mainly on waste collection and no attention paid to waste reduction, treatment and final disposal. However, for sustainable waste management, the stakeholder's involvement is often focused on promoting waste reduction/avoidance and resource recovery (Sanneh *et al.*, 2011).

Waste prevention, minimisation, and reuse, which are up on the waste hierarchy (see figure 2.2 in the literature review chapter), and which are equally the main components of waste reduction policies, are completely absent in the stakeholder involvement of waste management in Ghana. This explains why there is a high proportion of miscellaneous waste in the MSW stream in Ghana (5.1%), as waste is not sorted at the generation point (Miezah *et al.*, 2015).

Also, formal material recovery which is in the middle of the waste management hierarchy and an applicable waste reduction method in both developed and developing countries (Guerrero, et al., 2013; Laurent, Clavreul, *et al.*, 2014; Brunner and Rechberger, 2015), is not considered in the stakeholder's involvement in SWM in Ghana and the Wa Municipality. Similarly, formal recovery of inorganic waste through manual scavenging by private individuals which is the main means of material recovery in most developing countries (Brunner and Rechberger, 2015) is equally ignored, only the informal sector is involved in material recovery in the case study area.

However, since Rio 92, new priorities have been incorporated to the sustainable management of SW. The reduction of waste at the waste generating sources and the reduction of final disposal in the ground, the maximization of reuse and recycling with the socio-productive inclusion of waste pickers in addition to composting, and energy recovery are some of the priorities in stakeholder involvement in waste management

(Arafat, Jijakli and Ahsan, 2015; Brunner and Rechberger, 2015; Wanka, Münnich and Fricke, 2017).

In addition, the engagement of one private company (ZGL), which does not have the requisite capacity, for the provision of SW collection services in all the 216 MMDAs by the MLGRD, and the inability of both the MLGRD and ZGL to disclose the contractual agreement between them for waste collection, lacks the elements of private sector involvement in waste management - competition, transparency, and accountability (Cointreau-Levine, 1994; Van de Klundert and Lardinois, 1995).

Also, the World Bank debarring Zoomlion Ghana and Zoomlion Liberia (subsidiaries of Zoomlion Company Limited) for two years, because Zoomlion Company Limited was accused of fraud and paying bribes to secure waste management contracts sponsored by the World Bank in Liberia in 2013, has created a strong perception among some SWM stakeholders that, ZGL uses corrupt practices to enjoy monopoly in SW collection in Ghana. This does not augur well for the private sector's engagement in waste management.

6.2.3 Financing MSWM

Like other developing countries the central government is the sole fancier of SWM in Ghana, though the private sector engaged in SWC recoups some money from door-to-door collection service beneficiaries. Extreme poverty and high infrastructure deficits make the government incapable of providing adequate funds for recurrent SWM activities in most developing countries (Anku, 2010). Therefore, in most developing countries, it is common for municipalities to spend 20 to 50 percent of their available recurrent budget on SWM, while 30 to 60 percent of all the urban SW remains uncollected and less than 50 percent of the population is served (Hird *et al.*, 2014).

Consequently, the WMA and other municipalities in Ghana only concentrate on SW collection and neglects other SWM activities such as waste treatment/processing and safe final disposal. Even with the concentration on only waste collection, municipal authorities concentrates on the waste collection in the high-income residential areas where the residents are more vocal in complaints about poor collection services to the detriment of poor and slum dwellers (Majale, Oosterveer and Mireri, 2013; Clark, Palfreman and Rhyn, 2015; Eduful and Shively, 2015).

However, in most developed countries, the polluter pay principle, whereby the polluter bears the expenses of carrying out the measures decided by public authorities to ensure that the environment is in an acceptable state, has provided a secure funding source for SWM (Baldock, 1992). Thus, the polluter pay principle is worth considering in Ghana and other developing countries to provide a secure and a clear source of funding for SWM.

Furthermore, MSW has become a resource and should not be seen as a mere trash, as is the case in most developing countries. There have been reports of Sweden running out of waste for processing in her WTE plants and has resorted to the importation of SW to keep the plants in operation. The management of MSW is not just a public service but also an important economic sector which can provide business and job opportunities (Courtois, 2012). Therefore, the recognition of MSW as a resource and not just a mere trash in Ghana and other developing countries can create business and employment opportunities and provide avenues for alternative sources of funding for MSWM.

6.2.4 Technical Capacity for MSWM

The technical capacity for MSWM was assessed by comparing the technical expertise and the SWM equipment disposition of the WMA and ZGL. The results indicate that both the WMA and ZGL did not have the requisite expertise and equipment disposition for effective SWM. However, there was a wide variance in the human resource base and equipment disposition between the WMA and ZGL. Whereas ZGL had some minimal waste management equipment such compactor tracks, skip trucks, tipper trucks, tractors, and manual and motorised tricycles; the WMA only had a compactor track and a skip truck.

This supports other researchers who indicated that the private sector is usually properly resource and equipped than the public sector because the private sector is able to overcome bureaucracies and source for funds to purchase the appropriate waste management equipment through loans (Busse, 2012; Courtois, 2012; Is-haque and Huysman, 2013). In contrast, the failure of the municipal authorities to consider important parameters such as waste generation rates and characteristics in the purchase of waste management equipment may lead to the breakdown of the equipment and the wastage of huge sums of money (Coad, 2011; Is-haque and Huysman, 2013; Wiesmeth and Häckl, 2017).

On the other hand, the WMA had a greater skilled workforce than ZGL. The WMA had experts in SWM such as civil engineers, public health engineers, and environmental health officers, whereas, ZGL only had a public health engineer and other support staff who were not experts in SWM. This made the municipal authorities feel that they were better placed to effectively manage waste in the municipality than ZGL. However, the evidence on the ground proved that ZGL, even without the requite expertise in MSWM has drastically improved waste collection in the Wa municipality and other MMDAs in Ghana.

6.3 Baseline Scenario of MSW Disposal

The third objective of this doctoral research was to establish a baseline scenario of MSW disposal through material flow analysis and understanding of MSW handling practices in the case study area. The results showed that there is a minimal provision of MSW disposal infrastructures such as communal collection containers, open dump sites, and house-to-house collection of waste. Usually, the generators of SW are responsible for their storage and disposal. The major challenge to effective MSW disposal in the case study area and Ghana, in general, was the non-segregation of wastes at the various generation sources and throughout the management chain, despite the dominance of recyclable materials in the waste composition, which comprised of hazardous and non-hazardous waste.

Waste segregation is the prerequisite of any waste reduction strategy and resource recovery from waste, and for proper treatment and disposal of SW. For several reasons, resource recovery is a major element in SWM in most developing countries (Badgie et al., 2012; Thaiyalnayaki and Jayanthi, 2017). Reclaimable inorganic components (metals, glass, plastic, textiles, and others) traditionally have been recovered mostly by way of unregulated manual scavenging by private individuals (informal sector) (Srivastava et al., 2015; Leal Filho *et al.*, 2016; Stoeva and Alriksson, 2017).

However, waste reduction and waste separation were not practiced by waste generators, especially in households with the authorities' seemed helpless due to the poor waste management performance militating against sustainable waste management in Ghana and the Wa municipality as discussed in section 6.2 above. Therefore, the MSW disposal in the Wa municipality included the storage of mixed MSW in a single bin, improperly disposing of waste - into bushes, by burning, and by burring in pits – some waste collection, transportation, and finally open dumping at an un-engineered disposal site, located 5km away from the municipality in a different district (the Wa West District).

This disposal system has detrimental effects on the environment, ranging from polluting natural resources and the ecology to the creation of health problems which might lead to long-term public health complications, causing a public nuisance, and degradation of the environment and aesthetics. Various pollution (air, soil, water, and landscape) due to improper waste disposal would not only affect the natural environment but also exposed the community to various diseases.

There is substantial evidence that open dumping of MSW contaminates surface and groundwater supplies in most developing countries (Vasanthi and Kaliappan, 2008; Odukoya and Abimbola, 2010; Alam and Ahmade, 2013). This occurs through leachate from MSW disposal sites and run-off that carry MSW into water bodies, which lead to rising levels of biochemical oxygen demand (BOD) in watercourses, and the presence of microbial contaminants (Henry, et al., 2006).

It takes only a small amount of leachate to contaminate a large volume of groundwater, which in turn can contaminate and affect biodiversity and enter the food chains (Bakare *et al.*, 2007; Garaj-Vrhovac, et al., 2009; Mukherjee and Mukhopadhyay, 2015). Consequently, the Ghana Water Company recently hinted of the potential increase in water price due to the increase in the cost of water treatment as a result of massive pollution of the company's water sources from various pollutants including MSW (3new.com, 2017).

Additionally, the un-engineered dumping site attracts vermin and scavenging animals and provide food and habitat for disease vectors such as rats and mosquitoes. Gastro-intestinal infections such as typhoid fever, poliovirus infection, hepatitis E infection, and cholera are often transmitted through contaminated food or water (Boadi and Kuitunen, 2005; Cabral, 2010) by these disease vectors.

Furthermore, uncontrolled burning of the MSW at the disposal site to reduce its volume contributes significantly to air pollution. MSW contains considerable hazardous components and the open MSW burning in urban areas cause direct exposure of hazardous materials to citizens (Wang *et al.*, 2017). Globally, efforts are being made to control greenhouse gas (GHG) emissions from various sources, and the waste sector is one of them (Kumar *et al.*, 2004). This is because, GHG do not only contribute to climate change but also cause respiratory infection such as asthma, cardiopulmonary diseases, and lung cancer (Bruce and Perez-Padilla, 2002; Ayres *et al.*, 2009).

Notwithstanding these, the informal material recovery by metal waste merchants and scavengers at the disposal site was helping to ameliorate the impacts of MSW and also served as a source of livelihood to some people (*Zabarma*, children and women) in the Wa municipality and neighbouring district assemblies, as recovered materials are sold to support their needs.

The operation of the informal waste collectors buttresses other researchers, who found out that resource recovery has been a major element in SWM especially in developing nations through the informal sector, where scavenging for recoverable materials is a source of livelihood for many people (Guerrero, et al., 2013; Laurent, Clavreul, *et al.*, 2014; Brunner and Rechberger, 2015).

There was no formal recycling of SW in the Wa municipality, however, like in most developing countries, a lot of recovery and recycling takes place informally in such a way that some materials do not enter the municipal waste stream (Ali and Bella, 2016). Thus, formal recovery of materials and recycling will not only reduce the quantity MSW that have to be disposed of but will also ameliorate the adverse effects of improper MSW disposal in the case study area and other developing countries.

6.4 MSW Disposal Operational Performance

The operational performance of MSW disposal in the case study area was carried out through the modelling of five MSW disposal scenarios. The results of the disposal scenarios agreed with the integrated solid waste management (ISWM) concept, where different SW disposal options are combined in a waste disposal system to ensure sustainable waste management. The five modelled scenarios were:

- Mixed MSW disposal into a sanitary landfill
- A combination of composting and sanitary landfilling
- A combination of composting, combustion, RDF, and landfilling
- A combination of source separation, composting, combustion, RDF, and landfilling

- A combination of source separation, transfer stations, composting, combustion, RDF, and landfilling

The results showed that the MSW disposal into a sanitary landfill alone produced the highest potential health effects. This is because local environmental pollution is common in landfills due to the decomposition of waste into constituent chemicals (Domingo and Nadal, 2009; Keith-Roach *et al.*, 2015). Meanwhile, sanitary landfilling is the most customary means of MSW disposal globally and is the most cost-effective system of solid waste disposal, especially in developing countries (Cointreau-Levine, 2004; Agamuthu, 2013; Tozlu, Özahi and Abuşoğlu, 2016).

However, the problems of leachate and gas (methane) emissions are difficult to mitigate during the operation and decommissioning stages of landfills (Giusti, 2009; Datta and Kumar, 2016). This explains why the sanitary landfilling modelling scenario (scenario 1) generated the highest average health impact of 1.519E-04 lbs/year.

Consequently, sanitary landfilling is rapidly diminishing in some developed countries waste management systems in recent years (Khajuria, Yamamoto and Morioka, 2010; Cullen, 2016). However, it is still the best disposal option in most developing countries (Mudhoo, et al., 2015), because the cost of sanitary landfilling is far cheaper as compared to other disposal option such as composting and incineration (Cointreau-Levine, 2004; Agamuthu, 2013). Nevertheless, this study, found the engineering cost (1,210,000 $/year) of sanitary landfilling (scenario 1) to be higher than other disposal options.

On the other hand, ISWM system (scenarios 4 and 5) produced the least engineering cost of 1,150,000 $/year. A combination of source separation, transfer stations, composting, combustion, RDF, and sanitary landfilling disposal system (scenario 5) in an ISWM system optimised the minimisation of both the engineering cost and health effects. Accordingly, the SWM systems that operate successfully in various parts of the world indicate that a single option is not suitable to handle efficiently the full array of MSW (Marshall and Farahbakhsh, 2013; Badgie, Manaf and Samah, 2016). Thus, the need for the incorporation of waste management operations and strategies in an integrated approach.

The ISWM scenarios (4 and 5) incorporated WTE technologies. However, WTE technologies have a poor historical image in most countries (Defra, 2014), because many countries have depended on landfills for many years, and due to the fact that many of the earlier WTE technologies such as incineration were disposal-only plants, which simply burned waste to reduce its volume (Arushanyan *et al.*, 2017).

Also, WTE technologies tend to be among the most expensive SWM options and require highly skilled personnel and careful maintenance (Rand, Haukohl and Marxen, 2000; Mudhoo, Somaroo and Mohee, 2015). Thus, most developing countries' waste management systems (such as Ghana) which are contending with the barriers of socio-political, technological, regulatory, financial, and human resources constraints (Bufoni, et al., 2016), may not be able to effectively implement WTE technologies in an ISWM system.

Nevertheless, WTE technologies have been practiced in many developed countries such as Japan for decades in an effort to promote SD initiatives (Kadir *et al.*, 2013; Defra, 2014). WTE technologies such as incineration do not only reduce the quantities of MSW but can provide alternative sources of energy. Therefore, it is obvious that the implementation of WTE technologies - be it small or large-scale - in some developing countries such as Ghana is inevitable soon, because WTE technologies can contribute to the reduction of the current high-power deficit which is affecting economic development in many developing countries.

Ghana does not have a regular supply of power for both domestic and industrial purposes. The country (which is engulfed with filth) has been depending mainly on hydro and fossil fuels for her energy needs, however, due to climate change, the water level in the hydro dams over the years has reduced substantially, resulting in the two hydro dams generating about half of their generation capacity. Thus, WTE technologies can produce an alternative source of energy for Ghana and other developing countries.

6.5 Summary of the Discussion of the Key Research Findings

- The MSW generation rates in the Wa municipality, Ghana and other sub-Saharan African countries are lower (less than 0.65 kg/capita/day) compared to other developing countries such as countries in Asia (1.1 kg/capita/day) (World Bank, 2012), however, this still poses a burden on the municipal budget because of the high costs associated with its management (Guerrero et al., 2013).

The organic component forms 61% of the MSW composition in Ghana (Miezah *et al.*, 2015). The organic fraction is an important component, not only because it constitutes a significant portion of the MSW stream in Ghana and other developing countries, but also because of its potentially adverse impact on public health and environmental quality if not properly treated and/or disposed of. Therefore, appropriate management technologies are required to ameliorate the negative impacts of MSW in developing countries.

- The MSW disposal management performance examination showed that Ghana has a good institutional framework, sufficient and robust legislation, existing bylaws, policies and programmes regarding waste management. However, the challenge was the non-enforcement of and non-compliance with laws and regulations governing waste management. Also, waste management financing and technical capacity for waste management were woefully inadequate.
- The current MSW disposal in the Wa Municipality and Ghana in general, consist of the collection of mixed waste or indiscriminate disposal of waste, transportation and open dumping of the collected waste without pre-treatment.
- The evaluation of MSW disposal operational performance through the scenarios analysis showed that open dumping/landfilling of waste creates copious health effects, whereas, MSW disposal in an ISWM system optimises the minimisation of health effects.

The next chapter, chapter seven, presents a developed and validated framework for planning and decision making for MSW disposal in developing countries, in order to overcome the MSW disposal challenges identified in this study.

CHAPTER SEVEN - PLANNING FRAMEWORK FOR MSW DISPOSAL DECISION-MAKING

7.0 Introduction

Many waste management technologies are available at the current time with different waste management capacities and challenges. Cities in the developing world, who usually have a limited technical capacity and analytical tools for assessing the viability of waste management technologies, are besieged by private vendors selling technologies, most of which are inappropriate (Dedinec *et al.*, 2015).

Many inappropriate waste management systems have been built in some developing countries, only to close within months of costly start-up operations (Kamali *et al.,* 2016). The variables affecting municipal authorities' decision-making on SW technology and management choices in developing countries have become more complicated, especially when consideration for sustainable waste management and SD are involved (Soltani *et al.*, 2015; ThiKimOanh *et al.*, 2015).

The waste sector is a specialised industry, with high technological standards, therefore engagement with the sector requires in-depth experience, thorough research and engineering know-how. Therefore, decision-making in SWM is a complex issue which requires clear goals, appropriate methods, and reliable data of known uncertainty (Stanisavljevic and Brunner, 2014).

The development of the planning framework that relates the key variables for MSW disposal decision-making was the fifth and last objective of the study. The framework was developed based on the findings of the other four objectives of the study, namely:

- investigation on MSW generation and characteristics (see sections 2.1.2, 4.1, and 6.1 in chapters 2, 4 and 6 respectively),
- examination of MSW management performance (see sections 2.4.1, 4.2, and 6.2 in chapters 2, 4 and 6 respectively respectively)
- assessment of baseline scenario of MSW disposal (see sections 2.2 and 2.3, 4.3, and 6.3 in chapters 2, 4 and 6 respectively respectively) and
- evaluation of MSW disposal operational performance (see sections 2.3, 2.4 and 2.5, and 6.4, in chapters 2 and 6 respectively, and chapter 5).

The key findings of these objectives, as summarised in section 6.5 of the discussion of the results chapter (chapter 6) of this thesis, present a precarious situation of MSW disposal in the case study area and other developing countries. Therefore, in order to improve upon the MSW disposal scenario in the case study area, the researcher developed a framework for MSW disposal planning and decision-making which can be applied in the context of developing countries.

The framework proposes the integration of both MSW management and operational performances evaluation to obtain a holistic environmental performance (which is currently non-existent in the case study area and many other developing countries) to aid decision-makers to base their MSW disposal planning and decision-making on the environmental exchanges of the disposal system.

7.1 Conceptual Formulation of the Developed Framework

The developed framework consists of three main pillars of SWM elements: MSW generation and characteristics, the baseline scenario of MSW disposal, and MSW disposal environmental performance, as illustrated in Figure 7.1. There is a continuous-reversal sequence and an intrinsic relation between the three pillars, with equal importance placed on each pillar in the developed framework.

7.1.1 MSW Generation and Characteristics

This study and other researchers indicate that accurate prediction of MSW generation and knowledge of the waste characteristics provide the basic data on which a waste management system is planned, designed, and operated (Chen and Chang, 2000; Sharholy *et al.*, 2008; Miezah *et al.*, 2015; Abbasi and Hanandeh, 2016; Asante-Darko, Adabor and Amponsah, 2017). Sound waste management and optimisation of resource recovery from waste, equally, require reliable data on the generation rates and characteristics of waste (White et al., 2012; Williams, 2013; Edjabou *et al.*, 2015).

Thus, the MSW generation rates and characteristics, which depend on urban population, economic development, consumption rate, geographic location, and administrative systems (Wang and Nie, 2001; Dyson and Chang, 2005), have a direct impact on the baseline scenario of MSW disposal in a location. MSW disposal activities include MSW segregation at the point of generation, MSW reduction, storage, collection, transportation, processing/treatment, and final disposal.

Also, the adequate knowledge of the MSW generation and characteristics, assist in the formulation of targets for waste reduction and material recovery. These reduce the environmental effects of MSW and lead to the overall improvement of MSW disposal environmental performance (emissions from MSWM activities).

Furthermore, the handling and processing/treatment (operational performance) of organic and inorganic waste are quite different. For instance, WTE technologies such as incineration are not appropriate for the processing/treatment of organic waste which are high in moisture content, since the moisture content influences the calorific value of waste (Zhao *et al.*, 2014; Tom, et al., 2016). Thus, organic and inorganic MSW produce different environmental impacts, which in turn influence the overall MSW disposal environmental performance differently, especially MSW disposal operational performance (emissions).

On the other hand, MSW disposal environmental performance, particularly MSW management performance indicators such as policy, legal, institutional, and financial arrangements for SWM also affect MSW generation and characteristics. For instance, the enforcement of and compliance with SWM policies, regulation, and laws will determine the quantity and composition of MSW generated (in a particular location).

7.1.2 Baseline Scenario of MSW Disposal

The baseline scenario of MSW disposal include the handling practices of MSW, such as waste segregation, storage, collection, transfer/transport and processing/treatment, and the attitude of waste management stakeholders (waste generators, regulators, and service providers). The baseline scenario of MSW disposal depends on the MSW generation and characteristics and stimulates the overall MSW disposal environmental performance and vice-versa.

Effective waste management laws enforcement compels waste generators, especially households to comply with waste management laws and regulations, such as segregation of SW at the generation point. Waste segregation is the first step in material recovery from waste and waste reduction programmes. Material recovery from waste usually leads to a reduction in the quantity of MSW that has to be properly disposed of, and this eventual improves the overall MSW disposal environmental performance.

7.1.3 MSW Disposal Environmental Performance

The efficient operation of SWM systems (operational performance) is dependent on good MSW streams analysis and accurate predictions of SW quantities, the baseline scenario of MSW disposal, and good MSWM performance. For instance, the equipment used for waste management must match with the composition, quantities and qualities of waste delivered to waste management facilities, the local climatic conditions and the potential demand for products derived from waste (Mutz *et al.,* 2017).

MSW disposal environmental performance evaluation integrates environmental and human health risks in the assessment process, consequently ensuring that new policies are adopted by decision-makers under the concept of continuous improvement of waste management systems (Scipioni *et al.*, 2008). As discussed in section 2.4 of the literature review chapter (chapter two) of this thesis, waste management environmental performance is divided into two components: management performance (MP) and operational performance (OP).

MP indicators are generally related to the sustainability aspects (social indicators), which are the governance features (institutional, political, and financial issues) and the various groups of stakeholders involved in waste management, as discussed in sections 4.2 and 6.2 of the results presentation and discussion of research results chapters respectively, whereas the OP indicators are usually concerned with the physical system and its technological components, with more focus on the environmental sustainability (environmental indicators, such as emissions) aspect of the system, as discussed in chapter 5 of this thesis.

Thus, MSW disposal environmental performance covers not only operational aspects, such as the handling, transfer, transport, separation, processing, and disposal of waste, but also aspects on public perception, environmental, economic, and social issues. Waste management activities are apparently impossible to implement without high consciousness within the communities as well as a strong commitment and support from waste management authorities. Thus, a good/bad MSW disposal environmental performance depends on the MSW generation and characteristics, and the baseline scenario of MSW disposal.

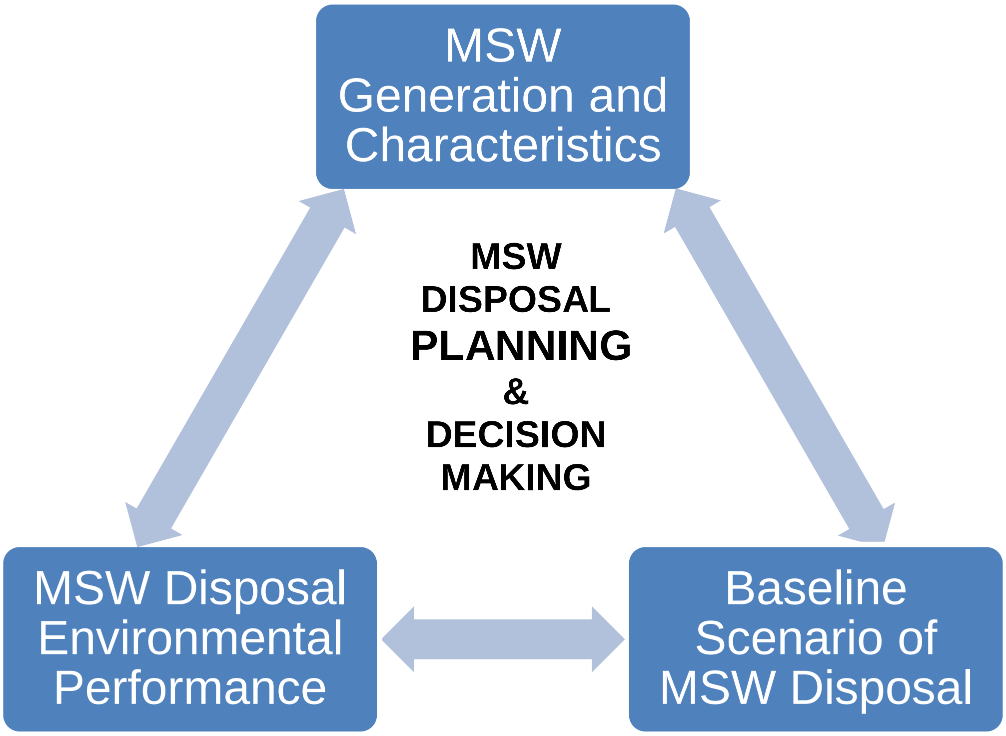

Figure 7.1: Planning framework for MSW disposal decision-making

7.2 Framework Validation

Senior staff of Ghana's EPA (regulators of waste management) in the Upper West Region (UWR) of Ghana, and a municipal engineer each (in a focused group) in *Wa*, *Lawra*, *Jirapa* and *Sissala East* municipalities in *UWR, Ghana*, were engaged to validate the developed framework. Given that, the best practice in managing SWM is through an ISWM system, and waste management regulators (such as EPA in Ghana) and service providers (local authorities) are solely responsible for MSW disposal decision-making in most developing countries, it was essential for the staff of EPA and municipal waste engineers to confirm or challenge the findings.

Thus, waste management regulators and service providers were selected to validate the framework in order to assess the theoretical perspectives of the framework. This ensured that the developed framework is theoretically fit for the purpose and provides a theoretical standpoint for the concept of MSW disposal and contributes to theories in ISWM. Answers to the framework validation questions are presented in Table 7.1 and the framework validation questionnaire is attached as Appendix G of this thesis.

Table 7.1: Findings from framework validation

Question	Responses	
	EPA	Municipal Engineers
How important are all the elements of the framework to effective MSW disposal?	Very important	Very important
How easy is it to understand the framework?	Arrows show a continuous sequence of the relationship between the elements of the framework	Explanation of the elements of the framework makes it easily understandable
To what extent will you say this framework is adequate for effective MSW disposal decision-making?	Very adequate	For MSW disposal, the framework is adequate but how the MSW generation and characteristics will be determined is challenging in the current circumstances
To what extent is this framework logical?	Logical	Very logical
Do the elements suggested in the framework address MSW disposal problems?	Yes	Yes
How transferrable is this framework to other MSWM activities?	It is transferable	Very transferable
What do you consider as the strengths and weakness of the framework?	Strength: sequence relationship and vivid description of elements Weakness: how to easily determine the adequacy of the framework elements	Strength: it is quite simple Weakness: needs resources to implement
What can be added to and/or removed from the framework?	Add: details of the framework elements Remove: nothing	Add: nothing Remove: nothing

From the answers in Table 7.1, the validators of the framework agreed that elements of the framework are very important to effective MSW disposal and MSWM in general.

They also approved that the framework is logical, addresses MSW disposal problems, adequate, and transferable to locations and other MSWM challenges. However, there was a suggestion by EPA validators that the details of the elements of the framework (MSW generation and characteristics, the baseline scenario of MSW disposal, and MSW disposal environmental performance), should be added to the framework. Thus, the researcher added the details of the elements of the framework as suggested by the EPA validators and produced the validated framework for MSW disposal planning and decision-making in developing countries, as shown in Figure 7.2.

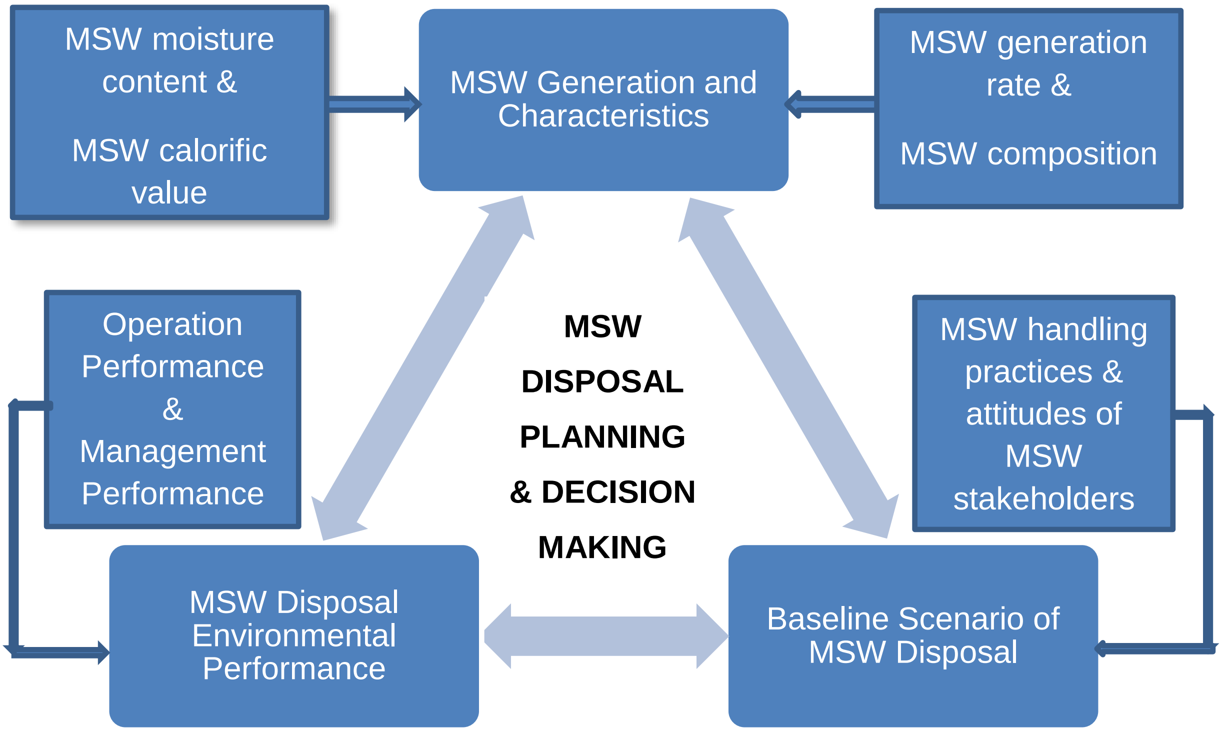

Figure 7.2: Validated planning framework for MSW disposal decision-making

This framework can assist waste management decision-makers to take the guesswork out of decisions for waste management planning in developing countries, as the framework incorporates a better picture of how a current waste management system works and what effects changes could have, through an integrated environmental performance evaluation. Thus, the application of this framework has the potential to increase the level of decision-makers' awareness of the environmental burdens of MSW disposal and possibly lead to the reduction of the future undesirable environmental effects of MSW disposal in developing countries.

7.3 Conclusion on the Developed and Validated Framework

Concerns of sustainable development (SD) has made improving MSWM, especially in developing countries, prominent in the current time. Consequently, the United Nations (UN) General Assembly, included MSWM in the 2030 Agenda for SD. The specific goals which focus on waste management include:

- sustainable development goal (SDG) 11 - "*Make cities and human settlements inclusive, safe, resilient and sustaina*ble". This is properly delineated in target 11.6:

  "By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.

- SGD 12 – "*Ensure sustainable consumption and production patterns",* and appropriately outlined in targets:
  12.2 - "*By 2030, achieve the sustainable management and efficient use of natural resources",*
  12.3 – "*By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses"*
  12.4 – "*By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment"*, and
  12.5 – "*By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse".*

(UN, 2015).

Therefore, this developed and validated framework for MSW disposal planning and decision-making, with its three main pillars (accurate prediction of MSW generation rates and characteristics, a good knowledge of the baseline scenario of MSW disposal, and a good MSW disposal environmental performance), has the potential of contributing to the attainment of the above mentioned targets and some of the other 2030 SDGs, through the improvement of planning and decision-making for MSW disposal in developing countries.

Chapter eight, which is the next and the concluding chapter of this thesis, presents the research conclusion on each research objective, together with the research limitations, and the research implications for policy, practice, theory, and further research.

CHAPTER EIGHT – CONCLUSION AND IMPLICATIONS

8.0 Introduction

This study sought to answer the primary research question:

> "*How can MSW disposal be improved in developing countries with similar circumstances and MSW problems as Ghana*"?

This was translated into the main research aim as:

> "*to improve planning and decision-making for MSW disposal in developing countries with similar circumstances and MSW problems as Ghana*".

The research aim was achieved through five objectives, namely, to:

1. Investigate MSW generation and characteristics reported in literature and official documents
2. Examine MSW disposal management performance
3. Establish a baseline scenario of MSW disposal
4. Evaluate MSW disposal operational performance
5. Develop a planning framework for MSW disposal decision-making in developing countries

These objectives were achieved through the review of relevant literature presented in chapter two of this thesis and through the adoption of appropriate research methodologies discussed in chapter three of this thesis. This chapter presents the research conclusion on each of the five objectives, the research limitations, the research implications for policy, practice, theory, and further research.

8.1 The Research Conclusion

This research contributes to the strategic process of improving planning and decision-making for MSW disposal in developing countries. This section concludes this doctoral thesis with highlights on the key findings of each research objective.

8.1.1 MSW Generation and Characteristics

The literature review for this study (chapter two) indicate that the global MSW generation rates are rising exponentially due to the increasing global population and improvement in living standards, and that the increasing waste generation rates is further exacerbating the problems of MSWM in developing countries such as Ghana, which are currently struggling with ineffective SWM systems due to the lack of the enabling environment for effective waste management.

The research results also indicate that organic fraction forms the highest (over 60%) of the MSW stream in Ghana and other developing countries. The organic fraction is an important component, not only because it constitutes a significant portion of the MSW stream in Ghana and other developing countries, but also because of its potentially adverse impact on public health and environmental quality if not properly treated and/or disposed of. This beckon the adoption of appropriate management technologies to ameliorate the impact of MSW in Ghana and other developing countries.

8.1.2 MSW Disposal Management Performance

The policy and legal framework, institutional arrangement, the financial arrangement, and technical capacity required for the effective functioning of a waste management system, were set as the key indicators for the MSW disposal management performance examination in this study. The research results indicate that Ghana has a good institutional framework, sufficient and robust legislation, existing bylaws, policies and programmes regarding waste management, however, there is non-enforcement of, and non-compliance with laws governing waste management.

Also, stakeholders' involvement in waste management is limited only to waste collection. There is private sector involvement in waste management, which has drastically improved waste collection in most parts of Ghana, nevertheless, the private sector engagement lacks the elements of competition, transparency, and accountability. This has led to dissatisfaction with the private sector engagement in waste collection in some municipalities in Ghana.

Additionally, waste management financing is woefully inadequate because of the over-reliance on central government, and the lack of budget sources for waste management financing, coupled with a poor technical capacity for effective MSW disposal due to the inadequate technical skills and equipment disposition of both the local authority and the private sector engaged in SWC. Therefore, the current scenario of waste management performance does not present an enabling environment for effective MSW disposal and thus, needs improvement for the attainment of waste management goals in Ghana and other developing countries.

8.1.3 Baseline Scenario of MSW Disposal

The current MSW disposal in the Wa Municipality (the case study area) consists of indiscriminate disposal of waste, some waste collection, transportation and open dumping, where the entire amount of waste is open dumped without pre-treatment. There is a minimal provision of MSW disposal infrastructures such as communal collection containers, open dump sites, and house-to-house collection of SW. The major challenge to effective MSW disposal in Ghana and other developing countries is the non-segregation of wastes at the various generation sources and throughout the waste management chain, despite the dominance of recyclable materials in the waste composition, which comprised of hazardous and non-hazardous waste.

Consequently, mixed MSW is stored in a single bin or improperly disposed of (into bushes, by burning, and by burring in pits), collected by door-to-door collection service or via communal containers located at vantages points in the communities, transported, and finally openly dumped at an un-engineered disposal site. This disposal system has detrimental effects on the environment, ranging from polluting natural resources and the ecology to the creation of health problems which might lead to long-term public health complications, causing a public nuisance, and degradation of the environment and aesthetics.

However, informal material recovery by metal waste merchants and scavengers are ameliorating the impact of MSW and serves as a source of livelihood to some people. There is no formal recovery or recycling of waste, however, like in most developing countries, a lot of recovery takes place informally in such a way that some materials do not enter the municipal waste stream (Ali and Bella, 2016). Thus, waste segregation at the point of generation, formal recovery of materials and recycling will not only reduce the quantity of MSW that have to be disposed of but will also reduce the adverse effects of improper MSW disposal in Ghana and other developing countries.

8.1.4 MSW Disposal Operational Performance

The operational performance of MSW disposal in the case study area was carried out through the modelling of five MSW disposal scenarios. The results showed that improper disposal of waste and finally disposing of MSW into an un-engineered landfill, and sanitary landfilling only (scenario 1) generate severe health effects, whereas, disposing of MSW in an ISWM system (scenario 5), optimises the minimisation of environmental effects.

Many developing countries, including Ghana, are engulfed with filth and do not have a regular supply of power for both domestic and industrial purposes. The adoption of an ISWM concept, including WTE technologies will not only help to solve the MSW disposal menace but can also produce alternative sources of energy in many developing countries.

8.1.5 Planning Framework for MSW Disposal Decision-Making

The development of the planning framework for MSW disposal decision-making was the fifth and last objective of this doctoral research and was based on the findings of the other four objectives of the study discussed above. Thus, this research led to the development and validation of a planning framework for MSW disposal decision-making, which shows the continuous sequence and an intrinsic relation between three pillars of SWM elements (MSW generation and characteristics, baseline scenario of MSW disposal, and MSW disposal environmental performance), for improving planning and decision-making for MSW disposal in the context of developing countries.

The developed and validated framework has the potential of contributing to the attainment of target 11.6 of the 2030 SDGs and some of the other SDGs through the improvement of MSW disposal in developing countries.

8.2 Research Limitations

This researcher acknowledges the following limitations in this study:

- The study applied Ghana and Wa municipality waste characterisation data available in literature in the modelling and analysis but could not determine the data quality.
- The scenarios modelling relied on some default data in the MSW DST model because of the non-availability of some site-specific data from Ghana and the Wa municipality. The default data used may be different from the data in the case study area, which may affect the quality of the results of the modelled scenarios.
- The fieldwork for the study was carried out in the case study area during the dry season due to the researcher's visa restriction (tier 4) of not staying more than five months outside the UK and a limited budget for data collection. Thus, the baseline scenario of MSW disposal undertaken in this study was a scenario for only dry seasons, however, the raining season could present a different baseline scenario, because MSW generation rates and characteristics, and the

handling practices vary between the dry and the raining seasons in most developing countries.

- The developed framework was validated with a focused group only in the Upper West Region of Ghana because the researcher could not secure funding to cover other regions in Ghana for the framework validation.

8.3 Research Implications for Policy

The research implications for policy that this study identifies are:

- There is non-enforcement of, and non-compliance with laws governing waste management in Ghana. Therefore, there is the urgent need for stringent enforcement of policies, regulation, and laws governing SWM for the achievement of waste management goals in Ghana and other developing countries.
- Private sector engagement in MSW collection in Ghana, lacks the elements of competition, transparency, and accountability. Thus, the processes for the engagement of the private sector in SW collection should be reviewed and the elements of competition, transparency, and accountability introduced to ensure good governance in the private sector's involvement in SW collection in Ghana.
- Informal material recovery from waste has ameliorated MSW disposal impacts and serves as a source of livelihood for some people, especially women and children. Thus, both formal and informal material recovery from MSW present business and job opportunities in Ghana and other developing countries and should be harnessed to create job opportunities for the teeming unemployed youth in Ghana and other developing countries.

8.4 Research Implications for Practice

The research implications for practice that this study produced are:

- There is too much institutional fragmentation for SWM in Ghana because many institutions are involved in the sector. Many institutions renege on their responsibility on a SWM problem thinking that another institution will tackle the problem, as there is confusion (in practice) about who is responsible. Thus, all the institutions involved in SWM should have clear distinct roles to avoid conflicts/confusion over their operations.
- MSWM financing is woefully inadequate in Ghana since the government is the sole financier of waste management. The polluter pays principle should be

introduced in Ghana and other developing countries to provide a secure and a clear source of funding for SWM.

- The technical capacity for MSWM of both the local authority and the private sector in Ghana is inadequate. Thus, there is the need for the purchase of the requisite SWM equipment and upskilling of the technical expertise of SWM service providers (the local assembly and private sector) in Ghana and other developing countries.

8.5 Research Implications for Theory

This doctoral research contributes to the strategic process of improving planning and decision-making for MSW disposal in developing countries, through the evaluation of MSW disposal environmental performance in the case study area. The developed and validated framework has bridged the gap of the non-existence of planning frameworks that relate key variables for MSW disposal decision-making in most developing countries. Theoretically, this research through the developed and validated framework provides a theoretical standpoint for the concept of MSW disposal in ISWM.

Also, the developed and validated framework, with its three main pillars (accurate prediction of MSW generation rates and characteristics, a good knowledge of the baseline scenario of MSW disposal, and a good MSW disposal environmental performance), contributes to the process that MSWM can possibly contribute to the attainment of targets 11.6, 12.2, 12.3, 12.4 and 12.5, and some of the other 2030 SDGs, through the improvement of planning and decision-making for MSW disposal in developing countries.

8.6 Research Implications for Further Research

This research has addressed planning and decision-making for MSW disposal in developing countries, using Wa Municipality in Ghana as a case study, and developed and validated a planning framework for MSW disposal decision-making in the context of developing countries. The research processes raised a few questions and areas that require further research within academia, industry, and local authorities responsible for MSWM. The following areas are identified for further research:

- Appropriate MSW disposal technologies for developing countries. The increasing generation rates of MSW coupled with the high organic waste component in developing countries call for research on appropriate waste management technologies, because of the potential adverse impact on public health and environmental quality if organic waste is not properly treated and/or disposed of.

- MSW characterisation and utilisation. The utilisation of MSW in a sustainable way, such as for energy production, has been implemented widely in many developed countries but the utilisation of MSW is very limited in most developing countries. Research on the utilisation of MSW in developing countries could lead to energy recovery from waste, sustainable waste management, and the creating of business and job opportunities.
- Application of capital efficiency in MSWM. Prudent management of investment in assets and payment management are essential for the long-term success of MSWM infrastructure. Therefore, research on the application of capital efficiency in MSWM, through a better understanding of SWM assets, their value and performance, can create opportunities for capital and operational efficiencies in MSWM in developing countries.

REFERENCES

3new.com (2017) *Water prices to go up – Ghana Water Company*, *General News*. Available at: https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Water-prices-to-go-up-Ghana-Water-Company-516614 (Accessed: 13 September 2017).

Abbasi, M., Abduli, M.A., Omidvar, B. and Baghvand, A., (2012) 'Forecasting municipal solid waste generation by hybrid support vector machine and partial least square model', *International Journal of Environmental Research*, 7(1), pp. 27–38.

Abbasi, M. and Hanandeh, A. El (2016) 'Forecasting municipal solid waste generation using artificial intelligence modelling approaches', *Waste Management*, 56, 13–22.

Abiti, B., Hartard, S. and Bradl, H. (2017) 'Resource Prospects of Municipal Solid Wastes Generatedin the Ga East Municipal Assembly of Ghana', *Journal of Health and Pollution*, 7(14), 37–47.

Acharya, A.S., Prakash, A., Saxena, P. and Nigam, A., (2013) 'Sampling: Why and how of it', *Indian Journal of of Medical Specialties*, 4(2), 330–333.

Achillas, C., Moussiopoulos, N., Karagiannidis, A., Banias, G. and Perkoulidis, G., (2013) 'The use of multi-criteria decision analysis to tackle waste management problems: a literature review', *Waste management & research : the journal of the International Solid Wastes and Public Cleansing Association, ISWA*, 31(2), 115–129. doi: 10.1177/0734242X12470203 [doi].

Adam, B., Adam, D. and Hussein, A. (2016) 'The Factors that Affecting on Solid Waste Generation in Zalingy Town – Central Darfur State', *World Journal of Engineering Research and Technology* , 2(6), 71–80.

Adler, P. A. and Adler, P. (1994) 'Observational techniques', *Handbook of qualitative research*, 1(3), pp. 377–392.

Adu, R. and Lohmueller, R. (2012) 'The Use of Organic Waste as an Eco-Efficient Energy Source in Ghana', *Journal of Environmental Protection*, 3(7), 553–562. doi: 10.4236/jep.2012.37066.

Aduah, M. and Aabeyir, R. (2012) 'Land Cover Dynamics in Wa Municipality, Upper West Region of Ghana', *Research Journal of Environmental and Earth Sciences*, 4(6), 658–664.

African Development Bank (2013) *African Development Report 2012: Towards Green Growth in Africa*. Tunis-Belvedere, Tunisia.

Agamuthu, P. (2012) ‘Waste Management and Recycling Performance Indicators: Priorities and Challenges Content’. Kuala Lumpur: University of Malaya.

Agamuthu, P. (2013) ‘Landfilling in developing countries’, *Waste management & research : the journal of the International Solid Wastes and Public Cleansing Association, ISWA*, 31(1), 1–2. doi: 10.1177/0734242X12469169 [doi].

Agbor, V., Carere, C., Cicek, N., Sparling, R. and Levin, D., (2014) ‘Biomass pretreatment for consolidated bioprocessing (CBP)’, in *Advances in biorefineries.Woodhead Publishing, Sawston*, pp. 234–258.

Aglanu, L. M. and Appiah, D. O. (2014) ‘The Korle Lagoon in Distress : The Stress of Urban Solid Waste on Water Bodies in Accra , Ghana’, *International Journal of Innovation and Applied Studies ISSN*, 7(2), 717–728.

Ahmad, W.M.A.W., Amin, W.A.A.W.M., Aleng, N.A. and Mohamed, N., (2012) ‘Some practical guidelines for effective sample-size determination in observational studies’, *Aceh International Journal of Science and Technology*, 1(2), 51–53.

Akhtar, M. N. (2014) ‘Prospective Assessment for Long-Term Impact of Excessive Solid Waste Generation on the Environment’, *International Journal Of Advancement In Earth And Environmental Sciences*, 2(2), 39–45.

Al-Khatib, I.A., Kontogianni, S., Nabaa, H.A. and Al-Sari, M.I., (2015) ‘Public perception of hazardousness caused by current trends of municipal solid waste management’, *Waste Management*, 36, 323–330.

Al-Rawi, S. M. and Al-Tayyar, T. A. (2013) ‘A Study on Solid Waste Composition and Characteristics of Mosul City/Iraq’, *Journal of University of Zakho*, 1(2), 496–507.

Alam, P. and Ahmade, K. (2013) ‘Impact of Solid Waste on Health and the Environment’, *International Journal of Sustainable Development and Green Economics (IJSDGE)*, 2(1), 165–168.

Aleluia, J. and Ferrão, P. (2016) ‘Characterization of urban waste management practices in developing Asian countries: A new analytical framework based on waste characteristics and urban dimension’, *Waste Management*, 58, 415–429.

Alhassan, A. R., Gabbay, O., Arguello, J. E. M. and Boakye-Boaten, N. A., (2010) *Solid Waste Composition Aryee Diki Electoral Area, Ayawaso Central Submetro, Accra New Town*. Accra.

Ali, M. and Bella, V. Di (2016) *Topic Guide: Solid Waste Managment*. doi: http://dx.doi.org/10.12774/eod_tg.april2016.alimetal.

Ali, S.M., Pervaiz, A., Afzal, B., Hamid, N. and Yasmin, A., (2014) 'Open dumping of municipal solid waste and its hazardous impacts on soil and vegetation diversity at waste dumping sites of Islamabad city', *Journal of King Saud University-Science*, 26(1), 59–65.

Aljaradin, M. and Persson, K. (2012) 'Environmental impact of municipal solid waste landfills in semi-arid climates-case study–Jordan', *The Open Waste Management Journal*, 5(1), 28–39.

Alqader, A. A. and Hamad, J. (2012) 'Municipal solid waste composition determination supporting the integrated solid waste management in Gaza strip', *International Journal of Environmental Science and Development*, 3(2), 172.

Amann, E. and Anderson, I. (2014) 'Development and validation of a questionnaire for hearing implant users to self-assess their auditory abilities in everyday communication situations: the Hearing Implant Sound Quality Index (HISQUI 19)', *Acta Oto-Laryngologica*, 134(9), 915–923. doi: 10.3109/00016489.2014.909604.

Andreadou, C. (2016) '*Modelling of Energy Production from Alternative Fuels*'.

Angen, M. (2000) 'Evaluating interpretive inquiry: Reviewing the validity debate and opening the dialogue', *Qualitative health research*, 10(3), 378–395.

Anku, K. S. (2010) *National Report for Ghana: Waste Management in Ghana*.

Ansah, E., Wang, L. and Shahbazi, A. (2016) 'Thermogravimetric and calorimetric characteristics during co-pyrolysis of municipal solid waste components', *Waste Management*. doi: http://dx.doi.org/10.1016/j.wasman.2016.06.015.

Antonopoulos, I.S., Perkoulidis, G., Logothetis, D. and Karkanias, C., (2014) 'Ranking municipal solid waste treatment alternatives considering sustainability criteria using the analytical hierarchical process tool', *Resources, Conservation and Recycling*, 86, 149–159. doi: http://dx.doi.org/10.1016/j.resconrec.2014.03.002.

Antwi, S. and Hamza, K. (2015) 'Qualitative and quantitative research paradigms in business research: A philosophical reflection', *European Journal of Business and Management*, 7(3), 217–225.

Appasamy, P. P. and Nelliyat, P. (2007) 'Financing Solid Waste Management: Issues and Options', in *The International Conference on Sustainable Solid Waste Management*. Chennai, India, 537–542.

Arafat, H. A., Jijakli, K. and Ahsan, A. (2015) 'Environmental performance and energy recovery potential of five processes for municipal solid waste treatment', *Journal of Cleaner Production*. Elsevier Ltd, 105, 233–240. doi: 10.1016/j.jclepro.2013.11.071.

Arber, S. (2001) 'Designing samples', in *Researching social life*, 2, pp. 58–82.

Ardolino, F., Berto, C. and Arena, U. (2017) 'Environmental performances of different configurations of a material recovery facility in a life cycle perspective.', *Waste management*, 68, 662–676. doi: 10.1016/j.wasman.2017.05.039.

Arena, U. (2012) 'Process and technological aspects of municipal solid waste gasification. A review', *Waste Management*, 32(4), 625–639. doi: http://dx.doi.org/10.1016/j.wasman.2011.09.025.

Arena, U., Ardolino, F. and Di Gregorio, F. (2015) 'A life cycle assessment of environmental performances of two combustion- and gasification-based waste-to-energy technologies', *Waste Management*. Elsevier Ltd, 41, 60–74. doi: 10.1016/j.wasman.2015.03.041.

Arena, U. and Gregorio, F. Di (2014) 'A waste management planning based on substance flow analysis', *Resources, Conservation and Recycling*, 85, 54–66.

Arena, U., Mastellone, M. L. and Perugini, F. (2003) 'The environmental performance of alternative solid waste management options: a life cycle assessment study', *Chemical Engineering Journal*, 96, 207–222. doi: 10.1016/j.cej.2003.08.019.

Arushanyan, Y., Björklund, A., Eriksson, O., Finnveden, G., Ljunggren Söderman, M., Sundqvist, J.O. and Stenmarck, Å., (2017) 'Environmental Assessment of Possible Future Waste Management Scenarios', *Energies*, 10(2), 1–27. doi: 10.3390/en10020247.

Asante-Darko, D., Adabor, E. S. and Amponsah, S. K. (2017) 'Forecasting solid waste generation: a Fourier series approach', *International Journal of Environment and Waste Management*, 19(4), 318–337.

Asomani-Boateng, R. (2016) 'Local Networks Commodity Queens and the Management of Organic Solid Waste in Indigenous Open-Air Markets in Accra, Ghana', *Journal of Planning Education and Research*, 36(2), 182–194.

Assefa, G., Björklund, A., Eriksson, O. and Frostell, B., (2005) 'ORWARE: an aid to environmental technology chain assessment', *Journal of Cleaner Production*, 13(3), 265–274.

Austrialian Capital Territory (ACT) (2011) *ACT Waste Management Strategy Towards a sustainable Canberra reducing waste and recovering resources to achieve a sustainable, carbon-neutral Canberra: 2011–2025*.

Awortwi, N. (2006) 'Technology and institutional arrangements in the delivery of public sanitation and solid waste services in Ghanaian cities', *International Journal of Technology Management & Sustainable Development*, 5(3), 221–239. doi: 10.1386/ijtm.5.3.221/1.

Aydiner, C., Sen, U., Koseoglu-Imer, D.Y. and Dogan, E.C., (2016) 'Hierarchical prioritization of innovative treatment systems for sustainable dairy wastewater management', *Journal of Cleaner Production*, 112, 4605–4617.

Ayres, J.G., Forsberg, B., Annesi-Maesano, I., Dey, R., Ebi, K.L., Helms, P.J., Medina-Ramon, M., Menne, B., Windt, M. and Forastiere, F., (2009) 'Climate change and respiratory disease: European Respiratory Society position statement', *European Respiratory Journal*, 34(2), 295–302.

Ayuba, K.A., Manaf, L.A., Sabrina, A.H. and Azmin, S.W.N., (2013) 'Current Status of Municipal Solid Waste Management Practise in FCT Abuja', *Research Journal of Environmental and Earth Sciences*, 5(6), 295–304. doi: 10.1504/IJEWM.2013.055592.

Baabereyir, A. (2009) *Urban Environmental Problems in Ghana: a Case Study of Social and Environmental Injustice in Solid Waste Management in Accra and Sekondi-Takoradi*. University of Nottingham.

Babaei, A.A., Alavi, N., Goudarzi, G., Teymouri, P., Ahmadi, K. and Rafiee, M., (2015) 'Household recycling knowledge, attitudes and practices towards solid waste management', *Resources, Conservation and Recycling*. Elsevier, 102, 94–100. doi: 10.1016/J.RESCONREC.2015.06.014.

Babayemi, J., Ogundiran, M. and Osibanjo, O. (2016) 'Overview of Environmental Hazards and Health Effects of Pollution in Developing Countries: A Case Study of Nigeria', *Environmental Quality Management*, 26(1), 51–71.

Badgie, D., Samah, M.A.A., Manaf, L.A. and Muda, A.B., (2012) 'Assessment of Municipal Solid Waste Composition in Malaysia: Management, Practice, and Challenges', *Polish Journal of Environmental Studies*, 21(3), 539–547.

Badgie, D., Manaf, L. A. and Samah, M. A. A. (2016) 'Municipal Solid Waste Generation and Composition in the Kanifing Municipal Council Area (KMC) -The Gambia.', *Journal of Solid Waste Technology & Management*, 42(1).

Bakare, A.A., Pandey, A.K., Bajpayee, M., Bhargav, D., Chowdhuri, D.K., Singh, K.P., Murthy, R.C. and Dhawan, A., (2007) 'DNA Damage Induced in Human Peripheral Blood Lymphocytes by Industrial Solid Waste and Municipal Sludge Leachates', *Environmental and Molecular Mutagenesis*, 48(1), 30–37.

Baker, R., Brick, J.M., Bates, N.A., Battaglia, M., Couper, M.P., Dever, J.A., Gile, K.J. and Tourangeau, R., (2013) 'Summary report of the AAPOR task force on non-probability sampling', *Journal of Survey Statistics and Methodology*, 1(2), 90–143.

Baldock, D. (1992) 'The Polluter Pays Principle And Its Relevance To Agricultural Policy In European Countries', *Sociologia Ruralis*. Wiley/Blackwell (10.1111), 32(1), 49–65. doi: 10.1111/j.1467-9523.1992.tb00918.x.

Ballardo, C., Abraham, J., Barrena, R., Artola, A., Gea, T. and Sánchez, A., (2016) 'Valorization of soy waste through SSF for the production of compost enriched with Bacillus thuringiensis with biopesticide properties', *Journal of environmental management*, 169, 126–131.

Baloyi, M.O., Sehaswana, M.D., Maringa, M.M., Sibande, M.J., Oelofse, S., Schubert, M.M., Swanepoel, M.H., Godfrey, L., Wakaba, L., Muswema, M.A. and Graasbøll, S., (2012) *National Waste Information Baseline Report*, *DEA Project Team*. Pretoria.

Banerjee, A., Duflo, E., Glennerster, R. and Kinnan, C., (2015) 'The miracle of microfinance? Evidence from a randomized evaluation', *American Economic Journal:*

Applied Economics, 7(1), 22–53.

Banful, A. B. (2009) *Operational Details of the 2008 Fertilizer Subsidy in Ghana—Preliminary Report*.

Bardos, R.P., Jones, S., Stephenson, I., Menger, P., Beumer, V., Neonato, F., Maring, L., Ferber, U., Track, T. and Wendler, K., (2016) 'Optimising value from the soft re-use of brownfield sites', *Science of the Total Environment*, 563(564), 769–782.

Barlett, J. E., Kotrlik, J. W. and Higgins, C. C. (2001) 'Organizational research: Determining appropriate sample size in survey research', *Information technology, learning, and performance journal*, 19(1), 43.

Barley, S. R. (1986) 'Technology as an occasion for structuring: Evidence from observations of CT scanners and the social order of radiology departments', *Administrative Science Quarterly*, 78–108.

Barr, S. (2017) 'Environment and Waste', in *The International Encyclopedia of Geography*.

Barriball, K. L. and While, A. (1994) 'Collecting Data using a semi-structured interview: a discussion paper', *Journal of advanced nursing*, 19(2), 328–335.

Behera, S., Arora, R., Nandhagopal, N. and Kumar, S., (2014) 'Importance of chemical pretreatment for bioconversion of lignocellulosic biomass', *Renewable and Sustainable Energy Reviews*, 36, 91–106.

Bello, O., Jolayemi, O., Akinwande, V. and Ibrahim, A., (2015) 'Open Data Portals in Africa An Empirical Analysis of Open Government Data Initiatives'.

Benavente, V., Fullana, A. and Berge, N. (2017) 'Life cycle analysis of hydrothermal carbonization of olive mill waste: Comparison with current management approaches', *Journal of Cleaner Production*, 42, 2637–2648.

Benbasat, I., Goldstein, D. K. and Mead, M. (1987) 'The case research strategy in studies of information systems', *MIS quarterly*, 369–386.

Beneroso, D., Bermúdez, J.M., Arenillas, A. and Menéndez, J.A., (2014a) 'Influence of the microwave absorbent and moisture content on the microwave pyrolysis of an organic municipal solid waste', *Journal of Analytical and Applied Pyrolysis*, 105, 234–

240. doi: http://dx.doi.org/10.1016/j.jaap.2013.11.009.

Beneroso, D., Bermúdez, J.M., Arenillas, A. and Menéndez, J.A., (2014b) ‘Integrated microwave drying, pyrolysis and gasification for valorisation of organic wastes to syngas’, *Fuel*, 132, 20–26.

Berg, B.L., Lune, H. and Lune, H., (2004) '*Qualitative research methods for the social sciences',* (Vol. 5). Boston, MA: Pearson

Bhada-Tata, P. and Hoornweg, D. (2016) ‘Solid Waste and Climate Change’, in *State of the World*. Island Press/Center for Resource Economics, pp. 239–255.

Bhander, G., Christensen, T. and Hauschild, M. (2010) ‘EASEWASTE—life cycle modeling capabilities for waste management technologies’, *The International journal of*, 15(4), 403–416.

Bing, X., Bloemhof, J. and Ramos, T. (2016) ‘Research challenges in municipal solid waste logistics management’, *Waste Management*, 48, 584–592.

Bisinella, V., Götze, R., Conradsen, K., Damgaard, A., Christensen, T.H. and Astrup, T.F., (2017) ‘Importance of waste composition for life cycle assessment of waste management solutions’, *Journal of Cleaner Production*, 164, 1180–1191. doi: 10.1016/j.jclepro.2017.07.013.

Björklund, A., Dalemo, M. and Sonesson, U. (1999) ‘Evaluating a municipal waste management plan using ORWARE’, *Journal of Cleaner Production*, 7(4), 271–280.

Black, R. E., Morris, S. S. and Bryce, J. (2003) ‘Where and why are 10 million children dying every year?’, *The lancet*, 361(9376), 2226–2234.

Boadi, K. O. and Kuitunen, M. (2005) ‘Environmental and Health Impacts of Household Solid Waste Handling and Disposal Practices in Third World Cities: The Case of the Accra Metropolitan Area, Ghana’, *Journal of Environmental Health*, 64(4), 32–36.

Boer, J. Den, Boer, E. Den and Jager, J. (2007) ‘LCA-IWM: a decision support tool for sustainability assessment of waste management systems’, *Waste management*, 27(8), 1032–1045.

Boldrin, A., Andersen, J. and Christensen, T. (2011) ‘Environmental assessment of garden waste management in the Municipality of Aarhus, Denmark’, *Waste*

Management, 31(7), 1560–1569.

Bolund, P. and Hunhammar, S. (1999) ‘Ecosystem services in urban areas’, *Ecological Economics*, 29(2), 293–301. doi: 10.1016/S0921-8009(99)00013-0.

Bosch, S. P. (2015) ‘*Transition to a Regional Circular Society: the case of Haarlemmermeer*’.

Bosmans, A., Vanderreydt, I., Geysen, D. and Helsen, L., (2013) ‘The crucial role of Waste-to-Energy technologies in enhanced landfill mining: a technology review’, *Journal of Cleaner Production*, 55, 10–23.

Bovea, M., Ibáñez-Forés, V. and Gallardo, A. (2010) ‘Environmental assessment of alternative municipal solid waste management strategies. A Spanish case study’, *Waste Management*, 30(11), 2383–2395.

Bowan, P. (2013) ‘Private Sector Capacity in the Management of Urban Solid Waste in Ghana–A Study of Zoomlion in the Wa Municipality’, *Journal of Studies in Social Sciences*, 5(2), 352–364.

Bowan, P. and Tierobaar, M. (2014) ‘Characteristics and Management of Solid Waste in Ghanaian Markets - A Study of Wa Municipality’, *Civil and Environmental Research*, 6(1), 114–119.

Boxall, P.C., Adamowicz, W.L., Swait, J., Williams, M. and Louviere, J., (1996) ‘A comparison of stated preference methods for environmental valuation’, *Ecological Economics*, 18(3), 243–253.

Boynton, P. and Greenhalgh, T., (2004) ‘Selecting, designing, and developing your questionnaire.’, *BMJ: British Medical Journal*. BMJ Publishing Group, 328(7451), 1312–1315. doi: 10.1136/bmj.328.7451.1312.

Brannen, J. (2005) ‘Mixed methods research: A discussion paper’.

Brannen, J. (2008) ‘The practice of a mixed methods research strategy: Personal, professional and project considerations’, *Advances in mixed methods research: Theories and applications*, 53–65.

Braun, V. and Clarke, V. (2006) ‘Using thematic analysis in psychology’, *Qualitative research in psychology*, 3(2), 77–101.

Breeze, R. (2012) '*Municipal Solid Waste Management in Dar Es Salaam'*.

Breivik, K., Armitage, J.M., Wania, F., Sweetman, A.J. and Jones, K.C., (2016) 'Tracking the global distribution of Persistent Organic Pollutants accounting for e-waste exports to developing regions', *Environmental science & technology*, 50(2), 798–805.

Bruce, N. and Perez-Padilla, R. (2002) 'Indoor air pollution in developing countries: a major environmental and public health challenge', *Indoor Air*, 12(3), 198–207.

Brunner, P. and Fellner, J. (2007) 'Setting priorities for waste management strategies in developing countries', *Waste Management & Research*, 25(3), 234–240.

Brunner, P. H. and Rechberger, H. (2015) 'Waste to energy–key element for sustainable waste management', *Waste Management*, 37, 3–12.

Brunner, P. and Rechberger, H. (2004) 'Practical handbook of material flow analysis', *The International Journal of Life Cycle*, 9(5), 337–338.

Bufoni, A., Oliveira, L. and Rosa, L. (2016) 'The declared barriers of the large developing countries waste management projects: The STAR model', *Waste Management*, 52, 326–338.

Bulsara, C. (2015) 'Using a mixed methods approach to enhance and validate your research', *Brightwater Group Research Centre*.

Burney, S. (2008) 'Inductive and deductive research approach', *Retrieved*, 9(21).

Burnley, S., (2007) 'The use of chemical composition data in waste management planning–A case study', *Waste Management*, 27(3), 327–336.

Busse, F. (2012) 'Financing waste projects, a challenging opportunity', *Private Sector & Development*, 25–27.

Cabral, J. P., (2010) 'Water Microbiology. Bacterial Pathogens and Water', *Journal of Environmental Research and Public Health*, 7, 3657–3703. doi: 10.3390/ijerph7103657.

Cai, L., Gao, D., Chen, T.B., Liu, H.T., Zheng, G.D. and Yang, Q.W., (2012) 'Moisture variation associated with water input and evaporation during sewage sludge bio-drying', *Bioresource technology*, 117, 13–19.

Caldwell, K. and Atwal, A. (2005) ‘Non-participant observation: using video tapes to collect data in nursing research, *Nurse researcher*, 13(2), 42–54.

Calhoun, C. (1998) ‘Explanation in historical sociology: Narrative, general theory, and historically specific theory’, *American journal of sociology*, 104(3), 846–871.

Cao, R. and Wang, H. (2017) ‘Research on the Pollution Hazard of Municipal Solid Waste in China and its Prevention and Control Legal Countermeasures’, *Nature Environment and Pollution Technology*, 6(2), 463–469.

Cesaro, A. and Belgiorno, V. (2014) ‘Pretreatment methods to improve anaerobic biodegradability of organic municipal solid waste fractions’, *Chemical Engineering Journal*, 240, 24–37.

Chaleunvong, K. (2013) ‘Data collection techniques’, *Training Course in Reproductive Health Research Vientine.*

Champ, P. A. (2003) ‘Collecting survey data for nonmarket valuation’, in. *Springer* (A primer on nonmarket valuation), 59–98.

Chandrappa, R and Das, D. (2012) *Solid Waste Management: principles and practice.* [S.l.]: Springer-Verlag Berlin AN.

Charmaz, K. and Smith, J. A. (2003) ‘Grounded theory’, in *Qualitative psychology: A practical guide to research methods*, pp. 81–110.

Chaudhuri, K.R., Martinez-Martin, P., Schapira, A.H., Stocchi, F., Sethi, K., Odin, P., Brown, R.G., Koller, W., Barone, P., MacPhee, G. and Kelly, L., (2006) ‘International multicenter pilot study of the first comprehensive self-completed nonmotor symptoms questionnaire for Parkinson’s disease: The NMSQuest study’, *Movement Disorders*, 21(7), 916–923. doi: 10.1002/mds.20844.

Chen, H. and Chang, N. (2000) ‘Prediction analysis of solid waste generation based on grey fuzzy dynamic modeling’, *Resources, conservation and Recycling*, 29(1), 1–18.

Chen, H., Chiang, R. and Storey, V. (2012) ‘Business intelligence and analytics: From big data to big impact.’, *MIS quarterly*, 36(4).

Chen, P., Xie, Q., Addy, M., Zhou, W., Liu, Y., Wang, Y., Cheng, Y., Li, K. and Ruan, R., (2016) 'Utilization of municipal solid and liquid wastes for bioenergy and bioproducts production', *Bioresource technology*, 215, 163-172.

Cheng, S., Chan, C. W. and Huang, G. H. (2003) 'An integrated multi-criteria decision analysis and inexact mixed integer linear programming approach for solid waste management', *Engineering Applications of Artificial Intelligence*, 16(5), 543–554.

Clark, M., Palfreman, J. and Rhyn, J. Van (2015) 'Where there's Muck, there's Brass: A Market Systems Approach to Conceptualising Solid Waste Management in Mombasa, Kenya'.

Plano Clark, V.L., Huddleston-Casas, C.A., Churchill, S.L., O'Neil Green, D. and Garrett, A.L., (2008) 'Mixed methods approaches in family science research', *Journal of Family Issues*, 29(11), 1543–1566.

Cleary, J. (2009) 'Life cycle assessments of municipal solid waste management systems: A comparative analysis of selected peer-reviewed literature', *Environment international*, 35(8), 1256–1266. doi: http://dx.doi.org/10.1016/j.envint.2009.07.009.

Coad, A. (2011) *Collection of Municipal Solid Waste: Key issues for Decision-makers in Developing Countries*.

Cobern, W. (1991) '*World view theory and science education research'*.

Coburn, J. B., Pingoud, K., Thorsen, G. and Wagner, F., (2006) 'Solid Waste Disposal', in *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. IPCC.

Cointreau-Levine, S. (1994) *Private sector participation in municipal solid waste services in developing countries*. Washington DC, US: World Bank.

Cointreau-Levine, S. (2004) *Sanitary Landfill Design and Siting Criteria*.

Cole, M. (1994) 'Assessing the impact of composting yard trimmings', *BioCycle*, 35(4), 92–96.

Colella, V. (2000) 'Participatory simulations: Building collaborative understanding through immersive dynamic modeling', *The journal of the Learning Sciences*, 9(4), 471–500.

Collis, J. and Hussey, R. (2013) *Business research: A practical guide for undergraduate and postgraduate students*. Palgrave macmillan.

Cooper, D. R., Schindler, P. S. and Sun, J. (2003) ‘*Business research methods*’.

Courtois, L. A. (2012) ‘Municipal Solid Waste: turning a problem into resource’, *Private Sector & Development*, 2–4.

Cowie, J. and Lehnert, W. (1996) ‘Information extraction’, *Communications of the ACM*, 39(1), 80–91.

Creswell, J. W. (2014) *Research design: qualitative, quantitative, and mixed methods approaches*. 4th edn. California, US: SAGE Publications, Inc.

Cronin, C. (2014) ‘Using case study research as a rigorous form of inquiry’, *Nurse Researcher*, 21(5), 19–27.

Cucchiella, F., D’Adamo, I. and Gastaldi, M. (2014) ‘Strategic municipal solid waste management: A quantitative model for Italian regions’, *Energy Conversion and Management*, 77, 709–720. doi: http://dx.doi.org/10.1016/j.enconman.2013.10.024.

Cullen, C. (2016) ‘Losing ground: the decline of England’s landfills’.

Curran, T. and Williams, I. D. (2012) ‘A zero waste vision for industrial networks in Europe’, *Journal of hazardous materials*, 207, 3–7. doi: http://dx.doi.org/10.1016/j.jhazmat.2011.07.122.

Currie, D. (2005) *Developing and applying study skills: writing assignments, dissertations and management reports*. CIPD Publishing.

Dahlén, L. and Lagerkvist, A. (2010) ‘Pay as you throw: strengths and weaknesses of weight-based billing in household waste collection systems in Sweden’, *Waste management*, 30(1), 23–31.

Daley, K., Castleden, H., Jamieson, R., Furgal, C. and Ell, L., (2015) ‘Water systems, sanitation, and public health risks in remote communities: Inuit resident perspectives from the Canadian Arctic’, *Social Science & Medicine*, 135, 124–132.

Dalmia, N. (2014) *Case for sustainability in strategy and operations: overcoming the challenges of product design in creating competitive advantages in circular supply chains*. Massachusetts Institute of Technology.

Damgaard, A. (2015) ‘*Anaerobic Digestion*’. NC State University & Technical University of Denmark..

Dana, L. and Dana, T. (2005) 'Expanding the scope of methodologies used in entrepreneurship research', *International Journal of Entrepreneurship and Small Business*, 2(1), 79–88.

Darke, P., Shanks, G. and Broadbent, M. (1998) 'Successfully completing case study research: combining rigour, relevance and pragmatism', *Information systems journal*, 8(4), 273–289.

Datta, M. and Kumar, A. (2016) 'Assessment of Subsurface Contamination Potential of Municipal Solid Waste (MSW) Dumps', *Indian Geotechnical Journal*. Springer India, 1–11. doi: 10.1007/s40098-017-0247-5.

Dedinec, A., Markovska, N., Ristovski, I., Velevski, G., Gjorgjievska, V.T., Grncarovska, T.O. and Zdraveva, P., (2015) 'Economic and environmental evaluation of climate change mitigation measures in the waste sector of developing countries', *Journal of Cleaner Production*, 88, 234–241.

Department of Environment, Food and Rural Affairs (Defra) (2014) *Energy from waste: A guide to the debate*.

Dentch, M. P. (2016) *The ISO 14001:2015 Implementation Handbook: Using the process Approach to Build an Environmental Management System*. Edited by M. Meinholz and P. D. O'Mara. Milwaukee, Wisconsin: ASQ Quality Press.

Desa, A., Kadir, N. and Yusooff, Y. (2011) 'A Study on the Knowledge, Attitudes, Awareness Status and Behaviour Concerning Solid Waste Management', *Procedia - Social and Behavioral Sciences*. Elsevier, 18, 643–648. doi: 10.1016/J.SBSPRO.2011.05.095.

Diaz, F., Savage, M. and Eggerth, L., (2005) *Solid Waste Management*. United Nations Environment Programme.

Diaz, R. and Warith, M. (2006) 'Life-cycle assessment of municipal solid wastes: Development of the WASTED model', *Waste management*, 6(8), 886–901.

Domingo, J. L. and Nadal, M. (2009) 'Domestic waste composting facilities: A review of human health risks', *Environment International*, 35, 382–389. doi: 10.1016/j.envint.2008.07.004.

Dong, J., Chi, Y., Zou, D., Fu, C., Huang, Q. and Ni, M., (2014) 'Energy –environment–

economy assessment of waste management systems from a life cycle perspective: Model development and case study', *Applied Energy*, 114, 400–408. doi: http://dx.doi.org/10.1016/j.apenergy.2013.09.037.

Dong, J., Chi, Y., Tang, Y., Ni, M., Nzihou, A., Weiss-Hortala, E. and Huang, Q., (2016) 'Effect of Operating Parameters and Moisture Content on Municipal Solid Waste Pyrolysis and Gasification', *Energy and Fuels*, 30(5), 3994–4001. doi: 10.1021/acs.energyfuels.6b00042.

Dreher, J. and López, D. (2015) 'Subjectivity and power', *Human Studies*, 38(2), 197–222.

Dubois, A. and Gadde, L. (2002) 'Systematic combining: an abductive approach to case research', *Journal of Business Research*. Elsevier, 55(7), 553–560. doi: 10.1016/S0148-2963(00)00195-8.

Dukhan, A., Bourbon-Séclet, C. and Yannic, N. (2012) 'Linking public and private action for sustainable waste management', *Private Sector & Development*, 9–11.

Dyson, B. and Chang, N.-B. (2005) 'Forecasting municipal solid waste generation in a fast-growing urban region with system dynamics modeling', *Waste Management*, 25(7), 669–679. doi: http://dx.doi.org/10.1016/j.wasman.2004.10.005.

Easterbay-Smith, M., Thorpe, R. and Jackson, P. (2008) *Management Research*. 3rd edn. Thousand Oaks.

Easterby-Smith, M. (1997) 'Disciplines of organizational learning: contributions and critiques', *Human relations*, 50(9), 1085–1113.

Easton, G. (2010) 'Critical realism in case study research', *Industrial marketing management*, 39(1), 118–128.

Edjabou, M.E., Jensen, M.B., Götze, R., Pivnenko, K., Petersen, C., Scheutz, C. and Astrup, T.F., (2015) 'Municipal solid waste composition: Sampling methodology, statistical analyses, and case study evaluation', *Waste Management*, 36, 12–23. doi: http://dx.doi.org/10.1016/j.wasman.2014.11.009.

Edmunds, K., Elrahman, S. and Bell, D. (2016) 'Recommendations for dealing with waste contaminated with Ebola virus: a Hazard Analysis of Critical Control Points approach', *Bulletin of the World Health Organization*, 94(6), 424–432.

Eduful, M. and Shively, D. (2015) ‘Perceptions of urban land use and degradation of water bodies in Kumasi, Ghana’, *Habitat International*, 50, 206–213.

Efraimsson, H., Wiebert, A. and Carroll, S., (2014) ‘*Clearance and recycling–how can radiation protection and application of the waste hierarchy be optimised*?’

Eiselt, H. A. and Marianov, V. (2015) ‘Location modeling for municipal solid waste facilities’, *Computers & Operations Research*, 62, 305–315.

Ejaz, N., Akhtar, N., Hashmi, H. and Naeem, U.A., (2010) ‘Environmental impacts of improper solid waste management in developing countries: A case study of Rawalpindi City’, *WIT Transactions on Ecology and the Environment*, 142, 379–387. doi: 10.2495/SW100351.

Ejaz, N. and Janjua, N. . (2012) ‘Solid Waste Management Issues in small Towns of Developing Countries: A Case Study of Taxila City’, *International Journal of Environmental Science and Development*, 3(2), 167–171.

El-Haggar, S. M. (2016) ‘Sustainability and the Green Economy’, *Sustainability and Innovation: The Next Global Industrial Revolution*, 1.

Elith, J., Graham, C.H., Anderson, R.P., Dudík, M., Ferrier, S., Guisan, A., Hijmans, R.J., Huettmann, F., Leathwick, J.R., Lehmann, A. and Li, J., (2006) ‘Novel methods improve prediction of species’ distributions from occurrence data’, *Ecography*, 29(2), 129–151.

Elo, S. and Kyngäs, H. (2008) ‘The qualitative content analysis process’, *Journal of advanced nursing*, 62(1), 107–115.

Environment Canada (2013) *Technical Document on Municipal Solid Waste Organics Processing*.

Eriksson, M., Strid, I. and Hansson, P.A. (2015) ‘Carbon footprint of food waste management options in the waste hierarchy – a Swedish case study’, *Journal of Cleaner Production*, 93, 115–125. doi: http://dx.doi.org/10.1016/j.jclepro.2015.01.026.

Eriksson, O., Frostell, B., Björklund, A., Assefa, G., Sundqvist, J.O., Granath, J., Carlsson, M., Baky, A. and Thyselius, L., (2002) ‘ORWARE—a simulation tool for waste management’, *Resources, Conservation and Recycling*, 36(4), 287–307.

Etikan, I., Musa, S. A. and Alkassim, R. S. (2016) ‘Comparison of Convenience Sampling and Purposive Sampling’, *American Journal of Theoretical and Applied Statistics*, 5(1), 1–4.

European Union (2008) ‘Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance)’.

European Commission (2017) *Municipal waste statistics - Statistics Explained*.

European Environement Agency (2007) *Municipal waste generation - outlook from OECD*. Copenhagen, Denmark.

European Investment Bank (2002) *Evaluation Report: EIB Financing of Solid Waste Management Projects*.

Evangelisti, S., Lettieri, P., Borello, D. and Clift, R., (2014) ‘Life cycle assessment of energy from waste via anaerobic digestion: a UK case study’, *Waste Management*, 34(1), 226–237.

Evangelisti, S., Tagliaferri, C., Clift, R., Lettieri, P., Taylor, R. and Chapman, C., (2015) ‘Life cycle assessment of conventional and two-stage advanced energy-from-waste technologies for municipal solid waste treatment’, *Journal of Cleaner Production*, 100, 212–223.

Ewijk, S. Van and Stegemann, J. A. (2016) ‘Limitations of the waste hierarchy for achieving absolute reductions in material throughput’, *Journal of Cleaner Production*, (132), 122–128. doi: http://dx.doi.org/10.1016/j.jclepro.2014.11.051.

Fakoya, M. B. (2014) ‘Institutional Challenges to Municipal Waste Management Service Delivery in South Africa’, *Journal of Human Ecology*, 45(2), 119–125.

Falconer, D. and Mackay, D. (2000) ‘The myth of multiple methods’, in *AMCIS 2000 Proceedings*. Association for Information Systems.

Fazeli, A., Bakhtvar, F., Jahanshaloo, L., Sidik, N.A.C. and Bayat, A.E., (2016) ‘Malaysia′ s stand on municipal solid waste conversion to energy: A review’, *Renewable and Sustainable Energy Reviews*, 58, 1007–1016.

Fei-Baffoe, B., Nyankson, E. A. and Gorkeh-Miah, J. (2014) ‘Municipal Solid Waste

Management in Sekondi-Takoradi Metropolis, Ghana', *Journal of Waste Management*, 2014.

Fernandes, M. L., Rodrigues, A. P., Soares, A.C., Gouvea Da Costa, S., Bortoluzzi, S.C. and Pinheiro De Lima, E. (2017) 'Criteria for Performance Evaluation in Municipal Solid Waste Management', in *Ten Years Working Together for a Sustainable Future*. São Paulo – Brazil.

Fife-Schaw, C. (2000) *Surveys and sampling issues*, *Research methods in psychology*. Sage.

Filippis De, P., Scarsella, M., Verdone, N. and Carnevale, G.B., (2014) 'Batch waste gasification technology: characteristics and perspectives', *WIT Transactions on State-of-the-art in Science and Engineering*, 84, 125–132.

Flowers, P. (2009) 'Research philosophies–importance and relevance', *MSc by Research*. Cranfield School of Management.

Flyvbjerg, B. (2006) 'Five Misunderstandings About Case-Study Research', *Qualitative Inquiry*, 12(2), 219–245. doi: 10.1177/1077800405284363.

Fobil, J. N., Carboo, D. and Armah, N. A. (2005) 'Evaluation of municipal solid wastes (MSW) for utilisation in energy production in developing countries', *International journal of environmental technology and management*, 5(1), 76–86. doi: 10.1504/IJETM.2005.006508.

Fodor, Z. and Klemeš, J. J. (2012) 'Waste as alternative fuel–Minimising emissions and effluents by advanced design', *Process Safety and Environmental Protection*, 90(3), 263–284.

Fontana, A. and Frey, J. (1994) 'The art of science', in *The handbook of qualitative research*, pp. 361–376.

Food and Agriculture Organisation (FAO) (2012) *International Year of Cooperatives Issue Brief Series: The role of producer organizations in reducing food loss and waste*. Rome, Italy.

Forza, C. (2002) 'Survey research in operations management: a process-based perspective', *International journal of operations & production management*, 22(2), 152–194.

Fouché, I., van Dyk, T. and Butler, G. (2016) ‘Impact measurement: towards creating a flexible evaluation design for academic literacy interventions’, *Stellenbosch Papers in Linguistics*, 45(1), 109–145.

Friedrich, E. and Trois, C. (2013) ‘GHG emission factors developed for the collection, transport and landfilling of municipal waste in South African municipalities’, *Waste Management*. doi: 10.1016/j.wasman.2012.12.011.

Firth Resources Management (FRM) (2013) *Mechanical Heat Treatment of Municipal Solid Waste*.

Fudala-Ksiazek, S., Pierpaoli, M., Kulbat, E. and Luczkiewicz, A., (2016) ‘A modern solid waste management strategy – the generation of new by-products’, *Waste Management*, 49, 516–529. doi: http://dx.doi.org/10.1016/j.wasman.2016.01.022.

Gabriel, D. (2013) *Inductive and deductive approaches to research*, *PhD Research Methods*.

Gaeta-Bernardi, A. and Parente, V. (2016) ‘Organic municipal solid waste (MSW) as feedstock for biodiesel production: A financial feasibility analysis’, *Renewable Energy*, 86, 1422–1432.

Gainer, M. (2013) *This Summer, Zero Waste is Fair Game*.

Gandy, M. (2014) *Recycling and the politics of urban waste*. Routledge.

Garaj-Vrhovac, V., Oreščanin, V. and Ruk, D. (2009) ‘In vitro assessment of genotoxic effects of electric arc furnace dust on human lymphocytes using the alkaline comet assay’, *Journal of Environmental Science and Health Part A*, 44(3), 279–287.

Gentles, S. J. *et al.* (2015) ‘Sampling in qualitative research: Insights from an overview of the methods literature’, *The Qualitative Report*, 20(11), 1772.

Gersten, R., Fuchs, L.S., Compton, D., Coyne, M., Greenwood, C. and Innocenti, M.S., (2005) ‘Quality indicators for group experimental and quasi-experimental research in special education’, *Exceptional children*, 71(2), 149–164.

Ghana Statistical Service (2012) *2010 Population and Housing Census Final Results*. Accra, Ghana.

Ghana Statistical Service (2014) *2010 Population & Housing Census: District*

Analytical Report, Wa Municipality. Accra, Ghana.

Gharfalkar, M., Court, R., Campbell, C., Ali, Z. and Hillier, G., (2015) 'Analysis of waste hierarchy in the European waste directive 2008/98/EC', *Waste Management*, 39, 305-313.

Ghinea, C. and Gavrilescu, M. (2010) 'Decision Support Models for Solid Waste Management - An Overview.', *Environmental Engineering & Management Journal (EEMJ)*, 9(6).

Gill, J. and Johnson, P. (2010) *Research methods for managers*. Sage.

Giusti, L. (2009) 'A review of waste management practices and their impact on human health', *Waste management,* 29(8), 2227–2239. doi: 10.1016/j.wasman.2009.03.028.

Goddard, W. and Melville, S. (2004) *Research methodology: An introduction*. Juta and Company Ltd.

Goduka, N. (2012) 'From positivism to indigenous science: A reflection on world views, paradigms and philosophical assumptions', *Africa Insight*, 41(4), 123–138.

Van Gog, T., Paas, F. and Van Merriënboer, J.J., (2008) 'Data collection and Analysis', in *Handbook of Research on Educational Communications and Technology 3e*, pp. 763–806.

Gogate, N. G., Kalbar, P. P. and Raval, P. M. (2017) 'Assessment of stormwater management options in urban contexts using Multiple Attribute Decision-Making', *Journal of Cleaner Production*, 142(4), 2046–2059. doi: 10.1016/j.jclepro.2016.11.079.

Golafshani, N. (2003) 'Understanding Reliability and Validity in Qualitative Research', *The Qualitative Report*, 8(4), 597–606.

Golden, M. (1998) 'Interest groups in the rule-making process: Who participates? Whose voices get heard?', *Journal of Public Administration Research and Theory*, 8(2), 245–270.

Gong, X. and Richman, M. B. (1995) 'On the application of cluster analysis to growing season precipitation data in North America east of the Rockies', *Journal of Climate*, 8(4), 897–931.

Gough, N. (2002) *Blank spots, blind spots, and methodological questions in* *postgraduate research*, *The Postgraduate Research Conference.*

Greene, K. and Tonjes, D. (2014) 'Quantitative assessments of municipal waste management systems: using different indicators to compare and rank programs in New York State', *Waste Management*, 34(4), 825–836.

Gregson, N. *et al.* (2013) 'Moving up the waste hierarchy: Car boot sales, reuse exchange and the challenges of consumer culture to waste prevention', *Resources, Conservation and Recycling*, 77, 97–107. doi: http://dx.doi.org/10.1016/j.resconrec.2013.06.005.

Griffith, D., Kelly-Hope, L. and Miller, M. (2006) 'Review of reported cholera outbreaks worldwide, 1995–2005', *The American journal of tropical medicine and hygiene*, 75(5), 973–977.

Guba, E. (1990) *'The paradigm dialog'*. Newbury.

Guendehou, S., Koch, M., Hockstad, L., Pipatti, R. and Yamada, M., (2006) 'Incineration and Open Burning', in *Guidelines for National Greenhouse Gas Inventories*. International Panel on Climate Change (IPPC).

Guerrero, L. A., Maas, G. and Hogland, W. (2013) 'Solid waste management challenges for cities in developing countries', *Waste Management*, 33(1), 220–232. doi: http://dx.doi.org/10.1016/j.wasman.2012.09.008.

Guillemin, M. and Gillam, L. (2004) 'Ethics, Reflexivity, and "Ethically Important Moments" in Research', *Qualitative Inquiry*, 10(2), 261–280. doi: 10.1177/1077800403262360.

Gukhool, O. (2015) 'Solid Waste Collection and Transportation', in Mohee, R. and Simelane, T. (eds) *Future Directions of Municipal Solid Waste Management in Africa*. Pretoria, South Africa: Africa Institute of South Africa, pp. 36–53.

Guo, M., Song, W. and Buhain, J. (2015) 'Bioenergy and biofuels: History, status, and perspective', *Renewable and Sustainable Energy Reviews*, 42, 712–725.

Gupta, Y. P. and Gupta, P. (2016) 'Green Construction And Clean Environment Through City and River Solid Waste Processing.', *Journal of Solid Waste Technology & Management*, 42(1).

Guyatt, H. L. and Snow, R. W. (2004) 'Impact of malaria during pregnancy on low birth weight in sub-Saharan Africa.', *Clinical microbiology reviews*. American Society for Microbiology, 17(4), 760–769. doi: 10.1128/CMR.17.4.760-769.2004.

Habib, K., Schmidt, J. H. and Christensen, P. (2013) 'A historical perspective of Global Warming Potential from Municipal Solid Waste Management', *Waste Management*, 33(9), 1926–1933. doi: http://dx.doi.org/10.1016/j.wasman.2013.04.016.

Hak, T. (2008) *Case study methodology in business research*. Taylor & Francis.

Håkansson, A. (2013) 'Portal of research methods and methodologies for research projects and degree projects', in *the International Conference on Frontiers in Education: Computer Science and Computer Engineering (FECS)*, 1.

Hall, D. O., Barnard, G. W. and Moss, P. A. (2013) *Biomass for energy in the developing countries: current role, potential, problems, prospects*. Elsevier.

Halpern, S., Karlawish, J. and Berlin, J. (2002) 'The continuing unethical conduct of underpowered clinical trials', *Jama*, 288(3), 358–362.

Ham, R.K. and Komilis, D.P., (2002) 'A Laboratory Study To Investigate Gaseous Emissions and Solids Decomposition During Composting of Municipal Solid Wastes'. Washington, DC, USA: US EPA.

Hamid, A., Ishak, M. Y. and Samah, M. A. A. (2015) 'Analysis of Municipal Solid Waste Generation and Composition at Administrative Building Café in Universiti Putra Malaysia: A Case Study.', *Polish Journal of Environmental Studies*, 24(5).

Hamilton, S., ElSawah, S. and Guillaume, J. (2015) 'Integrated assessment and modelling: overview and synthesis of salient dimensions', *Environmental Modelling & Software*, 64, 215–229.

Hansen, C. L. and Cheong, D. Y. (2013) 'Agricultural waste management in food processing', in *Handbook of farm, dairy and food machinery engineering,* pp. 619–666.

Haregu, T.N., Ziraba, A.K., Aboderin, I., Amugsi, D., Muindi, K. and Mberu, B., (2017) 'An assessment of the evolution of Kenya's solid waste management policies and their implementation in Nairobi and Mombasa: analysis of policies and practices', *Environment and Urbanization*. SAGE PublicationsSage UK: London, England, 29(2), 515-532. doi: 10.1177/0956247817700294.

Haregu, T., Ziraba, A. and Mberu, B. (2016) 'Integration of Solid Waste Management Policies in Kenya: Analysis of coherence, gaps and overlaps', *African Population Studies*, 30(2).

Hargittai, E. (2001) 'Second-level digital divide: mapping differences in people's online skills', *arXiv preprint cs/0109068*.

Hargittai, E. (2015) 'Is bigger always better? Potential biases of big data derived from social network sites', *The Annals of the American Academy of Political and Social Science*, 659(1), 63–76.

Haug, F. (1997) '*Memory-work as a method of social science research: A detailed rendering of memory-work method*'.

Haugh, H. and Talwar, A. (2010) 'How do corporations embed sustainability across the organization?', *Academy of Management learning & education*, 9(3), 384–396.

Henry, R. K., Yongsheng, Z. and Jun, D. (2006) 'Municipal solid waste management challenges in developing countries - Kenyan case study', *Waste Management*. doi: 10.1016/j.wasman.2005.03.007.

Herek, G. M. (2014) '*Not Equal Yet: Building Upon Foundations of Relationship Equality: Evaluating the Methodology of Social Science Research on Sexual Orientation and Parenting: A Tale of Three Studies*', *UC Davis L.Rev.*, 48, pp. 583–2077.

Hernandez, P.A., Graham, C.H., Master, L.L. and Albert, D.L., (2006) 'The effect of sample size and species characteristics on performance of different species distribution modeling methods', *Ecography*, 29(5), 773–785.

Herold, M. (2017) *Case Study Research: design and methods.*, *Organisatietools*.

Herva, M. and Roca, E. (2013) 'Ranking municipal solid waste treatment alternatives based on ecological footprint and multi-criteria analysis', *Ecological Indicators*, 25, 77–84.

Hilburn, A. M. (2015) 'At Home or to the Dump?: Household Garbage Management and the Trajectories of Waste in a Rural Mexican Municipio', *Journal of Latin American Geography*, 14(2), 29–52.

Hinkin, T. (1998) 'A Brief Tutorial on the Development of Measures for Use in Survey Questionnaires', *Organizational Research Methods*, 1(1), 104–121. doi: 10.1177/109442819800100106.

Hird, M.J., Lougheed, S., Rowe, R.K. and Kuyvenhoven, C., (2014) 'Making waste management public (or falling back to sleep)', *Social Studies of Science*, 44(3), 441–465.

Hirschheim, R. (1985) 'Information systems epistemology: An historical perspective', *Research methods* in *information systems*, pp:13–35.

Hjelmar, O. (1996) 'Disposal strategies for municipal solid waste incineration residues', *Journal of hazardous materials*, 47(1–3), 345–368.

Hoepfl, M. C. (1997) 'Choosing Qualitative Research: A Primer for Technology Education Researchers', *Journal of Technology Education*, 9(1). doi: 10.21061/jte.v9i1.a.4.

Hoornweg, D., Bhada-Tata, P. and Kennedy, C. (2013) 'Waste production must peak this century', *Nature*, 502(7473), 615–617.

Hoornweg, D. and Bhada-Tata, P. (2015) 'Peak waste: When is it likely to occur?', *Journal of Industrial Ecology*, 19(1), 117–128.

Hoornweg, D., Thomas, L. and Otten, L. (2000) *Composting and Its Applicability in Developing Countries*.

Huang, K., Li, F., Wei, Y., Fu, X. and Chen, X., (2014) 'Effects of earthworms on physicochemical properties and microbial profiles during vermicomposting of fresh fruit and vegetable wastes', *Bioresource technology*, 170, 45–52.

Hulme, D. (2000) 'Impact assessment methodologies for microfinance: Theory, experience and better practice', *World Development*, 28(1), 79–98.

Hultman, J. and Corvellec, H. (2012) 'The European Waste Hierarchy: from the sociomateriality of waste to a politics of consumption', *Environment and Planning A*, 44(10), 2413–2427.

Hunt, S. D. and Vitell, S. (1986) 'A General Theory of Marketing Ethics', *Journal of Macromarketing*, 6(1), 5–16. doi: 10.1177/027614678600600103.

Hussein, A. (2015) 'The use of triangulation in social sciences research: Can qualitative and quantitative methods be combined?', *Journal of Comparative Social Work*, 4(1).

Hyman, M. *et al.* (2013) *Guidelines for National Waste Management Strategies: Moving from Challenges to Opportunities*. United Nations Environment Programme.

Intergovernmental Panel on Climate Change (IPCC) (2015) *Climate change 2014: mitigation of climate change*. Cambridge University Press.

Intharathirat, R., Salam, P.A., Kumar, S. and Untong, A., (2015) 'Forecasting of municipal solid waste quantity in a developing country using multivariate grey models', *Waste Management*, 39, 3–14. doi: http://dx.doi.org/10.1016/j.wasman.2015.01.026.

Ionescu, G., Rada, E.C., Ragazzi, M., Mărculescu, C., Badea, A. and Apostol, T., (2013) 'Integrated municipal solid waste scenario model using advanced pretreatment and waste to energy processes', *Energy Conversion and Management*, 76, 1083–1092. doi: http://dx.doi.org/10.1016/j.enconman.2013.08.049.

Iqbal, H., Anwar Baig, M., Usman Hanif, M., Usman Ali, S. and Flury, M., (2015) 'Leaching of Metals, Organic Carbon and Nutrients fromMunicipalWaste under Semi-Arid Conditions', *International Journal of Environmental Research*, 9(1), 187–196.

Is-haque, I. I. and Huysman, M. (2013) '*Sustainable private sector solid waste collection & transportation: The case of Kwesimintsim*, STMA, Ghana'.

International Standardisation Organisation (ISO) (2006) *ISO 14040*, *Environmental management-Life cycle assessment-Principles and framework (ISO 14040: 2006)*. Brussels.

Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R. and Law, K.L., (2015) 'Marine pollution. Plastic waste inputs from land into the ocean', *Science (New York, N.Y.)*, 347(6223), 768–771. doi: 10.1126/science.1260352 [doi].

Japan International Cooperation Agency (JICA) (2009) *Thematic Guidelines on Solid Waste Management*.

Jasch, C. (2000) 'Environmental performance evaluation and indicators', *Journal of Cleaner Production*, 8, 79–88.

Jensen, K. (2002) 'The qualitative research process', in *A handbook of media and communication research:*, pp. 235–253.

Jessop, B. (2005) 'Critical Realism and the Strategic-Relational Approach.', *New Formations: A Journal of Culture, Theory and Politics*, 56, 40–53.

Jha, A.K., Sharma, C., Singh, N., Ramesh, R., Purvaja, R. and Gupta, P.K., (2008) 'Greenhouse gas emissions from municipal solid waste management in Indian mega-cities: A case study of Chennai landfill sites', *Chemosphere*. doi: 10.1016/j.chemosphere.2007.10.024.

Jick, T. D. (1979) 'Mixing qualitative and quantitative methods: Triangulation in action', *Administrative Science Quarterly*, 24(4), 602–611.

Johari, A. J., Ahmed, S.I., Hashim, H., Alkali, H. and Ramli, M., (2012) 'Economic and environmental benefits of landfill gas from municipal solid waste in Malaysia', *Renewable and Sustainable Energy Reviews*, 16(5), 2907–2912. doi: http://dx.doi.org/10.1016/j.rser.2012.02.005.

Johnson, R. B., Onwuegbuzie, A. J. A. and Turner, L. A. (2007) 'Toward a definition of mixed methods research', *Journal of mixed methods research*, 1(2), 112–133.

Johnson, R. and Onwuegbuzie, A. (2004) 'Mixed methods research: A research paradigm whose time has come', *Educational researcher*, 33(7), 14–26.

Kadafa, A., Manaf, L. and Sulaiman, W. A. (2014) 'Applications of System Analysis Techniques in Solid Waste Management Assessment.', *Polish Journal of Environmental Studies*, 23(4), 1061–1070.

Kadir, S.A.S.A., Yin, C.Y., Sulaiman, M.R., Chen, X. and El-Harbawi, M., (2013) 'Incineration of municipal solid waste in Malaysia: Salient issues, policies and waste-to-energy initiatives', *Renewable and Sustainable Energy Reviews*, 24, 181–186.

Kajiwara, N., Hirata, O., Takigami, H., Noma, Y., Tachifuji, A. and Matsufuji, Y., (2014) 'Leaching of brominated flame retardants from mixed wastes in lysimeters under conditions simulating landfills in developing countries', *Chemosphere*, 116, 46–53. doi: http://dx.doi.org/10.1016/j.chemosphere.2014.01.025.

Kalyani, K. A. and Pandey, K. K. (2014) 'Waste to energy status in India: A short review', *Renewable and sustainable energy reviews*, 31, 113–120.

Kamali, M. *et al.* (2016) ‘Anaerobic digestion of pulp and paper mill wastes–An overview of the developments and improvement opportunities’, *Chemical Engineering Journal*, 298, 162–182.

Kane, D. and Solutions, L. L. C. (2015) ‘Carbon sequestration potential on agricultural lands: A review of current science and available practices’, in *National Sustainable Agriculture Coalition*. Washington, DC, USA.

Karagiannidis, A. and Perkoulidis, G. (2009) ‘A multi-criteria ranking of different technologies for the anaerobic digestion for energy recovery of the organic fraction of municipal solid wastes’, *Bioresource technology*, 100(8), 2355–2360.

Karim, M.R., Kuraoka, M., Higuchi, T., Sekine, M. and Imai, T., (2017) ‘Assessment of heavy metal contamination from municipal solid waste open dumping sites in Bangladesh’, *International Journal of Environment and Waste Management*, 19(3), 191–202.

Keith-Roach, M., Grundfelt, B., Kousa, A., Pohjolainen, E., Magistrati, P., Aggelatou, V., Olivieri, N. and Ferrari, A., (2015) *Past experience of environmental, health and safety issues in REE mining and processing industries and an evaluation of related EU and international standards and regulations*, *Final Report of the EuRare Project; Kemakta Konsult AB: Stockholm, Sweden; Geological Survey of Finland*. Espoo, Finland .

Kershaw, P., Katsuhiko, S., Lee, S. and Woodring, D., (2011) *Plastic debris in the ocean*. United Nations Environment Programme.

Khajuria, A., Yamamoto, Y. and Morioka, T. (2010) ‘*Estimation of municipal solid waste generation and landfill area in Asian developing countries.*’

Khalili, N. R. and Duecker, S. (2013) ‘Application of multi-criteria decision analysis in design of sustainable environmental management system framework’, *Journal of Cleaner Production*, 47, 188–198.

Khatib, A. I. (2011) ‘Municipal Solid Waste Management in Developing Countries: Future Challenges and Possible Opportunities’, in Kumar, S. (ed.). In *Tech (Integrated Waste Management)*, pp. 36–48.

Kiran, E.U., Trzcinski, A.P., Ng, W.J. and Liu, Y., (2014) ‘Bioconversion of food waste to energy: A review', *Fuel*, 134, 389–399.

Kitchenham, B. and Pfleeger, S. L. (2002) 'Principles of survey research: part 5: populations and samples', *ACM SIGSOFT Software Engineering Notes*, 27(5), 17–20.

Kitzinger, J. (1995) 'Qualitative research. Introducing focus groups', *BMJ (Clinical research ed.)*, 311(7000), 299–302.

Koroneos, C. J. and Nanaki, E. A. (2012) 'Integrated solid waste management and energy production - a life cycle assessment approach: the case study of the city of Thessaloniki', *Journal of Cleaner Production*, 27, 141–150. doi: http://dx.doi.org/10.1016/j.jclepro.2012.01.010.

Koziol, N. and Arthur, A. (2011) 'An Introduction to Secondary Data Analysis', *Research Methodology Series*.

Kubin, E. (1998) 'Leaching of nitrate nitrogen into the groundwater after clear felling and site preparation'.

Kuenen, Katja; and Hjelgaard, J. (2016) *Biological treatment of waste - Solid waste disposal on land*. Trozzi, C (Ed). European Environment Agency.

Kuleape, R., Cobbina, S. and Dampare, S. (2014) 'Assessment of the energy recovery potentials of solid waste generated in Akosombo, Ghana', *African Journal of Environmental Science and Technology*, 8(5), 297–305.

Kumar, R. and Gupta, P. (2016) 'Air Pollution Control Policies and Regulations', in *Plant Responses to Air Pollution*. Singapore: Springer , 133–149.

Kumar, S., Mondal, A.N., Gaikwad, S.A., Devotta, S. and Singh, R.N., (2004) 'Qualitative assessment of methane emission inventory from municipal solid waste disposal sites: A case study', *Atmospheric Environment*, 38, 4921–4929. doi: 10.1016/j.atmosenv.2004.05.052.

Kurka, T. and Blackwood, D. (2013) 'Selection of MCA methods to support decision making for renewable energy developments', *Renewable and Sustainable Energy Reviews*, 27, 225–233.

Kurttila, M., Pesonen, M., Kangas, J. and Kajanus, M., (2000) 'Utilizing the analytic hierarchy process (AHP) in SWOT analysis—a hybrid method and its application to a forest-certification case', *Forest Policy and Economics*, 1(1), 41–52.

Langley, A. (1999) 'Strategies for theorizing from process data', *Academy of Management review*, 24(4), 691–710.

Larcher, D. and Tarascon, J. M. (2015) 'Towards greener and more sustainable batteries for electrical energy storage', *Nature chemistry*, 7(1), 19–29.

Laurent, A., Bakas, I., Clavreul, J., Bernstad, A., Niero, M., Gentil, E., Hauschild, M.Z. and Christensen, T.H., (2014) 'Review of LCA studies of solid waste management systems – Part I: Lessons learned and perspectives', *Waste Management*, 34(3), 573–588. doi: http://dx.doi.org/10.1016/j.wasman.2013.10.045.

Laurent, A., Clavreul, J., Bernstad, A., Bakas, I., Niero, M., Gentil, E., Christensen, T.H. and Hauschild, M.Z., (2014) 'Review of LCA studies of solid waste management systems – Part II: Methodological guidance for a better practice', *Waste Management*, 34(3), 589–606. doi: http://dx.doi.org/10.1016/j.wasman.2013.12.004.

Lawson, E. and Lawson, E. (2016) 'Negotiating stakeholder participation in the Ghana national climate change policy', *International Journal of Climate*, 8(3), 399–417.

Leal Filho, W., Brandli, L., Moora, H., Kruopienė, J. and Stenmarck, Å., (2016) 'Benchmarking approaches and methods in the field of urban waste management', *Journal of Cleaner Production*, 112, 4377–4386. doi: 10.1016/j.jclepro.2015.09.065.

Leardini, A. C. and Serventi, S. (2016) 'The cultural landscape of food', *Sustainable Urban Agriculture and Food Planning*.

Lee, G. and Jones-Lee, A. (2004) *Flawed technology of subtitle D landfilling of municipal solid waste*, *Report of G. Fred Lee & Associates, El Macero, CA*.

Lehmann, J. and Joseph, S. (2015) *Biochar for environmental management: science, technology and implementation*. Routledge.

Lenth, R. (2001) 'Some practical guidelines for effective sample size determination', *The American Statistician*, 55(3), 187–193.

Lepetit, V. and Fua, P. (2006) 'Keypoint recognition using randomized trees', *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 28(9), 1465–1479.

Levin, M. (1991) 'The reification-realism-positivism controversy in macromarketing: A philosopher's view', *Journal of Macromarketing*, 11(1), 57–65.

Levis, J. and Barlaz, M. (2015) '*Composting Process Modeling*'. NC State University & Technical University of Denmark.

Levis, J., Barlaz, M. and Jaunich, M. (2015) '*Collection Process Modeling*'.

Levis, J. and Damgaard, A. (2015) 'Sardinia Symposium - Solid Waste Life-Cycle Modeling Workshop Uncertainty and Sensitivity Analysis'. North Carolina State University & Technical University of Denmark.

Li, Z., Lu, H., Ren, L. and He, L., (2013) 'Experimental and modeling approaches for food waste composting: A review', *Chemosphere*, 93(7), 1247–1257.

Limoodehi, F. A., Tayefeh, S.M., Heydari, R. and Abdoli, M.A., (2017) 'Life Cycle Assessment of Municipal Solid Waste Management in Tehran', *Environmental Energy and Economic Research*, 1(2), 207–218. doi: 10.22097/eeer.2017.47247.

Lin, J., Babbitt, C. W. and Trabold, T. A. (2013) 'Life cycle assessment integrated with thermodynamic analysis of bio-fuel options for solid oxide fuel cells', *Bioresource technology*, 128, 495–504.

Linsky, A. S. (1975) 'Stimulating responses to mailed questionnaires: A review', *Public opinion quarterly*, 39(1), 82–101.

Liss, G. and Loomis, C. A. (2013) 'Zero Waste Communities', *Zero Waste International Alliance*.

Lohri, C., Camenzind, E. and Zurbrügg, C. (2014) 'Financial sustainability in municipal solid waste management–Costs and revenues in Bahir Dar, Ethiopia', *Waste Management*, 34(2), 542–552.

Lombardi, E. (2011) 'Zero Landfill is not Zero Waste', *Biocycle*, 52(7), 44–45.

Lomborg, K. and Kirkevold, M. (2003) 'Truth and validity in grounded theory – a reconsidered realist interpretation of the criteria: fit, work, relevance and modifiability', *Nursing Philosophy*, 4(3), 189–200.

Loppinet-Serani, A., Reverte, C., Cansell, F. and Aymonier, C., (2012) 'Supercritical water biomass gasification process as a successful solution to valorize wine distillery wastewaters', *ACS Sustainable Chemistry & Engineering*, 1(1), 110–117.

Lou, X. and Nair, J. (2009) ‘The impact of landfilling and composting on greenhouse gas emissions–a review’, *Bioresource technology*, 100(6), 3792–3798.

Ludwig, C., Hellweg, S. and Stucki, S. (2012) *Municipal solid waste management: strategies and technologies for sustainable solutions*. Springer Science & Business Media.

Mack, N. *et al.* (2005) ‘*Qualitative research methods: a data collectors field guide*.’

Mackenzie, C., McDowell, C. and Pittaway, E. (2007) ‘Beyond “Do No Harm”: The Challenge of Constructing Ethical Relationships in Refugee Research’, *Journal of Refugee Studies*. Oxford University Press, 20(2), 299–319. doi: 10.1093/jrs/fem008.

Madrigal, A. . (2011) *The Hardware Scavengers of Ghana*, *The Atlantic*.

Majale, C., Oosterveer, P. and Mireri, C. (2013) ‘7 Local governments and regional alliances in the delivery of municipal environmental services’, *Urban Waste and Sanitation Services for Sustainable Development: Harnessing Social and Technical Diversity in East Africa*, p. 108.

Makoni, F. S., Thekisoe, O. M. M. and Mbati, P. A. (2016) ‘Urban Wastewater for Sustainable Urban Agriculture and Water Management in Developing Countries’, in *Springer (Sustainable Water Management in Urban Environments)*, pp. 265–293.

Makwara, E. C. and Magudu, S. (2013) ‘Confronting the Reckless Gambling With People’s Health and Lives: Urban Solid Waste Management in Zimbabwe’, *European Journal of Sustainable Development*, 2(1), 67–98.

Manfredi, S. and Christensen, T. H. (2009) ‘Environmental assessment of solid waste landfilling technologies by means of LCA-modeling’, *Waste Management*, 29(1), 32–43. doi: 10.1016/j.wasman.2008.02.021.

Marcus, M. P., Marcinkiewicz, M. A. and Santorini, B. (1993) ‘Building a large annotated corpus of English: The Penn Treebank’, *Computational linguistics*, 19(2), 313–330.

Marine Litter Solutions (2017) *What is Marine Litter*. Available at: https://www.marinelittersolutions.com/about-marine-litter/ (Accessed: 28 June 2017).

Mariwah, S. (2012) ‘Institutional Arrangements for Managing Solid Waste in the

Shama-Ahanta-East Metropolis, Ghana', *Journal of Sustainable Development in Africa*, 14(6).

Marshall, R. and Farahbakhsh, K. (2013) 'Systems approaches to integrated solid waste management in developing countries', *Waste Management*, 33(4), 988–1003.

Mathieu, G. and Williams-Jones, B. (2015) 'Examining the National Regulatory Environment of Medical Devices: Major Issues in the Risk-Benefit Assessment of High-Risk Devices', *McGill JL & Health*, 9, 17.

Maxwell, J. (1992) 'Understanding and Validity in Qualitative Research', *Harvard Educational Review*, 62(3), 279–301. doi: 10.17763/haer.62.3.8323320856251826.

Maxwell, J. A. (2010) 'Using numbers in qualitative research', *Qualitative inquiry*, 16(6), 475–482.

Maxwell, S. (2000) 'Sample size and multiple regression analysis.', *Psychological methods*, 5(4), 434–458.

Maxwell, S., Kelley, K. and Rausch, J. (2008) 'Sample size planning for statistical power and accuracy in parameter estimation', *Annual Review of Psychology*, 9, 537–563.

May, T. (2011) *Social research*. London, UK: McGraw-Hill Education .

McDougall, F. and Hruska, J. (2000) 'Report: the use of Life Cycle Inventory tools to support an integrated approach to solid waste management', *Waste Management and Research*, 18(6), 590–594.

McKay, T. J. M., Mbanda, J. T.-D. and Lawton, M. (2015) '*Exploring the challenges facing the solid waste sector in Douala*, Cameroon'.

McLeod, S. A. (2007) 'S*tages of memoryencoding storage and retrieval'*.

McNamara, C. (1999) '*General guidelines for conducting interviews*, Minnesota', Missouri Institute of science.

Melaré de Souza, A.V., González, S.M., Faceli, K. and Casadei, V., (2017) 'Technologies and decision support systems to aid solid-waste management: a systematic review', *Waste Management*, 59, 567-584. doi: 10.1016/j.wasman.2016.10.045.

Memon, M. A. (2009) *Integrated Solid Waste Management Integrated Solid Waste Management: Stakeholders Roles*.

Memon, M. A. (2010) ‘Integrated Solid Waste Management based on 3R Approach’, *Journal of Material Cycles and Waste Management*, 12(1), 30–40.

Mendes, P., Santos, A.C., Nunes, L.M. and Teixeira, M.R., (2013) ‘Evaluating municipal solid waste management performance in regions with strong seasonal variability’, *Ecological Indicators*, 30, 170–177. doi: 10.1016/j.ecolind.2013.02.017.

Meredith, J. (1998) ‘Building operations management theory through case and field research’, *Journal of operations management*, 16(4), 441–454.

Meyer, I. and Wilson, P. (2009) ‘Sampling lesbian, gay, and bisexual populations.’, *Journal of Counseling Psychology*, 56(1), 23–31.

Miezah, K., Obiri-Danso, K., Kádár, Z., Fei-Baffoe, B. and Mensah, M.Y., (2015) ‘Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana’, *Waste Management*, 46, 15–27. doi: http://dx.doi.org/10.1016/j.wasman.2015.09.009.

Mingers, J. (2001) ‘Combining IS research methods: towards a pluralist methodology’, *Information systems research*, 12(3), 240–259.

Mingers, J. (2004) ‘Realizing information systems: critical realism as an underpinning philosophy for information systems’, *Information and organization*, 14(2), 87–103.

Mir, M.A., Ghazvinei, P.T., Sulaiman, N.M.N., Basri, N.E.A., Saheri, S., Mahmood, N.Z., Jahan, A., Begum, R.A. and Aghamohammadi, N., (2016) ‘Application of TOPSIS and VIKOR improved versions in a multi criteria decision analysis to develop an optimized municipal solid waste management model’, *Journal of Environmental Management*, 166, 109–115. doi: 10.1016/j.jenvman.2015.09.028.

Misra, V. and Pandey, S. (2005) ‘Hazardous waste, impact on health and environment for development of better waste management strategies in future in India’, *Environment international*, 31(3), 417–431.

Mmereki, D., Li, B., Baldwin, A. and Hong, L., (2016) ‘The Generation, Composition, Collection, Treatment and Disposal System, and Impact of E-Waste’, In E-Waste in Transition-From Pollution to Resource. InTech. p. 65.

Moh, Y. and Manaf, L. (2014) ‘Overview of household solid waste recycling policy status and challenges in Malaysia’, *Resources, Conservation and Recycling*, 82, 50–61.

Mohammed, Y.S., Mokhtar, A.S., Bashir, N. and Saidur, R., (2013) ‘An overview of agricultural biomass for decentralized rural energy in Ghana’, *Renewable and Sustainable Energy Reviews*, 20, 15–25.

Mohee, R. and Soobhany, N. (2014) ‘Comparison of heavy metals content in compost against vermicompost of organic solid waste: Past and present’, *Resources, Conservation and Recycling*, 92, 206–213.

Moksha, S. (2013) ‘Theorizing Middle-Way Research Approach from Nagarjuna’s Mulamadhyamaka Karika of 2nd Century AD’, *International Journal of Scientific Research and Reviews*, 2(4), 22–56.

Morgan, D. (2007) ‘Paradigms lost and pragmatism regained: Methodological implications of combining qualitative and quantitative methods’, *Journal of mixed methods research*, 1(1), 48–76.

Morrissey, A. J. and Browne, J. (2004) ‘Waste management models and their application to sustainable waste management’, *Waste Management*, 24(3), 297–308. doi: http://dx.doi.org/10.1016/j.wasman.2003.09.005.

Muchangos dos, L., Tokai, A. and Hanashima, A. (2017) ‘Application of material flow analysis to municipal solid waste in Maputo City, Mozambique’, *Waste Management & Research*, 35(3), 253–266.

Mudhoo, A., Somaroo, D. G. and Mohee, R. (2015) ‘Treatment of Solid Waste: Principles, Key Technologies and Selected Case Studies from Africa’, Mohee, R. and Simelane, T. (eds), in *Future Directions of Municipal Solid Waste Management in Africa*, South Africa: Africa Institute of South Africa, pp. 54–69.

Muijs, D. (2010) *Doing quantitative research in education with SPSS*. Sage.

Mukherjee, S. and Mukhopadhyay, S. (2015) ‘Contemporary environmental issues of landfill leachate: assessment and remedies’, *Critical reviews in environmental science and technology*, 45(5), 472–590.

Müller, C. (2007) ‘Anaerobic digestion of biodegradable solid waste in low-and middle-income countries', *Sandec Report*.

Municipal Waste Department (2010) *Wa Municipal Waste Composition*. Wa.

Muttalib, S. A. A., Ismail, S. N. S. and Praveena, S. M. (2016) '*Application of Effective Microorganism (EM) in Food Waste Composting: A review*'.

Mutz, D., Hengevoss, D., Hugi, C. and Gross, T., (2017) *Waste-to-Energy Options in Municipal Solid Waste Management: A Guide for Decision Makers in Developing and Emerging Countries*. Germany.

Mwangi, M. and Thuo, A. (2014) 'Towards conceptual and theoretical foundation for identifying problems, challenges and mechanisms for municipal waste management in developing countries', *International Journal of Innovation and Scientific Research*, 2(2), 230–251.

Myers, M. (1997) 'Qualitative research in information systems', *Management Information Systems Quarterly*, 21(2), 241–242.

Nabegu, A. B. and Mustapha, A. (2015) 'Institutional Constraints to Municipal Solid Waste Management in Kano Metropolis, Nigeria', *International Journal of Innovative Environmental Studies Research*, 3(3), 13–21.

Newman, I. and Benz, C. R. (1998) *Qualitative-quantitative research methodology: Exploring the interactive continuum*. SIU Press.

Ng, W.P.Q., Lam, H.L., Varbanov, P.S. and Klemeš, J.J., (2014) 'Waste-to-energy (WTE) network synthesis for municipal solid waste (MSW)', *Energy Conversion and Management*, 85, 866–874.

Nizami, A.S., Shahzad, K., Rehan, M., Ouda, O.K.M., Khan, M.Z., Ismail, I.M.I., Almeelbi, T., Basahi, J.M. and Demirbas, A., (2016) 'Developing waste biorefinery in Makkah: A way forward to convert urban waste into renewable energy', *Applied Energy*, 186, 189-196. doi: http://dx.doi.org/10.1016/j.apenergy.2016.04.116.

Nizami, A.S., Rehan, M., Waqas, M., Naqvi, M., Ouda, O.K.M., Shahzad, K., Miandad, R., Khan, M.Z., Syamsiro, M., Ismail, I.M.I. and Pant, D., (2017) 'Waste Biorefineries: Enabling Circular Economies in Developing Countries', *Bioresource Technology*, 241, 1101-1117. doi: 10.1016/j.biortech.2017.05.097.

Njunda, A.L., Ndzi, E.N., Assob, J.C.N., Kamga, H.L.F. and Kwenti, E.T., (2017) 'Prevalence and factors associated with urogenital schistosomiasis among primary school children in barrage, Magba sub-division of Cameroon', *BMC Public Health*, 17(618), 1–9. doi: 10.1186/s12889-017-4539-6.

Noble, H. and Smith, J. (2015) 'Issues of validity and reliability in qualitative research', *Evidence -Based Nursing*, 18(2), 34–35.

Noma, T., Ide, K., Yoshikawa, J., Kojo, K., Matsui, H., Nakajima, R. and Imai, K., (2012) 'Development of waste gasification and gas reforming system for municipal solid waste (MSW)', *Journal of Material Cycles and Waste Management*, 14(3), 153–161.

Norris, S., Guilbert, S. and Smith, M. (2005) 'A theoretical framework for narrative explanation in science', *Science Education*, 89(4), 535–563.

Obirih-Opareh, N. and Post, J. (2002) 'Quality assessment of public and private modes of solid waste collection in Accra, Ghana', *Habitat International*, 26(1), 95–112. doi: 10.1016/S0197-3975(01)00035-2.

Odukoya, A. M. and Abimbola, A. F. (2010) 'Contamination assessment of surface and groundwater within and around two dumpsites', *Abimbola Int. J. Environ. Sci. Tech*, 7(2), 367–376.

Oduro-Kwarteng, S. and Shaw, R. (2009) 'Institutional arrangements for private sector involvement in urban solid waste collection: case study of five cities in Ghana.', in *Water, sanitation and hygiene: sustainable development and multisectoral approaches. Proceedings of the 34th WEDC International Conference, United Nations Conference Centre, Addis Ababa, Ethiopia, 18-22 May 2009*. Water, Engineering and Development Centre (WEDC) Loughborough University of Technology, pp. 542–549.

OECD (2013) '*Policy roundtables: Water managment Services*'.

Ogwueleka, T. (2009) 'Municipal solid waste characteristics and management in Nigeria', *Journal of Environmental Health Science & Engineering*, 6(3), 173–180.

Ojo, G. and Bowen, D. (2014) 'Environmental and economic analysis of solid waste management alternatives for Lagos municipality, Nigeria', *Journal of Sustainable Development in Africa*, 16(1), 113–144.

Okot-Okumu, J. (2012) 'Solid waste management in African cities–East Africa', in

Waste Management-An Integrated Vision.

Olapiriyakul, S. (2017) ‘Designing a sustainable municipal solid waste management system in Pathum Thani, Thailand’, *International Journal of Environmental Technology and Management*, 20(1/2), 37–59. doi: 10.1504/IJETM.2017.086433.

Olukanni, D. O., Adebayo, R. A. and Tenebe, I. T. (2014) ‘Assessment of Urban Drainage and Sanitation Challenges in Nigeria’, *International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com ISO Certified Journal*, 4(12), 100–105.

Onyx, J. and Small, J. (2001) ‘Memory-work: The method’, *Qualitative Inquiry*, 7(6), 773–786.

Opdenakker, R. (2006) ‘Advantages and disadvantages of four interview techniques in qualitative research’, in *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research*.

Orum, A., Feagin, J. and Sjoberg, G. (1991) ‘Introduction: The nature of the case study’, in *A case for the case study*, pp. 1–26.

Osibanjo, O. *et al.* (2012) ‘Chemicals and Waste’, in *United Nations Environment Programme (Global Environment Outlook)*.

Östlund, U., Kidd, L., Wengström, Y. and Rowa-Dewar, N., (2011) ‘Combining qualitative and quantitative research within mixed method research designs: a methodological review’, *International journal of nursing studies*, 48(3), 369–383.

Oteng-Ababio, M. (2012) ‘The role of the informal sector in solid waste management in the GAMA, Ghana: Challenges and opportunities’, *Tijdschrift voor economische en sociale geografie*, 103(4), 412–425.

Oteng-Ababio, M. (2014) ‘Rethinking waste as a resource: insights from a low-income community in Accra, Ghana’, *City, Territory and Architecture*, 1(1), 1–14.

Oteng-Ababio, M., Arguello, J. E. M. and Gabbay, O. (2013) ‘Solid waste management in African cities: Sorting the facts from the fads in Accra, Ghana’, *Habitat International*, 39, 96–104. doi: http://dx.doi.org/10.1016/j.habitatint.2012.10.010.

Othieno, H. and Awange, J. (2016) ‘Options and Challenges’, in. *Springer (Energy*

Resources in Africa), pp. 291–320.

Ouda, O.K.M., Raza, S.A., Nizami, A.S., Rehan, M., Al-Waked, R. and Korres, N.E., (2016) 'Waste to energy potential: A case study of Saudi Arabia', *Renewable and Sustainable Energy Reviews*, 61, 328–340.

Palma, L. Di and Mecozzi, R. (2010) 'Batch and column tests of metal mobilization in soil impacted by landfill leachate', *Waste Management*, 30(8), 1594–1599.

Pandey, B.K., Vyas, S., Pandey, M. and Gaur, A., (2016) 'Municipal solid waste to energy conversion methodology as physical, thermal, and biological methods', *Curr. Sci. Perspect*, 2(2), 39–44.

Papargyropoulou, E., Lozano, R., Steinberger, J.K., Wright, N. and bin Ujang, Z., (2014) 'The food waste hierarchy as a framework for the management of food surplus and food waste', *Journal of Cleaner Production*, 76, 106–115. doi: http://dx.doi.org/10.1016/j.jclepro.2014.04.020.

Papargyropoulou, E., Colenbrander, S., Sudmant, A.H., Gouldson, A. and Tin, L.C., (2015) 'The economic case for low carbon waste management in rapidly growing cities in the developing world: The case of Palembang, Indonesia', *Journal of environmental management*, 163, 11–19.

Pathirage, C., Amaratunga, R. and Haigh, R. (2007) 'The role of philosophical context in the development of theory: Towards methodological pluralism', *The Built and Human Environment Review*, 1(1).

Patton, M., (1999) 'Enhancing the Quality and Credibility of Qualitative Analysis', *Health Services Research*, 34(5), 1189–1208.

Percival, R. V (2015) 'Regulatory Evolution and the Future of Environmental Policy', in *University of Chicago Legal Forum*, p. 7.

Permana, A.S., Towolioe, S., Aziz, N.A. and Ho, C.S., (2015) 'Sustainable solid waste management practices and perceived cleanliness in a low income city', *Habitat International*, 49, 197–205.

Perry, C. (1998) 'Processes of a case study methodology for postgraduate research in marketing', *European journal of marketing*, 32(9/10), 785–802.

Phillips, P.S., Tudor, T., Bird, H. and Bates, M., (2011) 'A critical review of a key waste strategy initiative in England: zero waste places projects 2008–2009', *Resources, Conservation and Recycling*, 55(3), 335–343.

Pipatti, Riitta; Sharma, Chhemendra; Yamada, Masato; Gao, Qingxian; and Guendehou, S. (2006) 'Waste Generation , Composition and Management Data', in *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. International Panel on Climate Change.

Pires, A., Martinho, G. and Chang, N. (2011) 'Solid waste management in European countries: A review of systems analysis techniques', *Journal of environmental management*, 92(4), 1033–1050.

Plack, M. (2005) 'Human nature and research paradigms: Theory meets physical therapy practice', *The Qualitative Report*, 10(2), 223-245.

Plastic Oceans Foundation (2017) *What We Protect: Rethink Plastic*. Available at: https://www.plasticoceans.org/?gclid=Cj0KCQjwp83KBRC2ARIsAGMWFzpm5dWX4_4JPO0FwLXXWyI6djaIOad3ADppSDHAjowZZjo825SdUYAaAkWcEALw_wcB (Accessed: 28 June 2017).

Poh, P.E., Tan, D.T., Chan, E.S. and Tey, B.T., (2015) 'Current Advances of Biogas Production via Anaerobic Digestion of Industrial Wastewater', in *Springer (Advances in Bioprocess Technology)*, pp. 149–163.

Pohekar, S. D. and Ramachandran, M. (2004) 'Application of multi-criteria decision making to sustainable energy planning—a review', *Renewable and sustainable energy reviews*, 8(4), 365–381.

Pope, C., Ziebland, S. and Mays, N. (2000) 'Qualitative research in health care. Analysing qualitative data', *BMJ (Clinical research ed.)*, 320(7227), 114–116.

Pouliot, V. (2007) '"Sobjectivism": toward a constructivist methodology', *International Studies Quarterly*, 51(2), 359–384.

Pragya, N., Pandey, K. K. and Sahoo, P. K. (2013) 'A review on harvesting, oil extraction and biofuels production technologies from microalgae', *Renewable and Sustainable Energy Reviews*, 24, 159–171.

Pressley, P.N., Levis, J.W., Damgaard, A., Barlaz, M.A. and DeCarolis, J.F., (2015) ‘Analysis of material recovery facilities for use in life-cycle assessment’, *Waste Management*, 35, 307–317. doi: 10.1016/j.wasman.2014.09.012.

Price, B. (2004) ‘Conducting sensitive patient interviews’, *Nursing standard (Royal College of Nursing (Great Britain) : 1987)*, 18(38), 45. doi: 10.7748/ns2004.06.18.38.45.c3623 [doi].

Procter & Gamble (2005) *‘IWM-2 an LCI computer model for solid waste management, model guide*’.

Proietti, I., Frazzoli, C. and Mantovani, A. (2014) ‘Identification and management of toxicological hazards of street foods in developing countries’, *Food and Chemical Toxicology*, 63, 143–152. doi: http://dx.doi.org/10.1016/j.fct.2013.10.047.

Prüss-Üstün, A. and Corvalán, C. (2006) *Preventing Disease Through Healthy Environments: Towards an estimate of the environmental burden of disease*.

Quadagno, J. and Knapp, S. (1992) ‘Have historical sociologists forsaken theory? Thoughts on the history/theory relationship’, *Sociological Methods & Research*, 20(4), 481–507.

Rada, E.C., Ragazzi, M., Villotti, S. and Torretta, V., (2014) ‘Sewage sludge drying by energy recovery from OFMSW composting: Preliminary feasibility evaluation’, *Waste Management*, 34(5), 859–866.

Ragsdale, C. T. (2015) *Spreadsheet Modeling and Decision Analysis: A Practical Introduction to Business Analytics*. 7th ed. CENGAGE Learning.

Rajaeifar, M.A., Tabatabaei, M., Ghanavati, H., Khoshnevisan, B. and Rafiee, S., (2015) ‘Comparative life cycle assessment of different municipal solid waste management scenarios in Iran’, *Renewable and Sustainable Energy Reviews*, 51, 886–898. doi: http://dx.doi.org/10.1016/j.rser.2015.06.037.

Rand, T., Haukohl, J. and Marxen, U. (2000) *Municipal Solid Waste Incineration: A Decision Maker’s Guide*.

Rathje, W. L. (2013) ‘The Garbage Project &" The Archaeology of’, *Changes*.

Ray, M. (no date) ‘Municipal Solid Waste Management: A Case Study of Koch Bihar Municipality, West Bengal, India’.

Remenyi, D. and Williams, B. (1995) ‘Some aspects of methodology for research in information systems’, *Journal of Information Technology*, 10(3), 191–201.

Remigios, M. V (2010) ‘An overview of the management practices at solid waste disposal sites in African cities and towns’, *Journal of Sustainable Development in Africa*, 12(7), 233–239.

Research Triangle Institute (2012) ‘*Decision Support Tool Training*’.

Research Triangle Instituite International, (2000) *‘A Decision Support Tool for Assessing the Cost and Environmental Burdens of Integrated Municipal Solid Waste Management Strategies: Users Manual*’.

Research Triangle Instituite International, (2006) *Application of Life-Cycle Management to Evaluate Integrated Municipal Solid Waste Management Strategies*.

Ripa, M., Fiorentino, G., Vacca, V. and Ulgiati, S., (2017) ‘The relevance of site-specific data in Life Cycle Assessment (LCA). The case of the municipal solid waste management in the metropolitan city of Naples (Italy)’, *Journal of Cleaner Production*, 142, 445–460.

Ristić, G. (2005) ‘Basic Indicators of Integrated Solid Waste Management’, *Series: Working and Living Environmental Protection*, 2(5), 383–392.

Roberts, D. (2015) ‘Characterisation of chemical composition and energy content of green waste and municipal solid waste from Greater Brisbane, Australia’, *Waste Management*, 41, 12–19.

Robson, C. (2002) *Real world research. 2nd*, *Blackwell Publishing. Malden*.

Roche, D. (1996) ‘Landfill failure survey: a technical note’, *Geological Society, London, Engineering Geology Special Publications*, 11(1), 379–380.

Rodic, L. and Wilson, D. (2017) ‘Resolving Governance Issues to Achieve Priority Sustainable Development Goals Related to Solid Waste Management in Developing Countries’, *Sustainability*, 9(3).

Rodríguez Díez, J.J., Cremades Oliver, L.V. and Ahumada Cervantes, B., (2015) ‘Addressing strategic environmental assessment of Mexico’s transition towards renewable energy.’, in *AEIPRO 2015: International Congress on Project Engineering*, pp. 1121–1132.

Rogge, N. and Jaeger, S. De (2013) ‘Measuring and explaining the cost efficiency of municipal solid waste collection and processing services’, *Omega*, 41(4), 653–664.

Rosengren, C. (2016) *‘How utilizing EPA’s Decision Support Tool can greatly improve waste management systems*’.

Roy, K., Zvonkovic, A., Goldberg, A., Sharp, E. and LaRossa, R., (2015) ‘Sampling richness and qualitative integrity: Challenges for research with families’, *Journal of Marriage and Family*, 77(1), 243–260.

Rozenberga, A. (2013) ‘*Municipal solid waste: Is it garbage or gold*?’

Ruddin, L. P. (2006) ‘You Can Generalize Stupid! Social Scientists, Bent Flyvbjerg, and Case Study Methodology’, *Qualitative Inquiry*, 12(4), 797–812. doi: 10.1177/1077800406288622.

Rugemalila, R. and Gibbs, L. (2015) ‘Urban water governance failure and local strategies for overcoming water shortages in Dar es Salaam, Tanzania’, *Environment and Planning C: Government and Policy*, 33(2), 412–427.

Rumyantseva, A., Berezyuk, M., Savchenko, N. and Rumyantseva, E., (2017) ‘Modern technologies of processing municipal solid waste : investing in the future’, in *Earth and Environmental Science*. IOP Publishing.

Rynk, R. and Richard, T. (2001) ‘Commercial compost production systems’, *Compost utilization in horticultural cropping*, 51–93.

Salim, M. R., Noor, Z. Z., Tin, L. C., Okabe, K., Shaharudin, N., Othman, S. N., Ting, T. S. and Tsong, T. B., (2014) ‘Sustainable Waste Management Towards a Low Carbon Society’, *Proceeding ISEE 2013*, 1(1).

Samraj, B. (2016) ‘Discourse structure and variation in manuscript reviews: Implications for genre categorization’, *English for Specific Purposes*. Pergamon, 42, 76–88. doi: 10.1016/J.ESP.2015.12.003.

Sanders, J., Rozeboom, D. and Loudon, T. (2010) ‘Quantifying nutrients in effluent from uncovered, intact mature bovine carcass compost piles subjected to storm events’, *Compost Science & Utilization*, 18(4), 216–231.

Sanford, A., Terrell, M.,Buckingham, W., Gay, E. and English, C., (2016) '*Waste Management Planning'.*

Sanjeevi, V. and Shahabudeen, P. (2015) 'Development of performance indicators for municipal solid waste management (PIMS): A review', *Waste Management & Research*, 33(12), 1052–1065. doi: 10.1177/0734242X15607428.

Sankoh, F., Yan, X. and Conteh, A. (2012) 'A Situational Assessment of Socioeconomic Factors Affecting Solid Waste Generation and Composition in Freetown, Sierra Leone', *Journal of Environmental Protection*, 3(7), 563–568.

Sanneh, E.S., Hu, A.H., Chang, Y.M. and Sanyang, E., (2011) 'Introduction of a recycling system for sustainable municipal solid waste management: A case study on the Greater Banjul area of the Gambia', *Sustainable Systems and Technology (ISSST), 2011 IEEE International Symposium on*, 1. doi: 10.1109/ISSST.2011.5936884.

Santibañez-Aguilar, J.E., Ponce-Ortega, J.M., González-Campos, J.B., Serna-González, M. and El-Halwagi, M.M., (2013) 'Optimal planning for the sustainable utilization of municipal solid waste', *Waste Management*, 33(12), 2607–2622. doi: http://dx.doi.org/10.1016/j.wasman.2013.08.010.

Sarris, D. and Papanikolaou, S. (2016) 'Biotechnological production of ethanol: Biochemistry, processes and technologies', *Engineering in Life Sciences*.

Saunders, M., Lewis, P. and Thornhill, A. (2009) 'Research Onion', in *Research methods for business students*, pp. 136–162.

Savenye, W. C. and Robinson, R. S. (1996) 'Qualitative research issues and methods: An introduction for educational technologists', in *Handbook of research for educational communications and technology*, pp. 1171–1195.

Schell, C. (1992) '*The value of the case study as a research strategy*', Manchester Business School, 2.

Schübeler, P., Christen, J. and Wehrle, K. (1996) *Conceptual framework for municipal solid waste management in low-income countries*. SKAT (Swiss Center for Development Cooperation).

Scipioni, A., Mazzi, A., Zuliani, F. and Mason, M., (2008) 'The ISO 14031 standard to guide the urban sustainability measurement process: an Italian experience', *Journal* *of Cleaner Production*, 16(12), 1247–1257.

Scotland, J. (2012) ‘Exploring the philosophical underpinnings of research: Relating ontology and epistemology to the methodology and methods of the scientific, interpretive, and critical’, *English Language Teaching*, 5(9), 9–16.

Seltenrich, N. (2016) ‘Emerging Waste-to- Energy Technologies: Solid Waste Solution or Dead End?’, *Environmental health perspectives*, 124(6), A106. doi: 10.1289/ehp.124-A106.

Sequeira, V. and Chandrashekar, J. S. (2015) ‘Vermicomposting of Biodegradable Municipal Solid Waste Using Indigenous Eudrilus Sp. Earthworms’, *Int.J.Curr.Microbiol.App.Sci*, 4(4), 356–365.

Shahir, S.A., Masjuki, H.H., Kalam, M.A., Imran, A., Fattah, I.R. and Sanjid, A., (2014) ‘Feasibility of diesel–biodiesel–ethanol/bioethanol blend as existing CI engine fuel: An assessment of properties, material compatibility, safety and combustion’, *Renewable and Sustainable Energy Reviews*, 32, 379–395.

Shamshiry, E., Mokhtar, M.B., Abdulai, A.M. and Komoo, I., (2015) ‘Using the Analytic Hierarchy Process to Enhance Sustainable Solid Waste Management: Case Study of Langkawi Island, Malaysia’, *Environmental Quality Management*, 24(4), 51–64. doi: 10.1002/tqem.21404.

Shareefdeen, Z., Elkamel, A. and Tse, S. (2015) ‘Review of current technologies used in municipal solid waste-to-energy facilities in Canada’, *Clean Technologies and Environmental Policy*, 17(7), 1837–1846. doi: http://dx.doi.org/10.1007/s10098-015-0904-2.

Sharholy, M., Ahmad, K., Mahmood, G. and Trivedi, R.C., (2008) ‘Municipal solid waste management in Indian cities–A review’, *Waste management*, 28(2), 459–467.

Sharma, R. and Sheth, P. N. (2015) ‘Thermo-Chemical Conversion of Jatropha Deoiled Cake: Pyrolysis vs. Gasification’, *International Journal of Chemical Engineering and Applications*, 6(5), 376–380. doi: http://dx.doi.org/10.7763/IJCEA.2015.V6.513.

Sheavly, S. and Register, K. (2007) ‘Marine debris & plastics: environmental concerns, sources, impacts and solutions’, *Journal of Polymers and the Environment*, 15(4), 301–305.

Shekdar, A. (2009) ‘Sustainable solid waste management: an integrated approach for Asian countries’, *Waste management*, 29(4), 1438–1448.

Shi, H., Mahinpey, N., Aqsha, A. and Silbermann, R., (2016) ‘Characterization, thermochemical conversion studies, and heating value modeling of municipal solid waste’, *Waste Management*, 48, 34–47.

Shonkoff, S., Hays, J. and Finkel, M. (2014) ‘Environmental public health dimensions of shale and tight gas development’, *Environmental health perspectives*, 122(8), 787.

Silke, A. (2001) ‘The devil you know: Continuing problems with research on terrorism’, *Terrorism and political violence*, 13(4), 1–14.

Silver, N., Best, S., Jiang, J. and Thein, S.L., (2006) ‘Selection of housekeeping genes for gene expression studies in human reticulocytes using real-time PCR.’, *BMC molecular biology*, 7(1), 33.

Sim, W. (2013) ‘*NUS undergraduate spur recycling with “green wardrobe*s”’,

Singh, J., Laurenti, R., Sinha, R. and Frostell, B., (2014) ‘Progress and challenges to the global waste management system’, *Waste management & research : the journal of the International Solid Wastes and Public Cleansing Association, ISWA*, 32(9), 800–812. doi: 10.1177/0734242X14537868 [doi].

Slagstad, H. and Brattebø, H. (2013) ‘Influence of assumptions about household waste composition in waste management LCAs’, *Waste Management*, 33(1), 212–219. doi: 10.1016/j.wasman.2012.09.020.

Smeets, E. and Weterings, R. (1999) *Environmental indicators : Typology and overview*, European Environment Agency.

Snieder, R. and Larner, K. (2009) ‘The art of being a scientist’, *A guide for graduate students and their mentors*. Cambridge: Cambridge University Press .

Soiferman, L. (2010) ‘Compare and Contrast Inductive and Deductive Research Approaches.’, *Online Submission*.

Solem, O. (2003) ‘Epistemology and logistics: a critical overview’, *Systemic Practice and Action Research*, 16(6), 437–454.

Soltani, A., Hewage, K., Reza, B. and Sadiq, R., (2015) ‘Multiple stakeholders in multi-criteria decision-making in the context of municipal solid waste management: a review’, *Waste Management*, 35, 318–328.

Søndergaard, R.R., Zimmermann, Y.S., Espinosa, N., Lenz, M. and Krebs, F., (2016) ‘Incineration of organic solar cells: efficient end of life management by quantitative silver recovery’, *Energy & Environmental Science*, 9(3), 857–861.

Song, Q., Li, J. and Zeng, X. (2015) ‘Minimizing the increasing solid waste through zero waste strategy’, *Journal of Cleaner Production*, 104, 199–210.

Spash, C. and Vatn, A. (2006) ‘Transferring environmental value estimates: Issues and alternatives’, *Ecological Economics*, 60(2), 379–388.

Spiegelman, H. and Sheehan, B. (2005) *Unintended Consequences: Municipal Solid Waste Management and the Throwaway Society*.

Spradley, J. P. (2016) *Participant observation*. Waveland Press.

Srirangan, K. *et al.* (2012) ‘Towards sustainable production of clean energy carriers from biomass resources’, *Applied Energy*, 100, 172–186.

Srivastava, V., Ismail, S.A., Singh, P. and Singh, R.P., (2015) ‘Urban solid waste management in the developing world with emphasis on India: challenges and opportunities’, *Reviews in Environmental Science and Biotechnology*, 14(2), 317–337. doi: http://dx.doi.org/10.1007/s11157-014-9352-4.

Stanisavljevic, N. and Brunner, P. (2014) ‘Combination of material flow analysis and substance flow analysis: A powerful approach for decision support in waste management’, *Waste Management & Research*, 32(8), 733–744.

Stegmann, R. (2017) ‘Global pollution….Time to act’, *Waste Management*, 66, 1–2. doi: 10.1016/j.wasman.2017.05.044.

Stewart, J. (2012) ‘Multiple-case study methods in governance-related research’, *Public Management Review*, 14(1), 67–82.

Sthiannopkao, S. and Wong, M. H. (2013) ‘Handling e-waste in developed and developing countries: Initiatives, practices, and consequences’, *Science of the Total Environment*, 463, 1147–1153.

Stoeva, K. and Alriksson, S. (2017) ‘Influence of recycling programmes on waste separation behaviour’. doi: 10.1016/j.wasman.2017.06.005.

Suddick, E.C., Whitney, P., Townsend, A.R. and Davidson, E.A., (2013) ‘The role of nitrogen in climate change and the impacts of nitrogen–climate interactions in the United States: foreword to thematic issue’, *Biogeochemistry*, 114(1–3), 1–10.

Sudore, R.L., Knight, S.J., McMahan, R.D., Feuz, M., Farrell, D., Miao, Y. and Barnes, D.E., (2014) ‘A Novel Website to Prepare Diverse Older Adults for Decision Making and Advance Care Planning: A Pilot Study’, *Journal of Pain and Symptom Management*. Elsevier, 47(4), 674–686. doi: 10.1016/J.JPAINSYMMAN.2013.05.023.

Sukholthaman, P. and Shirahada, K. (2015) ‘Technological challenges for effective development towards sustainable waste management in developing countries: Case study of Bangkok, Thailand’, *Technology in Society*, 43, 231–239.

Sukma, N., Haryono, A. T. and Wulan, H. S. (2016) ‘Analysis of the Influence of Personality Characteristics, Organizational Culture and Quality of Work Life on Employee Performance and Job Satisfaction as an Intervening Variable’, *Journal of Management*, 2(2).

Symonds, J. E. and Gorard, S. (2008) ‘The death of mixed methods: research labels and their casualties’, in *British Educational Research Association Annual Conference*. Citeseer.

Taiwo, A. M. (2011) ‘Composting as a sustainable waste management technique in developing countries’, *Journal of Environmental Science and Technology*, 4(2), 93–102.

Tan, S.T., Ho, W.S., Hashim, H., Lee, C.T., Taib, M.R. and Ho, C.S., (2015) ‘Energy, economic and environmental (3E) analysis of waste-to-energy (WTE) strategies for municipal solid waste (MSW) management in Malaysia’, *Energy Conversion and Management*, 102, 111–120.

Tang, J. and Brunner, P. (2014) ‘Globalising MFA–decision support for waste management in cities based on the software STAN’, *Resources and Waste Management*, 1–41.

Tanigaki, N., Ishida, Y. and Osada, M. (2016) ‘Landfill Minimization and Material

Recovery via Waste Gasification in a New Waste Management Scheme', in Rada, E. C. (ed.) *Thermochemical Waste Treatment: Combustion, Gasification, and Other Methodologies*, p. 71.

Taylor, S. and Edgar, D. (1999) *Lacuna or lost cause? Some reflections on hospitality management research*, *Handbook of Contemporary Hospitality Management Research*.

Tchobanoglous, G. (1993) '*Integrated solid waste management engineering principles and management issues*', 628(T3).

Teddlie, C. and Tashakkori, A. (2009) *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Sage.

Teixeira, C. A. and Neves, E. B. (2009) 'Municipal Solid Waste Performance Indicators', in Vieira, Ramísio, and Silveira (eds) *Turning Waste into Ideas*. Lisbon: APESB2009 World Congress.

Temgoua, E., Honorine, N.T., Simplice, K.K.G. and Emmanuel, N., (2015) 'Evolution of the Dominant Groups of Micro-organisms during the Composting Process of the Household Refuses from the Dschang Municipality–Cameroon', *British Microbiology Research Journal*, 8(1), 348–357.

Thaiyalnayaki, D. and Jayanthi, R. (2017) 'Characterisation of Household Solid Waste in the Town of Thanjavur', *Indian J.Sci.Res*, 14(1), 143–147.

The World Bank (2013) *Enforcing Accountability: World Bank Debars Ghanaian Company for Sanctionable Misconduct Relating to a Waste Management Project in Liberia*, *Press Release*.

The World Bank (2016) *GDP per capita (current US$)* | *Data*.

Thierry, M., Salomon, M. and Nunen, J. Van (1995) 'Strategie issues in product recovery management', *California management review*, 37(2), 114–135.

ThiKimOanh, L., Bloemhof-Ruwaard, J.M., van Buuren, J.C., van der Vorst, J.G. and Rulkens, W.H., (2015) 'Modelling and evaluating municipal solid waste management strategies in a mega-city: the case of Ho Chi Minh City', *Waste management & research : the journal of the International Solid Wastes and Public Cleansing*

Association, ISWA, 33(4), 370–380. doi: 10.1177/0734242X15572177 [doi].

Thorneloe, S., Weitz, K. and Jambeck, J. (2007) 'Application of the US decision support tool for materials and waste management', *Waste Management*, 27(8), 1006–1020.

Tian, H., Gao, J., Hao, J., Lu, L., Zhu, C. and Qiu, P., (2013) 'Atmospheric pollution problems and control proposals associated with solid waste management in China: a review', *Journal of hazardous materials*, 252, 142–154.

Tiwary, A., Williams, I.D., Pant, D.C. and Kishore, V.V.N., (2015) 'Emerging perspectives on environmental burden minimisation initiatives from anaerobic digestion technologies for community scale biomass valorisation', *Renewable and Sustainable Energy Reviews*, 42, 883–901.

Tom, A. P., Pawels, R. and Haridas, A. (2016) 'Biodrying process: A sustainable technology for treatment of municipal solid waste with high moisture content', *Waste management (New York, N.Y.)*, 49, 64. doi: 10.1016/j.wasman.2016.01.004.

Tongco, M. (2007) 'Purposive sampling as a tool for informant selection', *Ethnobotany Research and Applications*, 5, 147–158.

Topić, M., Zimmermann, F. and Fischer, W. (2013) 'Waste Management Planning: An analysis of the waste management system in Bosnia and Herzegovina', in *Planning and normative protection of space and environment: proceedings of the 7th scientific conference with international participation, Belgrade*, pp. 205–213.

Townsend, T.G., Powell, J., Jain, P., Xu, Q., Tolaymat, T. and Reinhart, D., (2015a) *Sustainable Practices for Landfill Design and Operation*. Springer.

Townsend, T.G., Powell, J., Jain, P., Xu, Q., Tolaymat, T. and Reinhart, D., (2015b) 'The Landfill's Role in Sustainable Waste Management', in. *Springer (Sustainable Practices for Landfill Design and Operation)*, pp. 1–12.

Tozlu, A., Özahi, E. and Abuşoğlu, A. (2016) 'Waste to energy technologies for municipal solid waste management in Gaziantep', *Renewable and Sustainable Energy Reviews*, 54, 809–815. doi: http://dx.doi.org/10.1016/j.rser.2015.10.097.

Tranfield, D., Denyer, D. and Smart, P. (2003) 'Towards a methodology for developing evidence-informed management knowledge by means of systematic review', *British* *journal of management*, 14(3), 207–222.

Transparency Market Research (2017) *Waste to Energy Market (Technology Type - Thermal and Biological) - Global Industry Analysis, Size, Share, Growth, Trends and Forecast 2013 - 2019*, *Energy and Mining*. Available at: http://www.transparencymarketresearch.com/waste-to-energy-market.html (Accessed: 11 July 2017).

Trevino, L., (1986) 'Ethical Decision Making in Organizations: A Person-Situation Interactionist Model', *The Academic of Management Review*, 11(3), 601–617.

Trochim, W. M. K. and Donnelly, J. P. (2001) '*Research methods knowledge base*'.

Tudor, T., Robinson, G.M., Riley, M., Guilbert, S. and Barr, S.W., (2011) 'Challenges facing the sustainable consumption and waste management agendas: perspectives on UK households', *Local Environment*, 16(1), 51–66.

Turki, M., Medhioub, E. and Kallel, M. (2017) 'Evaluation of a national food industry based on environmental performance and condition indicators: critical success and barriers of EMS implementation in Tunisia', *Environment Systems and Decisions*. Springer US. doi: 10.1007/s10669-017-9646-5.

Twardowska, I. and Szczepanska, J. (2002) 'Solid waste: terminological and long-term environmental risk assessment problems exemplified in a power plant fly ash study', *Science of the total environment*, 285(1), 29–51.

Tyagi, V. K. and Lo, S. L., (2013) 'Sludge: A waste or renewable source for energy and resources recovery?', *Renewable and Sustainable Energy Reviews*, 25, 708–728.

UN-HABITAT (2010) *Solid Waste Management in the World's Cities: Water and Sanitation in the World's Cities*. Earthscan.

United Nations, (2015) *Transforming our world: The 2030 agenda for sustainable development*.

UNEP (2013) *Guidelines for National Waste Management Strategies: Moving from Challenges to Opportunities*.

UNEP. (2005) *Solid Waste Managment*.

United Nations (2007) *Indicators of sustainable development: Guidelines and* *methodologies*. United Nations Publications.

United Nations Environment Programme (2010) *Waste and Climate Change: Global Trends and Strategy Framework*. International Environmental Technology Centre, Osaka/Shiga.

US, E. (2017a) *Nitrogen Dioxide (NO2) Pollution*, *Basic Information about NO2*. Available at: https://www.epa.gov/no2-pollution/basic-information-about-no2#Effects (Accessed: 28 March 2018).

US, EPA. (2017b) *Particulate Matter (PM) Pollution*, *Health and Environmental Effects of Particulate Matter*. Available at: https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm.

Vaccari, M., Tudor, T. and Perteghella, A. (2018) 'Costs associated with the management of waste from healthcare facilities: An analysis at national and site level', *Waste Management & Research*, 36(1), 39–47. doi: 10.1177/0734242X17739968.

Valenzuela, D. and Shrivastava, P. (2002) '*Interview as a method for qualitative research'*, Southern Cross University and the Southern Cross Institute of Action Research *(SCIAR)*.

Van de Klundert, A. and Lardinois, I. (1995) 'Community and private (formal and informal) sector involvement in municipal solid waste management in developing countries', *paper for the UMP Workshop in Ittingen*, 10–12.

Vandermeersch, T., Alvarenga, R.A.F., Ragaert, P. and Dewulf, J., (2014) 'Environmental sustainability assessment of food waste valorization options', *Resources, Conservation and Recycling*, 87, 57–64.

Vartanian, T. P. (2010) *Secondary data analysis*. Oxford University Press.

Vasanthi, P. and Kaliappan, S. (2008) 'Impact of poor solid waste management on ground water', *Environmental monitoring and assessment*, 143(1), 227–238.

Venkatraman, N. (1989) 'The concept of fit in strategy research: Toward verbal and statistical correspondence', *Academy of management review*, 14(3), 423–444.

Vohra, M., Manwar, J., Manmode, R., Padgilwar, S. and Patil, S., (2014) 'Bioethanol production: Feedstock and current technologies', *Journal of Environmental Chemical*

Engineering, 2(1), 573–584.

Voss, C., Tsikriktsis, N. and Frohlich, M. (2002) ‘Case research in operations management’, *International journal of operations & production management*, 22(2), 195–219.

Vrijheid, M. (2000) ‘Health Effects of Residence Near Hazardous Waste Landfill Sites: A Review of Epidemiologic Literature’, *Environmental Health Perspectives*, 108(Supplement 1), 101–112.

Vučijak, B., Kurtagić, S. . and Silajdžić, I. (2016) ‘Multicriteria decision making in selecting best solid waste management scenario: a municipal case study from Bosnia and Herzegovina’, *Journal of Cleaner Production*. Elsevier, 130, 166–174. doi: 10.1016/J.JCLEPRO.2015.11.030.

Wahyuni, D. (2012) ‘T*he research design maze: Understanding paradigms, cases, methods and methodologies*’.

Waksberg, J. (1978) ‘Sampling methods for random digit dialing’, *Journal of the American Statistical Association*, 73(361), 40–46.

Walsh, D. and Downe, S. (2005) ‘Meta-synthesis method for qualitative research: a literature review’, *Journal of advanced nursing*, 50(2), 204–211.

Wang, H. and Nie, Y. (2001) ‘Municipal solid waste characteristics and management in China’, *Journal of the Air & Waste Management Association*, 51(2), 250–263.

Wang, Y., Cheng, K., Wu, W., Tian, H., Yi, P., Zhi, G., Fan, J. and Liu, S., (2017) ‘Atmospheric emissions of typical toxic heavy metals from open burning of municipal solid waste in China’, *Atmospheric Environment*, 152, 6–15. doi: 10.1016/j.atmosenv.2016.12.017.

Wanka, S., Münnich, K. and Fricke, K. (2017) ‘Landfill Mining-Wet mechanical treatment of fine MSW with a wet jigger’, *Waste Management*, 59, 316–323.

Waters, M. C. (1990) *Ethnic options: Choosing identities in America*. University of California Press.

Watkins, P. and McKendry, P. (2015) ‘*Sustainable Energy Technologies and Assessments’.*

Wedawatta, G., Ingirige, B. and Amaratunga, D. (2011) 'Case study as a research strategy: Investigating extreme weather resilience of construction SMEs in the UK', in *7th Annual International Conference of International Institute for Infrastructure, Renewal and Reconstruction*.

White, P., Dranke, M. and Hindle, P. (2012) *Integrated solid waste management: a lifecycle inventory*. Springer Science & Business Media.

Wiedmann, T. O. *et al.* (2015) 'The material footprint of nations', *Proceedings of the National Academy of Sciences of the United States of America*, 112(20), 6271–6276. doi: 10.1073/pnas.1220362110 [doi].

Wiel, A. Van Der, Bossink, B. and Masurel, E. (2012) 'Reverse logistics for waste reduction in cradle-to-cradle-oriented firms: waste management strategies in the Dutch metal industry', *International Journal of Technology Management*, 60(1/2), 96–113.

Wiesmeth, H. and Häckl, D. (2017) 'Integrated environmental policy: A review of economic analysis', *Waste Management & Research*, 35(4), 332–345.

Wilhelmsen, C. A. and Dixon, R. A. (2016) 'Identifying Indicators Related to Constructs for Engineering Design Outcome', *Journal of Technology Education*, 27(2).

Williams, D. . (1990) 'Socioeconomic Differentials in Health: A review and Redirection', *Social Psychology Quarterly*, 53(2), 81–99.

Williams, P. T. (2013) *Waste treatment and disposal*. John Wiley & Sons.

Williamson, G. R. and Prosser, S. (2002) 'Action research: politics, ethics and participation', *Journal of Advanced Nursing*, 40(5), 587–593. doi: 10.1046/j.1365-2648.2002.02416.x.

Wilson, D. . (2007) 'Development drivers for waste management', *Waste Management & Research* , 25, 198–207. doi: 10.1177/0734242X07079149.

Wilson, D.C., Rodic, L., Scheinberg, A., Velis, C.A. and Alabaster, G., (2012) 'Comparative analysis of solid waste management in 20 cities', *Waste management & research : the journal of the International Solid Wastes and Public Cleansing Association, ISWA*, 30(3), 237–254. doi: 10.1177/0734242X12437569 [doi].

Wilson, D. C. and Ing, L. R. D. (2013) ‘Integrated sustainable waste management in developing countries’, *Proceedings of the Institution of Civil Engineers*, 166(2), 52.

Wilson, D., Velis, C. and Cheeseman, C. (2006) ‘Role of informal sector recycling in waste management in developing countries’, *Habitat international*, 30(4), 797–808.

Wilson, E. J. (2002) ‘Life cycle inventory for Municipal Solid Waste management Part 2: MSW management scenarios and modeling’, *Waste Management and Research*, 20, 23–36.

Wilson, V. and McCormack, B. (2006) ‘Critical realism as emancipatory action: the case for realistic evaluation in practice development’, *Nursing Philosophy*, 14(2), 87–103.

Winship, C. and Mare, R. (1992) ‘Models for sample selection bias’, *Annual review of sociology*, 8(1), 327–350.

Winston, W. (2016) *Microsoft Excel 2016 Data Analysis and Business Modeling*. Caperton, J. P. and Atkins K. (Eds). Washington, USA: Microsoft Press.

Woodruff, A. (2014) *Solid Waste Management in the Pacific: Financial Arrangements*.

Woolf, D., Lehmann, J., Fisher, E.M. and Angenent, L.T., (2014) ‘Biofuels from pyrolysis in perspective: trade-offs between energy yields and soil-carbon additions’, *Environmental science & technology*, 48(11), 6492–6499.

World Bank (1998) *Pollution Prevention and Abatement Handbook: Sulfur Oxides*.

World Bank (2012) *What a Waste: a Global Review of Solid Waste Management*, *Urban development series; knowledge papers no. 15.* Washington, DC.

World Bank (2014) *Results-based Financing for Municipal Solid Waste*. Washington, DC, USA.

Worldometers (2018) *Ghana Population*.

van Wyk, B. (2012) ‘Research design and methods Part I’. University of Western Cape.

Yang, N., Damgaard, A., Lü, F., Shao, L.M., Brogaard, L.K.S. and He, P.J., (2014) ‘Environmental impact assessment on the construction and operation of municipal solid waste sanitary landfills in developing countries: China case study’, *Waste*

Management, 34(5), 929–937. doi: http://dx.doi.org/10.1016/j.wasman.2014.02.017.

Yankson, P. W. . and Bertrand, M. (2012) '*Challenges of Urbanization in Ghana'. Accra: The Mobile City of Accra*, pp. 25–45.

Yee, J. S. R. (2010) 'Methodological innovation in practice-based design doctorates', *Journal of Research Practice*, 6(2), 15.

Yermán, L., Wall, H. and Torero, J. (2017) 'Experimental investigation on the destruction rates of organic waste with high moisture content by means of self-sustained smoldering combustion', in *Proceedings of the Combustion Institute*, 4419–4426.

Yigitcanlar, T., Dur, F. and Dizdaroglu, D. (2015) 'Towards prosperous sustainable cities: A multiscalar urban sustainability assessment approach', *Habitat International*, 45, 36–46.

Yin, R. (2003) *Case study research: Design and methods*. 3rd edn. London, UK: Sage publications.

Yin, R. K. (2013) *Case study research: Design and methods*. Sage publications.

Yolles, M. (2000) 'Organisations, complexity, and viable knowledge management', *Kybernetes*, 29(9/10), 1202–1222.

Yusoff, M. S. and Zamri, M. F. M. A. (2015) 'Design and Operation of Semi-Aerobic Landfill', in *Control and Treatment of Landfill Leachate for Sanitary Waste Disposal*, p. 102.

Zaccariello, L., Cremiato, R. and Mastellone, M. . (2015) 'Evaluation of municipal solid waste management performance by material flow analysis: Theoretical approach and case study', *Waste Management & Research*, 33(10), 871–885.

Zafar, S. (2016) 'Waste to Energy Conversion Routes'.

Zainu, Z. and Songip, A. (2017) 'Policies, challenges and strategies for Municipal waste management in Malaysia', *Journal of Science, Technology and Innovation*, 3(1), 18–22.

Zaki, T., Kafafi, A.G., Boushra, M. and El-Halim, A.M., (2013) *Annual Report for Solid Waste Management in Egypt*. Cairo.

Zalaghi, H. and Khazaei, M. (2016) ‘The Role of Deductive and Inductive Reasoning in Accounting Research and Standard Setting’, *Asian Journal of Finance & Accounting*, 8(1), 23–37.

Zaman, A. U. (2010) ‘Comparative study of municipal solid waste treatment technologies using life cycle assessment method’, *International Journal of Environmental Science & Technology*, 7(2), 225–234.

Zaman, A. U. (2013) ‘Life cycle assessment of pyrolysis-gasification as an emerging municipal solid waste treatment technology’, *International Journal of Environmental Science and Technology*, 10(5), 1029–1038. doi: 10.1007/s13762-013-0230-3.

Zaman, A. U. (2015) ‘A comprehensive review of the development of zero waste management: lessons learned and guidelines’, *Journal of Cleaner Production*, 91, 12–25. doi: http://dx.doi.org/10.1016/j.jclepro.2014.12.013.

Zaman, A. U. and Lehmann, S. (2013) ‘The zero waste index: a performance measurement tool for waste management systems in a “zero waste city”’, *Journal of Cleaner Production*, 50, 123–132. doi: http://dx.doi.org/10.1016/j.jclepro.2012.11.041.

Zhang, D., Tan, S. and Gersberg, R. (2010) ‘Municipal solid waste management in China: status, problems and challenges’, *Journal of environmental management*, 91(8), 1623–1633.

Zhang, Y. M., Huang, G. H. and He, L. (2011) ‘An inexact reverse logistics model for municipal solid waste management systems’, *Journal of environmental management*, 92(3), 522–530. doi: 10.1016/j.jenvman.2010.09.011.

Zhao, P., Shen, Y., Ge, S., Chen, Z. and Yoshikawa, K., (2014) ‘Clean solid biofuel production from high moisture content waste biomass employing hydrothermal treatment’, *Applied Energy*, 131, 345–367.

Zheng, L., Song, J., Li, C., Gao, Y., Geng, P., Qu, B. and Lin, L., (2014) ‘Preferential policies promote municipal solid waste (MSW) to energy in China: Current status and prospects’, *Renewable and Sustainable Energy Reviews*, 36, 135–148.

Ziraba, A. K., Haregu, T. N. and Mberu, B. (2016) ‘A review and framework for understanding the potential impact of poor solid waste management on health in developing countries’, *Archives of Public Health*. Archives of Public Health, 74(1), 55.

doi: 10.1186/s13690-016-0166-4.

Zodpey, S. (2004) ‘Sample size and power analysis in medical research’, *Indian Journal of Dermatology, Venereology, and Leprology*, 70(2), 123–128.

Zorpas, A.A., Lasaridi, K., Voukkali, I., Loizia, P. and Chroni, C., (2015) ‘Household waste compositional analysis variation from insular communities in the framework of waste prevention strategy plans’, *Waste Management*, 38, 3–11.

Zorpas, A., Voukkali, I. and Loizia, P. (2017) ‘Socio Economy Impact in Relation to Waste Prevention’, in *Sustainable Economic Development*. Springer International Publishing, pp. 31–48.

Zurbrügg, C., Gfrerer, M., Ashadi, H., Brenner, W. and Küper, D., (2012) ‘Determinants of sustainability in solid waste management – The Gianyar Waste Recovery Project in Indonesia’, *Waste Management*, 32(11), 2126–2133.

Zurbrügg, C., Caniato, M. and Vaccari, M., (2014) ‘How assessment methods can support solid waste management in developing countries - A critical review’, *Sustainability*, 6(2), 545–570. doi: http://dx.doi.org/10.3390/su6020545.

APPENDICES

Appendix A - Research Map

MUNICIPAL SOLID WASTE DISPOSAL IN DEVELOPING COUNTRIES: A CASE STUDY OF WA MUNICIPALITY, GHANA

Research Aim	Research Objectives	Sub-Research Questions	Data Required	Sources of Data	Research Methods	Data Analysis Techniques
To improve planning and decision-making for MSW disposal in developing countries with similar circumstances and MSW problems as Ghana	*Objective 1: to investigate MSW generation and characteristics reported in literature and official documents*	What are the MSW generation rates? Why is the MSW generation rate rising? What is the composition MSW (including MSW moisture content and calorific value)?	MSW generation rates and characteristics (composition, moisture content and calorific value)	Journal publications and official reports	Documentary view and literature review	Documentary analysis and content analysis
	Objective 2: to examine MSW disposal management performance	What are the policies and legal arrangements for MSW disposal? What is the institutional arrangement for MSW disposal? How is MSW disposal financed? How adequate is the technical capacity for MSW disposal?	Policies, legal, and institutional frameworks for MSW disposal, MSW disposal budget sources, recurrent MSW disposal financing, human resource capacity and technical expertise of MSW managers and equipment disposition for MSWM	Government decision makers, SWM stakeholders, journal publications and other reports	Documentary view / literature review, interviews, questionnaire survey, and memory-work	Documentary analysis and thematic analysis

	Research Objectives	Sub-Research Questions	Data Required	Sources of Data	Research Methods	Data Analysis Techniques
	Objective 3: to establish a baseline scenario of MSW disposal through material flow analysis and understanding of MSW handling practices	How is MSW handled? What is the MSW flow? What behavioural change interventions can be optimised?	MSW generation sources, storage, collection, transportation, transfer, processing / treatment and disposal methods	Government Departments and SWM stakeholders	Questionnaire survey, interviews, observation, and memory-work	Statistical analysis, situational analysis, and thematic analysis
	Objective 4: to evaluate MSW disposal operational performance based on scenarios analysis and to optimise the environmental burdens of MSW disposal	What is the situation of operational performance of MSW disposal? How can MSW disposal environmental burdens be optimise?	MSW generation rates and composition, MSWM options, and MSW environmental impact categories	Government decision makers, SWM stakeholders, journal publications and other reports, databases, and MSW DST default data	Documentary view / literature review, interviews, and questionnaire survey	Situational analysis, inventory analysis, sensitivity analysis, and uncertainty analysis.
	Objective 5: To develop a planning framework for MSW disposal decision making in developing countries	How are decisions for MSW disposal made? What are the criteria and determinants of MSW disposal decision-making?	Guidelines for decision making for MSW disposal	SWM stakeholders, Journal publications, and the results of the other four objectives of this research	Documentary view and questionnaire survey	Documentary analysis and thematic analysis

Appendix B - Wa Municipality's Households Questionnaire

As part of a research project I am undertaking with Loughborough University, UK I would greatly appreciate your help in answering a few questions about municipal solid waste disposal in your area. Answers to this questionnaire will be used for academic purposes only. Your cooperation is highly solicited.

INSTRUCTION: please, tick the box ☑ *to respond to the questions. For open ended questions, you are free to use an extra sheet of plain paper.*

A. BACKGROUND CHARACTERISTICS OF RESPONDENTS

1. Age group: 10 – 20 ☐ 21– 30 ☐ 31 – 40 ☐ 41 – 50 ☐
   51 and above ☐

2. Sex: Male ☐ Female ☐

3. Level of education: Basic ☐ Secondary ☐ Tertiary ☐ None ☐

4. Occupation:…………………………………………

5. Residential Typology: compound-house ☐ semi-detached ☐
   single-unit ☐

6. House number:………………… (optional)

B. MUNICIPAL SOLID WASTE COLLECTION

7. How do you store your waste? In a: Closed container ☐ Open container ☐
   Polythene bag/sack ☐ Other ☐

8. How do you dispose of your waste? In to Bush ☐ Burn ☐
   Communal container ☐ Curb-side ☐ Others, specify:…………

9. If disposal is into a communal container, how often is the container emptied? Once a week ☐ Once every two weeks ☐ Once a month ☐
   Others, specify:………

10. If your waste is collected at curb-side how often is the waste collected?
Once a week ☐ Once every two weeks ☐ Once a month ☐
others, specify………………

11. Do you sort your waste for collection/disposal? Yes ☐ No ☐

12. If no to question 11, are you aware of the need to sort your waste for collection/disposal? Yes ☐ No ☐

13. If yes to question 12, what influence you to sort your waste for collection/disposal?...

14. If no to question 12, what will influence you to sort your waste for collection/disposal?
……………………………………………………………………………………………

15. Who is responsible for waste collection in your area?
Local Assembly ☐ Private company ☐ Both ☐ None ☐

16. Do you pay for the collection of your waste? Yes ☐ No ☐

17. If yes to question 16, how much do you pay per month? GH₵………………

18. If No to question 16, will you be willing to pay for the effective collection of your waste? Yes ☐ No ☐

19. How satisfied are you with the waste collection service in your locality?
Very Satisfied ☐ Satisfied ☐ Unsatisfied ☐ Very unsatisfied ☐

20. Give reason(s) for your answer to question 19:………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
…………………………

21. What are your general comments on municipal waste management in your locality……………………………………………………………………………

Appendix C - Questionnaire to Zoomlion Ghana Limited, Wa

As part of a research project I am undertaking with Loughborough University, UK I would greatly appreciate your help in answering a few questions about municipal solid waste management in the Wa Municipality. Answers to this questionnaire will be used for academic purposes only. Your cooperation is highly solicited.

INSTRUCTION: please, tick the box ☑ *to respond to the questions. For open ended questions, you are free to use an extra sheet of plain paper.*

A. PERSONAL DATA

1. Name:…………………………………………………. (optional)

2. Title:………………………………………………......

3. Level of Education: Basic ☐ Secondary ☐ Tertiary ☐

4. If Tertiary education, state the highest qualification: …………………………….

B. MUNICIPAL SOLID WASTE MANAGEMENT

5. How often do you empty the communal containers?
   Once a week ☐ Once every two weeks ☐ Once a month ☐

   Others, specify:……………………………………

6. How often do you collect waste from curb-side/house-to-house?
   Once a week ☐ Once every two weeks ☐ Once a month ☐

   Others, specify:……………………………………

7. How much do you charge households per month for curb-side/house-to-house collection? GH₵ ....

8. Do waste generators sort their waste for collection? Yes ☐ No ☐

9. If no to question 8, do you sort the collected waste before final disposal?
   Yes ☐ No ☐

10. Do you process or treat the waste before final disposal?
    Yes ☐ No ☐

11. If yes to question 10, what are the processing/treatment options you use?

a) ....
b) ……………………………………………….
c) ………………………………………………...
d) ………………………………………………

12. If no to question 10, do you recover materials from the waste in any form before final disposal? Yes ☐ No ☐

13. If yes to question 12, what materials do you recover from the wastes?..
……………………………………………………………………………
……………………………………………………………………………..
.

14. Approximately, what percentage of municipal solid waste do you collect within the Wa Municipality?…………………..

15. What is your final disposal method for municipal solid waste in the Wa municipality? Engineered landfill ☐ Un-engineered landfill ☐ Open dumping ☐

16. Who owns the disposal site?...

17. If you do not own the disposal site, do you pay disposal charges? Yes ☐ No ☐

18. If yes to question 17, how much do you pay per ton of waste? GH₵................

19. What is the staff strength of your company in the Wa Municipality? Please categorise them in terms of skills in relation to waste management.

Title/Rank	**Number**	**Skill**	**Qualification**

20. What is the current fleet of waste management equipment disposition of your company in the Wa Municipality?

S/N	Type of Equipment	Number Operational	Number Broken Down	Number Ideal
1	Compactor tracks			
2	Skip trucks			
3	Tipper trucks			
4	Tractors			
5	Front End Loaders			
6	Bull Dozer			
7	Landfill Compactors			
8	Tricycles			
9	Others:			
10				
11				
12				
13				
14				

21. How was your company engaged for waste collection in the Wa Municipality?...……………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………..

22. How are you paid for your services in the Wa Municipality?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

23. Are there existing laws and policies that support your operation?
Yes ☐ No ☐

24. If yes to question 23, mention them:
a) ……………………………………………..
b) ……………………………………………...
c) ………………………………………………..
d) ………………………………………………..

25. Are these laws and policies adequate? Yes ☐ No ☐

26. If no to question 25, why are they not adequate?..
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
………………………………………………………………………………………….

27. Are the existing laws and policies properly enforced? Yes ☐ No ☐

28. If no to question 27, what are the challenges with enforcement?
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

29. What are the general challenges to your operations in the Wa Municipality?
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

30. What are your future plans for municipal solid waste management in the Wa Municipality?...
....
....
....
....

Appendix D - Questionnaire to Wa Municipal Assembly

As part of a research project I am undertaking with Loughborough University, UK I would greatly appreciate your help in answering a few questions about the municipal solid waste management in the Wa Municipality. Answers to this questionnaire will be used for academic purposes only. Your cooperation is highly solicited.

INSTRUCTION: please, tick in the box ☑ *to respond to the questions. For open ended questions you are free to use extra sheet of plain paper.*

A. PERSONAL DATA

1. Name:………………………………………………… (optional)

2. Title:………………………………………………......

3. Level of Education: Basic ☐ Secondary ☐ Tertiary ☐

4. If Tertiary education, state the highest qualification: ……………………………

B. MUNICIPAL SOLID WASTE MANAGEMENT

5. Are there existing laws and policies for municipal solid waste management?
   Yes ☐ No ☐

6. If yes, mention them:
   e) ……………………………………………..
   f) ……………………………………………...
   g) ………………………………………………..
   h) ………………………………………………..

7. Are these laws and policies adequate? Yes ☐ No ☐

8. If No, why are they not adequate?...
   ………………………………………………………………………………………
   ………………………………………………………………………………………
   ………………………………………………………………………………………
   ……………………………………………………………………………………….

9. Are these laws and policies properly enforced? Yes ☐ No ☐

10. If no, what are the challenges with enforcement?

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

11. Who is responsible for municipal solid waste collection in your assembly?
Local Assembly ☐ Private sector ☐ Both ☐

12. If waste is collected by private sector, how many companies are involved?
……………………………….

13. How was the private sector engaged?
…………………………………………………………………………………………
………………………………………………………………………………………….
…………………………………………………………………………………………..

14. What are the arrangements in terms of monitoring and supervising the private sector's operations?
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………..

15. Are you satisfied with the private sector involvement in waste collection?
Yes ☐ No ☐

16. Give reason(s) for your answer…………………………………………………...
…………………………………………………………………………………………
…………………………………………………………………………………………
……………………………………………………………………………………..

17. If Local Authority collects waste, what collection method do you use?
Communal container ☐ Curb-side ☐ Both ☐

18. If Local Authority collects waste, what type of collection vehicles do you use?
    a) …………………………………… number:………………..
    b) …………………………………… number:………………..
    c) ……………………………………. number…………………..

19. How often do you empty the communal containers?
Once a week ☐ Once every two weeks ☐ Once a month ☐

others, specify………………

20. If you collect waste by curb side, how often do you collect the waste?
Once a week ☐ Once every two weeks ☐ Once a month ☐
others, specify:……………………………………

21. Do you charge for waste collection? Yes ☐ No ☐

22. If yes, how much?..............................

23. Do waste generators segregate their waste for collection? Yes ☐ No ☐

24. Give reason for your answer to question 23:………………………………………
……………………………………………………………………………………………
…………………………………………………………………………………………….

25. Municipal solid waste generated and collected in key locations

Location within Metropolis/ Municipality	**Amount Generated (Tonnes)**	**Amount Collected (Tonnes)**	**Collection Rate (%)**

26. Do you process or treat the waste before disposal?
Yes ☐ No ☐

27. If yes, what are the processing/treatment options you use?
   e) ....
   f) ………………………………………………….
   g) ………………………………………………...
   h) ……………………………………………………

28. If no, is there recovery of materials from waste in any form?…………………
……………………………………………………………………………………………
……………………………………………………………………………………………

29. What is the method of final disposal for municipal solid waste:
Engineered landfill ☐ Un-engineered landfill ☐ Open dump ☐

30. How is municipal solid waste management financed in your assembly?
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

31. What is the current cost for municipal solid waste management per month?
……………………………………………………………………………………

32. What is the future projected costs for municipal solid waste management per year?..

33. What is the staff strength of your metropolitan/municipal Assembly? Please categorise them in terms of skills in relation to waste management.

Title/Rank	Number	Skill	Qualification

34. Current Fleet of waste management equipment disposition of your Metropolitan/Municipal Assembly

S/N	Type of Equipment	Number Operational	Number Broken Down	Number Ideal
1	Compactor tracks			
2	Skip trucks			
3	Tipper trucks			
4	Tractors			
5	Front End Loaders			
6	Bulldozer			
7	Landfill Compactors			
8	Tricycles			
9	Others, specify:			
10				
11				
12				
13				
14				

35. What is the future direction for municipal solid waste management in this Assembly?
………………………………………………………………………………………………
………………………………………………………………………………………………

Appendix E – Adult Participant Information Sheet

Investigator Details:

Patrick Aaniamenga Bowan, Loughborough University, School of Architecture, Building, and Civil Engineering, LE11 3TU, LIECS, P.A.Bowan@lboro.ac.uk

Introduction

I would like to invite you to take part in my study. Before you decide I would like you to understand why the research is being done and what it would involve for you. I will go through the information sheet with you and answer any questions you have. Talk to others about the study before making a decision if you wish.

What is the purpose of the study?

This study intends to address the increasing MSW generation along with the lack of waste separation at the source, and a common disposal of open dumping in Ghana and many other developing countries. I hope to contribute to improve planning and decision-making for MSW disposal in developing countries with similar circumstances and MSW problems to Ghana.

Who is doing this research and why?

This study is part of a Student research project sponsored by GETFund and undertaken at the Loughborough University, UK.

What will I be asked to do?

You will be asked to fill a questionnaire or answer a few questions in an interview.

Once I take part, can I change my mind?

Yes. After you have read this information and asked any questions you may have if you are happy to participate we will ask you to complete an Informed Consent Form, however if at any time, before, during or after the sessions you wish to withdraw from the study please just contact the main investigator. You can withdraw at any time, for any reason and you will not be asked to explain your reasons for withdrawing.

How long will it take?

Filling a questionnaire will take 15 minutes and an interview a maximum of 30 minutes

Will my taking part in this study be kept confidential?

Yes. The investigator understands data protection guidelines and will strictly observe them. Information will be anonymised or coded where possible.

What if I am not happy with how the research was conducted?

If you are not happy with how the research was conducted, please contact the Secretary of the Ethics Approvals (Human Participants) Sub-Committee, Research Office, Hazlerigg Building, Loughborough University, Epinal Way, Loughborough, LE11 3TU. Tel: +44 (0)1509 222423. Email: researchpolicy@lboro.ac.uk

The University also has policies relating to Research Misconduct and Whistle Blowing which are available online at http://www.lboro.ac.uk/committees/ethics-approvals-human-participants/additionalinformation/codesofpractice/.

Loughborough University

Appendix F - Informed Consent Form

Please put your initials in the box

The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethics Approvals (Human Participants) Sub-Committee. ☐

I have read and understood the information sheet and this consent form. ☐

I have had an opportunity to ask questions about my participation. ☐

I understand that I am under no obligation to take part in the study, have the right to withdraw from this study at any stage for any reason, and will not be required to explain my reasons for withdrawing. ☐

I agree to take part in this study. ☐

Use of Information

I understand that all the personal information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others or for audit by regulatory authorities. ☐

I understand that anonymised quotes may be used in publications, reports, web pages, and other research outputs. ☐

________________________ ______________________ ________

(Name of participant) Signature Date

Patrick Aaniamenga Bowan ________________________ ________

(Researcher) Signature Date

Appendix G – Framework Validation Questionnaire

This questionnaire aims to validate the attached framework (Figure 1) for municipal solid waste (MSW) disposal planning and decision-making. This framework was developed through research on improving planning and decision-making for MSW disposal in developing countries, using the Wa Municipality, Ghana as a case study.

1.0 Conceptual formulation of the framework

The framework consists of three elements of municipal solid waste management, namely: MSW generation and characteristics, the baseline scenario of MSW disposal, and MSW environmental performance.

1.1 MSW generation and characteristics

The accurate prediction of MSW generation and knowledge of the waste characteristics provide the basic data on which a waste management system is planned, designed, and operated. Sound waste management and optimisation of resource recovery from waste, equally, require reliable data on the generation rates and characteristics of waste. Thus, the MSW generation rates and characteristics, which depend on urban population, economic development, consumption rate, geographic location, and administrative systems, have a direct impact on the baseline scenario of MSW disposal. MSW disposal activities include, MSW segregation at the point of generation, MSW reduction, storage, collection, transportation, processing/treatment, and final disposal.

The handling and processing/treatment of organic and inorganic waste are quite different. Thus, organic and inorganic MSW produce different environmental impacts, which determine the overall MSW disposal environmental performance. On the other hand, MSW disposal environmental performance, especially MSW management performance indicators such as policy, legal, institutional, and financial arrangements for SWM also affect MSW generation and characteristics. For instance, the enforcement of and compliance with SWM policies, regulation, and laws will determine the quantity and composition of MSW generated.

1.2 Baseline Scenario of MSW Disposal

The baseline scenario of MSW disposal, which depends the MSW generation and characteristics, stimulates the overall MSW disposal environmental performance and vice-versa. MSW disposal covers the activities to minimise the quantity of produced MSW, to decrease or eliminate hazardous components in wastes, the activities to contain wastes in a location or facilities which meet environmental protecting standards. Effective waste management laws enforcement compels waste generators, especially households to comply with waste management laws and regulations, such as segregation of SW at the generation point. The segregation of waste at the point of generation is the first step in material recovery from waste and waste reduction programmes. Material recovery from waste leads to the reduction in the quantity of MSW that has be properly disposed of and eventual improves the overall MSW disposal environmental performance.

1.3 MSW Disposal Environmental Performance

The efficient operation of SWM systems (operational performance) are dependent on good MSW streams analysis and accurate predictions of SW quantities, the baseline scenario of MSW disposal, and good MSWM performance. For instance, the equipment used for waste management must match with the composition, quantities and qualities of waste delivered to waste management facilities, the local climatic conditions and the potential demand for products derived from the waste.

MSW disposal Environmental performance integrates environmental and human health risks in the assessment process, consequently ensuring that new policies are adopted by decision makers under the concept of continuous improvement of waste management systems. MSW disposal Environmental performance is divided into two components: management performance and operational performance.

management performance indicators are generally related to the sustainability aspects (social indicators), which are the governance features (institutional, political, and financial issues) and the various groups of stakeholders involved in waste management, whereas the MSW operational performance indicators are usually concerned with the physical system and its technological components, with more focus on the environmental sustainability (environmental indicators, such as emissions) aspect of the system.

Thus, MSW disposal environmental performance covers not only operational aspects, such as the handling, transfer, transport, separation, processing, and disposal of waste, but also aspects on public perception, environmental, economic, and social issues. Waste management activities are apparently impossible to implement without high consciousness within the communities as well as a strong commitment and support from waste management authorities. Thus, a good/bad MSW disposal environmental performance depend on the MSW generation and characteristics and the baseline scenario of MSW disposal.

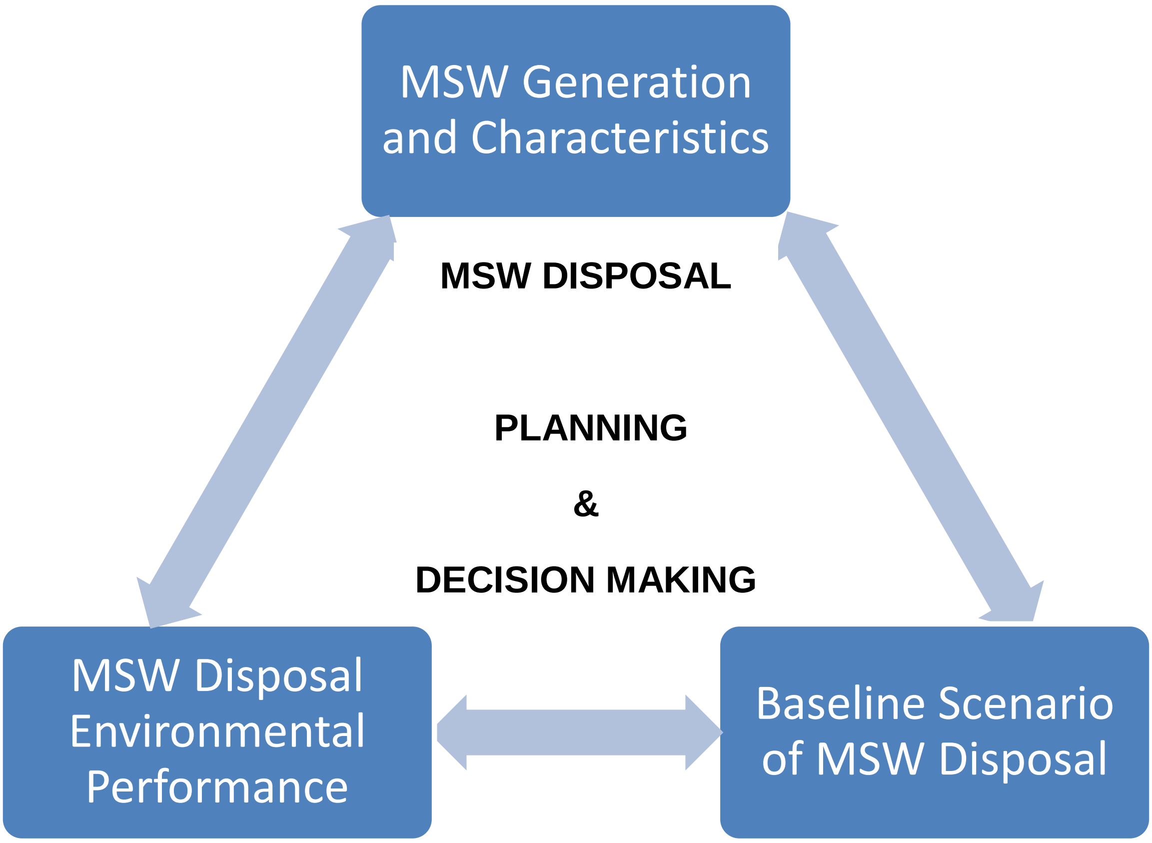

Figure 1: Developed planning framework for MSW disposal decision-making in developing countries

Questions

please, tick in the box ☐✓ *to respond to the questions and add comments when necessary. For open ended questions you are free to use extra sheet of plain paper.*

1. How important are the elements of the framework to effective MSW disposal?

   Very important ☐ Important ☐ Unimportant ☐

   Not Very Important ☐ Additional comments (if any)………………………

   ....

2. How easy is it to understand the framework?

   Very Easy ☐ Easy ☐ Difficult ☐ Very Difficult ☐

   Additional comments (if any)…………………………………………………………

   ……………………………………………………………………………………

3. To what extend is this framework logical?

   Very Logical ☐ Logical ☐ Illogical ☐ Very Illogical ☐

   Additional comments (if any)…………………………………………………………

   ....

4. To what extend will you say this framework is adequate for effective MSW disposal?

   Very Adequate ☐ Adequate ☐ Not Adequate ☐

   Not Very Adequate ☐ Additional Comments (if any) ……………

   ....

5. Do the elements suggested in the framework address MSW disposal problems?

   Yes ☐ No ☐ Not sure ☐

   Additional comments (if any) …………

6. How transferable is this framework to all solid waste management activities?
   Very Transferable ☐ Transferable ☐ Not Transferable ☐

   Not Very Transferable ☐ Additional comments (if any)…………………

   ....

7. What do you consider as the strengths and weakness of the framework?

   Strengths………………………………………………………………………………
   ……………………………………………………………………………………….

   Weakness……………………………………………………………………………
   ………………………………………………………………………………………

8. What can be added to and/or removed from the framework?

   Add………………………………………………………………………………………
   ……………………………………………………………………………………….

   Remove…………………………………………………………………………………
   ………………………………………………………………………………………..

Appendix H - Conference Paper

4TH INTERNATIONAL SEEDS CONFERENCE 2018: SUSTAINABLE ECOLOGICAL ENGINEERING DESIGN FOR SOCIETY

AN INVESTIGATION ON MUNICIPAL SOLID WASTE GENERATION AND CHARACTERISTICS

Patrick Aaniamenga Bowan[1]* Sam M. Kayaga[2] Andrew P. Cotton[2]
Julie Fisher[2]

1. Research Student, Water Engineering Development Centre (WEDC), School of Architecture, Building and Civil Engineering, Loughborough University, LE11 3TU, Liecs, UK

2. Senior Lecturer, Water Engineering Development Centre (WEDC), School of Architecture, Building and Civil Engineering, Loughborough University, LE11 3TU, Liecs, UK

* E-mail of the corresponding author: P.A.Bowan@lboro.ac.uk

AN INVESTIGATION OF MUNICIPAL SOLID WASTE GENERATION AND CHARACTERISTICS

Abstract

Accurate prediction of municipal solid waste (MSW) generation and knowledge of the waste characteristics provide the basic data on which a waste management system is planned, designed, and operated. However, reliable data on MSW generation and characteristics in most developing countries is absent. This paper examines MSW generation and characteristics in Ghana. The data was obtained from secondary data sources, using qualitative and quantitative research methods, through documentary analysis and content analysis of published literature and official documents. The secondary data obtained for the study is deemed valid, reliable, and accurate since the research design and methodology and data analysis of the documents viewed followed research protocols. The investigation found out that the MSW generation rates across Ghana, irrespective of the socioeconomic considerations range between 0.2 and 0.9 kg/person/day. The MSW composition in Ghana is heterogeneous with different chemical properties; the household MSW composition in Ghana is more organic (60%), 25% recyclables, and 15% miscellaneous. The high organic waste component of the MSW stream in Ghana has resulted in high moisture content (above 50% on average) of the MSW. This organic fraction is an important component, not only because it constitutes a significant portion of the MSW stream in Ghana, but also because of its potentially adverse impact on public health and environmental quality if not properly treated and/or disposed of. The impact of organic MSW on environmental quality takes the form of foul odours, unsightliness and leachate from open dumps, especially after rainfall, and emission of harmful gases. Unless an organic waste is appropriately treated and disposed of, its adverse impact will continue until it has fully decomposed or otherwise stabilised. Therefore, the study recommends the adoption of appropriate management technologies to ameliorate the impact of MSW in the country and other developing countries.

Keywords: Municipal solid waste, solid waste generation, solid waste characteristics, solid waste composition, Ghana

Introduction

The growing world population, economic growth, rapid urbanisation, and the rise of human living standards, especially in developing countries are resulting in high resource use in response to changing lifestyles. The accompanying increase in consumption is rising wastes generation far beyond the management ability of most municipal authorities in developing countries [1]. As a result, waste disposal is an immediate and critical issue for many developing countries now as ineffective or irresponsible disposal of solid waste (SW) pollutes the environment and pose health risk to the public [2].

The current state of municipal solid waste management (MSWM) in Ghana, for instance, leaves much to be desired. Less than 40% of urban residents are served with solid waste collection (SWC) services [3]–[5]. The traditionally applied methods of dealing with waste have been unsuccessful, and the resulting contamination of water and land has led to growing concern over solid waste management (SWM) in the country [6], [7].

Various pollution (air, soil, water, and landscape) due to improper waste disposal would not only affect the natural environment but also exposed the community to various diseases. An example is the contamination of surface and ground water supplies from indiscriminate dumping of wastes in most developing countries [8]–[10]. This occurs through leachate from MSW disposal sites and run-off that carry MSW into water bodies, which lead to rising levels of biochemical oxygen demand (BOD) in watercourses, and the presence of microbial contaminants [11]. It takes only a small amount of leachate to contaminate a large volume of groundwater, which in turn can contaminate and affect biodiversity and enter the food chains [12]–[14].

Open dumps, which are prominent in in Ghana and other developing countries, attract vermin and scavenging animals and provide food and habitat for disease vectors such as rats and mosquitoes. Clogging of storm drains and creation of stagnant water due to the choked drains (as illustrated in plate 1) are other problems of improper MSW disposal in urban areas in most developing countries and is the prime cause of flooding in the rainy season in cities in Ghana.

Plate 1: A choked drain in Accra, Ghana, after a rain

In addition, uncontrolled burning of MSW, which is wide spread in most developing countries, contributes significantly to urban air pollution. MSW contains considerable hazardous components and the open MSW burning in urban areas cause direct exposure of hazardous materials to citizens [15]. Globally, efforts are being made to control greenhouse gas (GHG) emissions from various sources, and the waste sector is one of them [16].

Thus, the objective of this paper is to investigate MSW generation and characteristics in Ghana reported in literature and official documents, with the aim of identifying possible interventions to ameliorate the impacts of MSW in Ghana and other developing countries.

Literature Review

MSW generation refers to the generation of any solid, non-hazardous substance or object within an urban area, excluding wastewater sludge [17]. The main constituents of MSW generated in general are similar throughout the world, but the quantity generated, the density and the proportion of streams vary widely from country to country, depending largely on the level of income and lifestyle, culture and tradition, geographic location and dominant weather conditions [18]–[21].

Sound waste management and optimisation of resource recovery from waste require reliable data on the generation rates and characteristics of waste [22]–[24], because the accurate prediction of MSW generation and knowledge of the waste characteristics provide the basic data on which a waste management system is planned, designed, and operated [25]–[29]. However, reliable data on MSW generation and characteristics that will inform effective planning for waste management in most developing countries is absent [25].

The World Bank (2012) indicates that the current global MSW generation levels are roughly 1.3 billion tonnes per year, and are expected to increase to approximately 2.2 billion tons per year by 2025 (see tables 1 and 2). This would signify a major increase in per capita waste generation rates, from 1.2 to 1.42 kg per person per day in the next five years. Waste management problems in most developing countries are likely to worsen, if appropriate plans are not put in place to effectively deal with this galloping generation rate.

Table 1: Waste generation per capita by regions

Region	Waste Generation Per Capita (kg/capita/day)		
	Lower Boundary	Upper Boundary	Average
Africa Region (AFR)	0.09	3.0	0.65
East Asia and Pacific region (EAP)	0.44	4.3	0.95
Europe and Central Asia region (ECA)	0.29	2.1	1.1
Latin America and the Caribbean region (LCR)	0.11	5.5	1.1
The Middle East and North Africa region (MENA)	0.16	5.7	1.1
Organisation for Economic Co-operation and Development (OECD)	1.10	3.7	2.2
South Asia region (SAR)	0.12	5.1	0.45

Source: [31]

Table 2: Waste generation projections for 2025 by regions

Region	Current Available data			Projection for 2025			
	Total Urban Population (millions)	Urban Waste Generation		Projected Population		Projected Urban Waste	
		Per Capita (kg/capita/day)	Total (tons/day)	Total Population (millions)	Urban Population (millions)	Per Capita (kg/capita/day)	Total (tons/day)
AFR	260	0.65	169,119	1,152	518	0.85	441,840
EAP	777	0.95	738958	2124	1229	1.5	1,865,379
ECA	227	1.1	254,389	339	239	1.5	354.810
LCR	399	1.1	437,545	681	466	1.6	728,392
MENA	162	1.1	173,545	379	257	1.43	369,320
OECD	729	2.2	1,566,286	1,031	842	2.1	1,742,417
SAR	426	0.45	192,410	1,938	734	0.77	567,545
Total	2,980	1.2	3,532,252	7,644	4,285	1.4	6,069,703

Source: [31]

Eiselt and Marianov (2015) note that the per capita waste generation rates in many developing countries have now crossed the one kilogram per day mark, which is a worrying trend because most municipal authorities do not have the capacity to effectively manage this waste. The waste generation in sub-Saharan Africa is nearly 62 million tons per year, though per capita waste generation is generally low in the region, the generation spans a wide range, from 0.09 to 3.0 kg per person per day with an average of 0.65 kg/capita/day [33].

Similarly, the waste generation for the Middle East and North Africa (MENA) is in tune with the rest of the world as the SW generation in MENA is 63 million tons per year and the per capita waste generation is 0.16 to 5.7 kg per person per day and has an average of 1.1 kg/capita/day [31]. This exponential increase in the waste generation comes with its management challenges, especially for developing countries where there are competing interests on the municipal budget. However, with the majority of the world's population now urbanized, MSW generation rates are likely to increase further, particularly in developing countries, where more and more people are migrating from rural areas to cities [34], [35].

Currently, high-income countries produce the most waste per capita, while low-income countries produce the least SW per capita [36]. This is not only because in low-income countries, there is less commercial and industrial activities, resulting in lower waste generation rates, but also because there is an overall correlation between the generation of MSW and wealth (Gross Domestic Product) [37], as illustrated in Table 3.

Table 3: Waste generation per capita by Income Levels

Income level	**Waste Generation Per Capita (Kg/capita/day)**		
	Lower Boundary	**Upper Boundary**	**Average**
High	0.70	14	2.1
Upper Middle	0.11	5.5	1.2
Lower Middle	0.16	5.3	0.79
Lower	0.09	4.3	0.60

Source: [31]

Furthermore, Like MSW generation, MSW composition is equally influenced by many factors, such as level of economic development, cultural norms, geographical location, energy sources, and climate [38], [39]. Oteng-Ababio (2014) supports this in his assertion that, as a country urbanizes, and populations become wealthier, consumption of inorganic materials (such as plastics, paper, and aluminium) increases, while the relative organic fraction decreases. This is event in the high volumes of inorganic waste generated in developed countries and the high organic waste generated in developing countries.

In general, low-income countries have a high percentage (between 40 to 85%) of organic matter in the urban waste stream, while paper, plastic, glass, and metal fractions dominate the waste stream of high-income countries [41], [42]. For instance, the East Asia and the Pacific Region has the highest fraction of organic waste (62%) compared to OECD countries, which have the least (27%) [43].

On the other hand, the amount of paper, glass, and metals found in the MSW stream are the highest in OECD countries (32%, 7%, and 6%, respectively) and lowest in the South Asia Region (4% for paper and 1% for both glass and metals) [43]. Similarly, sub-Saharan Africa also has the highest fraction of MSW being organics (57%) [31]. Table 4 indicates the MSW composition and generation rate in some selected cities in Africa. Only cities in Ghana have miscellaneous MSW fraction, probably due to the non-segregation of waste at the point of generation.

Table 4: MSW composition and generation rates in some selected cities in Africa

City	**Country**	**Per capita GDP (US$)** [44]	**Popula-tion of city (million)**	**Gener a-tion rate kg/p/day**	**Organics (%)**	**Inorga-nic (%)**	**Inert (%)**	**Miscell a-neous (%)**	**Source**
Accra			1.96	0.74	65.8	25.7	5.2	4.1	[25]
Kumasi	Ghana	1,513.5	1.47	0.75	48.4	33.2	10.7	7.8	
tamale			0.36	0.33	58.6	23.7	4.5	3.4	
Lagos	Nigeria	2,178.0	9.00	0.5	53	39	8		[45]
Freetown	Sierra Leone	496.0	0.80	0.56	59.2	10.2	19.9		[46]
Nairobi	Kenya	1,455.4	2.75	0.6	65	21	14		[47]
Cape Town	South Africa	5,273.6	3.43	0.7 – 1.3	47	32	21		[48]
Cairo	Egypt	3,514.5	7.73	1.3	56	34.7	9.4		[49]

Another important property of MSW is its moisture content. The moisture content of SW is expressed as the mass of moisture per unit mass of water or dry materials [50]–[52]. It is a very important factor that influences decisions on MSW collection and transportation [53]. Transfer of moisture takes place in garbage bins and collector trucks during storage and transportation of MSW, therefore, the moisture contents of various components change with time [54].

Moisture content equally plays a key role in the degradation and treatment of MSW. For example, in composting, moisture content affects the magnitude of heat generation, which can affect the quality of compost [55]–[57]. In a landfill, leachate is formed when the refuse moisture content exceeds its field capacity [58]. Also, many researchers have observed that high moisture content is a major hindrance in the field of thermal conversion of waste-to-energy (WTE) technologies [59], [60], because the moisture content influences the calorific value of the waste to be incinerated.

Methods

Data on MSW generation rates and characteristics in Ghana, such as composition, moisture content and calorific value were obtained, using qualitative and quantitative research methods, through documentary view of official reports and journal publications. The focus of the documentary view was on the content analysis of the quantitative data on MSW generation rates and characteristics in the documents viewed. The content analysis enabled the researchers to sift through large volumes of data with relative ease in a systematic manner [61]. The researchers depended on the secondary data, because the data was available and thus, saved time and money which otherwise would have been used to collect primary data as no field trips and surveys were involved [62]. The secondary data obtained for the study is deemed valid, reliable, and accurate since the research design and methodology, and data analysis of the documents viewed followed research protocols; the information was relevant and appropriate to the study objective; and because there was consistency in the data in the documents viewed [63]–[65].

Results and Discussion

MSW generation in Ghana

The MSW generation rates across Ghana, irrespective of the socioeconomic considerations range between 0.2 and 0.9 kg per person per day [25], [40], [66], as shown in table 5. The increasing MSW generation in the country is attributable to the increasing urban population. Ghana's rapid urbanisation has led to many sustainable development challenges, particularly regarding sanitation, including SWM and transportation infrastructure.

The proportion of the country's population living in towns, as officially defined (any settlement with at least 5,000 people), has increased rapidly over the years as shown table 6. The percentage of urban dwellers before independence in 1955 was 19.1%, it rose drastically to 40.1% by the end of the 19^{th} century. However, in recent decades, the country has experienced steady urbanisation with the current urban population being 52.7%.

Table 5: MSW generation in the regional capitals of Ghana

Regional Capital	2017 Population (based on 2010 Census)	High-class income areas (kg/p/day)	Middle - class income area (kg/p/day)	Low - class income areas (kg/p/day)	Average generation rate (kg/p/day)	Total Generation (population/ tons)
Accra	2237933	0.86	0.73	0.62	0.74	1656
Bolgatanga	147836	0.31	0.20	0.20	0.21	31
Cape Coast	205674	0.74	0.69	0.58	0.67	138
Ho	321544	0.34	0.33	0.27	0.31	100
Koforidua	213915	0.80	0.54	0.48	0.61	130
Kumasi	2425639	0.63	0.73	0.86	0.75	1819
Sunyani	144599	0.52	0.49	0.47	0.49	71
Tamale	446080	0.38	0.27	0.36	0.33	147
Takoradi	648940	0.76	0.68	0.65	0.70	454
Wa	128873	0.30	0.23	0.21	0.25	32
Average	691605	0.56	0.49	0.47	0.51	458

Source: modified from [25], [66]

Table 6: Urban population percentages between 1955 and 2018 in Ghana

Year	Total Population	Urban population (%)
2018	29,463,643	52.7
2017	28,656,723	54.2
2016	28,033,375	53.7
2015	27,409,893	53.2
2010	24,317,734	50.6
2005	21,389,514	47.3
2000	18,824,994	43.9
1995	16,760,991	40.1
1990	14,628,260	36.4
1985	12,716,238	32.9
1980	10,802,025	31.2
1975	9,831,409	30
1970	8,596,977	29
1965	7,710,547	26.1
1960	6,652,285	23.3
1955	5,680,406	19.1

Source: [67]

MSW composition in Ghana

The MSW composition in Ghana is heterogeneous and mixed (non-degradable materials and degradable components) with different chemical properties. The household MSW composition in Ghana is more organic (60%), 25% recyclables, and 13% miscellaneous (table 7 indicates the waste composition in Ghana). The high proportion of miscellaneous MSW (5% on average) calls for the separation of waste at the generation point.

The high organic waste component of the MSW stream in Ghana has resulted in high moisture content (above 50% on average) of the MSW, which conforms with the waste stream in other developing countries [68]–[70]. Table 8 outlines the chemical composition of the household waste in Ghana by different researchers.

Table 7: Household Waste Composition and generation in Ghana

Component	High class income areas (%)	Middle class income areas (%)	Low class income areas (%)	Average (%)
Yard waste (leaves)	17.334	7.562	8.915	11.270
Animal dropping/manure (Grass)	0.176	0.379	0.291	0.282
Wood (Branches)	1.301	1.346	1.282	1.310
News paper	0.674	0.388	0.414	0.492
Cardboard	3.223	3.215	2.233	2.890
Office paper	0.605	0.445	0.541	0.530
Tissue paper	1.148	1.520	1.677	1.448
HDPE - Translucent	3.075	2.751	3.418	3.081
HDPE - Pigmented	2.071	3.628	5.358	3.686
PET	3.315	3.297	2.104	2.905
PP rigid	1.554	1.521	1.126	1.400
PS	0.606	0.538	0.583	0.576
PVC	0.554	0.618	0.247	0.473
Other plastics	2.402	1.983	2.153	2.179
Ferrous Can	1.721	1.319	2.108	1.716
Ferrous metals	1.060	1.575	0.530	1.055
Plain glass	0.846	1.072	0.588	0.835
Coloured glass	2.864	1.991	0.00	1.618
Leather & Rubber	1.012	1.171	1.035	1.073
Food waste	44.201	50.595	49.358	48.051
Textiles	0.528	1.149	1.799	1.159
Miscellaneous	9.73	11.937	14.24	11.969
total	100	100	100	100

HDPE = High-density polyethylene, PET = polyethylene terephthalate, PP = Polypropylene, PS = Polystyrene, PVC = Polyvinyl chloride.
Source: modified from [25]

Table 8: Chemical composition of household wastes in Ghana

Property	Kuleape, et al., 2014	Fobil, et al., 2005	Adu & Lohmueller, 2012
Calorific value (kJ/kg)	$1.39 \times 10^4 – 2.99 \times 10^4$	$1.4 \times 10^4 – 2.0 \times 10^4$	1.69×10^4
Moisture Content (%)	25 - 76	40 - 60	50
Ash Content (%)	2.2 - 19	nd	nd
Volatile Solids (%)	31 - 88	nd	nd
Density (kg/m^3)	nd	$5.3 \times 10^2 – 5.4 \times 10^2$	nd

*nd = not determined

The MSW stream in many developing countries, including Ghana is more organic. The organic fraction is an important component, not only because it constitutes a significant portion of the MSW stream in Ghana and other developing countries, but also because of its potentially adverse impact on public health and environmental quality if not properly treated and/or disposed. A major adverse impact is its attraction of rodents and vector insects for which it provides food and shelter [74]. The impact of organic MSW on environmental quality takes the form of foul odours, unsightliness and leachate from open dumps, especially after rainfall, and emission of harmful gases [75]. These impacts are usually not limited only to the disposal site, they pervade the neighbouring area to the site and wherever the wastes are generated, spread, or accumulated. Unless an organic waste is appropriately treated and disposed of, its adverse impact will continue until it has fully decomposed or otherwise stabilised.

Conclusion

The study indicates that the global MSW generation rates are rising exponentially due to the increasing global population and improvement in living standards, and that the increasing waste generation rates is further exacerbating the problems of MSWM in developing countries such as Ghana, which are currently struggling with ineffective SWM systems due to the lack of the enabling environment for effective waste management. Organic fraction forms the highest (over 50%) of the MSW stream in Ghana and other developing countries.

The organic fraction is an important component, not only because it constitutes a significant portion of the MSW stream in Ghana and other developing countries, but also because of its potentially adverse impact on public health and environmental quality if not properly treated and/or disposed. This beckon the adoption of appropriate management technologies to ameliorate the impact of MSW in Ghana and other developing countries.

References

[1] T. Tudor, G. Robinson, M. Riley, and S. Guilbert, "Challenges facing the sustainable consumption and waste management agendas: perspectives on UK households," *Local*, vol. 16, no. 1, pp. 51–66, 2011.

[2] A. Desa, N. Kadir, and Y. Yusooff, "A Study on the Knowledge, Attitudes, Awareness Status and Behaviour Concerning Solid Waste Management," *Procedia - Soc. Behav. Sci.*, vol. 18, pp. 643–648, Jan. 2011.

[3] S. Mariwah, "Institutional Arrangements for Managing Solid Waste in the Shama-Ahanta-East Metropolis, Ghana," *J. Sustain. Dev. Africa*, vol. 14, no. 6, 2012.

[4] N. Awortwi, "Technology and institutional arrangements in the delivery of public sanitation and solid waste services in Ghanaian cities," *Int. J. Technol. Manag. Sustain. Dev.*, vol. 5, no. 3, pp. 221–239, Jan. 2006.

[5] N. Obirih-Opareh and J. Post, “Quality assessment of public and private modes of solid waste collection in Accra, Ghana,” *Habitat Int.*, vol. 26, no. 1, pp. 95–112, Jan. 2002.

[6] D. Badgie, M. A. Samah, L. A. Manaf, and B. A. Muda, “Assessment of Municipal Solid Waste Composition in Malaysia: Management, Practice, and Challenges,” *Polish J.*, vol. 21, no. 3, pp. 539–547, 2012.

[7] E. Lawson and E. Lawson, “Negotiating stakeholder participation in the Ghana national climate change policy,” *Int. J. Clim.*, vol. 8, no. 3, pp. 399–417, 2016.

[8] P. Alam and K. Ahmade, “Impact of Solid Waste on Health and the Environment,” *Int. J. Sustain. Dev. …*, vol. 2, no. 1, pp. 165–168, 2013.

[9] P. Vasanthi and S. Kaliappan, “Impact of poor solid waste management on ground water,” *Environ. Monit. Assess.*, vol. 143, no. 1, pp. 227–238, 2008.

[10] A. M. Odukoya and A. F. Abimbola, “Contamination assessment of surface and groundwater within and around two dumpsites,” *Abimbola Int. J. Environ. Sci. Tech*, vol. 7, no. 2, pp. 367–376, 2010.

[11] R. K. Henry, Z. Yongsheng, and D. Jun, “Municipal solid waste management challenges in developing countries - Kenyan case study,” *Waste Manag.*, 2006.

[12] A. A. Bakare *et al.*, “DNA Damage Induced in Human Peripheral Blood Lymphocytes by Industrial Solid Waste and Municipal Sludge Leachates,” *Environ. Mol. Mutagen.*, vol. 48, no. 1, pp. 30–37, 2007.

[13] V. Garaj-Vrhovac, V. Oreščanin, and D. Ruk, “In vitro assessment of genotoxic effects of electric arc furnace dust on human lymphocytes using the alkaline comet assay,” *J. Environ. Sci. Heal. Part A*, vol. 44, no. 3, pp. 279–287, 2009.

[14] S. Mukherjee and S. Mukhopadhyay, “Contemporary environmental issues of landfill leachate: assessment and remedies,” *Crit. Rev. Environ. Sci. Technol.*, vol. 45, no. 5, pp. 472–590, 2015.

[15] Y. Wang *et al.*, “Atmospheric emissions of typical toxic heavy metals from open burning of municipal solid waste in China,” *Atmos. Environ.*, vol. 152, pp. 6–15, 2017.

[16] S. Kumar, A. N. Mondal, S. A. Gaikwad, S. Devotta, and R. N. Singh, “Qualitative assessment of methane emission inventory from municipal

solid waste disposal sites: A case study," *Atmos. Environ.*, vol. 38, pp. 4921–4929, 2004.

[17] L. dos Muchangos, A. Tokai, and A. Hanashima, "Application of material flow analysis to municipal solid waste in Maputo City, Mozambique," *Waste Manag. Res.*, vol. 35, no. 3, pp. 253–266, 2017.

[18] A. Johari, S. I. Ahmed, H. Hashim, H. Alkali, and M. Ramli, "Economic and environmental benefits of landfill gas from municipal solid waste in Malaysia," *Renew. Sustain. Energy Rev.*, vol. 16, no. 5, pp. 2907–2912, 2012.

[19] R. Marshall and K. Farahbakhsh, "Systems approaches to integrated solid waste management in developing countries," *Waste Manag.*, vol. 33, no. 4, pp. 988–1003, 2013.

[20] I. Al-Khatib, S. Kontogianni, H. Nabaa, and M. Al-Sari, "Public perception of hazardousness caused by current trends of municipal solid waste management," *Waste Manag.*, vol. 36, pp. 323–330, 2015.

[21] M. Kamali, T. Gameiro, M. E. V Costa, and I. Capela, "Anaerobic digestion of pulp and paper mill wastes–An overview of the developments and improvement opportunities," *Chem. Eng. J.*, vol. 298, pp. 162–182, 2016.

[22] P. White, M. Dranke, and P. Hindle, *Integrated solid waste management: a lifecycle inventory*. Springer Science & Business Media, 2012.

[23] P. T. Williams, *Waste treatment and disposal*. John Wiley & Sons, 2013.

[24] M. E. Edjabou *et al.*, "Municipal solid waste composition: Sampling methodology, statistical analyses, and case study evaluation," *Waste Manag.*, vol. 36, pp. 12–23, 2015.

[25] K. Miezah, K. Obiri-Danso, Z. Kádár, B. Fei-Baffoe, and M. Y. Mensah, "Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana," *Waste Manag.*, vol. 46, pp. 15–27, 2015.

[26] D. Asante-Darko, E. S. Adabor, and S. K. Amponsah, "Forecasting solid waste generation: a Fourier series approach," *Int. J. Environ. Waste Manag.*, vol. 19, no. 4, pp. 318–337, 2017.

[27] M. Sharholy, K. Ahmad, G. Mahmood, and R. Trivedi, "Municipal solid waste management in Indian cities–A review," *Waste Manag.*, vol. 28, no. 2, pp. 459–467, 2008.

[28] H. Chen and N. Chang, "Prediction analysis of solid waste generation

based on grey fuzzy dynamic modeling," *Resour. Conserv. Recycl.*, vol. 29, no. 1, pp. 1–18, 2000.

[29] M. Abbasi and A. El Hanandeh, "Forecasting municipal solid waste generation using artificial intelligence modelling approaches," *Waste Manag.*, vol. 56, pp. 13–22, 2016.

[30] World Bank, "Results-based Financing for Municipal Solid Waste," Washington, DC, USA, 2014.

[31] World Bank, "What a Waste: a Global Review of Solid Waste Management," Washington, DC., 2012.

[32] H. A. Eiselt and V. Marianov, "Location modeling for municipal solid waste facilities," *Comput. Oper. Res.*, vol. 62, pp. 305–315, 2015.

[33] D. Hoornweg, P. Bhada-Tata, and C. Kennedy, "Waste production must peak this century," *Nature*, vol. 502, no. 7473, pp. 615–617, 2013.

[34] D. Hoornweg and P. Bhada-Tata, "Peak waste: When is it likely to occur?," *J. Ind. Ecol.*, vol. 19, no. 1, pp. 117–128, 2015.

[35] B. Adam, D. Adam, and A. Hussein, "THE FACTORS THAT AFFECTING ON SOLID WASTE GENERATION IN ZALINGY TOWN – CENTRAL DARFUR STATE," *World J. Eng. Res. Technol.* , vol. 2, no. 6, pp. 71–80, 2016.

[36] A. Gaeta-Bernardi and V. Parente, "Organic municipal solid waste (MSW) as feedstock for biodiesel production: A financial feasibility analysis," *Renew. Energy*, vol. 86, pp. 1422–1432, 2016.

[37] T. O. Wiedmann *et al.*, "The material footprint of nations," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 112, no. 20, pp. 6271–6276, May 2015.

[38] A. A. Zorpas, K. Lasaridi, I. Voukkali, P. Loizia, and C. Chroni, "Household waste compositional analysis variation from insular communities in the framework of waste prevention strategy plans," *Waste Manag.*, vol. 38, pp. 3–11, 2015.

[39] H. Slagstad and H. Brattebø, "Influence of assumptions about household waste composition in waste management LCAs," *Waste Manag.*, vol. 33, no. 1, pp. 212–219, Jan. 2013.

[40] M. Oteng-Ababio, "Rethinking waste as a resource: insights from a low-income community in Accra, Ghana," *City, Territ. Archit.*, vol. 1, no. 1, pp. 1–14, 2014.

[41] D. Zhang, S. Tan, and R. Gersberg, "Municipal solid waste management in

China: status, problems and challenges,” *J. Environ. Manage.*, vol. 91, no. 8, pp. 1623–1633, 2010.

[42] A. Zorpas, I. Voukkali, and P. Loizia, “Socio Economy Impact in Relation to Waste Prevention,” in *Sustainable Economic Development*, Springer International Publishing, 2017, pp. 31–48.

[43] K. Breivik, J. M. Armitage, F. Wania, A. J. Sweetman, and K. C. Jones, “Tracking the global distribution of Persistent Organic Pollutants accounting for e-waste exports to developing regions,” *Environ. Sci. Technol.*, 2016.

[44] The World Bank, “GDP per capita (current US$) | Data,” 2016. [Online]. Available: http://data.worldbank.org/indicator/NY.GDP.PCAP.CD. [Accessed: 05-Jul-2017].

[45] G. Ojo and D. Bowen, “Environmental and economic analysis of solid waste management alternatives for Lagos municipality, Nigeria,” *J. Sustain. Dev. Africa*, vol. 16, no. 1, pp. 113–144, 2014.

[46] F. Sankoh, X. Yan, and A. Conteh, “A Situational Assessment of Socioeconomic Factors Affecting Solid Waste Generation and Composition in Freetown, Sierra Leone,” *J. Environ. Prot. (Irvine,. Calif).*, vol. 3, no. 7, pp. 563–568, 2012.

[47] J. Okot-Okumu, “Solid waste management in African cities–East Africa,” in *Waste Management-An Integrated Vision*, Intech, 2012.

[48] O. Baloyi, D. Musa Maringa Sibande, S. Oelofse Manja Schubert Hulde Swanepoel Linda Godfrey Lulama Wakaba Aubrey Muswema, and D. Baldwin, “NATIONAL WASTE INFORMATION BASELINE REPORT,” Pretoria, 2012.

[49] T. Zaki, A. G. Kafaf, M. B. Mina, and A. E.-H. M. Abd El-Halim, “Annual Report for Solid Waste Management in Egypt,” Cairo, 2013.

[50] L. Cai, D. Gao, T. Chen, H. Liu, and G. Zheng, “Moisture variation associated with water input and evaporation during sewage sludge bio-drying,” *Bioresour. Technol.*, vol. 117, pp. 13–19, 2012.

[51] D. Beneroso, J. M. Bermúdez, A. Arenillas, and J. A. Menéndez, “Influence of the microwave absorbent and moisture content on the microwave pyrolysis of an organic municipal solid waste,” *J. Anal. Appl. Pyrolysis*, vol. 105, pp. 234–240, 2014.

[52] L. Yermán, H. Wall, and J. Torero, “Experimental investigation on the

destruction rates of organic waste with high moisture content by means of self-sustained smoldering combustion," in *Proceedings of the Combustion Institute*, 2017, vol. 36, no. 3, pp. 4419–4426.

[53] P. Watkins and P. McKendry, "Sustainable Energy Technologies and Assessments," 2015.

[54] P. Sukholthaman and K. Shirahada, "Technological challenges for effective development towards sustainable waste management in developing countries: Case study of Bangkok, Thailand," *Technol. Soc.*, vol. 43, pp. 231–239, 2015.

[55] E. Rada, M. Ragazzi, S. Villotti, and V. Torretta, "Sewage sludge drying by energy recovery from OFMSW composting: Preliminary feasibility evaluation," *Waste Manag.*, vol. 34, no. 5, pp. 859–866, 2014.

[56] C. Ballardo, J. Abraham, R. Barrena, and A. Artola, "Valorization of soy waste through SSF for the production of compost enriched with Bacillus thuringiensis with biopesticide properties," *J. Environ. Manage.*, vol. 169, pp. 126–131, 2016.

[57] V. Benavente, A. Fullana, and N. Berge, "Life cycle analysis of hydrothermal carbonization of olive mill waste: Comparison with current management approaches," *J. Clean. Prod.*, vol. 42, pp. 2637–2648, 2017.

[58] H. Iqbal, M. A. Baig, M. U. Hanif, S. U. Ali, and M. Flury, "Leaching ofMetals, Organic Carbon and Nutrients fromMunicipalWaste under Semi-Arid Conditions," *Int. J. Environ. Res.*, vol. 9, no. 1, pp. 187–196, 2015.

[59] P. Zhao, Y. Shen, S. Ge, Z. Chen, and K. Yoshikawa, "Clean solid biofuel production from high moisture content waste biomass employing hydrothermal treatment," *Appl. Energy*, vol. 131, pp. 345–367, 2014.

[60] A. P. Tom, R. Pawels, and A. Haridas, "Biodrying process: A sustainable technology for treatment of municipal solid waste with high moisture content," *Waste Manag.*, vol. 49, p. 64, 2016.

[61] C. A. Wilhelmsen and R. A. Dixon, "Identifying Indicators Related to Constructs for Engineering Design Outcome," *J. Technol. Educ.*, vol. 27, no. 2, 2016.

[62] P. A. Champ, "Collecting survey data for nonmarket valuation," Springer, 2003, pp. 59–98.

[63] N. Golafshani, "Understanding Reliability and Validity in Qualitative

Research," *Qual. Rep.*, vol. 8, no. 4, pp. 597–606, 2003.

[64] M. . Patton, "Enhancing the Quality and Credibility of Qualitative Analysis," *Health Serv. Res.*, vol. 34, no. 5, pp. 1189–1208, 1999.

[65] H. Noble and J. Smith, "Issues of validity and reliability in qualitative research," *Evid. -Based Nursing*, vol. 18, no. 2, pp. 34–35, 2015.

[66] P. Bowan and M. Tierobaar, "Characteristics and Management of Solid Waste in Ghanaian Markets- a Study of Wa Municipality," *Civ. Environ. Res.*, vol. 6, no. 1, pp. 114–119, 2014.

[67] Worldometers, "Ghana Population," 2018. [Online]. Available: http://www.worldometers.info/world-population/ghana-population/. [Accessed: 23-Aug-2017].

[68] D. Thaiyalnayaki and R. Jayanthi, "CHARACTERISATION OF HOUSEHOLD SOLID WASTE IN THE TOWN OF THANJAVUR," *Indian J.Sci.Res*, vol. 14, no. 1, pp. 143–147, 2017.

[69] V. Srivastava, S. S. A. Ismail, P. Singh, and R. P. Singh, "Urban solid waste management in the developing world with emphasis on India: challenges and opportunities," *Rev. Environ. Sci. Biotechnol.*, vol. 14, no. 2, pp. 317–337, Jun. 2015.

[70] D. C. Wilson, L. Rodic, A. Scheinberg, C. A. Velis, and G. Alabaster, "Comparative analysis of solid waste management in 20 cities," *Waste Manag. Res.*, vol. 30, no. 3, pp. 237–254, Mar. 2012.

[71] R. Kuleape, S. Cobbina, and S. Dampare, "Assessment of the energy recovery potentials of solid waste generated in Akosombo, Ghana," *African J. Environ. Sci. Technol.*, vol. 8, no. 5, pp. 297–305, 2014.

[72] J. N. Fobil, D. Carboo, and N. A. Armah, "Evaluation of municipal solid wastes (MSW) for utilisation in energy production in developing countries," *Int. J. Environ. Technol. Manag.*, vol. 5, no. 1, pp. 76–86, 2005.

[73] R. Adu and R. Lohmueller, "The Use of Organic Waste as an Eco-Efficient Energy Source in Ghana," *J. Environ. Prot. (Irvine,. Calif).*, vol. 3, no. 7, pp. 553–562, 2012.

[74] B. Fei-Baffoe, E. A. Nyankson, and J. Gorkeh-Miah, "Municipal Solid Waste Management in Sekondi-Takoradi Metropolis, Ghana," *J. Waste Manag.*, vol. 2014, 2014.

[75] M. N. Akhtar, "Prospective Assessment for Long-Term Impact of Excessive Solid Waste Generation on the Environment," *Int. J. Adv.*

EARTH Environ. Sci., vol. 2, no. 2, pp. 39–45, 2014.

Appendix I – Skills Development

Year 1

- MSc. Waste Management Module
- Working Effectively in a Team
- Reading & Writing Research Articles - Generic Structures & Features of Research Articles
- Reading & Writing Research Articles - Functions and Language in Methods Sections
- Essential Teaching Skills C1 - Demonstrating to Practical Classes
- Finding information for your Literature Review – Practice
- Making an Impact with Posters
- Copyright and Your Thesis
- Essential Teaching Skills D - Supporting Undergraduate Learning
- Writing your Doctoral Thesis
- Reading & Writing Research Articles - Functions and Language in Results Sections
- Plagiarism & Citation for PGRs
- Managing Your Research as a Project
- Reflective Practices and the Research Process
- Research Data Management
- Reading and Writing Research Articles - Exploring the Functions and Language of Discussion Sections
- Open access – why is it important to me?
- Engaging the Public with Your Research
- Career Management for Researchers
- Effective Job Applications (Academic and Industry)
- Essential Teaching Skills B - Preparing to Teach Undergraduates
- Postgraduate Induction Day
- Essential Teaching Skills C2 - Planning Classroom Teaching
- Embedding memory work/experience stories in your research and/or teaching practice
- What is a Literature Review?
- Getting Articles Published for Researchers
- Postgraduate Funding: Considering the Alternatives
- Creating an Effective Publication Strategy for PGRs
- 3 Minute Thesis - Heat 2
- Demystifying systematic reviews
- Ethical Thinking in Research
- Getting the Most out of Supervision
- Successful Interviews
- Marketing Your Research Skills
- Finding information for your literature review – Theory
- Keeping Up-to-Date

- CBE (Civil and Building Engineering) Doctoral seminar
- CBE Alumni Event

Year 2

- PhD Workshop
- Presentation at CBE July 2017 Doctoral Seminar
- Questionnaire Design
- Introduction to the Design of Surveys and Experiments
- Introduction to SPSS
- Introduction to Data Analysis Using SPSS
- Social Research Philosophies (ABCE brown-bag seminar)
- Enterprise for PhD students
- Referencing Software: Introduction to Mendeley
- WASH in low – and – middle income countries Conference
- 40th WEDC International Conference
- Sharing Data Between Researchers, Research Teams and the Institutional Repository

Year 3

- Proof Reading and Reviewing Written Work
- Research Methodologies
- Best Research Practices
- Presentation on PhD Experience to PhD Research Starters
- Peer Mentor Training
- Examinations Invigilation Training
- Loughborough Water Day
- Changing Environment and Infrastructure (CEI) Workshop with the International Water Association
- International Water Association Event on Global Water Management

Appendix J – Research Publications by the Researcher

1. **Bowan, A. P.,** Kayaga, M.S., Cotton, A.P & Fisher, J. (2018)**,** An Investigation on Municipal Solid Waste Generation and Characteristics, *a Conference Paper Accepted for the 4th International SEEDS Conference*, Dublin Institute of Technology, Dublin, Ireland, 6th & 7th September 2018

2. Sumah M. A., **Bowan A. P.** & Insah B., (2014), Decentralization in the Ghana Health Service: A Study of the Upper West Region. *Developing Country Studies*, 4(12), 45 - 52

3. **Bowan A. P.,** Anzagira L. F., & Anzagira C. A. (2014), Solid Waste Disposal in Ghana: A Study of Wa Municipality. *Journal of Environment and Earth Science*, 4(4), 10 - 16

4. **Bowan A. P.** & Timol M. T. (2014), Characteristics and Management of Solid Waste in Ghanaian Markets - A Study of Wa Municipality. *Journal of Civil and Environmental Research*, 6(1), 114 - 119

5. **Bowan A. P.** (2013), Private Sector Capacity in the Management of Urban Solid Waste in Ghana – A Study of Zoomlion in the Wa Municipality. *Journal of Studies in Social Sciences*, 5(2), 352 – 364

6. **Bowan A. P.** & Mumuni I. A. (2013), Urban Solid Waste Management in Ghana: An Assessment of Zoomlion's Approach to Waste Management in the Wa Municipality. *Journal of Environment and Earth Science,* 3(12), 73 - 79

7. Insah B., Mumuni I. A., & **Bowan A. P.** (2013), Demographic Factors and Students' Academic Achievement in Tertiary Institutions in Ghana: A study of Wa Polytechnic. *Journal of Education and Practice,* 4(20), 76 - 80

8. Mumuni I. A., Insah B., & **Bowan A. P.** (2013), Women in Entrepreneurship as a means to Sustainable Livelihood in Ghana: A Study of the Upper West Region. *African Journal of Social Sciences,* 3(3), 160 - 171

9. Mumuni I. A., **Bowan A. P.,** & Insah B. (2013), Competency-Based Approach to Entrepreneurship Education in Ghana. *International Journal of Social Sciences and Entrepreneurship,* 1 (5), 18 - 27.

10. **Bowan A. P.** & Kabobah T. A., **(**2012), The Future beyond – '*Pito*' brewing industry and its associated impact on forest degradation in the Upper West Region. *A paper presented at the Polytechnics Research Conference in Tamale Sports Stadium, Tamale Ghana*, 27th - 28th February 2012.

11. **Bowan A. P.,** (2012), Urban Solid Waste Management in Ghana: An Assessment of Zoomlion's Approach to Waste Management in the Wa Municipality. *A paper presented at the Polytechnics Research Conference in Tamale Sports Stadium, Tamale Ghana*, 27th - 28th February 2012.