Exploring alternatives to divert food waste from landfill disposal in Rustenburg, North-West

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PREFACE AND ACKNOWLEDGMENTS

This dissertation began to take shape a year ago in 2019 while I was also doing the theoretical component of my Masters' degree. It was during lessons in class when I discovered that there is need to address food waste management in South Africa. As the world has moved into a digital age, more technologies of how to solve current waste management issues is being introduced, phasing out the outdated landfilling methods. Which alternative food waste management will be best suitable? This dissertation explored some of the alternative methods that are being utilised in developed and developing countries that could be introduced locally in South Africa. Although the Rustenburg Local Municipality (RLM) was used as a case study, the alternative suggested is not only applicable to RLM, but also other local municipalities.

First and foremost, I would like to thank God Almighty for being there and for surrounding me with supportive and knowledgeable people.

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Last but no means the least, this accomplishment would not have been possible without the love of my family, more especially my siblings and partner. To my friends specifically Johannes, Kenneth, Nkhathu and Charity thank you for always cheering. A special thank you to Ms. Dineo Mapholo and Mr Walter Senne for encouraging me to do a Master's degree. I dedicate this research paper to my late parents, Mr Aaron and Agnes Mammburu.

ABSTRACT

Around one third of food produced for human consumption is wasted globally, with the majority of this waste being landfilled. This is troublesome, especially in developing countries, where access to food and hunger have been raised as concerns. Sources of food waste include household, commercial, industrial, and agricultural waste, and its composition differs, depending on source and type. The disposal of food waste leads to a loss of resources in the food production life cycle, while landfilling also leads to negative environmental impacts. The waste management hierarchy advocates the disposal of waste as the least preferable option, with alternatives such as re-use, recycling and treatment, being more preferable.

The aim of the study was to explore alternatives for the diversion of food waste from landfill disposal. The Waterval landfill site, located in the Rustenburg Local Municipality (RLM) was selected as a case example for what could typically be expected for a South African landfill site. Food waste was characterised (in quantity and type) over a five-day period, supported by secondary weigh bridge data, and data gathered during interviews. Two-hundred-and-twenty-one kilogrammes (221 kg) of waste was sorted during the waste characterisation study, with a total of 65,18 kg (29.5%) being food waste. Fruits and vegetables, bakery items and mixed food are the three types of food that were found to be present in the largest quantities. The results of the study compared well with what other researchers have found elsewhere in South Africa.

Literature was reviewed to determine which alternatives to landfilling would be the most suitable for the food waste characterised at the Waterval landfill site, based on factors such as food waste composition and estimated quantities, cost, technology required, creation of job opportunities, etc. The results of comparing alternative methods showed that composting and livestock feeding were the most suitable alternatives, based on the waste quantities and types. Anaerobic digestion was also considered, but not found feasible due to the amount of food waste required for sustainable, ongoing anaerobic digestion. Incineration was considered as an option, but were not considered feasible, due to its low position on the food waste hierarchy, and limited incineration capacity in RLM. Interviews with staff from the RLM indicated that alternative initiatives would be supported. Review of documentation, such as the integrated waste management plan (IWMP) and integrated development plan (IDP) has indicated that the reduction of food waste to landfill has been identified as a priority within the municipality. The allocation of operational budget towards the investigation and implementation of alternatives has, however, been identified as being a gap.

Keywords: Food waste, Food waste treatment, Landfill diversion, Recycling, Municipal Solid Waste, Rustenburg.

ACRONYMS AND ABBREVIATIONS

AD	Anaerobic digestion
BPD	Bojanala Platinum District Municipality
BPEO	Best Practicable Environmental Option
BOD	Biochemical Oxygen Demand
CCT	City of Cape Town
CGCSA	Consumer Goods Council of South Africa
CO_2	Carbon Dioxide
CoJ	City of Johannesburg
CSIR	Council for Scientific and Industrial Research
CSTR	Continuous Stirred-Tank Reactor
C/N	Carbon/Nitrogen
DEA	Department of Environmental Affairs (now DEFF)
DEFF	Department of Environment, Forestry and Fisheries
DTI	Department of Trade and Industry
EMRG	Environmental Management Research Group
EPA	Environmental Protection Agency
EU	European Union
EUD	European Union Dialogue Facility
E-Waste	Electronic Waste
FAO	Food and Agricultural Organization of the United Nations
FSC	Food Supply Chain

FW	Food Waste
FUSION	Food Use for Social Innovation by Optimising Waste Prevention Strategies
GDP	Gross domestic product
GHG	Green House Gases
GIZ	Deutsche Gesellschaft fur Internationale Zusammernarbeit
GN	Government Notice
IDP	Integrated Development Plan
IWM-DST	Integrated Waste Management Decision Support Tool
IWMP	Integrated Waste Management Plan
IWMS	Integrated Waste Management Strategy
JBA	Jarrod Ball & Associates
K	Thousand
KfW	Kreditanstalt fuer Wiederaufbau
Kg	kilogram
MFMA	Municipal Finance Management Act
MIG	Municipal Infrastructure Grant
MRF	Materials Recovery Facility
MMT	Million Metric Tons
MSW	Municipal Solid Waste
NEMA	National Environmental Management Act
NEMWA	National Environmental Management Waste Act
NEMAQA	National Environmental Management Air Quality Act
NGO	Non-Governmental Organisation

NOWCS	National Organic Waste Composting Strategy
NWMS	National Waste Management Strategy
NWU	North West University
NWU-SCRE	North West University Senate Committee for Research Ethics
PPE	Personal Protective Equipment
PPP	Public Private Partnership
R	Rand
REC	Research Ethics Committee
RLM	Rustenburg Local Municipality
RSA	Republic of South Africa
SDBIP	Service Delivery and Budget Implementation Plan
SDG	Sustainable Development Goals
TES	think-eat-save
Tpa	tonnes per annum
UK	United Kingdom
USA	United States of America
USD	United State Dollar
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USEPA	United States Environmental Protection Agency
WCG	Western Cape Government
WtE	Waste-to-energy

WRAP	Waste and Resource Action Programme
WWF	World Wide Fund for Nature
WWF- SA	World Wide Fund for Nature – South Africa

DEFINITIONS

Air pollution

Any change in the composition of the air caused by smoke, soot, dust (including fly ash), cinders, solid particles of any kind, gases, fumes, aerosols and odorous substances (National Environmental Management Air Quality Act, Act 39 of 2004).

Anaerobic Digestion

A biological process in which microorganisms break down biodegradable material in the absence of oxygen creating two important products: biogas and digestion (European Biogas Association).

Atmospheric emission

Any emission or entrainment process emanating from a point, non-point or mobile source that results in air pollution (National Environmental Management Air Quality Act, Act 39 of 2004).

Biogas

The primary product of AD is a methane-rich renewable gas composed of 50 to 65% methane and 35 to 50% carbon dioxide (European Biogas Association).

Business waste

Waste that emanates from premises that are used wholly or mainly for commercial, retail, wholesale, entertainment, wholesale, entertainment or government administration purposes

Co-digestion

Anaerobic digestion of multiple substrates. Often done by adding high strength waste, such as fats, oils and grease.

Composting

Composting is a controlled biological process in which organic materials are broken down by micro-organisms to form compost (National Organic Waste Composting Strategy, 2013).

Disposal

The burial, deposit, discharge, abandoning, dumping, placing, or release of any waste into, or onto, any land.

Digestate

The material (usually liquid) remaining after the anaerobic digestion of a biodegradable feedstock

Digestion

Breaking down of large organic molecules by micro-organisms

Domestic waste

Waste, excluding hazardous waste that emanates from premises that are used wholly or mainly for residential, educational, health care, sport or recreation purposes.

Environment

The surroundings within which humans exist and are made up of – (i) the land, water and atmosphere of the earth: (ii) micro-organisms, plant and animal life: (iii) any part or combination of and the interrelationships among and between them: (iv) and the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being.

General waste

Waste that does not pose an immediate hazard or threat to health or to the environment, and includes – domestic; building and demolition waste; business waste; and inert waste.

Greenhouse gas

Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and re-emit infrared radiation, and includes carbon dioxide, methane and nitrous oxide (National Environmental Management Air Quality Act, Act 39 of 2004).

Hazard

A source of or exposure to danger.

Hazardous waste

Any waste that contains organic or inorganic elements or compounds that may, owing to inherent physical, chemical or toxicological characteristics of that waste, have a detrimental impact on health and the environmental and includes hazardous substances, materials or objects within business waste, residue deposits and residue stockpiles

Incineration

Any method, technique or process to convert waste to flue gases and residues by means of oxidation. (National Policy on the Thermal Treatment of General and Hazardous Waste, GN 777 of July 2009)

Integrated Waste Management Strategy

A legislative requirement of the National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008). The purpose of the strategy is to achieve the objective of the Waste Act.

Integrated Waste Management Plan

A document that outlines how an organisation will reduce, manage, and dispose of its waste. It analysis and optimises the existing waste management system in any municipality.

Landfill

A system of trash and garbage disposal in which the waste is buried between layers of earth to build up low-lying land (Merriam-Webster, 1903).

Leachate

A liquid by-product of organic decomposition of landfilled waste or any liquid that comes in contact with solid waste in a sanitary landfill.

Minimisation

The avoidance of the amount and toxicity of waste that is generated and, in the event where waste is generated, the reduction of the amount and toxicity of waste that is disposed of.

Municipality

An institution established in terms of the Local Government: Municipal Structures Act, 1998 with the purpose of working with citizens and groups within the community to find sustainable ways to meet their social, economic and material needs and improve the quality of their lives.

Offensive odour

Any smell which is considered to be malodorous or a nuisance to a reasonable person *(National Environmental Management Air Quality Act, Act 39 of 2004).*

Recovery

The controlled extraction of a material or the retrieval of energy from waste to produce a product. (National Policy on the Thermal Treatment of General and Hazardous Waste, GN 777 of July 2009)

Recycling

A process where waste is reclaimed for further use, which process involves the separation of waste from a waste stream for further use and the processing of that separated material as a product or raw material. (National Policy on the Thermal Treatment of General and Hazardous Waste, GN 777 of July 2009)

Reduction

Involves various possible measures to reduce the amount of waste generated, e.g. manufacturing process optimisation, or raw material reduction or substitution. (National Policy on the Thermal Treatment of General and Hazardous Waste, GN 777 of July 2009)

Re-use

To utilise articles from the waste stream again for a similar or different purpose without changing the form or properties of the articles. (National Policy on the Thermal Treatment of General and Hazardous Waste, GN 777 of July 2009)

Sustainable development

The integration of social, economic and environmental factors into planning, implementation and decision-making so as to ensure that development serves present and future generations.

Thermal Treatment

Incineration, co-processing and other high temperature treatment of general and hazardous waste. (National Policy on the Thermal Treatment of General and Hazardous Waste, GN 777 of July 2009)

Treatment

Any method, technique or process that is designed to (a) change the physical, biological or chemical character or composition of a waste, or (b) remove, separate, concentrate or recover a hazardous or toxic component of a waste, or (c) destroy or reduce the toxicity of a waste, in order

to minimise the impact of the waste on the environment prior to further use or disposal. (National Policy on the Thermal Treatment of General and Hazardous Waste, GN 777 of July 2009)

Valorisation

The process of converting waste into more useful products (Arancon et al., 2013)

Waste

(a) any substance, material or object, that is unwanted, rejected, abandoned, discarded or disposed of, or that is intended or required to be discarded or disposed of, by the holder of that substance, material or object, whether or not such substance, material or object can be re-used, recycled or recovered and includes all wastes as defined in Schedule 3 to this Act; or (b) any other substance, material or object that is not included in Schedule 3 that may be defined as a waste by the Minister by notice in the Gazette, but any waste or portion of waste, referred to in paragraphs (a) and (b), ceases to be a waste—(i) once an application for its re-use, recycling or recovery has been approved or, after such approval, once it is, or has been re-used, recycled or recovered; (ii) where approval is not required, once a waste is, or has been re-used, recycled or recovered; (iii) where the Minister has, in terms of section 74, exempted any waste or a portion of waste generated by a particular process from the definition of waste; or (iv) where the Minister has, in the prescribed manner, excluded any waste stream or a portion of a waste stream from the definition of waste. (National Environmental Management Waste Act (59 of 2008), as amended).

Waste Management Hierarchy

The Waste Management Hierarchy reflects the different waste management options, from reduction (most preferred) through to re-use, recycling, recovery, treatment/destruction, and lastly disposal (least preferred), that should all form part of an integrated waste management system (National Waste Management Strategy, 2011)

Waste disposal facility

Any site or premises used for the accumulation of waste with the purpose of disposing of that waste at that site or on that premise.

Waste Management Services

Waste collection, treatment, recycling and disposal services etc.

TABLE OF CONTENTS

PREFACE AND ACKNOWLEDGMENTS ..... **I**

ABSTRACT ..... **II**

ACRONYMS AND ABBREVIATIONS ..... **III**

DEFINITIONS ..... **VII**

CHAPTER 1: INTRODUCTION **1**

1.1 Background **1**

1.2 Problem statement **2**

1.3 Research aim and objectives **4**

1.4 Delineation and scope of the study **5**

1.5 Assumptions and limitations of the study **6**

1.6 Outline of the study **6**

1.7 Chapter conclusion **7**

CHAPTER 2: LITERATURE REVIEW **9**

2.1 Introduction **9**

2.1.1 Defining “food waste” and “food loss” 10

2.1.2 The food waste issue 11

2.1.2.1 The global context 12

2.1.2.2 The South African context 13

2.1.3 The study area context, Rustenburg Local Municipality (RLM) 13

2.2 Drivers of food waste generation **14**

2.2.1 Technological drivers 15

2.2.2 Institutional drivers 16

2.2.2.1 Legislation and policy 16

2.2.3 Social drivers 16

2.3 Impacts of food waste 17

2.3.1 Economic impacts of food waste 17

2.3.2 Social impacts of food waste 17

2.3.3 Environmental impacts of food waste 18

2.4 Challenges with food waste management 19

2.5 Common practice: Landfilling of food waste 20

2.5.1 Potential value of food waste and benefits of diverting food waste from landfill 20

2.6 Food waste and the waste management hierarchy 21

2.6.1 Consideration of the best practicable environmental option (BPEO) 23

2.6.2 Food waste avoidance, reduction and separation at source 23

2.7 Alternatives to food waste disposal to landfill 24

2.7.1 Composting 25

2.7.2 Incineration 27

2.7.3 Anaerobic digestion and biogas to energy 29

2.7.4 Livestock feeding 31

2.8 Conclusion 32

CHAPTER 3: METHOLODOGY 33

3.1 Introduction 33

3.2 Description and demography of the study area 33

3.3 Research design 36

3.4 Data collection 38

3.4.1 Literature review 39

3.4.2 Food waste characterisation study 39

3.4.2.1 Sampling 40

3.4.2.2 Sorting and characterisation of waste 41

3.4.2.3 Determining the approximate food waste quantity based on monthly total waste data 45

3.4.3 Determining the existing institutional environment for the establishment of alternatives to divert food waste away from landfill 45

3.4.4 Establishing the capability of waste management officers to implement alternative options (to divert food waste away from landfill) through interviews and questionnaires 46

3.5 Data analysis and interpretation 47

3.6 Assumptions and limitations 47

3.7 Ethical considerations 48

3.8 Conclusion 48

4.1 Research objective 1: Waste characterisation results 49

4.1.1 Waste composition 49

4.1.1.1 Approximate quantity of food waste 50

4.1.1.2 Composition of food waste (food waste types) 51

4.2 Research objective 2: Investigating alternatives for food waste disposal, based on food waste characteristics 53

4.3 Research objective 3: Determining the enabling environment for implementing alternatives 60

4.3.1 Lessons learned from the study conducted by DEA at Waterval landfill site in 2020 60

4.3.2 Lessons learned from the IWMP 60

4.3.3 Lessons learned from the IDP and SDBIP 61

4.3.4 Lessons learned from the Waterval landfill license 62

4.3.5 Results of interviews/questionnaires 62

4.4 Chapter summary 64

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS 66

5.1 Conclusions 66

5.1.1 Conclusions related to Research Objective 1: Determining the characteristics (quantity and composition) of food waste received for landfilling 66

5.1.2 Conclusions related to Research Objective 2: Investigating the potential alternatives to landfilling for food waste in Rustenburg Local Municipality based on opportunities and limitations 67

5.1.3 Conclusions related to Research Objective 3: Understanding the existing supporting context for the implementation of food waste alternatives, within Rustenburg Local Municipality 68

5.2 Recommendations 68

5.2.1 Practical recommendations related to alternatives to food waste disposal at Waterval landfill site 68

5.3 Recommendations for further research 69

BIBLIOGRAPHY 71

ANNEXURE A: PERMISSION TO CONDUCT STUDY 84

ANNEXURE B: QUESTIONNAIRE ON FOOD WASTE 85

LIST OF TABLES

Table 3-1: Research questions and their methodologies 37

Table 3-2: Food waste categories and descriptions used when sorting food waste (as recommended by WRAP, 2008). 41

Table 3-3: Description and illustration of the waste sorting procedure 42

Table 4-1: Total amount of waste sorted per day and the relative (percentage) amount of food waste per bag 49

Table 4-2: Estimated quantities of food waste received at Waterval landfill site based on weigh bridge data of the total amount of waste received, and a 31.14±9.4% contribution of food waste to the total amount of waste received (as determined by this study) 51

Table 4-3: Comparison of alternatives to the disposal of food waste to landfill (DEA, 2009; DEA, 2013; Garcia-Garcia *et al.*, 2016; Oliveira *et al.*, 2017; Gao *et al.*, 2017; Dou *et al.*, 2018; Janson *et al.*, 2019; Ng *et al.*, 2019). 54

Table 4-4: Questions and responses from interviews using semi-structured questionnaires 63

Table 5-1: A summary of practical recommendations 69

LIST OF FIGURES

Figure 1-1: Outline of chapters 7

Figure 2-1: The waste management hierarchy, as proposed by the National Waste Management Strategy (DEA, 2011) 9

Figure 2-2: The process of how food waste occurs (DEA, 2016). 10

Figure 2-3: Food recovery hierarchy proposed by the US EPA (USEPA, 2014). 22

Figure 2- 4: Municipal Decision Support Tool – technical aspects and integration into municipal decision-making (Sango *et al.*, 2016). 25

Figure 3-1: Map of South Africa highlighting North West Province, Rustenburg 33

Figure 3-2: Map of a portion of RLM, indicating the location of Waterval Landfill site. (Source: RLM IWMP, 2017) 35

Figure 3-3: PPE worn by the researcher during sorting 44

Figure 4-1: Contribution of food waste categories (%) by weight to the total amount of food waste sampled 52

CHAPTER 1: INTRODUCTION

In this chapter the background, problem statement, research aim and objectives, and research questions are introduced. To provide context to the research, this chapter outlines the project statement, the aim, objectives and scope of the study, as well as assumptions and limitations.

1.1 Background

Around one third of all food produced for human consumption is wasted globally, while in a growing global population, many suffer from hunger. This is especially the case in developing countries (Palanivel & Sulaiman, 2014). The United Nations Development Programme reports that, as of 2017, there are approximately 821 million people estimated to be chronically undernourished, mostly from developing countries (UNDP, 2017). This brings about economic, social and environmental costs, and appeals for critical measures.

Food waste, as a special class of municipal solid waste, has the characteristics of high moisture, salinity, organic and oil content, which needs different methodologies of treatment from conventional municipal solid waste (Gao *et al.*, 2017). Sources of food waste include household, commercial, industrial, and agricultural residues, and the composition of food wastes differs largely based on the source and type (Tsang *et al.*, 2019). The total amount of food waste from industrial processes and agriculture is relatively large, but the composition is normally homogeneous. In contrast, the composition of household food waste is very heterogeneous (Tsang *et al*., 2019) and quantities are also significant (van Herpen *et al*., 2019). It is not only the wastage of the food itself which is cause for concern, but also related wasted products.

Food waste is mostly treated as a non-reusable product in the developed world (Oelofse, 2014). The disposal of food waste signifies loss of a huge amount of money and other resources provided in the complete food production life cycle to produce, store, and transport food meant to feed people. It also results in negative effects on the society and the environment (Bubzy & Hyman, 2012).

Landfilling is generally used as a means to dispose of food waste. Landfilling has negative impacts on the environment through methane production to the atmosphere and leaching of pollutants into the soil and groundwater, and may also cause negative health impacts and nuisance to communities (Desa *et al*., 2011; Malik *et al*., 2015). There is also the issue of landfills running out of air space (Oelofse, 2014) and the cost of mitigation of negative environmental impacts (Tsang *et al.*, 2019). The diversion of food waste from landfill, therefore, requires diverse strategies tailored to national as well as local contexts (Baig *et al*., 2018; Ng *et al.*, 2019).

All of these factors necessitate the development of measures and alternatives for the effective management of food waste. Such measures should target preventable food waste reduction; and non-preventable food waste valorisation (Morone *et al.*, 2019) which focuses on processes of converting food waste into more useful products (Arancon; *et al.*, 2013). Examples of alternatives include recovering waste at the source, recycling certain waste types, and re-application/disposal through sound disposal methods (such as organised storage through separation at source, reuse, composting, and energy recovery through anaerobic digestion, etc.) that are not harmful in the environment (Karatekin, 2014).

The quantity and value of food waste remains an arguable issue, and the uncertainty behind the scale of the problem is enhanced by the unclear definition and quantification of food waste (Philippidis *et al.*, 2019). Efforts in research and innovation are needed at all levels (e.g. social, technological and commercial) to enhance a feasible circular economy and in so doing increasing resource efficiency. Food waste issues should be addressed at a system level, through multi-stakeholder collaboration and interactions between various business and industrial sectors (Ng *et al.*, 2019).

Recognition of the importance of food waste is reflected in the growing academic literature, which aims to evaluate its causes, the scale of the problem, monitoring and management (Philippidis *et al.*, 2019).

1.2 Problem statement

Food waste as well as the disposal thereof is a universal crisis with effects on the environment and the economy. The problem is escalated due to the quantities of food waste, the pressure that is being caused on landfill airspace, and the negative impacts on environmental resources and people (De Menna *et al*., 2018). According to studies on food waste, between 9 and 10 million tonnes of food waste is created yearly in South Africa, of which the majority is disposed to landfill (Oelofse, 2014). The economic liability of food loss and waste in South Africa is calculated to be around R61,5 billion (Von Bormann, 2019).

In agreement with United Nation's (UN) Sustainable Development Goals, South Africa has devoted to decreasing food waste by 2030 (Von Bormann, 2019). The National Waste Management Strategy (NWMS) targets the diversion of waste from landfills, with 25% of recyclables diverted from landfill sites for re-use, recycling or recovery (DEA, 2011). This demands the invention of workable solutions to beneficially use food waste so as to minimise wastage and to reduce pressures on the environment. Various alternatives to the disposal of food

waste exists, however, not all of them are equally viable or suitable within the developing country context (Levis *et al.*, 2010).

Globally, the amount of food waste generated is not clear due to insufficient data availability. The quantification of food waste, through waste composition studies, can be utilised to acquire more accurate estimations of food waste discarding. Food waste can be measured by directly or indirectly methods. Direct methods are utilised to collect, sort, weigh and analyse collected samples at source or before discarding and indirectly is by estimating domestic food production and imported food and the quantities are ascribed by utilising the waste factors (van der Werf *et al.*, 2018). Records on food waste composition, production, and recycling are important for planning courses of collection, bin placements, supervising collection teams, and choosing suitable food waste disposal alternatives (Elzaki & Elhassan, 2019).

Most of the research and quantification studies that have been conducted in South Africa are on household and retail food waste. Some research has also been done on the opportunities and alternatives for food waste in South Africa. A study was done by McCarthy in 2016 on the characterisation of municipal solid waste (MSW) for certain municipalities in South Africa (Oelofse *et al.*, 2016). The study included the quantification of food waste, but did not focus on specific food waste categories. There is a need for further research on food waste and food waste alternatives in South Africa, as highlighted by (Oelofse *et al.*, 2016).

For the purposes of this study, a medium-sized municipality was selected as an illustrative example of what could be reasonably expected, as far as the characterisation of food waste and the identification of food waste alternatives for South African municipalities are concerned. Rustenburg Local Municipality (RLM) was chosen as a case example to determine the alternatives to food waste disposal. Food waste is mainly disposed of to landfill in the RLM. The municipality has closed one landfill site and all communal sites. Only one new landfill site is fully licensed and operational. One landfill site (Townlands) is in the process of being decommissioned and closed, and other smaller waste disposal sites are mainly owned by mines. Airspace within the RLM is, therefore, a commodity that should be managed well. By diverting food waste away from landfill, a substantial contribution could be made to conserving airspace at the landfill sites and reducing environmental impacts. This study aimed to understand the alternatives to the disposal of food waste to landfill, using RLM as a case study.

Studies explicitly focusing on food waste and food waste alternatives have not been conducted for the RLM before commencement of this research in January 2019. Only recently (in January 2020), a waste analysis and characterisation study was conducted by Department of

Environmental Affairs (DEA) and Rustenburg Local Municipality (RLM) at the Waterval Landfill site. The aim of their study was to verify if there is enough feedstock available to support the implementation of a biomass pre-treatment facility. In the context of this research, the results from the characterisation study by DEA will be used to verify the results of this study. It must be noted that the results and context of the study by DEA and RLM were not known when this research was commenced with in January 2019.

Although the study is conducted within the Rustenburg Local Municipality, the lessons learned from the study could be regarded as applicable to other municipalities within South Africa, or the developing country context and could assist with:

- improving knowledge on the food waste generated within a municipality;
- verifying quantities and characteristics (categories) of food waste generally disposed to landfill; and
- identifying alternatives to food waste disposal to landfill.

1.3 Research aim and objectives

The aim of the research is to ***explore alternatives for the diversion of food waste from landfill disposal.*** The study specifically focused on food waste currently destined for landfill disposal at the Waterval landfill site in Rustenburg Local Municipality (RLM) in the North West Province, South Africa, as a case study.

To achieve the aim of the study the following objectives (research questions) were explored:

- Determining the ***characteristics*** (quantity and composition) of food waste received for landfilling;
  Research question 1: What is the approximate quantity of food waste received at the Waterval landfill site?
  Research question 2: What is the composition of the food waste received at the Waterval landfill site?
- Investigating the potential ***alternatives to landfilling*** for food waste in Rustenburg Local Municipality based on opportunities and limitations;
  Research question 3: What are the alternative options for food waste (other than landfill disposal) in Rustenburg Local Municipality?
- Understanding the ***existing supporting context*** for the implementation of food waste alternatives, within Rustenburg Local Municipality.

Research question 4: What is the existing supporting context for the implementation of food waste alternatives, within Rustenburg Local Municipality (i.e. institutional arrangements, infrastructure, municipality's capability to be involved in alternative options, etc.)

1.4 Delineation and scope of the study

The study focused on exploring alternatives for *landfilling* of food waste, based on the quantities and characteristics (composition) of waste destined for disposal at the *Waterval landfill* site (only) in Rustenburg. The study did not quantify waste received at any other landfill sites or material recovery facilities within the Rustenburg Local Municipality.

The study did not aim to quantify and characterize the food waste generated by households (by doing household surveys and household waste characterization). The study quantified and characterized the waste offloaded at the Waterval landfill site for final disposal only, to determine whether it would be suitable (in quantity and composition) for use in alternative waste treatment and disposal methods. The quantities and composition found during this study may, therefore, differ from the food waste that was generated by households or businesses, because of the removal of certain edible or inedible components between generation and final disposal (i.e. waste picking in RLM is common practice). The intent of the study was, however, not to quantify the entire quantity of food waste generated in the RLM, but to determine the amount and composition of food waste (usually, but not always, inedible) arriving at the Waterval landfill site.

The quantification and characterisation of the waste were based on primary data collected during August 2019, and weigh bridge data from January 2019 to August 2019. Although landfilling at the Waterval landfill site commenced in November 2018, no historical or additional food waste characterisation data was available for the site. A study, commissioned by the RLM and DEA, to determine the feasibility of a biomass pre-treatment facility, was only completed after this research was close to completion, as mentioned earlier. This data was used for comparison.

Food waste characterisation focused on quantifying the following categories only: bakery items, dairy products, fruit and vegetables, animal products, dried food, drinks, confectionery, condiment and desserts, and mixed food waste – both edible and inedible, as suggested by other authors (WRAP, 2008). The data was used to estimate (by means of calculations) the average quantity and composition of the waste that would be destined for disposal to landfill per year (for the year 2019). No seasonal variations or adjustments made on population growth from the time of data collection to year end were taken into account. Some margin of error may, therefore, be expected.

1.5 Assumptions and limitations of the study

Apart from the limitations based on the delineation and scope of the study (Section 1.4), the following limitations and assumptions should be noted:

- The study was limited to only one municipality (RLM) and the food waste destined for disposal at one landfill site (Waterval landfill) site only. Although the results may be useful and applicable to other municipalities, and may not be generalizable to other landfill sites in the North West Province or in South Africa.
- The food waste characterisation study was conducted over five consecutive days in August 2019.
- The food waste characterisation study was conducted in one season (winter), this may be a limitation as waste generation is influenced by seasonal changes, and the data was not compared with data from other seasons it was outside the scope of the study.
- The food waste characterisation process (at the Waterval landfill site) presented challenges to the researcher, and data collection was delayed due to the fact that officials responsible for waste management insisted on being on site during the characterisation study, but were unavailable on many of the days requested to do sampling.
- Food waste quantities were estimated based on the results of the waste characterisation study, and estimations based on weighbridge data.
- Weighbridge data for the waste received at Waterval landfill site was only available to the researcher for the months of January to August 2019.
- Accessibility and availability of municipal officials who were responsible to participate in interviews were limited, although appointments were made.
- Although interviews were conducted anonymously, officials were concerned that by responding to the questionnaire, their responses would expose themselves or their municipality.

Further methodological limitations and assumptions are outlined in Section 3.6 of this dissertation.

1.6 Outline of the study

The outline of the dissertation. This study consists of five chapters. **Chapter one** gives the introduction and background information of food waste and their generation and issues. This chapter also covers the problem statement and substantiation for the study, research questions and aim and objectives of the study. **Chapter two** of this study presents a brief review of food waste management and also the challenges and potential value of food waste. It also presents various impacts that originates from food waste disposal, alternative applications of food waste

locally and internationally are outlined in this chapter. **Chapter three** describes the study area together with the research methods used including observation, interviews, waste characterisation survey and literature review. **Chapter four** presents the interpretation and discussion of the results. Results are analysed and presented in this chapter. **Chapter five** draws conclusions from the findings of the study and provides recommendations on what alternative of food is better to be adopted. Figure 1-1 shows outlines of the chapters:

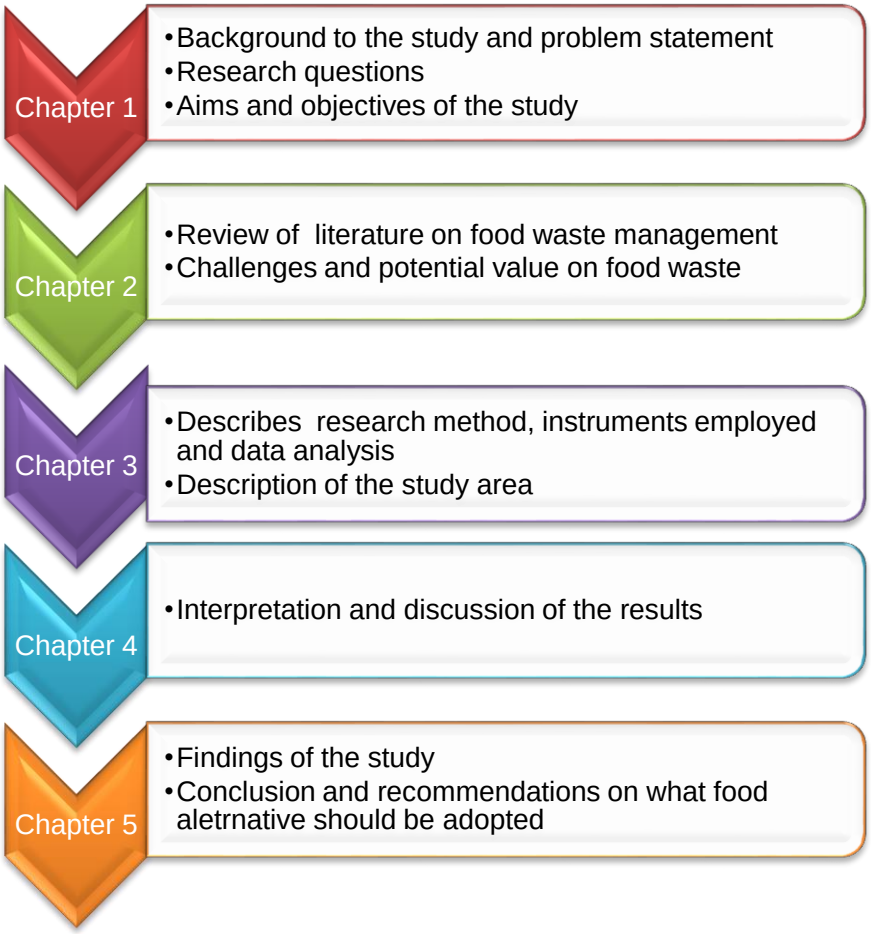


Figure 1-1: Outline of chapters

1.7 Chapter conclusion

This chapter provided the introduction and background information on food waste and related issues. It outlined the problem statement, substantiation for the study, research questions and the aim and objectives of the study. The delineated scope of the study and the assumptions and

limitations of the study are also included in this chapter. Chapter 2 provides the literature review for the purposes to outline the context of the study, and to address certain research questions.

CHAPTER 2: LITERATURE REVIEW

In this chapter, literature on food waste is reviewed and food waste descriptions are provided. Terms used in the study are described and must be read in collaboration with the “definitions” section earlier in this dissertation. This chapter also provides an overview of the challenges that RLM has on food waste and potential value of food waste. Various impacts that originate from food waste are discussed, followed by a discussion of alternative applications of food waste in South Africa and elsewhere in the world to inform research question 3: *What are the alternative options for food waste (other than landfill disposal) in Rustenburg Local Municipality?*

2.1 Introduction

Over 840 million people go hungry every day (UNEP, 2016). Better food logistics, processing or systems and sustainable consumption and production approaches are needed to achieve food security for all. Research shows that, globally, at least 1.3 billion tonnes of food produced each year is lost or wasted (UNEP, 2016). The focus should be on the avoidance of food waste, as a first resort. See Figure 2-1 to support the previous statement.

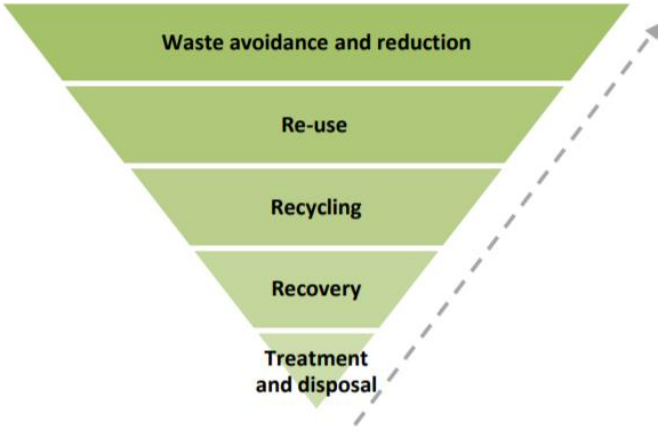


Figure 2-1: The waste management hierarchy, as proposed by the National Waste Management Strategy (DEA, 2011)

The study, however, focuses on options for the diversion of food waste (which has already been generated) from landfill by considering other potential beneficial uses.

2.1.1 Defining “food waste” and “food loss”

Minimising food losses and food waste may lead to the alleviation of challenges such as food security, climate change, and natural resources scarcities. In 2015 the ‘Sustainable Development Goals’ (SDG) identified food loss and the generation of food waste as important challenges for achieving sustainable food consumption (Liu *et al.*, 2016).

Before delving into the issues that we are facing, globally and locally, with regards to food waste and food loss, it is important to firstly define what is meant by the term *“food waste”*. Internationally, there is no single definition for the term “food waste”, which makes the comparison of data from different studies difficult, because of differences in the application of the definition and different components included in the sampling of food wastes (Abdelradi, 2018). There have been some attempts to standardize the definition, however, in South Africa, no legal definition has been gazetted for food waste.

Food lost during the post-harvest stage is described as “food losses” and “spoilage”, but at the later stages of the food supply chain it is described “food waste” and applies mainly to food lost because of behavioural issues. “Food loss” is food that spills, spoils, incurs an abnormal reduction in quality such as bruising or wilting, or otherwise gets affected before it reaches the consumer. Food loss may be the unintended result of an agricultural process or technical limitation in storage, infrastructure, packaging, or marketing (Lipinski *et al.*, 2013) and can be both qualitative and quantitative, for an example; reduced nutrient value and unattractive changes to taste, texture, or colour, measured by weight or volume respectively (Bubzy & Hyman, 2012). Figure 2-2 provides an overview where in the food life cycle, food loss and food waste are likely to occur.



Figure 2-2: The process of how food waste occurs (DEA, 2016)[1].

[1] In Figure 2-2: Agricultural production: Losses that occur in the production process such as unharvested crops and losses that occur during harvest.
Livestock production: Losses and lacks in the transformation of feed and grass into animal products.
Handling, storage and transportation: Losses as a result of spoilage during storage and distribution.

A European Union project on food waste, FUSIONS, (Food Use for Social Innovation by Optimising Waste Prevention Strategies) has been working on harmonising/standardising the definition of food waste. According to the authors, *"food waste is any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea)"* (Karin Östergren *et al*., 2014).

The South African definition of waste provided in the National Environmental Management Act (59 of 2008) (NEMWA), refers to waste as a substance that is unwanted, rejected, discarded, where the generator of that waste has no further purpose of use for that substance (regardless of the usability, or in this case, edibility, of the substance). The South African definition of "waste" in terms of NEMWA, can therefore be seen to make provision for both the edible and inedible parts of food (as provided for in the FUSIONS definition framework), which is thrown away. For the purposes of this study, the definition of waste provided by the FUSIONS Definitional Framework for Food Waste (Karin Östergren *et al.*, 2014), will be adopted and *food waste* will refer to the edible and inedible parts of food waste, which has been disposed and which arrives at the landfill site.

It must be noted that the waste which arrives at the Waterval landfill site in Rustenburg is not necessarily a good representation of the total amount of food waste produced by households in the Rustenburg Local Municipality. Some of the food waste generated may be composted by the generators of waste, disposed of through other means, or reclaimed from the waste stream by waste pickers (or reclaimers). The intent of the study is, however, not to quantify the entire quantity of food waste generated by the Rustenburg Local Municipality, but to determine the amount of food waste (usually, but not always, inedible) arriving at the Waterval landfill site for disposal purposes.

2.1.2 The food waste issue

Food wastage and the generation of food waste is a global issue. South Africa is no exception to this food crisis. The next sections will elaborate on the global and local (South African) food waste issues, and lastly provide an overview of food waste management in the Rustenburg Local Municipality (RLM), to provide context to the current study.

Processing: Losses during treating of products.
Consumer waste: Losses and waste between food arriving to the consumer and being eaten.
Over-consumption: Surplus food consumption over the compulsory human nutrition (Alexander *et al*., 2017).

2.1.2.1 The global context

Developing countries waste less food than developed countries[2] according to (Gustavsson *et al.*, 2011). However, developing countries have more challenges in food waste management than developed countries. Therefore these countries must identify and implement food waste management measures, including prevention, recycling and disposal (Ngoc *et al.*, 2015). The UN has predicted that globally the population will increase to 9.3 billion by 2050, and it is estimated that food production may have to increase by 70% to feed 9.3 billion people. However, a third of the annual global edible food produced, nearly 1.3 billion tonnes, goes to waste or is lost per year (WWF, 2017).

Food waste and loss, and the related environmental, social and economic effects, have turned out to be a subject of global interest (UNEP, 2018). With every bit of food that is produced and wasted, energy, water, capital and other resources are also wasted. Food wastage accounts for more than a quarter of total freshwater consumption world-wide (WCG, 2016). Large amounts of water is needed in order to produce food stuffs, this makes food waste avoidance a significant sustainability issue in an semi-arid area like South Africa (WCG, 2016).

To deal with food waste issues, researchers and environmentalists have made immense attempts on policy and management programmes (Xiao & Siu, 2018). A growing number of international policies has identified food waste as priority waste stream in response to concerns over escalating greenhouse gas (GHG) emissions (Papargyropoulou *et al.*, 2014).

The United Nations (UN) Sustainable Development Goal (SDG) 2, *End hunger, achieve food security and improved nutrition and promote sustainable agriculture,* focuses on addressing issues of world hunger through, inter alia, minimizing food losses and food wastage, while SDG 12 focuses on sustainable consumption and production patterns through reducing losses at the upstream the level of the supply chain and reducing waste at the consumer level. The UN's ultimate goal is halving global food waste and minimising worldwide food loss by 2030 (Sheahan & Barrett, 2017). The United Nations Environment Programme (UNEP) has launched its think-eat-save (TES) Food Waste Prevention Programme in South Africa in 2015. TES is a campaign

[2] For example: European and North American per capita food losses are 280-300 kg per year and in sub-Sharan Africa the per capita food losses are at 120 – 170 kg per year (FAO, 2011). In the United Kingdom (UK), nearly 15 million tonnes of food are wasted yearly, mostly disposed of in landfill. European Union (EU) guiding principles state that food waste should be utilised as animal feed although for majority food waste this method is now prohibited (Salemdeeb *et al.*, 2017). In China, millions of tonnes of food waste are discarded yearly, accounting for 37 - 62% of the municipal solid waste (MSW) generated, and it is anticipated to increase as a result of an increase in population growth and development (Xu *et al.*, 2018).

that seeks to drive extensive global, regional, and national actions to reduce food waste, and targets food wasted by consumers, retailers, and hospitality industry (Lipinski *et al.*, 2013). Such programmes are needed throughout Africa as in most African countries the total numbers of food waste generated is high because of poor food preservation and preparation (UNEP, 2018). This will also assist African countries and companies to be encouraged in quantifying their food loss and waste, UN Environment has set as baseline to track progress against towards 2030 (UNEP, 2017).

2.1.2.2 The South African context

Food losses and waste are generated during the entire food supply chain in Africa, from agricultural production to household consumption. While in South Africa, food wastage and loss usually take place relatively early in the food supply chain (UNEP, 2018). According to (Oelofse, 2014) between 9 and 10 million tonnes of food waste is generated per annum in South Africa.

A number of studies have been conducted on food waste in South African municipalities (Oelofse *et al.*, 2016). Studies done in Ekurhuleni and Johannesburg Metropolitan Municipalities have indicated that an average of 0.48 to 0.69 kg of food waste is discarded into municipal bins per household per week (Oelofse *et al.*, 2018). (Ramukhwatho, 2016) did a study on household food waste in Tswane and the study demonstrated that 82% of the households included in the study wasted food and threw away an average of one (averaged size refuse) bag of food per week. In the Western Cape it was found that households from informal settlements generate between 5.2 and 9.6 kg of food waste per week. These differences may be due to socio-demographic differences (such as income level, household size, etc.).

The proportion of food waste to the total amount of waste generated by low-income groups are generally higher than the proportion of food waste produced by higher income households, mainly due to the fact that low-income groups generally consume less and generate smaller amounts of waste in total (WWF, 2017). A study conducted in Rustenburg in 2001 indicated that the weight of food waste as a percentage of the total weight of domestic waste were 27% in low income areas, 13% in middle income areas, and 17% in high-income areas (Silbernagl, 2011).

2.1.3 The study area context, Rustenburg Local Municipality (RLM)

RLM has a *Waste Management Policy* which was adopted in 2006. Although food waste is not explicitly mentioned, the policy statement includes a few strategic objectives and indicates a specific target for waste minimisation *"Reduce the waste stream to landfill by 30% by 2010*

through waste minimisation activities including reusing, recycling and composting of waste" (JBA, 2006). No data was found to indicate whether the 30% goal was reached by 2010.

Currently, apart from recycling of cardboards, cans, and plastic bottles by waste pickers, there are no waste treatment activities conducted by the municipality at the Waterval landfill site. Separation at source at a household level was initiated, however, it was not successful because of challenges encountered by the RLM in carrying out collection for separated materials (KfW, 2017). The waste management licence of the Waterval Landfill site (NWP/WM/BP1/2011/02) has made provision for infrastructure allowing for the reclamation of waste from the waste stream prior to disposal. These include a material recovery facility (MRF), recycling yard and building, and composting facility. The waste management licence also provides for the composting of green waste[3] (KfW, 2017). However, none of the facilities have been constructed and therefore not in operation since Waterval Landfill site only became operational in 2018.

RLM in partnership with the German KfW (banking group) did a prefeasibility study which was aimed at establishing a centralised biomass pre-treatment facility for food waste at Waterval Landfill Site. The project was meant to include organic food waste, separated at source at households that would generate quantities of food waste collected by a separate collection system. The municipality was required to budget for the separate collection of food waste from households and also the operation and maintenance of the facility. Unfortunately, RLM did not commit to funding of the food waste treatment and the project was never implemented (KfW, 2017).

2.2 Drivers of food waste generation

There are numerous drivers of food waste generation (Thyberg & Tonjes, 2016). Identifying where and how much food is lost, and the value of food loss is important information that industry and lawmakers can utilise to promote awareness of the issue, reduce food waste, and increase the farm-to-fork food system and food recovery efforts to feed the increasing population (Bubzy & Hyman, 2012). The farm-to-fork food system focuses on minimizing food waste by improving sustainable food systems and ensuring food security (EU, 2020).The generation of food waste continues to be a global challenge and is high on the political agenda (Jagtap & Rahimifard, 2019). Drivers of food waste can occur at any phase of the food production and processing life cycle - between production, harvest, distribution, processing, and the consumer. Thirty to fifty percent (30 - 50%) of all food produced is lost or wasted before consumption (Oelofse, 2014; Guillou &

[3] Green waste: Refers to organic waste that can be composted, and includes grass clippings or leaves, and food waste.

Matheron, 2014). Food wastage in developing countries is likely to take place in the production and distribution phases, while in developed countries the wastage mostly occurs at the retail and consumer end (Oelofse, 2014; Guillou & Matheron, 2014). In South Africa it is estimated that 9.04 million tonnes is generated in a year (Oelofse & Nahman, 2012).

Understanding the drivers behind food waste generation is important for correctly planning the time frame for data collection on food waste generation, and gives insights on how to organize effective food waste reduction strategies (Corrado *et al.*, 2019). Food waste generation is affected by a number of factors such as population growth, employment levels, economic development and urban growth (DEA, 2017). The main reasons for why food is thrown away in South Africa is because it either "was not consumed in time, or because too much was cooked, prepared or served" (Oelofse *et al.*, 2018). Other underlying forces that causes food waste involves stock list control, wrapping, which do not market requisites, and damaged wrapping (Irani *et al.*, 2018:2) DEA, 2016).

The composition of food waste generally varies globally. The FAO provided regional estimates by food product, indicating that in North Africa, and in West and Central Asia, wasted food is comprised of 45% fruits and vegetables, 28% of fish and seafood, 26% roots and tubers, 18% dairy products, 14 -19% grains, 16% oilseeds and pulses, and 13% meats (Baig *et al.*, 2018). While in South Africa, the main categories of food waste are fruits and vegetables (47% of total food waste), and cereals 27% (WCG, 2016).

There are several drivers of food waste generation, while verified data on the definite sources are inadequate (Thyberg & Tonjes, 2016). The report on *Food Use for Social Innovation by Optimising Waste Prevention Strategies* (FUSIONS) identifies four main drivers of food waste, namely – technological drivers, institutional drivers (which includes operational/business management drivers), legislation and policy, and social drivers.

2.2.1 Technological drivers

Technological drivers include the following:

- Drivers of food waste which are fundamental to the characteristics of food, its production and consumption, where there are limitations on technology. Examples are lack of refrigeration, poor temperature management etc.;
- Drivers of food waste which are essential to the process design and a consequence of technologies used; and

- Drivers because of sub-optimal use of, and mistakes in the use of available food processing technology and chain management (Massimo Canali *et al.*, 2014).

2.2.2 Institutional drivers

The identified institutional drivers include:

- Drivers of food waste which are not addressed by management solutions. These drivers are linked to occurrences such as freshness of food and instability of food production and consumption, etc.;
- Drivers of food waste which can be addressed at a universal level and not at the level of the single business unit. Examples are the drivers initiated by different government policies, market conditions, and imbalanced negotiating power of food supply chain operators.
- Drivers of food waste which can be addressed within the business units through better organisation and improved management. This includes recognised drivers such as communication, staff training, supply chain, information sharing, and portioning (Massimo Canali *et al.*, 2014).

2.2.2.1 Legislation and policy

Legislation and policy drivers may include:

- Drivers related to legislation stemming from agricultural policy and agricultural product quality regulations, for example, product grading, overproduction, market conditions and market price, and marketing standards;
- Drivers related to legislation stemming from food safety, consumer health, and animal welfare policies. Examples include: 'Best before date ' and ' ban on feeding ABP (animal by-products) and catering waste to animals;
- Drivers related to legislation stemming from waste and tax policies and other policies, and includes examples such as 'tax on donations', 'tax policy', 'low cost for discarding food', and 'lack of policies to promote redistribution' (Massimo Canali *et al.*, 2014).

2.2.3 Social drivers

The identified social drivers include:

- Socio-demographic factors, for example, food waste drivers linked to households' characteristics, gender, population age and income, average culinary skills etc.;
- Unintentional fondness or preferences for certain aesthetic standards of food;

- Distinct conduct alterable via information and intensified awareness (Massimo Canali *et al.*, 2014).

The drivers of food waste can be context-specific and are not always predictable. As a result, interpretation of the drivers of food waste generation is a challenge, as is the availability of longitudinal data through which causation analysis can be carried out (Corrado *et al.*, 2019).

2.3 Impacts of food waste

The UN has estimated that if wasted food was a country, it would be the third largest greenhouse gas emitter and top user of water for agriculture (Baig *et al.*, 2018). Food waste reduction is seen as an ethical responsibility. Food waste minimisation also aims to decrease the misappropriation of economic resources and their resulting negative environmental impacts (Philippidis *et al.*, 2019). The impacts of food waste can be felt in three key areas: economic impacts, social impacts and environmental impacts.

2.3.1 Economic impacts of food waste

Food waste has a significant economic impact (Papargyropoulou *et al.*, 2014; Thyberg & Tonjes, 2016). Food waste can impact on the cost of food and add to drained commodity markets (WCG, 2016). Economically, food waste amounts to nearly USD 680 billion in industrialised countries and USD 310 billion in developing countries (Filho & Kovaleva, 2015). (Nahman *et al.*, 2012) estimated the financial cost of food loss and waste in South Africa at R61.5 billion, which represents 2.1 % of the national GDP (WWF, 2017). Of the R61.5 billion wasted, R21.2 billion is wasted due to household (domestic) food waste generation (UNEP, 2018). Economic impacts of food waste may include the costs to dispose of food waste, as well as the wasted resources used to grow, produce, ship and sell the food (Papargyropoulou *et al.*, 2014).

2.3.2 Social impacts of food waste

In addition to economic impacts, food waste also has social impacts. Social impacts relate to the ethical and moral dilemmas of wasting food, particularly in relation to the disparity between wasteful practices and food poverty (Papargyropoulou *et al.*, 2014). Wasting of food is linked with internal and external norms of conduct, which might impose social (in the form of social sanctions) or hedonic (in the form of feelings of guilt) costs on those who waste food (Bellemare *et al.*, 2017). An unequal population as South Africa, wasting food that could have offered to the less privileged is an overlooked chance to tackle the social ills in a cost-effective and sustainable conduct (WCG, 2016).

Food wastage and the generation of food waste have impacts on food security (Grobler, 2016). Food security is described as a state in which *"all people at all times have both physical and economic access to sufficient food to meet their dietary needs for a productive healthy life."* As the issue of global food security is becoming more and more significant in local and global programmes, the minimisation of food losses and waste throughout the FSC, in addition to alternative diets, are considered as a first step to accomplishing food security (Papargyropoulou *et al.*, 2014). With proper food waste management, jobs can be created and the people from the community can be trained and be equipped with various food waste innovation skills (Heuer *et al.*, 2016).

Other food waste related social impacts may include health impacts and nuisance of food waste to communities, because of offensive odours and the attraction of vector-borne diseases.

2.3.3 Environmental impacts of food waste

The relation between food waste and the misuse of natural resources is an extensively discussed issue (Chaboud & Daviron, 2017). The impact of food waste on the environment is alarming. Population growth and consumption patterns are continually changing, globally, which lead to a higher demand for food and an intensified environmental burden (Thyberg & Tonjes, 2016). The environmental trail of global food waste is measured through carbon footprint, water use; land deprivation effect, and possible biodiversity effects (Oelofse, 2014).

Activities related to the production of food, for example, agriculture, processing, manufacturing, transportation, storage, refrigeration, distribution and retail have an entrenched GHG effect. It is estimated that the food sector is the cause of about 22% of the global warming potential in the EU (Papargyropoulou *et al.*, 2014). The highest carbon footprint of food waste transpires at the consumption stage. This is because of the energy utilised for heating food, and in addition it consists of the entrenched energy utilised for growing, storing, processing, distributing and discarding food (WCG, 2016).

Other environmental impacts of food waste include natural resources exhaustion, the disturbance of the biogenic cycle of nitrogen and phosphorus utilised in agriculture as fertilisers, and the environmental pollution potential throughout the food production cycle, but mainly during waste disposal (Papargyropoulou *et al.*, 2014).

One of the main environmental impacts of food waste is linked to its final disposal in landfills (Papargyropoulou *et al.*, 2014). Negative impacts of landfilling are discussed in Section 2.7 of this dissertation.

2.4 Challenges with food waste management

South Africa does not have legislation that governs food waste exclusively. However, the view of the food production industry is that it is greatly controlled by the food labelling legislation and it often leads to usable products being condemned. This means that regardless of the food being fit for eating, it is treated as waste. The food labelling legislation is often seen to represent the producer's food standards, rather than health standards (WWF, 2018). Food waste is regulated by legislation that includes waste management in general, namely the National Environmental Management Waste Act (59 of 2008). The Food Waste Dialogue that was hosted in April 2019 by DTI, CGCSA and EUD indicated the lack of a combined and well-defined legislative framework as one of the challenges in achieving food waste improvements in South Africa (DTI, 2019). According to (Oelofse, 2017), the absence of national strategy to tackle food waste and the shortage of data on food waste at every phase of the value chain is also an obstacle (Oelofse, 2017).

Data on industrial and municipal solid waste usually does not show how food waste is generated (Berjan *et al.*, 2019). Up to the present time there is no single standardized definition/description of food waste, globally, which makes the comparison of the results of studies difficult.

There is lack of awareness on food waste, and citizens are disinterested with what happens to the food after it has been discarded to bins at their households (Pienaar, 2017). Communication campaigns should aim to promote public awareness to change the behaviour of citizens as it relates to food wastage (Berjan *et al.*, 2019).

Most African countries are faced with challenges of lacking technologies (to divert food away from landfilling) and these are due to the expensive nature of certain technologies. Shortage of experienced and well trained personnel who can utilise waste to energy technologies is also a challenge (Letlape & Gumbo, 2016). Alternative technologies (such as waste to energy) require a stable input of enough food waste. Within certain smaller municipalities, the stable supply of enough food waste may be a limiting factor, which might necessitate that food waste needs to be transported in from other areas (DEA, 2017) for alternative technologies to function. The transportation costs also add to the cost of the alternative technology and may deem waste to energy options unfeasible.

Despite the challenges that are facing Africa, and elsewhere in the world, if managed correctly, food waste may be a valuable commodity (Redcorn *et al.*, 2018) and be turned into products such as compost, ethanol or a source of biofuel etc. (Lai *et al.*, 2017).

2.5 Common practice: Landfilling of food waste

Disposal of waste to landfill has been considered the most convenient and cheapest form of waste disposal in many countries around the world, including South Africa where approximately 90% of all waste generated is disposed to landfill (Lacovido *et al.*, 2012); (Lai *et al.*, 2017); (Oelofse & Muswema, 2018).

Landfilling of biodegradable organic material may seem logical, as it would close its life cycle by returning it to nature (Fehr *et al.*, 2002), however, the landfilling of waste may result in various environmental impacts. Landfills that are not adequately engineered or maintained may contribute significant environmental harm, with emissions of leachate, waste sludge, methane, and odours (Baig *et al.*, 2018).

The high moisture content of food waste accelerated high microbial degradation activity, which releases leachate and methane in an anaerobic environment after landfilling that causes secondary pollution to groundwater, soil and the atmosphere (Ng *et al.*, 2015). Methane has 25 times global warming potential of CO_2 and landfills contribute towards 34% of all human-related methane emissions in the United States (De Clercq *et al*., 2017). Each tonne of organic waste (which includes food waste) disposed of in landfills generates equal to1.4 tonnes of CO_2. In addition it generates fluid leachate (Heuer *et al.*, 2016), which may contaminate soil and ground water (DEA, 2018). The quality of leachate in the landfill depends on the quantity of organic waste fraction disposed. The higher the organic fraction, the higher the biochemical oxygen demand (BOD) of leachate.

One of the major problems facing South Africa in terms of waste management is the lack of space for landfills. Landfills have a disadvantage of requiring large areas of land, as well as intensive operational management requirements (Gao *et al.*, 2017). The lack of landfill airspace in several municipalities, stringent specifications for landfill design, negative environmental impacts, along with national government priorities to divert waste from landfills have resulted in landfilling becoming a less attractive option, with some municipalities participating in feasibility studies to divert waste away from landfill (Oelofse & Muswema, 2018; Oelofse *et al.*, 2016).

2.5.1 Potential value of food waste and benefits of diverting food waste from landfill

Due to increase in intensity of environmental guidelines, with the objective to minimise the amount of biodegradable municipal waste and food waste going to landfill, alternatives methods to handle food waste have been presented (Lacovido *et al.*, 2012). The disposal of biodegradable waste to landfill has been prohibited in many countries and the phasing out of the disposal of many waste

streams is becoming a priority in South Africa (Oelofse & Muswema, 2018) through interventions such as cleaner technologies, separation and recycling of waste etc.

In order to achieve more sustainable resource management and maximum environmental and socio-economic benefits, it is recommended to transform the current waste management approaches from the linear model to a circular economy model; where waste becomes a resource to another value-added production process (Ng *et al.*, 2019).

Food waste can be a valuable resource if it is handled effectively, simultaneously minimising the impacts on the environment (Gao *et al.*, 2017). According to (Heuer *et al.*, 2016), food waste has entrenched value, which if diverted from landfill sites, could be a source of energy, preventing greenhouse gases discharges and protecting the environment from pollution (Seguela *et al.*, 2017). Food waste can be re-used in other production processes and may be transformed into a source of innovation, employment, revenue etc. (Chaboud & Daviron, 2017).

There are a variety of applications for food waste. The high organic content of food waste has the ability to be changed into highly added value end products, for example ethanol or source of biofuel (Lai *et al.*, 2017). The use of food waste to produce energy provides an opportunity to move away from coal-based energy production (Letlape & Gumbo, 2016). The conversion of food waste into value-added products is the preferred end use for food waste (Tsang *et al.*, 2019). Utilising food waste for uses other than landfill disposal will increase the lifespan of the landfill site. Diversion from landfill will also help to alleviate the potential environmental impacts of food waste on the environment (Letlape & Gumbo, 2016).

2.6 Food waste and the waste management hierarchy

The food recovery hierarchy, proposed by the US EPA is outlined in Figure 2-3 (USEPA, 2014). The hierarchy promotes source reduction, feeding people, feeding animals, industrial conversion, and composting, while landfill disposal or incineration are deemed to be the last resort (Dou *et al.*, 2016); (Ng *et al.*, 2019).

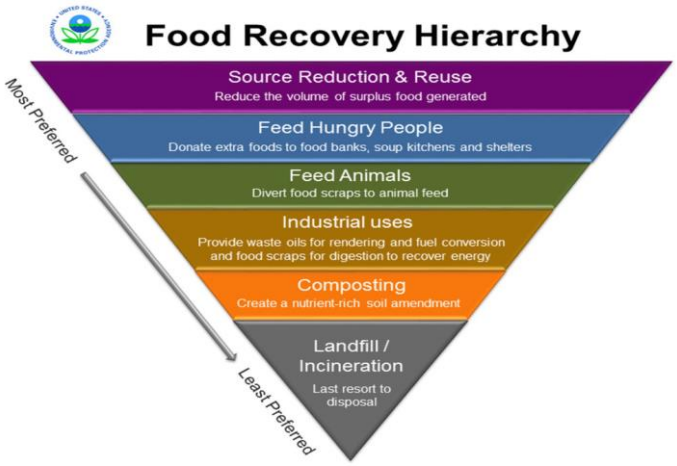


Figure 2-3: Food recovery hierarchy proposed by the US EPA (USEPA, 2014).

Similarly, in South Africa, the waste management hierarchy (as outlined in the National Waste Management hierarchy, 2011) (Figure 2-1) advocates the disposal of waste as a last resort, because of the adverse impacts of waste on the environment. For food waste, the avoidance and reduction/minimisation of waste is the most preferred option. Because many foods may not be re-use or recycled, energy recovery may be the next feasible step, followed by treatment (physical, chemical, biological, which includes compositing) and lastly, disposal (Figure 2-1).

Goal 1 of the National Waste Management Strategy concentrates on putting into action the waste management hierarchy with the fundamental target of re-routing waste from landfill (NWMS, 2011). In South Africa, in most municipalities, food waste is currently collected by municipal services and transferred straight to landfills for disposal (DEA, 2012). Initiatives aiming at household food minimisation and diversion from landfill have the potential to alter huge volumes of food waste from landfill (Oelofse *et al.*, 2018).

There are increasing attempts, globally, to minimise landfill loads with options such as composting, anaerobic digestion, incineration, or feeding food waste to livestock animals (Dou *et al.*, 2018). There are various technologies available for energy generation from MSW, which include landfill gas capture, incineration, gasification, generation of biogas and utilisation in a combined heat and power plant, generation of biogas and conversion of fuel. There is a pressing need to move towards a more advanced technological approach in valorising food waste into higher value applications such fuels and chemicals via biorefinery technologies (Ng *et al.*, 2019).

The next sections will provide context to the alternative options available, other than landfill disposal, for food waste.

2.6.1 Consideration of the best practicable environmental option (BPEO)

Apart from considering the waste management hierarchy (favourable to least favourable options for waste management), it is also important to consider the principle of selecting the "best practicable environmental option (BPEO)" as required by Section 2 of the National Environmental Management Act (107 of 1998) (NEMA). Section 2(4)(b) of the NEMA requires *that environmental management must be integrated acknowledging that all elements of the environment are linked and interrelated, and it must take into account the effects of decisions on all aspects of the environment and all people in the environment by pursuing the selection of the best practicable environmental option* (BPEO). The BPEO is means the *option that provides the most benefit or causes the least damage to the environment as a whole, at a cost acceptable to society in the long term as well as in the short term* (RSA, 1998).

When considering appropriate technologies for food waste, the BPEO must therefore be considered and the following aspects need to be taken into account: (i) the option that provides the most benefit; (ii) or caused the least damage to the environment as a whole; (iii) with an acceptable cost – in the long and short term.

2.6.2 Food waste avoidance, reduction and separation at source

Most municipalities in SA have challenges with receiving large amounts of food waste at their landfill sites. Furthermore, the waste management hierarchy (as proposed by the NWMS) advocates that the disposal of waste should be the last resort (DEA, 2011). Many municipalities have plans on how to manage food waste in their Integrated Waste Management Plans (IWMPs), however, many of these plans or projects are not implemented due to operational and financial constraints and other factors.

The main barriers to the uptake of separate food collection include the uncertainty of recovering the cost of food waste collection and insufficient funding to support the collection service; and low participation rate of households, i.e. perception that "separating food waste for collection is unpleasant and smelly" (Ng *et al.*, 2019). Not every person is keen to contribute in the separation of food waste at source, the underlying problem being the odour and the ability to handle it (Metcalfe *et al.*, 2012). Community participation in waste and recycling programme is relatively low, due to a lack of awareness and limited exposure to the advantages of recycling in the long term (Malik *et al.*, 2015). Most of the people think that food waste separation is the municipality's concern (Woolley *et al.*, 2016). There are, however, a couple of South African municipalities with examples of food waste minimisation and avoidance of landfill disposal practises that have been implemented with success.

In the Cape Winelands District Municipality, a food waste minimisation program has been implemented in informal areas, where buckets are hung on fences for pig farmers to collect. Source separation takes place mostly in formal areas in Breede Valley Municipality. A fly farm exists for the management of food waste and can probably be utilised for abattoir waste, which will no longer be accepted at municipal landfill sites in Breede Valley Municipality. Anaerobic digestion has been suggested as an alternative to the disposal of animal waste (DEA, 2017). At the City of Cape Town (CCT), all abattoir waste goes to the Vissershok hazardous waste disposal facility as other landfill sites currently do not accept this waste stream. Composting of abattoir waste is considered as a suitable approach (DEA, 2017).

In the City of Johannesburg (CoJ), the Pikitup Waste Management Strategy indicated that there are large quantities of food waste generated in the CoJ. Therefore, Pikitup targets to divert 130 000 tonnes of food waste per year from landfill (Merwe *et al.*, 2017). A study by CSIR revealed that Johannesburg households throw away more or less 8 to 12 kilograms (kg) of food per capita per annum. Presently food waste in being disposed of, however, the CoJ is also exploring alternative waste treatment technologies to recycle food waste (CoJ, 2011). It is, therefore, essential to establish and standardise the strategies for food waste management. Furthermore, it is important to improve regulations to enforce effective separate food waste collection and reduction strategies, which will enable the move towards zero (food) waste to landfill (Ng *et al.*, 2019).

2.7 Alternatives to food waste disposal to landfill

The following sub-sections will explore some of the alternatives to food waste disposal to landfill, outlined in literature. These include composting, incineration, anaerobic digestion and food waste to biogas, as well as livestock feeding. The purpose of these sections is not to give a full account of all of the technologies for food waste available for food waste treatment, but rather to be illustrative of feasible alternatives for food waste, within the South African context, that RLM can choose from. The purpose is also to give a short overview, as well as advantages and disadvantages of these alternative technologies.

The selection of a particular WtE technology is guided by a range of factors. These comprises of waste feedstock features, current and future waste obtainability, marketability of energy products and by-products. Feedstock category is one of the important elements of classifying the appropriate WtE technology and the feedstock includes waste material that is distributed for energy production (Sebola *et al.*, 2014). Sustainable provision of feedstock determines if the intended energy production is sustainable too. An integrated waste management decision support

tool (IWM-DST) was created by GreenCape to help municipalities in assessment of the application alternative technologies. The achievement of the municipality depends on them having accurate data on their waste generation and the management thereof. When followed properly the IWM-DST can be utilised to advice municipalities on their processes starting from IWMPs to IDPs.

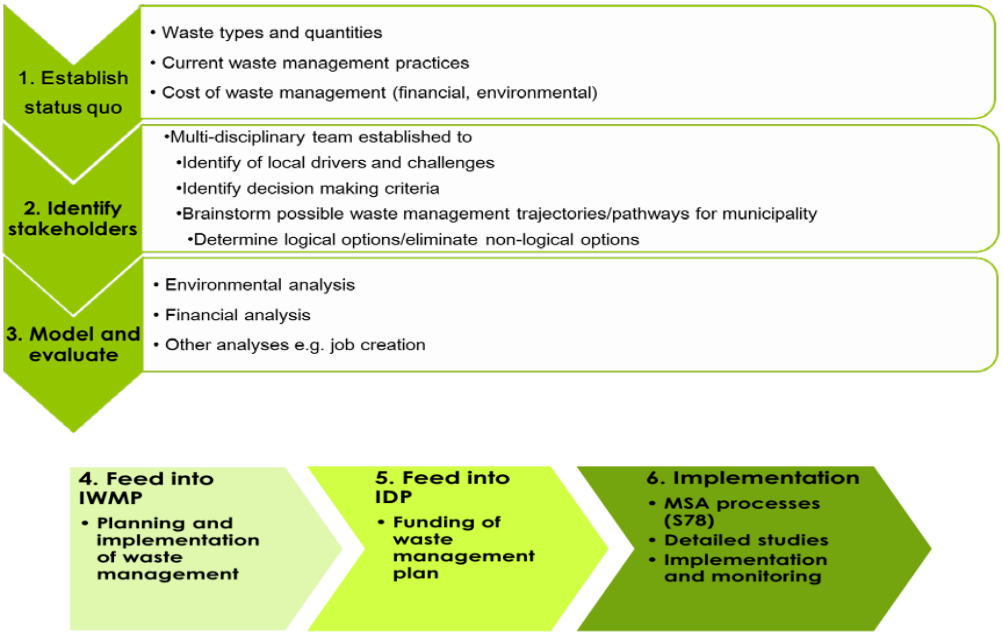


Figure 2- 4: Municipal Decision Support Tool – technical aspects and integration into municipal decision-making (Sango *et al.*, 2016).

The following sub-sections provide an overview of the alternatives to food waste disposal to landfill that were explored for the purposes of this study:

2.7.1 Composting

Composting is *a controlled biological process in which organic materials are broken down by micro-organisms* to form compost[4] (DEA, 2013). The NWMS encourages composting as one of the methods towards achieving the objectives of the waste management hierarchy. The National Organic Waste Composting Strategy (NOWCS) has the goal of developing and promoting the diversion of organic waste from landfill sites for soil beneficiation and other uses through

[4] Compost: A stabilised, homogenous, fully decomposed substance of animal or plant origin to which no plant nutrients have been added and that is free of substances or elements that could be harmful to man, anima1, plant or the environment.

composting. This strategy focusses on composting as the organic waste treatment option available to try and achieve diversion of organic waste. The implementation of the Strategy can significantly reduce the amount of organic waste going to landfill sites and resulting in saving landfill airspace (DEA, 2013).

South Africa has gazetted draft national norms and standards for organic waste composting (GN 1135 in GN 42681 of 4 September 2019). These norms and standards provides for minimum requirements for design, construction and operation of composting facilities, general requirements for composting, training and capacity building, monitoring, auditing and reporting, as well as requirements for decommissioning. These draft standards have been published for public comment in September 2019.

Diverting MSW material from landfills to composting has numerous environmental advantages. A decrease in landfill discharges of greenhouse gases (GHGs) and enhancement of soil properties via compost usage are emphasised. Composting provides the recycling of nutrients, and the reuse of the organic fraction of the waste, therefore minimizing environmental pollution (Oliveira *et al.*, 2017).

Creation of good compost necessitates that the process should be appropriately regulated and handled. Inaccuracies in the early stage formulation and regulation of the mixture with normal bulking drivers or in the monitor method will result in stench discharges. The draft norms and standards for organic waste composting attempts to standardize composting practice to optimize the composting process and to prevent unintended negative consequences.

An even better alternative to large composting is mini composting or home composting, used for small amounts of waste, as it has advantages such as: reducing the environmental impact of the slurry produced by the deposition of organic materials in landfills; strengthening environmental awareness and social responsibility of the population; low operating costs; no need for transportation; and reduced occupation of space (Oliveira *et al.*, 2017).

According to (Gao *et al.*, 2017), composting is a favourable option because is an uncomplicated, relatively inexpensive procedure (Gao *et al.*, 2017). Drum or bin composting is exercised in several parts of the world, and such system is urged in developing countries to promote recycling of organic waste at the source of production (Manu *et al.*, 2016).

India has more the 70 composting facilities, which recycles up to 5,9% of a total food waste to generate nearly 4,3 million tonnes of compost each year. In Thailand composting is used for

organic solid waste treatment, of which around 0.59 million tonnes of food waste is recycled into organic fertiliser.

In South Africa, the *Composting Registration Regulations* regulate composting. These regulations state that, in order to sell compost - it first needs to be certified as such (as compost). This certification is regulated by the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Act (Act 36 of 1947). This certification process is expensive and limits the variety of feedstock. There is still so much inefficiencies of composting production caused by tainted waste feedstock which results from incomplete source-separated food waste system in most developing countries, which results in a composting-market which is weak (Ngoc *et al.*, 2015). Separation of waste at source could optimize the amount of waste available for composting. The organic fraction attained from source-sorted collection is usually more suitable for composting than the robotically separated organic waste from bulk collected MSW (De Clercq *et al.*, 2017). While the International NGO's have programs to fund the costs for developing countries to establish composting to enhance awareness of food waste recycling in some African countries, the composting quality could still not be improved (Ngoc *et al.*, 2015).

Extensive research has been performed to determine the environmental impact of food waste composting, such as emissions of greenhouse gases and odours. Food waste composting process contributes to GHG emissions, because food waste has a high content, high bulk density, and low C/N ration, which are linked to GHG emissions (Cerda *et al.*, 2018). The GHG emissions from compositing is, however, less than the emissions caused by landfilling.

2.7.2 Incineration

The NEMWA defines incineration as *any method, technique or process to convert waste to flue gases and residues by means of oxidation*. Uncontrolled incineration is known to have negative impacts on air quality, because of the particulate matter and other pollutants being formed during the incineration process. South Africa, therefore, strictly regulates the incineration, also referred to as thermal treatment, of waste. In the country, incineration of waste is regulated in terms of the NEMWA (GNR 921 of 2013) (under the treatment[5] of waste), as well as the National Environmental Management Air Quality Act (39 of 2004) (NEMAQA) in terms of GNR 893 of 2013 (which regulates the thermal treatment of general and hazardous waste[6]). The GNR 893 of 2013,

[5] Treatment, where thermal treatment or incineration may be implied, is listed in Category A activity 6 (general waste) and 7 (hazardous waste), and Category B activity 4 (hazardous waste) and 6 (general waste)

[6] Sub-category 8.1 refers to facilities where general and hazardous waste are treated by the application of heat, applicable to all installations treating 10 kg per day (or more) of waste.

in terms of NEMAQA, also provides atmospheric emissions standards, which are comparable to EU standards. In addition to the licence requirements of the NEMWA and NEMAQA, South Africa has also gazetted a *National policy on thermal treatment of general and hazardous waste* (GN. 777 of July 2009) in terms of the NEMWA in 2009. This policy aims to accept and advance the application of an integrated waste management system for South Africa in line with the waste management hierarchy, this is done by enabling the move away from single waste management solutions to integration of thermal waste treatment technologies, as well as incineration and cement kiln co-processing and it also encourage resource utilisation and synchronisation of the environment and the economy amongst other things (DEA, 2009).

These regulatory frameworks have the implication that: licences with stringent conditions need to be adhered to. These conditions include the regular monitoring and auditing of atmospheric emission and the implementation of abatement technologies and mitigation measures to minimize air pollution.

Apart from the regulatory context, there may be other factors restricting incineration as a suitable option for the treatment of food waste, these include: the adequate supply of food waste to justify the technology, the availability and cost of the incineration technology, ability to meet atmospheric emission standards and operational criteria, as well as the characteristics of the waste as it relates to suitability for incineration. The relatively high moisture content for food waste may make it unsuitable for incineration (Gao *et al.*, 2017). Feedstock characteristics such as composition, moisture content and particles sizes are critical to the operation of WtE technologies. But, this is not a problem with AD systems as water is essential for the digestion process. Therefore the digestion process is more efficient for feedstock with high moisture content, studies show that high methane (biogas) production rates occur at 60-80% of moisture content (Bouallagui *et al.*, 2003).

Incineration is the key treatment procedure for MSW consisting of domestic waste in Japan. Incineration is utilised to yield thermal energy and can seriously diminish the quantity of food waste. Food waste from China has a very high moisture content, which is unfavourable for incineration (Gao *et al.*, 2017). Treatment of food waste with waste to energy incineration (WTE) is not deemed to be beneficial because of the high moisture content of food waste, which results in a lower heating value than other materials. WTE is not able to catch valuable nutrients within food waste and numerous environmental pollution concerns may arise from ineffective air pollution control measures (Thyberg & Tonjes, 2016). Singapore did not only successfully address the issue of food waste reduction with incineration, but gained advantages in minimising land scarcity burden (Ng *et al.*, 2015).

In terms of the waste management hierarchy, it may be argued that incineration may be a more favourable option than landfill disposal, however, that other technologies, such as composting, or waste to energy options, where the value of waste may be harnessed, may be preferred to incineration. These practices are widely adopted in the U.K due to government support (e.g. subsidies) offered to these technologies. However, these technologies have limited the potential for utilisation of resources embedded in food waste (Ng *et al.*, 2019).

2.7.3 Anaerobic digestion and biogas to energy

Anaerobic digestion (AD) is a biological method for the treatment of organic waste, in the absence of oxygen, which results in the production of methane-enriched biogas and a nutrient-rich deposit that can be utilised for land application. When carbon dioxide and trace gases in biogas are removed, a methane rich renewable natural gas substitute is left in the form of *biomethane*. Biomethane can be injected into the gas grid, used as a vehicle fuel or used for combined heat and electricity generation (Zhong *et al*., 2011). These beneficial uses of the methane offset other fuels such as coal and natural gas, that would been used to produce electricity and heat (Levis *et al.*, 2010).

AD can be utilised with every kind of food waste (Garcia-Garcia *et al.*, 2016). Food waste does not only supply a low-priced substrate for AD but also enriches biogas production, which is why AD is regarded as a more sustainable and economic food waste management compared to other technologies (Hegde & Trabold, 2019).

The main reason for anaerobically digesting food waste is capturing the energy content (USEPA). Commercial food and beverages, for example, breweries, cheese plants and fruit and vegetable processing can utilise their waste to produce energy. In South Africa, abattoirs offer the utmost substantial prospect for anaerobic digester application because of limiting laws on risky abattoir waste treatment and the advantage of the heat and electricity needed for the abattoir's operative needs (GIZ, 2016).

Taking into account the harmful environmental impacts of landfilling and incineration, AD has been suggested as a good option for renewable energy production and waste treatment of this high-moisture and energy-rich material (Xu *et al.*, 2018). Judging against other than bioenergy technologies, AD can have capacity to treat a huge variety of substrates, even those high moisture contents and impurities, and can be conducted in large and small scale digesters and at all geographic areas. AD is therefore appropriate for all types of food waste (Xu *et al.*, 2018). Wet-AD of food waste is a popular exercise, however lately the focus is on dry-AD with the aim of minimising water content in the reactor and the digestate and making the procedure inexpensive

(Janson *et al.*, 2019). The legislative framework applicable to the treatment of waste, in terms of NEMWA, may also be application to AD technologies, since AD is regarded as a form of treatment.

AD technology is emerging as a leading option in the latest food waste treatment facilities (De Clercq *et al.*, 2017). However, the technology still has some limitations and challenges differing from country to country, as seen in a case example in China, mentioned by De Clercq *et al*. (2017). Stable and sufficient food waste supply may be a limiting factor.

In China, with 118 AD food waste treatment plants that was built (with a total volume of 21,500 t/day), there was a food waste deficit of 8500 t/day. However, in the US, AD is widely used to alleviate wastewater bio-solids but there are only a few pilot scale operations in the US utilising food waste. Solid waste treatment by AD is more conventional in Europe where energy costs are higher and the EU Landfill Directive 199/31/EC mandate that members States minimise the amount of organic waste that is landfilled (Levis *et al.*, 2010). However infrastructures like wastewater treatment facilities allows for the capture of the methane which can be used as an energy source, this are cost savings from combining food waste into anaerobic digesters (USEPA). In the USA there has been a drive to start adding food waste to anaerobic digesters already in place at wastewater treatment facilities (USEPA).

The operational costs of the AD food treatment facility, as well as costs of separation and collection of food waste (for AD purposes) may also be a challenge. Food waste treatment plants are greatly dependant on state's grants. Issues throughout the process and selling stages may, for instance, include minimal biogas yield, too expensive biogas end-use and minimal cost-effectiveness (De Clercq *et al.*, 2017). The growing interest in AD could contribute substantially to the goal of food waste reduction (Dou *et al.*, 2016).

The UK Government promotes food waste to be recycled through AD to produce biogas and hence diverting the waste from landfill (Ng *et al.*, 2019). As a preferred option to treat food waste, the processes of AD, can be improved to extremely minimise the environmental impact (Gao *et al.*, 2017). Its main advantage includes on-site energy offset through biogas applications (Rattanapan *et al.*, 2019). The possibility for AD application in SA is existent where agricultural waste is not presently forwarded for other uses (GIZ, 2016). AD is seen as a favourable technology for food waste management, however it has not been quiet utilised as a result of a number of technical and social challenges, such as high cost of transportation and operation (Xu *et al.*, 2018).

2.7.4 Livestock feeding

For wasted food that is beyond recovery for humans, diversion for animal feeding is the next priority at the food recovery hierarchy (Figure 2-2) (Dou *et al.*, 2016). Recovering food waste for animal feeding (ReFeed) is a sustainable alternative that has the ability to tackle waste management, food security, resource and environmental issues. Livestock animals act as bio-processors for changing food resources that are one or the other indigestible or no-longer-wanted by people into meat, eggs, and milk (Dou *et al.*, 2018). Only farmed animals are included in the concept of "livestock feeding", while pets are excluded (Garcia-Garcia *et al.*, 2016). Lately there has been an increase in feed manufactured from food waste owing to increases in costs of grains for feeding livestock (Sugiura *et al.*, 2009).

South Africa's Fertilizers, Farm Feeds, Agricultural Remedies Act controls feeding food waste to livestock. According to the Act (Act 36 of 1947), no person can sell waste as feed unless it is registered as feed. In addition, no person can manufacture or sell feed containing bone or any other substance derived from animal carcass, unless such substance has been sterilised at a registered plant. It is also controlled by the Animal Disease Act (Act 35 of 1984) which allow the feeding of food waste that contains or has contact with meat or meat products. To divert more wasted food from the landfill to animal feed requires technological innovation such as, technologies that can efficiently dehydrate, sanitize, and homogenize food waste materials that will help overcome the current barriers concerning animal health (Dou *et al.*, 2016). The use of food waste for livestock feeding is preferable, but requires collection of appropriate and properly handled (non-contaminated) food waste (Muth *et al.*, 2019). Therefore obstacles of food waste as livestock feeding involve transportation restrictions, obligation matters, expenses to remove food waste from wrapping, and lastly distress about health and safety issues of food for livestock ingestion (USEPA, 2014).

The European Union guidelines state that food waste should preferentially be used as an animal feed. However, concerns around disease control were raised (Tsang *et al.*, 2019). If animal products are included, heat treatment is needed to prevent disease outbreaks such as foot and mouth diseases. Furthermore, the food waste must not be contaminated so that it can be valid for livestock feeding (Garcia-Garcia *et al.*, 2016). Agriculturist have a valuable role to play in characterising and distributing best practising for food product collection and treatment (Baig *et al.*, 2018). Food discards destined to feed animals and livestock should be subject to a variety of regulations and guidelines, in order to reduce potential risk and liability (Muth *et al.*, 2019).

2.8 Conclusion

Drivers, challenges, impacts of food waste were summarised in this chapter. The potential value of food waste was investigated, and different food waste alternatives from South Africa and other countries were explored.

Social, economic and environmental impacts caused by food waste is not only a South African problem, but a global issue. The problem of food waste is universal and is being experienced by both developed and developing countries (Ramukhwatho, 2016).

Food waste needs to be regarded and treated as a valuable resource. This can only be achieved through a change in attitude towards waste; raising awareness in communities and informing the population to its usefulness (Morar & Bucur, 2017). If waste management choices such as composting, recycling and energy recovery are to be practised more in the future, there is an opportunity of minimising huge amounts of waste stream to be discarded to the landfill (Palanivel & Sulaiman, 2014).

Decisions on implementing alternatives other than the landfilling of food waste need to be informed by actual data on the quantity and composition of the food waste.

Chapter 3 outlines the methods employed for the research.

CHAPTER 3: METHOLODOGY

3.1 Introduction

This chapter presents an overview of the study area, methodologies used and the data collected. The methodology for research design, research methodology, data collection and data analysis are discussed in this chapter.

3.2 Description and demography of the study area

The Rustenburg Local Municipality (RLM) was selected as the study area for this research project. RLM was selected because it was considered as a good case study for determining food waste composition to inform alternative uses within the South African and developing country context, since:

- The RLM provides a good representation of an "average" South African local municipality. It is a populated and urbanised area in the North West Province, and therefore have the potential to generate large quantities of waste;
- The RLM is currently exploring or working towards implementing one of the mentioned alternatives, meaning that they are in a favourable position for a study such as this;
- The RLM is located in close proximity to the researcher (convenience) in terms of time and financial resources of being able to conduct such study.

Rustenburg is situated at the foot of the Magaliesburg mountain range in North West Province of South Africa (refer to Figure 3-1). RLM is one of five local municipalities in the Bojanala Platinum District Municipality (BPDM) in the North West Province.



Figure 3-1: Map of South Africa highlighting North West Province, Rustenburg

RLM is divided into 45 wards, with a total population of 588 718 (approximately 199,044 households) in 2013, and projected to exceed a million by 2030. RLM covers an area of 3,423.26 km^2. The economic, social and physical characteristics of the RLM are largely determined by the presence of mining activities (RLM, 2017).

A comprehensive waste generation forecast for the next years has been prepared based on the population forecast and an assessment of specific waste generation quantities. For the period 2017 to 2026, total household and garden waste is expected to increase from 175,255 tonnes/annum to 225,513 tons/annum; total commercial waste from 15,474 tons/annum to 91,304 tonnes/annum; and industrial waste from 87,296 tonnes/annum to 91,304 tons/annum (RLM, 2017). Waste collection coverage is lower in low-income areas (20 - 60 %) and increases to up to 80 % of waste collected in high-income income areas. Up to 91% of commercial waste is assumed to be collected and it is anticipated that by 2026 100% of commercial waste will be collected (RLM, 2017). To date, no waste characterisation studies explicitly focusing on food waste has been done, therefore, the amount of food waste in the RLM is uncertain, and is further justification for this study.

The Waterval landfill site was selected as the study site, with the purpose of quantifying and characterising food waste arriving at the site, which is destined for landfill disposal. Waterval landfill is a new sanitary landfill site that started operation in 2018, it is the main and only landfill site that caters the needs for the municipality however the municipality does not collect in all the areas in Rustenburg. RLM provides waste collection services within the Rustenburg Town and the remainder of RLM area is collected by private service providers. Farmlands, rural areas and informal settlement areas do not receive waste collection services. According to the RLM IWMP, 56% of the waste generated in the RLM is collected by waste collection services (KfW, 2017).

The majority of the waste generated in RLM is disposed of at the Waterval landfill site. There also areas that get their waste collected and dumped at mine landfill sites.

Two cells (856 000 m^3 in total) were constructed for disposal and if no waste is diverted from the landfill, two new cells will need to be constructed within five years after the start of the landfill operations (i.e. by 2023).The construction of new cell will be costly, and the diversion of food waste away from landfill will save airspace, and, consequently, money. As mentioned earlier, the waste management licence of the Waterval Landfill site (NWP/WM/BP1/2011/02) has made provision for infrastructure allowing for the reclamation of waste from the waste stream prior to disposal. These include a material recovery facility (MRF), recycling yard and building, and

composting facility. The waste management licence also provides for the composting of green waste which is currently not being composted.

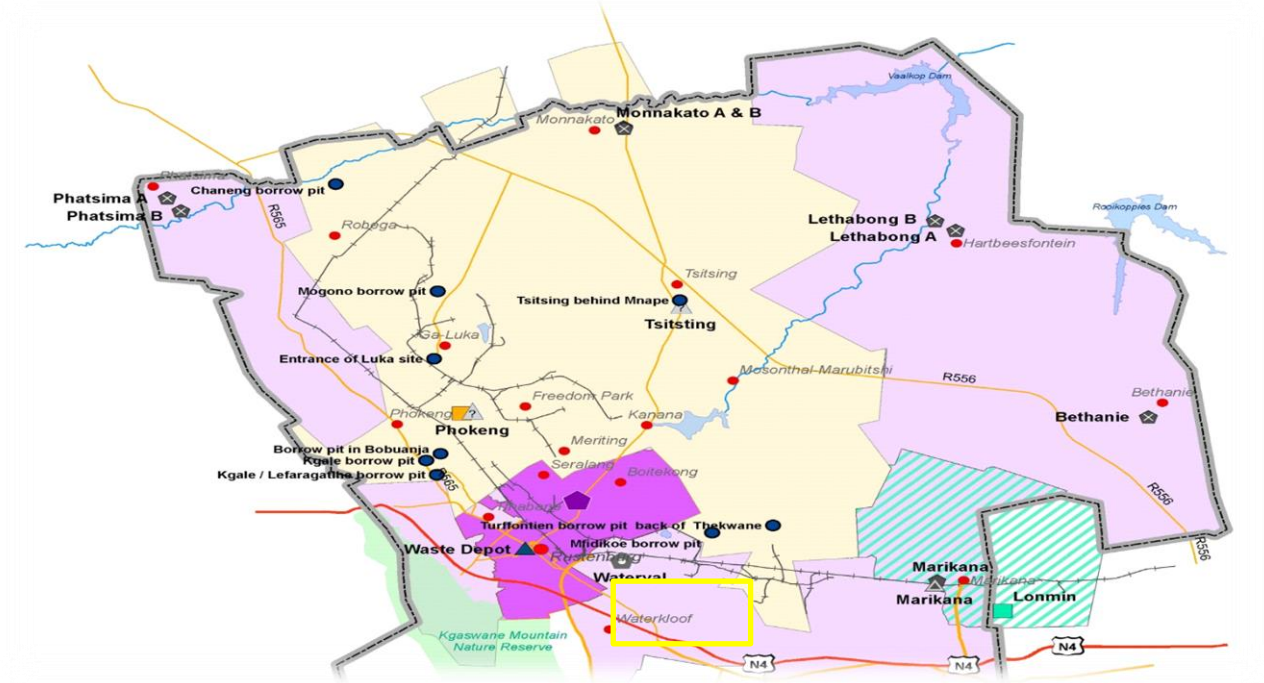


Figure 3-2: Map of a portion of RLM, indicating the location of Waterval Landfill site. (Source: RLM IWMP, 2017)

The overall purpose of the data collection from the Waterval landfill site was to establish the approximate *quantities* and *characteristics* of the food waste received at the landfill site. This data will assist with understanding the food waste streams and its suitability for different alternatives to landfilling, to ultimately conclude which alternative may be suitable for the reduction of food waste disposal at the Waterval landfill site.

As stated before, the waste which arrives at the Waterval landfill site is not necessarily indicative of the total amount of food waste produced by the whole of RLM. Some of the food waste generated may be composted by the generators of waste, disposed of through other means, or reclaimed from the waste stream by waste pickers (or reclaimers) before reaching the landfill site. The intent of the study is, however, not to quantify the entire quantity of food waste generated by the RLM, but to determine the amount of food waste (usually, but not always, inedible) arriving at the Waterval landfill site for disposal purposes.

3.3 Research design

The research study was designed to have a mixed-method approach because of the nature of the research objectives and questions. Table 3-1 provides an outline of the research questions and methodologies used for data collection.

Table 3-1: Research questions and their methodologies

Research objective	Research question	Methodology
Determining the characteristics (quantity and composition) of food waste received for landfilling	*Research question 1: What is the approximate quantity of food waste received at the Waterval landfill site?*	*Quantitative:* Waste characterisation and quantification of selected bags (based on a sample of bags per off-loaded waste truck) expressed as a percentage of the total amount of waste received per truck (which will be based on weigh bridge data). Finally, monthly reports compiled from weighbridge reports were used to deduce the approximate quantity of food waste received per month.
	Research question 2: What is the composition of the food waste received at the Waterval landfill site?	*Quantitative:* A waste characterisation study were conducted where food waste was categorised into different categories, to inform the characteristics of the food waste.
Investigating the potential alternatives to landfilling for food waste in Rustenburg Local Municipality based on opportunities and limitations	*Research question 3: What are the alternative options for food waste (other than landfill disposal)?*	*Qualitative:* Literature review of national and international publications on food waste alternatives
Understanding the existing supporting context for the implementation of food waste alternatives, within Rustenburg Local Municipality	*Research question 4: What is the existing supporting context for the implementation of food waste alternatives, within Rustenburg Local Municipality (i.e. institutional arrangements, infrastructure, municipality's willingness to be involved in alternative options, etc.)*	*Qualitative:* The IWMP and other waste policies and documents from the RLM were reviewed to determine the existing institutional environment to support the implementation of alternative options for food waste A site visit and semi-structured interviews with open-ended questions were conducted.

The study used a field/natural experimental design approach, combined with a literature review approach. It was quantitative in nature where waste characterisation studies were done in field, where primary data was collected through sources such as categorising and weighing of food waste, and interviews and observation. Secondary data was obtained from document review and literature review, with reference to publications on food waste and food waste treatment options in South Africa, and elsewhere in the world. The study was designed not only to quantify the amounts and types food waste being disposed at Waterval landfill site, but also to make links between the amounts and types of food waste and the attitude of RLM officials towards food waste diversion. This is in response to research question 4, which aims at understanding the existing supporting context for the implementation of food waste alternatives, which includes the willingness of the municipality to be involved in alternative options to divert food waste away from landfill. Surveys by means of structured interviews (self - administered questionnaire), to test the municipal officers responsible for waste management's ability and attitude towards implementing food waste management alternatives, were also used. A questionnaire is a list of questions gathered by the researcher to be answered by the participants. It commonly comes with information on what is required of the participants plus guidelines on how participants should fill in the questions. The aim was to gather first hand evidence of the officers' attitude and practices wherein the researcher gathered information first hand (rather than depending on secondary sources).

3.4 Data collection

Data was collected from the following sources:

a) Visits in the month of August 2019 to the Waterval landfill site for purpose of categorising and quantifying food waste received at the site;
b) An analysis of the RLM's monthly weigh bridge reports from the landfill site (provided by the site manager or the municipal landfill foreman) to determine the approximate quantities of food waste, relative to the total amount of waste received at the site;
c) Semi-structured interviews with RLM's manager of landfill disposal, the foreman and the site supervisor; and
d) Document review (RLM IWMP, IDP and Waterval landfill site waste management licence and others) and literature review to obtain information on food waste and alternative treatment options for food waste, and the existing institutional framework for the establishment of waste treatment options in RLM.

As mentioned earlier, data collection methods were informed by the research questions, as outlined in Table 3-1.

3.4.1 Literature review

The literature review aimed to provide context to this study and to identify historical data and research on alternatives available for waste treatment. Special emphasis has been placed on food wastes as the research is focused on diverting food waste away from landfill. The purpose was also to identify the key concepts of food waste treatment, also based on lessons learned.

The main aim of the literature review was to:

- *Provide context to the current study;*
- *Understand food waste challenges and opportunities; and*
- *Understand the different options available for the treatment of food waste (in order to divert food waste away from landfill) based on research done by others.*

The literature review also informed the *methodological design* of the study, based on methods used elsewhere in the world to answer the question regarding food waste characterisation studies. Chapter 2 of this dissertation provides the full literature review.

3.4.2 Food waste characterisation study

The success of waste management requires correct data on generation and composition of waste is essential for the choices towards the suitable waste management system (Palanivel & Sulaiman, 2014). Waste composition and volume by waste stream would assist with decision making on how to divert municipal solid waste from landfill. Information like this offers significant info on the effectiveness of the material for either composting, incineration or anaerobic digestion (Abdel-Shafy & Mansour, 2018). Waste characterisation is described as a technique utilised to categorise the components and calculate the quantity of waste generated (Martinho *et al.*, 2008). (Wang *et al.*, 2004) explained waste quantification as method to determine the types of materials being discarded in a waste stream and in what proportion they are discarded. Waste quantities are commonly estimated on the basis of past records of waste generation. The techniques utilised to measure the quantities are load count analysis; weight volume analysis; and material balance analysis (Gawaikar & Deshpande, 2006).

Locally and international there is no standard method for waste characterisation studies, which therefore mean that there is no standard against which to assess requests for or results from municipal waste characterisation studies (Oelofse *et al.*, 2016). The guidance provided by the

Waste and Resources Action Programme (WRAP, 2008)) and the (ASTM D5231-92, 2016) *Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste*, as well as (Oelofse *et al.*, 2016) and the dissertation by (Matinise, 2018) were used for the quantification and characterisation of food waste.

The waste quantification and characterisation were conducted between 21 and 25 August 2019. For this study, characterisation of the food waste (generated by households and businesses) that was received at the Waterval landfill site was carried out during five consecutive days during the week (Monday to Friday) to capture the difference in waste composition. The origin of waste could not be determined and was not taken into consideration. According to Oelofse *et al*. (2016), a minimum number of ten samples for a characterisation campaign is mandatory, if the sample size is 100 kg or more. Ten bags were sampled per day and the total amount of waste sampled and characterised were 50 bags in 5 days.

Waste generation is influenced by seasonal change and preferably waste analysis should be conducted at a minimum of two surveys six months apart in order to increase knowledge of the seasonal change influencing the samples being collected. It is also advised that sampling should not be conducted during holidays such as Christmas, Easter other public holidays due to waste generation during these times will not be normal (EPA, 1996). The samples of this study were collected in one season (August), which was a limitation of the research (refer to Section 3.6 of this dissertation).

3.4.2.1 Sampling

Shorten and Moorley (2014) state that good sampling strengthens a study while saving time, money and resources. To ensure good sampling, (Devers & Frankel, 2000) further suggest the development of a sampling frame which is done by identifying the criteria for selecting sites, identifying participants that will provide rich information and also ensuring that those participants in the study. There are a number of methods to attain samples from the municipal solid waste. Sampling can either include direct sampling at source (e.g. household) or from a vehicle load (e.g. landfill site or transfer station). Waste collected by direct sampling is associated with geographical areas and household types generating the waste, whilst vehicle load sampling is not (Stejskal & Masicek, 2016). The size of the sample is influenced by factors such as food habits, cultural tradition, socio-economic and climatic conditions.

Waste characterisation was undertaken using bulk sampling with randomised grab sampling, covering a representative sample of the municipal waste destined for disposal at the Waterval landfill site. Bags were sampled by the researcher accompanied by one waste management

municipal official. The sampling methodology for the study involved direct sampling from vehicle loads delivered at the Waterval landfill site for disposal. Ten bags were randomly selected from different garbage trucks entering the Waterval landfill site, on each day of the five consecutive days on which the study was conducted (making it a total of fifty bags that was used for the characterisation study).

3.4.2.2 Sorting and characterisation of waste

After waste bags (10 bags per day) were sampled, they were brought to a sorting area and each bag was weighed to determine the total mass of the bag before sorting. Each bag was hand sorted into various food waste categories (as outlined in Table 3-2), as recommended by (WRAP, 2008). In some cases, packaging could not be removed from the food waste (because of the integrity of the food waste sample), and packaging were included in the total weight of the food waste category. The weight of the packaging included in the food waste samples were, however, considered to be negligible.

Categories of waste was placed in refuse bags for weighing and volume estimation. Each sorted food waste category was then weighed using a calibrated scale, and recorded on a data-capturing sheet for analysis. Further descriptions (supported by photographs) are provided in Table 3-3.

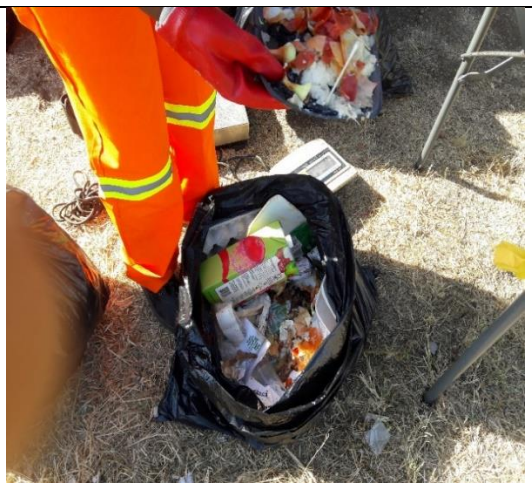
Table 3-2: Food waste categories and descriptions used when sorting food waste (as recommended by WRAP, 2008).

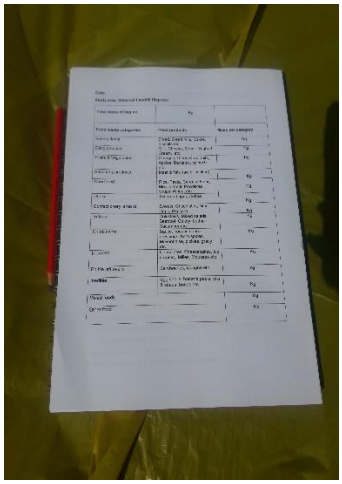
Food waste category	Description	Mass
Bakery items	Bread, Bread rolls, Cakes, Biscuits, Pasta	In kilograms (kg)
Dairy products	Milk, Cheese, Butter, Yoghurt , Cream etc.	In kilograms (kg)
Fruits & Vegetables	Oranges, Other citrus fruits, Apples, Bananas etc.	In kilograms (kg)
Animal by products	Meat & fish	In kilograms (kg)
Mixed food waste	Mixed food waste that is indistinguishable into other categories	In kilograms (kg)
Egg shells	From poultry products	In kilograms (kg)
Dried food	Rice, Pasta, Cereals, Flour, Mealie meal, Powdered soups, Wheat	In kilograms (kg)
Drinks	Tea, Coffee	In kilograms (kg)
Confectionery and snacks	Sweets, Chocolates, Nuts, Crips, Popcorn	In kilograms (kg)
Bones	Bones from animal food products	In kilograms (kg)

Food waste category	Description	Mass
Salads	Coleslaws, Mixed salads, Beetroot, Celery, Lettuce, Cucumber	In kilograms (kg)
Condiments	Sauce, cook-in sauce, dressings, herb spices, mayonnaise, pickles, gravy,	In kilograms (kg)
Desserts	Chocolates, Cheesecakes, Ice creams, Jellies, Mousses	In kilograms (kg)
Other foods	Any others not falling into the above categories	In kilograms (kg)

Table 3-3: Description and illustration of the waste sorting procedure

Step 1: Sample of black bags collected from garbage trucks destined for disposal at Waterval landfill site.	
Step 2: Weighing of the waste in the plastic bag before sorting	

Step 3: Sorting of waste from each bag.	
Step 4: Sorting of waste into different food waste categories.	
Step 5: Weighing of waste into yellow plastics per food category.	

Step 6: Recording of waste quantities into waste spread sheet	

The process outlined in Table 3-3 was repeated for each of the sampled bags on each of the days of the characterisation study. For safety purposes, sorting was conducted at a dedicated sorting area on the landfill site, away from the workface, with the necessary personal protective equipment (PPE) (gloves, safety boots, overalls and masks which was worn at all times - see Figure 3-3). At the end of each day, the sorted waste was returned to the workface for proper disposal.



Figure 3-3: PPE worn by the researcher during sorting

3.4.2.3 Determining the approximate food waste quantity based on monthly total waste data

To address research objective 1*(determine approximate quantities of food waste received at the Waterval landfill site),* the average percentage of food waste generated per month (based on data from the waste characterisation study) was calculated as a percentage of the total quantity of waste received per month at the landfill site, based on weigh bridge data from January 2019 to August 2019 (month of sampling). This means that the percentage of food waste (based on food waste sampled from 50 bags) were used to calculate the total amount of food waste produced per month, based on weigh bridge records.

3.4.3 Determining the existing institutional environment for the establishment of alternatives to divert food waste away from landfill

To address research objective 4 *(understanding the existing supporting context for the implementation of food waste alternatives, within Rustenburg Local Municipality)*, the content of secondary data sources, as outlined below, was analysed:

- Rustenburg Local Municipality integrated waste management plan (IWMP) (2017),
- Rustenburg Local Municipality integrated development plan (IDP) (2020/21) with accompanying Service Delivery and Budget Implementation Plan (SDBIP) (2019/20); and
- The Waterval landfill site waste management licence (NWP/WM/BP1/2011/02).

The results of the study performed by DEA and RLM to determine the feasibility of a biomass pre-treatment facility were also considered.

These documents were analysed to determine whether the RLM has set goals, targets and/or actions to addresses food waste diversion away from landfill. Furthermore, the evaluation aimed to determine whether the RLM has infrastructure in place, or plans to establish infrastructure, that enables food waste diversion from landfilling. The IWMP and IDP were reviewed to determine alignment, i.e. to determine whether the waste diversion projects planned for, was budgeted for in terms of the IDP.

The researcher also aimed to establish whether any waste characterisation information informed the *status quo* analysis of the RLM IWMP.

The researcher reviewed the contents of the Waterval landfill site waste management licence to determine whether the licence permits for the establishment and operation of infrastructures and activities (alternative technologies) that will make it possible for food waste diversion to take place

at the Waterval landfill site, as well as the resources available to implement food waste alternatives.

3.4.4 Establishing the capability of waste management officers to implement alternative options (to divert food waste away from landfill) through interviews and questionnaires

Semi-structured interviews, using questionnaires (Annexure B) were used to support interviews with selected waste management officials within the RLM, landfill disposal manager, foreman and site supervisor at the Waterval landfill site. The landfill disposal manager was selected to give insights of plans RLM might have concerning food waste. The foreman was selected to give information on the possibilities of implementing separation at source of food waste and its viability, while the site supervisor gave information on how food waste is currently managed and the willingness to implement food waste alternatives.

Semi-structured interviews are defined as the *interaction between the participant and the researcher through the use of predetermined questions as a guideline to the interview* (Petty *et al.*, 2012). This method was chosen due to its flexibility as it allowed the partakers to present their outlook of reality and diversity of their experiences in their own words unlike the structured interviews which does not allow the partakers to explore more with their answers. (Wilson, 2014) proposes that a semi-structured interview could last between a few minutes to an hour as short interviews are seen as a disadvantage that could lead to shallow answers. The researcher administered interviews with participants in July 2019.

The interviews were recorded by means of taking notes. The questions that were asked focused on: *How much food waste is received at the site?*, Does *RLM have a separation at source programme for food waste?, What alternatives is the municipality currently using for food waste? What are their perceptions about food waste? Are they willing to implement alternatives for food waste?*

The aim of conducting interviews was to understand the respondents' perception towards diversion of food waste from the landfill site. Questionnaires (Table 4-4) were sent to participants via email to prepare them for interviews. According to (Wilson, 2014) main questions must be sent in advance to give the participant time to prepare. The researcher then followed up the responses to questionnaires telephonically or face-to-face, where possible.

3.5 Data analysis and interpretation

The data was analysed by electronic capturing of the recorded data, which was put into a Microsoft Excel spreadsheet. The qualitative data was recorded in the narrative form and the content was analysed. The quantitative data (waste volumes and waste characterisation) was captured and analysed appropriately.

Questionnaires were distributed to the municipal officials and interviews and site visits were conducted to attain the required data. The data captured by questionnaires and field notes were analysed to establish the key patterns and trends concerning the research problem.

3.6 Assumptions and limitations

The assumptions and limitations provided in this section, should be considered when interpreting the result of this study (Chapter 4), together with the scope of the study (Section 1.4) and the limitations outlined in Section 1.5 of this dissertation. The following limitations were encountered during the study:

1. No all participants could avail themselves on the appointments made with the researcher due to time constraints and institutional commitments which caused delays to the study.
2. Mistrust to the nature of the study might have been one of the reasons why there was hesitation to fully participate in the study. Only three interviews were conducted with the participants and they could not fully provide information on questions that were asked.
3. Sampling was only conducted in one season (Winter) which is not ideal due to season variation as waste generation is also influenced by seasonal change.
4. Food waste quantities were based on estimations from the food waste characterisation study as a percentage of the total amount of waste received as outlined on weighbridge data from the Waterval landfill site. Accurate weigh bridge records were only available from January to August 2019. The results found during the study were verified by comparing with the RLM/DEA waste characterisation study.
5. Food waste estimations (average amount of food waste received at the Waterval landfill site per month) were based on the results of the characterisation study, which indicated that food waste contribution to the total amount of waste received at the Waterval landfill site is 31.14±9.4%.
6. This study was limited to one municipality, with the aim of determining the types and quantities of found waste destined for disposal at one landfill site, and it is not possible to assume the results of the study to the neighbouring municipalities in the North West province or to the whole of South Africa.

7. Most waste collection trucks in the RLM use compaction mechanisms and it is not viable to use samples from such vehicles because the waste is mechanically stressed and blended which lead to difficulties in distinguishing individual material during sorting. Waste was, therefore, mostly sampled from waste collection vehicles which did not use compaction.

3.7 Ethical considerations

According to the North-West University (NWU) (2018), ethical considerations should be acknowledged and taken into consideration during research. An ethical clearance for this study was obtained to ensure that the research is conducted in an ethical manner, ethics number: NWU-01413-20-A9 (Annexures A and C) was given to the researcher by the North-West University Senate Committee for Research Ethics (NWU-SCRE). The nature of this research does not include any animal or vulnerable human participants. The research proposal for this study has been reviewed by the Scientific Committee of the Environmental Management Research Group (EMRG) in the Unit for Environmental Sciences and Management and was exempted from full review by the Faculty of Natural and Agricultural Science's Research Ethics Committee (REC), because the methodology followed was considered to be a minimal ethical risk.

3.8 Conclusion

This chapter presented an outline of the study area, research design and methodological framework conducted in this study. The process of data collection was discussed, and a brief discussion of data analysis was given. Chapter 4 discusses the results as it relates to the three research objectives.

CHAPTER 4 RESULTS AND DISCUSSIONS

Chapter 4 depicts the results and discussion of the study as it relates to the three research objectives:

- *Research objective 1: Determining the characteristics (quantity and composition) of food waste received for landfilling;*
- *Research objective 2: Investigating the potential alternatives to landfilling for food waste in Rustenburg Local Municipality based on opportunities and limitations;*
- *Research objective 3: Understanding the existing supporting context for the implementation of food waste alternatives, within Rustenburg Local Municipality.*

4.1 Research objective 1: Waste characterisation results

This section provides the results of the waste characterisation section of the study, where the types and quantities of food waste were determined.

4.1.1 Waste composition

To determine the food waste composition, a total of **221 kg** of waste (being representative of 10 bags of waste being sampled per day, over 5 days) was sampled and sorted, and the weight of each category was recorded (as explained in Section 3.4.2 of this dissertation). A total of **65,18 kg** of food waste was recorded, which represented approximately 29,5% of the total amount of waste sampled. Table 4-1 provides a summary of the total amount of waste sorted per day, as well as the relative (percentage) amount of food waste per bag, with standard deviations.

Table 4-1: Total amount of waste sorted per day and the relative (percentage) amount of food waste per bag

Days	Total weight of 10 bags (kg) per day	Total weight of food waste sorted(kg) per day	Percentage (%) of Food in the bag
Day 1	48,1	16,24	33.7%
Day 2	47	15,04	32%
Day 3	61,5	9,7	16%
Day 4	26,2	8,3	32%
Day 5	38,2	15,9	42%
Total (kg)	**221**	**65,18**	**29,5%**
Average (kg)	**44,26**	**13,04 (Standard deviation: ±3,74)**	**31,14% (Standard deviation:± 9,4%)**

4.1.1.1 Approximate quantity of food waste

Due to the relatively small sample size, the average contribution of food waste as a relative percentage of the total amount of waste sampled (collected over the five days) were used for further calculations. From the total **221 kg** of waste sorted, **65, 18 kg** comprised of food waste, which was calculated at an average of approximately **31.14±9.4%**. The average percentage of food waste in the total waste for RLM is similar to that reported for developed countries such as the USA (27%), UK (28%) and Kuwait (37,5%) (Bernache-Perez *et al.*, 2001). Locally, in South Africa, the 31% average determined for food waste contribution in RLM during this study, is similar to that reported for Polokwane in 2016 (31%), eThekwini in 2017 (31%), and Nelson Mandela Metropolitan Municipality in 2017 (33%). In contrast, it is different to what was determined by McCarthy in 2016 (16%) (Oelofse, 2019). The standard deviation of 9.4% (for this study), however, needs to be taken into consideration, and no further assumptions can be made regarding changes in food waste towards total waste composition over time at RLM.

Comparing this average contribution of food waste with the **5002,04** tonnes of waste received at the landfill in August 2019, and considering the contribution of food waste to the total amount of waste received at 31.14±9.4%, it is estimated that between **1087,44 and 2027,82** tonnes of food waste was received in the month of August 2019. Weigh bridge data from January 2019 to August 2019 was used to estimate the quantity of food waste received at the Waterval landfill site per month (Table 4-2). The data was ultimately used to calculate the average amount of food waste received per month, based on the assumption that 31.14±9.4% of the waste received per month consists of food waste. The average amount of food waste received at the Waterval landfill site per month was calculated at **1058,94 – 1974,68** tonnes (Table 4-2). If this estimated monthly average is multiplied by twelve, to calculate a yearly average, approximately **12 707,28 – 23 696,16** tonnes of food waste are expected to be received at the Waterval landfill site (Table 4-2). Considering the results of the DEA/RLM study (conducted in January 2020), which state that approximately **13 000 tonnes** of food waste are received at the Waterval landfill site (DEA, 2020), the more conservatively estimated average amount of food waste (based on a food waste contribution of 31.14-9.4%) received at the Waterval landfill site of **12 707,28** tonnes seems to be more accurate (Table 4-2). The assumptions and limitations outlined in Section 3.6, however, need to be taken into consideration when considering these results.

The amount of food waste disposed in Ekurhuleni and Johannesburg were between **25 198** and **51 462** tonnes per annum in a study conducted by (Oelofse & Pienaar, 2016), which is more than the results found for Waterval landfill site. However, this was only for households food waste. Very few published studies estimating food waste quantities at disposal sites have been

conducted and those that have been done use different techniques, which makes it difficult to compare findings across studies.

Table 4-2: Estimated quantities of food waste received at Waterval landfill site based on weigh bridge data of the total amount of waste received, and a 31.14±9.4% contribution of food waste to the total amount of waste received (as determined by this study)

Month	Total amount of waste received at Waterval landfill site per month (tonnes)	Estimated quantity of food waste (based on an average food waste percentage contribution of 31.14±9.4%) (tonnes)
January 2019	5234,2	1135,82 – 2121,94
February 2019	4890,61	1063,21 – 1982,65
March 2019	5183,14	1126,81 – 2101,24
April 2019	4615,6	1003,43 – 1871,16
May 2019	3626,04	788,30 – 1469,99
June 2019	5406,53	1175,38 – 2191,81
July 2019	5009,28	1089,02 – 2030,76
August 2019	5002,04	1087,44 – 2027,82
Average	4870,93	1058,94 – 1974,68

The waste characterisation study conducted by DEA and RLM in January 2020 (DEA, 2020) indicated that the estimated 13 280 tonnes of food waste received per annum was considered to provide enough feedstock for a biomass pre-treatment facility project, which has been planned to be implemented.

The food waste quantities (tonnes) required per alternative are elaborated on in Table 4-3. Based on the information in Table 4-3, it seems that the quantities of food waste may be suitable for most of the alternatives mentioned, except for anaerobic digestion, which requires larger quantities of food waste (190 000 – 230 000 tonnes per annum). This is further elaborated on in Section 4.2.

4.1.1.2 Composition of food waste (food waste types)

Figure 4-1 outlines the contribution of different food waste types/categories to the total composition of food waste, as determined during the waste characterisation study.

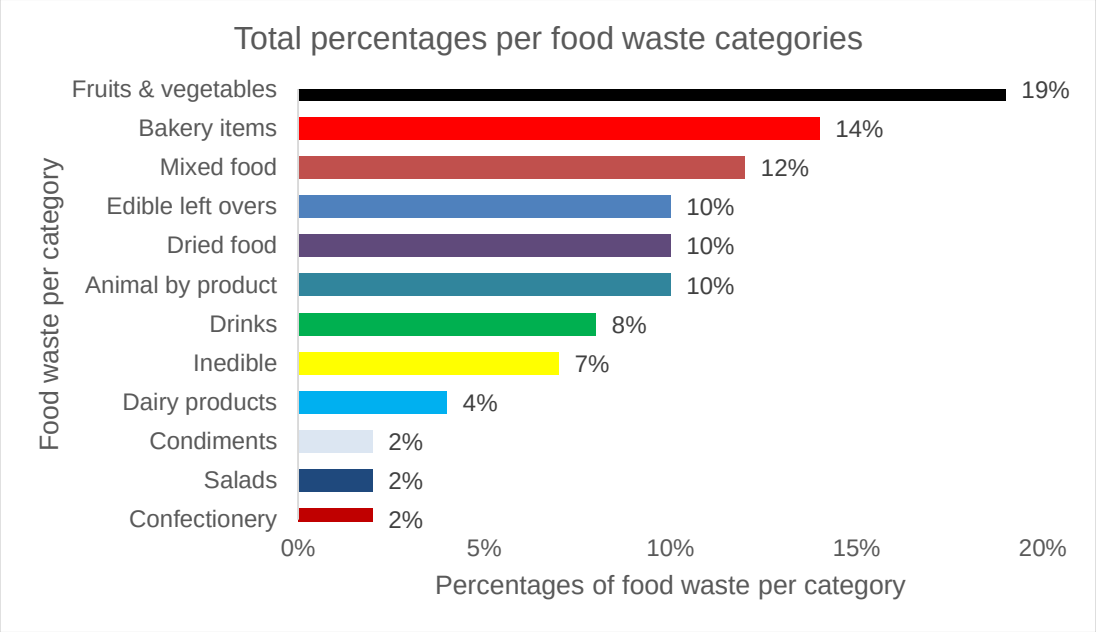


Figure 4-1: Contribution of food waste categories (%) by weight to the total amount of food waste sampled

The three types of food that were recorded in the highest quantities at the Waterval landfill site included **fruits and vegetables (19%), bakery items (14%),** and **mixed food (12%).** This finding is supported by the results of other studies done in the South African context. In a study conducted by (Oelofse & Nahman 2013) in South Africa, fruit and vegetables contributed up to 50% to the total food waste stream. Studies by Nahman & de Lange (2013) and WWF-SA also confirmed that fruit and vegetables are the most wasted at different stages along the supply chain up until disposal (Notten *et al.*, 2014). According to (Cronje *et al.*, 2018), the high wastage of fruits and vegetables seems to be equivalent with the relatively high consumption of fruits and vegetables in South Africa. Studies in the UK and Australia also show that fruit and vegetables are the most wasted food items (WRAP, 2008). Regionally FAO's estimations indicate that in North Africa, West and Central Asia fruits and vegetables are the most wasted food at 45% (Baig *et al.*, 2018), which further supports the results of this study. Edible left overs, dried food and animal by products (10%) were also present significantly more than drinks (8%), edibles (7%) and dairy products (4%), while condiments, salads and confectionery (2%) were available in the least quantities (see Figure 4-1). It should, however, be emphasized that the results of the waste characterisation study are indicative of the food waste that is destined for disposal at the Wateral landfill site, and not necessarily indicative of the amount and types of food waste generated by households (since some of the food waste, especially edible parts, could have been recovered by waste pickers, for example).

The overall composition of the food waste (mixed food, dominated by organic wastes, such as fruit and vegetables) received for disposal at the landfill site is considered to be suitable for diversion from landfill site and can still be used as additional feedstock for the preferred alternative technology to stabilise the supply of food waste (also refer to Table 4-3).

4.2 Research objective 2: Investigating alternatives for food waste disposal, based on food waste characteristics

The most common alternatives for food waste diversion from landfill disposal within the developing country context (composting, anaerobic digestion, incineration and livestock feeding) were explored (as part of the literature review) and outlined in Section 2.7 of this dissertation. These options are compared in Table 4-3 to determine which of the options would be a suitable alternative to landfilling of food waste, depending on factors such as the required food waste volumes and types (feedstock), operational costs, lifespan and job creation opportunities, amongst others.

Table 4-3: Comparison of alternatives to the disposal of food waste to landfill (DEA, 2009; DEA, 2013; Garcia-Garcia *et al.*, 2016; Oliveira *et al.*, 2017; Gao *et al.*, 2017; Dou *et al.*, 2018; Janson *et al.*, 2019; Ng *et al.*, 2019).

Determining factors	Composting	Incineration	Anaerobic digestion	Livestock feed
Required quantities of food waste (tonnes)	5000 to 15 000 tonnes per annum	Undetermined	190 000 to 230 000 tonnes of per annum	Undetermined
Feedstock	Mixed food waste, especially organic waste	Mixed food waste, preferably with a low moisture content	Mixed food wastes which can be mixed with other municipal waste.	High costs and quality food waste. Not all types of food waste
Indicative capital cost	Upwards of R7,75m for small scale system	R1,39m - R1860m for 100k tpa facility	R124m - R217m for a 25k wet AD process	NA
Operational costs	Low	High	High	High
Skills requirements (i.e. skills to operate technology)	Low	High	High	Low
Waste regulatory requirements	Waste management licence (supported by guidelines/ norms and standards for composting)	Waste management licence, atmospheric emissions licence	Waste management licence	Norms and standards may be applicable for the storage of waste
Produces	Fertilizers	Electricity and heat produced from thermal energy (potentially)	Renewable energy(electricity) and digestate can be used as liquid fertilizer and soil conditioner	Animal feeds

Determining factors	Composting	Incineration	Anaerobic digestion	Livestock feed
Process considerations	Process acceleration by bulking agent additions and regulations	Air quality and regulations	Pre and post treatment requirement and regulations	Separation and collection of food waste. Safety regulations
Advantages	Creates a soil amendment product and reduces landfill emissions of greenhouse gases.	Prevents the release of methane to the atmosphere and allows for recovery of heat to generate electricity.	Reduces environmental pollution as the process prevents exit of methane into the atmosphere. Low energy requirement for operation and low biomass production.	Food waste can be used to replace expensive livestock food sources that is needed for other uses.
Disadvantages	Long process time and critical care required. Pathogen spread	Potential source of dust and vapor emissions to the environment, and the greatest potential fire hazard.	Technical knowledge, and process failures under poor conditions. The biggest challenge with digestion of food waste is obtaining suitable condition for a stable process.	Without proper treatments some raw food transfer diseases and fever to animals.
Global warming potential	74kg of CO_2 from 1 tonne of food waste	342 kg of CO_2 from 1 tonne of food waste	211 kg of CO_2 from 1 tonne of food waste	
CO_2 and air pollutants emission	Low	High	Low	Low
Lifespan	15-20 years	20 -30 years	20-30 years	15-20 years
Job creation opportunity	High	Low	Low	Low

While Table 4-3 provides an overview on the aspects considered during this study, some aspects require elaboration in the context of the results of this study. The sections below summarises the determining factors (Table 4-3) for the four alternatives explored in relation to the results of the food waste characterisation study (quantities and composition), as well as the reviewed results of Waterval landfill license and the RLM's documents.

- **Required food waste volumes –** From the waste characterisation study, it is estimated that approximately 12 707,28 – 23 696,16 tonnes of food waste are expected to be received at the Waterval landfill site per annum (Table 4-2). Considering the results of the DEA/RLM study (conducted in January 2020), which state that approximately 13 000 tonnes of food waste are received at the Waterval landfill site (DEA, 2020), it seems that the more conservative estimation (of approximately 12 700 tonnes per annum) may be more accurate. The estimated quantities of food waste received at the Waterval landfill site, are suitable for three of the four alternatives mentioned, except for anaerobic digestion, which requires larger quantities of food waste (190 000 – 230 000 tonnes per annum).
- **Feedstock (waste types) –** Mixed food waste are suitable for all of the alternatives identified. The food waste composition determined during this study are the most suitable for composting and anaerobic digestion, due to it relatively high organic and moisture content (consisting mostly of fruit and vegetables). Although mixed food waste may be incinerated, incineration is more suitable for waste with a lower moisture content. For livestock feeding, high quality (uncontaminated) food waste are preferred. Mixed (with other, potentially hazardous waste), compacted food waste retrieved from wasted disposal sites may not be of an acceptable quality for livestock feeding.
- **Indicative capital cost –** Considering capital cost required, composting seems to be the most financially viable alternative (at approximately R7,75 million), while anaerobic digestion and incineration are more expensive technologies (Table 4-3). Considering the current priorities and financial allocation of RLM as it relates to waste management (as reflected in their IWMP, IDP and SDBIP), composting may be the most financially viable alternative to food waste disposal to landfilling, unless additional grants are applied for. Section 4.3.3 provides more information on waste-related financial provisions of RLM.
- **Operational costs –** Composting has low operational costs compared to the other options investigated.
- **Skills requirements –** Composting and livestock feed require low skills, while anaerobic digestion and incineration require high skills levels to operate and maintain. Considering

the current capacity challenges at RLM (refer to Section 4.3.5), an alternative with low skills requirements may be a more suitable alternative for RLM.

- **Waste regulatory requirements –** The alternatives explored during this study (except for livestock feeding) are considered to be waste *treatment* activities, according to GN. 921 of November 2013, and depending on their capacity, may require a waste management licence. Waste treatment are defined as:

"any method, technique or process that is designed to -(a) change the physical, biological or chemical character or composition of waste; or (b) remove, separate, concentrate or recover a hazardous or toxic component of a waste; or (c) destroy or reduce the toxicity of a waste, in order to minimise the impact of the waste on the environment prior to further use or disposal" (according to the NEMWA).

The storage of waste (depending on the capacity of the storage facility) may further be required to be performed in accordance with norms and standards for the storage of waste. Furthermore, each alternative may have its own regulations that should be considered when implementing it. For instance, for alternatives involving incineration, an atmospheric emissions licence may be required in terms of the National Environmental Management Air Quality Act (NEMAQA).

According to the review of Waterval landfill license (Section 4.3.4), the site has already been authorised to have a composting facility, which again favours composting as a suitable alternative to landfilling.

- **Lifespan –** All of the alternatives considered have life spans of 15 years or more. Alternatives with a longer lifespan will save airspace, and may postpone the need to construct new cells at the Waterval landfill site by 2023, as forecasted in the waste management licence.
- **Job creation opportunity –** According to Table 4-3, composting has a high job creation opportunity, compared to the other alternatives, which have lower job creation opportunities. How composting creates job opportunities depends on the type of mechanism selected to make compost. The number of people who can be employed also depends on the size of the facility. Any composting project is labour intensive during the construction-, operational-, and maintenance phases. Not all jobs created will be long term some will be short term (Maia *et al*., 2011). Job creation can be both for men and women as composting generally requires less labour-intensive activities. In the operational phase, for example, open windrow composting processes have different process stages. Each of these stages need workers from: preliminary treatment (reject removal, shredders), biological treatment (composting), outputs (compost) and preparation for market (packaging) and sales (DEA, 2017).

Considering the fact that job creation is outlined as a priority in the RLM IDP (Section 4.3.3), composting may be a favourable alternative to the landfilling of food waste.

Considering the aspects discussed above, composting is considered the most feasible and viable alternative to the landfilling of food waste at the Waterval landfill site. The feedstock to produce composting is also not limited to one type of food waste category, it needs a mixture of food waste plus other organic waste. Open windrow composting is a low capital waste treatment option (DEA, 2013), with high opportunities for job creation, requiring low skills levels. The market demand for compost in Rustenburg and around the North West Province is mainly comprised of local farmers of agricultural crops, golf courses and landscaping business, and lastly smaller users such as local households and businesses.

Incineration was explored as an option, but found to be less suitable as an alternative to landfilling of the food waste received at the Waterval landfill site, due to the relatively high moisture content of the food waste (mainly fruit and vegetables) currently received for disposal at the landfill. Incineration may also have additional licencing requirements in terms of the NEMAQA, and are further considered to be a "less favourable" option in terms of the food waste management hierarchy. Although incineration will reduce the amount of waste being disposed to landfill, as well as the GHG emissions (such as methane) generated from decomposing food waste, the emissions from incineration (such as dioxins, furans, carbon dioxide and polycyclic aromatic hydrocarbons) have the potential to cause impacts to air quality. A study conducted by (Gao *et al.*, 2017) indicated that incineration of food waste was found to produce dioxins at quantities that were measured to be twice as much as emissions produced during anaerobic digestion and composting, which is detrimental (Gao *et al.*, 2017). Compared to composting, incineration has high capital and operational costs, low opportunities for job creation, and requires high levels of skill. Furthermore, the current waste management licence of the Waterval landfill site does not allow for incineration, and further environmental authorisation processes may be required.

Anaerobic digestion (AD) was explored as an alternative (Table 4-3). The Continuous Stirred-Tank Reactor (CSTR) digester design is the most common and effective AD technology and accounts for up to 80% of digesters installed in South Africa (Mutungwazi *et al.*, 2018). The typical feedstock for CSTR digesters are abattoirs, fruit and vegetable and food processing plants. Fruit and vegetable waste are easily decomposable and their high moisture enables biological treatment for AD (Babaee & Jalal, 2010). Based on the results of the food waste characterisation study, anaerobic digestion (AD) is not currently considered to be a feasible option, based on the quantities of feedstock required (although the composition of the food waste, with a relatively high moisture content is considered to be suitable). AD requires high capital and operational costs,

and high skills levels to operate, but also produces a high value product (power generation and digestate). Compared to composting and incineration, AD is considered to have a low climate change impact. AD could be considered as an alternative to food waste disposal to landfill, should the feedstock (quantities of food waste) increase over the next couple of years, or if other suitable sources of feedstock can be sourced from elsewhere and combined with the current quantities of food waste received at the Waterval landfill site.

Livestock feeding may have an advantage of replacing useful feed for other uses. For an example, between 2015 and 2018, South Africa utilised 5050 MMT (million metric tons) of corn for human consumption and 5300 MMT for livestock feeding. The 5300 MMT that was used for livestock can be diverted and be used for human consumption, if food waste is used for livestock feeding (Truong *et al.*, 2019). High quality food waste (not contaminated with hazardous wastes) are required for livestock feeding, and the processing of the food waste can alter the value of the feedstock (Salemdeeb *et al.*, 2018). In a study done by (Truong *et al.*, 2019), bakery items **(comprising 14% of food waste during this study)** were found to be good for broiler feed as dried bakery goods has little disparity compared to feeding them with soy/corn (Truong *et al.*, 2019). However, not all food waste categories are suitable for livestock feeding. Food with too much water, salts or coffee are unsafe for livestock (USEPA, 2014), and problematic to integrate in livestock feeds as they are created to be eaten by humans (Georganas *et al.*, 2020). The moisture content of the feedstock material should not be more than 13,5% in order to be permitted for livestock feeding (Sugiura *et al.*, 2009). Another challenge is that using food waste for livestock feeding has sterility challenges and lately the guidelines about livestock feeding are more firmer (Matsakas & Christakopolous, 2015). Due to livestock feeding having stringent conditions that need to be adhered to, and the food types currently received at the Rustenburg landfill site being compressed, and mixed with other, potentially hazardous, waste streams, livestock feeding is not currently considered to be a suitable alternative to landfilling.

Based on the above discussion, composting is considered to be the most suitable, feasible and viable alternative to food waste disposal at the Waterval landfill site. It should, however, be noted that food waste is currently disposed of (by generators of waste) with other waste streams and compacted during transportation. Manual separation of food waste is not a viable option since the waste is mechanically blended and contaminated which lead to difficulties in distinguishing individual material during sorting. Manual separation does not only cause contamination but it also lessens the value of food waste, which in turn reduces the value of compost (Sehlabi & Morton McKay, 2016). Source separation of food waste from other organic waste by generators is a key factor to achieve clean feedstock in order to produce high quality compost. Source separation is a method which is easy to implement if good public awareness, collection and

transportation system is put in place. As outlined in Section 4.3.2 (on the review of RLM's IWMP), the budget that will be needed in order to execute separate collection of food waste is mentioned. As mentioned earlier, the municipality alone cannot do this, waste generators (households and businesses) have the biggest role play for the success of a source separation programme.

4.3 Research objective 3: Determining the enabling environment for implementing alternatives

Lessons learned from reviewing a study done at the Waterval landfill site, and other RLM documents are outlined in the sub-sections to Section 4.3 in response to research objective 3 *"Determining the enabling environment for implementing alternatives".*

4.3.1 Lessons learned from the study conducted by DEA at Waterval landfill site in 2020

The study by DEA and RLM (2020) aimed to determine source generated waste using the Sustainable Development Goals 11.6.1 approach to assess waste generated at the houses and their waste composition. *Goal 11 of Sustainable Development is: Make cities and human settlements inclusive, safe, resilient and sustainable. Target 11.6 states that: By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal waste management. Indicator 11.6.1: Proportion of municipal solid waste collected and managed in collected facilities out of total municipal waste generated* (UN, 2018).

The feasibility of the implementation of a biomass pre-treatment facility at the Waterval landfill site in RLM was determined. The proposed site (Waterval landfill site) was also reviewed for its capability and suitability to implement such project. Waterval landfill site was found to have enough space and provision to enforce the project. The study suggested that the pre-treated food waste can be marketed to private contractors and be treated by means of AD, composting etc.

A pre-treatment facility, as proposed by the authors of the study, may be advantageous to pre-treat food waste prior to composting (which is considered to be the most suitable alternative to landfilling, based on this study).

4.3.2 Lessons learned from the IWMP

According to the final draft of Rustenburg Local Municipality IWMP (2017), RLM had partnered with GIZ as a beneficiary of assistance with the *Waste Management Flagship Programme* for diversion of waste from landfills. The project aimed to establish a central biomass pre-treatment facility for food waste at Waterval landfill site (which predated the RLM and DEA study of 2020). The project was meant to include food waste separated at source from households that would be

collected by a separate collection system. The municipality was required to budget for the separate collection of food waste from households and also the operation and maintenance of the pre-treatment facility for food waste. Unfortunately, RLM could not commit to funding of the food waste treatment and the project was not implemented, and put on hold.

The following is a list of the planned activities and measures of RLM's implementation plan (RLM IWMP, 2017) on food waste:

- Follow-up on grant funding options for establishing of treatment plant at Waterval Landfill, with an estimated budget for the plant at R185 million and an operational budget of R30 million.
- Execution of separate collection of food waste (if food waste treatment plant is constructed), with an estimated operational budget of R15 million.
- Establishing of centralised biomass pre-treatment facility for food waste at Waterval landfill site (should grant funding be available), with the estimated budget for the facility being R18 million and an operational budget of R7,5 million.

The IWMP implementation plan make reference to diverting food waste using alternative technologies, however, there is no clear mention of how the whole process will work i.e. goals, targets etc. With no policy identification and backing, activating alternative technologies and programmes can difficult to put into action. According to (Sango *et al.*, 2014),*"technical content is still lacking in many municipal IWMPs, which ultimately contribute to the absence of waste management projects in the IDPs and limiting waste related development."*

Considering waste unit organogram of RLM to evaluate if the current staff will be able to manage source separation of food waste, it was discovered that there is a challenge of lack of capacity and skilled staff to provide effective operations and service delivery at RLM. It will be difficult to implement source separation of food waste as RLM's waste collection service is hampered by inadequate planning, low worker attendance, and lack of monitoring of the work force. One of their biggest challenges, currently, is low availability of collection trucks which is caused by slow repairs, theft etc. Therefore, the implementation of separation at source (by the generators of waste) must be considered in the context of existing financial and organisational challenges.

4.3.3 Lessons learned from the IDP and SDBIP

Municipalities must align their IWMPs and IDPs in order to tackle the current waste management programs and alternatives to landfilling (Mutezo, 2015).

The RLM IDP (RLM, 2020/21) has a target of diverting organic waste from the Waterval landfill site and their objective is to implement a piloting project for organic waste treatment. The IDP recommends the implementation of separate collection of food waste if the food waste treatment facility is constructed and their operational costs will allow them to construct it. It also recommends establishing of a centralised biomass pre-treatment facility for food waste at Waterval landfill site if grant is available. Recently (in January 2020), DEA and RLM did a waste characterisation study in which the results verified that there is enough feedstock at Waterval landfill site to support the project. To achieve this RLM has planned to conduct workshops, as part of their education and awareness, with businesses that produces food waste and communities.

To determine if RLM has allocated any budget for the establishment of biomass pre-treatment facility for food waste, or any other food waste related projects, the researcher reviewed RLM's Service Delivery and Budget Implementation Plan (SDBIP) 2019/2020. In terms of the Municipal Finance Management Act (Act 56 of 2003) (MFMA) Circular 13, "*the SDBIP gives effect to the IDP and budget of the municipality and its application will be possible if the IDP and budget are aligned with each other*". The SDBIP acts as a pledge by the municipality where the planned goals and estimated accomplishments are stated in order to make sure that they are applied on the next year.

RLM's SDBIP only focussed on the operational objectives of managing and providing waste removal services and maintaining of the existing municipal facilities, and RLM has not provisioned any budget for food waste-related projects. The costs for different types for new projects is not known, with the focus currently being on investment costs i.e. acquisition of Municipal Infrastructure Grant (MIG) funds or other grants sources.

4.3.4 Lessons learned from the Waterval landfill license

According to the Waterval landfill license conditions (NWP/WM/BP1/2011/02), the site is authorised to have a composting facility and a material recovery facility (MRF) as part of the landfill site infrastructure which enables the landfill environment for alternative technologies to be utilised for food waste that is received daily. Upon site visit it was noted that the composting facility and the MRF have not yet been constructed and that all the waste that is currently being received, is being landfilled.

4.3.5 Results of interviews/questionnaires

As explained in Section 3.4.4, interviews, using semi-structured questionnaires were used to establish the capacity and support or RLM waste management officers as it relates to alternatives

to the landfilling of food waste. The questionnaire consisted of eight questions, with three sections (current practices at Waterval landfill site, waste-to-energy technologies and diversion of food from landfilling) related to waste management practices at RLM.

Table 4-4: Questions and responses from interviews using semi-structured questionnaires

Questions	Summary of responses
1. *How much food waste is received at the landfill site?*	The participants could not estimate the exact figure of the food waste that goes to the landfill site.
2. *How much do each of the waste types contribute to the total waste profile 100% disposed of the waste types received at the landfill site?* *(E-waste, metal, food waste, paper, plastic, rubber, glass and rubble)*	All participants estimated that they mostly receive rubble waste (22%), and that food waste (5%) contribute the least to their total waste profile.
3. *Do you know of any programmes by RLM to separate food waste from other domestic waste type at the source of generation?*	The site supervisor's response was that he was not aware of any programs since he is only based at the landfill site. The manager and foreman spoke of the separation at source programme to be implemented by RLM that will not specifically focus on food waste.
4. *Choose the waste management options that the municipality is currently implementing:* *(Landfilling; composting; incineration; recycling; WtE; other)*	All the participants indicated that landfilling is used as the primary waste management option by RLM and that waste is reclaimed by informal recyclers at the landfill site. When asked about challenges about their current waste management option: the site supervisor indicated that, *"the landfill site space is filling up fast",* while the foreman indicated that "*the challenges regarding recycling is the allocation of separation mode of transport to collect from the sources".* The manager indicated *"RLM is currently faced with financial crisis to even support the current waste management practices."*
5. Is RLM considering or implementing WtE?	All of the participants that RLM are considering WtE at the landfill site, and the manager indicated that "*RLM still has to conduct a feasibility study to implement WtE for food waste and also that RLM is not sure if their volume of food waste that is currently generated will sustain any project that is related to WtE".*

Questions	Summary of responses
6. *What are the challenges that RLM is facing when it comes to diverting food waste away from landfilling?*	Participants indicated that it was difficult to divert food waste that is already mixed with other types of waste when it reaches the landfill site.
7. *What can be done to encourage diversion of food waste from Waterval landfill site?*	Participants suggested that separation at source programs should be introduced to all citizens of Rustenburg.
8. *What assistance/support is needed by RLM to divert food waste from landfilling?*	Participants felt that if funds and relevant equipment were available, that the diversion of food waste would be possible. They also mentioned that public awareness must be prioritised. It is important to consult the people during planning and decision making when the municipality implement source separation programs (Keramitsoglou & Tsagarakis, 2013).

4.4 Chapter summary

This chapter provided an account of the quantities and types of food waste received at the Waterval landfill site in RLM in an effort to explore alternatives to the landfill disposal of food waste. Selecting of the suitable alternative for this study was also informed by the information on the literature review, results of the characterisation study and the results reviews of the IWMP and IDP of RLM, and the interviews.

Based on the food waste composition and quantities, and other aspects such as operational and capital costs, skills requirements and job creation, composting was regarded as the most suitable option to landfilling. By using composting food waste as an alternative to landfilling, RLM will be reducing the amount of waste currently disposed to landfill, saving costs, and creating jobs – all of which are mentioned as priorities in the RLM IDP.

Anaerobic digestion is considered the second most suitable option, since has the potential to produce heat or electricity which could solve energy issues that we have around Rustenburg and in South Africa. Shortage of electricity has become an everyday challenge in South Africa with experiences of load shedding almost every day. Currently, however, quantities of food waste received at RLM would not be enough to sustain AD. Other sources of waste may need to be added with the food waste, or sourced from other areas to make it more viable.

Livestock feeding could be the third most suitable option if the safety regulations are followed (especially if food waste separation are implemented at source). It is suitable for areas that have large amounts of livestock, such as Rustenburg and its surroundings.

Incineration were not considered to be a suitable alternative, due to the moisture content of the food waste currently received at the Waterval landfill site, coupled with high capital costs, need for high levels of skilled staff, as well as additional licencing requirements and potential emissions (with relatively strict and costly monitoring programmes).

There are challenges that were raised by participants, such as the need to separate food waste from other waste types at source, since it is difficult to divert food waste when it is already mixed other domestic waste. During the study the researcher also gathered that in order for RLM to incorporate food waste alternatives, funding is needed because most of the alternative options are expensive to implement. The municipality should incorporate source separation of food waste in their IDP and IWMP. Budget or funding is also required for the necessary equipment, and promote awareness to the private sector and the citizens regarding food separation at source. As raised by the participants, funding and awareness raising is the support that the municipality need to divert food waste from the landfill site. From the responses given by the participants and the waste characterisation study conducted by DEA and RLM it was gathered that RLM is considering a food waste diverting program and the officials are willing to implement the program.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

This chapter draws conclusion on the findings of the study and provide recommendations. The aim of the study was to explore on the alternatives of food waste and understand how food waste is managed and can be managed in future at Waterval Landfill site in Rustenburg, North West Province.

5.1.1 Conclusions related to Research Objective 1: Determining the characteristics (quantity and composition) of food waste received for landfilling

Based on the results of the food waste characterisation study, it is estimated that approximately **29,5%** of the waste received at the Waterval landfill site comprised of food waste, which is similar to that reported for developed countries such as the USA (27%), UK (28%) and Kuwait (37,5%) (Bernache-Perez *et al.*, 2001), and locally to what has been reported for Polokwane in 2016 (31%), eThekwini in 2017 (31%), and Nelson Mandela Metropolitan Municipality in 2017 (33%). In contrast, it is different to what was determined by McCarthy in 2016 (16%) (Oelofse, 2019). The standard deviation of 9.4% (for this study), however, needs to be taken into consideration, and no further assumptions can be made regarding changes in food waste towards total waste composition over time at RLM. The average amount of food waste received at the Waterval landfill site per year was estimated at **12 707,28 – 23 696,16** tonnes. Considering the results of the DEA/RLM study (conducted in January 2020), which state that approximately **13 000 tonnes** of food waste are received at the Waterval landfill site (DEA, 2020), the more conservatively estimated average amount of food waste (based on a food waste contribution of 31.14-9.4%) received at the Waterval landfill site of **12 707,28** tonnes seems to be more accurate. The assumptions and limitations outlined in Section 3.6, however, need to be taken into consideration when considering these results.

The three types of food that were recorded in the highest quantities at the Waterval landfill site included **fruits and vegetables (19%), bakery items (14%),** and **mixed food (12%).** This finding is supported by the results of other studies done in the South African context. In a study conducted by (Oelofse & Nahman 2013) in South Africa, fruit and vegetables contributed up to 50% to the total food waste stream. The overall composition of the food waste (mixed food, dominated by organic wastes, such as fruit and vegetables) received for disposal at the landfill site is considered to be suitable for diversion from landfill site and can still be used as additional feedstock for the preferred alternative technology to stabilise the supply of food waste. It should, however, be

emphasized that the results of the waste characterisation study are indicative of the food waste that is destined for disposal at the Wateral landfill site, and not necessarily indicative of the amount and types of food waste generated by households (since some of the food waste, especially edible parts, could have been recovered by waste pickers, for example).

Reliable estimations of food waste generation are important for proper waste management planning and it is advised that RLM should also invest in conducting waste characterisation studies on a regular basis. The quantities of the food waste disposed is also significant for the improvement of a thought out food waste management policies, this can be utilised to decide if alternative options can alter the composition of the waste stream (Thyberg *et al.*, 2015). There is a need to substitute landfilling with alternatives treatment methods that will allow sustainable utilising of the value of waste food streams (Slorach *et al.*, 2019).

5.1.2 Conclusions related to Research Objective 2: Investigating the potential alternatives to landfilling for food waste in Rustenburg Local Municipality based on opportunities and limitations

Composting, anaerobic digestion, incineration and livestock feeding were considered as alternatives to the landfill disposal of food waste received at the Waterval landfill site.

Based on the food waste composition and quantities, and other aspects such as operational and capital costs, skills requirements and job creation, composting was regarded as the most suitable option to landfilling. By using composting food waste as an alternative to landfilling, RLM will be reducing the amount of waste currently disposed to landfill, saving costs, and creating jobs – all of which are mentioned as priorities in the RLM IDP. Anaerobic digestion is considered the second most suitable option, since has the potential to produce heat or electricity which could solve energy issues that we have around Rustenburg and in South Africa. Shortage of electricity has become an everyday challenge in South Africa with experiences of load shedding almost every day. Currently, however, quantities of food waste received at RLM would not be enough to sustain AD. Other sources of waste may need to be added with the food waste, or sourced from other areas to make it more viable. Livestock feeding could be the third most suitable option if the safety regulations are followed (especially if food waste separation are implemented at source). It is suitable for areas that have large amounts of livestock, such as Rustenburg and its surroundings. Incineration were not considered to be a suitable alternative, due to the moisture content of the food waste currently received at the Waterval landfill site, coupled with high capital costs, need for high levels of skilled staff, as well as additional licencing requirements and potential emissions (with relatively strict and costly monitoring programmes).

If RLM considers composting as an option, food waste separation at source is important in order to produce high-quality compost. Source-sorted collection is applicable for composting than mechanically separated food waste from other collected municipal waste (Cerda *et al.*, 2018).

There are challenges that were raised by participants such as the need source separation of food waste as it is difficult to divert food waste when it is already mixed other domestic waste. During the study the researcher also gathered that in order for RLM to incorporate food waste alternatives, funding is needed due to that most options seem to be expensive to implement. The municipality should incorporate source separation of food waste in their IDP and IWMP. Budget or funding is required for the necessary equipment, and promote awareness to the private sector and the citizens regarding food separation at source. As raised by the participants, funding and awareness raising is the support that the municipality need to divert food waste from the landfill site. From the responses given by the participants and the waste characterisation study conducted by DEA and RLM it was gathered that RLM is considering a food waste diverting program and the officials are willing to implement the program.

5.1.3 Conclusions related to Research Objective 3: Understanding the existing supporting context for the implementation of food waste alternatives, within Rustenburg Local Municipality

Lastly, the RLM IWMP, IDP and SDBIP, as well as the Waterval landfill site waste management licence were reviewed to understand the existing supporting context for food waste alternatives within the municipality. Although the IWMP and IDP provide for a food waste pre-treatment facility, this is not budgeted for in the SDBIP.

Considering composting as the preferred alternative (based on the results of this study), the strategic documents of RLM supports this alternative, considering the RLM's targets for waste reduction to landfill and job creation. Furthermore, the Waterval landfill site waste management licence provides for the construction of a composting facility.

5.2 Recommendations

The outcomes of this study led to the following recommendations:

5.2.1 Practical recommendations related to alternatives to food waste disposal at Waterval landfill site

Table 5-1 provides practical recommendations that RLM can implement, along with their preferred alternative to food waste management, based on some challenges identified during this study:

Table 5-1: A summary of practical recommendations

Challenges	Recommendations
Inadequate knowledge of waste management alternatives from landfilling by decision makers and political leaders	Decision-makers should visit municipalities or countries that have successfully implemented food waste programmes in order to get knowledge on the process and requirements for implementing food waste alternatives.
Poor integration of better waste management alternatives into waste management planning.	RLM's IWMP and IDP must incorporate less costing and viable waste management alternatives into the municipality waste management planning.
Lack of data on food waste generation, composition and quantities.	RLM needs to conduct waste characterisation studies in order to obtain up to date information on the quantities of waste generated and be able to estimate possible waste diversion from their waste disposal facilities.
Application for environmental authorisations	Many waste management alternatives are not considered or implemented due to the costs and time related with the application for environmental authorisations.
Lack of implementation of separation at source of food waste by waste generators (businesses and households)	RLM should introduce source separation programmes which must simultaneously go with intensive public awareness and also initiate a separate bag system or a two bin system with the assistance of waste service providers.
Limited awareness from the public	RLM should use different platforms to promote waste management alternatives to the public. The public and businesses must be aware of their waste disposal responsibilities.
Lack of skills to match the new waste management innovation	RLM can form partnerships with tertiary institutions and offer programmes to students who are conducting researches on food waste.

5.3 Recommendations for further research

During the course of study, it was noticed that through mainly the limitations, there is a need for further research. More research is required on how to divert food waste from landfill disposal, by implementing alternatives. Further areas of research are as follows:

- The main limitation of the study was the limited availability of information on food waste and waste management. Further studies must be done to have more information on South African food waste management and sustainable alternative methods that other municipalities are utilising.

- The food waste quantities determined through this study were based on several assumptions and limitations. More in-depth waste characterisation studies are required, which covers more days, seasonal variation (all four seasons), the source of generation and source of disposal, etc.

- More research must be done to show different techniques of waste characterisation studies not only for food waste but to other waste stream components.

- Research needs to be done on ways of incorporating alternatives to landfilling into strategic documentation (such as IWMPs, IDPs and SDBIPs) of municipalities.

- Research on the effectiveness of implementing alternatives (in terms of operational, environmental, and financial effectiveness/savings) may be useful to support the adoption of these alternatives by local municipalities.

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ANNEXURES

Annexure A: Permission to conduct study

North-West University
Private Bag X6001
Potchefstroom
2520

The Unit Manager
Rustenburg Local Municipality (Waste Management)
P. O Box 16
Rustenburg
0299
Date: 04 June 2019

Dear sir/madam

REQUEST FOR PERMISSION TO CONDUCT RESEARCH

I, Claudine Roos, supervisor of Ms. Mammburu, confirm that Portia Mammburu is a registered Masters' student in the Faculty of Natural and Agricultural Sciences at the North-West University, Potchefstroom Campus. Her research topic is: **Exploring alternatives to divert food waste from landfill disposal in Rustenburg, North West.** The objectives of the study are:

a) To investigate and characterise food waste in Rustenburg, based on composition and relative quantities.
b) To investigate the potential uses of food waste in Rustenburg, based on opportunities, limitations and uses of food waste.
c) To suggest future alternatives for food waste in the Rustenburg Local Municipality.

I am hereby seeking your consent for Ms. Mammburu to conduct a waste characterisation study at the Waterval Landfill site. This study will include the sorting of food waste and using a scale to weigh the food waste. We do not foresee the study having any risk to the Rustenburg Municipality or to the Waterval Landfill site, specifically. We believe that the outcomes of the study will be advantageous to the Municipality and provide recommendations that may be adopted by the Municipality.

The results of the study will be published as part of a mini-dissertation as part of the NWU Library repository.

Should you require any further information, please do not hesitate to contact me or Ms. Mammburu. Our contact details are as follows:

Ms. Portia Mammburu: 083 982 0814 and portia38@hotmail.com

Dr. Claudine Roos: 018 299 1477 and claudine.roos@nwu.ac.za

Upon completion of the study, the student undertakes to provide the Municipality with a copy of the mini-dissertation.

Your permission to conduct this study will be greatly appreciated.



Dr. Claudine Roos
North-West University, Potchefstroom Campus

Annexure B: Questionnaire on food waste

Title: Exploring the alternatives to divert food waste landfill disposal, Rustenburg, North-West.

My name is Portia Mammburu. I am post-graduate student at the North-West University, Potchefstroom Campus. I am under the supervision of Dr. Claudine Roos, who is a staff member and a senior lecturer at the North-West University. This research forms part of my Masters studies and it is on exploring the alternatives that can be used to divert food waste away from the Waterval Landfill site in Rustenburg, and how it can benefit the municipality, the community and the environment. It will concentrate on the options that are available for the diversion of food waste to prevent it from being disposed at the landfill site (together with other domestic waste) and convert it to other beneficial alternatives.

Introduction

The primary aim of this research is to investigate the potential uses of food waste in Rustenburg and also to suggest future alternatives for food waste in the Rustenburg Local Municipality.

Invitation to participate

This is an invitation for you, an official responsible for waste management, to participate in the study.

What is involved in the study?

Your involvement in the study would be that of a participant in semi-structured interview. The process will not be a long one and should take a maximum time of 30 minutes or less.

Risks

The interview only focuses on food waste management practices. The results presented will be anonymous. No risks have been identified with regards to your participation in this research.

Benefits

You could find participation beneficial in that it may clarify some of the issues pertaining to solid waste management. As a participant, the results of the study will be made available to you, should you be interested.

Participation is voluntary

The refusal to participate will have no penalty or loss of benefits to which the participant is otherwise entitled. The participant may discontinue participation at any time without penalty loss of benefits to which they are otherwise entitled.

Reimbursements

There are no reimbursements.

Confidentiality

All personal information will be kept confidential and responses are captured anonymously. Results will be captured in a manner that will ensure confidentiality.

Contact details of researcher

Please contact me directly on: 0839820814 or portia38@hotmail.com

For further information you can contact my supervisor, Dr. Claudine Roos on: 018 299 1477 or Claudine.roos@nwu.ac.za

Consent Document

Annexure C: Ethical approval

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ETHICS APPROVAL LETTER OF STUDY

Based on approval by the **Faculty of Natural and Agricultural Sciences Ethics Committee (FNASREC)**, the Faculty of Natural and Agricultural Sciences Ethics Committee hereby **approves** your study as indicated below. This implies that the North-West University Senate Committee for Research Ethics (NWU-SCRE) grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: Exploring alternatives to divert food waste from landfill disposal in Rustenburg, North-West
Study Leader/Supervisor: Dr C Roos
Student: P Mammburu

Ethics number: N W U - 0 1 4 1 3 - 2 0 - A 9

Application type: Single **Risk Category:** Minimal

Commencement date: 01/02/2020
Expiry date: 01/04/2021

Approval of the study is initially provided for a year, after which continuation of the study is dependent on receipt and review of the annual (or as otherwise stipulated) monitoring report and the concomitant issuing of a letter of continuation.

Special in process conditions of the research for approval (if applicable):

- The following documentation are archived by FNASREC and should be complete and kept up to date:
  - Research proposal
  - Signed approval from the scientific committee indicating the proposed risk category
- All researchers involved in the study should submit signed NWU code of conduct statements annually.
- All researchers of low risk studies should submit proof of relevant ethics training every two years.
- All researchers that take part in activities that pose a safety and security threat to the researchers or the environment should submit a risk assessment form annually.
- All research involving human interaction should follow best ethical practise and keep documents as proof. This includes informed consent, questionnaires, incorporation of risk-benefit, and responsible data management.
- Any research at governmental or private institutions, permission must still be obtained from relevant authorities and provided to the FNASREC. Ethics approval is required BEFORE approval can be obtained from these authorities.