Characterization, Management and Utilization of Landfill Municipal Solid Waste: A Case Study of Soweto

by

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DISSERTATION

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UNIVERSITY OF JOHANNESBURG

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October, 2016

DECLARATION

I, the undersigned, hereby declare that this dissertation, which I herewith submit for the research qualification of

MASTERS OF CHEMICAL ENGINEERING TECHNOLOGY

To the University of Johannesburg, Department of Chemical Engineering is my original work, apart from the valuable inputs of my supervisors; I have not previously in its entirety or in part submitted it at any University for a degree.

Signature: …………………

Date: ……. /……. /………….

DEDICATION

This work is dedicated to my late Father, Pa. Olawore Nathaniel Ayeleru who passed on to glory on the 8^{th} of April, 2016 while I was carrying out this study.

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PRESENTATIONS AND PUBLICATIONS

Journal Articles (Under Review)

- Olusola O. Ayeleru, Felix N. Okonta and Freeman Ntuli, Municipal Solid Waste Composition Determination and Characterization of Organic Fraction of Municipal Solid Waste, submitted to International Journal of Environmental Science and Technology.

- Olusola O. Ayeleru, Felix N. Okonta and Freeman Ntuli, Economic Utilization and Potential Revenue from Municipal Solid Waste Recycling submitted to The Engineering Economist.

- Olusola O. Ayeleru, Felix N. Okonta and Freeman Ntuli, Public Perception, Participation and Role of Informal Sector in the Implementation of Sustainable Solid Waste Management submitted to International Journal of Environmental Science and Technology.

Conference Papers

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- Olusola O. Ayeleru, Freeman Ntuli and Charles Mbohwa. "Utilization of Organic Fraction of Municipal Solid Waste (OFMSW) as Compost: A Case Study of Florida, South Africa." Proceedings of the World Congress on Engineering and Computer Science 2016 Vol II WCECS 2016, October 19-21, 2016, San Francisco, USA. ISBN: 978-988-14048-2-4.

ABSTRACT

The management of solid waste (SW) has become a crucial issue confronting low and middle income countries. This problem emanates from the generation of SW which is currently on a large scale as cities expand. The aims of this study were to determine the composition of the various waste components disposed of to the Marie Louise landfill site (LS), evaluates the elemental composition and proximate analysis of the organic fraction of municipal solid waste (OFMSW), conducts an economic analysis of setting up a recycling facility and to finally evaluating the perception of the general public with regards to the current waste management (WM) services in the City of Johannesburg (CoJ). The objectives of this study were to determine the various waste components disposed of to the LS as a baseline to propose complete diversion of wastes from going to the LS; to determine the suitability of food waste (FW) generated as a potential source of compost and biogas generation; to carry out an economic evaluation of setting up a recycling facility as a source of revenue to the municipality and potential source of jobs opportunities for the youths in the municipality and finally to assess the level of awareness of the people towards municipal solid waste management (MSWM). The waste composition studies were conducted during the summer in 2015 and during the winter in 2016 at the LS. The results of the analysis were classified into two groups based on two of the services offered by Pikitup (PU) (the municipality) (Dailies non compacted and Round collected refuse (RCR) compacted wastes collection services). STATA 12 software was used to determine seasonal variation on the main components of the wastes generated between the summer and the winter exercises for both services. The results obtained showed that p-values were too extreme (when the null hypothesis is true, the p-value is the probability of obtaining a result equal to or “more extreme” than what was actually observed. The p-values obtained for both the Dailies and for the RCR were (p-value = 0.9775) and (p-value = 0.9760) respectively. Analysis of variance (ANOVA) was also used to evaluate seasonal variation in both seasons on both services for the sub-division of the waste streams. Results obtained showed (p-value = 0.9999) for Dailies and (p-value = 0.9913) for RCR. These results show that the differences between the winter and summer for both services were not statistically significant. The elemental composition and proximate analysis of the FW was also evaluated. The analysis gave a C/N of 22.66 and an empirical formula of $C_{27}H_{44}NO_{16}$. An engineering economic evaluation was conducted to determine the financial feasibility of this project. From the analysis, IRR on investment was found to be 41%, IRR on equity was found to be 80%, the NPV was R 135,950,000, the breakeven point was 211 tons of recycled waste items, the total benefit of recycling was R 940,558,054 and it was envisaged that a total of 1,286 potential jobs would be created on this project. The perception of the general public was also evaluated. A questionnaire consisting of 48 questions was formulated and distributed in four suburbs comprising an informal settlement, two middle income areas and a high income area. A total number of 150 questionnaires were distributed, 118 questionnaires were gotten, the confidence level was 95% and the margin of error was 4.19%. Data were collected and analysed using SPSS software. Results obtained showed that about 51% of the respondents were not satisfied with the services rendered by PU, 71% said they do not know where their collected waste is taken to for final disposal and about 77% respondents said they do not know who to contact if they have any issue with their waste collection services. About 89% said they have not heard about ZW and about 95% said they are willing to participate on recycling and ZW related activities. Based on the results of these findings, it was concluded that people from the municipality were not properly educated on WM issues. The FW from the LS is a potential source of compost and biogas when it is blended with fruit wastes, leaves, corn silage and horse manure. The waste components disposed of to the LS were not separated from source, thus a recycling facility will be a viable project.

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LIST OF ACRONYMS

AGT	Argentona
ASTM	American Society for Testing and Materials
C	Carbon
CAC	Command and Control
CAP	Capannori
CBD	Central Business District
CE	Circular Economy
CF	Circular Flow
CH_4	Methane
CoJ	City of Johannesburg
CO_2	Carbon dioxide
CO	Carbon monoxide
C2C	Cradle to Cradle
C & D	Construction & Demolition
C2G	Cradle to Grave
DCs	Developing Countries
EBITDA	Earnings Before Interest, Taxes, Depreciation and Amortization
EI	Economic Instrument
EIs	Economic Instruments
EoS	Emirate of Sharjah
EIS	Economic Instrument for Sustainability
EPA	Environmental Protection Agency

FW	Food Waste
FFVs	Fresh Fruits and Vegetables
GP	Gauteng Province
GHG	Greenhouse Gas
GDP	Gross Domestic Product
GNP	Gross National Products
GOCF	Gross Operating Cash Flow
H	Hydrogen
H_2O	Water
HCl	Hydrogen Chloride
HW	Household Waste
H2	Hydrogen Gas
HDPE	Higher-density Polyethylene
IETC	International Environmental Technology Centre
ISWM	Integrated Solid Waste Management
IWM	Integrated Waste Management
IRR	Internal Rate of Return
LCA	Life Cycle Assessment
LLDPE	Linear Low-density Polyethylene
LDPE	Low-density Polyethylene
LSs	Landfill Sites
LF	Linear Flow
MRDCs	Municipal Recycling Drop-Off Centres

MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
N	Nitrogen
NGOs	Non-Governmental Organizations
NO	Nitrogen dioxide
NPV	Net Present Value
O	Oxygen
OFMSW	Organic Fraction of Municipal Solid Waste
O_2	Oxygen Gas
PAT	Profit After Tax
PBT	Profit Before Tax
PPP	Polluter Pays Principle
PU	Pikitup
RCR	Round Collected Refuse
S	Sulphur
SD	Sustainable Development
SOC	State Owned Company
SW	Solid Waste
SCH	Solid Waste Characterization
SWC	Solid Waste Composition
SWM	Solid Waste Management
SWQ	Solid Waste Quantification
Soweto	South-Western Townships

SO_2	Sulphur dioxide
SIWM	Sustainable Integrated Waste Management
SWMP	Solid Waste Management Plan
SRM	Sustainable Resource Management
SSWM	Sustainable Solid Waste Management
SPSS	Statistical Package for Social Science
3R	Reduce, Reuse and Recycle
UAE	United Arab Emirates
UNEP	United Nation Environment Protection
USWMS	Urban Solid Waste Management System
WEEE	*Waste of Electric and Electronic Equipment*
WM	Waste Management
ZW	Zero Waste
ZWE	Zero Waste Europe

1.0 CHAPTER 1: INTRODUCTION

1.1 General Background

1.1.1 Municipal Solid Waste Management (MSWM)

Municipal Solid Waste Management (MSWM) involves numerous environmental and socio-economic principles [Soltani et al., 2015]. The rate of MSW generation is increasing owing to the rate at which people migrate from the rural areas to the cities and also as a result of industrialization. This is becoming a challenge of major concern for governments at all levels. About 2.02 billion tons of MSW was said to be generated in 2006 all over the world. Between 2007 and 2011, the rate of generation of MSW rose by 37.3% [Danbuzu et al., 2014]. It was estimated by the World Bank that developing countries (DCs) spend about 20-50% of their annual budget on waste management (WM) yet about 30-60% of wastes in these cities are not being collected. These are the major challenges that DCs like South Africa are facing [UNEP/IETC, 2009b]. Due to these problems, most DCs are presently looking for methods of redirecting wastes that go to landfill to resources and recouping materials, creating income and jobs. It was this that prompted the Integrated Solid Waste Management (ISWM) approach which focuses on 3R (reduce, reuse and recycle) [UNEP/IETC, 2009b]. The present material stream in most DCs is linear flow (LF) yet the entire World is tending towards circular flow (CF) [Lehmann, 2011]. In a linear economy, raw materials are extracted from natural resources and are converted to finished products and the products are distributed to the final consumers while the final consumers dispose the products at the end-of-its-life [Ellen MacArthur Foundation, 2013b]. A circular economy (CE) on the other hand, helps to minimize pressure on the earth's natural resources. Rather than extracting virgin materials from natural resources, items are reused and recycled. Circular economy increases the potential for material and energy recovery from waste items [ESA (Environmental Services Association), 2013]. Between 1960 and 2013, the rates of MSW generated in the United States of America (USA) were 88 and 254 million tons (Figure 1.1) and the amount that were recycled and composted were 6 and 87 million tons (Figure 1.2). Right now, the ISWM which is also referred to as Solid Waste Management Plan (SWMP) is not adequate to handle the issue so a better alternative was developed which is circular flow (CF) [SCRD Solid Waste Management Plan Update Working Group, 2011].

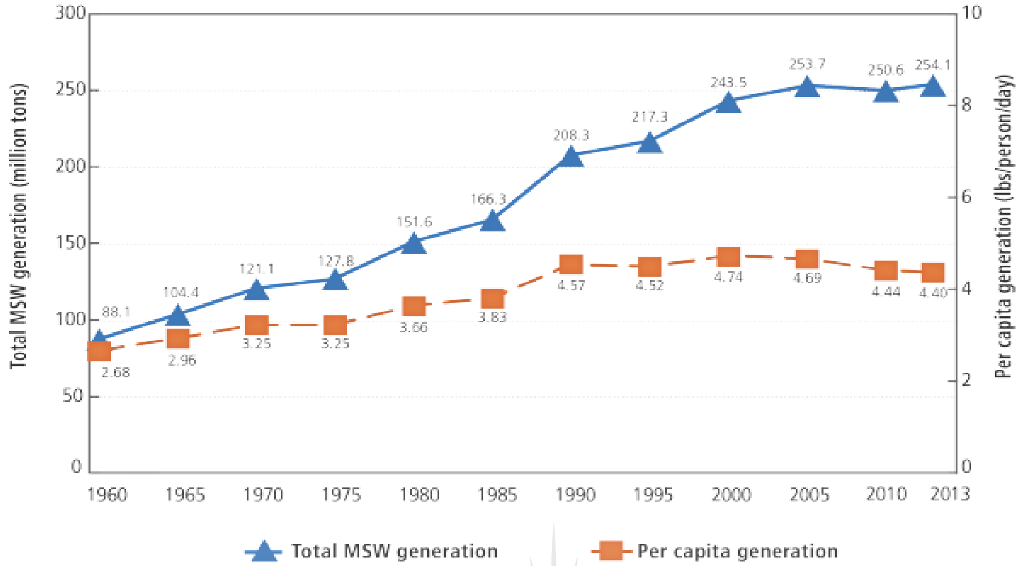

Figure 1: 1: MSW Generation Rates in USA, 1960-2013 [EPA (Environmental Protection Agency), 2015]

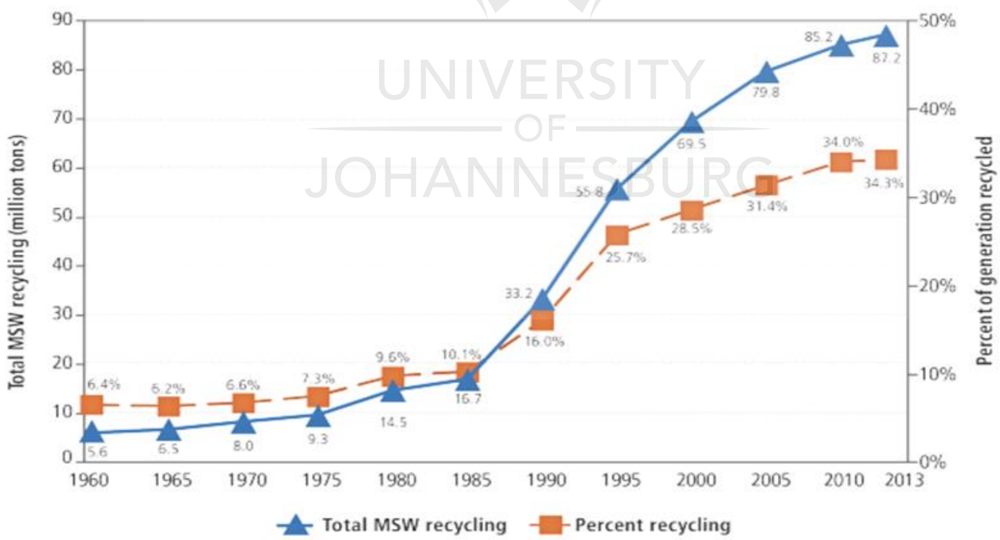

Figure 1: 2: MSW Recycling Rates in USA, 1960 to 2013 [EPA (Environmental Protection Agency), 2015]

1.2 Problem Statement

Man has abused the assets on earth in his efforts to survive. Man has additionally used the environment for the disposal of the wastes created by his activities [Uriarte, 2008]. Waste generation became a problem when man began to live together in settlements, groups and towns several decades ago; thus waste has been accumulating in substantial amounts. Influx of rural dwellers to the urban centres, industrialization and improvement in the living standards of the people have largely contributed to the acute growth rate of MSW [Worrell and Vesilind, 2012, Asian Productivity Organization, 2007, Abdoli et al., 2016]. Waste can be seen as items which are discarded [Sasikumar and Krishna, 2009]. SW has turned into a noteworthy result of development and industrialization; still a portion of the difficulties to its management are being felt pointedly in the developing countries (DCs) [Thomas-Hope, 1998]. Expansion is always accompanied with an impact on the environment and waste generation is one of them. Currently, waste has turned into a noteworthy point of talk by researchers in the institutions of higher learning and has additionally been surfacing in articles by columnists to the overall population.

In the fast growing urban areas of developing countries (DCs), urban solid waste management system (USWMS) is seen as the most awkward and strenuous issue confronted by the city. In high income countries, the issues regularly concentrate on the shortcomings and high cost of disposing of the large volumes of domestic and industrial wastes. In lower income countries, the essential issues are related to collection and disposal, with 33% of all SW generated in the DCs remaining uncollected. Hence, increased SW generation causes more environmental issues in third world countries, since most urban zones are not organized to manage it in the context of institutional, regulatory, budgetary, and technical frameworks and also lack of public participation [Sankoh and Yan, 2013].

South Western Townships (Soweto) was chosen as a case study given its uniqueness of having one of the eleven depots (Zondi depot) operated by Pikitup (PU) and the depot was the second location where separation of waste at source was launched. The depot is also not far from one of the functional landfill sites (Marie Louise) controlled by PU. The whole idea was to assess the effectiveness of the source separation of waste project currently running at Zondi and thereafter conduct waste composition studies at the Marie Louise landfill site (LS) in order to evaluate the various components of the waste streams disposed of to the LS. This was for easy access to the site in order for the composition studies to be carried out. Source separation of waste has been in place in the Waterval area since 2009 before it kicked off on the 1st of October, 2012 at Zondi community in Soweto. The essence of the source separation of waste project is to get people involved in waste management (WM) that will ultimately lead to sustainable solid waste management (SSWM). The project will cause the people to have a change of attitude towards waste. Hence, rather than seeing waste as problem, people will begin to see it as resource and consequently through its separation from the source; income will be earned by the people through the sales of recyclables and jobs will also be created when industries make use of the recyclables; in the long run, rates of crime will be drastically reduced in the society.

1.3 Overview of Pikitup Johannesburg (SOC) Limited

Pikitup (PU) Johannesburg (JHB) (SOC) (State Owned Company) Limited came into existence on the 1st of November, 2001 as an independent municipal organization. It is owned by the CoJ and its responsibility is to provide waste management (WM) services in the CoJ. CoJ has made an agreement with PU concerning service delivery to her residents [Pikitup (Pikitup Johannesburg SOC Ltd), 2015/16]. Around 4.4 million people are being given different WM services by PU. The municipality does collect and dispose around 1.2 million tons of waste every year. PU is charged with the mandate of providing sustainable integrated waste management (SIWM) services [Pikitup (Pikitup Johannesburg SOC Ltd), 2012/13]. It has eleven depots, four operational landfill sites (LSs) and two closed LSs, forty-six garden sites and one composting site as areas of operations. One of the depots is situated in Soweto and the depot is known as Zondi depot. Also the landfill site (LS) where this study was carried is located at Roodepoort (Figure 1.3) [Pikitup (Pikitup Johannesburg SOC Ltd), 2011/12].

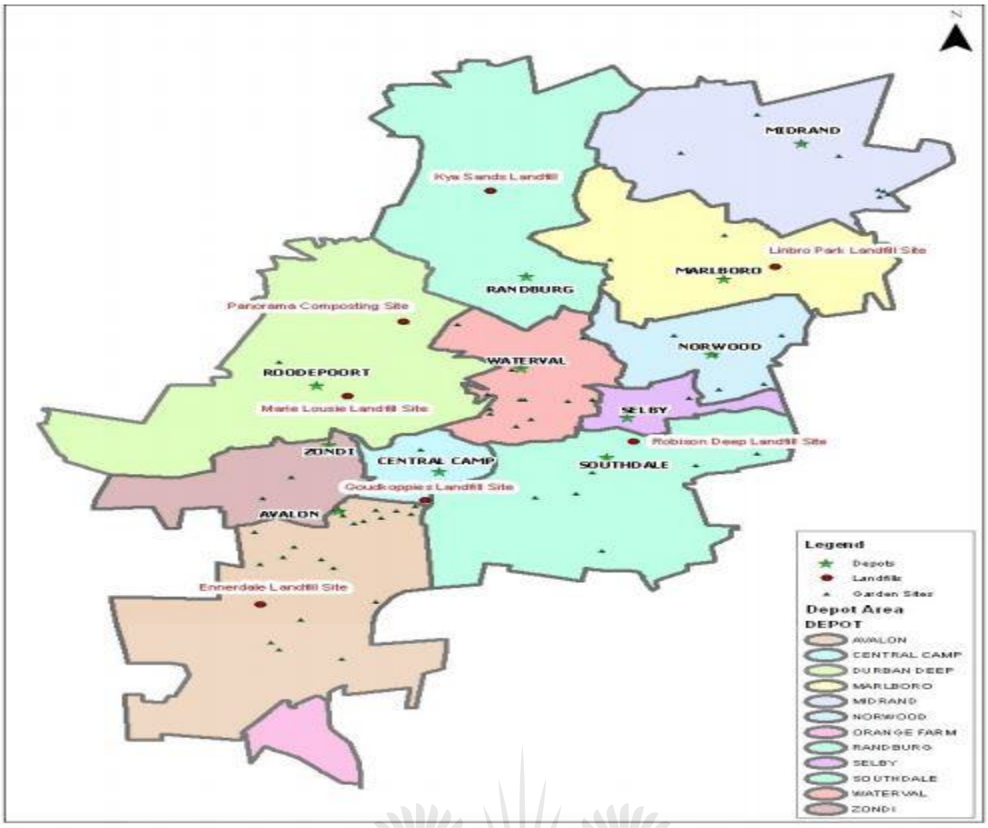

Figure 1: 3 : Pikitup Area of Operations [Pikitup (Pikitup Johannesburg SOC Ltd), 2009/10]

1.4 Motivation for the study

Governments in developing countries (DCs) like South Africa are confronted with problems that result from waste that is being generated by the citizens through domestic and industrial activities. The impact of this waste is so enormous and it includes pollution of water, land, air and the environment as a whole. There are various kinds of social and economic problems that are associated with the disposal of this waste such as disposal of used tyres. Piles of waste tyres often result in fire hazards and it lead to wanton destruction of lives and properties. It could also harbour mosquitoes and rat which can transmit diseases to the inhabitant and air pollution could also result from its burning. Also, polythene nylons, take-away plastic and plastic bottles, cans etc., often litter in the streets in DCs and these block waterways during rainy season and the resultant effect on the environment is flooding. These items can be reused, recycled and can serve as resources to industries and some persons can also earn income from the sales of these items to industries.

1.5 Project Objectives

The primary aim of this research work was to develop a Zero Waste (ZW) Project involving the characterisation, utilisation and management of landfill municipal solid waste (MSW) for Soweto and its environs.

The aim would be achieved through the following objectives:

- ✓ To find out the various components of the wastes generated in the municipality as baseline for complete diversion of MSW from going to the landfill.
- ✓ To find out whether people are properly educated on environmental matters.
- ✓ To identify the problems associated with the collection and disposal of solid waste (SW) in the municipality.
- ✓ To determine an economic evaluation of setting up a recycling facility.

1.6 Research Questions

- What are the characteristics and quantities of MSW generated in Soweto?
- What are the perceptions of the people of Soweto on municipal solid waste management (MSWM)?
- What are the social and economic problems that result in inefficient solid waste management (SWM) in Soweto and the steps required to mitigating these problems?
- What are the potential utilization of food waste (FW) and potential revenue from MSW recycling in Soweto?

1.7 Contribution to Knowledge

The research study on the characterisation, utilisation and management of MSW (Zero Waste) is expected to:

1. Provide information on how MSW has potential economic benefits when it is being used as resources to other industries rather than sending it to landfills.
2. Provide information on how downstream jobs can be created through MSWs diversion from going to landfills.

3. Provide information on specific local industry sectors for ZW process components and/or on how to reduce the amount of retailer and 'carry home' packaging items.
4. Provide information on the benefits of ZW to both the government and the general public.
5. Provide information on the various economic instruments (EIs) in developing countries (DCs).

1.8 Scope of the Project

This study on ZW project was carried out in Soweto and its environs, GP, South Africa. Waste composition studies were carried out during the winter and summer at the Marie Louise landfill site (LS). Data were collected and analysed. Experiments were carried out on the food waste (FW) samples that were collected from the LS. The experiments that were conducted are Elemental Composition Analysis and Proximate Analysis of the food waste (FW) fractions. Finally, an engineering economic analysis was conducted to determine the financial feasibility of this project.

2.0 CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

The literature review focuses on Municipal Solid Waste (MSW), problems of MSWM in DCs, solid waste quantification, solid waste classification, solid waste composition and characterization, Integrated Solid Waste Management (ISWM), current waste handling methods and their evaluation in DCs, waste treatment methods, economic instrument for sustainability and ZW and its implementation.

2.1.1 Waste and Waste Management

Waste has continued to become an issue everywhere and at all levels. This is because the general public are not ready to have a shift or change of lifestyle in terms of their consumption habits [Read, 2001]. Waste is legally defined as any object which the generator plans to get rid of. Waste can be categorised into municipal waste (household waste and commercial waste); industrial (including agricultural) and commercial waste; construction and demolition waste and hazardous waste [DEFRA (Department for Environment Food and Rural Affairs), 2013b]. Waste is an aftermath of different tasks and can serve as an input to productive tasks by means of energy recovery [DEFRA (Department for Environment Food and Rural Affairs), 2011]. Human activities often generate wastes and majority of them are solid in nature [Babayemi and Dauda, 2009]. Waste management (WM) encompasses reduction of waste, reuse, recycling, separation at source, collection and transport, composting, energy recovery and eventually its disposal to the landfill sites (LSs) [Ethiopia Public Health Training Initiative (EPHTI), 2004]. WM consists of two sectors. These sectors are formal and informal. The formal sector comprises of both the municipality and the private organizations. The primary responsibility of the municipality is the collection, storage, transport and ultimately disposal of the waste through the LSs and other means of disposal. The private organizations help to recycle the waste products and thereafter sell them to industries that make use of recyclables. The informal sector comprises of the waste Reclaimers (scavengers), scrap dealers and buyers who buy waste items from the scavengers and then sell them to industries. Householders can also be co-opted into the informal sector if source separation is taking place within the households. WM hierarchy is depicted in

Figure 2.1. It is represented on a pyramid from the most preferred options to the least preferred options. The preferred options include prevention, reduction, recycling and energy recovery and the least preferred option is the final disposal to the LSs [Karagiannidis and Kontogianni, 2012, Suchada et al., 2003, Ahmed and Ali, 2004]. Table 2.1 shows types of wastes and their sources.

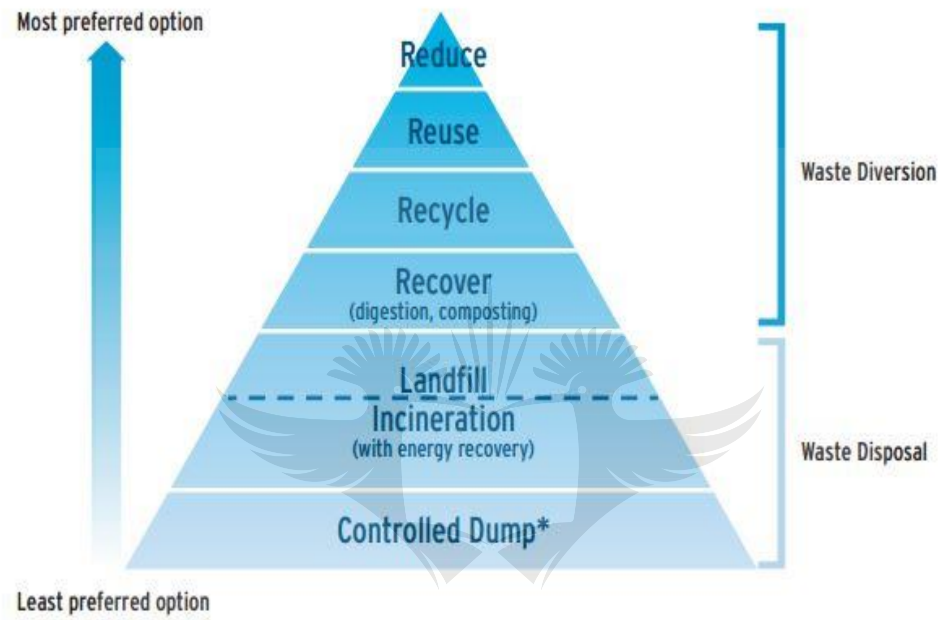

Figure 2: 1 : The hierarchy of waste management [European Union, 2010]

Table 2: 1 : Generators and Types of Solid Waste [Hoornweg and Bhada-Tata, 2012]

Source	Typical Waste Generators	Types of Solid Wastes
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g. bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes (e.g., paints, aerosols, gas tanks, waste containing mercury, motor oil, cleaning agents), e-wastes (e.g., computers, phones, TVs)
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants (excluding specific process wastes if the municipality does not oversee their collection)	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes
Commercial	Stores, hotels, restaurants, markets, office buildings	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes, e-wastes
Institutional	Schools, hospitals (non-medical waste), prisons, government buildings, airports	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes, e-wastes
Construction and Demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, bricks, tiles
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants	Street sweepings, landscape and tree trimmings, general wastes from parks, beaches, and other recreational areas sludge
All of the above should be included as municipal solid waste (MSW). Industrial, commercial, and institutional (ICI) wastes are often grouped together and usually represent more 50% of MSW. C&D waste is often treated separately: If well managed, it can be disposed separately. The items below are usually considered MSW if the municipality oversees their collection and disposal.		
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process wastes, scrap materials, off-specification products, slag, tailings
Medical waste	Hospitals, nursing homes, clinics	Infectious wastes (bandages, gloves, cultures, swabs, blood and body fluids), hazardous wastes (sharps, instruments, chemicals), radioactive waste from cancer therapies, pharmaceutical waste
Agricultural	Crops, orchards, vineyards, dairies, feedlots, farms	Spoiled food wastes, agricultural wastes (e.g., rice, husks, cotton stalks, coconut shells, coffee waste), hazardous wastes (e.g., pesticides)

2.1.2 Municipal Solid Wastes (MSW)

MSW could be described as any object or item that originates from household waste (HW), household hazardous waste, activities within communities, commercial and institutional operations but exclude radioactive and hazardous wastes [Cooper et al., 2012]. MSW covers all wastes that fall within the jurisdiction of the municipality and for which adequate plans have been made for its collection and disposal [WastesWork &

AEA Technology, 2010]. MSW covers food wastes, packaging items, street sweepings, garden wastes, recyclable materials, residue from production activities from industries and other wastes [Fewtrell, 2012]. MSW generated varies from place to place because of some factors. These factors include the high living standard of the people, increased movement of rural dwellers to urban centres; economic and industrial growth and climatic and geographical changes [Grover and Singh, 2014].

2.1.3 Challenges of MSWM in DCs

To manage MSW in urban centers is one of the greatest challenges in DCs owing to insufficient budget, rapid population growth and influx of people to urban centers [Pokhrel and Viraraghavan, 2005]. Fundamentally, it absorbs up to 1 per cent of Gross National Product (GNP) and 20 to 40 per cent of municipal revenues in DCs. Notwithstanding, when SW is managed well, it offers job to up to 6 workers for each **1,000** unemployed persons [Coffey and Coad, 2010]. This figure could account to up to **2%** of the national workforce. Generally, refuse collection is as frequently as could be expected under the given circumstances, however, more than **50%** of the refuse generated in South Africa remain uncollected and other populated districts of the urban zones do not receive regular attention. Hence, poor communities remain underserviced by MSWM [Coffey and Coad, 2010]. In many urban areas in DCs, the waste collection vehicles break down frequently. Consequently, there is typically accumulation of wastes and in rural areas there is no service coverage. There is illegal dumping in DCs. Constrained spending plans are discharged to the districts; henceforth, no quality services can be ensured [Ogwueleka, 2009, Khatib, 2011]. These issues are both social and economic in nature. The effects of all of these are pollution of water bodies and a threat to health and hygiene. One of the economic facets of the issue of MSWM is lack of adequate labour to discharge the SW services efficiently. Most officers charged with the responsibility are unprofessional in the field and there is also inadequate planning for solid waste management (SWM) at all levels [Hisashi and Kuala, 1997, Henry et al., 2006, Mian et al., 2013, Rana et al., 2015]. The challenges of managing SW has escalated recently owing to the fact that there are no more available spaces in the cities to site new landfill sites (LSs) due "not in my backyard" (NIMBY) complaint and also as a result of urbanization and industrialization [Asian Productivity Organization, 2007, Modak, 2010].

2.1.4 Solid Waste Quantification (SWQ)

Solid waste quantification is the critical facet of WM for sustainable development (SD). It helps the solid waste manager to make informed decision on the size of the equipment that will be needed for the management of waste. Quantities are estimated with respect to weight and volume. Quantification of SW is largely determined with respect to the previous data. Load count analysis, weight volume analysis and material balance analysis are the customary procedures that are utilized [Ejaro and Jiya, 2013, Gawaikar and Deshpande, 2006]. Waste generation factor is calculated by tracking the total waste generation per the population of a city at a given period of time (Equation 1) [MoUD (Ministry of Urban Development), November 2012].

$$Waste\ Generation\ Factor = \frac{Total\ Waste\ Generation}{Population\ of\ a\ City} \qquad (1)$$

2.1.5 Solid Waste Composition (SWC)

Waste composition shows the physical and chemical characteristics of waste [MoUD (Ministry of Urban Development), November 2012]. Household waste (HW) forms a major part of MSW. In order to get information on the sustainability of developing cities, data on quantity and quality of HW is very essential. Through HW, the socio-economic conditions of the households and urban society can be determined. There is a relationship between the standard of living of the population living in the cities and amount of the waste generated, and this can only be revealed through SWC study. The composition of waste also reveals the trends of waste reuse/recycling habits. Reliable data on solid waste composition study is required for WM for resource recovery [Edjabou et al., 2015, Matsunaga and Themelis, 2002, Suthar and Singh, 2015]. Nations are now required to meet the international standard of zero waste (ZW) and to achieve this reduction of MSW going to landfills, detailed information on the amounts of MSW generated and their compositions is the only strategy to achieve this [Burnley et al., 2007]. The composition of SW is largely determined by culture, economic development, climate and sources of energy. For a sustainable solid waste management (SSWM) program to be a success, data on composition study that highlights the quantity and type of waste components that are generated must be readily available. MSW composition studies become very crucial for the following reasons which include, evaluation of potential for material recovery, identification of origin of waste components, facilitation of design of processing equipment, determination of physical, chemical and thermal properties of waste and monitoring of compliance with both national and international standards [Gidarakos et al., 2006, Bandara et al., 2007, Palanivel and Sulaiman, 2014, Miezah et al., 2015]. The frequency of collection and disposal of SW impacts its composition [Hoornweg and Bhada-Tata, 2012].

2.1.6 Solid Waste Characterization (SCH)

MSW quantities can be quantified at all levels of government using site-specific and materials flow methods:

i. The site-specific method involves sampling, sorting, and weighing of each item of the waste stream. This procedure is essential when local waste stream is to be determined most especially if the number of samples collected over a period of time is very large. Organic wastes such as food wastes (FWs) and yard wastes can only be estimated through sampling and weighing. One of the drawbacks of sampling of waste is that they are based on few samples and may be misleading. For instance, if circumstances like unusually wet or dry season occurs, delivery of some unusual wastes during the sampling period and errors during sampling are experienced, any errors of this kind will be obvious when few samples are taken to represent a community's entire waste stream for a whole year. If this data is to be used at national level, the errors will be very noticeable. Also, sampling studies do not provide information about trends unless when it is performed in a consistent manner over a long period of time. These figures may not be acceptable at national levels unless if each province/state is ready to carry out this exercise consistently but studies have shown that it is not feasible [EPA (Environmental Protection Agency), 2013].

ii. MSW can also be quantified through the materials flow method. The materials flow method is based on weight of materials and products in the waste stream. Specific adjustment is always required to be made on the production data for each item category in order to estimate generation data.

Adjustments is also required for inputs and outputs for diversions from MSW like building materials made of plastic and paperboard that become construction and demolition debris. Lifespans of products are also required to be adjusted. In addition, organic wastes and other miscellaneous inorganic wastes are accounted for by compiling data from a variety of waste sampling studies. The drawback of materials flow method is that product residues like food left in a jar, detergent left in a box or bottle, and dried paint in a can and some household hazardous wastes left in a can are not accounted for [EPA (Environmental Protection Agency), 2008].

Solid waste characterization provides information on how to tackle the issue of WM. A clear idea of the characterization is necessary in order to define the reason for the characterization and to specify the method to be used. Some of the reasons may be: [Christensen, 2011].

(i) to make data on waste quantities and composition available for use either in regional or national waste statistics as a premise for setting up policy on recycling.
(ii) it will also serve as a means of grouping waste in line with national regulation that will determine the set rules for the handling of waste.
(iii) it will help in facilitating the design of incinerators.
(iv) it will help to track the extent to which quality standards for recycling items have been adhered to.
(v) it will serve as a means to measure the effectiveness of a recycled strategy when the amount of recovered and non-recover waste items are estimated.

2.2 Integrated Solid Waste Management (ISWM)

ISWM is a detailed exercise that encompasses many fields of study. It involves factors like environmental factors, cost of running the program and the needs of the community. ISWM comprises of the following elements: [National Institute of Industrial Research (NIIR), 2005]

i. Source identification of waste and its characterization.
ii. Structured waste collection.
iii. Minimization of the volume of toxic substances to be discarded.

iv. Land disposal of the waste beyond the reduction target.

v. Development of the first four steps to reduce cost and environmental impacts.

With Integrated Waste Management (IWM) in place, studies have shown that waste is reduced at minimal cost but there is risk involved in managing waste that is being minimised [Bagchi, 2004]. ISWM incorporates methods, scientific know-how and management programs in order to achieve WM objectives [Davis and Cornwell, 2008]. Figure 2.2 illustrates ISWM from the point of generation of waste to its collection; then to the transfer stations and finally transportation of the waste to treatment plant or LS. ISWM also encompasses waste avoidance, recycling, composting and disposal exercise [EPA (Environmental Protection Agency), 2002].

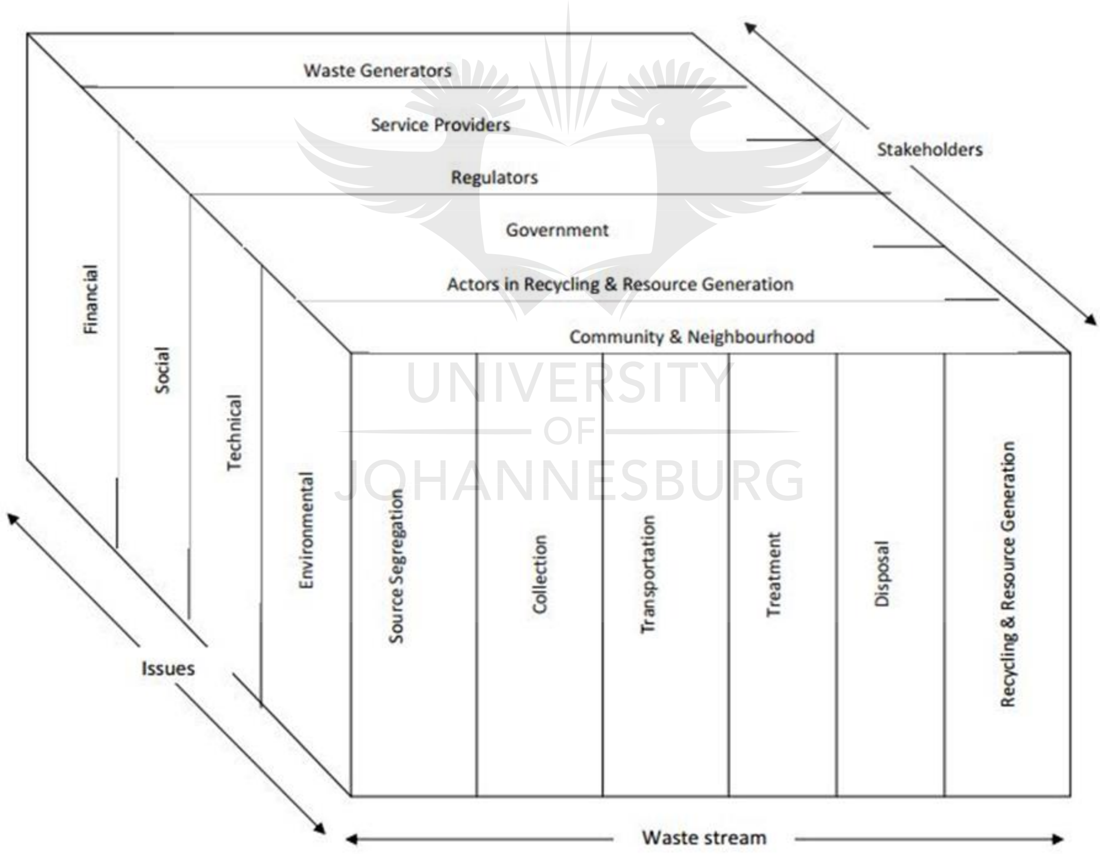

Figure 2: 2 : Integrated Solid Waste Management [UNEP/IETC, 2009a]

2.3 Current Waste Handling Methods and Its Evaluation in DCs

In South Africa or any DC, waste management methods include; waste generation and its storage; its segregation from point of source, its reuse and recycling both at household's level and at the informal sectors; also its collection primarily from the source and its transportation to either the community bin or transfer station. It also involves sweeping of streets and cleaning of public places like market squares, motor parks and tourism parks. Additionally, it encompasses management of transfer stations and community bins and ultimately the conveyance of waste from the transfer station to the disposal sites [Zhu et al., 2008]. Figure 2.3 shows the sequence of events on how waste is currently being managed in DCs.

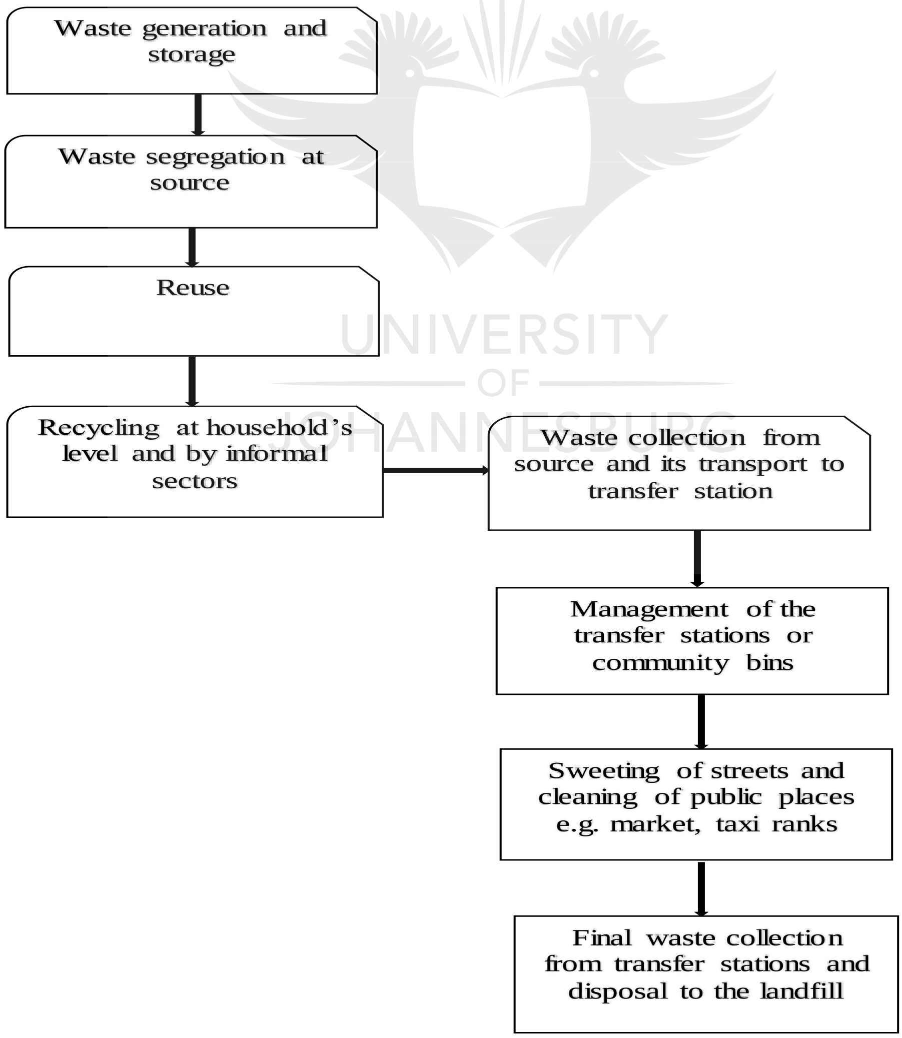

Figure 2: 3 : Ongoing MSW prevention, reuse and recycling programmes

2.3.1 Reuse

The public has several means of managing waste once it is generated. One of the means is reuse. People reuse the same product for the same purpose after it has been used. For instance, an individual may buy milk or oil in a container for use and after usage, the container may be returned to the store for refilling. Reuse extends the life span of a product [Vesilind and Morgan, 2004]. When reuse strategy is in place, materials are reused again in their original form. Reuse is one of the methods to handle plastic waste [Chartered Institute of Purchasing & Supply, 2007]. The moment the society begins to reuse material; the amount of waste, the consumption of energy and the amount of money spent will be reduced [Ngoc and Schnitzer, 2009]. The impacts of waste reduction by reusable products would be appreciated when single-use items are no longer in circulation. Household items can be reused and can also be donated to non-governmental organizations in order to minimized waste [Liu and Liptak, 1997].

2.3.2 Recycling

Recycling helps people to recoup valuable resources from waste items [Kaosol, 2009]. Landfilling of MSW is becoming unpopular owing to unavailability of land space in the urban centres and due to the fact that resources are being recouped from the waste disposed to the landfill through recycling [Choy et al., 2004a]. Recycling leads to the minimization of the cost of landfilling, conservation of the environment and elongation of the life-span of the LS. Recycling is also a method of waste treatment that is environmental-friendly. There are key actors that are to work together for the success of a recycling program. The actors are the consumers, the Reclaimers, the municipality, the informal sectors, the non-governmental organizations (NGOs) and the manufacturers [Isa et al., 2005]. Most of the recyclables in DCs are collected by the informal sectors like buy-back centres. These centres are funded through the sale of recyclables. The buy-back centres often times sell the recyclables to industries and exporters. Studies have shown that rates of recycling attained by the informal sectors is within the range of 20-50% which is closer to what is obtainable in the high income countries. Separation of waste at source is very essential for high percentage of recycling rates to be attained. To reduce the costs of managing landfills, pollution impacts of SW and the health threats of the public, recycling is one of the best options. Oftentimes, recycling is substantiated as the best because of the numerous benefits such as conservation of natural resources, prevention of pollution and prohibition of climate change [Casanova et al., 2009, Sealey and Smith, 2014, Tonjes and Mallikarjun, 2013].

2.3.2.1 Benefits of Recycling

Several environmental benefits accrue from recycling and these include conservation of natural resources, conservation of energy, minimization of both water and air pollution, minimization of the generation of greenhouse gas (GHG). Recycling also provides economic benefits and these include creation of jobs and saving of cost. Studies have shown that recycling encourages industrial growth and about **27,000** jobs have been created through recycling in some parts of the world [Department of Ecology, 2015, New Jersey WasteWise Business Network, 2013]. Studies have also shown that recycling creates **9** jobs for every **15,000** tonnes of waste that is diverted from going to the landfill. When the same tonnage of waste is incinerated, only **2** jobs are created and when the same amount of waste is also landfilled, only 1 job is created. It has been established by Environmental Protection Agency (EPA) that when **10,000** tonnes of waste is recycled, **36** jobs are created while only 6 jobs are created if the same amount of waste is sent to landfill [Oldman and Ogishi, 2001, Abdul-Rahman and Wright, 2014]. Other benefits of recycling are that landfilling is avoided and waste materials are reused [Department of Environment Climate Change and Water NSW, 2010]. When organic wastes are deposited at the LS, it undergoes chemical reactions whereby the waste is broken down and produces biogenic carbon dioxide (CO_2) and methane (CH_4). CH_4 contributes greatly to global warming since it has about **21** times the impact of CO_2 [Sánchez et al., 2015, EPA (Environmental Protection Agency), 2014]. As recycling continues, more industries will emerge and more jobs will be created. Recycling is an economical alternative of managing waste. The taxes required are lesser, energy is saved and it brings about a cleaner environment [Abdul-Rahman and Wright, 2014].

2.3.2.2 Method of Collection of Recyclables

Recycling methods of collection of recyclables include kerbside collection, drop-off centres and buy-back centres; [Abdul-Rahman and Wright, 2014]

(i) Kerbside collection: Waste generators separate their waste from the source by segregating the inorganic from the organic wastes. The wastes are collected by different collection trucks by the road side.

(ii) Drop-off centres may be located by the entrance of a supermarket or parking lots hence people drop off their recyclables there for collection.

(iii) Buy back centres are mostly controlled by cooperatives societies. They buy recyclables from waste pickers and from the community and they sell it to industries or to exporters.

2.3.3 Landfilling

A landfill is used to describe the physical facilities that are used to dispose SW and its residue into the surface soils [Moscone, 2014]. A landfill can be likened to a biochemical reactor where the feeds are SW and water and the products are landfill gas and leachate. SWs that are landfilled undergo different kind of changes which include physical, biological and chemical reactions. The chemical reactions that occur in landfill include dissolution and suspension of materials and the biological includes the conversion of products which result in evaporation and emission to the atmosphere. The major gases generated in the landfill are carbon dioxide and methane (CH_4) [Tchobanoglous and Kreith, 2002, Kjeldsen et al., 2002, Białowiec, 2011]. Emission of these gases from landfills can be hazardous to human health and the environment. These can lead to explosions and fires, odour nuisance, vegetation effects, local air quality effects and emission of greenhouse gases (GHG) into the atmosphere [Donovan et al., 2010, Schmid et al., 2000]. When waste is disposed of at the landfill site, it contains some carbon, this carbon decomposes gradually and it is emitted into the atmosphere. This is as a result of the various reactions that take place during the degradation of the SW. The reactions taking place in a landfill are very slow. One of the major challenges faced by WM agencies is in the siting of new sanitary landfills because there is no available land area in the urban centers [El Alfy et al., 2010]. Figure 2.4 illustrates how gas and lechate flows in a landfill and Figure 2.5 shows Marie Louise landfill site in the CoJ.

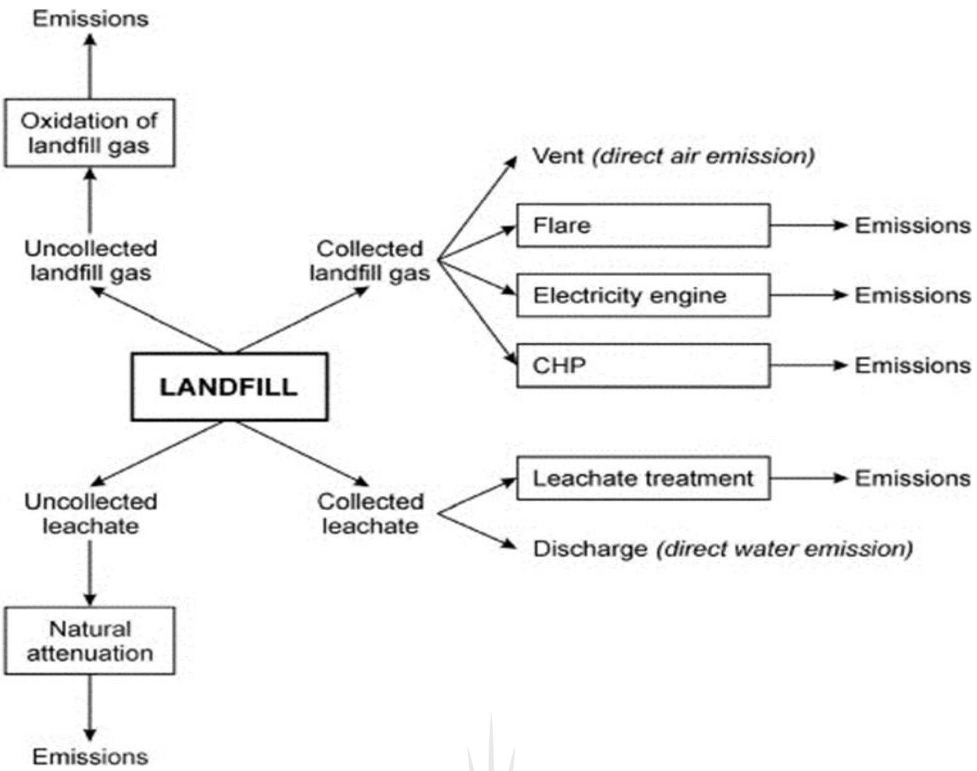

Figure 2: 4 : Gas and leachate flows in the landfilling model [Kirkeby et al., 2007]

Figure 2: 5 : Landscape Overview of Marie Louise Landfill Site

2.3.4 Incineration

Incineration of MSW is the costliest alternative of managing SW. Trained workers and high cost of maintenance are needed if incineration will be employed to manage waste. Hence, incineration may not be a better option where other easier and cheaper methods are available. High investment and operating costs are required to set up an incineration plant [The World Bank, 1999a]. Incineration has become the major method of managing MSW in most parts of the world because of lack of landfill sites in the cities [Zhang et al., 2014]. Incineration technology for MSW treatment is being used mainly to minimize the quantity of waste to as low as **95%**. WM using incineration is now a disputable disposal option in some countries owing to the hazard it poses to human health and the environment**.** Technical and economic reasons have made incineration of waste unpopular. MSWM is primarily concerned about human health and little or no impacts on the environment which cannot be guaranteed through the adoption of incineration as a disposal method. The main aims of incineration are to reduce volume, toxicity and reactivity of MSW. The volume can be reduced to about **90%** or more and the mass to about **75%** yet it is not a solution since there are solid residues like fly ashes that will be left as residue [Kadir et al., 2013, Zhao et al., 2012]. The minimum requirement for combustion of MSW to take place is at the temperature of **850 ^{o}C** and residence time of **2s** [DEFRA (Department for Environment Food and Rural Affairs), 2013a]. The products of combustion are nitrogen dioxide (NO), hydrogen chloride, (HCl), carbon monoxide, (CO), sulphur dioxide (SO_2), dust and heavy metals [DEFRA (Department for Environment Food and Rural Affairs), 2013a]. Figure 2.6 illustrates a MSW incineration facility.

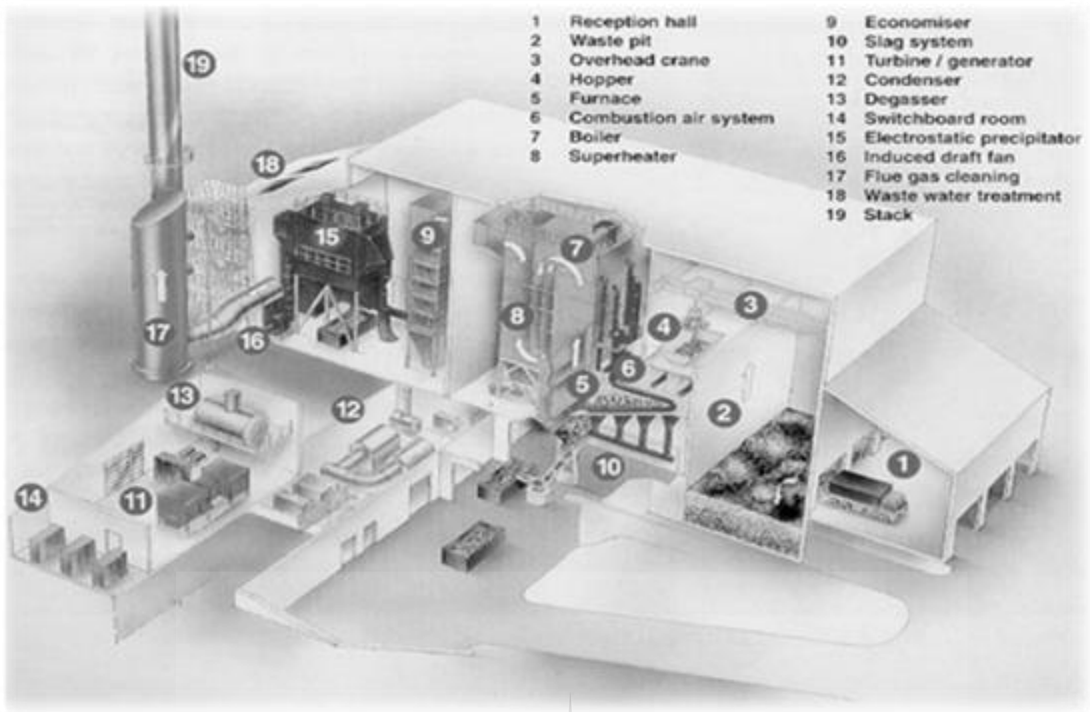

Figure 2: 6 : Expanded view of MSW incineration facility [The World Bank, 1999b]

2.3.5 Pyrolysis

Pyrolysis is a form of burning of SW through which organic substances are decomposed by heat in the absence of oxygen (O_2) [Onyango, 2014]. This reaction takes places under an operating temperature which is about 430 ^{o}C. In the course of this reaction, organic substances are converted to gases, liquid and solid residues which contain carbon and ash [Cheremisinoff, 2003]. When waste is decomposed through this process using heat in the absence of air, recyclable products are produced. Research has shown that this process has been used to produce charcoal from biomass several years ago. When the process is applied to waste prevention, MSW can be turned into fuel and safely disposable substances [Chen et al., 2014]. The products that are formed from pyrolysis process are carbonaceous char, oil and combustible gases. Pyrolysis may be classified into three categories: conventional, fast and slow pyrolysis. Conventional pyrolysis has to do with moderate heating of about 20 ^{o}C/min and the range of temperature of 400-600 ^{o}C. Fast pyrolysis is associated with high heating and low residence time (Figure 2.7). In slow pyrolysis, charcoal is produced at low temperature and high residence time [Uher et al., 2012, Ni et al., 2006]. Production of charcoal is favoured when temperature is lower and residence time is higher. When the temperature is high and the residence time is long, conversion of biomass to gas increases. Liquids are produced when the residence time is shorter and the temperature is at optimum [Wilson et al., 2013]. Table 2.2 shows how product formed in pyrolysis is dependent on temperature and residence time.

Table 2: 2 : Liquid, char and gas production as a function of temperature and residence time

Process	Fast Pyrolysis	Carbonization	Gasification
Conditions	Moderate temperature, short residence time especially for vapour	Low temperature, very long residence time	High temperature, low residence time
Liquid	75%	30%	5%
Char	12%	35%	10%
Gas	13%	35%	85%

Sourced: [Wilson et al., 2013]

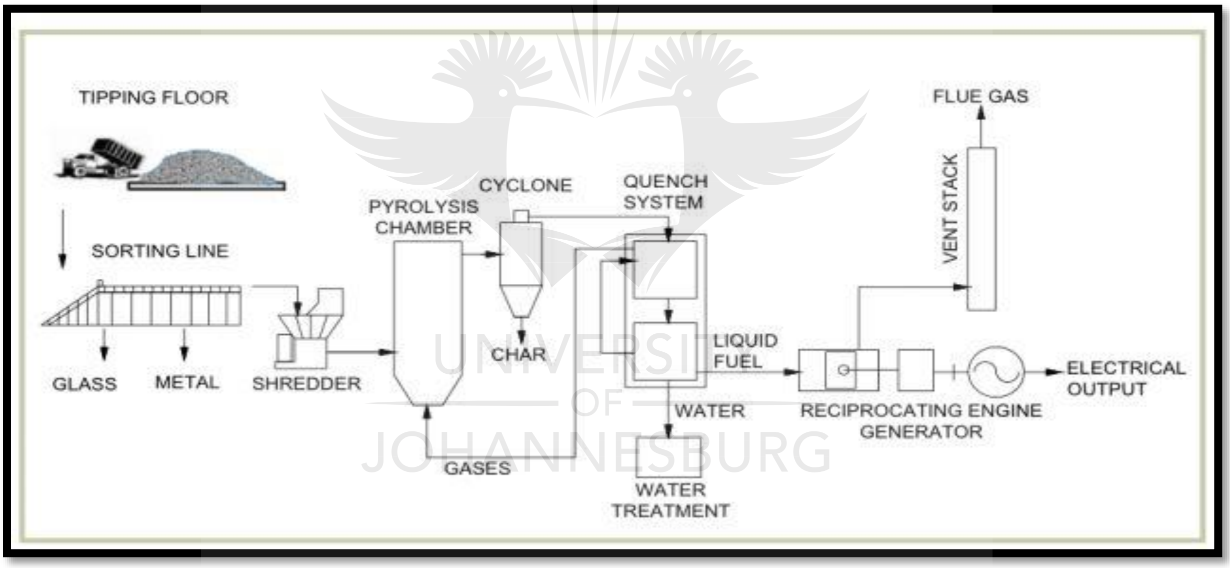

Figure 2: 7 : Process diagram for a fast pyrolysis system in which the char is entrained in the flow from the first reactor and recovered from the second chamber [Wilson et al., 2013]

2.3.6 Gasification

When organic materials break down at a high temperature in a reactor that is deficient of oxygen to form a synthesis gas, it is referred to as gasification. The synthesis gas is made up of CO_2, CO, hydrogen (H_2), methane (CH_4) and water vapour (H_2O) [Wilson et al., 2013]. It could also be referred to as the thermochemical decomposition of MSW using a fraction of oxidizing agent. It is considered as the best process for recovering energy from waste [Couto et al., 2015]. It could also be described as the "incomplete decomposition of carbon-based feedstock to produce synthesis gas. This process is close to pyrolysis; the only difference is that oxygen is included to keep a reducing atmosphere, where the amount of oxygen that is available is less than the stoichiometric ratio for complete combustion [Ray et al., 2014]. The synthesis gas can be used for heat, power, fuels, and fertilizers and can as well generate char, inert slag and steam. Landfilling of the char and slag may be required when it is generated. A Gasification facility often produces GHG, contaminants and toxins. Gasification equipment will require large quantities of residuals as feedstock which is about 75-330 tons per day and this does not agree with the ZW concept [Ray et al., 2014]. There are four kinds of gasifiers. These are fixed bed, fluidized bed, entrained flow, and plasma reactors. One of the most commonly used is the fixed bed reactor system. Fixed bed is of two types. They are counter-current (up-draft) (Figure 2.8) and co-current (down-draft) (Figure 2.9). Both gasifiers depend on downward fuel flow which is caused by gravity and it is naturally slow. For counter-current gasifier, the feed is fed from the top and flows down slowly through drying, pyrolysis, reduction and oxidation zone. Then, for the co-current gasifier, the feed and air move in the same direction; the volatiles from pyrolysis pass through the oxidation zone and the tar cracked partly and low tar content is left at the bottom as the gas products [Valkenburg et al., 2008]. A comparative study of the different treatment methods of MSW is illustrated in (Figure 2.10).

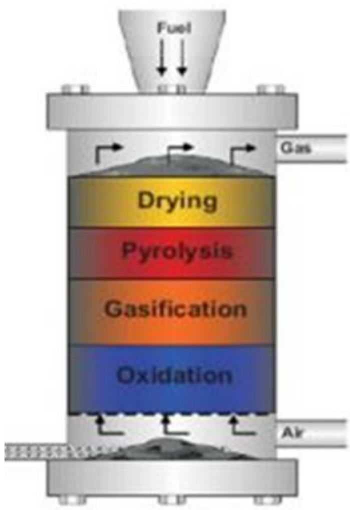

Figure 2: 8: Up-draft Gasifier [Mandl et al., 2010]

Figure 2: 9 : Down-draft [Beohar et al., 2012]

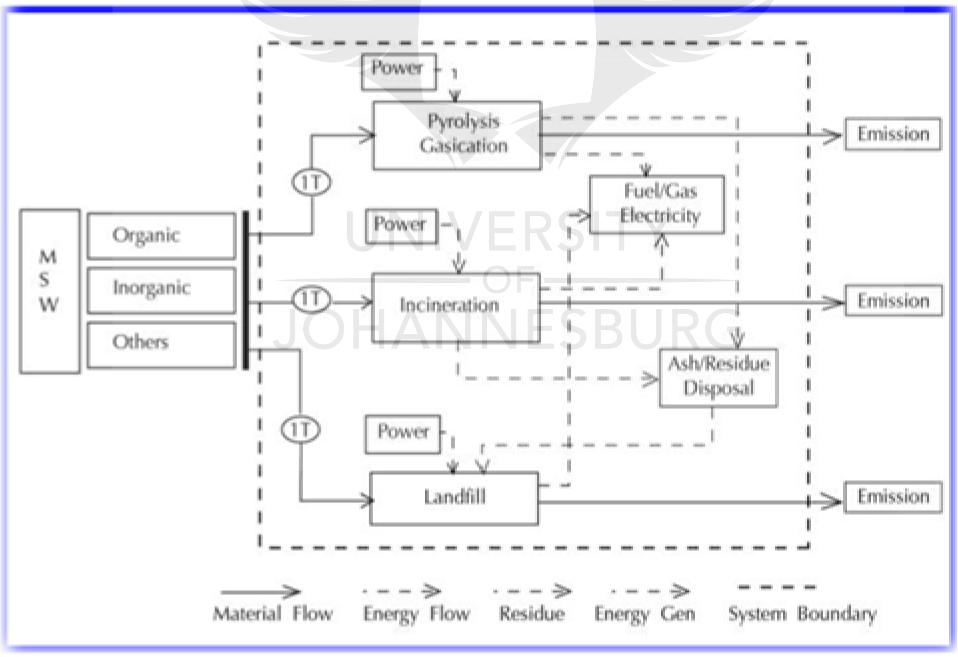

Figure 2: 10 : System Boundary for Different MSW Treatment Processes [Zaman, 2010]

2.3.7 Composting

Composting is closely related to biological decomposition of organic material. It is the controlled decomposition of organic matters by microorganisms into stable humus material. The process is controlled in the sense that it aims at accelerating decomposition, optimizing efficiency of compost and reducing any bad odour that could arise [Dickson et al., 1991]. Composting could be structured to deal with trimming of leaves, grass and tree pruning. Recycling and composting are the preferred MSWM options. Composting is a form of recycling. Like any recycling effort, compost can help to minimize the quantity of MSW going to landfill [Beyea, 1994]. Composting is used in WM as a means of recovering organic waste. It is a strategy for sustainable resource management (SRM). Composting of MSW is an effective means of managing waste since it recovers organic waste and useful end-product is also formed. Composting can serve many purposes such as reduction of odour and recycling of nutrients to soil through the action of microorganisms on MSW [Pathak et al., 2011].

2.3.7.1 Composting Methods

Composting methods include bin composting, passive windrows, turned windrows, aerated static piles and in-vessel channels [British Columbia Ministry of Agriculture Food and Fisheries, 1996].

(i) When compost is produced in a bin, it is referred to as Bin Composting. This is achieved by natural aeration and through turning. Tractor front-end loader is used in turning the mix compost. It requires cheap technology, average labour cost and average product quality. Bin composting is used for yard waste; poultry, pork mortalities and producing small quantities of manure. The required temperature ranges from 32 ^{o}C to 60 ^{o}C. Figure 2.11 illustrates Bin Composting.

(ii) When compost is produced in piles or windrows by natural aeration over a long period of time, it is known as Passive Windrow Composting. This also requires cheap technology and moderate labour techniques. Here, porosity of the initial mix, uniformity of the product mixing and the size of particle are thoroughly examined and these contribute to the process speed and the quality of the product.

(iii) When compost is produced in a windrow with the aid of mechanical aeration, it is known as Turned Windrow Composting. Here, the windrow turner which is powered by a farm tractor or self-propelled equipment is used to aerate mix compost. This requires cheap technology and average labour technique and the product is usually uniform compost.

(iv) In Aerated Static Pile Composting, compost is produced using mechanical aeration. Air is drawn through compost material in order to achieved aeration. Electrical motors, fans and ducting or other various sensors and alarms can be used for aeration systems. This composting method provides cheap technology and average labour technique and occasionally it results in non-uniform product.

(v) When compost is produced using silos, drums, or channels that make use of high-rate controlled aeration system, it is called “In-Vessel Composting” and is designed to operate optimally. Aerating machines provide continuous agitation and through this, aeration of material is achieved. This offers high technology but average labour techniques and product is usually uniform.

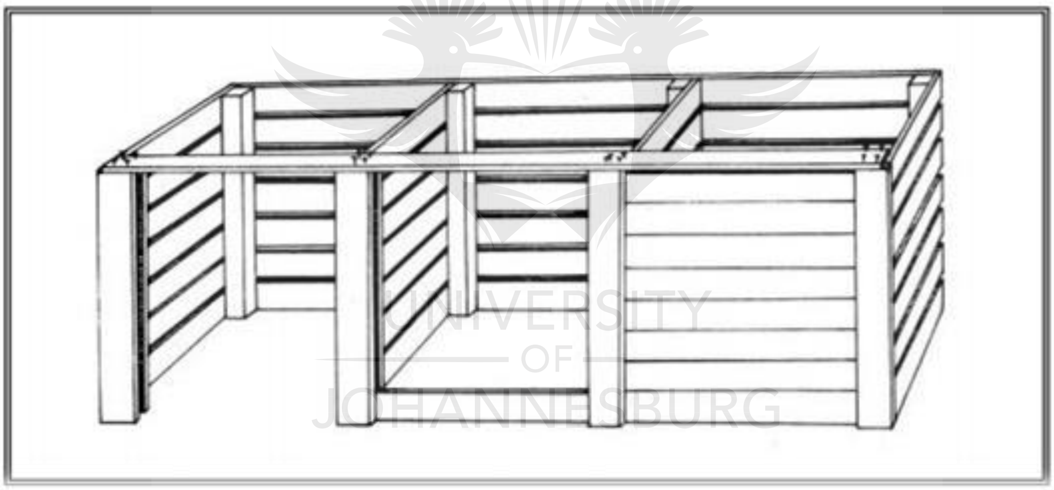

Figure 2: 11 : A Wooden Bin Unit, with Three Compartments [British Columbia Ministry of Agriculture Food and Fisheries, 1996]

2.4 Current Waste Handling Methods and their Evaluation

2.4.1 Source Separation of MSW

Source separation of MSW is capable of leading DCs to sustainable solid waste management (SSWM). With source separation of MSW in place, it will be very easy to attain sustainability in South Africa. Through the adoption of source separation in some parts of Soweto; raw materials become readily available to industries that make use of recyclables. Source separation cause people to view MSW as resources and not as a problem; it boost recovery schemes and also extends the life of landfills [Oduro-Appiah and Aggrey, 2013]. Separation of waste at source has been taken as the only successful method to reduce waste and to improve recycling [Yang et al., 2011]. Several methods of waste management have been adopted yet it has been established that the fruitful means to manage wastes is through source separation [Yang et al., 2011]. Source separation of waste can be accomplished through the use of separate bins at households and delivery of recyclables directly to drop-off centres. Construction and demolition waste, organic waste, plastic waste, textiles, electronic waste and paper waste are mostly earmarked for separation at source. Source separation of waste helps to produce homogenous waste streams hence recovery of valuables become effortless [Western Australia, 2014].

2.4.2 Landfilling of Organic MSW

Organic wastes collected by PU are often landfilled. These are left to degrade naturally in landfill sites. The continuous dumping of these organic wastes to the landfill site brings about significant adverse environmental impacts. These wastes have a very high potential of methane production which can impact the environment negatively and consequently poses a threat to human health. Hence, most municipalities today are tending towards reuse, recycling and energy recovery in order to have zero emission to the environment. There are two key types of wastes here that need urgent attention since the municipality is not doing anything about them than to send them to the landfill sites to be compacted with the soil. These are food waste and garden wastes. The compaction of these wastes reduces the space requirement and life span of the LSs [Al Seadi et al., 2013, Weber et al., 2011, Hanson et al., 2010, Waste & Resources Action Programme, 2014].

2.4.2.1 Food waste

Food waste implies loss of resources which can be utilized in energy production and also as an input to production processes. The more the quantity of food waste in the waste streams, the more urgent separation of waste at source needs to be implemented. When food waste and other organic wastes are separated from source from other waste streams, compost can be produced as soil amendment and biogas as a renewable energy. Food waste results in emission of CO_2 into the atmosphere and this impact the environment negatively. Food waste refers to food that was meant for human consumption but was diverted to other forms or is disposed of, probably as a result of excessive production or it is harvested too early [Gustavsson et al., 2013, ISWA (International Solid Waste Association), 2013]. Food waste could also mean discarding food intended for human consumption even if the food has not expired. There are factors that are responsible for food wastes and these include; inadequate infrastructure, inadequate logistics, shortfall of technology; shortage of skills, knowledge and capacity to manage food items and inability to access the market [Food Agriculture Organization of the United Nations, 2013, Aschemann-Witzel et al., 2015]. Studies have shown that about 33% of the food that is intended for human consumption globally is disposed of every year. Most of this waste food emanates from high-income countries. This occurs when the manufacturers hike the prices of food, not willing to reduce the price and consumers likewise not willing to buy. It also results from the manner in which consumers handle their food items [Graham-Rowe et al., 2014]. A study done in the United Kingdom shows that consumers disposed about 33% of their food; hence a thorough change of attitude has to be employed [Krzywoszynska and Stuart, 2011]. Figure 2.12 shows the Food Recovery Hierarchy.

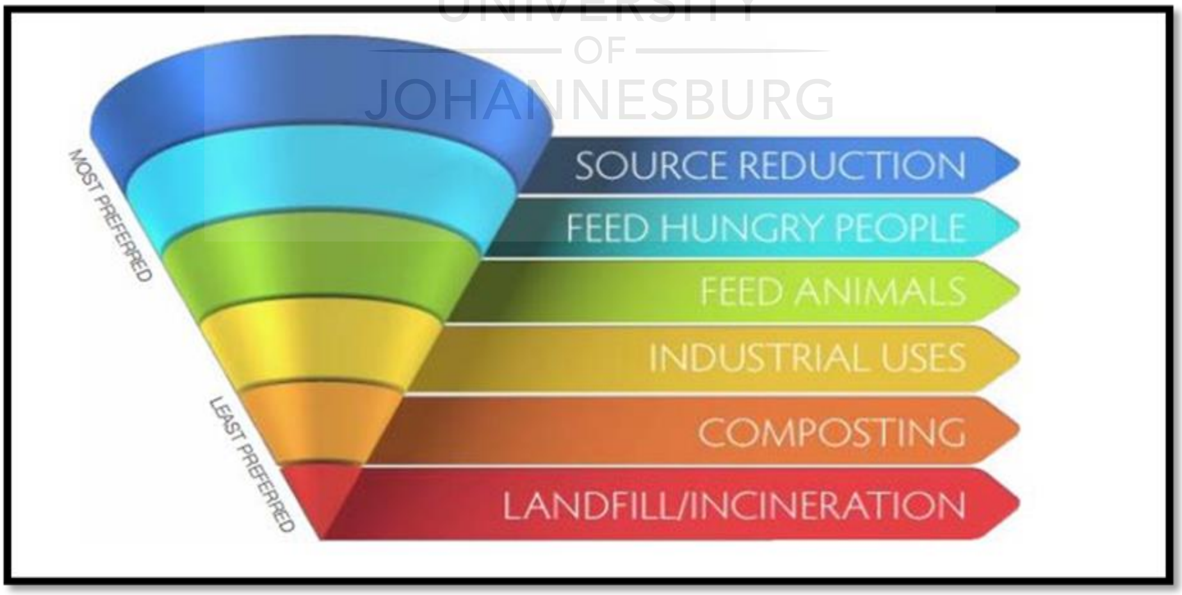

Figure 2: 12 : EPA Food Recovery Hierarchy [Food Marketing Institute (FMI) Grocery Manufacturers Association (GMA) and National Restaurant Association (NRA), 2014]

2.4.2.2 Yard Waste

Yard waste includes leaves, garden residues, chipped shrubbery; tree trimmings and grass clippings [Department of Environmental Protection Bureau of Waste Management, 2009, Northeast Recycling Council Inc., 2010]. Yard waste comprises of all vegetation materials that can decompose. Some of them are tree trunks, bushes, shrubs, branches of trees, flowers and festive plants. Yard waste can be best managed when data are collected; when reduction at source of generation is promoted or source separations are encouraged and the residuals are treated by composting. Yard wastes are biodegradable materials that can be easily separated from other waste streams from source and can be composted and use as soil a conditioner in agricultural purposes. The source of generation of yard waste is often from landscape and vegetation. Yard waste can be managed properly when the 3R is employed [FC (Franklin County), 1999, The Government of the Hong Kong Special Administrative Region, 2014, Evanylo et al., 2009].

2.4.3 Pikitup's Landfill Operation

Currently, the mode of operation and management of SW at the four functional LSs operated by PU is daily compaction of MSW, specifically the organic wastes. This is done to prevent windblown litter, odour, vermin and dust. The four operational LSs are Marie Louise, Robinson Deep, Goudkoppies and Ennerdale. In 2009, an unconventional audit was conducted on all the four LSs; results were obtained and the overall average score for all the sites was 77% [Pikitup (Pikitup Johannesburg SOC Ltd), 2010/11]. The overall compliance score was 68.5% in 2013 and 80.2% in 2014 [Pikitup (Pikitup Johannesburg SOC Ltd), 2013/14]. The LSs are controlled in agreement with Section 20 of Environment Conservation Act 73 of 1989. All these LSs have limited lifespan before they will be closed. Marie Louise landfill site has less than six years left as it will be closed on the 1st of January, 2021; Robinson Deep has less than seven years left as it was forecasted that it will be closed on the 1st of May 2021, Ennerdale has about thirteen years left and Goudkoppies has about fifteen years left and both are anticipated to be closed on the 1st of July 2027 and 1st of January 2030 respectively [Pikitup (Pikitup Johannesburg SOC Ltd), 2013/14]. Table 2.3 shows the capacity details of the active LSs operated by PU in the City of Johannesburg.

Table 2: 3 : Capacity details of landfill sites in the City of Johannesburg

Disposal site	Available space (m3)	Remaining life of dump site (years)	Expected date of closure (month & year)
Marie Louise	1744613	6	2021/01/01
Robinson Deep	4972680	7	2021/05/01
Ennerdale	1112271	13	2027/07/01
Goudkoppies	4581290	15	2030/01/01
Total	12410854		

Sourced: [Pikitup (Pikitup Johannesburg SOC Ltd), 2013/14]

2.4.3.1 Pikitup's Mode of Operation

PU has been charged with the responsibility of maintaining the cleanliness of the entire CoJ. Some of the responsibilities are to clean public hostels and housing owned by the public sectors. PU also goes the extra mile by cleaning areas that are used for informal trading and taxi ranks but these are done for a charge. Currently, PU operates two major services. These are council services and commercial services; [Pikitup (Pikitup Johannesburg SOC Ltd), 2013/14]

i. The council services encompass collection and disposal of domestic waste, cleaning of streets, flushing of lanes, cleaning of areas, management of litter bins, illegally dumped waste collection and collection of animals found dead in public areas.

ii. The commercial services include collection of bulky wastes, composting of wastes, cleaning of venues used for special events and recycling of wastes. PU also offers services referred to as Round Collected Refuse (RCR); Dailies Services and Bulk services. The RCR service is made up of compacted wastes collected from different locations. The dailies service is made up of non-compacted wastes collected from places like restaurant, shopping mall and street sweeping [Pikitup (Pikitup Johannesburg SOC Ltd), 2013/14]. The bulk service includes the collection of furniture, electrical appliances, mattresses and many more [Pikitup (Pikitup Johannesburg SOC Ltd), 2015].

2.4.4 Life Cycle Assessment (LCA)

Life cycle assessment (LCA) is the general estimation of the normal assets that are used and the effect of the outflow from the material on the environment [World Steel Association, 2015]. LCA is occasionally referred to as cradle to grave (C2G). LCA includes four components. These are the objective and extension; stock, sway appraisal and change evaluation [Department of Environmental Affairs and Tourism (DEAT), 2004]. Ecological features and potential effects of an 'item' life from crude material procurement to its production, its usage and final disposal are investigated through LCA. This is achieved by collating the list of appropriate inputs and outputs of a system, assessing the likely aftermath of the inputs and outputs and translating the outcome with respect to the goal of the investigation. An excellent structure to assess MSWM policies are provided to SW managers and decision makers through LCA approaches [Banar et al., 2009]. Studies have shown that LCA has been used as a tool for managing MSW effectively. It helps to access the environment for other WM options. LCA has been used to compare different WM methods in order to determine the waste disposal option with the least environmental impact [Yay, 2015]. LCA surveys the utilization of assets and the release of outflows to air, water, land and the generation of valuable items [Abeliotis, 2011]. Figure 2.13 illustrates the life cycle of MSW.

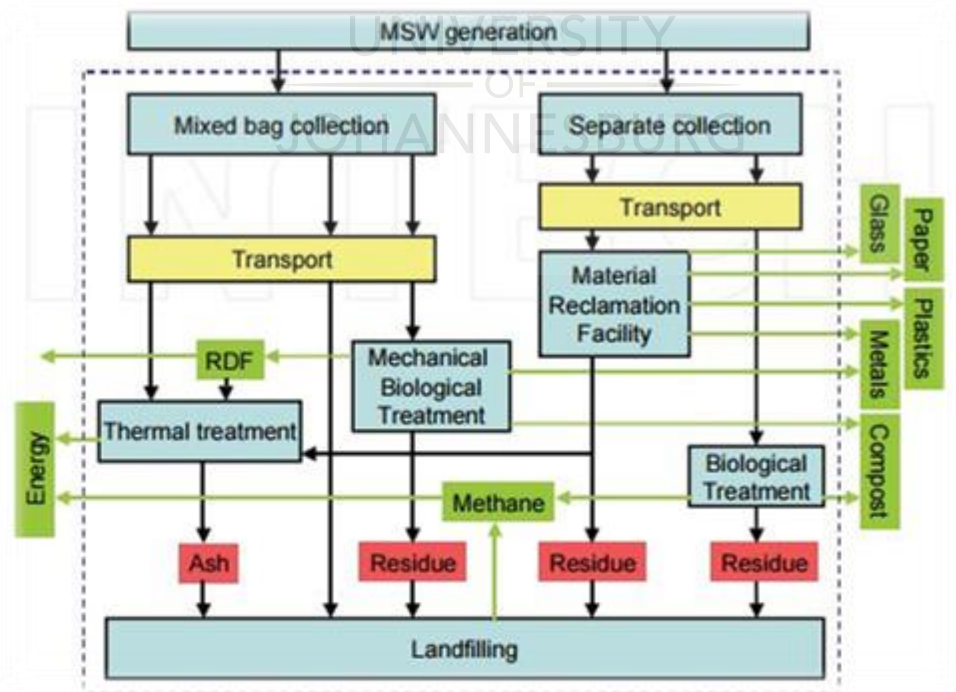

Figure 2: 13 : Life Cycle of MSW [Abeliotis, 2011]

2.4.5 Economic Instrument for Sustainability (EIS)

Economic instrument (EI) is often used by provincial and local government. EI includes variable waste disposal fees, advance disposal fees, taxes, tax credits, deposit/refund systems and financial bonuses. The variable disposal fees provide motivation in order to reduce and recycle since the garbage generated is proportional to the money charged for the disposal. Taxes and fees are structured in such a way that the cost of waste disposal will be included into the price of the product and these are called advance disposal fees. Tax credits grants can also be given to businesses and institutions that have taken giant steps to reduce waste at the source [Jessen, 2003].

2.4.5.1 Pay as You Throw (PAYT) Systems

''Pay as you throw" **(PAYT)** systems which is also referred to as variable rates programs or user-pay is a systems designed for households to pay more if they generate more wastes or pay less if they generate less wastes [Skumatz and Green, 2002]. To implement a PAYT system, a legal framework for the implementation of local waste charges has to be put in place [Puig-Ventosa, 2008]. PAYT systems encourage residents and businesses to participate in order to meet objectives for which the system is created and it is also of an economic incentive that can establish a link between waste charge payment and the amount and type of waste that is generated [Agència de Residus de Catalunya, 2010].

2.4.6 Economic Instruments (EIs) for MSWM in DCs

EIs for MSWM of some Cities around the world are randomly chosen and are briefly discussed. Some of these Cities are as follows;

2.4.6.1 EIs in Maputo, Mozambique

Maputo is the capital city of Mozambique and has a population of about 1.2 million people. The waste generated by the population was estimated to be about 1,000 tons of waste per day. The charge for waste collection is between 10 to 25 USD per ton and the fee is charged with the electricity fee. The main EIs in Maputo are household waste fee, for large scale non-household waste producers, revenue from commercial services provided by the municipality, disposal fee for current and future sites and other fines [Federal Ministry for Economic Cooperation and Development (FMECD), 2012]. Maputo province has an area of 23,669 km^2. Its boundaries are Gaza province to the north, South Africa to the south, Swaziland to the west and Indian Ocean to the east. Maputo province is further divided into eight administrative districts which include Magude, Moamba, Manhiça, Marracuene, Matola, Boane, Namaacha and Matutuine [Zacarias and Andersson, 2010].

2.4.6.2 EIs in Kenya

The management of MSW in Kenya depends solely on command and control strategies. This method has not been efficient in managing SW in Kenya. EIs have not been well implemented. Some of the instruments that are used are user charges, financial instruments like subsidies and licenses; fiscal instruments like imports duty waiver; deposit-refund systems, property rights, institutional reforms and regulations [Dauthy et al., 2005]. Command and control (CAC) is a tool employed to regulate attitude and some specific operations and to also correct any act of non-conformity through the use of fines [Nahman and Godfrey, 2010]. With CAC in place; when City powers promulgate a law, people are obligated to comply [PIDS (Philippine Institute for Development Studies), 2002]. CAC is a conventional method of SWM. This method compels the waste generators, waste collectors and the municipality to be conscious of the environment. The waste generators are compelled to manage their waste in a safe way. The waste collectors are also compelled to use proper equipment and safe means in the collection of waste and the municipalities are also compelled to provide a sanitary landfill site and a safe method of disposal that is environmentally friendly [Cointreau and Hornig, 2003].

2.4.6.3 EIs in Hatfield, Harare, Zimbabwe

Harare is the capital city of Zimbabwe. The city connects with other cities like Bulawayo, Masvingo, Mutare, Gweru and other cities at the border. Harare had a population of about 1.9 million people according to the population census figure of 2002. Highfield is one of the suburbs in Harare and it is situated at the south-west of Harare [Parliament Research Department, 2011]. The EIs employed by the Harare municipality for solid waste charge is a flat rate. This form of payment does not commensurate with the rate of waste generated. Hence, members of the public do not make any attempt to reduce, recycle or reuse their wastes since the fee is at a flat rate [Chikobvua and Makarati, 2011].

2.4.6.4 EIs in Johannesburg, South Africa

There are a number of issues confronting WM in SA. These issues range from inadequate collection services, illegal dumping of wastes, non-availability of land space for landfills, insufficient information on waste minimisation and recycling, absence of enforcement of regulations etc. Currently, in SA, the tool that is more pronounced is the CAC, though the polluter pays principle (PPP) is still being proposed either as EI or CAC. The EI that is very effective in SA at the moment is the plastic bags levy, although proposition is ongoing on the introduction of levy on tyres, packaging, batteries and electronics. The waste collection charges vary from one municipality to the other in SA [Nahman and Godfrey, 2010, Nahman and Godfrey, 2008].

2.5 Zero Wastes (ZW) and its Implementation in some Countries of the World

ZW is a well-planned and resourceful idea that guides people to copy nature so that waste materials can become resources for others to use**.** Zero waste helps in designing and managing processes well so that wastes can be eliminated [O'Malley and Brown, 2014]. Zero Waste (ZW) is often referred to as closed loop systems or cradle to cradle (C2C). ZW helps people to see waste as resources rather than problem. As far as nature is concerned, waste does not exist since all waste materials generated at a particular production stage can serve as raw materials at other stages [Recycling Council of British Columbia (RCBC), 2002].

2.5.1 Zero Waste Organizations

Zero Waste Europe (ZWE) is an organization that brings all the municipalities owned by the Europeans and other non-profit organizations together with the primary objective of waste prevention and economy flexibility in order to attain sustainability [Zero Waste Europe, 2013].

2.5.1.1 ZW in Capannori (CAP)

CAP is located in the North of Italy. The town achieved success on ZW through her strong policy decision and community participation. The population of the town is 46,700. Zero waste strategy was signed in 2007 and their goal was to achieve 40% waste reduction in 10 years but today it has achieved 82%. This community fought the construction of incinerators which led to her success. The Community then developed a door-to-door waste collection pilot scheme. This was done by separating waste from the source. Between 2005 and 2010, 82% ZW has been achieved through source separation and leaving just about 18% wastes to go to landfill. In 2012, the rate of waste separation at source increased to 90% [Zero Waste Europe, 2014].

2.5.1.2 Zero Waste in Argentona (AGT)

AGT is located in the northeast of Barcelona. In 2004, door-to-door collection was introduced and her recycling rates were doubled and this made her to be a reference point. In 1900, its population was 2,014 and in 2010, it was 11,718. The population has increased to 12,000 as of 2004. The door-to-door system was introduced in the old town where about 75% of the population resides while the remaining 25% lives in outskirts of the municipality [Vliet, 2014, Revolvy]. The door-to-door waste collection led to her success. At first, it was not an easy task since some few people opposed the process but the Council stood strong on her decision and remained focused. Thereafter, within few weeks the process began to run smoothly. In 2005, the door-to-door collection reached 70% and the overall separate collection rates stood at 50%. The overall recycling rates in AGT has increased and it was 68.5% as of 2012 [Zero Waste Europe, 2014].

2.5.1.3 Zero Waste in Emirate of Sharjah (EoS)

EoS is one of the States in the United Arab Emirates (UAE). EoS covers an area of 2,590 square kilometres. It has three enclaves which are situated on the east coast that makes it share border with Gulf of Oman. The enclaves are Kalba, Khor Fakkan and Dibba al-Husn. EoS is the third largest emirate in UAE [International Business Publications, 2013]. EoS is the only emirate that share borders with all the other emirates. The population of EoS is approximately 19% of the total population of the United Arab Emirates (UAE). The total population of EoS is **946,000** and about **85%** of the people lives in the city [FDi Supplement, 2013]. About **60%** of the wastes generated are recyclable. EoS was on course towards **100%** ZW in 2015. EoS has been moving progressively. It started from 5% in 2007 to 20% in 2008; 25% in 2009; 34% in 2010; 40% in 2011; 52% in 2012; 62% in 2013; 67% in 2014 and finally her set-target for 2015 was to attain 100% ZW to landfill and has resolved to be the first State in UAE that will attain 100% ZW to landfill [Bee'ah, 2015].

2.6 Zero Waste Models

The rates at which resources are been used up is on the increase and the level at which materials are being consumed is proliferating all over the world, hence, waste reduction has become a subject of more attention by governments and various organisations. For products, systems and the environment to be improved upon, the amount of raw materials being utilized must be reduced**.** Waste which is the by-product of every lifestyle poses threat to the environment since its generation is increasing on a daily basis [Lehmann and Crocker, 2013, Chartered Institute of Purchasing & Supply, 2007, Manitoba Conservation and Water Stewardship (MCWS), 2014]. This is not sustainable. Sustainability can only be attained when everyone is ready to make certain behavioural changes in terms of consumption habits. It becomes very crucial for people to change their consumption pattern [Dresner, 2008, Hubacek et al., 2007, Karwala, 2005, Asian Development Bank Institute for Global Environmental Strategies, 2008]. 'Sustainability is a form of advancement 'that meets the needs of the present without compromising the ability of the future generations to meet their own needs'[Emas, 2015]. For any system to be adjudged as a sustainable economy, waste must have been completely eradicated from such a system. Studies have shown that there is a link between living standard of the people and their waste generation. It is very obvious that this kind of lifestyle is not sustainable [Australian Bureau of Statistics, 2007, Bandara et al., 2007] . There are several issues at the moment that require urgent attention; one of it is global warming that has revealed that the current waste hierarchy, 3R (reduction, reuse, recycling) is not enough to address this social menace. Therefore, different methods of SWM must be employed. **N**ature itself produces no waste because it is self-sufficient and complete, therefore emulation of nature becomes very paramount for sustainability to be attained [Khan and Islam, 2012, Thompson, 2015, Gurjar et al., 2010]. Equation 2 shows the calculation of the waste diversion rate and the internationally accepted diversion = 85% [City of Boulder, 2015]. Figure 2.14 illustrates a sustainable economy.

$$\% \, Waste \ Diversion = \frac{Weight \ of \ total \ material \ recycled \ and \ composted}{Weight \ of \ total \ material \ discarded} \qquad (2)$$

Three models were developed for sustainable solid waste management (SSWM) in Soweto. The first model (Figure 2.15) shows that waste is minimized but no job is created. Figure 2.16 shows that waste is not minimized but jobs are created. The last model (Figure 2.17) shows that waste is minimized and several jobs are created at every stage of the WM. Figure 2.17 is adjudged as the best option if the municipality really wants to alleviate poverty of the general public and at the same provide qualitative service.

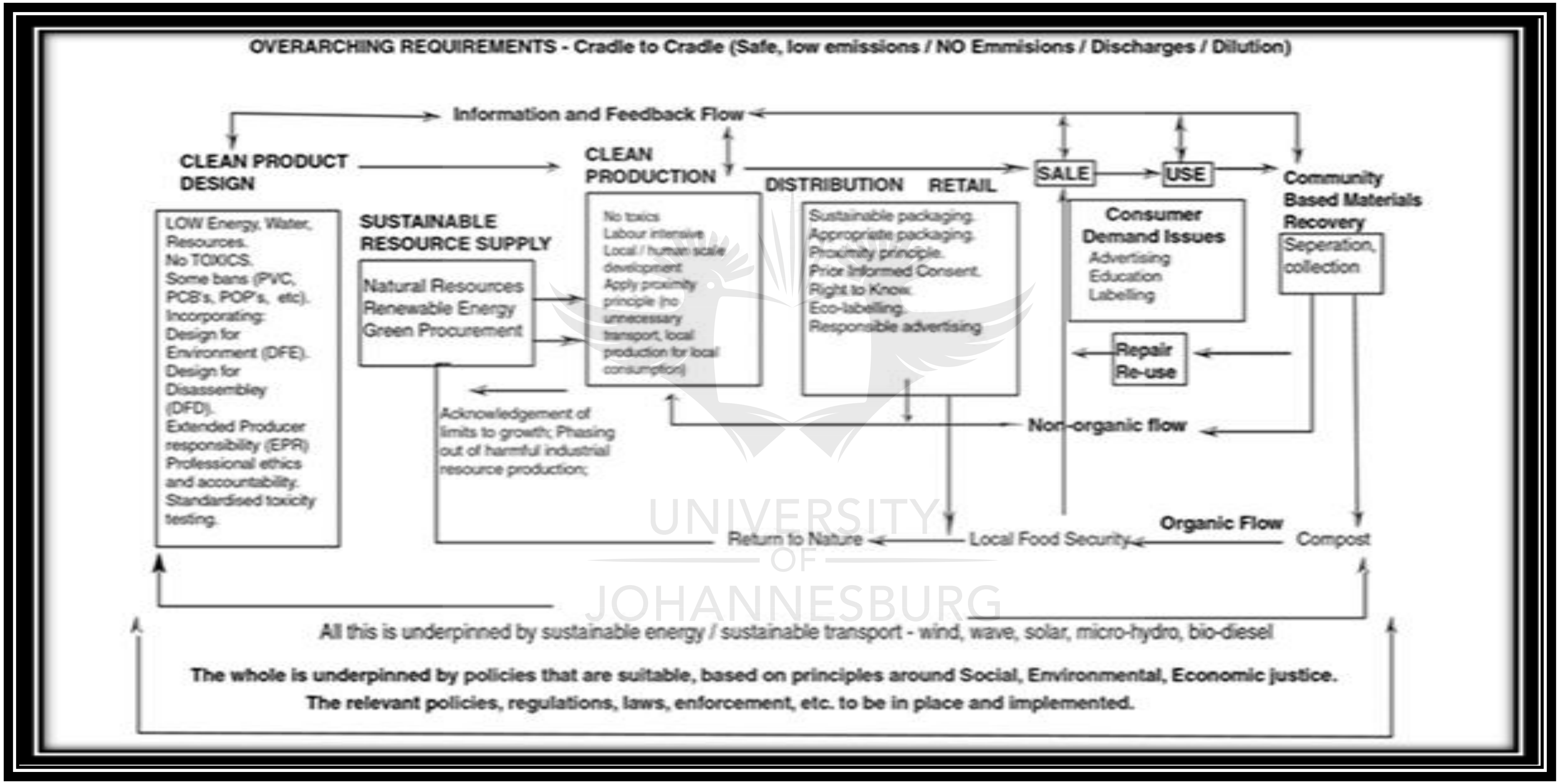

Figure 2: 14: Sustainable Economy Flow Chart [IZWA (Institute for Zero Waste in Africa), 2006]

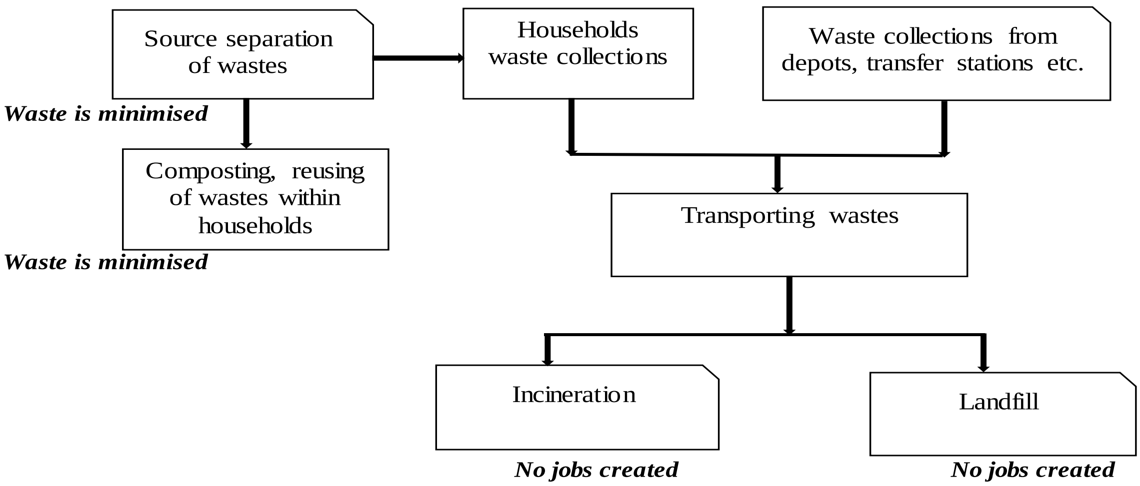

Figure 2: 15: Model that minimizes waste but does not create jobs

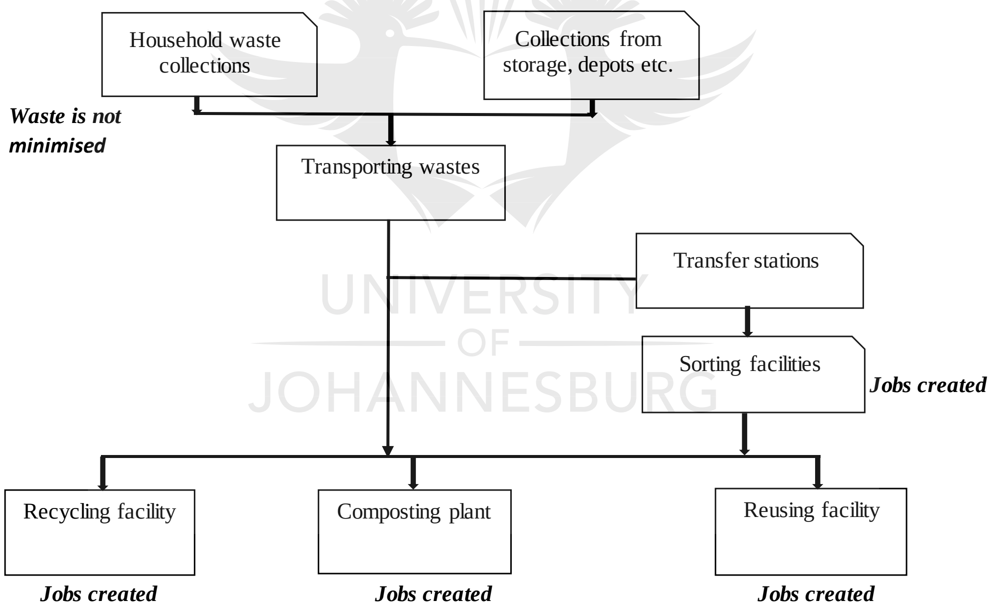

Figure 2: 16: Model that does not minimize waste but create jobs

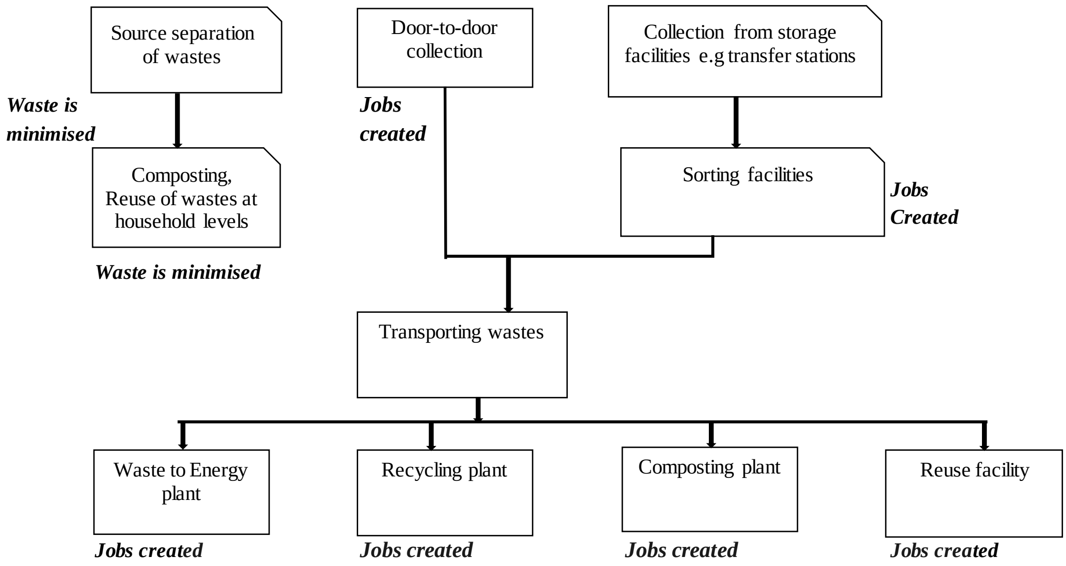

Figure 2: 17: Model that minimizes waste and also create jobs

2.6.1 Benefits of Zero Waste to the Government, the Economy and the Society

The objective of ZW is to recoup resources from the waste streams and to protect limited natural resources through diversion of wastes from landfills, dumping sites and incinerators [EEA (European Environment Agency), 2009]. This objective can be achieved through waste minimization, composting, recycling, reuse, drastic change in patterns of consumption and redesigning of processes. ZW helps the society to respect ecological limits and the right of the people. It sees to it that all discarded items are recycled. In the concept of ZW, WM becomes the responsibility of everyone, it is not left to the municipalities and politicians to handle alone [Global Alliance for Incinerator Alternatives (GAIA), 2012, Modak, 2010, City of Austin, 2011]. Several other benefits accrue from ZW to the general public, governments and the environment. Through ZW farmers are able to get fertile soils for production of food. This is achieved when food scraps are returned to the compositing facilities by consumers and thereafter they are reprocessed into organic manure which the farmers in turn apply to the soil for better yield. When organic waste is being taken to the composting facilities regularly, there will be no need for landfills; incinerators and the fuel required to convey waste to the landfill sites would drastically reduce. Hence, there will be a reduction in the threat being posed to the health of the general public through incinerators and landfilling of organic wastes and consequently there will be drastic reduction in GHG emissions to the atmosphere

[Edgerly and Borrelli, 2007, Ling, 2006, Chiras, 2004, U.S. Environmental Protection Agency]. ZW provides jobs through repair, servicing and maintenance and reusing of items such as waste electrical appliances rather than discarding them and through this, the negative impacts from landfilling, incineration and extraction of virgin materials are prevented. Sorting of waste items; recycling and remanufacturing of materials already considered as wastes will go a long providing downstream jobs. Studies have shown that 100% recycling of waste materials alongside sourcing and processing done locally will generate about 12,300 downstream jobs [Lee et al., 2013, Tanse, 2014, Goldstein, 2014].

2.6.2 Management of 'carry home' packaging items or plastic bags

Across the globe, the majority of the consumers prefer to use plastic bags after purchase of items from malls, groceries store etc., rather than reed baskets that can easily be reused. People feel that plastic bags do not have weight; they are bendable, durable and water-repellent and can also be used for several purposes [Burnett, 2013, BIO Intelligence Service, 2011]. Polyethylene is made from petroleum, crude oils and gases extricated from natural resources. Plastic bags are then produced from polyethylene. Plastic bags are of three types which include the linear low-density polyethylene (LLDPE), low-density polyethylene (LDPE) and high-density polyethylene (HDPE). LLDPE is used for plastic sheets, toys and bags used for promotion. LDPE is used for packaging and containers and HDPE is used for plastic bags used in grocery stores; for lumber, plastic bottles. Studies have shown that the quantity of plastic packaging used across the globe is estimated to be around 500 billion annually [Stanley et al., 2010, CIEC Promoting Science, 2016]. Plastic bags are non-biodegradables; it takes from 20 to 1000 years for it to breakdown [NPCS (NIIR Project Consultancy Services), 2014]. The problem with plastic bag is that it litters around and blocks drainage which subsequently leads to flooding. This is because it is very light and it can easily be blown away by the wind [Rayne, 2008]. Plastic bags pose great threat to aquatic life. They are very harmful to aquatic organisms. When aquatic animals ingest plastic bags, the animal will die; and as soon as the remains of the animal breakdown, the plastic bag is released again to the water-body and made available to another animal and the mortality rate increases [Sigler, 2014, Webb et al., 2012, Barnes and Milner, 2005, Wright et al., 2013, BIO Intelligence Service, 2011]. Several approaches have been employed around the world to mitigate the issues of plastic bags. For instance, in Bangladesh, plastic bags were banned in

2002. This was due to flooding that occurred when drainages were blocked. The incident was connected to the litters of plastic bags and a lot of lives were lost. In Canada, plastic bags have been included in the kerbside collection services. Residents place their waste plastic bags on the pavement or by the roadside for collection. Denmark has also introduced 'green' tax that includes packaging tax. With the introduction of this tax, plastic and paper bags utilization have decreased by about 66%. Recovery facilities have been put in place in Hong Kong and also retailers are not allowed to be given out plastic bags for free. In Delhi, the use plastic bags were banned in 2009. China also banned the use of single-use plastic bags in 2008 [Smith, 2004, Sigler, 2014, Rayne, 2008, Jalil et al., 2013, Gupta, 2011, Clean Up (CU), 2010, Gupta and Somanathan, 2011, Clapp and Swanston, 2009].

Studies have shown that about 8 billion plastic bags are used in South Africa every year with about 96% of it ended up at the LSs [Dikgang et al., 2012]. In 2002, the regulation to ban the production and usage of plastic bags in South Africa was first made but it was received with mixed feelings from different stakeholders but the regulation later came into effect in 2003 [Witbooi, 2003]. In 2004, plastic bags tax was introduced for the purpose of having a cleaner environment. As of 2012, the amount of plastic bags recycled was less than 5% which shows that recycling rate is very poor [McLellan and Aquarium, 2014].

2.6.3 Specific local industry sectors for ZW process components

In many nations of the world, Municipal Recycling Drop-Off Centres (MRDCs) have been established. The aim of these centres is to serve as an avenue to completely divert waste from the landfill, which simply involve the collection of reusable household and construction materials from the waste streams [Town of New Paltz, 2012]. Reuse centres originated from Netherlands and were adopted in other parts of the world in the early 1990s. The responsibility of the reuse centre is to collect, sort, and repair and resell discarded items thus extending the lifespan of discarded items and the LSs and also educating the general public on a sustainable way of life. The means of collection of discarded items at reuse centres include; picking up at home, delivery to reuse centres and delivery to MSW collection centres [Kringloop Reuse Centres, 2009, City of Edmonton, 2014, European Union, 2012]. The benefits of reuse centres include saving of energy, reduction of GHGs, creation of downstream jobs, offering of tax benefits and generation of revenues through the sales of refurbished items or recyclables [Reuse Alliance, 2011]. Currently, there are twenty-four recycling and drop-off centres in the City of Cape Town. These centres offer residents to drop-off their discarded items on any of the day of the week and the residents are permitted to drop-off items up to 1300 kg [Green Map System Inc., 2013].

2.6.4 Movement from linear flow (LF) to circular flow (CF) of materials

The material flow that has currently dominated the world's economy is the linear flow (LF) of material. The LF is the process in which raw materials are extracted from natural resources; products are manufactured, sold, used and are discarded as MSW [Ellen MacArthur Foundation, 2015]. The LF is also referred to as take-make-consume and dispose means of material flow [Wilts et al., 2016]. This system of material flow is limited and it results to losses along the value chain [Ellen MacArthur Foundation, 2013a]. The LF tends to make people assume that resources are in abundance, easily accessible and its means of disposal is not costly but with the pressure on the earth's resources and the burden on the environment which are resulting in environmental degradation; it is now obvious that LF is unsustainable [EU Commission, 2014, ESA (Environmental Services Association), 2013].

A circular flow (CF) of material on the other hand is one in which resources are restored and regenerated and its main objective is to keep product's quality. The CF reduces burden on natural resources and this ultimately leads to sustainability [ESA (Environmental Services Association), 2013]. CF replaces the end-of-life concept and it is currently impacting businesses positively since resources are being recouped from discards [Ellen MacArthur Foundation and McKinsey & Company, 2014]. Circular economy (CE) or CF is related to efficient use of resources, cleaner production and pollution treatment. CE can also be used to achieve optimal production, sustainable consumption and less waste alongside minimum resource consumption and less impact on the environment [Hongchun, 2006]. Therefore, a movement from LF to CF becomes very crucial since this shift focuses on reusing, repairing, refurbishing and recycling of items that have already been considered as discards [Zhijun and Nailing, 2007]. This shift requires the participation and support of different stakeholders for it to be successful. These stakeholders include the police makers, businesses, non-governmental organisations (NGOs), academics and the general public [Kiørboe et al., 2015].

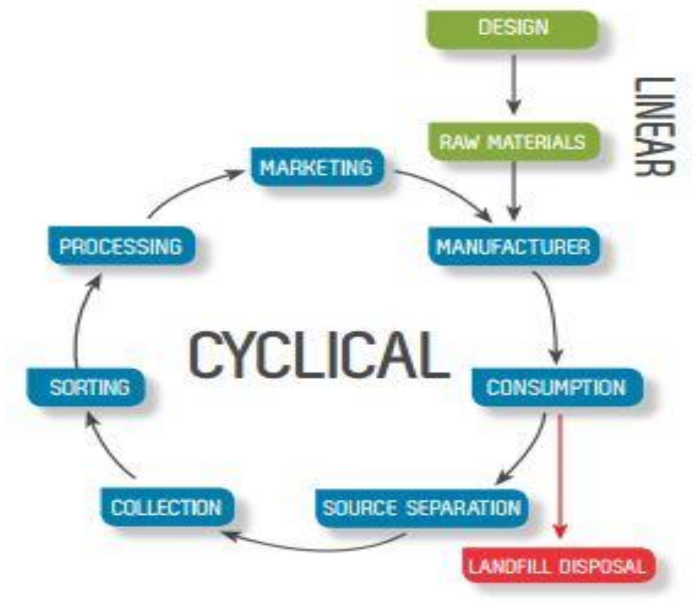

Figure 2: 18: Linear and Circular flow of resources [Auckland Council, 2012]

CHAPTER 3: METHODOLOGY, EQUIPMENT AND MATERIALS

3.1 Introduction

This chapter presents the methodologies, equipment, materials and detailed approaches used at every stage in this research in order to achieve the specific objectives of the study and finally the general objective of the study.

3.1.1 Waste Composition Study at Marie Louise Landfill Site

3.1.1.1 Methodology

The waste composition studies were carried out at Marie Louise landfill site (LS). The studies were carried out in accordance with two international standards. The standards are ASTM - American Society for Testing and Materials - Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste (D5231 – 92 – 2008) and UNEP/IETC - Developing Integrated Solid Waste Management Plan, Volume 1, Waste Characterisation and Quantification with Projections for Future (2009). The first exercise was conducted from the 9th to 13th of November of 2015 (a period of 5 days) during the summer and the second phase was carried out from the 6th to 10th of June, 2016 (a period of 5 days) during the winter at the Marie Louise LS in agreement with the standards. Waste samples were collected and sorted manually at the site. A sample of 100kg of each waste stream was weighed as stipulated in the standard (ASTM D 5231- 92 -2008). The activity ran through the week days from Monday to Friday. A sum of fifty-two samples were analysed as stated in ASTM standard in order to provide statistical accuracy of 90% confidence level. In this study, the waste samples were classified into nine broad groups for the quantification activity at Marie Louise LS. The nine groups were further sub-divided into fifty-two divisions. The nine groups comprised of the following: paper and paperboard, glass, metal, plastic, textiles, organics, construction and demolition (C & D), special care wastes and other wastes. Truckloads of wastes were sampled randomly and loads of wastes were discharged in a designated area. 100kg of each sample of waste was weighed in refuse bin containers meant for the activity. The Researcher and the Waste Reclaimers (waste pickers) did the collection, sorting and characterization of the waste samples. As established in the standard ASTM (D5231- 92 -2008), the number of sorting samples (that is vehicle loads) (n) that are needed in order to arrive at a desired level of accurate estimation is dependent on the component (s) being discussed and the level of confidence. Equation 3 gives the relation to determine n [ASTM, 2008, UNEP/IETC, 2009b].

$$n = \left(t * s / e \cdot \bar{x}\right)^2 \qquad (3)$$

Where $t*$ is the student t statistic corresponding to the desired level of confidence, s is the estimated standard deviation, e is the desired level of accuracy and $\bar{x}$ is the estimated mean. For this study, n^0 was obtained as 50; $t* = 1.645$ at $n = \infty$, $s = 0.06$, $e = 0.10$, $\bar{x} = 0.14$, confidence level = 90% and precision level was 10%. Also, at $t* = 1.677$, $s = 0.06$, $e = 0.10$, $\bar{x} = 0.14$, and n^1 was obtained as 52. The number of samples can be determined by the proportion of waste streams in a sample. For instance, if a particular waste stream in a sample has lower percentage compared to other streams, it therefore means the number of samples to be chosen will be very large in order to confirm the amount of such waste stream when compared with other waste streams with higher percentages. Corrugated was chosen as the governing component since its standard deviation is lower to that of newsprint but the mean is higher which makes the number of samples chosen not to be too large. This is an iterative procedure. Therefore, the number of samples for this study was 52.

3.1.1.2 Equipment and Materials

The apparatus and materials that were used for the study comprised of the following: A crane scale which has a capacity of 500kg (Model: STS-QAL) was used for weighing the waste samples. Heavy-duty tarps were spread on the ground and sorting of waste samples were carried out on them in order to prevent contamination of waste samples with the soil. Excavator was also used for thoroughly mixing of the wastes before samples were taken. Hand brooms were used to gather the residual waste samples after characterization. Fifty-two refuse bin containers of 120 litres capacity provided by PU already labelled for each sub-division of wastes were used. Two traffic cones were used to demarcate the sampling and analysis areas to prevent moving trucks from coming in. One large First Aid kit was provided in order to use to attend to any emergency or minor accident. Personal Protective Equipment

(PPE) was provided for the Researcher which included over-all, gloves, rubber boots, disposable face masks, helmets and safety goggles. Washing-hand basins with liquid soap and disinfectant were also provided to be used for washing of hands after each day exercise.

3.1.1.3 Procedure

In this study, the approaches that were used are as follows; a discussion was carried out with the Management of PU and the officials of PU at Marie Louise LS on the intention of the Researcher to conduct waste composition and quantification study at the site both during the summer and winter, an agreement was reached and approval was given to conduct the study at the site. A region inside the site was mapped out for the waste composition analysis and high visibility activity cones were utilized as boundaries to guarantee the safety of the team. The outlined territory was a level surface and was near the tipping cell with the goal that it would be easier to convey the wastes. The large tarps were spread on the level surface inside the zone mapped out for the movement. The capacity of the tarps was very wide to prevent contamination of the waste samples with the hidden soil. Each of the fifty-two waste containers was labelled with the waste stream chosen for analysis and was positioned outside of the tarps. Tare weight of each of the labelled containers was taken and recorded and it was rechecked occasionally. The scale was placed on a level ground surface very close to the tipping cell. The scale was calibrated to ensure its accuracy. This was done by ensuring the fluid at the calibration region of the scale settled at the centre and occasionally a known (reference) weight was utilized. 100kg of waste samples were taken from any in-coming truckload that was randomly selected. Details of the point of generation and the kind of waste samples were analysed and recorded in tabular form on the waste composition data sheet developed by the Researcher. Data that were recorded on the sampling form were date of sampling, time of sampling, vehicle details, source of the wastes and the climatic conditions. The waste samples were set on the tarpaulin and a 100kg specimen was taken and weighed with the aid of the scale. The Researcher and the Reclaimers did the sorting and the Researcher recorded the data on the waste composition data sheet. Each container was discharged of its contents and was kept aside. Sorting of waste samples continued until the most extreme particle size of the remaining waste particles was about 10 mm and thereafter the remaining particles were classified as other wastes. After the sorting exercises, every waste sub-category was placed in the refused bin labelled accordingly. The gross weights of the wastes and refuse bin containers were recorded on the sampling form [Cowing, 2013a, Cowing, 2013b]. The data were recorded on the waste composition sheet as Round Collection Refuse (RCR) compacted and Dailies non-compacted wastes and were analysed and represented graphically.

3.2 Questionnaire Design and Analysis

3.2.1 Research Design & Methodology

The central goal of this research methodology was to find out how people are conversant with their environment and to identify the issues that are connected with the collection and disposal of SW in their communities. In order to achieve the research objectives, information was gathered from four communities through quantitative research methods. Quantitative data were gathered by means of a structured questionnaire survey conducted on the households within the chosen study area. The chosen communities include informal settlement (low income), middle income and high income classes. The communities are Naledi extension and Dobsonville estate. Secondary information was gathered through articles, reports, books, published and unpublished materials and from the internets.

3.2.2 Area of Study

South-western townships (Soweto) came into existence when African mine workers were forced from Brickfields to a “sanitary camp” on the farm Klipspruit after a plague broke-out in 1904. The township gradually emerged from there in 1963. It is located on 15 km south-west of the Johannesburg Central Business District (CBD) and bordered by the Westrand District Municipality in the west, N1 highway in the east, a mining belt in the north and the N12 in the south. Soweto (Figure 3.1) is the largest township in the whole of South Africa. Its estimated population was 1.3 million according to Joburg archive of 2008 and the population of women constituted about 57%. It occupies about 150 km^2 of the City of Johannesburg (CoJ). It constitutes about 43% of the entire population of CoJ [City of Johannesburg (CoJ), 2006 – 2011, SAHO (South African History Online), 2011]. CoJ has seven regions which include regions A, B, C, D, E, F and G. Region D covers the entire Soweto where

Dobsonville extensions and Naledi extensions are two of the suburbs in region D [City of Johannesburg (CoJ), 2008, City of Johannesburg (CoJ), 2007].

Soweto is located in Gauteng Province (GP). GP occupies 17,010 km^2 of land which is about 1.4% of South Africa land mass. GP has a population of about 12.3 million and its density is 723 per km^2. The growth rate in GP is proportional to the rate of waste generated which is around 2.5 - 4% [Ligneris, 2013]. There are nine provinces in South Africa and GP is one of them. GP accounts for about 45% of the total waste generated in all the nine provinces and the per capita of waste generated in GP stood at 761 kg/capita/annum in 2011 [DEA (Department of Environmental Affairs), 2012]. GP contributes about 33% to the nation's gross domestic product (GDP). GP is home to different nationalities in terms of race, religion and cultural differences. The population of GP accounts for about 23.7% of the overall population of South Africa. GP is growing at a fastest rate in terms of its population growth. It is the major centre of commercial activities in South Africa. GP province is made up of CoJ, Tshwane and Ekurhuleni metropolitan municipalities (Figure 3.2) [Gauteng Growth and Development Agency (GGDA), 2013/14].

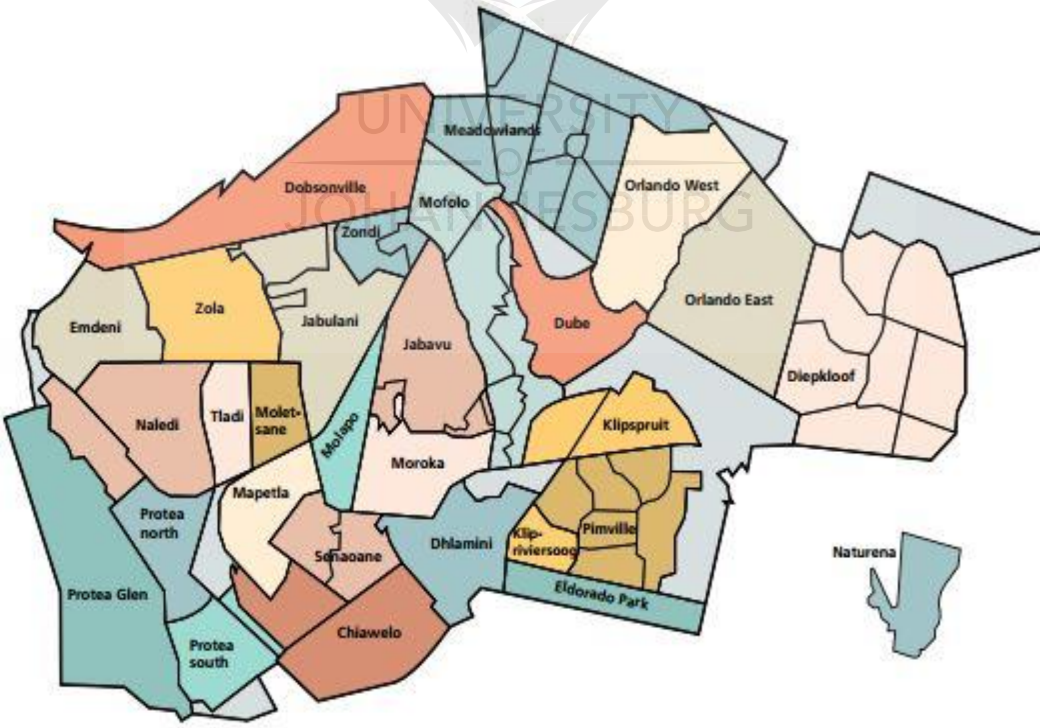

Figure 3: 1 : Map of Soweto [City of Johannesburg (CoJ), 2006 – 2011]

Figure 3: 2: Map of Gauteng [Gauteng Growth and Development Agency (GGDA), 2013/14]

3.2.3 Primary Data Collection and Analysis (Qualitative)

Qualitative method of research measures the behaviour of the consumer, their knowledge and opinions. This attempts to provide answers to questions like how much, how often, how many, when, who and what; using a data collection instrument called questionnaire. A questionnaire is the instrument that is mostly used in research. To develop one is partly science and partly art [Cooper and Schindler, 2008]. A structured questionnaire was administered to households in four suburbs (Figure 3.1). The population size was 150, the sample size was 118, the margin of error was 4.19% and the confidence level was 95%. These were evaluated using statistical analysis. The distributions of questionnaire to the sampled population were done by the Researcher alongside some staff of Pikitup (PU) (the municipality). 16% of the questionnaires were filled on the spot and were returned after they had been completed. The respondents' identities were not requested. This made them feel relaxed; hence, they responded honestly. Households were interviewed with the help of the questionnaire. Households' levels of awareness, attitudes, concerns, and willingness to participate in ZW project and other general issues of concern with respect to solid waste management (SWM) were evaluated using the questionnaire. Data were obtained from the households' survey through the use of stratified random sampling technique. The data were analysed using Statistical Package for the Social Sciences (SPSS) statistics descriptive program.

Figure 3: 3 : The Researcher administering questionnaire at Naledi extension

3.2.4 Secondary Data Collection (Literature Review)

Secondary data was reviewed and this was very helpful in this research. Official reports, books, encyclopaedia, international standards, articles, legal documents, published and unpublished literature and case studies were consulted. The information extracted from all these resource materials cover a wide range of issues around municipal solid waste management (MSWM) and the ZW concept [Hox and Boeije, 2005]. The use of secondary data is becoming popular. In this study, the area of study and the research questions are the parameters that determined the method used by the researcher [Johnston, 2014].

3.2.5 Limitations of the Study

Like any research, no matter how it is structured, it has its limitation. Limitations are challenges encountered in the course of conducting a study and they are usually beyond the control of the researcher [Simon and Goes, 2013]. This study has several features that limit the generalization of its findings. Some of the challenges encountered were in the distribution of questionnaires and the collection of data owing to the attitudes of some of the respondents. Some of the respondents were very hostile and also some questionnaires were incomplete and some answers did not make sense.

3.3 Elemental and Proximate Analysis of Food Waste

3.3.1 Elemental Analysis of Food Waste

This section discusses the elemental composition in terms of carbon, hydrogen, nitrogen, sulphur and oxygen (C, H, N, S, and O) of the organic fraction of the municipal solid waste (MSW) stream. The goal was to develop an empirical formula that reports the ratio of various elements that can be found in the organic fraction of municipal solid waste (OFMSW) as a function of its elemental constituents. The MSW component that was used was food wastes (FWs). The organic fraction of the MSW was sampled from Marie Louise LS and was sent to the testing facility and was analysed for those parameters. The testing equipment used was CHNS analyser (Figure 3.2) (used for analysis of carbon, hydrogen, nitrogen and sulphur). Data obtained from the analyser were computed in weight percent (wt. %). The percentage weights were converted to masses in grams. The masses were then converted to moles. Finally, the moles were divided by the lowest in order to seek for the smallest whole-number ratio[Komilis et al., 2012].

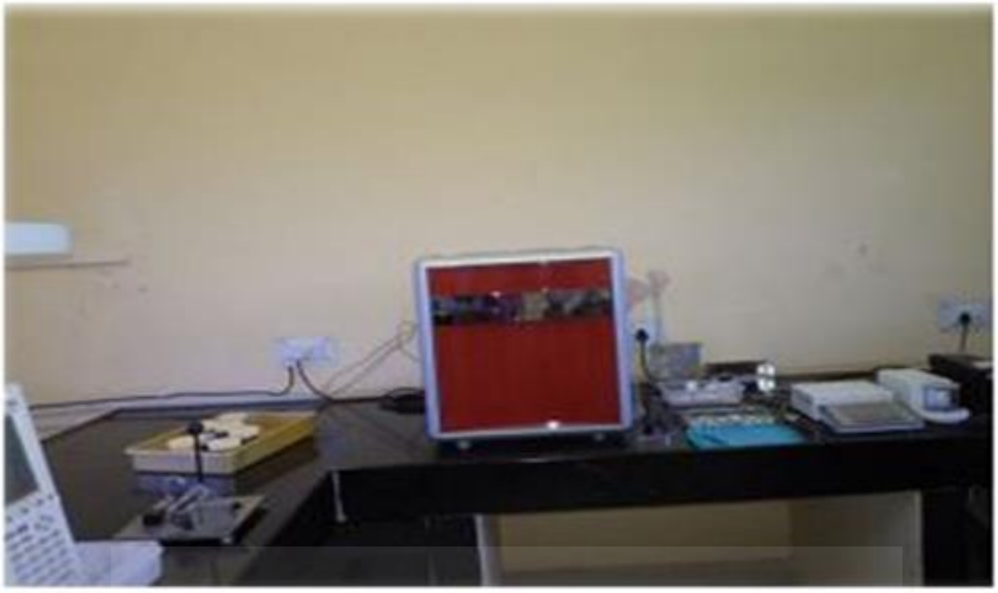

Figure 3: 4 : CHNS Analyser [Chandrappa and Brown, 2012]

3.3.2 Proximate Analysis of Food Waste

Proximate analysis is considered here. Proximate analysis comprises of the moisture content, ash content, volatile matter and fixed carbon. The analyses of these parameters were carried out in line with American Standard Test Method (ASTM) standards [Kalanatarifard and Yang, 2012].

3.3.2.1 Moisture Content

The percent moisture of the food waste sample was determined by preparing 5 samples of 10g each. The essence of the 5 samples was for 5 repetitions in order to determine the average. The samples were made to homogenize since waste is always heterogeneous. Homogenizing is simply breaking or reducing the particle sizes. The samples were weighed in 5 dishes and were dried in an oven (Model: LABOTEC) (Figure 3.3) at a temperature of 105°C according to ASTM D3173. The samples were crushed using Roll crusher (Figure 3.4) and they were pulverized using Pulverizing machine (Figure 3.5) The samples were then sieved using Filtra Sieve Shaker (Modelo: FTL-0200) (Figure 3.6). The percentages of the moisture content were then calculated as a percentage weight loss before and after drying and the average was determined as shown in Equation 4 [ASTM, 2011a].

$$Percentage\,Moisture = \frac{E - F}{E} \times 100\% \qquad (4)$$

Where E is the weight of wet sample and F is the weight of dry sample

Figure 3: 5 : LABOTEC Oven

Figure 3: 6 : Roll Crusher

Figure 3: 7 : Pulverized Machine

Figure 3: 8 : Filtra Sieve Shaker

3.3.2.2 Volatile Matter Content

To determine the volatile matter content, the method of ignition was utilized in which the sample was ignited at 950°C. The samples used to determine moisture content were utilized. The samples were placed in 5 crucibles, weighed and heated in a muffle furnace for a period of 7 minutes at a temperature of 950°C according to ASTM D3175. The crucibles were removed from the furnace and were made to cool and weighted as soon as they were cold. Volatile matter was then determined as the difference between weight loss in percent and the percentage moisture and is given by Equation 5 and 6 [ASTM, 2011b].

$$Percentage\ loss\ in\ weight = \frac{X-Y}{X} \times 100\% \qquad (5)$$

Where X is the weight of sample before heating and Y is the weight of sample after heating

$$\%\ volatile\ matter = \%\ weight\ loss - \%\ moisture \qquad (6)$$

3.3.2.3 Ash

To determine the ash, samples from moisture content analysis were weighed. After weighing, they were placed in an oven and were heated to a temperature of about 750 ^{o}C for 1 hour in agreement with ASTM D3174. Samples were then removed from the oven and allowed to cool and then weighed. The percentage ash is given by Equation 7 [ASTM, 2012].

$$\% \ Ash = \frac{K - L}{M} \times 100\% \qquad (7)$$

Where:

K is the weight of crucible + cover + ash,

L is the weight of empty crucible + cover and M is the weight of sample.

3.3.2.4 Fixed carbon (FC)

Fixed carbon (FC) is calculated by summing up of % moisture content, % volatile matter and % ash and the total sum is taken away from 100. This is given by this relation in Equation 8 [Kamran et al., 2015].

$$FC = 100 - (\% \, wt.moisture + \% \, wt.volatile \ matter + \% \, wt.ash) \qquad (8)$$

4.0 CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents results of the waste composition studies and data from the elemental and proximate analysis of food waste. Chapter 5 presents the results from the analysis of questionnaire on public perception and level of awareness on SW management and Chapter 6 present the economic analysis and potential of setting up MSW recycling facility from the Chemical Engineering point of view.

4.1.1 Waste composition studies during summer and winter

The waste characterisation activities were undertaken in the summer period of 2015 and winter of 2016 at the Marie Louise LS. Towards the end of the exercise there was a change in weather patterns which resulted in a heavy storm.

4.1.1.1 Waste composition studies during summer

The results of the study carried out during the summer (Appendix A, (A1 and A2)) at the Marie Louise LS in November 2015 are represented in tabular form and graphically as seen in Table 4.1 and Figure 4.4 for Dailies non-compacted waste. The daily non-compacted waste originates from hotels, restaurants, fast food joints, butcher shops and street sweeping. They are collected daily in order to avoid offensive odour that may emanate as a result of its decay and which can pose threat to the health of the general public.

4.1.1.1.1 Dailies Non-Compacted Waste Characterization Results

Table 4: 1: Dailies Non-Compacted Waste

S/No.	Waste Components	% by Weight
1	Organics	13
2	C & D	1
3	Glass	15
4	Platics	28
5	Textiles	3
6	Paper	19
7	Metal	7
8	Other wastes	14
	TOTAL	100

The main components of MSW from Marie Louise LS for Dailies wastes as represented in Table 4.1 above are further sub-divided as discussed below.

4.1.1.1.1.1 Plastic wastes

Plastics had the largest percentage of about 28% of the total waste streams. Plastic waste was further broken down into sub-categories (Figure 4.1). It was observed during the exercise that all the plastic wastes were recycled by the Reclaimers and were sold to the Middle-Men who in turned sold them to recycling companies.

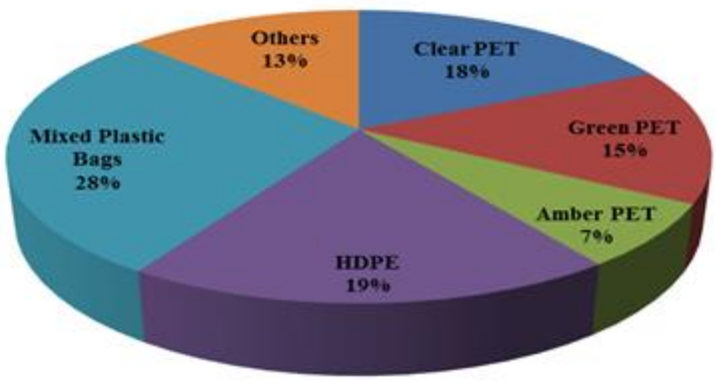

Figure 4: 1 : Plastics wastes

4.1.1.1.1.2 Paper and Paperboard wastes

Paper and Paperboard occupied about 19% within the main components of the waste streams. Paper was further divided into sub-categories (Figure 4.2). There was no indication of paper and paperboards being recycled by the Reclaimers since all the waste papers were compacted.

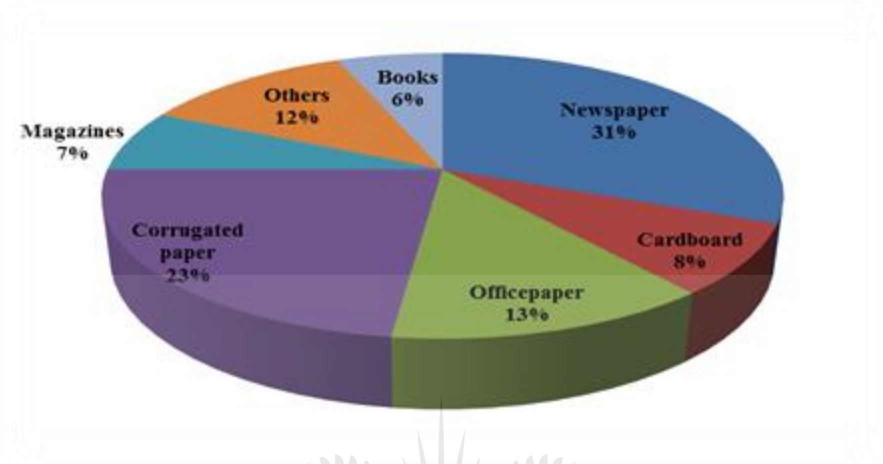

Figure 4: 2 : Paper and Paperboard wastes

4.1.1.1.1.3 Glass wastes

Glass occupied about 15% of the main component of the overall waste streams. It is sub-divided into different classes (Figure 4.3). There was no clear evidence of bottles being recycled by the Reclaimers since they set the glass wastes aside and only concentrated on other recyclables.

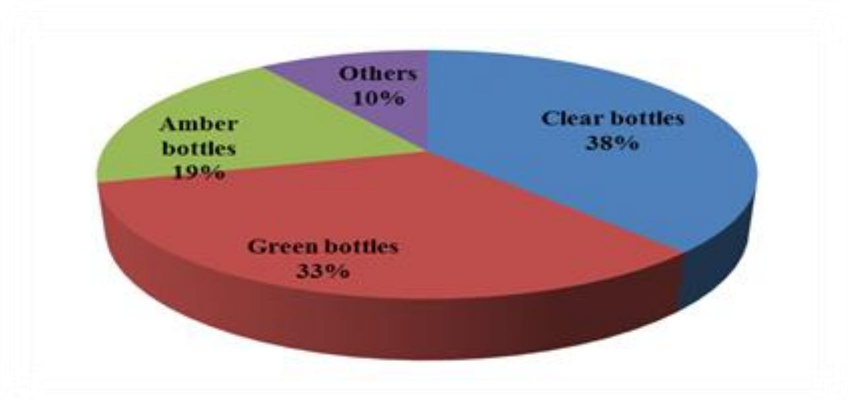

Figure 4: 3 : Glass wastes

4.1.1.1.1.4 Other Wastes

Other wastes occupied a percentage of 14% of the overall waste streams. For other wastes; diaper/sanitary products occupied the largest percentage of 37% (Figure 4.4). Every waste in this category was recycled except for diapers which were not recycled but were only compacted and covered with soil. WEEE (Figure 4.4) stands for Waste Electrical and Electronic Equipment.

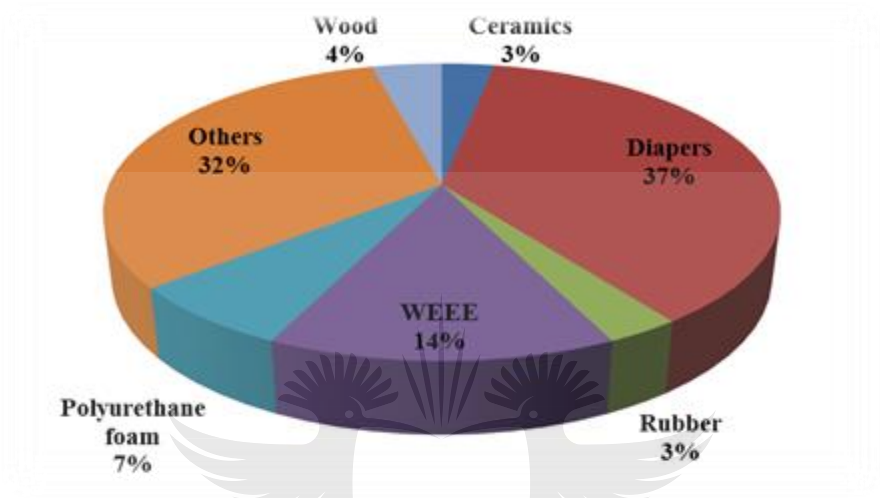

Figure 4: 4 : Other Wastes

4.1.1.1.1.5 Organic Wastes

Organic wastes had a percentage of 13% within the main components of the waste streams. Inside the organic, food waste occupied the largest percentage of 55% (Figure 4.5). It was observed during the exercise that organic wastes were not recycled by the Reclaimers. They only reclaimed the inorganic wastes while the organic wastes were compacted and covered with soil. This does not contribute to the economy since resources are being sent to the landfill site and leachate is also being produced from the compacted organic waste which thereafter percolates to contaminate underground and surface water.

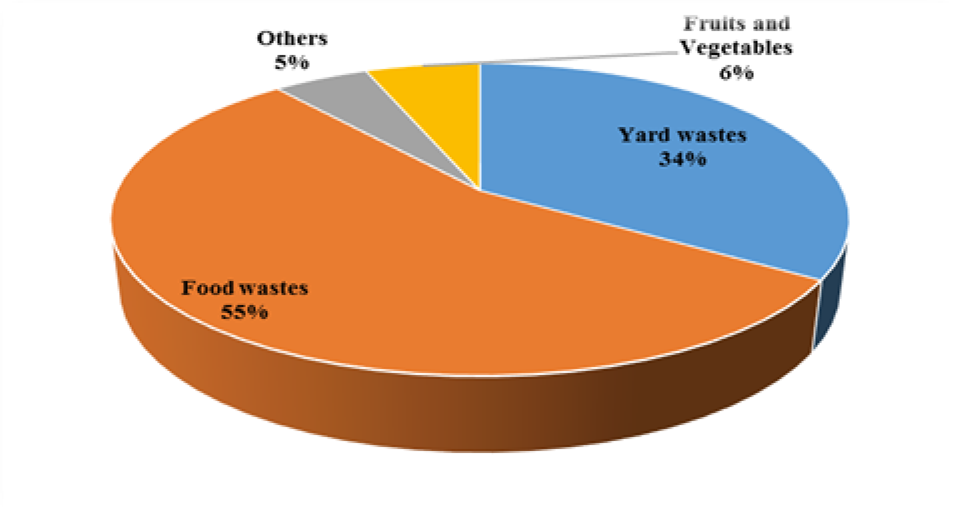

Figure 4: 5: Organic Wastes

4.1.1.1.1.6 Metal wastes

Metals occupied about 7% of the main component of the overall waste streams. This category was further classified (Figure 4.6). The entire waste streams in this category were recycled by the Reclaimers.

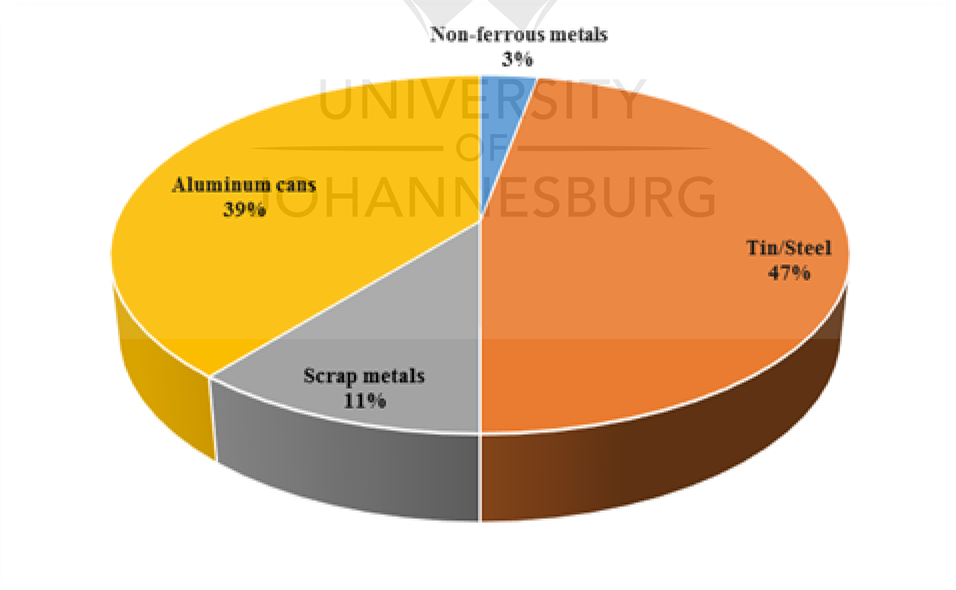

Figure 4: 6 : Metal wastes

4.1.1.1.1.7 Textile wastes

Textiles occupied about 3% of the main component of the overall waste streams. These were further sub-divided (Figure 4.7). There was no any clear evidence that any of the wastes in this category are being recycled by the Reclaimers. They are compacted with soil as observed during the activities at the site.

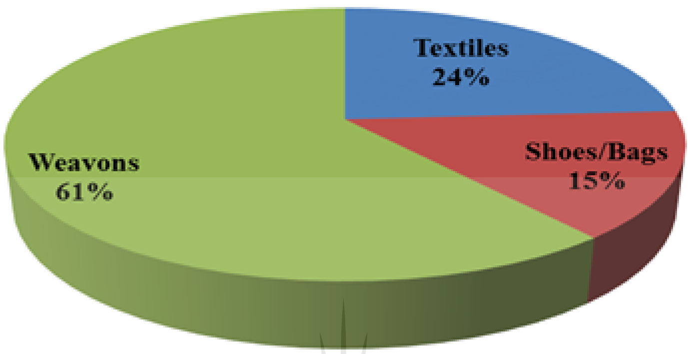

Figure 4: 7 : Textile wastes

4.1.1.1.2 Round Collected Refuse (RCR) Characterization Results

The results of the waste composition study carried out during the summer at the Marie Louise LS in November 2015 are represented in tabular form and graphically as seen in Table 4.2 for Round Collected Refuse (RCR) compacted wastes. The RCR originates from households in formal residential areas and businesses and are routinely collected weekly. They are commonly stored and collected in a 240 litres container. The main components of MSW for RCR as in Table 4.2 above are further sub-divided as represented below.

Table 4: 2 : Round Collected Refuse

No.	Waste Components	% by Weight
1	Organics	28
2	Glass	8
3	Metals	5
4	Plastics	18
5	Textiles	6
6	Paper and Paperboard	16
7	Other wastes	19
	TOTAL	100

4.1.1.1.2.1 Organic Wastes

Organic wastes had the highest percentage of 28% within the main components. It is further divided into different classes (Figure 4.8). It was observed during the exercise that organic wastes were not recycled. The Reclaimers only reclaimed the inorganic wastes while the organic wastes are compacted and covered with soil. In this method of treatment of organic wastes, nothing is contributed to the economy since resources are sent to the LS and leachate is also produced from the compacted organic wastes which thereafter contaminate both the underground and surface water.

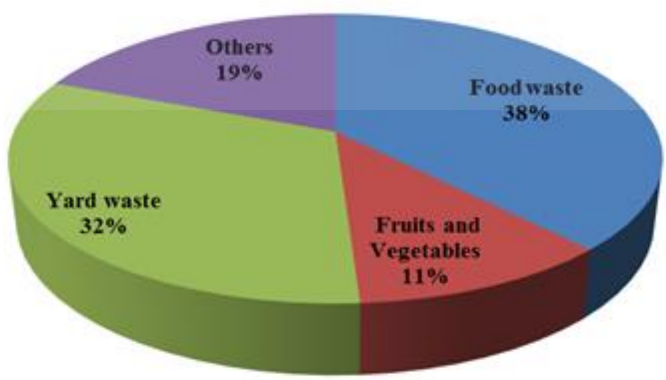

Figure 4: 8 : Organic Wastes

4.1.1.1.2.2 Other Wastes

Other wastes occupied the third largest percentage of 19% of the overall waste streams. This category was further divided into different classes (Figure 4.9). Every waste in this category was recycled except diapers which were not recycled but were only compacted and covered with soil. WEEE (Figure 4.14) stands for Waste Electrical and Electronic Equipment.

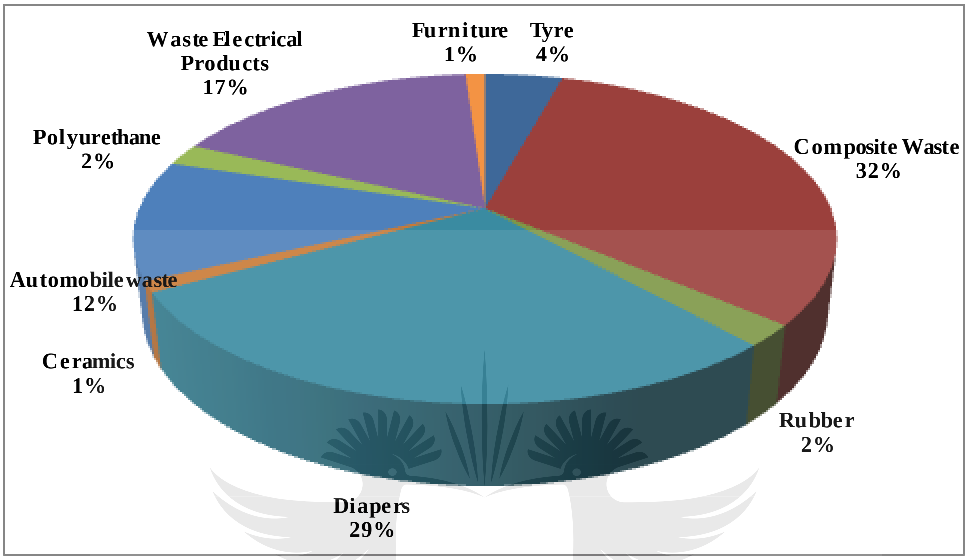

Figure 4: 9 : Other Wastes

4.1.1.1.2.3 Plastic wastes

Plastics had a percentage about 18% of the total waste streams. Within the plastics; HDPE had the highest percentage of 24%, followed by clear PET (Figure 4.10). There was no film plastic hence it is at 0%. It was observed during the exercise that all the plastic wastes were recycled by the Reclaimers.

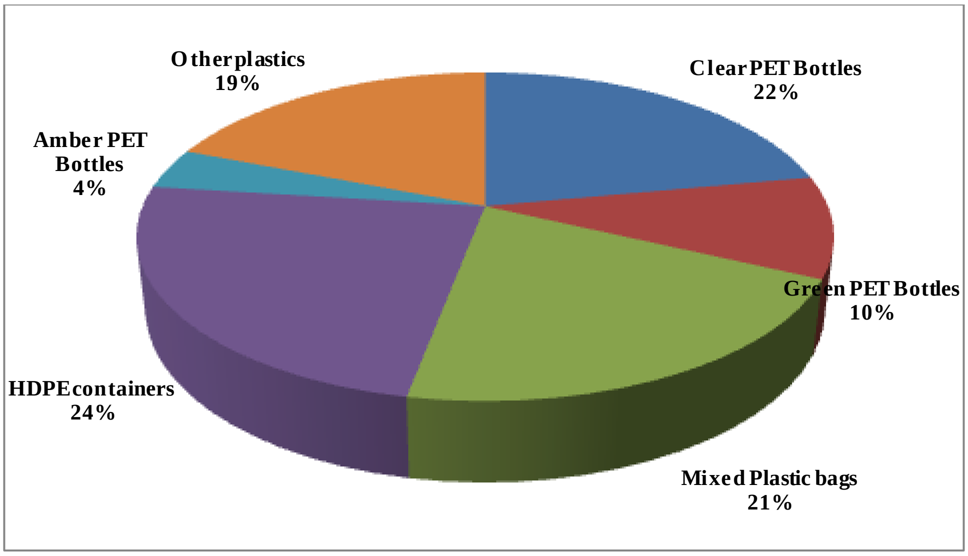

Figure 4: 10 : Plastic wastes

4.1.1.1.2.4 Paper and Paperboard wastes

Paper and Paperboard occupied about 16% within the main components of the waste streams. Inside paper and paperboard; corrugated paper had the largest percentage of 30% followed by newspaper at 27% (Figure 4.11). There was no any indication of paper and paperboard being recycled by the Reclaimers since they only focus on inorganic wastes.

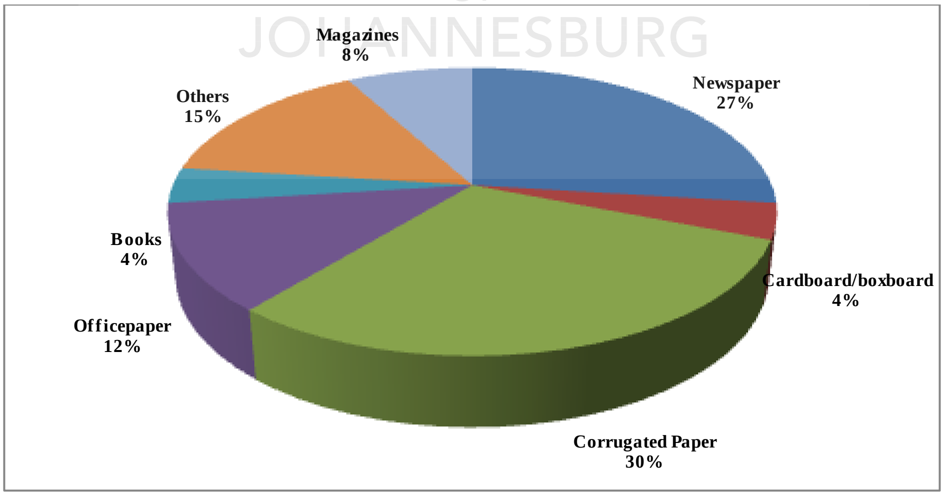

Figure 4: 11 : Paper and Paperboard wastes

4.1.1.1.2.5 Glass wastes

Glass wastes occupied about 8% of the main component of the overall waste streams. Within glass; clear bottles had the highest percentage of 42% by weight (Figure 4.12). There was no clear evidence that bottles are being recycled by the Reclaimers.

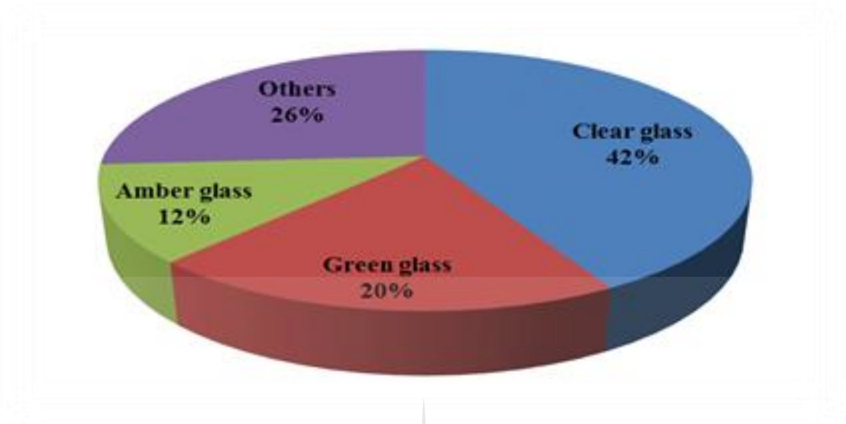

Figure 4: 12: Glass wastes

4.1.1.1.2.6 Textile wastes

Textiles occupied about 6% of the main component of the overall waste streams. Within the textiles/weavons/shoes and bags; textiles occupied 88% (Figure 4.13). There was no any clear indication that any of the wastes in this category are recycled by the Reclaimers since their main focus is only on other recyclables.

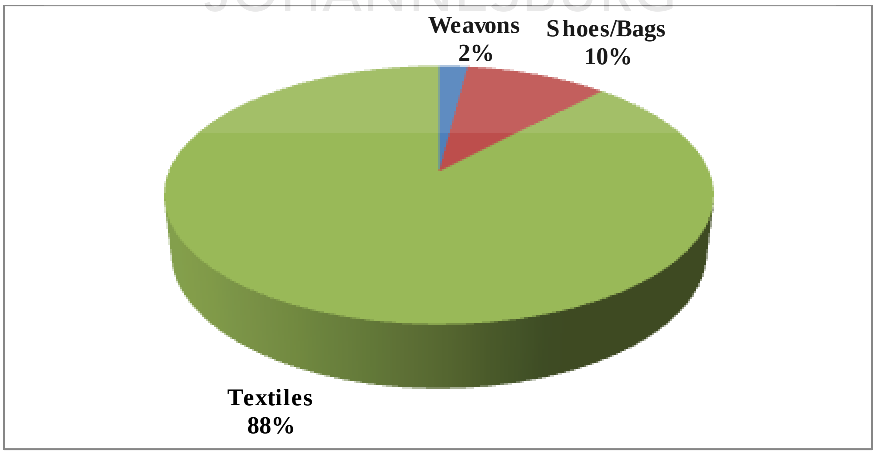

Figure 4: 13 : Textiles wastes

4.1.1.1.2.7 Metal wastes

Metal waste occupied about 5% of the main component of the overall waste streams. Within metals; each of aluminium and tins/steels had the largest percentage of 33% by weight (Figure 4.14). The entire waste streams in this category are recycled by the Reclaimers. They pay more attention on the wastes in this category since according to them they usually make more income on these wastes.

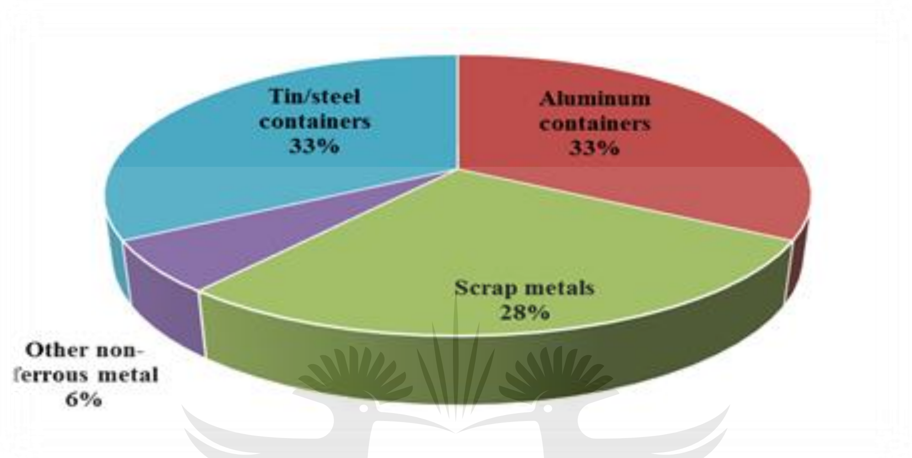

Figure 4: 14 : Metal wastes

4.1.1.2 Waste composition study during winter

The results of the study carried out during the winter (Appendix A, (A3 and A4)) at the Marie Louise LS in June 2016 are represented in tabular form and graphically as seen in Table 4.3 for Dailies non-compacted waste. The daily non-compacted waste originates from hotels, restaurants, fast food joints, butcher shops and street sweeping. They are collected daily in order to avoid offensive odour that may emanate as a result of its decay and which can pose threat to the health of the general public.

4.1.1.2.1 Dailies Non-Compacted Waste Characterization Results

Table 4: 3 : Dailies Non-Compacted Waste

No.	Waste Components	% by Weight
1	Organic	14
2	Paper	18
3	Glass	5
4	Metal	10
5	Plastics	26
6	Textiles	7
7	Other wastes	20
8	C & D	0
	TOTAL	100

The main components of MSW from Marie Louise LS for dailies wastes as represented in Table 4 are further sub-divided as represented below.

4.1.1.2.1.1 Plastic wastes

Plastics had the largest percentage of about 26% of the total waste streams. Plastic waste was further broken down into sub-categories (Figure 4.15). It was observed during the exercise that some of the plastic wastes such as HDPE and PET bottles are being recycled by the Reclaimers and were being sold to the Middle-Men.

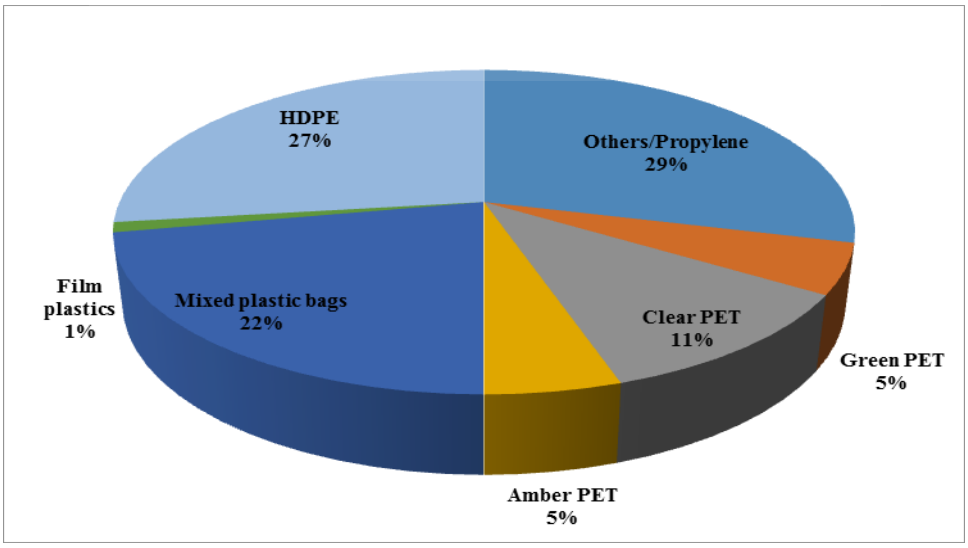

Figure 4: 15 : Plastics wastes

4.1.1.2.1.2 Other Wastes

Other wastes occupied the third largest percentage of 20% of the overall waste streams. This category was further divided into different classes (Figure 4.16). Most of the wastes in this category are being recycled except diapers which were normally compacted with soil. WEEE stands for Waste Electrical and Electronic Equipment.

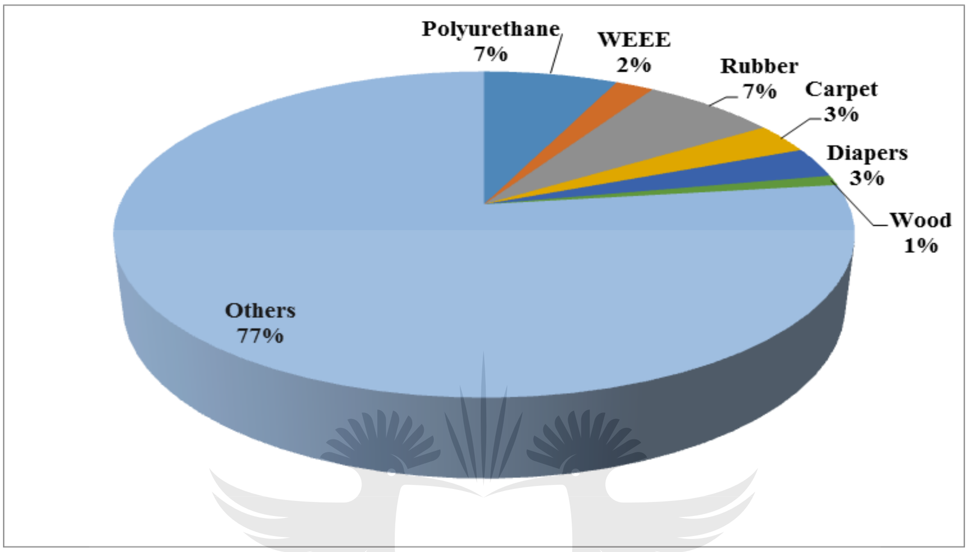

Figure 4: 16 : Other wastes

4.1.1.2.1.3 Paper and Paperboard

Paper and Paperboard accounted for 18% within the main components of the waste streams. Inside paper and paperboard; corrugated paper had the largest percentage of 36% followed by newspaper at 25% (Figure 4.17). There was no any indication of paper and paperboard being recycled by the Reclaimers since they only focus on inorganic wastes.

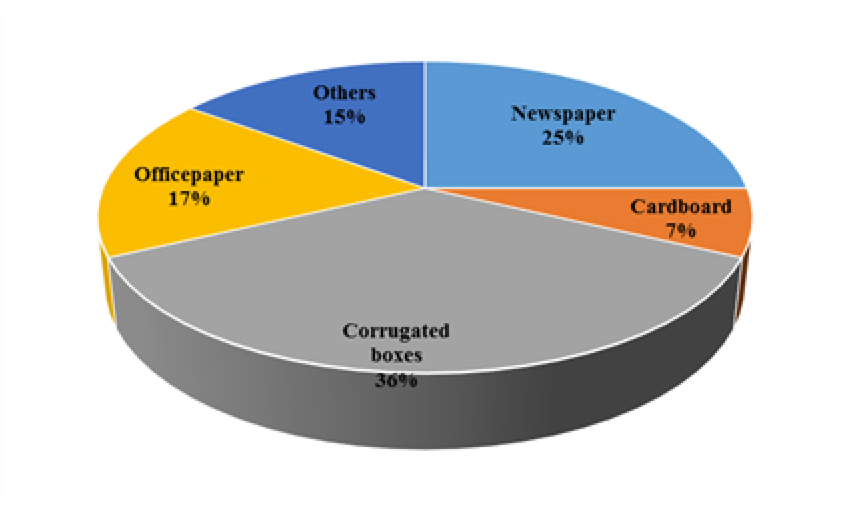

Figure 4: 17 : Paper and Paperboard

4.1.1.2.1.4 Organic wastes

Organic wastes had the highest percentage of 14% of the main components. It was further divided to different classes (Figure 4.18). During the exercise, all the organic wastes were compacted with soil. When organic wastes are treated this way, nothing is contributed to the economy since resources are sent to the landfill and leachate is produced continuously from the compacted organic wastes and these contaminate both the underground and surface water.

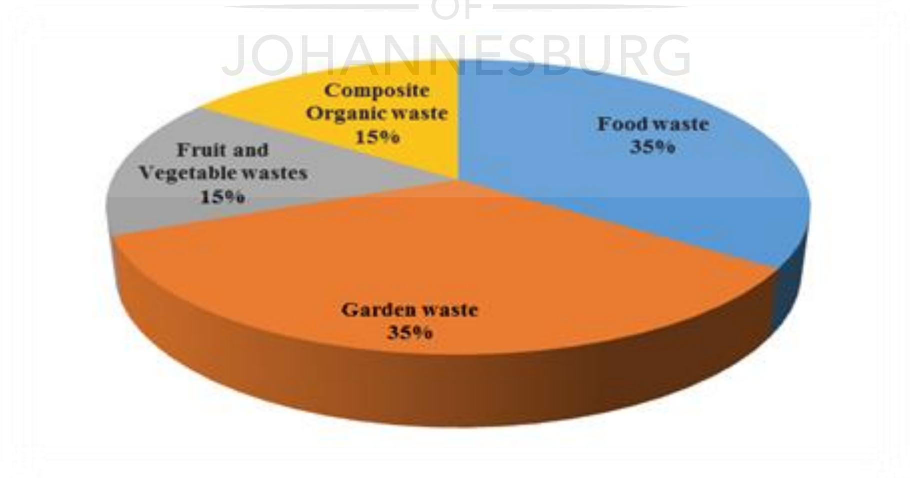

Figure 4: 18 : Organic wastes

4.1.1.2.1.5 Metals

Metals occupied about 10% of the main component of the overall waste streams. This category was further classified (Figure 4.19). The entire waste streams in this category are recycled by the Reclaimers.

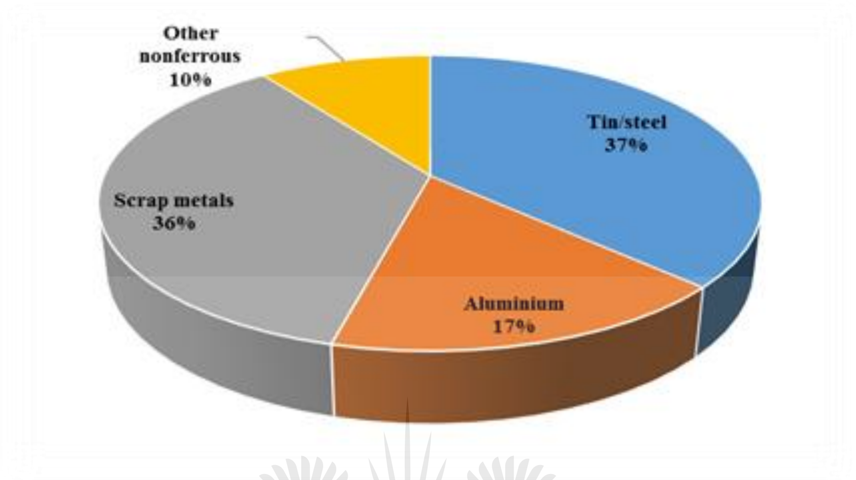

Figure 4: 19 : Metal waste

4.1.1.2.1.6 Textiles

Textiles occupied about 7% of the main component of the overall waste streams. These were further sub-divided (Figure 4.20). There was no clear evidence that any of the wastes in this category was recycled by the Reclaimers. The wastes are compacted with soil as observed during the activities at the site.

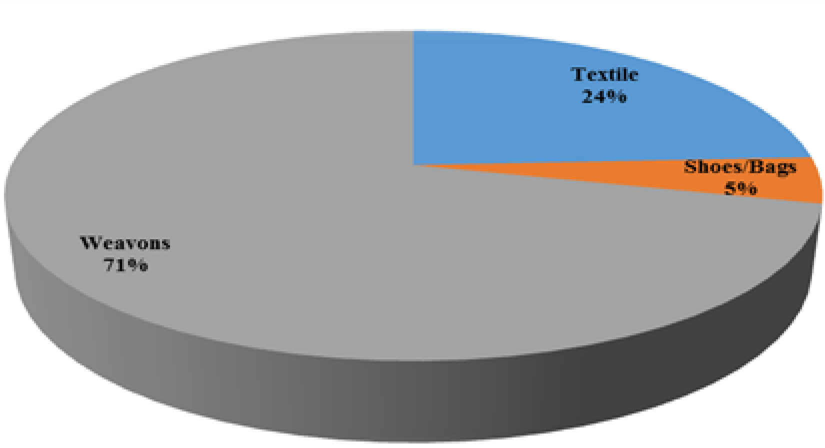

Figure 4: 20 : Textiles wastes

4.1.1.2.1.7 Glass

Glass wastes occupied about 5% of the main component of the overall waste streams. Within glass; clear bottles had the highest percentage of 36% by weight (Figure 4.21). There was no clear evidence that bottles are being recycled by the Reclaimers

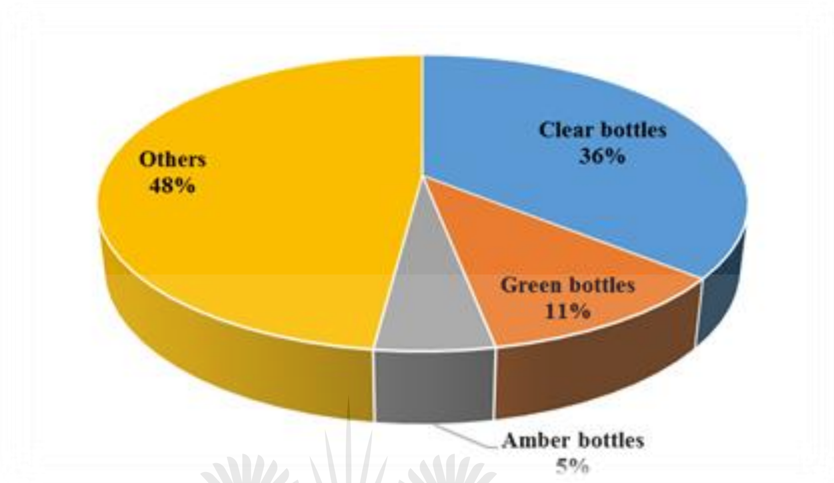

Figure 4: 21 : Glass

4.1.1.2.2 Round Collected Refuse (RCR) Characterization Results

The results of the waste composition study carried out during the winter at the Marie Louise LS in June 2016 are represented in tabular form in Table 4.4 for Round Collected Refuse (RCR) compacted wastes and are further sub-divided as shown below. The RCR originates from households in formal residential areas and businesses and are routinely collected weekly. They are commonly stored and collected in a 240 litres container.

Table 4: 4 : Round Collected Refuse

No.	Waste Components	% by Weight
1	Organic	29
2	Paper	12
3	Glass	4
4	Metal	5
5	Plastics	19
6	Textiles	11
7	Other wastes	20
	TOTAL	100

4.1.1.2.2.1 Organic wastes

Organic wastes accounted for the highest percentage of 29% of the main components. It was further divided to different classes (Figure 4.22). All the organic wastes were compacted with soil.

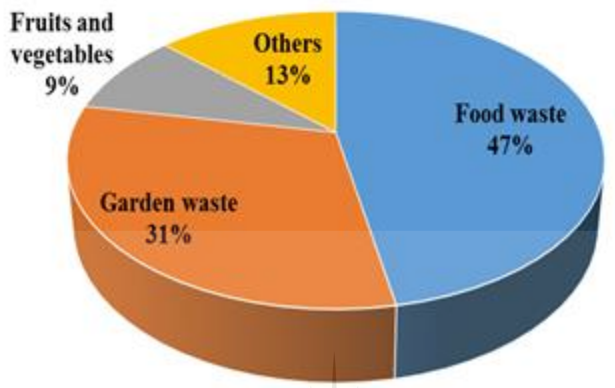

Figure 4: 22 : Organic wastes

4.1.1.2.2.2 Other wastes

Other wastes occupied the second largest percentage of 20% of the overall waste streams. This category was further divided into different classes (Figure 4.23). Most of the wastes in this category were recycled except diapers. WEEE in Figure 4.23 stands for Waste Electrical and Electronic Equipment.

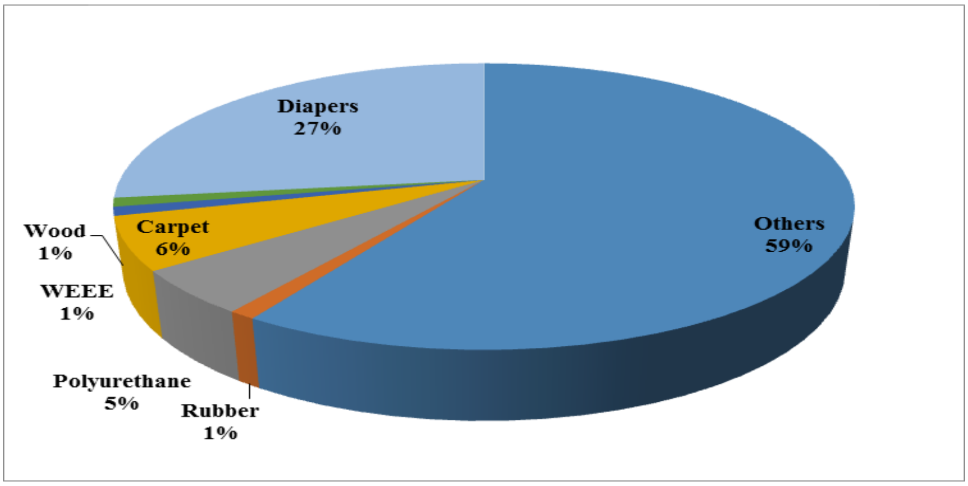

Figure 4: 23 : Other wastes

4.1.1.2.2.3 Plastics

Plastics accounted for the third largest percentage of about 19% of the total waste streams. Plastic waste was further divided into sub-categories (Figure 4.24). Plastic wastes such as HDPE and PET bottles were recycled by the Reclaimers and were sold to the Middle-Men who in turned sold them to recycling industries.

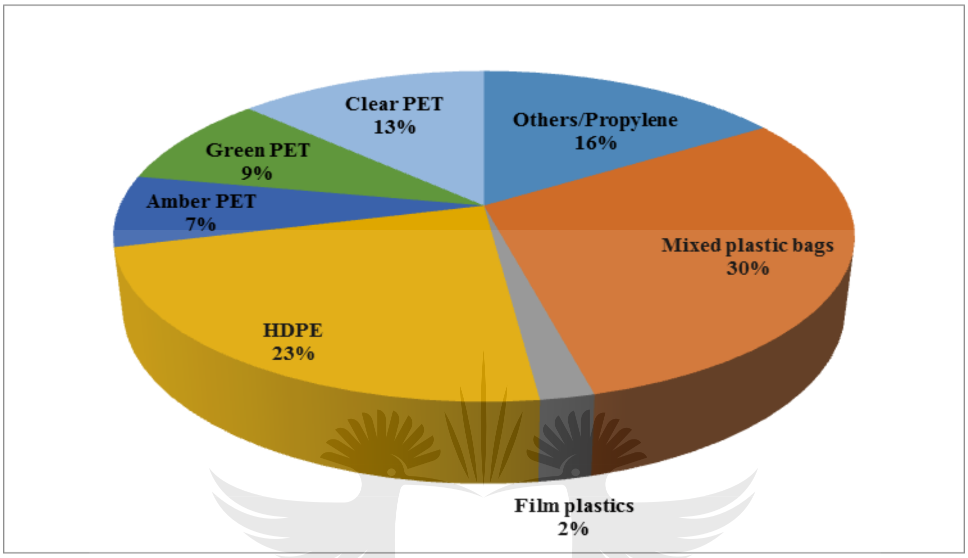

Figure 4: 24 : Plastic wastes

4.1.1.2.2.4 Paper and Paperboard

Paper and Paperboard occupied 12% of the main components of the waste streams. Within paper and paperboard category; newspaper had the largest percentage of 32% followed by corrugated paper at 18% (Figure 4.25). There was no any indication of paper and paperboard being recycled by the Reclaimers since they only focus on inorganic wastes.

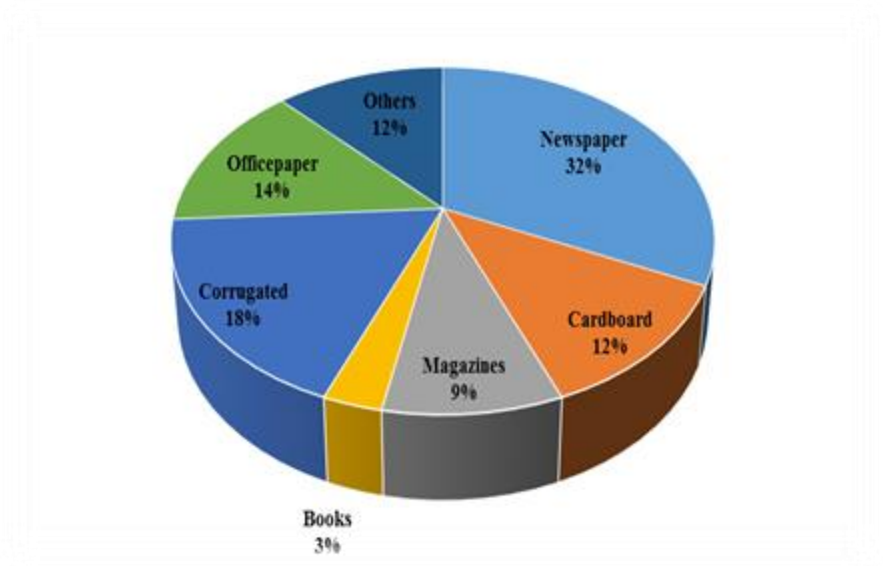

Figure 4: 25 : Paper and Paperboard

4.1.1.2.2.5 Textile wastes

Textiles occupied about 11% of the main component of the overall waste streams. These were further sub-divided (Figure 4.26). There was no clear evidence that any of the wastes in this category was recycled by the Reclaimers. The wastes are compacted with soil as observed during the activities at the site.

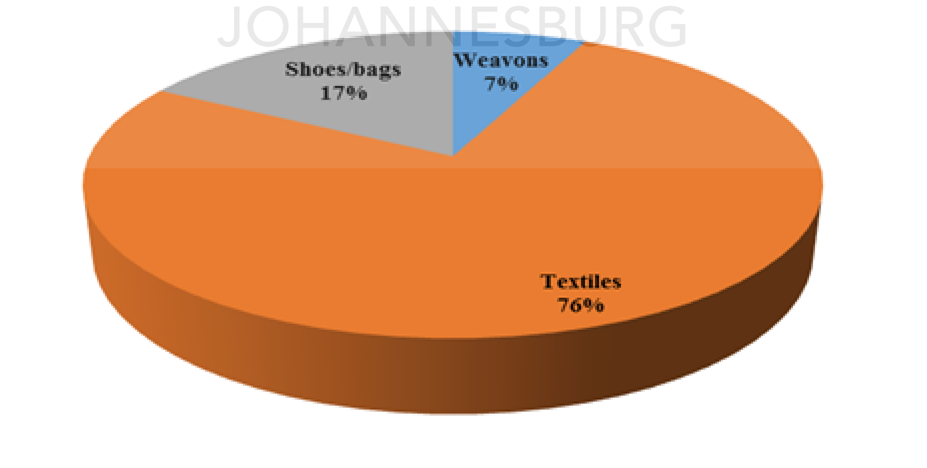

Figure 4: 26 : Textile wastes

4.1.1.2.2.6 Metal wastes

Metal waste occupied about 5% of the main component of the overall waste streams. Inside metals; aluminium had the largest percentage of 38% by weight (Figure 4.27). The entire waste streams in this category are recycled by the Reclaimers.

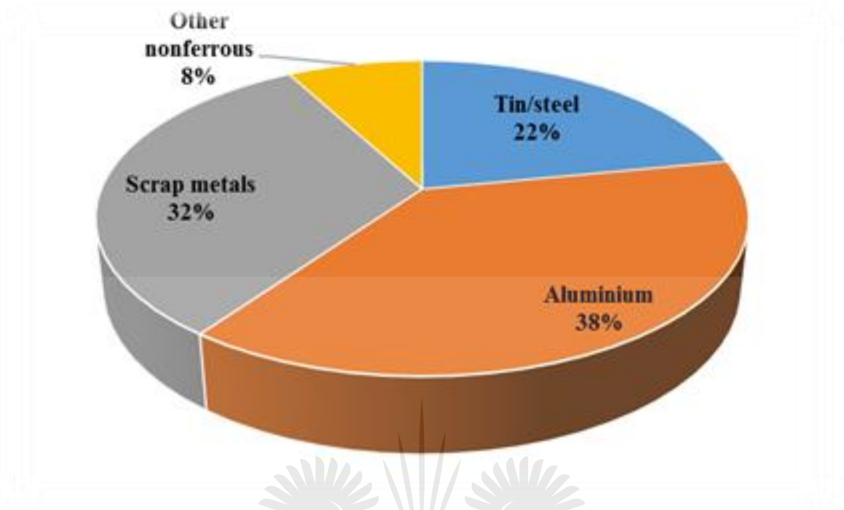

Figure 4: 27 : Metal wastes

4.1.1.2.2.7 Glass wastes

Glass wastes occupied about 4% of the main component of the overall waste streams. Within glass category; clear bottles had the highest percentage of 42% by weight (Figure 4.28). There was no clear evidence that bottles are being recycled by the Reclaimers.

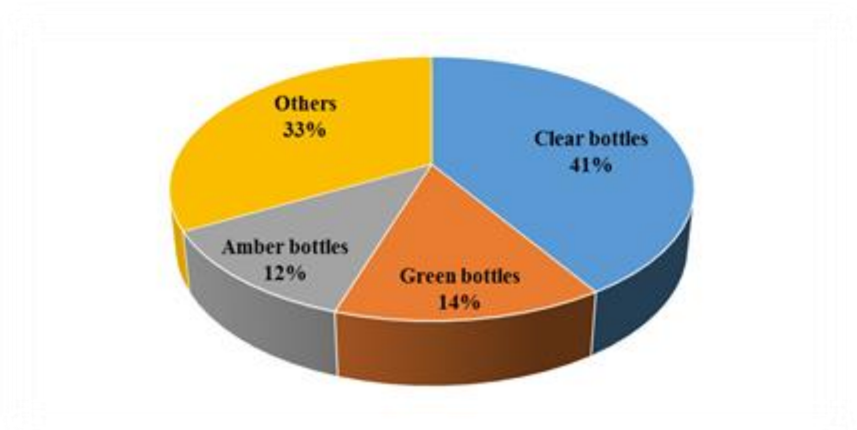

Figure 4: 28 : Glass wastes

4.1.2 Statistical Comparison using Analysis of variance and STATA 12 software

A statistical analysis was conducted to evaluate seasonal variation between the waste generated during summer in 2015 and in winter of 2016. Two types of statistical techniques were employed using Excel software. They are Analysis of variance (ANOVA) and STATA 12. One-way analysis of variance (ANOVA) test is employed to test the importance of differences between two or more means. ANOVA evaluates any form of variations within the group [Mertler and Vannatta, 2002]. One-way ANOVA is capable of comparing more than two groups. However, the means of the groups need to be equal [Park, 2003]. In this study, the ANOVA was evaluated using Microsoft Excel software. The Anova was used to check if the differences are significant.

From the results of the analysis using ANOVA software; the sub-divisions of Dailies non-compacted wastes generated during the summer and winter and the sub-division of RCR compacted wastes generated in both seasons were compared. Results showed p-value = 0.9913 for Dailies and p-value = 0.9999 for the RCR. From statistical analysis, if *F > F crit*, the null hypothesis was rejected. In these cases, for both the RCR compacted wastes and the Dailies non-compacted wastes during the summer and winter exercises, *F crit > F*, therefore, the null hypotheses are accepted. These show that the two populations for the RCR are equal and those for the Dailies are also equal. The means for RCR are 100.4 and 100.1 and those for Dailies are 100 for the first column and 100 for the second column (Appendix A, (A5, A6 and A7)).

STATA 12 is a software package employed by Statisticians to manage, analyse, explore, summarize and to graph data. It can be used as a point-and-click application or as a command driven package. It is widely used in social sciences and is the mostly used statistical software. It is very robust, good and affordable [Rabe-Hesketh and Everitt, 2004, Torres-Reyna, 2007, Eichorst, 2009]. The main categories of Dailies and RCR wastes generated in both seasons were also compared using STATA 12 software. Results obtained showed p-value for Dailies to be 0.9775 and p-value for RCR was obtained as 0.9760 (Appendix A, (A8)). From the analysis, it was clearly shown that there were no significant variations in the amount of RCR wastes and Dailies wastes generated in both seasons. It was therefore established that the differences in the wastes generated in both seasons for the Dailies services and for the RCR services were not statistically significant.

4.2 Elemental and Proximate Analysis of Organic Fraction of MSW

With the aid of CHNS analyser, the CHNS of the RCR compacted wastes were determined. Oxygen (O) was determined by summing up the percentage weights of ash, C, H, N and S and subtracting them from 100%. From the analysis of the samples, it was found that carbon was 45.32%, hydrogen 6.22%, oxygen 41.06%, nitrogen 2%, there was no sulphur present and C and N ratio was found to be 22.66. From the results obtained, an empirical equation was developed. The calculated chemical empirical formula for the organic fraction of MSW (OFMSW) was $C_{27}H_{44}NO_{16}$. Proximate analysis which includes the moisture content, ash, volatile matter and fixed carbon were determined based on the ASTM standards. The result of the analysis is summarised in Table 4.5. The Carbon (C) to nitrogen (N) ratio (C/N) is essential for the bacteria activities in order to process the OFMSW into compost. The best ratio to start with is around 25:1 to 30:1 [Public Works and Government Services of Canada, 2013]. As soon as composting process commences, the ratio decreases gradually from 30:1 to about 10-15:1 until the process is completed and the finished product is obtained. This is due to the fact that as organic materials are being used up by microorganisms, about 2/3 of C element is effused as carbon dioxide (CO_2) and the other 1/3 is combined with N element into the cells of the microbes but will afterwards be discharged to be utilized as soon as the cells of the microbes die. The C/N ratio must not be too high, if it is too high, it means there is limited supply of N element, hence the rate of decomposition will be slowed down. Also, if the C/N ratio is too low, it means there is surplus supply of N resulting in compost with an offensive odour and this can result in the loss of N as ammonia gas. The ideal moisture content of the composting process is between 55% and 65% [Jolanun et al., 2005, Chai et al., 2013]. The moment the level of moisture is too low, the action of the microorganisms will be restrained and when the level of the moisture is too high, pore spaces will be created between particles fill with water and movement of air will be hindered as a result of the pore spaces created. The microbes will be drowning and the resulting process will be anaerobic digestion or composting with smelly compost [Risse and Faucette, 2012, Public Works and Government Services of Canada, 2013, Chen et al., 2011]. From the results obtained, the C/N ratio was 22.66 and the moisture level content was 63.93%. The moisture content of 63.93 is healthy and ideal for good compost. The C: N ratio obtained was 22.66, this is quite low compared to the optimum C: N ratio of 25:1 to 30:1 for an active composting process [Zhu, 2007].

The C:N ratio can be increased to the range of 25:1 and 30:1 by blending fruit wastes, leaves, corn silage and horse manure with the feedstock and the C:N will increase to the range of 26 and 30 [Tanimu et al., 2014, Augustin and Rahman, 2010, Equine Facilities Assistance Program, 2003].

Table 4: 5 : Elemental and Proximate Analysis of Food Waste Sample

	Range	Average
Elemental analysis		
C (%)	45.25 - 45.39	45.32
H (%)	6.18 - 6.25	6.22
N (%)	1.96 - 2.04	2
S (%)	0	0
O (%)	41.00 - 41.12	41.06
C:N		22.66
Proximate analysis		
Ash (%)	5.39 - 5.42	5.41
Moisture content (%)	60.92 - 67.10	63.93
Volatile matter (%)	21.78 - 23.00	22.55
Fixed carbon (%)	4.41 - 11.91	8.16

4.3 Chapter summary

During the waste composition exercise, it was observed that; low-income areas generated more waste than high-income areas. This figure is at variance with the trend globally in which waste generation increases as the standard of living improves. It was also observed that the low income areas generate high percentage of organic wastes than the middle income and high income areas; the latter generate more inorganic wastes such as plastics, bottles, cans, tins etc. 28% organic waste was generated from RCR compacted wastes and 13% by Dailies non-compacted wastes during the summer. Also, 29% organic waste was generated from RCR and 14% organic wastes from Dailies during the winter. The Reclaimers play a very important role in the management of the wastes. On a daily basis they reclaim a large quantity of recyclables and through this process; they make their earnings daily when they sell the recyclables to industries. Their recycling activities help to extend the lifespan of the site. Effect of seasonal variation on both the Dailies and RCR for the main components was evaluated using STATA 12 software. Results obtained from the analysis showed p-value = 0.9775 for Dailies and p-value = 0.9760 for RCR. ANOVA software was also used to evaluate the seasonal variation of the sub-categories for both the Dailies and RCR. Results obtained from the analysis also showed p-value = 0.9999 for Dailies and p-value = 0.9913 for RCR. These clearly showed that the differences between the wastes generated during winter and summer for both services are not statistically significant.

Food wastes samples obtained from the Marie Louise LS when it is separated from the source or diverted from landfills and is sent to the composting plants will be a good source of compost having satisfied the condition of the moisture content of 63.93%. The C: N ratio obtained was 22.66. Though, it was too low but it can be increased by blending fruit wastes, leaves, silage and horse manure with the feedstocks and thereafter the C: N ratio can be increased to the range of 25:1 to 30:1. Thus, composting facilities can be sited in localities.

5.0 CHAPTER 5: QUESTIONNAIRE DATA ANALYSIS

5.1 Introduction

The results of the questionnaire (shown in Appendix B) are discussed in this section. The raw data of the overall analysis of the questionnaire are tabulated and are as shown in Appendix C (C1 to C48).

5.1.1 Household Identification

The demographics of the respondents and their households' identification (Appendix B and Appendix C (i-vi)) are presented in Table 5.1 and the responses from the communities where the survey was carried out are presented in Figure 5.1. The groups comprised of Naledi extension informal settlement (NEIS) which represent the low income class, Naledi extension RDP (Reconstruction and Development Programme) which represents a middle income class, Dobsonville RDP also represents a middle income class and Dobsonville Bond represents a high income class. There were more men among the respondents than women. The respondent code of household members is as shown in Figure 5.2 and Figure 5.3 shows the respondent codes of those who indicated others.

Table 5: 1: Demographics of the respondents and their households' identification

Background identification	**Respondent Groups**			
Respondent codes	Husband	Wife	Others	No response
	39%	33%	27%	1%
Responses from the communities	Naledi extension informal settlement	Naeldi extension RDP	Dobsonville RDP	Dobsonville Bond
	35%	28%	19%	18%
Gender	Male		Female	
	51%		49%	

5.1.1.1 Groups

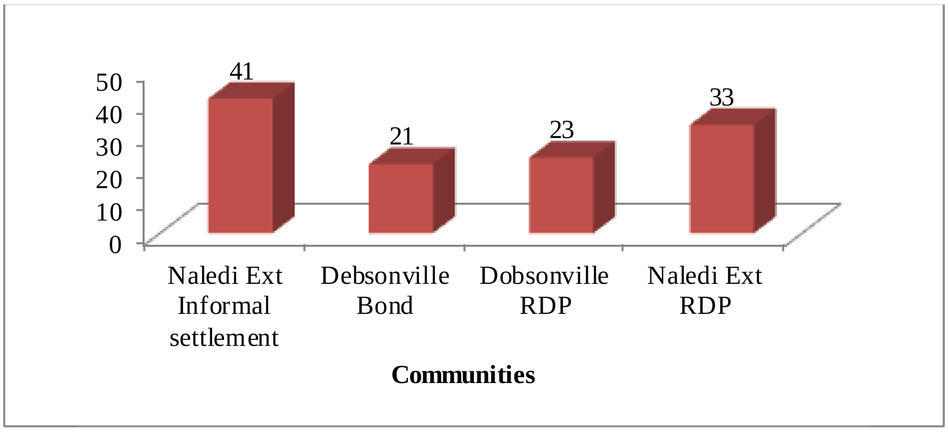

Figure 5: 1 : Communities where survey was carried out

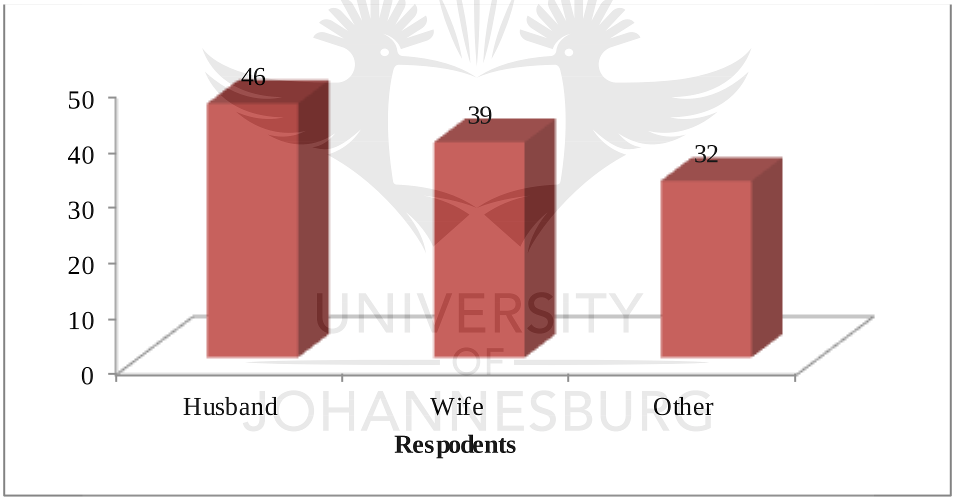

Figure 5: 2 : Respondent code of household members

From the sampled population (Figure 5.2), 46 (39%) were husbands, 39 (33%) were wives, 32 (27%) were others which include the grannie, grandpa, sisters-in-law, brothers-in-law, uncles and tenants; and 1 person (less than 1%) did not respond. The largest parts of the population of the respondents were men. This is an indication that men are also concerned about the state of their WM.

5.1.2.1 Other Respondent code other than husband and wife

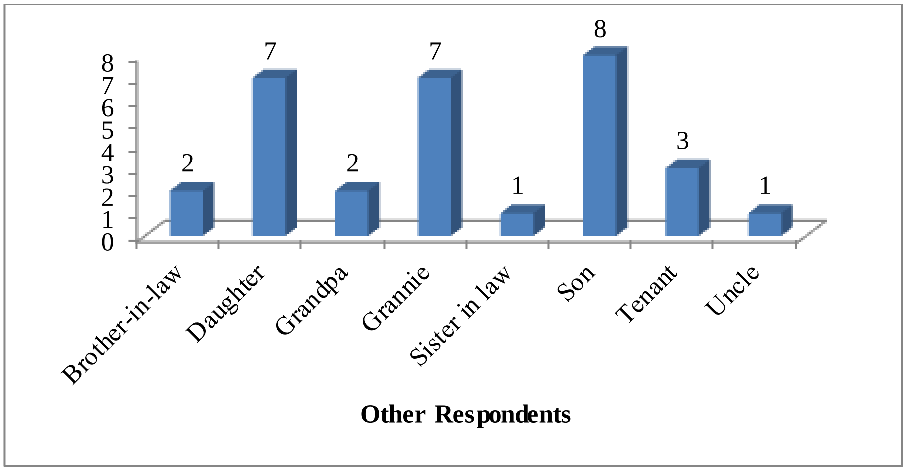

Figure 5: 3 : Respondent codes

From the 'others' category (Figure 5.3); the total number of respondents was 31, 1 person did not respond. The rate at which the respondents avail themselves to attend to the questionnaires shows how eager they have been yearning to be properly educated on environmental matters.

5.1.2.2 Gender of Respondents

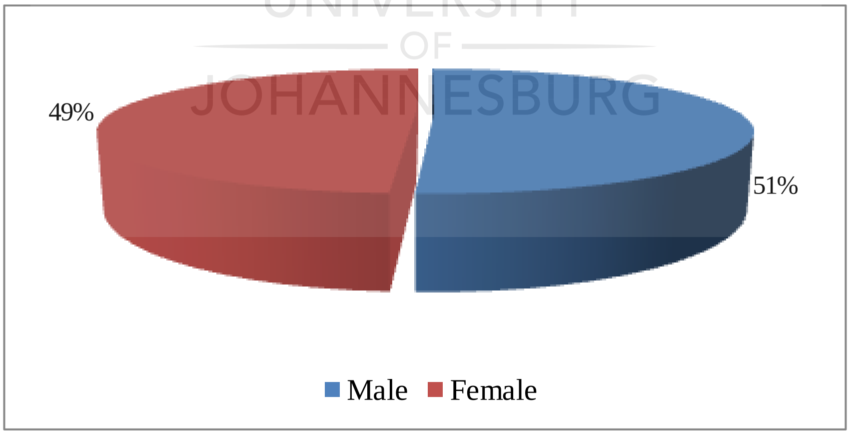

Figure 5: 4 : Gender of Respondents

About 51% of the respondents were male and about 49% were female (Figure 5.4). This is an indication that men are also interested in environmental matters and they are also looking forward to an improved waste collection services.

5.2 General Household Information

The questionnaire used in this study addressed the perception of the people about SWM and their levels of awareness on ZW. The household information (Appendix B, questions 1, 2, 3, 4, 5 and 7 and Appendix C, (C1, C2, C3, C4, C5 and C7)) is as shown in Table 5.2. From the sampled population; about 87% of the respondents said household members are the owners of their apartments, about 4% said their apartments are owned by government and about 9% said their apartments are owned by private owners. This shows that the majority of the population may not be paying house rents since their apartments are owned by the members of their households. The study also showed the distribution of people living in various households. 3% said only 1 person lives in a household, 28% said only 2 persons live in a household, 23% said 3 people live in a household, 22% said 4 people live in their households and 24% of the respondents gave different responses which are from 5 persons to 10 persons living in a household. Retired adults were about 19% of the sampled population. Therefore, most likely the majority of the population may be working class who are young and energetic adults that can put their energy into productive use. About 32% of the respondents said it is only one person in their households that is on a seasonal income and about 42% of the respondents said there is only 1 person on regular income in their households. About 46% of the sampled population had secondary education and about 13% had high school. Figure 5.5 shows the respondents who indicated other qualifications. This is an indication that the communities will be receptive to education and broadcasting of environmental matters. Hence, the municipality must devise various means of reaching out to the community through media such as print, campaigns and workshops.

The economic situation of a community can best be determined by the poverty level of the populace. Decision makers often used poverty rate to measure the economic conditions within communities and compare it with sections of the population. It is easier to determine the number of people who fall below poverty level through this means [Bishaw and Fontenot, 2014]. The municipality must make it its goal to educate the general public on environmental matters and to also get them involved in the implementation process of any WM plan and in the siting of any waste recycling plant around them [Robinson and Nolan-Itu 2002]. Figure 5.5 illustrates public participation and engagement hierarchy. The municipality can influence the member of the general public through its education campaign, inform them on their WM plan, consults the various groups in the communities, involve them; partner with them and empower most especially their youths.

Table 5: 2 : Households information

Household information	Respondents						
Number of people living in a household	1	2	3	4	Others	No response	
	3%	28%	23%	22%	24%	0%	
Retired adults in a household	0	1	2	3	Others	No response	
	0%	19%	5%	2%	33%	48%	
Owners of the apartments	Household members		Government		Private owners		
	87%		4%		9%		
Pensioners living in a household	0	1	2	3	Others	No response	
	20%	20%	2%	0%	0%	58%	
Adults with with regular income	0	1	2	3	4	No response	
	8%	42%	18%	3%	1%	28%	
Adults with with seasonal income	0	1	2	3	4	No response	
	15%	32%	21%	3%	1%	28%	
Highest qualification	Never been to school		Primary school	Secondary school	High school	University	No response
	5%		30%	46%	13%	5%	1%

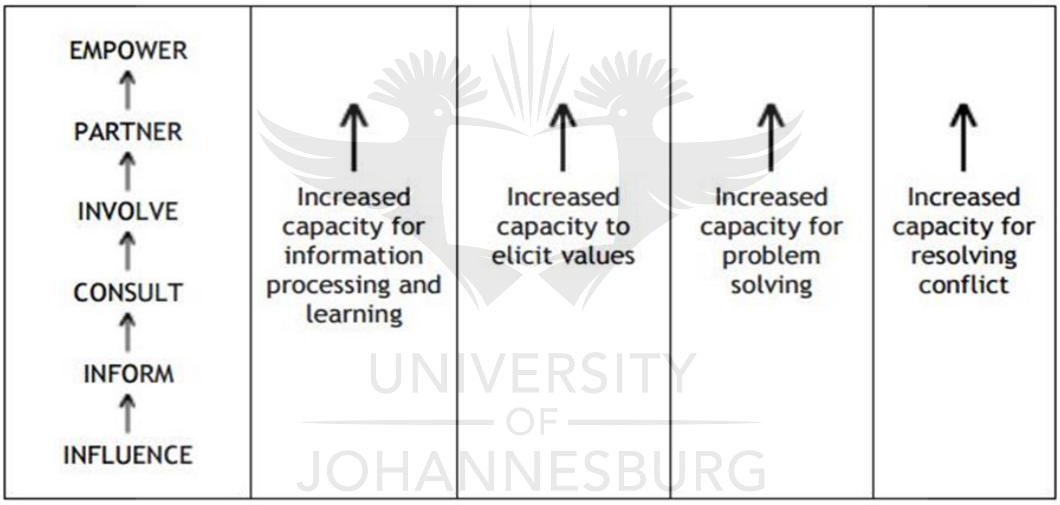

Figure 5: 5 : Public Engagement Ladder [Robinson, 2002]

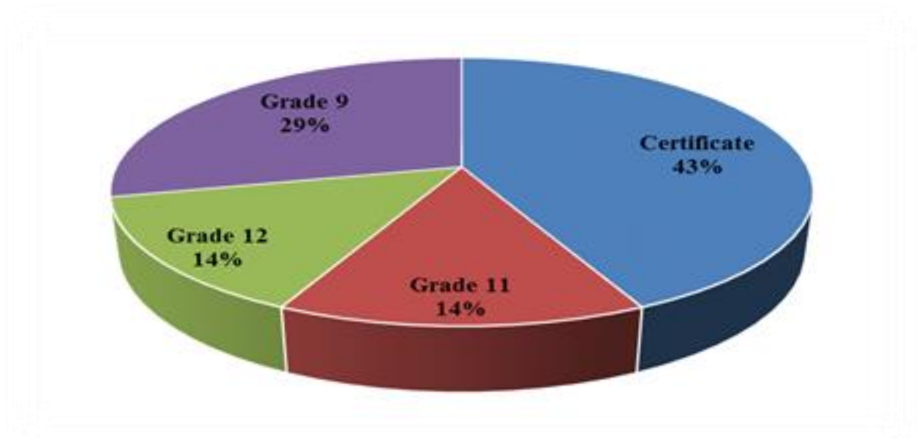

Figure 5: 6 : Other Higher Qualifications

The average amount and distribution of amount spent by households per month (Appendix B, question 6 and Appendix C6) are as shown in Figure 5.6 and Figure 5.7. From the total of 118 participants, 115 respondents responded and 3 people did not respond. Most times when it gets to do with finance, people tend to be very reserved. People who spent from R 500 to R 1700 per month formed about 50% (median) of the distribution. This expenditure is on food, transport, utilities and other general expenses. The respondents who spent R 1800 and above formed the remaining 50% of the entire distribution. People who spent from R 7000 to R 10,000 are less than 1% for each group. This shows that the level of poverty may be very high in those communities. The mean and standard deviation of the distribution were calculated as R 2587 and R 1915 respectively.

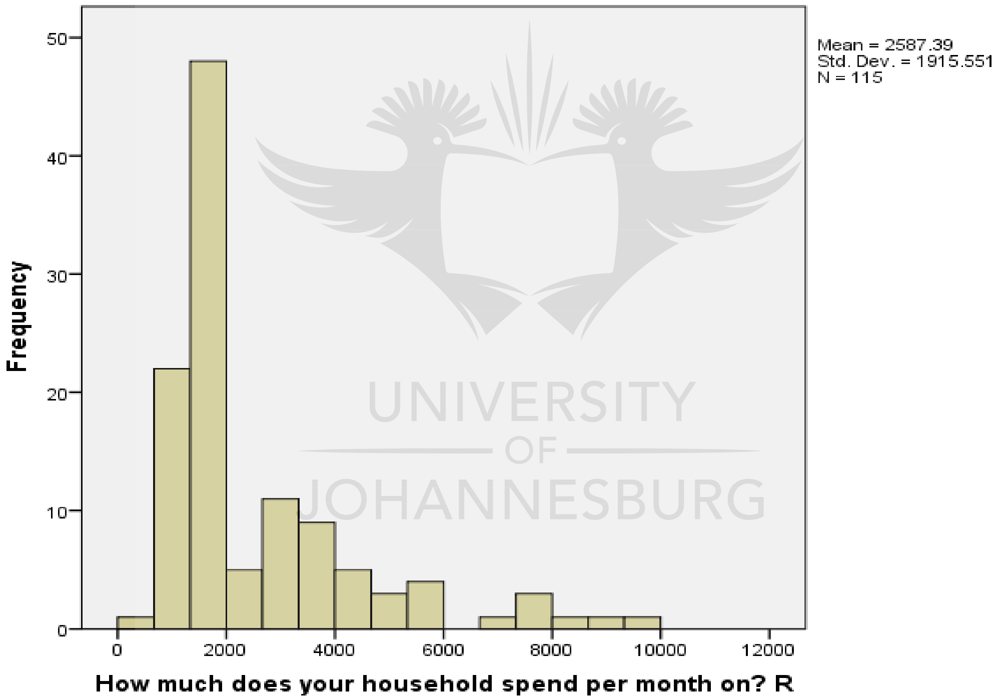

Figure 5: 7 : Amount spent monthly

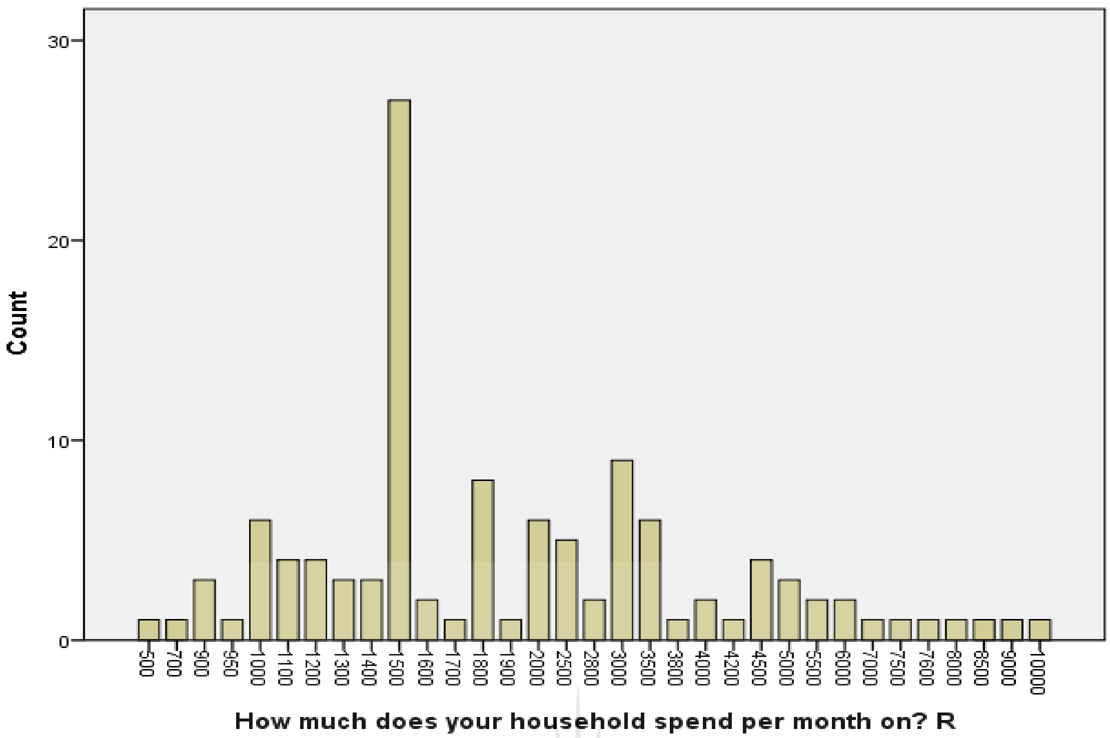

Figure 5: 8: Distribution of amount spent by household per month

5.3 Major Concerns

The major issues faced by the people (Appendix B, question 8 and Appendix C8) are as shown in Figure 5.9. About 36% of the sampled population said they are experiencing air pollution from the landfill site around them. Given the large percentage of people that are experiencing issues of air pollution and poor waste collection services; the municipality needs to review its landfill management methods and also needs to improve its collection services most especially in Naledi extension informal settlement since the majority of the residents said they are not being offered any services since the municipality does not have any regard for them because of the nature of where they are residing.

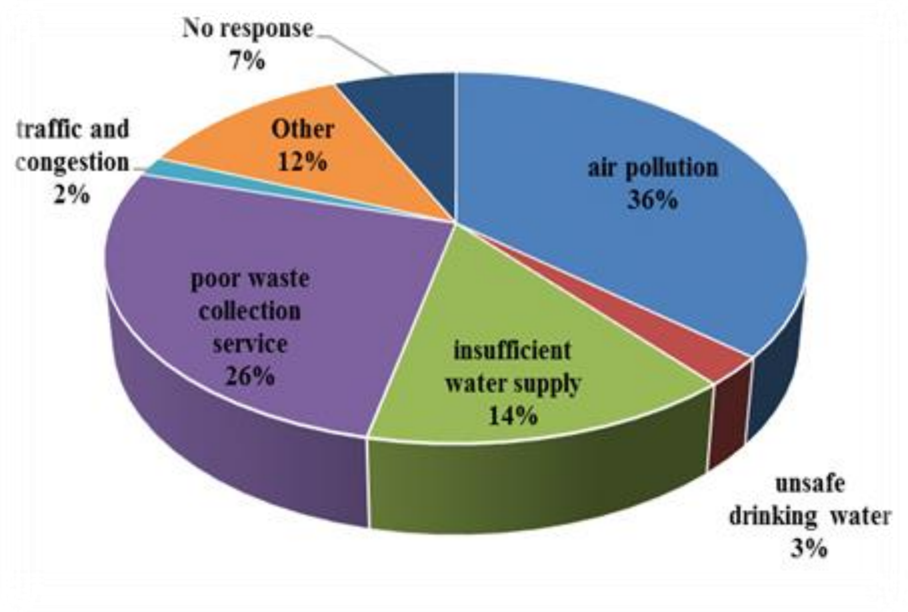

Figure 5: 9 : Environmental Problem

Air pollution has become one of the major environmental problems experienced by the populace since most of the waste disposed of at the landfill is being compacted, hence during the wet season, emission results [Lingan et al., 2014]. Emission of chemicals, radiations and infectious diseases from the landfill poses risk to the health of the general public. Hence, management of landfill needs to be strictly controlled in such a way that its design and operation will have no impact on human health and the environment [Macklin et al., 2011].

5.4 Household waste collection service

Household waste collection service (Appendix B, questions 9 to 28 and Appendix C, (C9 to C28)) are addressed here.

Q9. Does your household have a waste bin for storing household waste?

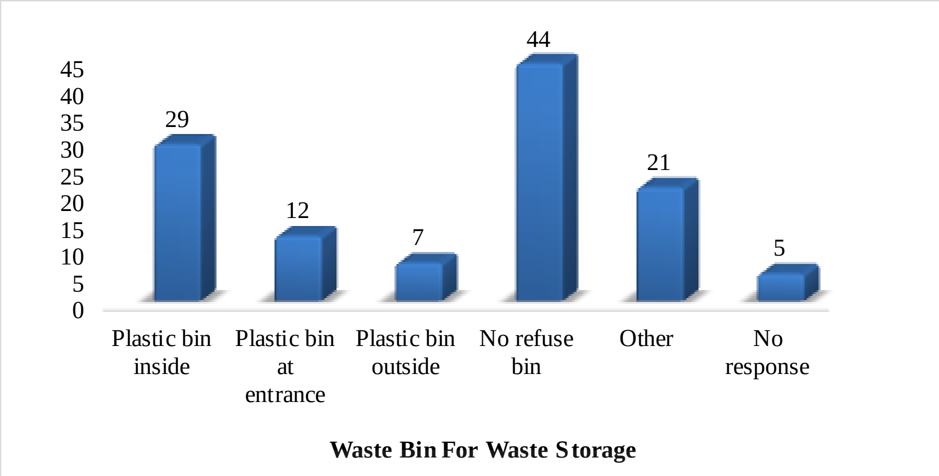

Figure 5: 10 : Responses on Bin for Waste Storage

From the sampled population (Figure 5.10); about the 25% of the respondents said they have plastic bin inside their apartment, 10% said they have plastic bin at the entrance, 6% said they have plastic bin outside the apartment, 37% said they do not have refuse bin and about 18% gave different feedback. With the bulk percentage of 37% of the respondents not having refuse bins, this is an indication that illegal dumping of wastes is inevitable in those communities. This shows that municipalities have a lot of work to do in terms of replacing the refuse bins of the people in order to prevent illegal dumping.

Q9 (e). Does your household have a waste bin for storing household waste if other, specify?

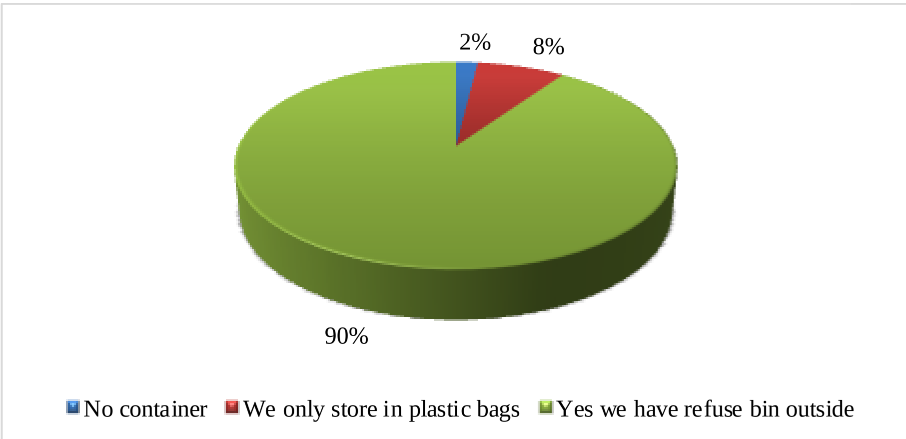

Figure 5: 11 : Other Responses on Waste Bin

From the sampled population (Figure 5.11); about 52 respondents gave different responses. 1 person said there is no container in their community, 4 people said they only have plastic bags and the other 47 people said they have refuse bins outside their apartment which were given to them by the municipality.

Q 10. If yes, how is the condition of the bin?

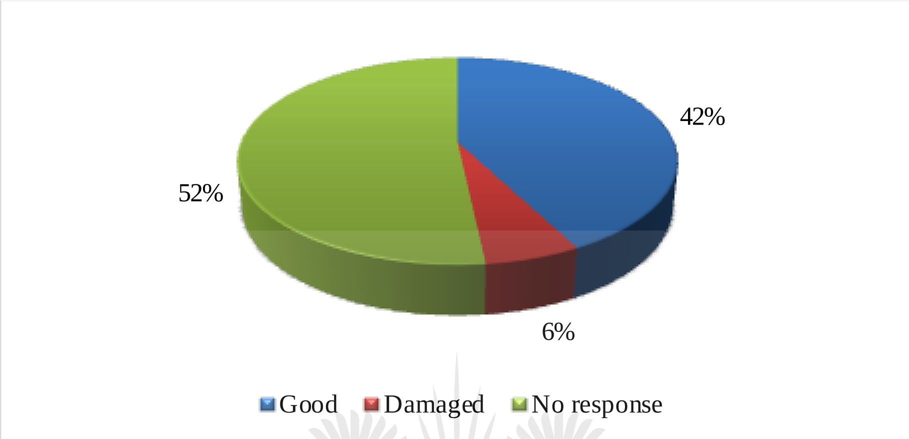

Figure 5: 12 : Condition of the Waste Bin

From the sampled population (Figure 5.12); 42% said their refuse bins are good, 6% said their refuse bins are damaged while about 52% did not respond. With the largest percentage of 52% who did not respond, then the municipality need to expedite action by identifying households in those communities who do not have refuse bins and those whose bins have been damaged so that replacement can be made.

Q 11. If yes, for how long has your household been offered the bin?

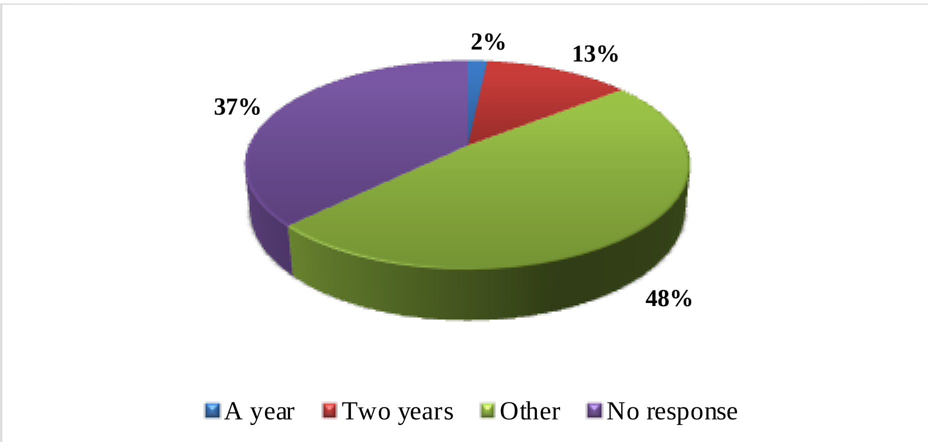

Figure 5: 13 : Period in which the Bin has been offered

From the sampled population (Figure 5.13); about 2% said they had received refuse bin for just a year, about 13% said it was for two years, about 48% gave different responses other than these responses and about 37% did not respond. The 37% who did not respond is as equal to those who do not have bins. Thus, the municipality owes the communities a duty to find out those who have and those do not have bins so that provision can be made.

As a matter of urgency, the municipality needs to introduce community development workers (CDWs) in order to serve as an intermediary between the communities and the municipality. The CDWs are meant to act as agents of change in the communities where they live. Their responsibilities are to assist the members of the communities in terms of their right to basic necessities of life and they can also help to educate the members of the communities on the need to be part of SSWM [Raga et al., 2012].

Q11 (c). How long have the households been offered refused bin, if others, specify?

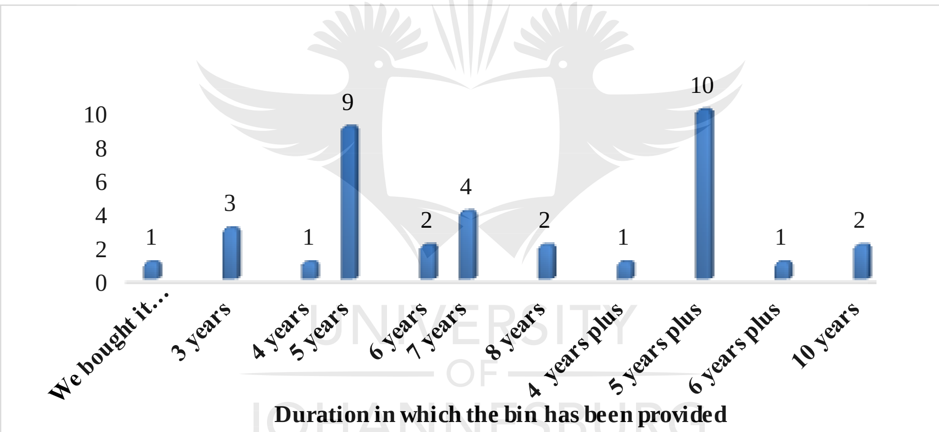

Figure 5: 14 : Other Period the bin has been offered

From the sampled population (Figure 5.14); about 6% said they have been given the refuse bin for 10 years, 8% said it is for 3 years, 3% said it is for 4 years, 25% said it has been given for 5 years, 6% said 6 years, 11% said 7 years, 6% said 8 years, 3% said more than 4 years, 28% said more than 5 years, 3% said more than 6 years and about 3% said they bought it by themselves. It becomes very paramount for the municipality to expedite action to put CDWs in place and if they are already in place, they need to be re-assigned their duties in order to get close to the communities to find out from them if their refuse bins are still in good shape or not. By so doing, illegal dumping will be eliminated and the people will enjoy quality service.

Q12. If no, why is the household without a refuse bin?

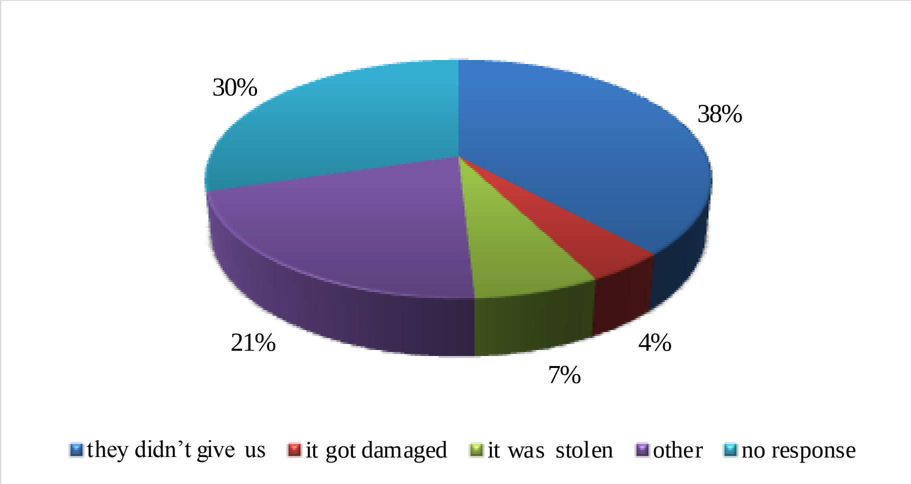

Figure 5: 15 : Reasons the household does not have bin

From the sampled population (Figure 5.15); 38% said they were not given refuse bin. With about 38% indicating they were not given bins, it is very essential that the municipality act speedily in those communities to provide refuse bin to them in order to prevent illegal dumping.

Q13. Does the household normally take out the bin and additional plastic bags on refuse collection day?

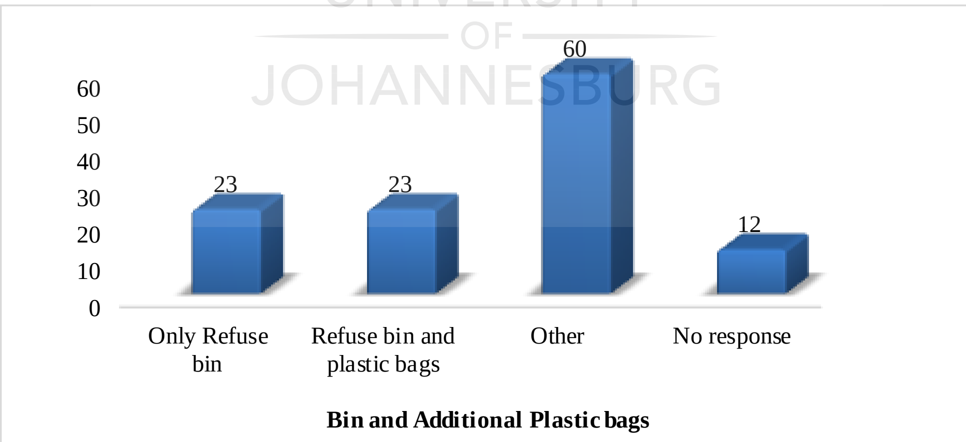

Figure 5: 16 : Bin and additional plastic bags on refuse collection day

From the sampled population (Figure 5.16); about 20% said they do bring out only their refuse bins provided by the municipality on refuse collection day, another 20% said they do bring out refuse bin and plastic bags, 51% gave different responses in which majority of them said they only bring out plastic bags while 10% did not respond.

Q14. On which day of the week does PIKITUP collect waste in your area?

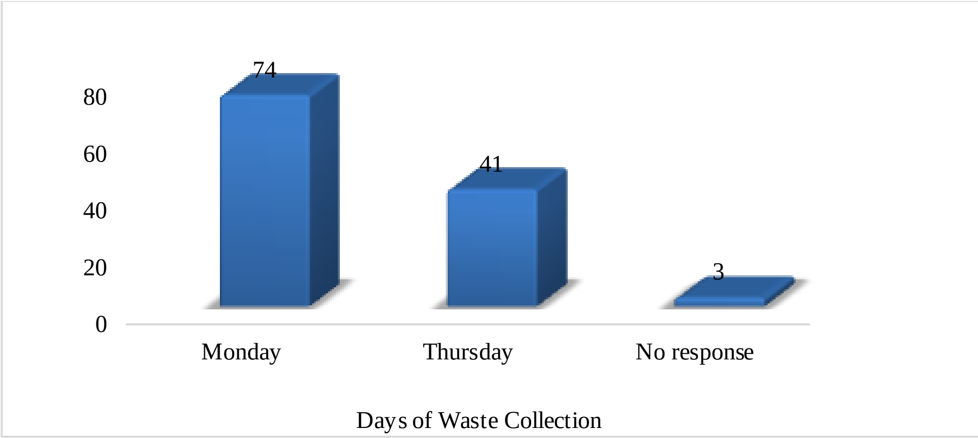

Figure 5: 17 : Days of waste collection

From Figure 5.17; the sampled population of NEIS and Naledi RDP which formed about 63% of the respondents said their waste collection day is every Monday and the sampled population of Dobsonville RDP and Dobsonville Bond which is about 35% of the overall said their waste collection day is every Thursday. About 2% of the sampled population did not give any answer. With about 98% respondents who gave the days of their waste collection is an indication that the municipality has done well in this area since each community is aware of its waste collection day.

Q15. Are there dumping sites in your area? If yes indicate the state?

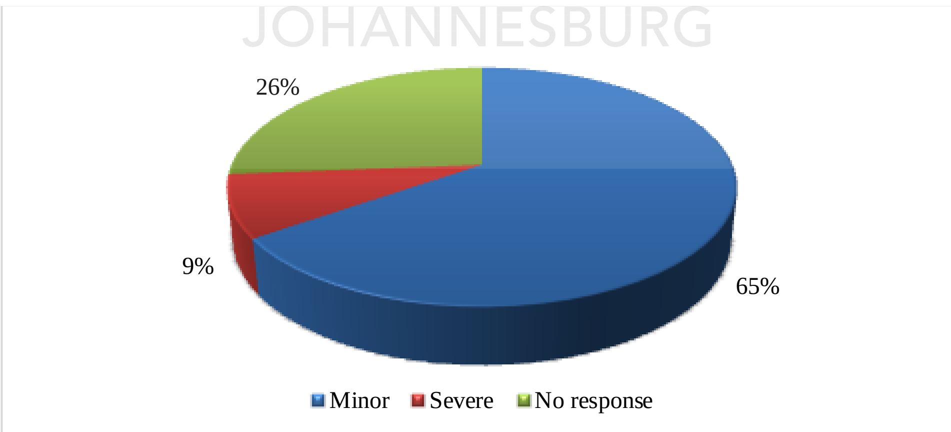

Figure 5: 18 : Dumping sites in the area

About 65% of the sampled population (Figure 5.18) said they only have minor dumping sites around them, 9% said it is severe and 26% did not respond. With the bulk of the sampled population of 65% indicating that there are minor dumping sites around them shows there are areas where people are carrying out illegal dumping. This might be due to the fact that they were not been offered services by the municipality or probably they were not given refuse bin and plastic bags for storage of wastes. Hence, the municipality needs to visit the communities; see to it that they clear every form of illegal dumping and also position a CDW in the community who will be representing the municipality and will be also be educating the community on the need to stop illegal dumping and to embrace SSWM.

Illegal dumping results when the general public is not informed. It is the responsibility of the municipality to educate the communities on environmental issues. The municipality should get the general public and schools involved. The municipality should be able to educate the communities on the health hazards that may ensue from illegal dumping [Lotz-Sisitka et al., 2005].

Q16. Type of waste reused by household

Table 5: 3 : Waste reused by household

	Reused	Not reused	Total
Plastic	73%	27%	100%
Glass	49%	51%	100%
Paper	22%	78%	100%
Cardboard	18%	82%	100%
Compostable	14%	86%	100%
Metals	29%	71%	100%
Others	14%	86%	100%

From Table 5.3, only 49% of the glass was reused; about 73% of plastics are reused, 22% paper are reused; 18% cardboard are reused; 14% organic wastes are reused, 29% metal cans are reused and 29% other wastes are also reused. This shows that about 51% of glass, 27% of plastic, 78% of paper, 82% of cardboard, 86% of compostable, 71% of metal cans and 86% of other wastes ended up in the landfill. With the bulk of these wastes ending up at the landfill site, the municipality needs to act as soon as possible to divert all these waste streams from going to the landfill site in order to extend the life span of the site.

The municipality needs to educate the communities on the need to reduce the amount of waste generated per person; increasing recycling and diversion of organic wastes from going to the landfill site through source separation [City of Alameda, 2010].

Q17. Type of waste used for recycling

Table 5: 4 : Waste used for recycling

	Recycled	Not recycled	Total
Paper	39%	61%	100%
Metal	53%	47%	100%
Compostable	18%	82%	100%
Cardboard	22%	78%	100%
Glass	65%	35%	100%
Plastic	69%	31%	100%

From Table 5.4; about 65% of glass are recycled, about 70% of plastics are recycled, only 39% of paper is recycled, only 22% of cardboard is recycled, only 18% of organic wastes are recycled, about 53% of metal cans are recycled and 14% of other wastes are also recycled. With 18% of compostable wastes being recycled, it is very obvious that about 78% of the organic wastes ended up in the landfill. This is not good for the economy of South Africa since resources are not fully utilised.

Organics need to be diverted from going to landfill and should be recovered through composting and anaerobic digestion. When these organics are buried at the landfill site, they break down and pose a threat to the health of the general public and the environment since methane is release to the atmosphere and this contributes greatly to global warming [US Composting Council, 2010].

Q18. Types of waste sold by household

Table 5: 5 : Waste sold by household

	Sold	Not sold	Total
Paper	3%	97%	100%
Cardboard	1%	99%	100%
Metals	3%	97%	100%
Compostable	1%	99%	100%
Glass	2%	98%	100%
Plastic	4%	96%	100%
Other	23%	77%	100%

From Table 5.5; only about 2% of glass is sold; only 4% of plastic is sold; about 3% of paper is sold; less than 1% of cardboard is sold; less than 1% of compostable is sold; about 3% of metal cans are sold and about 23% of other wastes are also sold. With these low percentages of waste items being sold, this is an indication that households rarely sell waste items, hence the bulk of the waste ends up at the landfill.

The municipality needs to formalise the activities of the informal sectors and scavengers who earn their living through the sales of waste items and also integrate them into the sector so that the amount of recycling can increase. The activities of the informal sector makes a positive impact on the environment by providing a cleaner environment; reducing expenses that ordinary people need to incur as a result of waste management and large groups of people make their income through this exercise thus reducing crime rates [Gerdes and Gunsilius, 2010]. Municipalities ought not to view waste pickers as a problem but as a resource. When these waste pickers are properly organized, they can become very active in the process of development; they can put an end to poverty at the base and they will begin to get good prices for their waste items when middlemen are eliminated in the process [Medina, 2008].

Q19. How much income (Rand per month) on average do you get from selling these wastes?

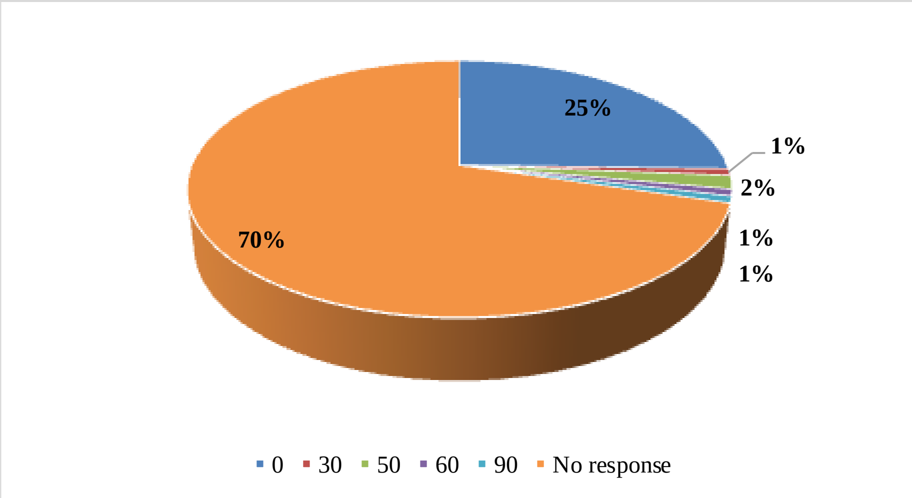

Figure 5: 19 : Income per month on average from selling wastes

From Figure 5.19; about 25% of the sampled population said they are not selling recyclables, less than 1% said they are making R30, about 2% said they are making R50, less than 1% said they are making R 60, less than 1% also said they are making R90 on average every month through the sales of recyclables and about 70% did not respond. With about 25% who said they are not selling waste items and about 70% who did not respond; this is an indication that households hardly sell waste items. Therefore, the municipality needs to act fast by involving other stakeholders in WM.

The informal waste sector i.e. reclaimers, scavengers or waste pickers contribute immensely to resource recovery and recycling in DCs. Since households rarely recycle, reuse or sell waste items, it is best for the municipality to co-opt this sector into WM [Gunsilius, 2011].

Q20. How would you rate your satisfaction with PIKITUP?

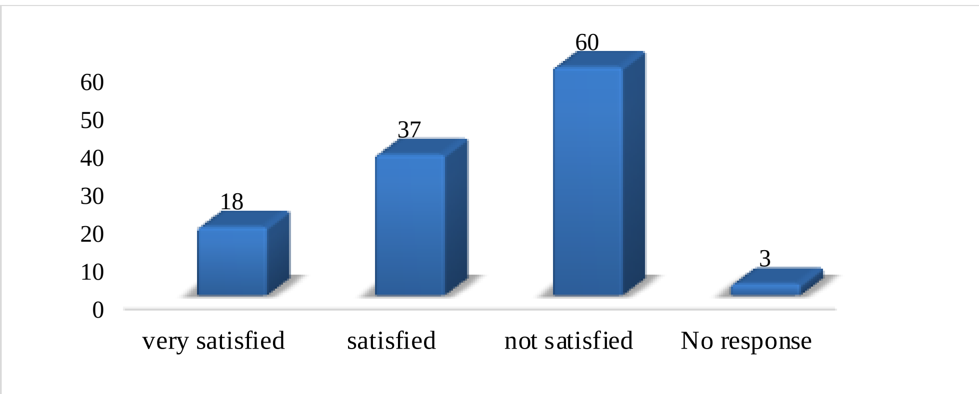

Figure 5: 20 : Satisfaction with PIKITUP

From the sampled population (Figure 5.20); about 15% said they were very satisfied with the services offered to them by Pikitup, 31% said they were satisfied and about 51% said they were not satisfied. With about of 51% who said they were not satisfied, the municipality needs to swing into action by finding out what the expectation of the people are and ensure that the expectations are being met through discharge of quality services to the general public.

Q21. Reasons for lack of Satisfaction with Pikitup

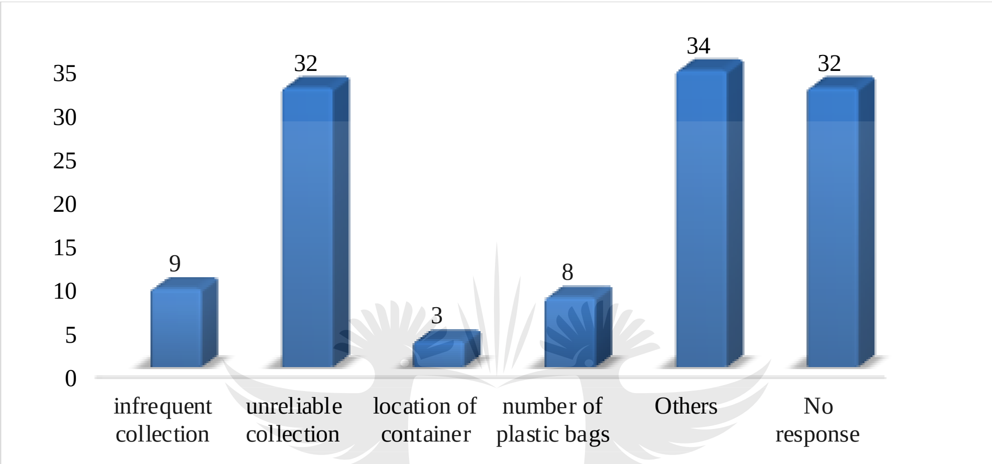

Figure 5: 21 : Reasons for lack of Satisfaction with Pikitup

From Figure 5.21; about 8% of the sampled population said they were not satisfied because of infrequent collection of their wastes, about 27% said the reason for non-satisfaction is because of unreliable collection of their wastes, about 3% said it is because the location of the communal container is very far from them, about 7% said the reason is because the number of plastic bags provided are not sufficient and about 29% of the respondents gave different responses. With about 27% of the respondents who said the issue they had was unreliable collection of their waste, it therefore means the municipality needs to improve its services in these communities. Also, about 29% who did not say anything may decide not to respond but may as well be having some issues with their waste collection services, hence the municipality may need to deploy the CDWs to the communities in order to find out the issues they are experiencing and ensure that the issues are resolved as soon as possible.

The municipality must strive to provide qualitative services that will sustain the environment and should also make an effort to create jobs for the unemployed youths in the community through green technology [Ethekwini Municipality, 2011].

Q21 (e). Other Reasons stated for Lack of Satisfaction with Pikitup

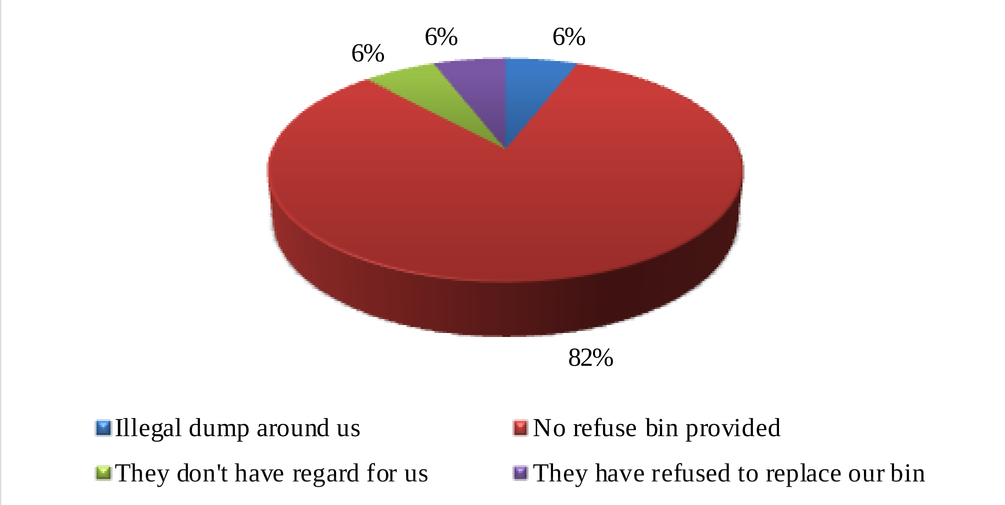

Figure 5: 22 : Other Reasons stated for Lack of Satisfaction with Pikitup

From the sampled population (Figure 5.22); 17 of the respondents gave different reasons for their lack of satisfaction with the services offered by Pikitup. About 6% said they have an illegal dumping site around them, about 82% of the respondents who gave different reasons said there are no refuse bin provided to them by the municipality, another 6% said the waste collection officials do not have regard for them because they are residing in an informal settlement and finally another 6% said Pikitup has refused to replace their refuse bins. The municipality needs to act very fast in order to attend to the need of all these respondents.

The municipality must strive to satisfy the need of the general public since the essence of bringing government closer to people is for the needs of the people to be met. If the needs of the citizens are not met by the local authority most especially in the area of WM, it will be very difficult for the municipality to enjoy any form of cooperation from the citizens [Montalvo, 2009].

Q22. Do you know where the collected waste is taken for final disposal?

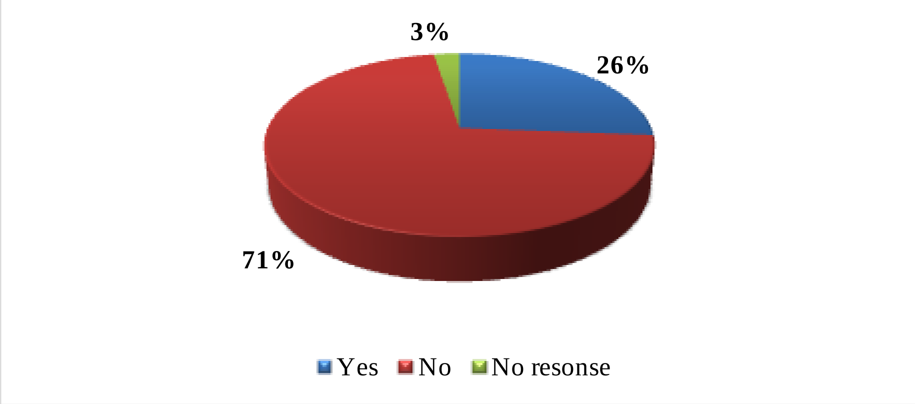

Figure 5: 23 : Responses on final waste disposal

From the sampled population (Figure 5.23); 31 of the respondents (26%) said they knew where their waste is taken to for final disposal, 84 respondents (71%) said they did not know where their waste is taking to for final disposal and 3 people (about 3%) did not respond. This shows that the knowledge of the people on environmental matters is very shallow.

When the municipality creates awareness and citizens are well-informed; citizens will support the services being offered and there will be an improvement in service delivery. Hence, it becomes very paramount for the municipality to design means of publicising waste related matters through initiatives such as public campaigns, media interventions etc. Education is the most effective tool the municipality can employ to get citizens involved and for improved service delivery [Almarshad, 2015].

Q23. Do you know who to contact if you have any problem with your waste collection service?

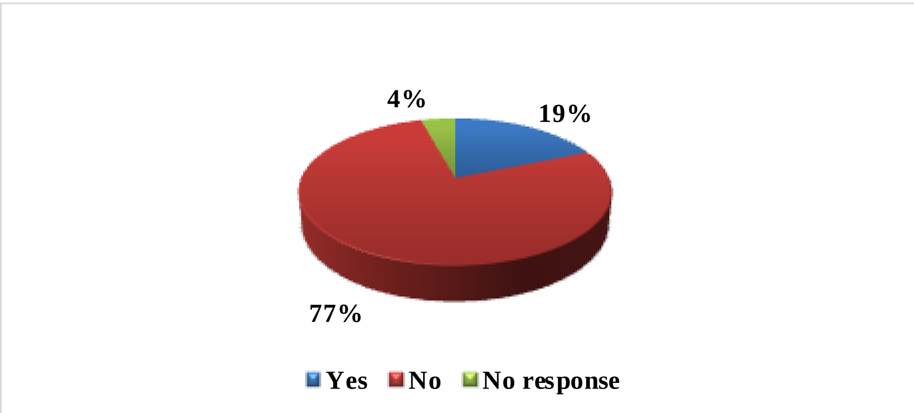

Figure 5: 24 : Responses on personnel to contact

From the sampled population (Figure 5.24); about 19% of the respondents said they knew who to contact if they have issues with their waste collection services, 77% said they did not know who to contact and 4% did not respond. With about 77% respondents who did not know who to contact if they have issues with their waste collection services is an indication that the people of the communities are not informed on matters relating to the environment. Thus, the municipality must increase her level of awareness so that people can be properly informed.

Q24. If yes, who would you call?

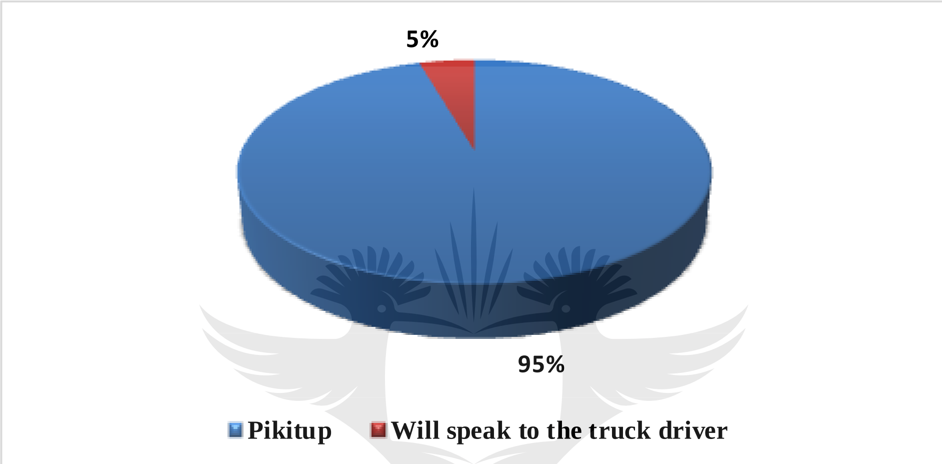

Figure 5: 25 : Responses on whom to speak to

From the sampled population (Figure 5.25); about 95% of the respondents said they will contact Pikitup while about 5% said they will speak to the truck driver about the issues. The majority of the respondents said they will contact Pikitup and the remaining respondents said they will speak to the truck driver. This is an indication that the municipality has not done enough in the area of educating the people on environmental issues. It becomes very important for the municipality to educate the people by setting up a contact centre if there is none and if there is one already in place; its services should be improved.

The people of the communities should be informed on the contact persons if peradventure they have any issue with their waste collection service and also the place of final disposal of waste through campaigns; radio jingles media prints, pamphlets, adverts, banners, and posters [Islamic Republic of Afghanistan, 2012 – 2013].

Q25. If you have ever called this office, were you satisfied with their response?

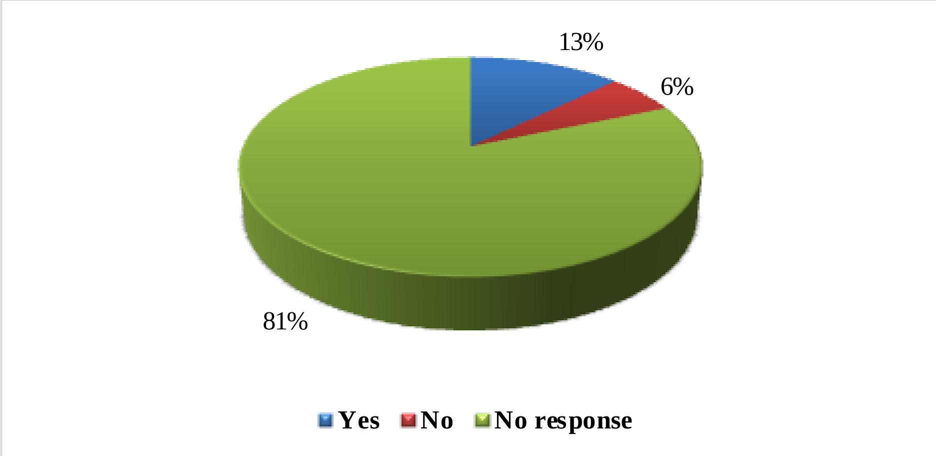

Figure 5: 26 : Responses on satisfaction with Pikitup service

From the sampled population (Figure 5.26); about 13% of the respondents said they were satisfied when they made calls through to the municipality, about 6% said they were not satisfied and 81% did not respond. With about 81% who did not response, this shows that the people of the communities may not be satisfied with the services offered by Pikitup.

Q.26 If you have ever called this office, were you satisfied with their response? If no, what problems did you experience?

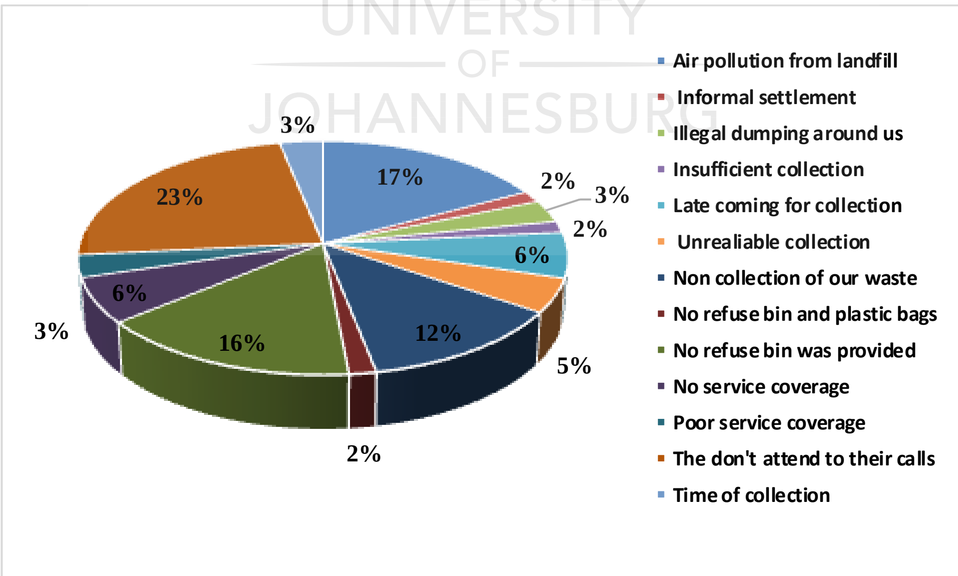

Figure 5: 27 : Responses on the problems encountered

From the sampled population (Figure 5.27), the respondents gave different responses on the reasons for the lack of satisfaction with the services offered by the municipality. About 3%

said the time of collection was not convenient since some of them might have gone to work before the collection period. Another 6% said the waste collectors usually come late and about 23% said that the municipality do not attend to calls whenever they try to contact them through phone calls.

Municipalities need to seek to address issues being faced by people, hence, quality services will be enjoyed and also the privilege of having government closer to people will be enjoyed by the people.

Q27. Is sufficient information made available to you about your waste management system (for example, information about collection times, payment of cleansing tax, risks associated with improper waste handling?

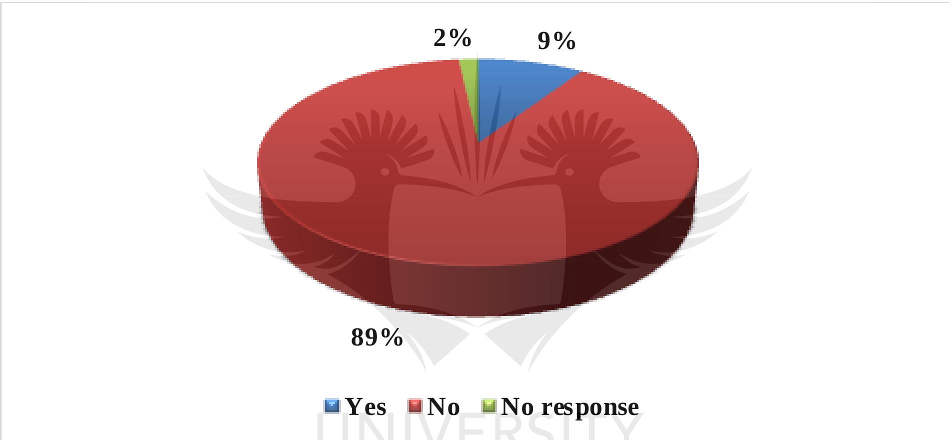

Figure 5: 28 : Responses on information made available

From the sampled population (Figure 5.28); about 9% of the respondents said they had sufficient information about their waste collection services, 89% respondents said they did not have any information about their waste collection services and 2% did not respond. This shows that the people of the communities are not informed on issues relating to the environment; hence the municipality needs to swing into action in order to get the people to be properly informed.

Q28. If no, what type of information do you want to have?

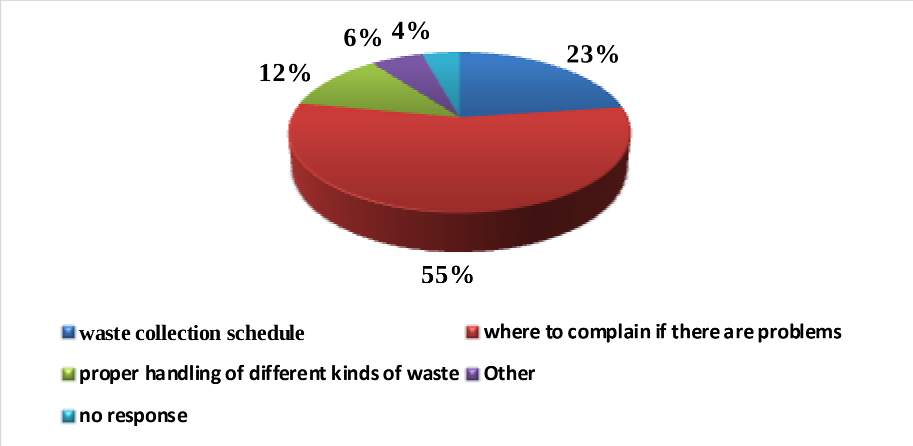

Figure 5: 29 : Responses on the information needed

From the sampled population (Figure 5.29); about 23% respondents said they need information on waste collection schedule; about 55% said they need information on where they can channel their complaints should they have any; about 12% said they need information on the proper ways of handling different kinds of waste, about 6% gave other information such as more plastic bags to be provided to aid source separation of wastes and finally about 4% did not respond.

5.5 Willingness to Pay (WTP)

The willingness of the people to pay more (Appendix B, questions 29 to 33 and Appendix C29 to C33) for an improved service is addressed in this section.

Q29. Do you know that you are supposed to pay for your waste service?

Figure 5: 30 : Responses on awareness to pay waste charge

From the sampled population (Figure 5.30); about 41% of the respondents said they were aware that they have to pay for their waste collection services and about 59% said they were not aware. This is an indication that citizens need to be educated and should be informed of the amount they are to pay for the services being offered to them since some of them think because they are paying taxes, hence, they do not need to pay for the service.

The municipality needs to set up a contact centre which will serve as the organisational unit in the municipality where citizens and businesses can channel their compliant and also get answers to their queries and if one is already in place, its services may need to be improved since this will serve as an avenue to answer about 80% of queries forthwith. Municipalities need to be transformed into organisations that are more focused on customers. They should not hesitate to introduce changes in their work plans and service ideology [The Smart Cities project, 2009]. Figure 5.31 illustrates the processes through which customers' requests are processed.

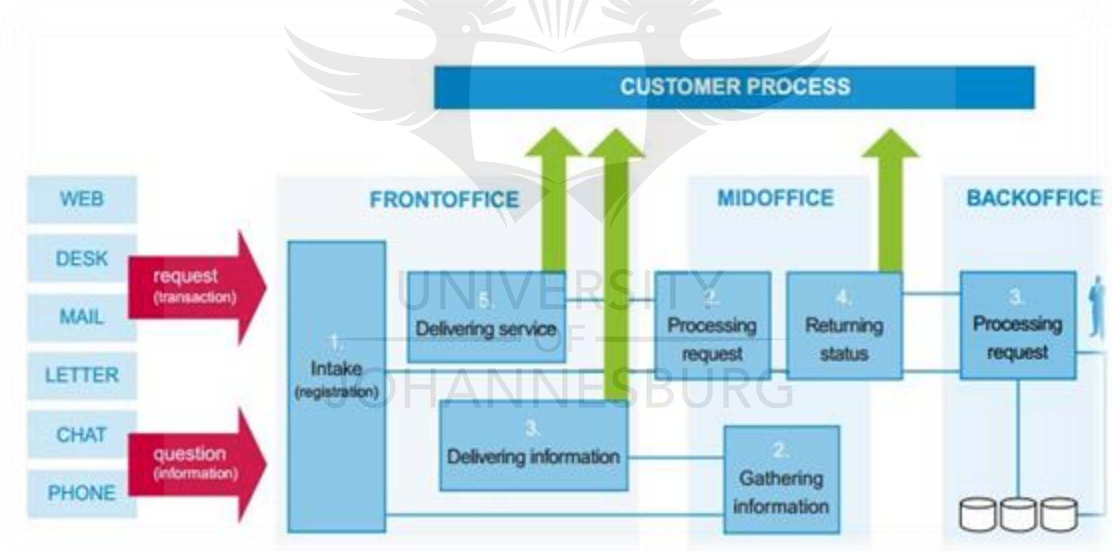

Figure 5: 31 : Customer Process [The Smart Cities project, 2009]

Q30. If yes, how much money are you supposed to pay for waste collection service?

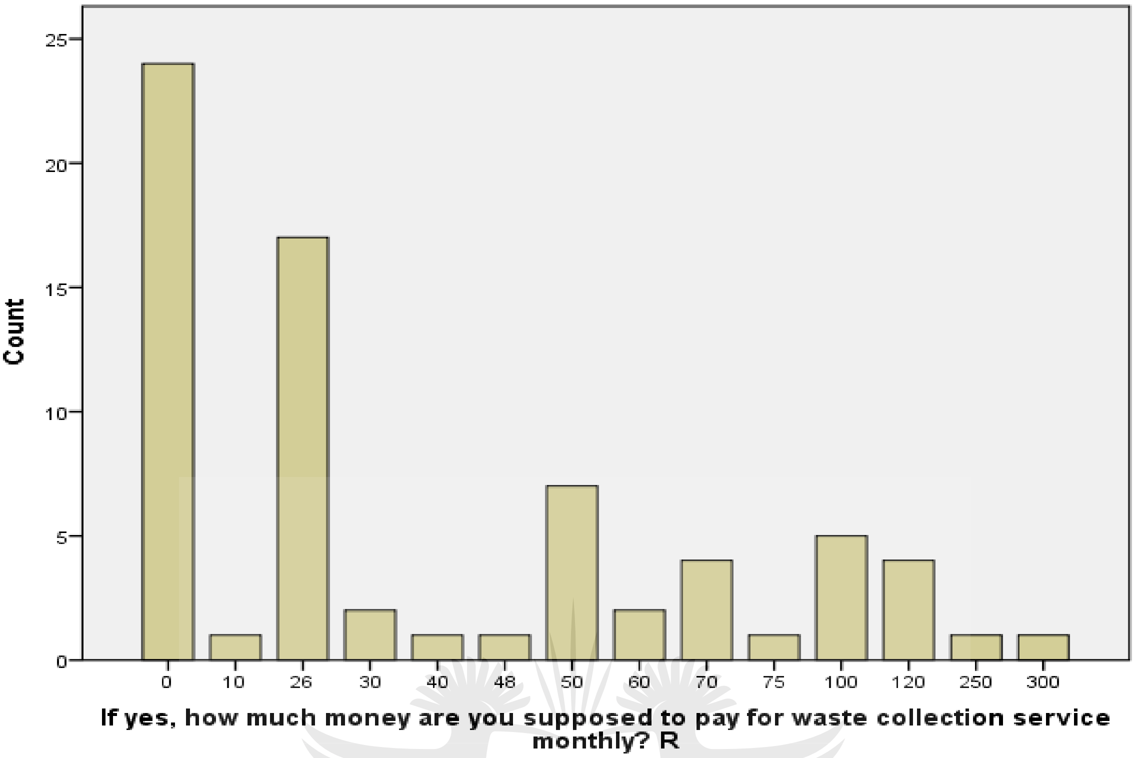

Figure 5: 32 : Responses reflecting proposed rates for waste collection

From the sampled population (Figure 5.32); 20.3% respondents said it is supposed to be a free service since they are paying their taxes, 0.8% said they are to pay R10, 14.4% said they are to pay R26, 1.7% said they are to pay R30, 0.8% said they are to R40, 0.8% said they are to pay R48, 5.9% said they are to pay R50, 1.7% said they are to pay R60, 3.4% said they are to pay R70, 0.8% said they are to pay R75, 4.2% said they are to pay R100, 3.4% said they are to pay R120, 0.8% said they are to pay R250, 0.8% also said they are to pay R300 and 39.8% did not give any answer. The mean and standard deviation of the distribution were determined as R 41.62 and R 54.03 respectively. The majority of the respondents (20.3%) were not willing to pay for their waste collection services and most of them (39.8%) did not respond. Given the number of respondents who said it supposed to be a free service and the number of people who did not give any definite answers, it shows that about 60% of the respondents were not ready to pay for their waste collection services.

Q31. Do you regularly pay your waste charge?

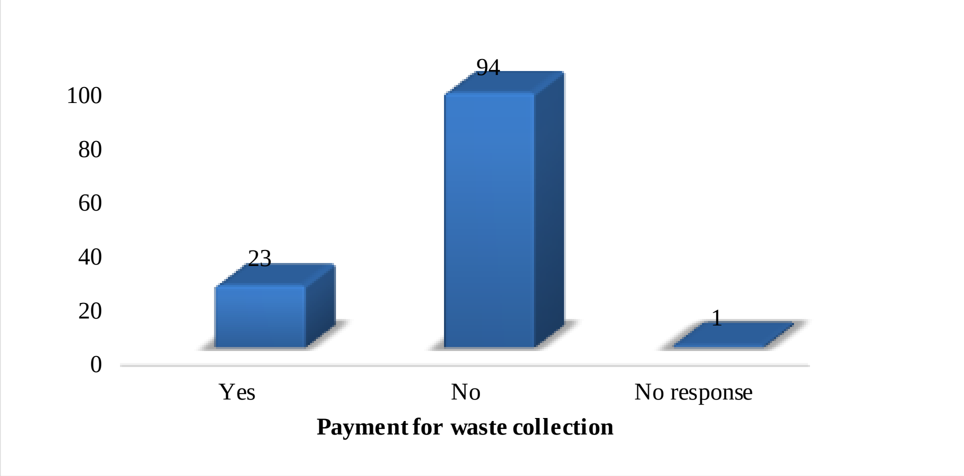

Figure 5: 33 : Responses on frequency of payment of waste charge

From the sampled population (Figure 5.33); about 19% said they do pay their waste charge regularly, about 80% said they do not pay and less than 1% did not respond. The majority of the respondents said they are not aware that they are supposed to pay and some said they do not need to pay since they are paying their taxes. This is an indication that the people are not informed hence the municipality needs to address this issue and get the people informed.

Q32. If no, what is the reason why you are not paying your waste collection charge regularly?

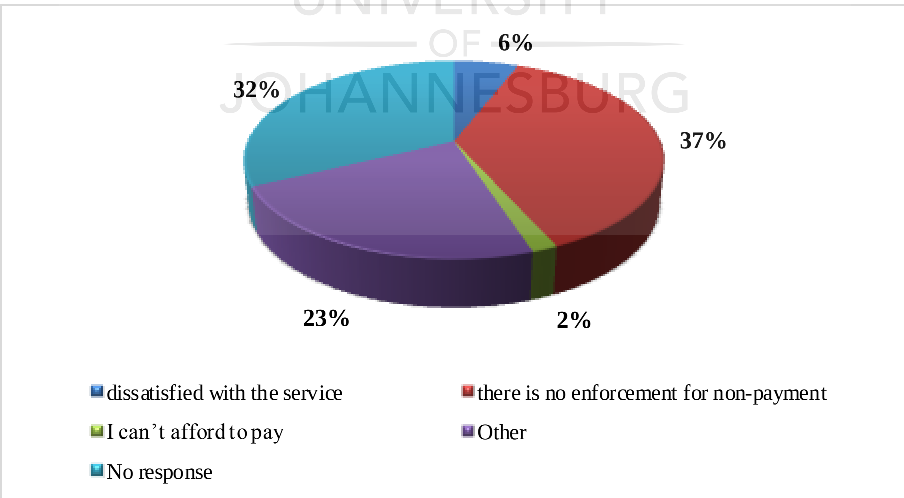

Figure 5: 34 : Responses on causes of non-payment of waste charge

From the sampled population (Figure 5.34); 6% of the respondents said the reason they are not paying for their waste collection charge is because they were dissatisfied with the service, 37% said there is no enforcement for non-payment, and 2% said they cannot afford to pay, about 23% gave different responses and 32% did not respond. With about 37% of the sampled population who claimed that there is no enforcement for non-payment, this is an indication that the people are not properly educated on issues relating to the environment. Thus, the municipality needs to make it a duty to keep the general public informed on the amount they are to pay for the services being rendered to them and should also let them know the reasons they are to pay regularly.

Q32 (d). Other Reasons for Non-Payment of Waste Collection Charge

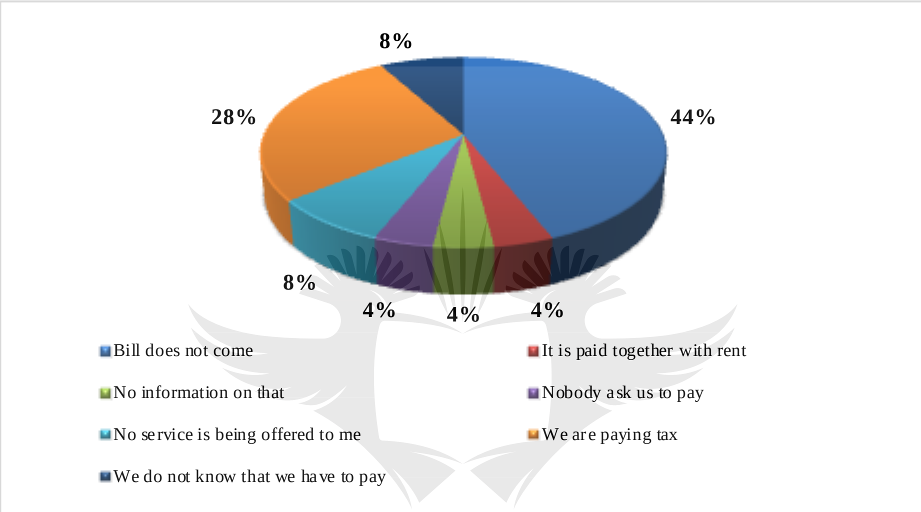

Figure 5: 35 : Other responses on causes of non-payment of waste charge

From the sampled population (Figure 5.35); 27 people (23%), who gave "other" as reasons for non-payment of waste charges; only 25 respondents gave specific reasons. 44% of the respondents said their reasons for non-payment is because bills are not delivered, 4% said it is paid alongside their rent, another 4% said there is no information about the payment of waste collection charge, another 4% of the respondents said no one asked them to pay, 8% said there is no service being offered to them, 28% of the people said it is because they are paying tax so there is no need to pay for waste charge and finally the last 8% of the respondents said they are not aware that they need to pay. Therefore, the municipality has a lot of work to do in the area of educating the people on matters relating to WM.

The municipality needs to educate the people and to also create awareness both in the communities and the general public as this will lead to change in attitudes of people towards the environment. Educating the general public and creating awareness on the need to protect the environment will lead to sustainable development.

Q33. If yes, would you be willing to pay double this amount for an improved service by PIKITUP?

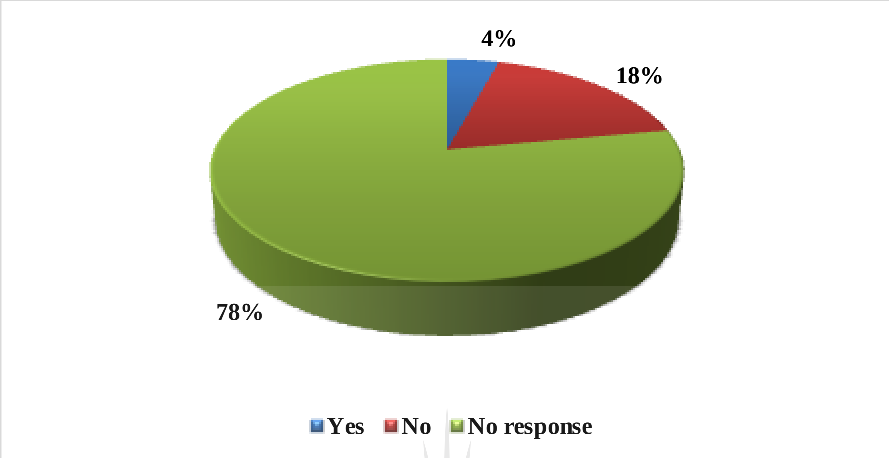

Figure 5: 36 : Responses on willingness to pay more

From the sampled population (Figure 5.36); about 4% of the respondents said yes that they will be willingly to pay more for an improved service, 18% said no that they are not willing to pay more and 78% did not respond. This shows the level of poverty in these communities since it is only 4% of the entire sampled population that is willing to pay more for an improved service.

Most households are not willing to pay more because they think it will impact the budget they have already made for the running of their households welfare [Eshun and Nyarko, 2011]. As cities are growing daily in the developing countries so also is waste generation on the increase but municipalities do not have the resources to provide quality services regardless of the fact that citizens are requesting for such services [Hagos et al., 2012]. The willingness to pay (WTP) more for a better service by the community is linked to the level of civilization of the people and also the level of awareness created by the municipality [Addai and Danso-Abbeam, 2014].

5.6 Zero Waste Alternative

Zero waste (ZW) helps societies to consume resources and produce goods but at the same time respect ecological limits and rights of the people. ZW as an alternative (Appendix B, questions 34 to 45 and Appendix C34 to C45) is discussed in this section.

Q34. Have you heard about Zero Waste?

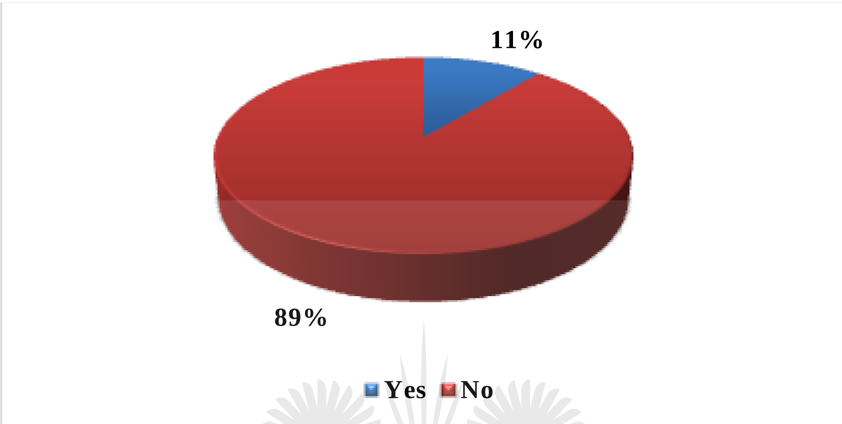

Figure 5: 37 : Responses on awareness on Zero Waste

From the sampled population (Figure 5.37); only 11% of the respondents said they have heard about Zero waste (ZW) while the remaining 89% said they have not heard about it. This shows that the people need to be educated on separation of waste at source, reduce, reuse and recycling and composting since these are all constituents of ZW.

Q35. Would you be willing to support Zero Waste?

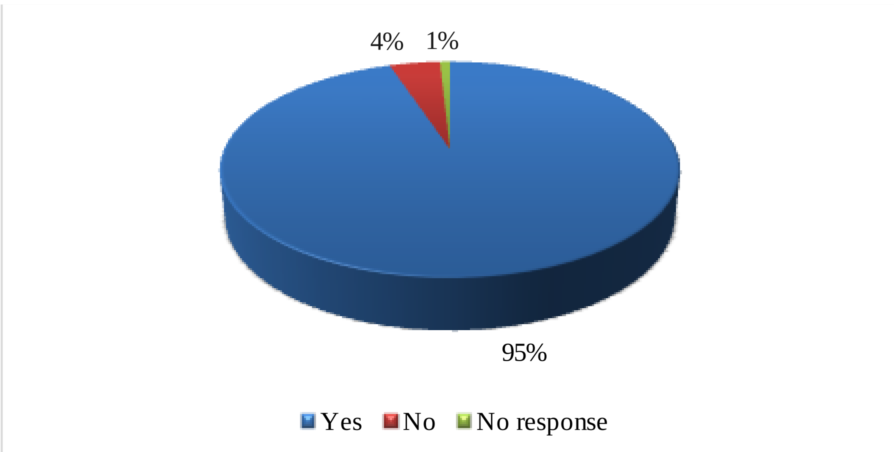

Figure 5: 38 : Responses on willingness to support Zero Waste

From the analysis of the data (Figure 5.38); about 95% of the sampled population said they are willing to support ZW, 4% said they are not willing and less than 1% did not respond. This is an indication that implementation of ZW will thrive in these communities since the bulk of the respondents are willing to embrace the study.

Q36. In what ways do you think you can contribute to the success of Zero Waste?

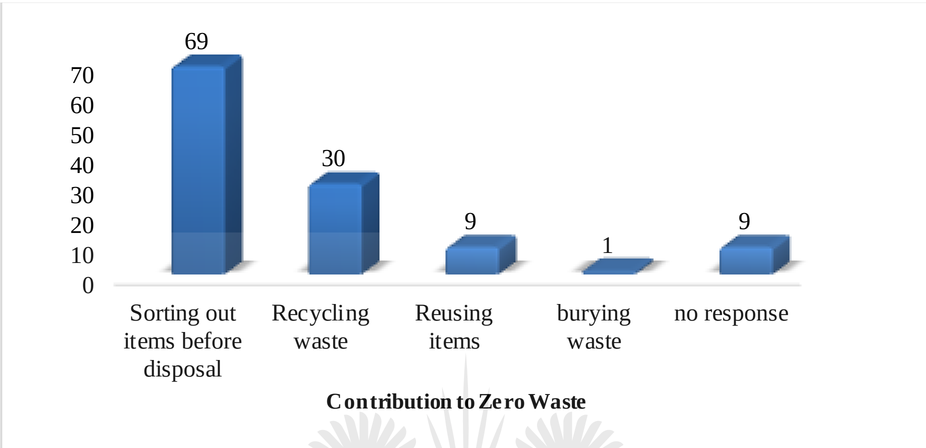

Figure 5: 39 : Responses on ways to contribute to ZW

From the data analysis (Figure 5.39); about 58% of the respondents said the means in which they can support ZW is through source separation of waste, about 25% said it is through recycling, about 8% said it is through reuse of waste items, less than 1% said it is by burying wastes and about 8% did not respond. This is an indication that the people of the communities will embrace ZW since about 91% are willing to conduct activities aimed at achieving ZW.

Q37. Are you currently separating recyclable wastes?

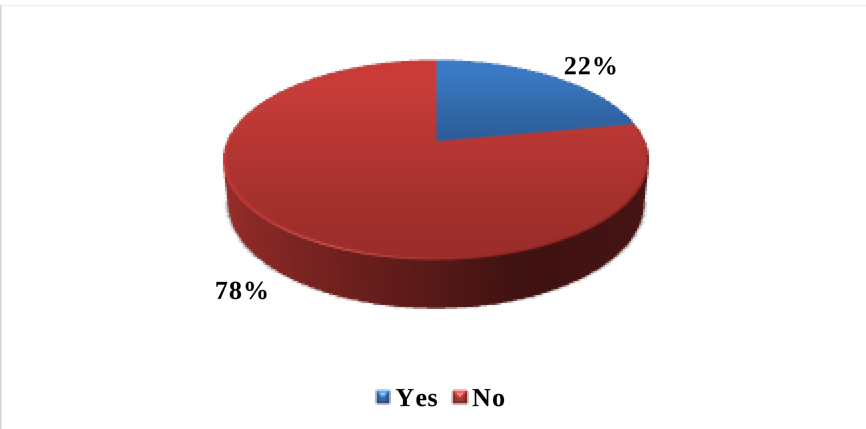

Figure 5: 40 : Responses on separation of Recyclables

From the analysis of the data (Figure 5.40); 22% of the respondents said they are currently separating recyclables from other waste streams and 78% said they are not. This simply shows that the municipality has a lot of work to do in order to sensitise the people and also encourage them to begin to separate the recyclables since this will go a long way to extend the life of the landfill sites.

To recover resources from solid waste streams, separation at source must be an utmost priority. Source separation of waste has not been considered a priority in developing nations. Waste separated at source can be recycled, composted and can be converted to energy. The municipality has a very great task to do and this task is to encourage members of the communities to be actively involved in source separation [Dagadu and Nunoo, 2011].

Q38. If yes, would you be willing to continue to separate recyclable wastes?

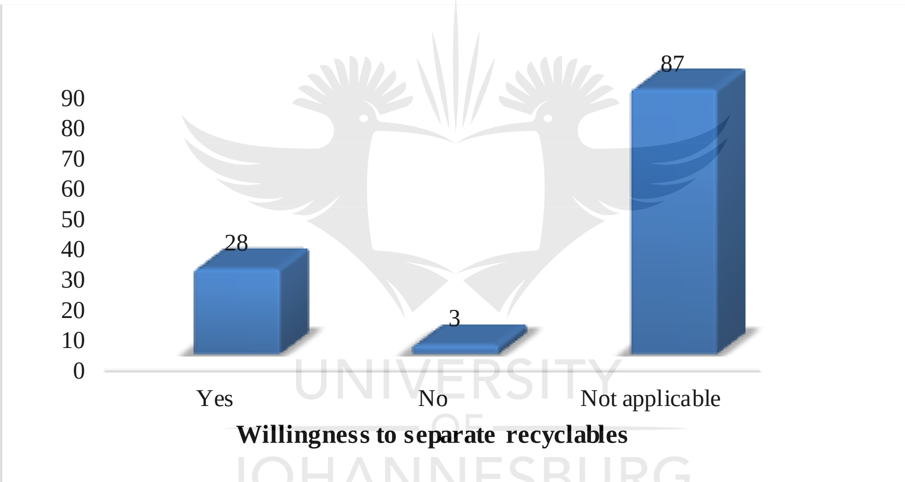

Figure 5: 41 : Responses on willingness to continue to separate recyclables

From the result of the analysis of the data (Figure 5.41); about 24% of the respondents said they are willing to continue to separate recyclables, about 3% said they are not willing and about 73% did not give any answer. With the 3% who said no and the other 73% of the respondents who did not give any answer, is an evidence to show that the rate of recycling is very low. Therefore, the municipality has a crucial role to play in order that the rates of recycling are stepped up.

Where recycling of waste is very vibrant, there will be no need to extract or process new resources, hence fossil-fuel energy will be conserved and climatic impacts that are bound to occur when different methods of waste management are not utilized will be avoided. Organic wastes are to be separated from inorganic wastes in order to prevent contamination of other recyclable items. This is because when organic wastes are landfilled, emission of methane occurs and this poses a threat to human health and the environment [FOE (Friends of the Earth), 2009].

Q39. Are you currently separating food wastes?

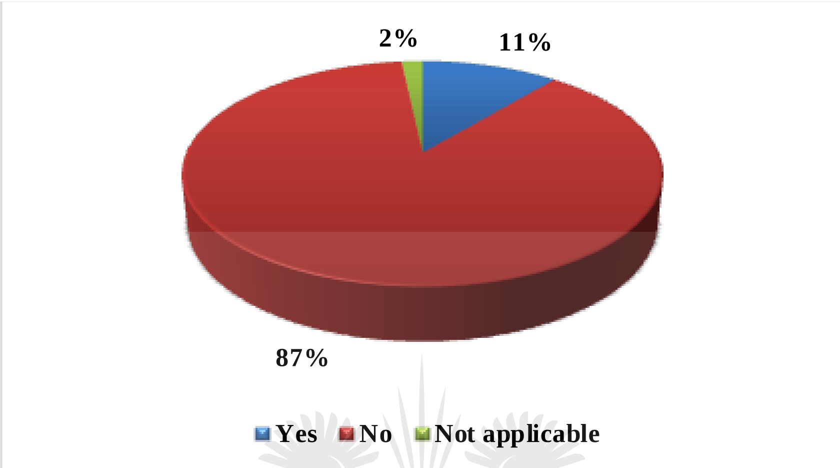

Figure 5: 42 : Responses on separation of food waste

From the analysis of the data (Figure 5.42); only 11% of the respondents are currently separating food wastes from other waste streams; about 87% said they are not separating food wastes and about 2% did not give any answer. This means about 87% of food wastes are sent to the landfill. Apart from the impact it has on both the health of the general public and the environment, it is also a waste of resources since these resources can be composted into organic manure and can also be converted to biogas or electricity.

Separation of food waste at source is cost-effective, more convenient and it is very hygienic rather than disposing it to the landfill site [Evans, 2007]. If an efficient source separation of organic waste is in place, a lot of money will be saved. Food waste will be used as feed to a bio-digester which will in turn generate energy for heating or fuelling vehicles. Therefore, financial benefits will accrue and emission of carbon will be drastically reduced [Schmieder, 2012].

Q40. If yes, would you be willing to continue to separate food waste?

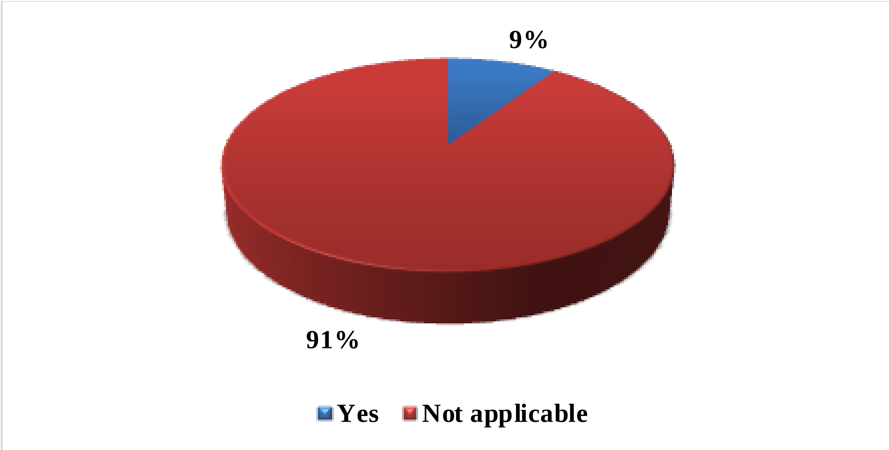

Figure 5: 43 : Responses on willingness to continue to separate food waste

From the analysis of the data (Figure 5.43); only 9% of the sampled population showed interest in continuing to separate food waste from other waste streams. About 91% did not give any answer. This shows that the rate of segregation of waste at source is very low, hence the municipality has great role to play by encouraging source separation of waste.

It is the responsibilities of the municipality to encourage source reduction, source separation, reuse, recycling and composting of organic wastes. As a matter of urgency, separate collection of organic wastes should be promoted and home composting should also be encouraged [Allen, 2012].

Q41. If yes, how would you achieve that?

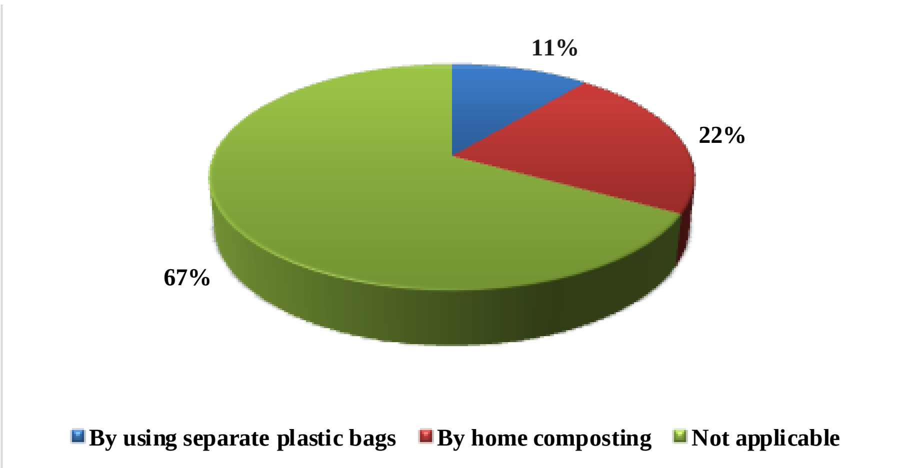

Figure 5: 44 : Responses on the ways to achieve recycling of food wastes

From the analysis of the data (Figure 5.44); 11% of the respondents said they can only achieve the recycling of food waste when more plastic bags are provided to them by the municipality. About 22% said they can divert food waste from going into the waste stream through home composting and the last 67% of the respondents did not give any definite answer. For organic wastes to be completely diverted from going to the landfill, the municipality has several roles to play. One of the roles is to provide more plastic bags if possible with different colours for different waste streams and also encourage home composting.

Q42. Do you think this Zero Waste project can succeed?

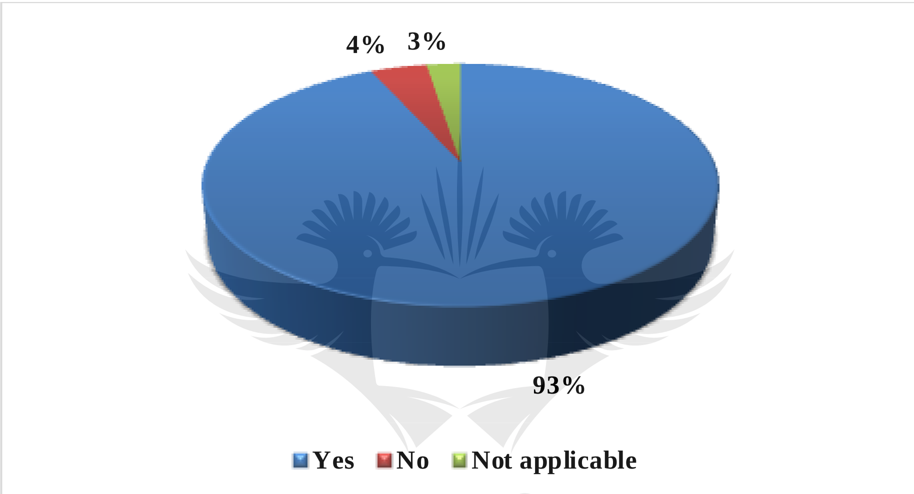

Figure 5: 45 : Responses on whether Zero Waste can succeed?

From the data analysis (Figure 5.45); 93% of the sampled population agreed that ZW project can be successful, 4% of the respondents said no, it cannot be successful and the remaining 3% did not give any answer. With the bulk of 93% of the respondents who indicated interest and were very optimistic that the project can succeed is an indication that the project will be viable.

Q43. If yes, in what ways do you think it can succeed?

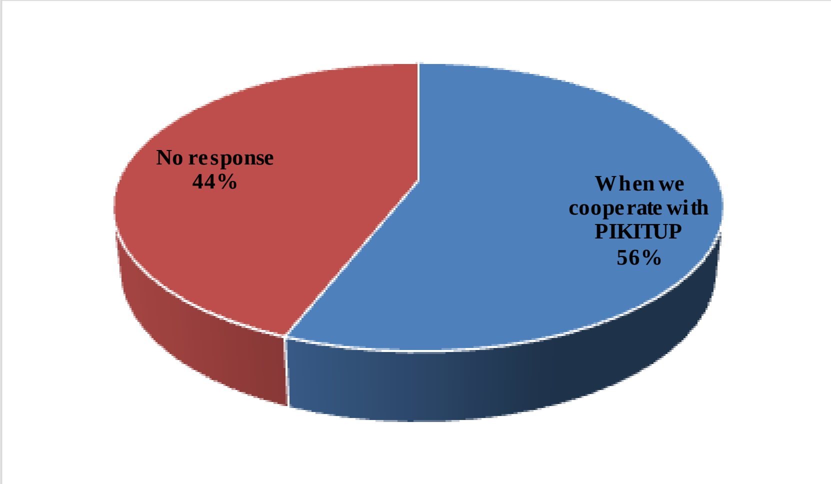

Figure 5: 46 : Responses on ways ZW can succeed

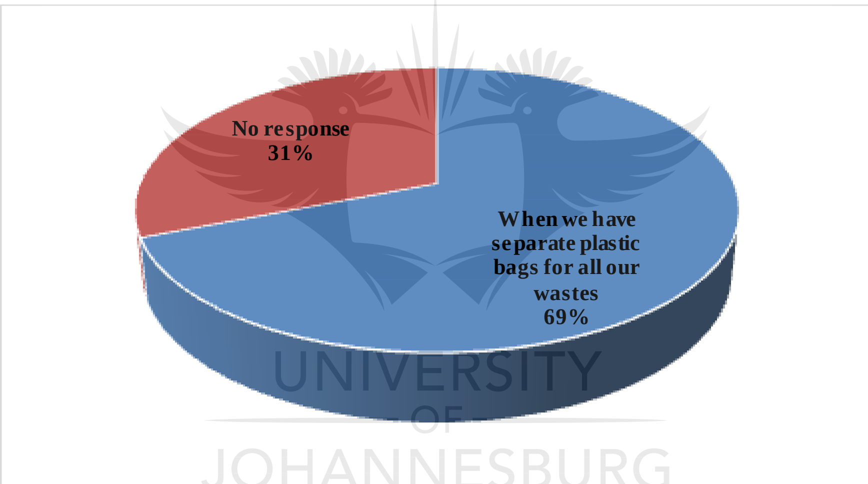

Figure 5: 47 : Responses on ways ZW can succeed

From the analysis of the data; about 114 respondents gave their different responses. 56% said ZW will be successful when the communities cooperate with the municipality, the remaining 44% did not respond (Figure 5.46); 69% said it will succeed when the municipality provides them with separate plastic bags to sort out their wastes into different streams, the remaining 31% did not give any answer (Figure 5.47) and finally 17.5% gave ‘other’ as ways in which they thought ZW project can be successful while the remaining 82.5% did not give any answer. These responses are shown in Figure 5.48.

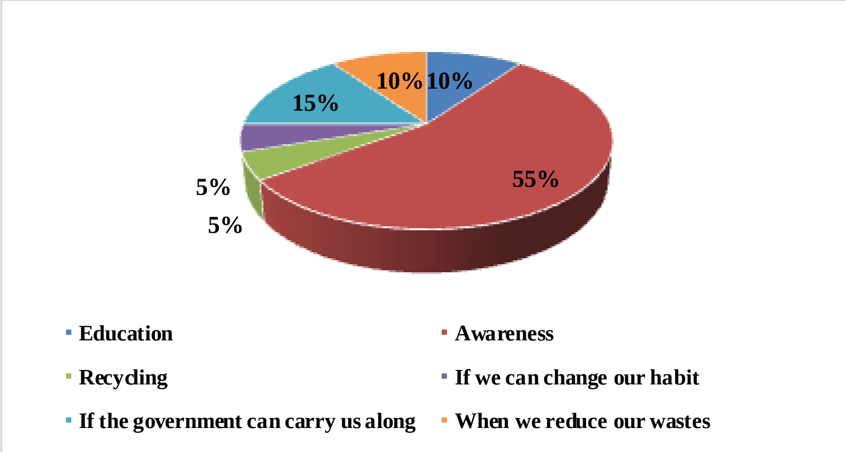

Figure 5: 48 : Other ways in ZW can succeed

The responses of the 17.5% of the respondents who gave different views are shown in Figure 5.48. From the analysis of the data; 55% said ZW can succeed if the municipality can create awareness, 5% said it is when wastes are recycled, another 5% said if they can only change their consumption habit, another 10% said if the municipality can educate them, another 15% said if the government can get them involved at every stage of the implementation process and finally 10% said if they can only reduce the quantity of waste being generated then ZW will succeed. Therefore, the municipality has a great task to do in order to have a green city. This can be achieved when the education teams of the municipality are strengthened.

Q44. What benefits do you think can be derived from Zero Waste?

Table 5: 6 : Responses on benefits from Zero Waste

	Unmarked	Marked	Total
It reduces cost	65.8%	34.2%	100.0%
Provides jobs for others since the discarded goods need to be collected for recycling	29.1%	70.9%	100.0%
Makes all discarded materials to become raw materials for companies to use	65.0%	35.0%	100.0%
Other	94.0%	6.0%	100.0%

From the result of the analysis (Table 5.6), a total of 117 respondents answered the question, only 34% of the respondents said Zero waste reduces cost; another 71% said it provides jobs since discards will be recycled; 35% said it makes discards to become raw materials for industries and finally 6% provided other answers. The response provided by the 6% is that it facilitates a cleaner environment.

Q45. How can Zero Waste be implemented in your community?

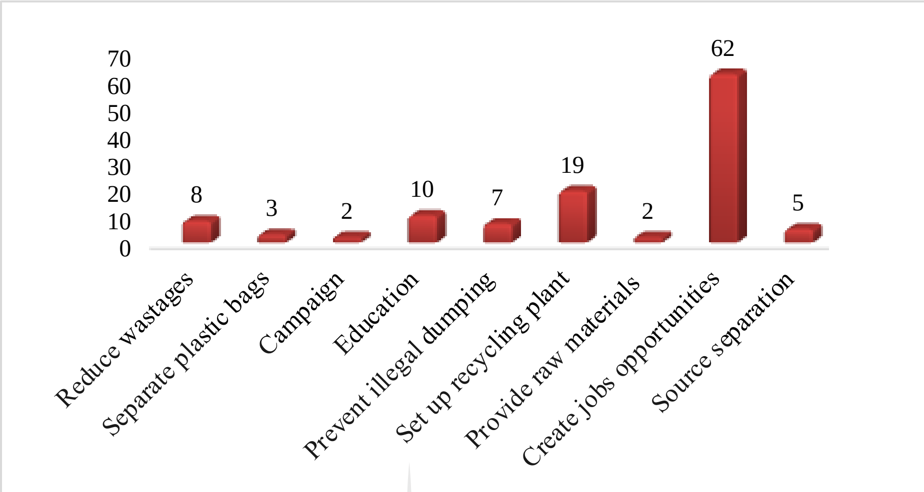

Figure 5: 49 : Responses on ways ZW can be used

Analysis of the data (Figure 5.49) showed the various responses of the respondents on how Zero waste can be implemented in their communities. 52.5% of the sampled population said ZW project will create job opportunities for the unemployed South Africans.

5.7 Personal details about the households

Some personal questions about the respondents and their family (Appendix B, questions 46 to 48 and Appendix C46 to C48) were asked and these are presented in this section.

Q46. Does your household have a business here in their house?

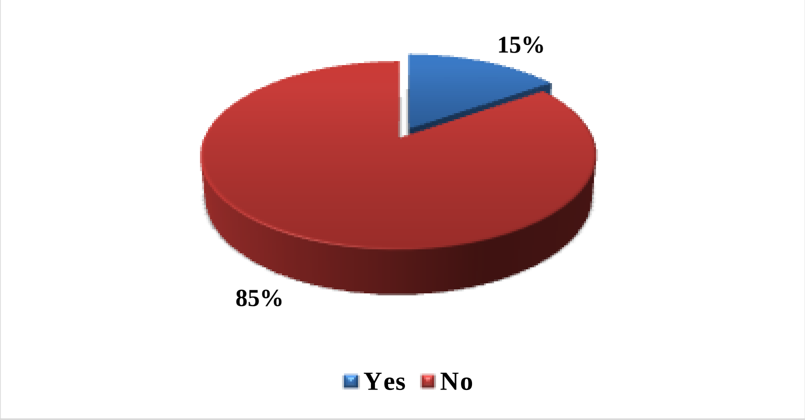

Figure 5: 50 : Responses on whether there is business in the household?

From the analysis of the data (Figure 5.50); only 15% of the sampled population said they run businesses in their house, the remaining 85% said they do not run businesses in their houses.

Q47. What type of business is it?

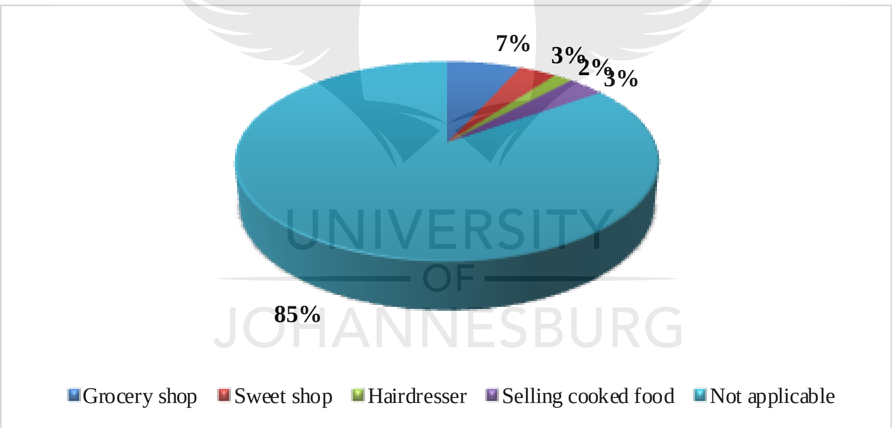

Figure 5: 51 : Responses on type of business in the household

From the result of the analysis (Figure 5.51); 7% of the sampled population said they have grocery shops; 3% said they have sweet shops; 2% said they have hairdressing saloons; 3% said they are selling cooked food and about 85% did not give any answer.

Q48. What is the average income of your household monthly (R)?

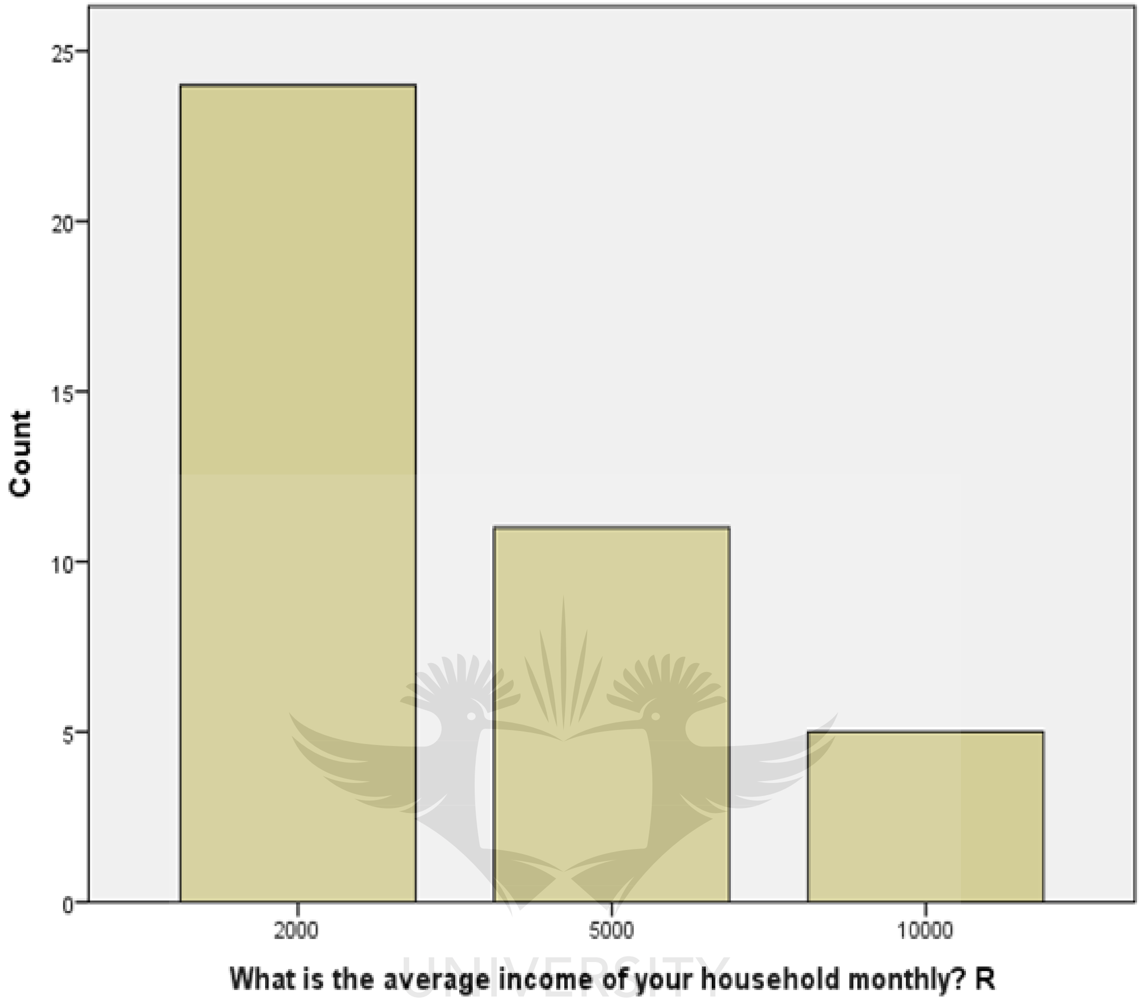

Figure 5: 52 : Responses showing average household income in R

From the analysis of the data (Figure 5.52); 24 respondents said their monthly income is R2000, 11 respondents said it is R5000 and 5 respondents said it is R10000. This shows that the living standard of the people is very low.

A poverty line is when people are deprived of basic necessities of life as a result of the scanty resources at their disposal to maintain minimum standard of living. Some of the basic necessities of life are food, clothing, shelter, water, electricity, and education and healthcare services. Most households earn less than $1.25/day hence they cannot afford all these necessities of life. This shows that majority of the people are living below the poverty datum line. The poverty line has recently been updated to $1.90/day [World Bank Group & International Monetary Fund, 2014, Cruz et al., 2015].

Q48 (d). Graph (for those who said 'Other' in Q48)

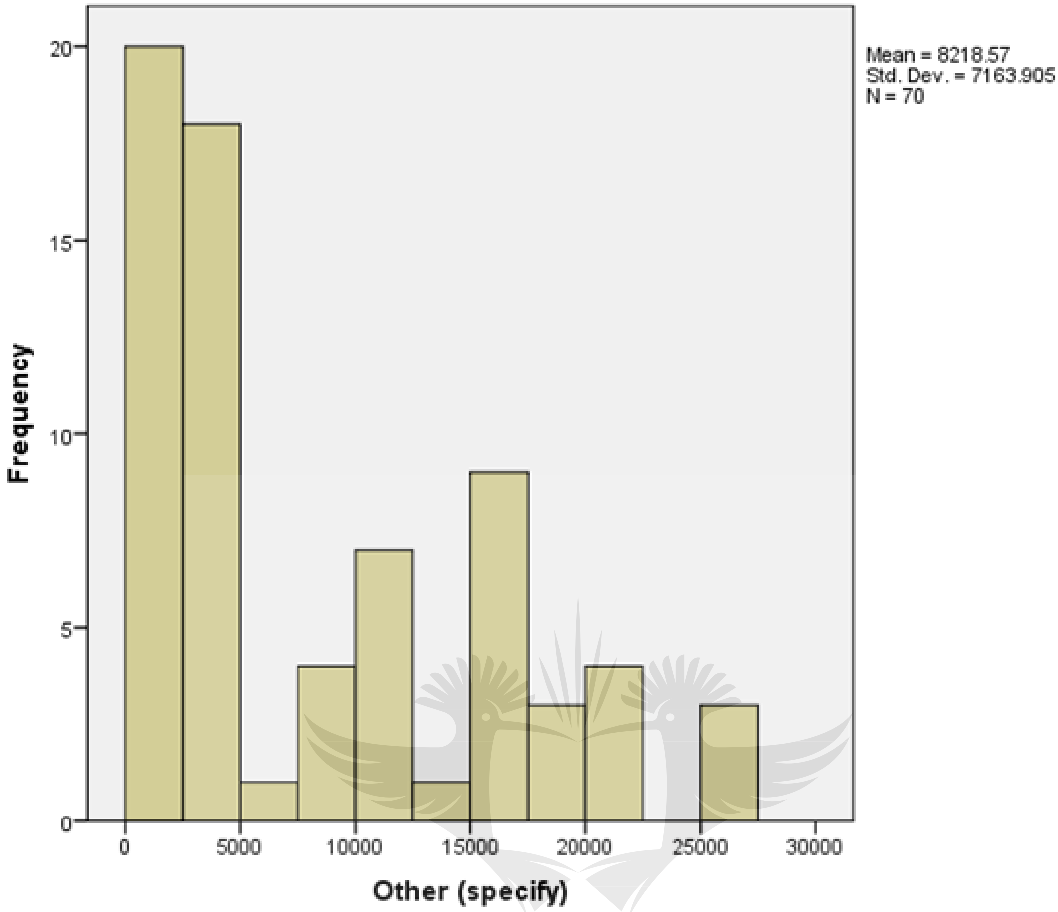

Figure 5: 53 : Responses on other incomes

Figure 5.53 shows the income of those who specified their monthly earning other than those that were stated in the questionnaire. It was discovered that only 4 respondents earned about R 20000 and only 3 respondents earned about R 25000 monthly. This shows that the most of the people living in the communities are living below the poverty datum line.

5.8 Chapter summary

It was discovered that the majority of the general public do not have an idea of where and how their wastes are being disposed of. This may also be a major challenge and hindrance to getting the support of the general public on the quest to achieving circular economy through SSWM. People who reside in the informal settlement are not being offered any services by PU. Most of these people do not have access to basic WM services such as provision of plastic bags or refuse bins for waste storage. This factor is the major cause of illegal dumping. It was also gathered that waste reduction at source, source separation of waste and recycling are at a minimal level since the people do not really know the significance of this. Currently, most of the residents do not pay for their waste collection services and many of them do not see the need to pay more for an improved service. This can be attributed to the fact that most of the people are not even aware that they need to pay. The people want an improved waste collection services but they are not ready to pay more. The majority of the respondents showed an interest in ZW and they are very ready to support the project. The study also revealed the majority of the respondents are living below the poverty line since most of them earn less than R 10,000 per month because where someone is working on a regular income; he or she is the only person working in the household. This makes it difficult to enforce payment of waste charges on those who have not been paying. However, if the ZW project is implemented, people will be able to generate income around wastes, many downstream jobs will be created and people will be able to make a living around wastes and the rate of crime will be reduced drastically in the society.

6.0 CHAPTER 6: CHEMICAL ENGINEERING ECONOMIC EVALUATION OF A PROJECT

6.1 Economic Evaluation of MSW Recycling Facility

This chapter presents the economic evaluation of setting up a recycling facility as an annex to the current waste management (WM) practice that is being practiced by the PU (municipality) in Johannesburg (JHB).

6.1.1 Economic Utilization of MSW

This economic analysis is based on the quantity of wastes disposed of at the Marie Louise LS and on two of the services offered by the municipality. The services are Round collected refuse (RCR) compacted waste and Dailies non-compacted waste collection services. The RCR compacted waste originates from households in formal residential areas and businesses and are routinely collected weekly. The Dailies non-compacted waste originates from hotels, restaurants, fast food joints, butcher shops and street sweeping. They are collected daily in order to avoid offensive odour that may emanate as a result of its biodegradability which can pose threat to the environment and the health of the general public. From the historical data of about 6 years of annual reports of PU (SOC), a total of about 1,114 tons of wastes were being disposed of at the Marie Louise LS on a daily basis [Pikitup (Pikitup Johannesburg SOC Ltd), 2010/11, Pikitup (Pikitup Johannesburg SOC Ltd), 2013/14, Pikitup (Pikitup Johannesburg SOC Ltd), 2009/10, Pikitup (Pikitup Johannesburg SOC Ltd), 2011/12, Pikitup (Pikitup Johannesburg SOC Ltd), 2012/13, Pikitup (Pikitup Johannesburg SOC Ltd), 2015/16]. From the total tonnages of 1,114 (Table 6.1), only 609 tons fall into the category of RCR compacted wastes and Dailies non-compacted, which were the wastes considered in this study, while the remaining 505 tons were said to be in the categories of Bulky wastes, C & D waste and other wastes that were not considered in this study. The percentages of the RCR and Dailies wastes received at the site per day are equally shown in Table 6.1. Figure 6.1 shows the flow of MSW from truck sampling to further processing until the recycled waste items are sold as raw materials to industries.

Table 6: 1 : Daily tonnages of waste disposed at the Marie Louise landfill site in JHB, South Africa

Landfill Site	**Marie Louise**	
Total Tons/day	**1114.92**	
	Wt. %	**Tons/day**
Dailies	0.015	17.17
RCR	0.531	592.02

Waste Components	Dailies	(Ton/day)	RCR	(Ton/day)	Total (Ton/day)
Organics	0.13	2.23	0.28	165.77	168.00
Paper	0.19	3.26	0.16	94.72	97.99
Plastics	0.28	4.81	0.18	106.56	111.37
Metal	0.07	1.20	0.05	29.60	30.80
Textile	0.03	0.52	0.06	35.52	36.04
C&D	0.01	0.17	0	0.00	0.17
Other waste	0.14	2.40	0.19	112.48	114.89
Glass	0.15	2.58	0.08	47.36	49.94
TOTAL	**1**		**1**		609.19

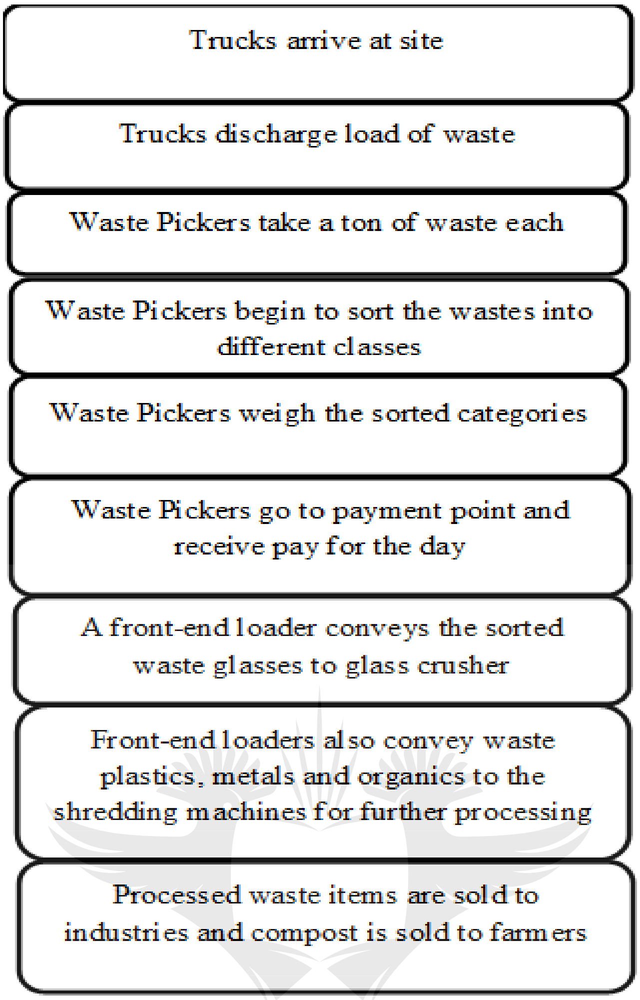

Figure 6: 1 : Flow of municipal solid waste from sampling to further processing

6.1.1.1 Sourced equipment costs and other related costs

All equipment costs were locally sourced in JHB, South Africa since the goal of the project was to make use of locally fabricated machineries which can be easily accessed and readily available and which spare parts can be sourced locally. Another objective for sourcing the equipment cost locally was to exclude shipping and forwarding costs; payment of custom duties and other importation related costs so to as save foreign currency. The cost of transportation and cost of disposal of wastes were not considered in this project since the project is an annex to the existing operation of the municipality. Furthermore, in this project, the salaries of the operators of the equipment were not considered since the workers will be co-opted into the main category of the staff of the municipality and it is at the discretion of the municipality to decide on the amount of money the workers will be paid per month.

6.1.1.2 Parameters consider for cost estimation

There are various parameters that were considered in order to establish the economic viability of this MSW recycling facility (Appendix D). The cost estimation is split into units and is discussed extensively in the next segments. The parameters include purchased equipment cost (PEC), direct costs, indirect costs, working capital, fixed capital investment (FCI), total capital investment (TCI), net present value (NPV), internal rate of return (IRR), Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA) and cost of collection of wastes.

6.1.1.2.1 Purchased Equipment Cost (PEC)

Purchased equipment cost is the baseline to estimate a capital investment. PEC comprises of the prices of equipment, methods to adjust the capacity of equipment and method to estimate the auxiliary equipment [Peters et al., 2003]. The PEC for this study is R 9,685000. The breakdown of PEC, the list of equipment required, the various processes involved and the processes for which the equipment will be used for are shown in Appendix D1.

6.1.1.2.2 Direct Costs (DC)

The direct cost of setting up a recycling facility involves several factors and several parameters are considered. These parameters include: purchased equipment cost; service facilities and yard improvement; land; installation, insulation and painting; building and electrical installation [Sinnott, 1999]. The total direct cost of the MSW recycling facility is R 19,660,550. The summary of the total direct cost is as shown in Table 6.2.

Table 6: 2 : Summary of the total direct cost and its factors

	Values used in the Recycling Facility	Rand/year
Electrical Installation	10% of purchased equipment cost	968,500
Building	20% of purchaed equipment cost	1,937,000
Land	8% of purchased equipment cost	774,800
Service Facilities & Yard Improvement	40% of purchased equipment cost	3,874,000
Installation, insulation & Painting	25% of purchased equipment cost	2,421,250
Purchased Equipment Cost		9,685,000
Total Direct Cost per year		19,660,550

Sourced: [Peters et al., 2003, Sinnott and Towler, 2009, Sinnott, 2005]

6.1.1.2.3 Indirect Costs (IDC)

The indirect cost of setting up a capital project also has some parameters to be considered. These parameters are the cost incurred in the construction of the facility. The parameters include: engineering and supervision; construction expense and contractor's fee; contingency and legal expenses [Peters et al., 2003]. Therefore, the fixed-capital investment of the recycling facility is the sum of direct cost and the indirect cost and it is equal to R 25,755,320.50. The summary of the total indirect cost is shown in Table 6.3.

Table 6: 3 : Summary of the total indirect cost and its factors

	Values used in the Recycling Facility	Rand/year
Engineering & Supervision	10% of direct of cost	1,966,055
Construction Expense and Contractor's Fee	10% of direct cost	1,966,055
Contingency	7% of direct cost	1,376,238.50
Legal Expenses	4% of direct cost	786,422
Total Indirect Cost per year		6,094,770.50

Sourced: [Peters et al., 2003, Choy et al., 2004b]

6.1.1.2.4 Working Capital (WC)

The working capital of a capital investment comprises of the amount of money earmarked for the purchased of raw materials and supplies, both finished products and semi-finished products, account receivable, payment of salaries, taxes, wages and other operating expenses [Sinnott and Towler, 2009]. The percentage is mostly taken as 5-30% of Fixed Capital Investment (FCI). For this study, the working capital was taken to be 15% of FCI [Sinnott, 2005]. The working capital is equal to R 3,863,298.08.

6.1.1.2.5 Fixed Capital Investment (FCI)

Fixed capital investment (FCI) is the overall cost of a plant that is ready to commence operation. This cost is the sum of the cost of all direct costs and indirect costs. This cost is the only cost that is not recovered at the end of the project life. It is only recovered as either salvage value, scrap value or terminal value [Sinnott and Towler, 2009].

6.1.1.2.6 Total Capital Investment (TCI)

TCI is the sum of money required to commence operation of a plant. Part of the operations include; purchase and installation of equipment, land, building, money earmarked for the purchase of raw material, payment of wages and salaries and other overhead costs. TCI is the sum of FCI and WC [Choy et al., 2004b]. The total capital investment for this study was given as R 29,618,618.58 and this is as shown in Appendix D2. TCI is given by Equation 9. The means of financing the project is shown in Appendix D3, cost of power consumption in Appendix D4 and water consumption cost in Appendix D5.

$$TCI = FCI + WC \qquad (9)$$

Where

TCI = Total Capital Investment

FCI = Fixed Capital Investment

WC = Working Capital

6.1.1.2.7 Overview of TCI

The sum of the total direct cost, total indirect cost and the working capital also give the total investment cost. The total capital investment (TCI) for this recycling facility is summarised in Table 6.4.

Table 6: 4 : Summary of the TCI for the MSW Recycling Facility

	Percent	**Rand**
Direct cost (including purchased equipment cost)	66.4	19,660,550
Indirect cost	20.6	6,099,771
Working capital	13.0	3,863,298
Total capital investment	100.0	29,618,619

6.1.1.2.8 Net Present Value (NPV)

Net present value (NPV) of a recycling facility is the total of the present values of the future cash flows [Sinnott and Towler, 2009]. It is given by the relation in Equation 10. For this study, the NPV is R 135,950,000 at 12% discount rate. The NPV was calculated using excel software.

$$NPV = \sum_{n=1}^{n=t} CFn/(1+i) \tag{10}$$

Where:

CFn = cash flow in year n

t = project life in years

i = interest rate

6.1.1.2.9 Depreciation

The concept of depreciation comes into play when facilities have reached their deteriorating state or terminal state and the asset has decreased in value. The decrease in value of an asset is characterized by wear and tear, corrosion, accident and/or deterioration resulting from age [Peters et al., 2003]. Straight line method of depreciation is used in this project. When straight line method of depreciation is employed, fixed amount of money is charged all through the life of the equipment so that the accumulated sum equal the original cost of the asset [Panneerselvam, 2012]. The depreciation of machinery was charged at 10% and that of buildings at 5% all for a period of ten years and the sum is R 1,067,000. It is given by Equation 11. The depreciation using straight line method is shown in Appendix D6.

$$Dt = (P - F)/n \tag{11}$$

Where:

Dt = depreciation amount for period t

F = salvage value of the asset

N = life of the asset

P = first cost of the asset

6.1.1.3.0 Interest rate

Interest rate is the amount of money charged over a particular loan or on the amount of money borrowed (debt) at the end of a year. This is often expressed as a percentage and mostly charged annually except otherwise stated [Couper, 2003]. The lower the discount rate, the higher the return value of the project's future costs and benefits. Alternatively, the higher the discount or interest rates the lower the future return value will be. It becomes very crucial to select appropriate discount rate to ensure that future project returns are not being over- or under-estimated in today's value. Therefore, lower interest rate was chosen and the one used in this study was 12%. The repayment and interest schedule of loans is shown in Appendix D7. Income statement and projected fund flow statement are as shown in Appendix D8 and Appendix D9.

6.1.1.3.1 Internal Rate of Return (IRR)

Internal rate of return (IRR) also referred to as return on investment (ROI) is the interest rate at which the worth of an investment cash inflows equals the worth of cash outflows. Here, the benefits (receipts) equal expenditures (cost) [Omitaomu, 2006]. For this study, the IRR on investment is 41% and that on equity is 80% (Appendix D10). IRRs in this study were calculated using excel software. The projected balance sheet is as shown in Appendix D11.

6.1.1.3.2 Earnings before Interest, Tax, Depreciation and Amortisation (EBITDA)

Earnings before Interest, Tax, Depreciation and Amortisation (EBITDA) are a financial measure that is utilised in financial markets for reasons like financial statement analysis, credit analysis and valuation. EBITDA gives a point of reference against which the income of a company can be evaluated when it is reconciled to gross operating cash flow (GOCF). It can also give a measure of income that is not misreported by variation in the way depreciation and amortisation is treated. EBITDA provides the basis for the calculation of free cash flow and it also provides a signal of the probable debt that a company may experience [Luciano, 2003]. EBITDA in this study was determined by taking the difference between the sales revenue and the estimated cost of production and it was given as R 23, 820,000 (Appendix D8).

6.1.1.3.3 *Cost of Collection*

Since waste collection services are already in place and service is consistent; thus the cost of transportation and disposal of waste to the new site was not considered. The project will be an extension of the existing operations of the municipality and its main objective is to serve as a platform to improve upon the current operations. The cost that was considered is the cost of collection of waste and this is given in Equation 12 and is represented in Table 6.5 [Yedla, 2003, Yedla and Kansal, 2003] . The capital cost of equipment is considered separately since new equipment are to be procured for operations at the new site and this equipment may be different from the existing machineries owned by the municipality. The parameters considered are outlined as follows;

Cost of collection per year	e_1
Waste generated daily (million tons)	W_d
Waste that can be collected by each worker daily	W_w
Number of workers per ton of waste daily	$1/W_w$
Salary of each worker daily	w
Collection cost per day (millions)	$[1/W_w\ w]\ W_d$
Waste generated annually	$W_d \times 365 = W_a$

$$Annual\ cost\ of\ collection\ \ (e1) = \left[(\frac{1}{Ww} \times w) + misc \right] \times Wa \qquad (12)$$

[Misc. includes cost of minor equipment, shovels, trolleys, bins etc.]

Table 6: 5 : Annual Cost of Collection of Wastes

Annual Cost of Collection of wastes		
Municipal solid waste generated yearly (million tonnes)	W_a	
Cost of collection (R. million)	e_1	
benefits	b_1	
Total waste genrated per day (RCR, Dailies and Bulky wastes) (tonnes)		1114
W_d (tonnes/day) (waste of interest, RCR and Dailies)		609
Waste that can be collected by each waste worker per day (tonnes)		1
Number of workers per ton of waste per day		1
Salary of each waste picker per day (R. million)		0.00015
Total number of workers required		609
Waste generated per year (assume 21 public holiday out of 366 days in 2016)		210105
Cost of collection per annum (R. millions)		31.51575
Number of bins used for sorting (assume 5 bins to one worker)		3045
Cost of each bin (R. million)		0.0005
Total cost of bins		1.5225
Total annual cost of collection (R. million)		**33.03825**

6.1.1.3.4 Sensitivity Analysis

The technique to evaluate the degree of uncertainty in a project proposition is referred to as sensitivity analysis. This helps to notice any form of deviation from the anticipated target. It also assists to evaluate which of the factors may be sensitive when it is altered. Data are provided to decision-makers through sensitivity analysis on the changes that will occur as soon as some important elements in a project change from the values that were formerly estimated. Before the start-up of the project, the important elements are just estimates. The changes may be either positive or negative on the project result. The Sensitivity analysis is represented in Figure 6.2 and is shown Appendix D12. The project breaks even at the point where the total costs equal the total sales and it is equivalent to 211 tons of recycled wastes items on the chart (Figure 6.2). Some parameters were varied in this sensitivity analysis in which four different cases were considered. They are; (1) 10% increase in variable cost, (2) 10% increase in fixed cost, (3) 10% increase in project cost and (4) 10% increase in variable cost, 5% increase in fixed cost and 5% decrease in selling price [Perry and Green, 1997, MoEA (Ministry of Economic Affairs), 2011b, MoEA (Ministry of Economic Affairs), 2011a]. The annual turnover of recycled waste items, the details on equipment and capacity utilization and wages of the Reclaimers at the site are as shown in Appendix D13, D14 and D15 respectively.

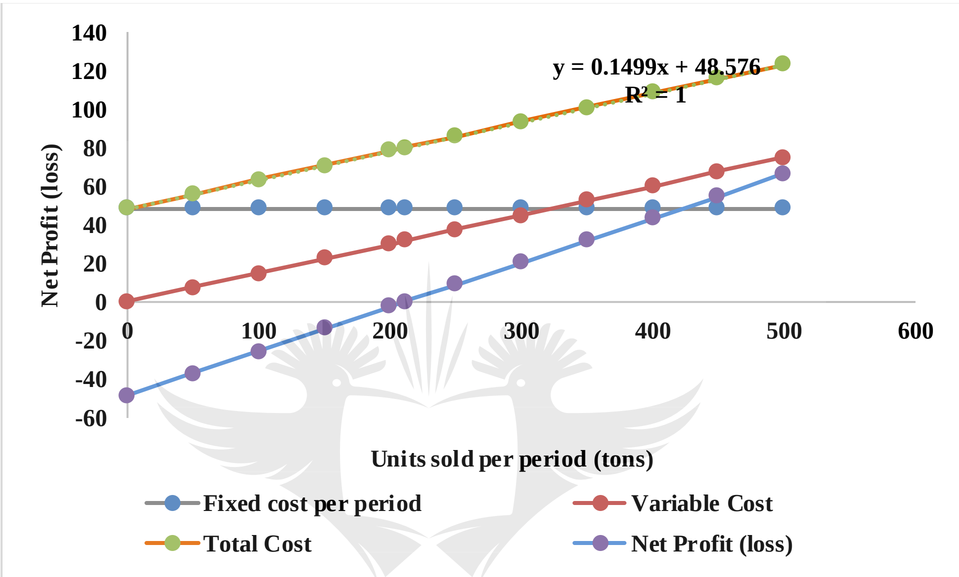

Figure 6: 2: Sensitivity Analysis and Break Even Point

6.1.2 Benefits of Recycling of Materials

Suppose the fractions of the following waste items such as organic, paper, metal, plastics, textiles, glass and other wastes (non-recyclable wastes) are f_{wo}, f_{wp}, f_{wm}, f_{pl}, fw_g, f_{nr} respectively and v_o, v_p, v_m, v_{pl}, v_g, v_{nr} are the market values of the recyclable waste items, then the benefits that accrue from recycling calculated using Equation 4 and summarized in Table 6.6 [Yedla, 2003]. This is given in Equation 4 and summarized in Table 6.6.

$$by = Wa[(vo \times fwo) + (vp \times fwp) + (vm \times fwm) + (vpl \times fpl) + (vg \times fwg) + (vnr \times fnr)] \quad (12)$$

Table 6: 6 : Benefits of Recycling of Materials

Waste Components	Fractions for Dailies (FD)	Fractions for RCR (FR)	Unit values of wastes (Rand/ton)	FD × Unit values (FDU)	FR × Unit values (FRU)	Total (FDU + FRU)
Organics	0.13	0.28	188.63	24.52	52.82	77.34
Paper	0.19	0.16	744.47	141.45	119.12	260.56
Plastics	0.28	0.18	3119.54	873.47	561.52	1434.99
Metal	0.07	0.05	2270.00	158.90	113.50	272.40
Textile	0.03	0.06	367.38	11.021	22.04	33.06
C&D	0.01	0.00	87.50	0.88	0.00	0.88
Other waste	0.14	0.19	367.38	51.43	69.80	121.24
Glass	0.15	0.08	490.00	73.50	39.20	112.70
TOTAL						**2313.17**

Source (Unit values of wastes) [Council for Scientific and Industrial Research (CSIR), 2014]

The total waste generated per annum is given by W_a where W_a is equal to $W_d \times 365$. W_d is the total waste generated per day as shown in Table 6.1. W_d is 1,114 tons. W_a is 406,610. Therefore, the total benefit of recycling ($W_a \times$ (FDU + FRU)) is given as R 94, 0558,054.

6.2 Chapter summary

Based on the economic evaluation; the total outflow equals total inflow; against the cost of capital of 12%, the IRR on investment was 41% and IRR on equity was 80% (Appendix D10). Also, total liabilities equal to total assets and it was found to be R 161,200,000. (Appendix D11), annual turnover was R 113,749,131.60 (Appendix D13), the project breakeven was 211 tons of recycled waste items (Figure 6.2), the total benefit of recycling was R 94, 0558,054 and the NPV was R 135,950,000. These are all healthy for this project. When NPV > 0, a project may be accepted, when NPV < 0, a project will be rejected and when NPV = 0, a company becomes uninterested in the project since it will be paying exactly what the asset worth is. In this study, the NPV is greater than zero, hence this project is viable.

7.0 CHAPTER 7: CONCLUSION, RECOMMENDATIONS, AND FUTURE WORK

7.1 Introduction

This chapter presents the recommendations, the conclusion drawn from the study and some interesting research areas for the future.

7.1.1 Conclusion

The waste composition exercises (Appendix E) that were conducted are a giant step towards the implementation of SSWM in the CoJ. It was discovered that large quantities of inorganic wastes like PET plastics, scrap metals, tins and aluminium are being recycled daily by the Reclaimers. Large quantities of textile wastes were generated during the winter exercise compared to the summer. During the summer exercise, Dailies accounted for 3%, RCR accounted for 6% textile wastes but during the winter, the quantity of textile wastes for Dailies was 7% and that for the RCR was 10%. All the textile wastes ended up at the landfill since recycling of textile wastes is not taking place. The dailies waste collection services generate more inorganic waste than organic since most people depend on packaged food items most especially as soon as their standard of living improves. RCR generates more organic waste since most people prepare almost all their basic meals. The effect of seasonal variation was evaluated on both the Dailies and the RCR. STATA 12 software and ANOVA statistical technique were utilized. The ANOVA was conducted using Excel software. The results obtained from the analysis using STATA 12 gave a (p-value = 0.9775) for Dailies and (p-value = 0.9760) for RCR. Results obtained using ANOVA gave (p-value = 0.9913) for Dailies and (p-value = 0.9999) for the RCR. The mean ($\bar{x}$) for RCR during the summer exercise was 1.931, that of the winter exercise was 1.925, average mean ($\bar{x}\,ave$) was 1.928, the standard deviation (s) for the summer was 2.368 and that for the winter was 2.991. The mean for Dailies wastes are 1.923 and 1.863 for the summer and winter exercises, the standard deviations are 2.196 and 2.844 for both seasons and the average mean ($\bar{x}\,ave$) was 1.893. These were all evaluated using Excel software. It was therefore concluded that the differences between the wastes generated during the winter and the summer for both services were not statistically significant because P_{values} were greater than 0.05 (since $P < 0.05$ means it is statistically significant).

Food wastes from the Marie Louise LS are a potential source of compost. It satisfies the condition of the moisture content of 63.93%. Though, the C: N ratio of 22.66 was low but blending fruit wastes, leaves, corn silage and horse manure with the feedstock will increase the C/N ratio. When these organic wastes are converted into compost, it will serve as an amendment to improve physical, chemical and biological properties of soils. Several other benefits would be realised when organic wastes are diverted from landfills. The benefits include reduction of leachate production; reduction in methane generation which automatically leads to reduction of greenhouse gases (GHG) emissions and the life of the LS will be extended. Source separation of wastes at household levels and at commercial centres is key to achieving complete diversion of wastes from landfill.

From the analysis of the questionnaire, it was gathered that utilizing engineering solutions to manage SW may not necessarily offer adequate solutions to address the problem. This is because solid waste management (SWM) is a complex procedure and it involves many disciplines. For instance, the collection and disposal of SW are very complex and these require costs such as collection costs, transportation costs, storage costs, tipping fees and disposal costs. It was also discovered that reduction of waste from source and source separation of wastes into different streams most especially the organic waste will go a very long way to extend the life of the LSs and will consequently leads to reduction in negative impact it poses on the environment and the health of the general public when it is disposed of to the sites and it degrades. It was noted that the people are not properly enlightened on WM matters. It was also discovered that the majority of the general public do not have the idea of where and how their wastes are being disposed of. This may also be a major challenge and hindrance to getting the support of the general public on the quest to achieving a circular economy through SSWM. People who are residing in the informal settlements were not being offered any services by PU. Most of these people do not have access to basic WM services such as provision of plastic bags or refuse bins for waste storage. This is one of the major causes of illegal dumping since people keep generating wastes as long as they are still living and these wastes will need to be disposed of but since the municipality does not offer them any service, then illegal dumping becomes the only option. It was also observed that waste reduction at source, source separation of waste and recycling are at a minimal level since the people do not really know their significance.

Currently, most of the residents do not pay for their waste collection services and many of them do not see any need to pay more for an improved service. This can be attributed to the fact that most of the people are not enlightened on the issues of SWM. The people are looking forward to an improved waste collection services but they are not ready to pay more. The majority of the respondents showed interest in ZW and they are very ready to support the project. This shows that the project will be viable in those communities.

It was also noted that the majority of the respondents are earning less than R 10,000 per month and where someone is working and receiving a regular income, he or she is the only person working in the household. This makes it difficult to enforce payment of waste charges on those who have not been paying. However, if the ZW project is implemented, people will be able to generate income around wastes, many downstream jobs will be created and people will be able to make a living around wastes and rate of crime will be reduced drastically in the society.

An economic feasibility study was carried out to evaluate the viability of setting up a recycling facility in the Soweto vicinity. Four cases were tested apart from the normal case to determine the viability of the project. Apart from the normal case and case 3 where the project breaks-even at 46%; the other three cases; 1, 2 and 4, the project breaks-even at 50%, 51% and 59% respectively. The IRR on investment was 41%, that on equity was 80% and NPV was R 135,950,000. When NPV > 0, a project is financially acceptable, when NPV < 0, a project is rejected and when NPV = 0, it is unlikely the project will be implemented since it will be paying exactly what the asset is worth. In this study, the NPV was greater than zero; making this project financially viable. The total benefit of recycling the wastes was R 940,558,054. A total of 1,286 potential jobs (68 personnel will be running the machineries at the recycling facility, 609 personnel will be travelling with the trucks to various locations and the other 609 personnel will be working at the recycling facility and will be helping with the sorting of the recyclables) is envisaged would be created on this project which is the main objective of this study of creating downstream jobs.

7.1.2 Recommendations

There are many international organizations that support SWM in DCs as a prime concern and are ready to release support to developing nations. DCs should collaborate with these

Organizations and seek support from them and there will be improvement in MSWM. SWM agencies should clearly define the roles of their staff and also ensure that they employ experts in the field of SWM so that there can be good service delivery. Roles of different government agencies should be clearly defined so as to know which agencies are responsible for issues relating to the environment. For sustainability to be attained in DCs, human resources with technical expertise in SWM should be developed and these should comprise of; (i) key personnel in the national coordinating unit of the central or federal governments; (ii) operational managers of selected local or municipal governments; and (iii) universities and other higher educational institutions. Without this group in place, the collaborative effort by external organizations will stop since there would not be a medium of communication with the external agencies. The human resources should be strengthened and given support while the support for the other two arms of government should be short term, the Universities or any other higher educational institutions should be given long term support since they do conduct research from time to time and also invent new methods of managing wastes. DCs are to follow up carefully designed SWM methods and ensure that they are fully implemented. Also, public awareness should be created and the members of the public should be involved in the implementation process. The monetary allocation for MSWM yearly ought to be augmented so that the municipalities can provide quality WM services. The municipality can likewise devise different methods for creating incomes which incorporate; polluter-pay systems, pay-as-you-throw framework and execution of bio-gas generation ventures in a joint effort with outside financial specialists. Municipalities should also formulate SWM frameworks. This includes avoidance, source separation, reusing and recycling of solid waste in a viable way that will ensure both human wellbeing and the environment [Hisashi and Kuala, 1997, Ally et al., 2014].

PU must increase its effort to raise the consciousness of the people of the communities towards environmental protection in order for SSWM to be achieved. The municipality needs to continue to educate the people and also to continue creating awareness both in the communities and for the general public as this will lead to changes in attitudes of people towards the environment. Educating the general public and creating awareness on the need to protect the environment will lead to sustainable development. People want to know more about their waste collection, how to handle their wastes and a proper means of disposal of their wastes. The local authority must seek to recognize the waste pickers and others who are already involved in the waste recycling business. Informal waste workers also known as Reclaimers, scavengers or waste pickers are referred to as informal simply because they are not on contract, they do not have regular income and no one recognizes or cares about them making them very vulnerable. This informal waste sector contributes immensely to resource recovery and recycling in developing countries. Since households rarely recycle, reuse or sell waste items, it is best for the municipality to co-opt this sector into WM. The general public must also be carried along in the implementation stages of the ZW project [Landfill Consult, 2011, Muller and Hoffman, 2001, Gunsilius, 2011, Scheinberg, 2001] As part of the awareness campaigns, the municipality needs to set up a contact centre which will serve as the organizational unit in the municipality where citizens and businesses can channel their complaints and also get answers to their queries almost immediately and if one is already in place, it should be improved upon since this will serve as an avenue to answer about 80% of the queries promptly [Millard, 2009]. Municipalities need to be transformed into organizations that are more focused on customers. They should not hesitate to introduce changes in their work plans and service ideology. Municipalities should open new composting plants and those already in place should be revitalized. The organic fraction of municipal solid waste (OFMSW) produced can be composted rather than sending them to the landfill site where they can cause further environmental problems such as leachate and GHG generation. Composting is the decomposition of the OFMSW in a controlled environment. It is a natural process in which microorganisms break down complex organic wastes and the resulting products are water vapour (H_2O) and carbon dioxide (CO_2) which produce nutrients that can be used to improve soil and to help in the growth of plants [Dulac, 2001].

For ZW to be a success, all sectors which include the government, private sectors, informal sectors and the general public must be willing to be fully involved. The goal of ZW is to ensure that all participating sectors adhere to sustainability. This involves reduction of waste from source, recycling, reuse and the manufacturers taking full responsibilities of the collection and recycling of their products at the end of its life (extended producer responsibility). To achieve this cooperation from all the sectors most especially the communities and the general public, the municipality must put an incentive model in place in such a way that people will be rewarded for being actively involved in ZW [World Bank, 2009].

7.1.3 Future Work

- It is recommended that a waste composition study should be carried out in all the four functional LSs managed by PU in order to make informed decisions on the steps towards ZW in CoJ so that sustainability can be attained and hence a green city will be developed. Furthermore, the study should be specifically carried out on the application of plastic waste as a substitute to bitumen in road construction as this will serve as a platform to determine the total quantity of plastic wastes that are generated in CoJ.

- It is further recommended that a structured questionnaire be developed and be administered to residents in other areas like Sandton, Kempton Park, Yeoville, Hillbrow, Alexandra etc., in CoJ in order to evaluate their level of education and awareness on environmental matters and to also serve as a platform for the municipality to know where and how to improve their services.

- It is recommended that further study should be carried out on the elemental compositions of MSW and should be extended to all the waste streams which include plastics, metals, papers, textiles and glass wastes.

- It is also recommended that economic evaluation should be conducted on all the waste compositions data that will be obtained from the studies that will be carried out in all the four functional LSs in CoJ in order to devise the proper means of managing or diverting the wastes that are being disposed of to those LSs so that CoJ can also attain 85% ZW to landfill which is the internationally accepted standard.

- It is further recommended that comprehensive laboratory analysis should be carried out on the leachate produced from the decomposed MSW to determine the various elements that are present; also on the soil on the landfill and the underground water around the dumping site to determine the level of contamination that might have been done to the soil and the water table.

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APPENDIX A

Raw data from the Waste Composition Studies conducted during the summer of 2015 and winter of 2016

A1 DAILIES NON COMPACTED WASTES (SUMMER SEASON)

WASTE TYPE	SAMPLE NUMBER (%)											
	1	2	3	4	5	6	7	8	9	10	11	TOTAL (%)
ORGANIC												
Food Waste	8.4	5.7	2.2	8.6	6.7	7.7	8.7	8.6	7.8	7.1	9.2	7.3
Fresh Fruits and Vegetables	0	3.6	2.3	0	0	0	0	0	0	2.5	0	0.8
Yard Waste	6.4	5.3	7.3	6.2	3.1	5.2	2.1	0	5.9	4.6	4.2	4.6
Composite Organic Waste	0	0	0	0	3.8	1.6	0	2.4	0	0	0	0.7
	14.8	14.6	11.8	14.8	13.6	14.5	10.8	11	13.7	14.2	13.4	13.4
PAPER & PAPERBOARD												
Newspaper	6.4	0	9.6	0	0	13.8	8.3	3.5	19.3	3.8	0	5.9
Cardboard/boxboard	8.2	0	0	0	0	0.6	1.2	0	2.1	3.3	1.2	1.5
Magazines/catalogues	0	8.4	0	0	0	0	5.6	1.2	0	0	0	1.4
Office paper	5.4	0	1.5	5.4	1.1	0	2.1	10.2	0	0	1.3	2.5
Books	0	9.5	0	0	0	0	1.1	0.5	0.6	0	0	1.1
Corrugated Paper	10	0	2.8	0	3.2	8.9	0.4	5.3	5.1	6.5	7	4.5
Other/ miscellaneous paper	3.4	0	9.4	2.6	1.5	0	0	2.3	3.2	0	3.2	2.3
	33.4	17.9	23.3	8	5.8	23.3	18.7	23	30.3	13.6	12.7	19.2
GLASS												
Clear containers	3.8	4.6	7.8	5.2	7.9	1.3	3.1	13.1	4.2	5	4.7	5.5
Green containers	0	3.5	8.9	3.4	11.6	2.7	1.2	11.3	1.7	4.1	2.7	4.7
Amber containers	0	0	1.3	2.2	12.4	2.2	5.4	0.5	0	4.3	2.2	2.8

Remainder/composite glass	4	0	0	0	0	0	0	3.2	1.3	6.3	0	1.4
	7.8	8.1	18	10.8	31.9	6.2	9.7	28.1	7.2	19.7	9.6	14.4
METAL												
Aluminium containers	1.8	2.1	0.5	5.6	3.8	1.2	0.8	0.3	4.8	6.4	3.4	2.8
Scrap metals	0	0	1.2	0	6.5	0	0	0	0	0	1.2	0.8
Other ferrous metal	0	0	0	0	0	0	0	0	0	0	0	0
Other non-ferrous metal	0	0	0	1.3	0.5	0	0.5	0	0	0	0	0.2
Tin/steel containers	0	3.7	1.2	2.8	4.3	6.6	7.5	0.2	3.6	1.3	6.6	3.4
	1.8	5.8	2.9	9.7	15.1	7.8	8.8	0.5	8.4	7.7	11.2	7.2
PLASTICS												
Clear PET Bottles/containers	0.9	3.4	0	3.1	3.8	12.7	1.7	5.9	4.5	6.6	12.7	5
Green PET Bottles/containers	3.6	5.6	5.1	5.4	4.5	3.5	0	0.3	4.6	7.6	3.5	4
Amber PET Bottles/containers	0	0	3.2	4.2	1.7	5.6	0	0.5	1.3	0	5.6	2
HDPE containers	6.9	2.5	2.4	6.8	0	0	15	5.7	9.6	9.6	0	5.3
Film plastics	0	0	0	0	0	0	0	0	0	0	0	0
Mixed plastic bags	10.8	4.1	6.8	6.8	17	9.9	1.3	5.3	4.3	10.5	9.9	7.9
Other plastics	4	0	0	3.6	0	0	15.3	10.1	5.3	0	1.2	3.6
	26.2	15.6	17.5	29.9	27	31.7	33.3	27.8	29.6	34.3	32.9	27.8
TEXTILE/FABRIC/ LEATHER												
Textile	0	4.1	0	0	0	0	2.1	1.1	0.4	0	1.5	0.8
Shoes/Bags	0	3.7	0	0	0	0	0	2	0	0	0	0.5
Weavons	3.9	0	0	10.6	2.1	0	0.8	0.3	0	0	4.1	2
	3.9	7.8	0	10.6	2.1	0	2.9	3.4	0.4	0	5.6	3.3
CONSTRUCTION & DEMOLITION MATERIAL												
Lumber	0	0	0	0	0	0	0	0	0	0	0	0
Concrete	0	0	0	0	0	0	6.6	0	0	0	3.1	0.9
Remainder/composite C & D	0	0	0	0	0	0	0	0	0	0	0	0
	0	0		0	0	0	0	0	0	0	3.1	0.9
SPECIAL CARE WASTES												

Paint	0	0	0	0	0	0	0	0	0	0	0	0
Paint container	0	0	0	0	0	0	0	0	0	0	0	0
Hazardous materials	0	0	0	0	0	0	0	0	0	0	0	0
Biomedical	0	0	0	0	0	0	0	0	0	0	0	0
Batteries	0	0	0	0	0	0	0	0	0	0	0	0
Oil Filters	0	0	0	0	0	0	0	0	0	0	0	0
Remainder/composite S.C. waste	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
OTHER WASTES												
Furniture/Bulky waste	0	0	0	0	0	0	0	0	0	0	0	0
Ceramics	0	0	3.2	0	1	0	0	0	0	0	0	0.4
Rubber	0	0	1.4	2.3	0	0.3	0	0	0	0	0	0.4
Carpet/rug	0	0	0	0	0	0	0	0	0	0	0	0
Diapers/sanitary products	4.5	13.4	6.6	6.3	3.1	8.9	0	2.1	3.1	4.1	5.6	5.3
Wood/ply wood	0	0	0	0	0.4	0	5	0	0	0	0	0.5
Car seat/Automobile waste/safety kits	0	0	0	0	0	0	0	0	0	0	0	0
Office chair	0	0	0	0	0	0	0	0	0	0	0	0
Polyurethane/ Extended polyurethane foam	0	5.2	0	1.3	0	0	2.5	0	1.8	0	0	1
Waste Electrical Products (WEEE)	0	0	5.4	5.2	0	3.7	0	1.7	5.5	0	0	2
Tyre	0	0	0	0	0	0	0	0	0	0	0	0
Other/Composite Waste	7.6	11.6	9.9	1.1	0	3.6	1.7	2.4	0	6.4	5.9	4.6
	12.1	30.2	26.5	16.2	4.5	16.5	9.2	6.2	10.4	10.5	11.5	14.2
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100

A2 ROUND COLLECTED REFUSE (RCR) COMPACTED WASTES (SUMMER SEASON)

WASTE TYPE	SAMPLE NUMBER (%)																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL (%)
ORGANIC	Zondi 1	Malboro	Roodeport 1	Florida 1	Soweto	Dobsonville 1	Northcliff	Florida 2	Sampson	Zondi 2	Four Ways	Florida 3	Roodeport 2	Zondi 3	Central Camp	Florida 4	Emerential	Bram Fische 1	Bram Fische r 2	Dobsonville 2	Freedom Park	Roodeport	Northcliff	Alexandra	
Food Waste	15.6	18.3	16.3	14.8	15.7	5.8	0	8.1	18	5	11.3	3.5	0	10.8	9.4	8	37.5	0	24.7	0	0	0	21.5	14	10.8
Fruits and Vegetables	6.8	5.1	0	3.8	3.8	0	1	0	0	25.2	3.2	4.6	0	0	2.3	3	0	0	2.6	0	0	0	5	4.8	3
Yard Waste	7.2	11.3	6.6	10.8	4.3	0	18.2	25.5	14.1	0	6.2	20	2.9	4.3	3.7	12.4	0	36.7	8.9	0	3.2	0	0	18.3	8.9
Composite Organic	6.4	7	10.2	9.2	5.6	5	11.3	0	0	0	25.1	7.2	10	8.9	12.3	10	0	0	0	0	0	0	0	4.5	5.5
	36	41.7	33.1	38.6	29.4	10.8	30.5	33.6	32.1	30.2	45.8	35.3	12.9	24	27.7	33.4	37.5	36.7	36.2	0	3.2	0	26.5	41.6	28.2
PAPER																									
Newspaper	4.4	2.1	5.1	3.1	0	0	10.5	3.6	5.5	0	2.3	6.7	0	9.4	0	6.8	0	4.9	1.3	2	23.1	0	1.9	8	4.2
Cardboard	3.5	3.2	0	0	1.3	0	1	0	2.2	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6
Magazines/catalogues	0	0	5	5.7	0	3.2	0	3.8	0	0	0	6.3	0	0	0	5.2	0	0	0.1	0	0	0	0	0	1.2
Office paper	5.6	5.3	0	0	3.3	2.9	1.6	0	0	3.4	3.5	2.9	0	0	0	0	0	0	0	0	5.3	10.2	0	0	1.8
Books	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	3.2	5.7	0	0	0	3	0	0	4.8	0	0.7
Corrugated Paper	5.4	5	2.9	3.3	6.7	3.4	7.9	3.8	5.7	0	3.9	8.3	3.7	5.3	0	4.5	0	6	4.5	3.3	7.8	15.4	2.1	4.4	4.7
Other paper	1.5	0.8	1.1	5.7	6.7	3.5	0	3.5	4.8	4	2.6	1.8	3.2	0	9.5	0	0	0	0.2	0	0	0	2.8	2.4	2.3
	20.4	16.4	14.6	17.8	18	13	21	14.7	18.2	7.4	15.5	26	6.9	14.7	12.7	22.2	0	10.9	6.1	8.3	36.2	25.6	11.6	14.8	15.5
GLASS																									
Clear containers	5.1	2.9	3.5	4.6	3.4	1.1	3.8	3.2	2.4	2.2	1.5	3.1	0	5.9	2.4	5.2	1.7	1.2	3.2	10.6	10.2	0	4.3	3.4	3.5
Green containers	2.3	3.6	1.1	3.2	1.6	0.4	2.1	0	2.2	0	2.1	1.4	0	2.3	0	1.4	0	0	1.2	7.4	3.6	0	2.4	1.6	1.7
Amber containers	0	0	2.3	1.8	1.4	1.8	1.2	0	0.6	0	1.2	1.5	0	1.7	0	1.6	0	0.2	1.1	3.6	3.4	0	0	0	1
Composite glass	0	3	0.9	2.9	0	2	1.7	1.8	1.7	3	0.4	3.1	0	2	1.3	2.2	9.5	0.8	3.2	3.4	3.3	0	3.6	2.4	2.2
	7.4	9.5	7.8	12.5	6.4	5.3	8.8	5	6.9	5.2	5.2	9.1	0	11.9	3.7	10.4	11.2	2.2	8.7	25	20.5	0	10.3	7.4	8.4
METAL																									
Aluminium containers	3.5	4.8	1.1	2.3	1.1	0	0	0.8	1.3	2.5	5.1	2.3	0.9	0.3	1.6	2	0.5	0	1.4	5.4	0.7	0	0.6	0.5	1.6
Scrap metals	3.6	0	3.1	0	3.1	0.6	0.7	1.2	1.2	0	1.3	0.6	0.8	9.5	3.2	1.6	0	0.3	0	1.6	0	0	1	0	1.4

Other ferrous metal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other non-ferrous metal	0.4	0	1.2	0	0.3	0	0	0.1	0.5	0	0.5	0.9	0	0	0	0	0	0	0	0	0	0	2.2	0	0.3
Tin/steel containers	1.1	1.2	3.3	1.2	3.9	3.3	0	1.8	2.3	3.2	1.8	3.4	0.6	1.2	0	1.4	0	0	0	4	1.2	0	0	2.5	1.6
	8.6	6	8.7	3.5	8.4	3.9	0.7	3.9	5.3	5.7	8.7	7.2	2.3	11	4.8	5	0.5	0.3	1.4	11	1.9	0	3.8	3	4.9
PLASTICS																									
Clear PET containers	3	5.3	7.5	1.8	3.3	4	3.1	2.8	3.9	6.8	1.2	1.8	6.3	8.6	1.2	1.5	1.7	0.6	3.2	5.7	4.3	0	9.9	3	3.8
Green PET Bottles	0.5	2.1	2.4	0	4.2	2.6	0	0	0.9	5.3	1.7	0	0	4.8	1.2	0	0.5	0	2.1	5.4	3.4	0	4.4	0	1.7
Amber PET Bottles	0	1.2	1.1	1.2	0	2	0	1.2	0.5	0	0.6	0	0	0	0.8	0	0.6	0	1.2	2.7	4.7	0	2.4	0	0.8
HDPE containers	7.8	3.3	1.3	9.3	2	2.9	2.5	0.7	3.3	12.4	2.6	1.7	4.1	7	0.6	0.5	3.5	2.7	4.8	3.8	4.1	0	14.8	7.8	4.3
Film plastics	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixed plastic bags	9.7	1.9	4.7	0	17	2.6	3.4	2.6	7	0	2.1	4.5	5.7	0.3	7.4	2.7	0	0.5	4.8	3.6	2.2	0	4.9	0	3.7
Other plastics	0	0	0	3.7	0	3.5	0	21.4	2.1	0.3	3.4	0	0	3.2	0.3	1.6	0.5	2.9	0.5	13.4	8.9	0	2.9	9.7	3.3
	21	13.8	17	16	26.5	17.6	9	28.7	17.7	24.8	11.6	8	16.1	23.9	11.5	6.3	6.8	6.7	16.6	34.6	27.6	0	39.3	20.5	17.6
TEXTILE/FABRIC/ LEATHER																									
Textile	0	0	3.1	0.4	3.8	30.1	3	2.2	14.1	0.3	0	0.4	33	0.1	1.5	0.8	0	18.2	10.1	5.1	0	0	0	0	5.3
Shoes/Bags	0	0	0	0.5	0	0.3	0.3	0	2.9	0	0	0.5	1.2	0.9	0.7	0.1	0	1.4	6.5	0	0	0	0	0	0.6
Weavons	0	0	0	0	0.8	0.1	0	0	0.2	0	0.6	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0.1
	0	0	3.1	0.9	4.6	30.5	3.3	2.2	17.2	0.3	0.6	0.9	34.2	1	2.5	0.9	0	19.6	16.6	5.1	0	0	0	0	6
CONSTRUCTION & DEMOLITION WASTE (C & D)																									
Lumber	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Concrete	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Composite C & D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.9	0	0	0	0	0	0	0	0	0	0.3
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.9	0	0	0	0	0	0	0	0	0	0.3
SPECIAL CARE (S.C.) WASTES																									
Paint	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paint container	0	0	0	0	0	0	0	0	0	0	0	0	0.9	1.1	1.9	0	0	0	0	0	0	0	0	0	0.2
Hazardous materials	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Biomedical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Batteries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil Filters	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Composite S.C. waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0.9	1.1	1.9	0	0	0	0	0	0	0	0	0	0.2
OTHER WASTES																									
Furniture/Bulky waste	0	0	0	0	0	0	0	0	0	4.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2
Ceramics	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	3	0	0	0	0	0	0	0	0	0	0.2
Rubber	0	0	5	0	0	0	0	0.2	2.6	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0.4
Carpet/rug	0	0	0	0	0	0	0	0	0	0	0	0	15.8	0	0	0	0	0	0	0	0	0	0	0	0.7
Diapers	5.8	9.3	3.3	0	2.3	1.4	3.9	10	0	10.5	3.2	6.3	0	0	6.3	13.2	35.7	4	9	0	0	0	0	0.8	5.2
Wood/ply wood	0	0	0	6.7	0	0	1.3	0	0	0	0	0	0	0	0	0	0	3.6	0	0	0	0	0	0	0.5
Automobile waste	0	0	0	0.3	0	0	0	0	0	0	0	0.3	0	0	0	0.3	0	0	0	0	0	50.1	0	0	2.1
Office chair	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Extended polyurethane foam	0	0	0	0	0	0	0.3	0	0	0.9	3.3	0	0.9	0	0	0.5	0	0	0.4	0	0	0	0	0	0.3
WEEE	0.8	0	0.5	0	0.6	2.6	1.3	0	0	6.3	2.5	0	2.4	7.1	0	0	0	0	0	8.3	5.4	24.1	8.5	3.8	3.1
Tyre	0	0	0	0	0	0	0	0	0	0	0	0	6.8	0	3	0	0	8.3	0	0	0	0	0	0	0.8
Other/Composite Waste	0	3.3	6.9	3.7	3.8	14.9	19.9	1.7	0	4	3.6	6.9	0	5.3	15	7.8	8.3	7.7	4.5	7.7	5.2	0	0	8.1	5.8
	6.6	12.6	15.7	10.7	6.7	18.9	26.7	11.9	2.6	26.4	12.6	13.5	26.7	12.4	27.3	21.8	44	23.6	14.4	16	10.6	74.2	8.5	12.7	19.3
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

A3 DAILIES NON COMPACTED WASTES (WINTER SEASON)

WASTE TYPES	SAMPLE NUMBER (%)									
	Newland Mayfair	Ramburg 1	Ramburg 2	Ramburg 3	Florida	Roodepoort	Dobsonville	Kya Sands	Zondi	TOTAL (%)
ORGANIC										
Food waste	6.5	0	15.3	3.1	3.9	2	0	3.6	10	4.9
Garden waste	16.1	0	0	0	6.4	0	4.8	10.6	6.2	4.9
Fruit and Vegetable wastes	0	6.1	4.1	0	2.2	0	0	1.5	6.1	2.2
Remainder/Composite Organic waste	0	0	0	0	0	7.4	11.3	0	1.5	2.2
	22.6	6.1	19.4	3.1	12.5	9.4	16.1	15.7	23.8	14.3
PAPER & PAPERBOARD										
Newspaper	14.5	0	0	21.3	0	0	1.4	4.7	0	4.7
Cardboard/boxboard	2.1	3.7	0	0	0	0	6.2	0	0	1.3
Magazines/catalogues	0	0	0	0	0	0	0	0	0	0
Books	0.1	0	0	0	0	0	0	0	0	0.0
Corrugated box/cartons	1.4	3.9	15.6	3.1	10.1	2	1.7	12	10.6	6.7
Office paper	0	4.2	3	11.2	0	0	6.3	0.9	2.5	3.1
Other/ miscellaneous paper	5	0	0	11.1	0	0	0	10	0	2.9
	23.1	11.8	18.6	46.7	10.1	2	15.6	27.6	13.1	18.7
GLASS										
Clear containers	1.2	0	0	1.2	5.3	0	3.2	1.6	2.1	1.6
Green containers	0.4	0	0	0.7	1.2	0	1.3	0	1.1	0.5
Amber containers	0	0	0	0.3	0.2	0	1.6	0	0	0.2
Remainder/composite glass	1	0	4.2	0.7	1.4	2.6	5.9	1.7	1.5	2.1
	2.6	0	4.2	2.9	8.1	2.6	12	3.3	4.7	4.5
METAL										
Tin/steel containers	1.5	9.6	5.1	0	0.2	15.1	0	0	0.8	3.6
Aluminium containers	0.2	0.8	0.5	0	11.4	0.2	0	0.4	1	1.6

Scrap metals	0	0	5.8	3.9	0	21.9	0	0	0	3.5
Other ferrous metal	0	0	0	0	0	0	0	0	0	0
Other non-ferrous metal	0	8.5	0.4	0	0	0	0	0	0	1.0
	1.7	18.9	11.8	3.9	11.6	37.2	0	0.4	1.8	9.7
PLASTICS										
Clear PET Bottles/containers	2.8	3.8	2.1	3.2	4.8	2.6	5.4	0.4	0	2.8
Green PET Bottles/containers	1.4	1.2	1.5	1.3	3.5	0	2	0	0	1.2
Amber PET Bottles/containers	0	1.8	1.5	1.8	2.5	0	3.3	0	0	1.2
HDPE containers	1.5	14.3	3.9	9.3	17	9.2	1.8	6.4	0.3	7.1
Film plastics	0	1.2	0	0.2	0.2	1	0	0	0	0.3
Mixed plastic bags	1.3	10.8	11.8	3.6	5.5	0.4	2.5	4.8	10.9	5.7
Other plastics/Polypropylene	14.1	3.2	9.7	0.6	0.3	19.9	1.2	2.3	19	7.8
	21.1	36.3	30.5	20	33.8	33.1	16.2	13.9	30.2	26.1
TEXTILE/FABRIC/ LEATHER										
Textile	4	3.5	0	0	0	0	6.8	0	0	1.6
Shoes/Bags	0	0	0	0	0	0	2.7	0	0	0.3
Weavons	0	10.8	0	2	15.2	8.5	0.3	5.4	0	4.7
	4	14.3	0	2	15.2	8.5	9.8	5.4	0	6.6
CONSTRUCTION & DEMOLITION MATERIAL										
Concrete	0	0	0	0	0	0	0	0	0	0
Lumber	0	0	0	0	0	0	0	0	0	0
Remainder/composite C & D	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
SPECIAL CARE WASTES										
Paint	0	0	0	0	0	0	0	0	0	0
Paint container	0	0	0	0	0	0	0	0	0	0
Biomedical	0	0	0	0	0	0	0	0	0	0
Batteries	0	0	0	0	0	0	0	0	0	0
Oil Filters	0	0	0	0	0	0	0	0	0	0

Remainder/composite S.C. waste	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
OTHER WASTES										
Waste Electrical Products (WEEE)	0	1.9	0	2	0	0	0	0	0	0.4
Tyre	0	0	0	0	0	0	0.3	0	0	0.0
Furniture/Bulky waste	0	0	0	0	0	0	0	0	0	0
Ceramics	0	0	0	0	0	0	0	0	0.6	0.1
Rubber	6.2	2.9	3.7	0	0	0	0	0	0.6	1.5
Carpet/rug	0	0.9	0	0	3.5	0	0	0	0	0.5
Diapers/sanitary products	3.5	0	0	0	0	0	0	0	1.3	0.5
Wood/ply wood	0	1.8	0	0	0	0	0	0	0	0.2
Office chair	0	0	0	0	0	0	0	0	0	0
Polyurethane/ Extended polyurethane foam	0	5.1	0	0	5.2	2.8	0	0	0	1.5
Roofing sheet	0	0	0	0	0	0	0	0	0	0
Automobile waste/safety kits/car seat	0	0	0	0	0	0	0	0	0	0
Other/Composite waste	15.2	0	11.8	19.4	0	4.1	30.3	33.7	23.9	15.4
	24.9	12.6	15.5	21.4	8.7	6.9	30.6	33.7	26.4	20.1
TOTAL	100	100	100	100	100	100	100	100	100	100

A4 ROUND COLLECTED REFUSE (RCR) COMPACTED WASTES (WINTER SEASON)

WASTE TYPE	SAMPLE NUMBER (%)																						
	North Cliff	Zondi 1	Zondi 2	Zondi 3	Ba ra	Zola	Roodepo ort 1	Roodepo ort 2	Roodep oort 3	Discove ry 1	Discove ry 2	Bram Fischer 1	Bram Fischer 2	Westg ate	Chiawelo	Klipsp ruit	Fleur hof	Malb oro	Emd eni	Molets ane	Honey dew	Dobson Ville	TOTAL
ORGANIC																							
Food waste	10.1	19.1	21.1	15.3	21.5	20.8	14.4	0	22.2	21.2	13.5	14.5	3.6	13.2	25.2	8.7	17.5	7.1	3.4	5.9	1.8	23.7	13.8
Garden waste	9.4	14.7	0	0	1.3	5.1	0.9	3.8	17.8	6.3	29.1	4.1	13.6	1.2	10	22.2	0	21.5	6	15.2	21	0	9.2
Fruit and Vegetable wastes	3.1	2.7	4.5	2.5	3.2	3.5	5.1	0	3.5	0.4	2.4	5.1	0.4	1.5	3.4	0	4.7	2.6	0	1.6	0	5.1	2.5
Remainder/Composite Organic waste	0	0.3	3.5	0	2.1	4.9	6.5	0.4	7.5	0.2	3.5	5.5	6.6	1.9	11.7	5.5	3.1	6.4	8.3	2.6	0	0	3.7
	22.6	36.8	29.1	17.8	28.1	34.3	26.9	4.2	51	28.1	48.5	29.2	24.2	17.8	50.3	36.4	25.3	37.6	17.7	25.3	22.8	28.8	29.2
PAPER & PAPERBOARD																							
Newspaper	12.7	2.2	2.8	0.5	0	2.1	1.7	15.6	0	0.4	3.9	19.2	0	3.7	1.1	1.4	1.7	2.1	1.9	2.2	4.8	3.1	3.8
Cardboard/boxboard	1.3	3.8	3	0	3.2	2.1	0.3	0	1.3	0	0.3	0.2	0.3	5.2	0	1.2	0	0.3	3.6	3.5	0	0.2	1.4
Magazines/catalogues	0	0	1.7	0	0	1.7	1.1	6.1	0	0.2	2.9	4.2	0	0.7	0	0.2	0.5	0.2	0	2.5	0	1.6	1.1
Books	0	0	0	1.4	1.2	0	0	0	0	0		0.1	1.5	2.6	0	0	0	0	1.4	0.5	0	0	0.4
Corrugated box/cartons	2.4	0	3.4	0	7.5	1.1	0.7	0	3.5	0	0.8	0.4	1.8	6.7	1.5	3.8	0	2.3	6.4	4	0	2.3	2.2
Office paper	0	0	0	0	2	0	0	3.9	1.2	1	0.3	0.4	0	0.8	8.4	0	1.2	1	0	1	16.6	0	1.7
Other/ miscellaneous paper	0.4	0	0	0	1.3	0	0	0.4	2.9	0.2	0	0	0	7.3	0	1.3	0	16	0	1	0	0	1.4
	16.8	6	10.9	1.9	15.2	7	3.8	26	8.9	1.8	8.2	24.5	3.6	27	11	7.9	3.4	21.9	13.3	14.7	21.4	7.2	11.9
GLASS																							
Clear containers	1.3	0.3	2.6	1.8	1.2	0.4	0	0.2	1.3	0.6	2.8	3.9	2.1	0	1.2	0.2	8.2	2.1	0.6	0	2.8	3.1	1.7
Green containers	0.9	0	1.3	0.3	0.6	0.1	0	0.5	0.3	0	0.7	1.1	0.2	1.3	0.1	0	5.3	0.3	0.3	0	0.5	0.2	0.6
Amber containers	0.6	0.2	0.8	0.5	0.5	0.1	0	0.2	0.6	0	1.2	1.3	0.3	0	0.3	0.2	3.5	0.3	0.3	0	0.9	0.2	0.5
Remainder/composite glass	0	0.4	2.8	1.2	2.7	2	0.5	0.9	1.1	0.9	0.8	1.6	1.1	0	0.2	5.8	3.6	0.4	0.3	0	1.5	2.1	1.4
	2.8	0.9	7.5	3.8	5	2.6	0.5	1.8	3.3	1.5	5.5	7.9	3.7	1.3	1.8	6.2	20.6	3.1	1.5	0	5.7	5.6	4.2
METAL																							
Tin/steel containers	2.9	0.3	0.8	3.9	0	1.2	0.7	2.2	0.1	1.8	0.2	0.2	0.6	1.8	0.1	5.3	0.6	0.1	0	1.2	0	0	1.1
Aluminium containers	1.2	0.7	2	4.1	0	8.9	1	1.9	0.9	2.6	2.6	1.3	6.4	0.6	0.5	4.1	0	1.5	0	1.4	0	0	1.9
Scrap metals	0	0	5.7	1.1	0	0.7	0	13.5	0	0.1	0	0	0	0	0	1.2	0	0.1	3.8	0	3.3	5.2	1.6

Other ferrous metal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other non-ferrous metal	0	0	1.1	3.5	0	0	0	0	0	1.4	0	0.1	0	1.2	0	1.8	0	0.1	0	0	0	0	0.4
	4.1	1	9.6	12.6	0	10.8	1.7	17.6	1	5.9	2.8	1.6	7	3.6	0.6	12.4	0.6	1.8	3.8	2.6	3.3	5.2	5.0
PLASTICS																							
Clear PET Bottles/containers	5.2	0.2	0	2.1	0.3	0.3	1.3	6	0.9	7.6	0.7	1.4	4.6	3.3	0.6	1.4	2.3	1.8	2.1	0.6	9.7	2.7	2.5
Green PET Bottles/containers	3.1	0	0	3.6	0.2	0.2	0.4	7	0.2	2.5	0.4	1.6	1	4.7	0.5	0	4.5	0.5	1.3	0.2	4.2	2.2	1.7
Amber PET Bottles/containers	2.1	0	0	1.9	0.3	0.5	0.4	6.3	0.6	3.9	0.3	1.4	2.3	1.1	0.3	0.7	3.7	0.6	0.7	0.2	0.8	2.1	1.4
HDPE containers	11.3	0.2	3.0	14.0	1.4	4.6	0.1	6.9	0	9.5	5.3	2.4	9.7	2.2	7.4	0.8	4	2.5	1.5	2.7	5.1	1.7	4.4
Film plastics	0.7	0.3	0	0.5	0	0	1.9	0	0	0.3	0	0	1.8	0.7	0	0.6	0	0.1	1	0.6	0.5	0.4	0.4
Mixed plastic bags	6.3	12.9	14.5	7.3	6.9	5.4	0.8	7.9	1.4	2.8	0.2	0.3	3.9	8	0	7.4	6	1.5	13.7	5.7	3.2	8.8	5.7
Other plastics/Propylene	0.4	1.7	0	5.8	5.1	0.1	0.7	2.6	1.9	4.7	0.6	0.7	9.6	6.7	0.2	0	5.1	2.8	9.2	2.4	3.7	1.5	3.0
	29.1	15.3	17.5	35.2	14.2	11.1	5.6	36.7	5	31.3	7.5	7.8	32.9	26.7	9	10.9	25.6	9.8	29.5	12.4	27.2	19.4	19.1
TEXTILE/FABRIC/ LEATHER																							
Textile	10.1	7.9	24.1	0.3	4.3	5	23.6	4.4	2.7	5.5	4.9	2	3.1	1.3	10.9	3.4	1.9	2.5	11.5	21.3	0	20.9	7.8
Shoes/Bags	0.8	0.9	1.3	0	3.5	1.2	12.6	0	0	0.8	0	0	2	1.7	0.3	0.6	0.3	0.6	1.4	2.1	0	9.2	1.8
Weavons	0	1.6	0	0	0.5	3.1	0.6	0	0	1.5	0	3.5	0	0	0	0.8	0.6	0	1.5	0.9	0	0.6	0.7
	10.9	10.4	25.4	0.3	8.3	9.3	36.8	4.4	2.7	7.8	4.9	5.5	5.1	3	11.2	4.8	2.8	3.1	14.4	24.3	0	30.7	10.3
CONSTRUCTION & DEMOLITION MATERIAL																							
Concrete	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lumber	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Remainder/composite C & D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SPECIAL CARE WASTES																							
Paint	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paint container	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomedical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Batteries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil Filters	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Remainder/composite S.C. waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHER WASTES																							
Waste Electrical Products (WEEE)	0.9	0	0	0.2	0	0.5	0	1.2	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0.2
Tyre	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Furniture/Bulky waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceramics	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rubber	0	0.9	0	0	0	2.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2
Carpet/rug	0	7.2	0	0	4	0	0	0	2.7	0	0	0	7.3	0	0	0	0	0	0	6.8	0	0	1.3
Diapers/sanitary products	7.4	9	0	0	13.8	5.1	9.2	0	15.1	3.3	14.8	11.6	1.9	0	4.8	6.6	10.6	5.2	3.6	0	0	0	5.5
Wood/ply wood	0	0	0	0.3	0	0	0	0	0	0	0	1.5	0	0	0	0	0.2	0	0	0	0	3.1	0.2
Office chair	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polyurethane/ Extended polyurethane foam	0	0	0	2.3	8.4	0	0	0	0	0	0	1.6	0	0	0	0.4	0	0	3.1	3.9	0	0	0.9
Roofing sheet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Automobile waste/safety kits/car seat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other/Composite waste	5.4	12.5	0	25.3	3	16.4	15.5	8.1	10.3	20.3	7.8	8.8	13.5	20.6	11.3	14.4	10.9	17.5	13.1	10	19.6	0	12.0
	13.7	29.6	0	28.4	29.2	24.9	24.7	9.3	28.1	23.6	22.6	23.5	23.5	20.6	16.1	21.4	21.7	22.7	19.8	20.7	19.6	3.1	20.3
TOTAL	100	100	100	100	100	10 0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

A5 Output of the Seasonal Variation of MSW using Anova

Table 1: Anova: Single Factor for the RCR compacted wastes

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	52	100.4	1.9307692	5.6076621
Column 2	52	100.1	1.925	8.9477941

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.0008654	1	0.0008654	0.0001189	0.9913209	3.9342534
Within Groups	742.32827	102	7.2777281			
Total	742.32913	103				

Table 2: Anova: Single Factor for Dailies non-compacted wastes

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	52	100	1.923076923	4.822202112
Column 2	52	100	1.923076923	8.043770739

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.41061E-13	1	3.41061E-13	5.30174E-14	0.9999998	3.934253
Within Groups	656.1646154	102	6.432986425			
Total	656.1646154	103				

A6 Waste composition data (wt. %) from Marie Louise landfill site during the summer in 2015

Waste Components	Dailies (wt. %)	RCR (wt. %)
Organic		
Food Waste	7.3	10.8
Fresh Fruits and Vegetables	0.8	3.0
Yard Waste	4.6	8.9
Composite Organic Waste	0.7	5.5
	13.4	28.2
Paper & Paperboard		
Newspaper	5.9	4.2
Cardboard/Boxboard	1.5	0.6
Magazines/Catalogues	1.4	1.2
Officepaper	2.5	1.8
Books	1.1	0.7
Corrugated Paper	4.5	4.7
Other/ Miscellaneous Paper	2.3	2.3
	19.2	15.5
Glass		
Clear Glass	5.5	3.5
Green Glass	4.7	1.7
Amber Glass	2.8	1.0
Composite Glass	1.4	2.2
	14.4	8.4
Metals		
Aluminum containers	2.8	1.6
Scrap metals	0.8	1.4
Other ferrous metal	0.0	0.0
Other non-ferrous metal	0.2	0.3
Tin/steel containers	3.4	1.6
	7.2	4.9
Plastics		
Clear PET Bottles	5.0	3.8
Green PET Bottles	4.0	1.7
Amber PET Bottles	2.0	0.8
HDPE containers	5.3	4.3
Film plastics	0.0	0.0
Mixed plastic bags	7.9	3.7
Other plastics	3.6	3.3
	27.8	17.6
Textiles		
Textiles	0.8	5.3
Shoes/Bags	0.5	0.6
Weavons	2.0	0.1
	3.3	6.0
C & D Materials		
Lumber	0.0	0.0
Concrete	0.5	0.0
Composite C & D	0.0	0.3
	0.5	0.3
Special Care Wastes		
Hazardous Materials	0.0	0.0
Composite S.C wastes	0.0	0.0
Paint	0.0	0.0
Paint container	0.0	0.2
Oil Filters	0.0	0.0
Biomedical	0.0	0.0
Batteries	0.0	0.0
	0.0	0.2
Other Wastes		
Furniture/Bulky waste	0.0	0.2
Other Composite Wastes	4.6	5.8
Rubber	0.4	0.4
Carpet/rug	0.0	0.7
Diapers/sanitary products	5.3	5.2
Wood/ply wood	0.5	0.5
Car seat/Automobile waste/safety kits	0.0	2.1
Office chair	0.0	0.0
Polyurethane/ Extended polyurethane f	1.0	0.3
Tyre	0.0	0.8
Ceramics	0.4	0.2
WEEE	2.0	3.1
	14.2	19.3
Total	**100**	**100**

A7 Waste composition data (wt. %) from Marie Louise landfill site during the winter in 2016

Waste Components	Dailies (wt.%)	RCR (wt.%)
Organic		
Food waste	4.9	13.8
Garden waste	4.9	9.2
Fruit and Vegetable wastes	2.3	2.5
Composite Organic waste	2.2	3.7
	14.3	29.2
Paper & Paperboard		
Newspaper	4.7	3.8
Cardboard/boxboard	1.3	1.4
Magazines/catalogues	0	1.1
Books	0	0.4
Corrugated box/cartons	6.7	2.2
Officepaper	3.1	1.7
Other/ miscellaneous paper	2.9	1.4
	18.7	12.0
Glass		
Clear containers	1.6	1.7
Green containers	0.5	0.6
Amber containers	0.2	0.5
Remainder/composite glass	2.1	1.4
	4.4	4.2
Metals		
Tin/steel containers	3.6	1.1
Aluminum containers	1.6	1.9
Scrap metals	3.5	1.6
Other ferrous metal	0	0
Other non-ferrous metal	1.0	0.4
	9.7	5.0
Plastics		
Clear PET Bottles/containers	2.8	2.5
Green PET Bottles/containers	1.2	1.7
Amber PET Bottles/containers	1.2	1.4
HDPE containers	7.1	4.4
Film plastics	0.3	0.4
Mixed plastic bags	5.7	5.7
Other plastics/Polypropylene	7.8	3.0
	26.1	19.1
Textiles/Leather/Fabrics		
Textile	1.6	7.8
Shoes/Bags	0.3	1.8
Weavons	4.7	0.7
	6.6	10.3
C & D Material		
Concrete	0	0
Lumber	0	0
Remainder/composite C & D	0	0
	0	0
Special Care Wastes		
Paint	0	0
Paint container	0	0
Biomedical	0	0
Batteries	0	0
Oil Filters	0	0
Remainder/composite S.C. waste	0	0
	0	0
Other Wastes		
Waste Electrical Products (WEEE)	0.4	0.2
Tyre	0	0
Furniture/Bulky waste	0	0
Ceramics	0.1	0
Rubber	1.5	0.2
Carpet/rug	0.5	1.3
Diapers/sanitary products	0.5	5.5
Wood/ply wood	0.2	0.2
Office chair	0	0
Polyurethane/ Extended polyurethane foam	1.5	0.9
Roofing sheet	0	0
Automobile waste/safety kits/car seat	0	0
Other/Composite waste	15.4	12
	20.1	20.3
Total	**100**	**100**

A8 Output of the Seasonal Variation of MSW using STATA 12 software

Dailies

A. TTEST

Two-sample t test with equal variances

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
winter	8	12.5	3.047247	8.618916	5.294406	19.70559
summer	8	12.375	3.104936	8.782084	5.032994	19.71701
combined	16	12.4375	2.101525	8.406099	7.958206	16.91679
diff		.125	4.350441		-9.205769	9.455769

```
    diff = mean(winter) - mean(summer)                          t =   0.0287
Ho: diff = 0                                     degrees of freedom =       14

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.5113         Pr(|T| > |t|) = 0.9775          Pr(T > t) = 0.4887
```

RCR

B. TTEST

Two-sample t test with equal variances

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
winter	7	14.14286	3.404679	9.007933	5.811909	22.47381
summer	7	14.28571	3.167651	8.380817	6.534751	22.03668
combined	14	14.21429	2.234049	8.359045	9.387917	19.04065
diff		-.1428571	4.65036		-10.27512	9.989407

```
    diff = mean(winter) - mean(summer)                          t =  -0.0307
Ho: diff = 0                                     degrees of freedom =       12

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.4880         Pr(|T| > |t|) = 0.9760          Pr(T > t) = 0.5120
```

APPENDIX B

Questionnaire Design On Zero Waste Project

2015/10/07

Dear Sir/Madam

I, a Postgraduate Student of the University of Johannesburg is undertaking a research project on "Zero Waste Project". To this end I kindly request that you complete the following short questionnaire to know the issues that are associated with waste collection service offer to you by PIKITUP and to also seek your opinion on what you think you can achieve around waste. Your response is of the utmost importance to me. The questionnaire will only take about 40 minutes and all answers will be treated confidentially.

Please do not enter your name or contact details on the questionnaire. It remains anonymous.

Kindly return the completed questionnaire as soon as you have completed it.

Should you have any queries or comments regarding this survey, you are welcome to contact us at PIKITUP Zondi Depot; Chemical Engineering and Civil Engineering, University of Johannesburg Doornfontein campus.

Yours sincerely

Olusola Ayeleru

Postgraduate Research Student
Department of Chemical Engineering
University of Johannesburg

HOUSEHOLD IDENTIFICATION

Type of housing: ___________________

(a) Apartment in multi-story apartment building (5 or more floors) (b) Apartment in low-rise apartment building (1 to 4 floor)

(c) Private single family house

(d) Other (please specify) (e.g. Informal, RDP, Bond) _______________

Respondent code: ____________________

(a) Husband

(b) Wife

(c) Other (specify) _________________

Gender of Respondent: ________________

(a) Male

(b) Female

GENERAL HOUSEHOLD INFORMATION

1. Who owns this house/apartment? _____________ (a) household member(s) (b) government (c) private owner

2. How many people live in your household? ___________________________

   (a) 1 (b) 2 (c) 3 (d) 4 (e) if other, please specify ____________________

3. How many retired adults live in this household? __________ (a) 1 (b) 2 (c) 3 (d) other ______________________

4. Among the retired adults in your household, how many received pension? ______________________

5. How many of the adults are employed (employed with regular income and seasonal income)?

Regular income	
Seasonal income	

6. How much does your household spend per month on? R ________________________

(a) food (b) transport (c) rent (d) utilities (e.g., heating, electricity, water, waste collection, telephone) (e) education (f) health and services (g) clothing and shoes (h) other expenses

7. What is your highest qualification? ________________ (a) I have never been to school (b) primary school (b) secondary school (c) high school (d) university (e) If other, please specify ______________________________

MAJOR CONCERNS

8. What would you say is the most important environmental problem in your community? ______________________

(a) air pollution (b) unsafe drinking water (c) insufficient water supply (d) poor waste collection service (e) traffic and congestion (f) if other, please specify ________________________

HOUSEHOLD WASTE COLLECTION SERVICE

9. Does your household have a waste bin for storing household waste? ______________________

(a) yes, we have plastic bin inside house or apartment (b) yes, we have plastic bin at the entrance

(c) yes, we have plastic bin outside (d) no refuse bin (e) if other, please specify ___________

10. If yes, how is the condition of the bin? _______________ (a) good (b) damaged

11. If yes, for how long has your household been offered the bin? ___________ (a) a year (b) two years (c) If other, please specify __________________

12. If no, why is the household without a bin? (a) they didn't give us (b) it got damaged (c) it was stolen (d) If other, please specify __________________

13. Does the household normally take out bin and additional plastic bags on refuse collection day? (a) only bin (b) bin and plastic bags (c) plastic bags only (d) if other, please specify ____________

14. On which day of the week does PIKITUP collect waste in your area? ___________________

(a) Monday (b) Tuesday (c) Wednesday (d) Thursday (e) Friday (f) Saturday

(g) they don't come to my area

15. Are there dumping sites in your area? If yes indicate the state ___________ (a) minor (b) severe (c) none

16. What type of waste does your household reuse (you can indicate more than one)?

(a) glass ____________
(b) plastic __________
(c) paper _______________
(d) cardboard ____________
(e) compostable ___________
(f) metal cans __________
(g) other ___________

17. What type of waste does waste pickers pick up for recycling (you can indicate more than one)?

(a) glass ____________

(b) plastic ___________

(c) paper ___________

(d) cardboard ____________

(e) compostable ___________

(f) metal cans ____________

(g) other ____________

18. Which of the following types of waste does your household sell (you can indicate more than one)?

(a) glass __________

(b) plastic _________

(c) paper ___________

(d) cardboard __________

(e) compostable ___________

(f) metal cans ___________

(g) If other, please specify _____________

19. How much income per month on average do you get from selling these wastes? R ______

20. How would you rate your satisfaction with PIKITUP? ________ (a) very satisfied (b) satisfied (c) not satisfied

21. If you are not satisfied, what bothers you most about PIKITUP? ___________

(a) infrequent collection (b) unreliable collection (c) location of container

(d) number of plastic bags provided (e) if other (specify) ____________

22. Do you know where the collected waste is taken for final disposal? _______ (a) yes (b) no

23. Do you know who to contact if you have any problem with your waste collection service? ___________________
(a) yes (b) no

24. If yes, who would you call? __________________________

25. If you have ever called this office, were you satisfied with their response? _____________________
(a) yes (b) no

26. If no, what problems did you experience? ______________________

27. Is sufficient information made available to you about your waste management system (for example, information about collection times, payment of cleansing tax, risks associated with improper waste handling? __________________________ (a) yes (b) no

28. If no, what type of information do you want to have? __________ (a) waste collection schedule (b) where to complain if there are problems (c) proper handling of different kinds of waste (d) if other, please specify

WILLINGNESS TO PAY

29. Do you know that you are supposed to pay for your waste service? __________ (a) yes (b) no

30. If yes, how much money are you supposed to pay for waste collection service monthly? R _________

31. Do you regularly pay your waste charge? _________________ (a) yes (b) no

32. If no, what is the reason why you are not paying your waste collection charge regularly?

_______________ (a) dissatisfied with the service (b) there is no enforcement for non-payment

(c) I can't afford to pay (d) if other, please specify _____________

33. If yes, would you be willing to pay double this amount for an improved service by PIKITUP? ____________ (a) yes (b) no

"Now I would like to present to you the identified waste management service which might be implemented in your neighbourhood. PIKITUP is aware of this Zero Waste alternative and support the idea because it helps societies to produce and consume goods while at the same time respect ecological limits and the rights of communities. In order to receive the service, you are also asked to pay a small fee."

34. Have you heard about Zero Waste? ______ (a) yes (b) no

35. Would you be willing to support this study? _____ (a) yes (b) no

36. In what ways do you think you can contribute to the success of Zero Waste (you can indicate more than one? _______________ (a) burning all waste items (b) sorting out items before disposal (c) recycling waste (d) reusing discarded items e.g. bottle (e) reducing wastage

37. Are you currently separating recyclable wastes? ________ (a) yes (b) no

38. If yes, would you be willing to continue to separate recyclable wastes? ________ (a) yes (b) no

39. Are you currently separating food wastes? ________ (a) yes (b) no

40. If yes, would be willing to continue to separate food wastes? ________ (a) yes (b) no

41. If yes, how would you achieve that? _____________________ (a) by using separate plastic bags

(b) by home composting (c) if other, please specify ___________________

42. Do you think this Zero Waste project can succeed? ____________ (a) yes (b) no

43. If yes, in what ways do you think (you can indicate more than one)? ________________ (a) when we cooperate with PIKITUP (b) when we have separate plastic bags for all our wastes (c)If other, please specify ______________________

44. What benefits do you think can be derived from Zero Waste? _______________________

(a) it saves costs (b) provides jobs for others since the discarded goods need to be collected for recycling (c) makes all discarded materials to become raw materials for others to use (d) all the above

(e) if other, please specify __________________

45. How can Zero Waste be used in your community?

____

____

____

____

____

"I will soon be ending this interview. Before I do, however, I would like to ask you some questions about you and your family (ask the questions)."

46. Does your household have a business here in the house? _________________ (a) yes (b) no

47. If yes, what type of business is it? _______________

(a) grocery shop (b) sweet shop (c) butchery (d) hairdresser (e) selling cooked food (f) bakery

(g) video shop

48. What is the average income of your household monthly? R ______________ (a) R 2000 (b) 5000

(c) 10000 (d) if other, please specify _____________

End

"Thank you very much for your contribution to this survey. Do you have any questions or comments? (record the question(s) and/or comment (s)).

Thank you very much for your co-operation. We hope to use these results to determine how best to provide affordable and desirable services to the people of your neighbourhood. Good bye.

APPENDIX C

Questionnaire Design and Analysis of data

C (i) Groups

	Frequency	Percent
Naledi Ext Informal settlement	41	34.7
Dobsonville Bond	21	17.8
Dobsonville RDP	23	19.5
Naledi Ext RDP	33	28.0
Total	118	100.0

C (ii) Types of Housing

		Frequency	Percent
	Private single family house	1	.8
	Other (please specify) (e.g. Informal, RDP, Bond)	112	94.9
	Total	113	95.8
	No response	5	4.2
Total		118	100.0

C (iii) Other Types of Housing

	Frequency	Percent
	2	1.7
RDP Bond	21	18.1
Informal settlement	40	34.5
RDB Dobsonville	24	20.7
RDP Naledi Ext	31	26.7
Total	118	100.0

C (iv) Respondent Code

		Frequency	Percent
	Husband	46	39.0
	Wife	39	33.1
	Other	32	27.1
	Total	117	99.2
	No response	1	.8
Total		118	100.0

C (v) Other Respondent Code

	Frequency	Percent
	87	73.7
Brother-in-law	2	6.5
Daughter	7	22.6
Grandpa	2	6.5
Grannie	7	22.6
Sister in law	1	3.2
Son	8	25.8
Tenant	3	9.7
Uncle	1	3.2
Total	118	100.0

C (vi) Gender of Respondent

	Frequency	Percent
Male	60	50.8
Female	58	49.2
Total	118	100.0

C1 Who owns this house/apartment?

	Frequency	Percent
Household member(s)	103	87.3
Government	4	3.4
Private owner	11	9.3
Total	118	100.0

C2 How many people live in your household?

		Frequency	Percent
	1	3	2.5
	2	31	26.3
	3	26	22.0
	4	24	20.3
	Other	26	22.0
	Total	110	93.2
	No response	8	6.8
Total		118	100.0

C2 (b) If other, please specify.

		Frequency	Percent
	5	11	9.3
	6	7	5.9
	7	4	3.4
	8	5	4.2
	9	1	.8
	12	1	.8
	Total	29	24.6
	No response	89	75.4
Total		118	100.0

C3 How many retired adults live in this household?

		Frequency	Percent
	1	23	19.5
	2	6	5.1
	3	2	1.7
	Other	39	33.1
	Total	70	59.3
	No response	48	40.7
Total		118	100.0

C4 Among the retired adults in your household, how many received pension?

		Frequency	Percent
	0	24	20.3
	1	23	19.5
	2	2	1.7
	Total	49	41.5
	No response	69	58.5
		118	100.0

C5 How many of the adults are employed (employed with regular income and seasonal income)?

(a) Regular income

		Frequency	Percent
	0	10	8.5
	1	49	41.5
	2	22	18.6
	3	3	2.5
	4	1	.8
		85	72.0
	No response	33	28.0
Total		118	100.0

(b) Seasonal Income

		Frequency	Percent
	0	18	15.3
	1	38	32.2
	2	25	21.2
	3	3	2.5
	4	1	.8
	Total	85	72.0
		33	28.0
Total		118	100.0

C6 How much does your household spend per month? R

		Frequency	Percent
	500	1	.8
	700	1	.8
	900	3	2.5
	950	1	.8
	1000	6	5.1
	1100	4	3.4
	1200	4	3.4
	1300	3	2.5
	1400	3	2.5
	1500	27	22.9
	1600	2	1.7
	1700	1	.8
	1800	8	6.8
	1900	1	.8
	2000	6	5.1
	2500	5	4.2
	2800	2	1.7
	3000	9	7.6
	3500	6	5.1
	3800	1	.8
	4000	2	1.7
	4200	1	.8
	4500	4	3.4
	5000	3	2.5
	5500	2	1.7
	6000	2	1.7
	7000	1	.8
	7500	1	.8
	7600	1	.8
	8000	1	.8
	8500	1	.8
	9000	1	.8
	10000	1	.8
	Total	115	97.5
	No response	3	2.5
Total		118	100.0

C7 What is your highest qualification?

		Frequency	Percent
	I have never been to school	6	5.1
	Primary school	35	29.7
	Secondary school	55	46.6
	High school	15	12.7
	University	6	5.1
	Total	117	99.2
	No response	1	.8
Total		118	100.0

C7 (b) If other, please specify.

		Frequency	Percent
		111	94.1
	Certificate	3	42.9
	Grade 11	1	14.3
	Grade 12	1	14.3
	Grade 9	2	28.6
	Total	118	100.0

C8 What would you say is the most important environmental problem in your community?

		Frequency	Percent
	Air pollution	43	36.4
	Unsafe drinking water	3	2.5
	Insufficient water supply	17	14.4
	Poor waste collection service	31	26.3
	Traffic and congestion	2	1.7
	Other	14	11.9
	Total	110	93.2
		8	6.8
Total		118	100.0

C9 Does your household have a waste bin for storing household waste?

		Frequency	Percent
	Yes, we have plastic bin inside house or apartment	29	24.6
	Yes, we have plastic bin at the entrance	12	10.2
	Yes, we have plastic bin outside	7	5.9
	No refuse bin	44	37.3
	Other	21	17.8
	Total	113	95.8
	No response	5	4.2
Total		118	100.0

C10 If yes, how is the condition of the bin?

		Frequency	Percent
	Good	50	42.4
	Damaged	7	5.9
	Total	57	48.3
	No response	61	51.7
Total		118	100.0

C11 If yes, how long has your household been offered the bin?

		Frequency	Percent
	A year	2	1.7
	two years	15	12.7
	Other	57	48.3
	Total	74	62.7
	No response	44	37.3
Total		118	100.0

C11 (b) If other (specify)

		Frequency	Percent
		82	69.5
	10 years	2	5.6
	3 years	3	8.3
	4 vears	1	2.8
	5 vears	9	25.0
	6 years	2	5.6
	7 years	4	11.1
	8 years	2	5.6
	More than four years	1	2.8
	More than five years	10	27.8
	Over six years	1	2.8
	We bought it ourselves	1	2.8
	Total	118	100.0

C12 If no, why is the household without a waste bin?

		Frequency	Percent
	They didn't give us	45	38.1
	It got damaged	5	4.2
	It was stolen	8	6.8
	Other	25	21.2
	Total	83	70.3
	No response	35	29.7
Total		118	100.0

C12 (b) If other (specify)

		Frequency	Percent
		113	95.8
	Informal Settlement	4	80.0
	It get damaged	1	20.0
	Total	118	100.0

C13 Does the household normally take out the bin and additional plastic bags on refuse collection day?

		Frequency	Percent
	Only bin	23	19.5
	Bin and plastic bags	23	19.5
	Other	60	50.8
	Total	106	89.8
	No response	12	10.2
Total		118	100.0

C13 (b) If other (specify)

		Frequency	Percent
		73	61.9
	Only bin	2	4.4
	Plastic bags only	43	95.6
	Total	118	100.0

C14 On which day of the week does PIKITUP collect waste in your area?

		Frequency	Percent
	Monday	74	62.7
	Thursday	41	34.7
	Total	115	97.5
	No response	3	2.5
Total		118	100.0

C15 Are there dumping sites in your area? If yes indicate the state

		Frequency	Percent
	Minor	77	65.3
	Severe	10	8.5
	Total	87	73.7
	No response	31	26.3
Total		118	100.0

C16 What type of waste does your household reuse?

		Unmarked	Marked	Total
glass	Count	60	58	118
	Row N %	50.8%	49.2%	100.0%
plastic	Count	32	86	118
	Row N %	27.1%	72.9%	100.0%
paper	Count	92	26	118
	Row N %	78.0%	22.0%	100.0%
cardboard	Count	97	21	118
	Row N %	82.2%	17.8%	100.0%
compostable	Count	102	16	118
	Row N %	86.4%	13.6%	100.0%
metal cans	Count	84	34	118
	Row N %	71.2%	28.8%	100.0%
other	Count	101	17	118
	Row N %	85.6%	14.4%	100.0%

C17 What type of waste does waste pickers pick up for recycling?

		Unmarked	marked	Total
glass	Count	41	77	118
	Row N %	34.7%	65.3%	100.0%
plastic	Count	36	82	118
	Row N %	30.5%	69.5%	100.0%
paper	Count	72	46	118
	Row N %	61.0%	39.0%	100.0%
cardboard	Count	92	26	118
	Row N %	78.0%	22.0%	100.0%
compostable	Count	97	21	118
	Row N %	82.2%	17.8%	100.0%
metal cans	Count	55	63	118
	Row N %	46.6%	53.4%	100.0%
other	Count	102	16	118
	Row N %	86.4%	13.6%	100.0%

C18 Which of the following types of waste does your household sell?

		Unmarked	marked
glass	Count	116	2
	Row N %	98.3%	1.7%
plastic	Count	113	5
	Row N %	95.8%	4.2%
paper	Count	115	3
	Row N %	97.5%	2.5%
cardboard	Count	117	1
	Row N %	99.2%	.8%
compostable	Count	117	1
	Row N %	99.2%	.8%
metal cans	Count	114	4
	Row N %	96.6%	3.4%
other	Count	91	27
	Row N %	77.1%	22.9%

C19 How much income per month on average do you get from selling these wastes? R

		Frequency	Percent
	0	30	25.4
	30	1	.8
	50	2	1.7
	60	1	.8
	90	1	.8
	Total	35	29.7
	No response	83	70.3
Total		118	100.0

C20 How would you rate your satisfaction with PIKITUP?

		Frequency	Percent
	Very satisfied	18	15.3
	Satisfied	37	31.4
	Not satisfied	60	50.8
	Total	115	97.5
	No response	3	2.5
Total		118	100.0

C21 If you are not satisfied, what bothers you most about PIKITUP?

		Frequency	Percent
	1	9	7.6
	2	32	27.1
	3	3	2.5
	4	8	6.8
	5	34	28.8
	Total	86	72.9
	No response	32	27.1
Total		118	100.0

C22 Do you know where the collected waste is taken for final disposal?

		Frequency	Percent
	Yes	31	26.3
	No	84	71.2
	Total	115	97.5
	No response	3	2.5
Total		118	100.0

C23 Do you know who to contact if you have any problem with your waste collection service?

		Frequency	Percent
	Yes	22	18.6
	No	91	77.1
	Total	113	95.8
	No response	5	4.2
Total		118	100.0

C24 If yes, who would you call?

		Frequency	Percent
		96	81.4
	Pikitup	21	95.5
	Will speak to the truck driver	1	4.5
	Total	118	100.0

C25 If you have ever called this office, were you satisfied with their response?

		Frequency	Percent
	Yes	15	12.7
	No	7	5.9
	Total	22	18.6
	No response	96	81.4
Total		118	100.0

C26 If no, what problems did you experience?

	Frequency	Percent
	54	45.8
Air pollution from landfill	11	17.2
Informal settlement	1	1.6
Illegal dumping around us	2	3.1
Insufficient collection	1	1.6
Late coming for collection	4	6.3
Lot of rubbles and unrealiable collection	3	4.7
No collection of our waste	8	12.5
No refuse bin and plastic bags	1	1.6
No refuse bin was provided	10	15.6
No service coverage	4	6.3
Poor service coverage	2	3.1
The don't attend to their calls	15	23.4
Time of collection	2	3.2
Total	118	100.0

C27 Is sufficient information made available to you about your waste management system (for example, information about collection times, payment of cleansing tax, risks associated with improper waste handling?

		Frequency	Percent
	Yes	11	9.3
	No	105	89.0
	Total	116	98.3
	No response	2	1.7
Total		118	100.0

C28 If no, what type of information do you want to have?

		Frequency	Percent
	waste collection schedule	27	22.9
	where to complain if there are problems	65	55.1
	proper handling of different kinds of waste	14	11.9
	Other	7	5.9
	Total	113	95.8
	No response	5	4.2
Total		118	100.0

C29 Do you know that you are supposed to pay for your waste service?

		Frequency	Percent
	Yes	48	40.7
	No	70	59.3
	Total	118	100.0

C30 If yes, how much money are you supposed to pay for waste collection service monthly? R

		Frequency	Percent
	0	24	20.3
	10	1	.8
	26	17	14.4
	30	2	1.7
	40	1	.8
	48	1	.8
	50	7	5.9
	60	2	1.7
	70	4	3.4
	75	1	.8
	100	5	4.2
	120	4	3.4
	250	1	.8
	300	1	.8
	Total	71	60.2
	No response	47	39.8
Total		118	100.0

C31 Do you regularly pay your waste charge?

		Frequency	Percent
	Yes	23	19.5
	No	94	79.7
	Total	117	99.2
	No response	1	.8
Total		118	100.0

C32 If no, what is the reason why you are not paying your waste collection charge regularly?

		Frequency	Percent
	dissatisfied with the service	7	5.9
	there is no enforcement for non-payment	44	37.3
	I can't afford to pay	2	1.7
	Other	27	22.9
	Total	80	67.8
	No response	38	32.2
Total		118	100.0

C32 (b) If other, please specify

		Frequency	Percent
		93	78.8
	Bill does not come	11	44.0
	It is paid together with rent	1	4.0
	No information on that	1	4.0
	No service is being offered to me	1	4.0
	Nobody ask us to pay	1	4.0
	They are not offering any service to me	1	4.0
	We are paying tax	7	28.0
	We do not know that we have to pay	2	8.0
	Total	118	100.0

C33 If yes, would you be willing to pay double this amount for an improved service by PIKITUP?

		Frequency	Percent
	Yes	5	4.2
	No	21	17.8
	Total	26	22.0
	No response	92	78.0
Total		118	100.0

C34 Have you heard about Zero Waste?

		Frequency	Percent
	Yes	13	11.0
	No	105	89.0
	Total	118	100.0

C35 Would you be willing to support this study?

		Frequency	Percent
	Yes	112	94.9
	No	5	4.2
	Total	117	99.2
	No response	1	.8
Total		118	100.0

C36 In what ways do you think you can contribute to the success of Zero Waste (you can indicate more than one?

		Frequency	Percent
	Sorting out items before disposal	69	58.5
	Recycling waste	30	25.4
	Reusing discarded items e.g bottle	9	7.6
	Burying wastage	1	.8
	Total	109	92.4
	No response	9	7.6
Total		118	100.0

C37 Are you currently separating recyclable wastes?

		Frequency	Percent
	Yes	26	22.0
	No	92	78.0
	Total	118	100.0

C38 If yes, would you be willing to continue to separate recyclable wastes?

		Frequency	Percent
	Yes	28	23.7
	No	3	2.5
	Total	31	26.3
	No response	87	73.7
Total		118	100.0

C39 Are you currently separating food wastes?

		Frequency	Percent
	Yes	13	11.0
	No	103	87.3
	Total	116	98.3
	No response	2	1.7
Total		118	100.0

C40 If yes, would be willing to continue to separate food wastes?

		Frequency	Percent
	Yes	11	9.3
	No response	107	90.7
Total		118	100.0

C41 If yes, how would you achieve that?

		Frequency	Percent
	by using separate plastic bags	13	11.0
	by home composting	26	22.0
	Total	39	33.1
	No response	79	66.9
Total		118	100.0

C42 Do you think this Zero Waste project can succeed?

		Frequency	Percent
	Yes	110	93.2
	No	5	4.2
	Total	115	97.5
	No response	3	2.5
Total		118	100.0

C43 If yes, in what ways do you think it can succeed?

		Unmarked	marked	Total
When we cooperate with PIKITUP	Count	50	64	114
	Row N %	43.9%	56.1%	100.0%
When we have separate plastic bags for all our wastes	Count	35	79	114
	Row N %	30.7%	69.3%	100.0%
Other	Count	94	20	114
	Row N %	82.5%	17.5%	100.0%

C43 (b) If other, please specify.

		Frequency	Percent
		100	84.7
	Awareness	11	61.1
	Education	3	16.7
	I am not interested	1	5.6
	If the government can carry us along	1	5.6
	If the government can educate us	1	5.6
	When we reduce waste	1	5.6
	Total	118	100.0

C44 What benefits do you think can be derived from Zero Waste?

	Unmarked	Marked	Total
It reduces cost	65.8%	34.2%	100.0%
Provides jobs for others since the discarded goods need to be collected for recycling	29.1%	70.9%	100.0%
Makes all discarded materials to become raw materials for companies to use	65.0%	35.0%	100.0%
Other	94.0%	6.0%	100.0%

C44 (b) If other, please specify

	Frequency	Percent
	113	95.8
I am not sure	1	20.0
I don't know	1	20.0
I don't think it can work	1	20.0
May give us clean environment	1	20.0
No benefit	1	20.0
Total	118	100.0

C45 How can Zero Waste be implemented in your community?

	Frequency	Percent
	86	72.9
Create job oppotunities for the unemployed South Africans	4	3.4
Campaign must precede	1	.8
Makes raw material available	2	1.7
A platform to educate the community	1	.8
A platform to label waste bins according to different waste streams	1	.8
To provide different separate plastic bags for different kinds of waste	1	.8
To initiate separation at source	4	3.4
To set up recycling facilities in the community	2	1.6
To provide electricity when organics are separated at source	1	.8
To prevent illegal dumping	1	.8
To save costs	1	.8
To stop wastages	13	11.0
Total	118	100.0

C46 Does your household have a business here in the house?

	Frequency	Percent
Yes	18	15.3
No	100	84.7
Total	118	100.0

C47 If yes, what type of business is it?

		Frequency	Percent
	Grocery shop	8	6.8
	Sweet shop	4	3.4
	Hairdresser	2	1.7
	Selling cooked food	4	3.4
	Total	18	15.3
	No response	100	84.7
Total		118	100.0

C48 What is the average income of your household monthly? R

		Frequency	Percent
	2000	24	20.3
	5000	11	9.3
	10000	5	4.2
	Other	70	59.3
	Total	110	93.2
	No response	8	6.8
Total		118	100.0

C48 (b) If other, please specify.

		Frequency	Percent
	1200	1	.8
	1400	6	5.1
	1500	6	5.1
	1800	3	2.5
	1900	1	.8
	2000	1	.8
	2100	1	.8
	2200	1	.8
	2400	1	.8
	2500	6	5.1
	3000	4	3.4
	3500	6	5.1
	3800	2	1.7
	4000	3	2.5
	4500	2	1.7
	4600	1	.8
	6500	1	.8
	7500	1	.8
	8000	1	.8
	8500	1	.8
	9000	1	.8
	9500	1	.8
	10000	2	1.7
	12000	5	4.2
	13500	1	.8
	15000	7	5.9
	16000	2	1.7
	18000	2	1.7
	19000	1	.8
	20000	4	3.4
	25000	3	2.5
	Total	78	66.1
	No response	40	33.9
Total		118	100.0

APPENDIX D

Economic Evaluation and Costs Parameters of the MSW Recycling Facilities

D1 Purchased Equipment Costs and the Processes the Equipment will be used for

Processes	Equipment required	Cost (Rand)	Processes the equipment will be used for
Glass waste recycling	2 Glass Crushers	200000	For pulverization of glass
	Front-end loader	400000	For loading of crushed glasses
Paper Waste Recycling	Baling machine and Conveyor	800000	Baler will used to compress papers into bales
	Front-end loader	700000	The conveyor will be used to move the papers Front-end loaders for loading baled papers
Plastic Wastes Recycling	3 Shredders	690000	Used for shredding plastics into flakes
	Front-end loader	400000	For loading of shredded plastics
PET Bottles Recycling	2 Baling Machines	660000	To compress PET bottles into bales
Metal Waste Recycling	Shredder	230000	Used for shredding metals
	Front-end loader	400000	For loading shredded metals
Aluminium Cans Recycling	Big Density Baler	350000	To compress aluminum cans into bales
Organic Waste Recycling	2 Shredders	700000	To shred organic wastes into fractions
	4 Front-end loaders	2800000	To load the shredded organic wastes
	50 bins	75000	Used to convey organic wastes for shredding
	Weigh bridge	700000	Used to weigh entire waste collection vehicles and their contents
	20 Weighing Scales (PT 310S with Capacity of 3000 kg)	380000	Used to measure weight of an item
	Anciliary Equipment	200000	Spare parts or accessory to equipment
Total Purchased Equipment Cost		**9685000**	

D2 Project Assumptions

Assumption at a Glance		
S/No.	**Items**	**Amount**
1	Total Capital Investment	29618618.58
2	Debt	70%
3	Equity	30%
4	Rate of Interest	12%
5	Depreciation (Building)	SLM 10 years
6	Depreciation (Machinery)	SLM 10 years
7	Tax	30%
8	Construction Cost (Building)	1937000
9	Repayment Period of Debt	7 years
10	Moratorium Period	1 year
11	Installed Capacity (tonnes)	457.92
12	Capacity Utilization	95%
13	Working Capital Cycle	1 month

D3 Means of Finance

Debt	20733033.01	70%
Equity	8885585.57	30%
Total Capital Investment	**29618618.58**	100%

D4 Cost of Power Consumption

Miniflex Tariff from Eskom for Businesses

Services	Daily Charge (Rand)	Monthly Charge (Rand)	Annual Charge (Rand)
Service charge (R/account/day)	187.01	5797.31	
Administration charge (c/kWh)	84.29	2612.99	
Ancillary charge (c/kWh peak and standard)	0.33	10.23	
Network demand (R/kVA/month) for 132kV or Transmission connected	15.2	471.2	**116365.32**
Urban low voltage charge	13.14	407.34	
Electrical and rural network subsidy charge	7.28	225.68	
Reactive energy charge	5.56	172.36	
Total Charges		**9697.11**	

D5 Water Consumption Cost in the City of Johannesburg (Approved Tariffs for 2015/16)

Assumption: Site consumes 20 kilo liter per month			
(Deemed consumption areas) Unit Price (Rand)	**Total Monthly Consumption (kl)**	**Total Monthly Charge (Rand)**	**Total Annual Charge (Rand)**
162.67	20	162.67	1952.04

D6 Depreciation

Operating Years	1	2	3	4	5	6	7	8	9	10
Machinery at 10%	0.970	0.970	0.970	0.970	0.970	0.970	0.970	0.970	0.970	0.970
Building at 5%	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097
Total	1.067	1.067	1.067	1.067	1.067	1.067	1.067	1.067	1.067	1.067

D7 Repayment and Interest Schedule for Loans

											TCI	Loan	Repayment
											29.620	20.734	2.962

Operating Years	1	2	3	4	5	6	7	8	9	10
Rate of Interest	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Loan (Outstanding)	20.734	17.772	14.810	11.848	8.886	5.924	2.962	0.000	0.000	0.000
Interest	2.49	2.13	1.78	1.42	1.07	0.71	0.36	0.00	0.00	0.00
Moratorium										
Repayment	2.962	2.962	2.962	2.962	2.962	2.962	2.962	0.000	0.000	0.000
Closing Balance	17.772	14.810	11.848	8.886	5.924	2.962	0.000	0.000	0.000	0.000

D8 Income Statement

Operating Years	1	2	3	4	5	6	7	8	9	10
Capacity										
Installed Capacity (tons)	458.09	458.09	458.09	458.09	458.09	458.09	458.09	458.09	458.09	458.09
Capacity Utilization	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
PRODUCTION (tons)	435.19	435.19	435.19	435.19	435.19	435.19	435.19	435.19	435.19	435.19
Sales Revenue	**113.75**	**113.75**	**113.75**	**113.75**	**113.75**	**113.75**	**113.75**	**113.75**	**113.75**	**113.75**

Cost of collection		33.04	33.04	33.04	33.04	33.04	33.04	33.04	33.04	33.04	33.04
Utilities											
Power		0.1164	0.1164	0.1164	0.1164	0.1164	0.1164	0.1164	0.1164	0.1164	0.1164
Water		0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195
Wage & Salaries		42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02	42.02
Sub Total		42.16	42.16	42.16	42.16	42.16	42.16	42.16	42.16	42.16	42.16
Factory Overhead		0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
General Overhead		0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Lease											
Land		0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Construction		1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
Electrical Installed		0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Service Facilities and Yard Improvement		3.87	3.87	3.87	3.87	3.87	3.87	3.87	3.87	3.87	3.87
Installation, Insulation and Painting		2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42
Engineering and Supervision		1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
Legal Expenses		0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Contingency		1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38
Estimated Cost of Production		89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93
EBITDA		23.82	23.82	23.82	23.82	23.82	23.82	23.82	23.82	23.82	23.82
Interest		2.49	2.13	1.78	1.42	1.07	0.71	0.36	0.00	0.00	0.00
Depreciation		1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07
PBT		20.26	20.62	20.97	21.33	21.68	22.04	22.39	22.75	22.75	22.75
Taxation		6.08	6.19	6.29	6.40	6.51	6.61	6.72	6.83	6.83	6.83
PAT		14.18	14.44	14.68	14.93	15.18	15.43	15.68	15.93	15.93	15.93

D9 Projected Funds Flow Statement

	Construction Period	Operating Period									
Years	1	1	2	3	4	5	6	7	8	9	10
SOURCES OF FUND											
Equity	8.88										
Debt	20.72										
PBDIT		23.82	23.82	23.82	23.82	23.82	23.82	23.82	23.82	23.82	23.82
TOTAL SOURCES A	29.60	23.82	23.82	23.82	23.82	23.82	23.82	23.82	23.82	23.82	23.82
APPLICATION OF FUNDS											
Fixed Assets Purchase	28.03										
Ancilliary Fixed Assets	0.39										
Increase in Current Assets	1.18										
Repayment of Loan Payment		2.962	2.962	2.962	2.962	2.962	2.962	2.962	0.000	0.000	0.000
Payment of Interest on Term Loan		2.49	2.13	1.78	1.42	1.07	0.71	0.36	0.00	0.00	0.00
Taxation		6.08	6.19	6.26	6.40	6.51	6.61	6.72	6.83	6.83	6.83
TOTAL APPLICATION B	29.60	11.53	11.28	11.00	10.78	10.54	10.28	10.04	6.83	6.83	6.83
SURPLUS/DEFICIT A-B	0.00	12.29	12.54	12.82	13.04	13.28	13.54	13.78	16.99	16.99	16.99
OPENING CASH & BANK BALANCES		0.00	12.29	24.83	37.65	50.69	63.97	77.51	91.29	108.28	125.27
CLOSING CASH & BANK BALANCES	0.00	12.29	24.83	37.65	50.69	63.97	77.51	91.29	108.28	125.27	142.26

D10 Discounted Cash Flow Statement (Total Investment)

	Discounted Cash Flow Statement (Total Investment)											
	Construction Period		**Operation Period**									
Years	t=0	t=1	1	2	3	4	5	6	7	8	9	10
Inflows												
Net Cash Accruals After Interest & Tax			15.25	15.51	15.75	16.00	16.25	16.50	16.75	17.00	17.00	17.00
Less: Change in Working Capital			0	0	0	0	0	0	0	0	0	0
Add Back Financial Expenses			2.49	2.13	1.78	1.42	1.07	0.71	0.36	0	0	0
Terminal Value												0.52
Total Inflow			17.74	17.64	17.53	17.42	17.32	17.21	17.11	17.00	17.00	17.52
Outflows												
Investment	28.42	1.18										
Bridge Loan	0	0										
Total outflow	28.42	1.18										
Net Cash flow	-28.42	-1.18	17.74	17.64	17.53	17.42	17.32	17.21	17.11	17.00	17.00	17.52
IRR on Investment (%)	41%											
NPV (12% Discount Rate)	R 135.95											
Pay Back Period	7 Years											
	Discounted Cash Flow Statement (Equity)											
Years	t=0	t=1	1	2	3	4	5	6	7	8	9	10
Inflows												
Net Cash Accruals After Interest & Tax			15.25	15.51	15.75	16.00	16.25	16.50	16.75	17.00	17.00	17.00
Less: Change in Working Capital			0	0	0	0	0	0	0	0	0	0
Less: Loan Repayment			2.962	2.962	2.962	2.962	2.962	2.962	2.962	0	0	0
Terminal Value												0.52
Total Inflow			12.29	12.54	12.79	13.04	13.29	13.54	13.78	17.00	17.00	17.52
Outflows												
Equity	8.52	0.36										
Total Outflow	8.52	0.36										
Net Cash Flow	-8.52	-0.36	12.29	12.54	12.79	13.04	13.29	13.54	13.78	17.00	17.00	17.52
IRR on Equity	80%											

D11 Projected Balance Sheet

S/No	Decscription	Construction Period	Operation Period									
		1	1	2	3	4	5	6	7	8	9	10
1.1	Equity	8.89	8.89	8.89	8.89	8.89	8.89	8.89	8.89	8.89	8.89	8.89
1.2	General Reserves		14.18	28.62	43.30	58.23	73.41	88.84	104.52	120.45	136.38	152.31
1.3	Debt	20.73	17.77	14.81	11.85	8.89	5.92	2.96	0.00	0.00	0.00	0.00
	Total Liabilities	**29.62**	**40.84**	**52.32**	**64.03**	**76.00**	**88.22**	**100.69**	**113.41**	**129.34**	**145.27**	**161.20**
	Assets											
2.1	Gross Fixed Assets	28.435	28.435	28.435	28.435	28.435	28.435	28.435	28.435	28.435	28.435	28.435
2.2	Accumulated Depreciation		1.07	2.14	3.21	4.28	5.35	6.42	7.49	8.56	9.63	10.70
2.3	Net Fixed Assets	28.435	27.37	26.30	25.23	24.16	23.09	22.02	20.95	19.88	18.81	17.74
2.4	Working Capital Assets	1.185	1.185	1.185	1.185	1.185	1.185	1.185	1.185	1.185	1.185	1.185
2.5	Cash & Bank Balances	0	12.29	24.84	37.62	50.66	63.95	77.49	91.28	108.28	125.28	142.28
	Total Assets	**29.62**	**40.84**	**52.32**	**64.03**	**76.00**	**88.22**	**100.69**	**113.41**	**129.34**	**145.27**	**161.20**

D12 Sensitivity Analysis and Breakeven Point

	Normal	Case 1	Case 2	Case 3	Case 4
Variable Cost (Rand)					
Waste Collection Cost (Cost of Raw Material	33.04	36.34	33.04	33.04	36.34
Utilities	0.14	0.15	0.14	0.14	0.15
Repairs and Maintenance	0.38	0.42	0.38	0.38	0.42
Miscellaneous	11.40	12.54	11.40	11.40	12.54
Total Variable Cost	44.96	49.45	44.96	44.96	49.45
Average Variable Cost (per piece)	0.15	0.17	0.15	0.15	0.17
Fixed Cost (Rand)					
Wages and Salaries	42.02	42.02	46.22	42.02	44.12
Lease	2.75	2.75	3.03	2.75	2.89
General Overheads	0.20	0.20	0.22	0.20	0.21
Financial Expenses	2.49	2.49	2.74	2.74	2.89
Depreciation	1.07	1.07	1.18	1.18	1.24
Total Fixed Cost (Rand)	48.53	48.53	53.39	48.89	51.35
Average Fixed Cost	0.16	0.16	0.18	0.16	0.17
Average Selling Price (unit)	0.38	0.38	0.38	0.38	0.36
Project Break Even Point (tons)	211.00	231.10	232.13	212.57	268.85
Project Break Even (%)	46%	50%	51%	46%	59%
Cash Break Even Point (Rand)	80.18	87.82	88.21	80.78	96.79

D13 Annual Turnover of Recycled Waste Items

Total Turnover (Per annum)	Quantity Produced/ day (tons)	Price Per ton (Rand)	Sales/ day	Sales/ Month	Sales/ Annum
Glass sands	47.44	400	18976	493376	5920512
Baled waste paper	93.09	600	55854	1452204	17426448
Organic wastes	39.90	300	11970	311220	3734640
Aluminium cans	10.53	4000	42120	1095120	13141440
Metal scraps	18.91	800	15128	393328	4719936
Baled PET bottles	58.40	2400	140160	3644160	43729920
Plastic (HDPE, PP)	47.41	2100	99561	2588586	31063032
Sub total	315.68		383769	9977994	119735928
Wastages (5%)	15.784		19188.45	4988997	5986796.4
Total	**299.90**		**364580.55**	**4988997**	**113749131.60**

D14 Equipment Types, Capacity Utilization and Number of Workers per Equipment

Recycling Equipment	Capacity Utilization	Ton of waste generated per day	Production (tons/day)	Equipment Capacity (tons/hr)	Number of workers per equipment	Total number of workers
Glass waste						
Crushers (2)	0.95	49.94	47.44	3	2	4
Front-end loader					1	1
Paper waste						
Bailing machine and conveyor	0.95	97.95	93.09	15	4	4
Plastic waste (HDPE, PP, Plastic bags)						
Shredder (3)	0.95	49.90	47.41	5	3	9
PET bottles						
Baling machines (2)	0.95	61.47	58.40	4	3	6
Metal wastes						
Shredder	0.95	19.91	18.91	3	3	3
Aluminium cans						
Big Density Baler	0.95	11.09	10.53	2	2	2
Organic waste						
Shredders (2)	0.95	167.99	159.59	4	6	36
Weighbridge					3	3
Weighing scales (20) (PT 310S with capacity of 3000 kg)						
Total number of Jobs						**68**

D15 Salary and Wages of the Reclaimers

Designation of Employees	Number of Employees	Wages Per Day (Rand)	Total Wages Per Month	Total Wages Per Annum
Reclaimers	609	200	3532200	42021000

APPENDIX E

E1 Waste Composition Activities at the Marie Louise landfill sites in Johannesburg

Recording of data

Excavator mixing wastes before sampling

Compactor truck discharging load

Sorting exercise ongoing

Weighing of sorted samples and recording of data

Reclaimers collecting pay for the day

Reclaimers collecting samples for sorting

Sorting exercises ongoing by the Reclaimers and the Researcher

Reclaimers collecting samples for laboratory analysis

Fruits and Vegetables Wastes at the Johannesburg Fresh Fruits and Vegetables Market (Joburg Market)

Waste composition exercise at the Joburg Market City Deep, Johannesburg

Waste Composition Activities at the Marie Louise Landfill Site, Johannesburg, South Africa

E2 Updated capacity details of landfill sites in the City of Johannesburg as of 2016

Disposal site	Remaining life of dump site (years)	Expected date of closure (month & year)
Marie Louise	4.11	01 April 2021
Robinson Deep	5.6	01 November 2021
Ennerdale	10.4	01 September 2026
Goudkoppies	13.9	01 February 2030

Source: [Pikitup Johannesburg (SOC) Limited Regional Manager's Forum Business Meeting January 2017]