Evaluating the existing residential solid waste management system and its environmental impact in low income areas: The case of the Olievenhoutbosch Township, City of Tshwane

by

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DECLARATION

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ABSTRACT

Residential Solid Waste (RSW) management is an environmental problem in low income areas such as the Olievenhoutbosch township. Growing population, improved economic growth and urbanization have caused over-consumption of materials which eventually is the source of large amounts of waste landing in the environment. Existing systems are under pressure as they are inadequate to deal with the increasing quantities. This then leads to inadequate collection rates and ineffective disposal approaches (such as illegal dumping, open burning and open dumping) which eventually contributes to environmental problems such as water and soil pollution, greenhouse gas emissions and plastics build-ups on land, in rivers and in oceans. The aim of this study was to evaluate the existing RSW management system in the Olievenhoutbosch Township which is located in the City of Tshwane's Metropolitan Municipality (CTMM). The specific focus was mainly on the collection and disposal methods impacting on the environment, and with the extended goal of improving the sustainability of the management system.

The study utilized both primary and secondary data to explore the current RSW situation. This included desktop study, visual observations and interviews with CTMM waste officers. The collected data was then stored in Microsoft Excel 2010.

Analysis of these data revealed that municipalities are indeed under pressure due to increasing RSW volumes caused by the increasing number of people moving into the townships, growing backyard dwellers in existing yards and increasing informal settlement dwellers. The municipality indicated that collection services provided for formal dwellers are sufficient and informal dwellers are currently not served. Transportation concerns involved difficulty in accessing some areas in the township and long distances from collection points (household yards) to CTMM landfill sites. RSW minimization is absent, collection of recyclables is only through informal waste pickers, meaning that all RSW collected ends up in landfill sites. Additionally, the study found that the municipality is focusing mainly on ensuring that RSW is collected from households. RSW minimization initiatives are overlooked due to a lack of budgets, capacity and infrastructure. Based on the findings, recommendations have been made.

OPSOMMING

Residensiële vaste afvalbestuur (RSW) is 'n omgewingsprobleem in lae-inkomstegebiede soos die Olievenhoutbosch-township in die Stad Tshwane se Metropolitaanse Munisipaliteit (CTMM). Toenemende bevolking, verbeterde ekonomiese groei en verstedeliking het oorverbruik van materiale veroorsaak, wat uiteindelik die bron is van groot hoeveelhede afval wat in die omgewing beland. Bestaande stelsels is onder druk omdat hulle nie gerat is om die toenemende hoeveelhede die hoof te bied nie. Dit lei dan tot onvoldoende invordering en ondoeltreffende opruimingsbenaderings (soos onwettige storting, oop verbranding en oop storting) wat uiteindelik tot omgewingsprobleme soos water- en grondbesoedeling, kweekhuisgasvrystellings en die opbou van plastiek op land, in riviere en in oseane, bydra. Die doel van hierdie studie was om die bestaande RSW-bestuurstelsel in die Olievenhoutbosch-township, te evalueer. Die spesifieke fokus was hoofsaaklik op die versamelings- en oprumingsmetodes wat die omgewing raak, en met die uitgebreide doel om die volhoubaarheid van die bestuurstelsel te verbeter.

Die studie het primêre en sekondêre data gebruik om die huidige situasie ten opsigte van RSW te ondersoek. Dit het lessenaarstudie, visuele waarnemings en onderhoude met CTMM-afvalbeamptes ingesluit. Die versamelde data is vervolgens in Microsoft Excel 2010 gestoor.
’n Ontleding van hierdie data het getoon dat munisipaliteite inderdaad onder druk verkeer as gevolg van toenemende RSW-volumes wat veroorsaak word deur die groeiende aantal mense wat na die townships trek, meer en meer agterplaasbewoners op bestaande erwe en die vermeerdering van informele nedersettings. Die munisipaliteit het aangedui dat opruimingsdienste wat aan formele inwoners verskaf word, voldoende is en dat informele inwoners tans nie bedien word nie. Vervoerprobleme word ondervind om toegang tot sekere gebiede in die dorp te verkry en die lang afstande vanaf versamelpunte (huise) tot stortingsterreine van die CTMM bemoeilik die situasie. RSW-bestaan nie, en herwinning vind alleenlik plaas deur informele operateurs, wat daarop neerkom dat alle RSW wat bymekaar gemaak word, op stortingsterreine beland. Die studie het ook bevind dat die munisipaliteit hoofsaaklik daarop gerig is om te verseker dat RSW by huishoudings afgehaal word. Inisiatiewe wat betref die minimalisering van RSW, word oor die hoof gesien as gevolg van gebrekkige begrotings, kapasiteit en infrastruktuur. Aanbevelings is gedoen op grond van dié bevindings.

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Abbreviations and Acronyms

AMMC	Accra Metropolitan Municipality City
BOC	Brazilian Occupation Classification
CBO	Community Based Organisation
CoE	City of Ekurhuleni
CoJ	City of Johannesburg
CoT	City of Tshwane
CTMM	City of Tshwane Metropolitan Municipality
DEA	Department of Environmental Affairs
EAC	East Africa Countries
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IWMP	Integrated Waste Management Plan
IWP	Informal Waste Picker
NEMA	National Environmental Management Act
NEMWA	National Environmental Management Waste Act
NGO	Non-Governmental Organization
NWMS	National Waste Management Strategy
OECD	Organisation for Economic Co-operation and Development
PPE	Personal Protective Equipment
RSA	Republic of South Africa
RSW	Residential Solid Waste
RSWM	Residential Solid Waste Management
STATSSA	Statistics South Africa

CHAPTER ONE: INTRODUCTION

Working title

Evaluating the existing residential solid waste management system and its environmental impact in low incomes areas: The case of the Olievenhoutbosch Township, City of Tshwane.

1. Introduction

1.1 Background

Residential Solid Waste (RSW) remains a significant challenge in developing countries. The quantity in which RSW is generated continues to rise. Insufficient budgets, weak organisational structures, lack of technical skills, knowledge and understanding of RSW, coupled with aging and dilapidated roads and infrastructure, are identified as some aspects that have an impact on RSW management (McKay, Mbanda & Lawton, 2015). No less than 87% of RSW managing authorities in South Africa still have no adequate resources to pursue RSW management strategies (Department of Environmental Affairs, 2012). RSW is not only a managerial, technical or financial problem, but an environmental health burden as well (Oteng-Ababio, Arguello & Gabbay 2010). For instance, the aforementioned authors point out that in most African countries inadequate collection of RSW is still a problem which forces residents to dump their waste in open spaces – where it eventually attracts diseases causing organisms and leaves the environment littered in an un-aesthetic manner.

While RSW is a problem in the developing world, solid waste generated continues to rise at an alarming rate due to growing populations and unplanned urbanisation. Rapid growing populations and rising urbanisation are found to be some of the major factors having a serious effect on solid waste management (Department of Environmental Affairs, 2018). The DEA (2018) in its South Africa State of Waste Report points out that there is positive correlation between population and urbanization and solid waste generated. Developing countries continue to grow rapidly and it is forecast that between 2010 and 2035 the population in Sub-Saharan Africa will increase from 298 million to 987 million (United Nations, 2013). This means the rate of solid waste generated will continue to rise during those years placing more pressure on the managing authorities and their

RSW systems. As a result, solid waste managing authorities within developing countries are required to have operational plans for both best- and worst-case scenarios in place in order to meet the changes that will be required.

1.2 Motivation and Rationale

Despite much research, awareness and seminars conducted by researchers around the globe, RSW management remains an environmental, health and social challenge. Water, soil and air pollution are some well-known problems attributed to poor RSW. Public health is compromised when waste is not collected as people opt for dumping their waste illegally in any open areas. Illegally or poorly dumped RSW contaminates the living surrounding and local rivers and, in some cases, it blocks drainage systems consequently causing sewer blockages which eventually become breeding areas for disease causing organisms (Alam & Ahmade 2013).

Poor RSW management remains a threat to the environmental sustainability and to public health (Sibanda, Obange & Awuor, 2017). Uncollected waste is a risk to public health. It is one of the breeding areas for disease causing organisms (Hoornweg & Bhada-Tata, 2012). For example, some 22 disease were attributed to poor RSW management and identified by the United States Public Health Services (Alam & Ahmade 2013). Improper RSW management is also an environmental concern. Certain collection and disposal methods have adverse impacts on the environment. Alam and Ahmade, (2013) and Hoornweg and Bhada-Tata, (2012), point out that collection trucks and disposal methods such as incineration at landfill site contribute to greenhouse gas generation.

The Constitution of South Africa (previously referred to as Act 108 of 1996) (now only referred to as The Constitution) states clearly that everyone has the right to an environment that is not harmful to their health and wellbeing. Moreover, the same environment must be protected from pollution and anything that might degrade its natural state (RSA, 1996). Yet, in most low-income areas this right is often compromised due to poor RSW management systems. Within these areas RSW generated is often left unmanaged.

With the rapidly increasing environmental problems caused by poor solid waste management, comprehensive solid waste management studies are imperative. Understanding and knowledge of the technical, social, environmental, legal, institutional and economical aspect of RSW are mandatory when sustainable RSW management is to be achieved. This study seeks to study and address the impact of latter issues in RSW management within low income areas. The findings of this study will be of great significance to all people that will be involved. Stakeholders (municipal authorities, local leaders and community members) involved in the study stand to gain a greater awareness and in-depth understanding and knowledge of aspects that lead to the success and failure of RSW management. The recommendations made will serve mainly as inputs to bring about a more sustainable solid waste management system. The outcome of this study ought to be an asset to be used in effective planning and management of RSW by managing authorities.

1.3 Research Problem

Proper management of Residential Solid Waste (RSW) is a common challenge for waste authorities in developing regions (Abdel-Shafy & Mansour 2018). This is primarily due to increasing RSW triggered by rapid growth in populations, urbanisation and improved lifestyles (World Bank, nd.). The existing municipal RSW systems in developing countries are inadequate to be able to deal with the quantity of RSW generated and this also places a burden on municipal budgets (Yoada, Chirawurah and Adongo, 2014). This then results in inadequate collection rates and ineffective disposal approaches (illegal dumping, open burning and open dumping) which eventually contributes to environmental impacts such as water and soil pollution, greenhouse gas emissions and plastic build-ups on land, in rivers and oceans, as well as posing a human health risk (Alam & Ahmade, 2013; Department of Environmental Affairs, 2011). Poor infrastructure, financial instabilities, institutional challenges and lack of technical skills are some of the identified problems in RSW management within developing countries (Ekeu-wei, Azuma & Ogunmuyiwa, 2018; Mckay *et al.*, 2015).

The City of Tshwane Metropolitan Municipality (CTMM), like many other municipalities in South Africa and developing regions, is faced with increasing RSW due to rapid urbanisation and mushrooming consumption patterns. The current landfill sites are also reaching their operational

designed volume. Moreover, there are several other reported challenges facing the CTMM and these include insufficient budgets, weak organisation capacity, lack of RSW services in other areas (according to the 2011 census the CTMM provided 81% of households with RSW services), illegal dumping, outdated by-laws which overlook waste minimisation initiatives and lack of implementation of waste by-laws (CTMM, 2014 and CTMM, 2015). Given this current scenario of RSW management in developing countries, the CTMM's efforts to evaluating the existing RSW management system in low income areas such as the Olievenhoutbosch Township became imperative as this could be of value in learning all about the new challenges and opportunities in managing RSW.

1.4 Research aim and objectives

1.4.1 Aim

The aim of this study is to explore the state of the Residential Solid Waste (RSW) management system in the Olievenhoutbosch Township with specific focus on the impacts there are on the environment mainly from collection and disposal methods, and with the extended goal of improving the sustainability of the management system.

1.4.2. Objectives:

The specific objectives of this study are to:

- Explore the current methods for Residential Solid Waste (RSW) management (collection, transport, processing, disposal and landfilling) in a township
- Explore the CTMM guidelines, procedures and governance of RSW

1.4.3 Research questions

- What are the challenges with regards to the RSW system (collection, transport, processing and disposal and landfilling system) in the Olievenhoutbosch Township?
- What are the limitations of the current CTMM and Olievenhoutbosch RSW environmental guidelines, procedures and governance of RSW?

1.5 Study area

The study will be carried out in the township called Olievenhoutbosch Township, which is situated in the City of Tshwane (CTMM) Municipality in the Gauteng Province of South Africa. The CTMM municipality is divided into seven regions and Olievenhoutbosch falls under region 4. During the 2011 official general census, region 4 had 379,349 inhabitants of which 70,863 were residing in Olievenhoutbosch (STATSSA, 2011). However, as no other general census has been carried out after 2011, the population in Olievenhoutbosch is estimated to have increased. Similar to many other townships in South Africa, Olievenhoutbosch is characterised by insufficient, or a lack of, community services (water, electricity, health and waste facilities, dilapidated roads), high unemployment, low incomes and poverty (Pernegger & Godehart, 2007). Three socio-economically different residences will be selected, namely middle income, low income and informal settlement. Although the study focused on Olievenhoutbosch, its findings could in all probability be applicable to any other South African and international township.

1.6 Preliminary literature review

1.6.1 Solid waste phenomena

Solid waste pollution presents devastating and concerning challenges to the environment (Wang & Nie 2001). Solid waste is a 100% anthropogenic activity in which used materials, classified as unwanted and useless, are discarded. The Waste Amendment Act 26 of 2014 (Republic of South Africa 2014) of South Africa defines waste as “any substance, material or object that is unwanted, rejected, abandoned, discarded or disposed by the holder of the substance, material or object whether or not such substance, material or objective can be re-used, recycled or recovered”. Moreover, it classifies waste into two categories namely: general waste and hazardous waste. This study focuses mainly on general waste which is often called municipal, domestic or residential waste. The term “residential” will be used throughout. Residential Solid Waste (RSW) originates from residential areas and is characterized by household waste items such as food waste, plastics, glass, clothing rags, garden waste, and paper, and in some cases where adequate sanitation is still a problem; RSW may also comprise sanitary waste in areas where sanitation systems are inadequate (Department of Environmental Affairs, 2018).

1.6.2 Residential Solid Waste management in South Africa and in the City of Tshwane Metropolitan Municipality

1.6.2.1 RSW management system

A RSW management system entails the control of the generation, storage, collection, transport, treatment and disposal and recycling of RSW materials (Henry, Yongsheng & Jun 2006). Generally, its main objective is to reduce, minimize and if possible, eliminate the negative impact of waste products on public health and environment in order to promote environment, social and economic sustainability (Sharma & Gupta, 1995; Brunner and Feller 2007). RSW management aims may be more complex, and they include recovering resource and achieving zero waste (Snyman & Vorster 2011). On the other hand, as of now, developed countries are adopting a new RSW management system known as "Integrated Solid Waste Management (ISWM)". This approach seeks to simultaneously address RSW by focusing on stakeholders such as Non-Governmental Organisations (NGOs), users, Community Based Organizations (CBOs), authorities, formal and informal sectors, elements which include generation, separation, collection, treatment, disposal and recovery, and involve environmental, socio-cultural, technical, legal and political aspects (Hoornweg and Bhada-Tata, 2012).

1.6.2.2 RSW management system components

A waste management system consists of different components. This includes waste generation, waste collection, waste transport, treatment and disposal and those discussed below:

1.6.2.3 Residential solid waste generation

Residential Solid Waste (RSW) is rising globally (World Bank, 2019; Salhofer *et al.* 2008). At present 1.3 billion tons of RSW are produced annually around the globe and it's expected to increase to 2.2 billion tons in 2025 (Hoornweg and Bhada-Tata, 2012). These generation rates are directly or indirectly affected by different factors namely: population size, density and growth, economy, income, and urbanisation (DEA, 2018). For instance, increased RSW has been linked with rapid population growth, urbanisation and improved economy (DEA, 2018).

The CTMM waste generation rate is 685 000 tons per annum. However, this estimate is based on maximum load per truck due to malfunctioning weighbridges at CTMM landfill sites (CTMM, 2014).

Estimating and forecasting RSW generation is one of the important steps in RSW management in fast growing industrial regions with rapidly growing populations (Khajuria, Yamamoto & Morioka 2010). This depends on accuracy and the availability of historical records of quantity of waste (Dyson & Chang 2005; Sharholy et al. 2008). Poor RSW generation data reliability is linked to absence of equipment (weigh-bridges), low collection rates and poor data compilation systems (Kawai & Tasaki 2016). CTMM (2014) states that they still have discrepancies in generation rates estimates due to a lack of functional weighbridges at the landfill.

Residential Solid Waste (RSW) quantities and the rate at which they are produced have a serious impact on the RSW management system. For instance, if the rate of RSW continues to rise it will force managing authorities to expand their systems (collection, disposal and treatment) to meet the growing demand and this may affect their budgets. Then developing countries which normally have financial challenges will struggle to cope in dealing with RSW (Guerrero, Maas & Hogland, 2013). This will eventually affect the collection disposal and treatment effectiveness consequently affecting the environment and public health. Therefore, knowledge of RSW generation trends – current and future – is essential for the success of RSW management.

1.6.2.4 RSW collection

Waste collection involves collecting the waste from generators, or sources, and transporting it to a destination where it is treated and then disposed of (Mohee & Simelane 2015). There are various methods that are used around the globe to collect waste and these include collection by humans, animals and trucks. For instance, in South Africa initially in 1786 animal carts were used but since the situation has improved in that motorised trucks are used (CSIR, n.d).

RSW collection in the developing world remains a challenge. Only half of waste generated is collected and 95% of it is not even contained or recycled. It is illegally dumped on open spaces or in rivers. In low income countries conditions are even worse. For instance, in Lesotho 70% of

residents have collection systems, whereas in other countries such as Botswana and Mozambique waste are disposed in open fields (Mohee and Simelane, 2015). The RSW collection rate in developed countries and developing countries varies. In developed countries all waste is collected while in developing countries the low collection rate is still a problem. For example, developed countries' collection rate is 100%, while in developing countries (illustrated in figure 1.1) it ranges from 61% (in Nigeria) to 83% (Brazil).

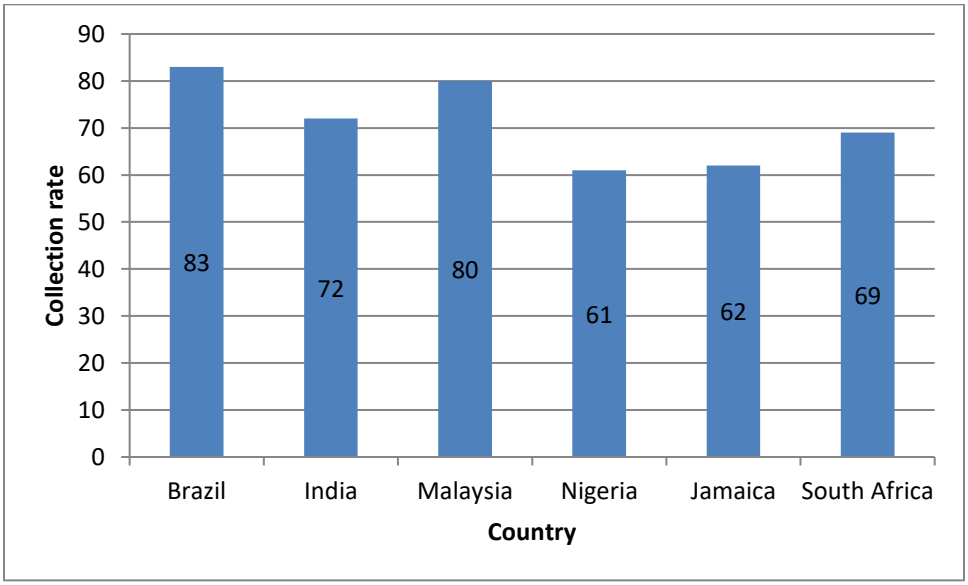


Figure 1.1: RSW collection rate in developing countries
(Source: Mohee and Simalane, 2015)

Similar to these developing countries, the collection rate in South Africa (SA) is also not 100%. Table 1.2 illustrates the waste collection activities across major cities in SA. The majority of cities collect waste using their own services; it is only Johannesburg that fully relies on outsourced service providers for collection. According to Statistics South Africa (STATSSA) (2011), waste removed weekly from households ranges from 70.4% in Buffalo City to 95% in the City of Johannesburg. The CTMM relies both on in-house (municipal owned trucks) and community-based contractors for RSW collection.

Table 1.1: Residential solid waste collection contracting and weekly removal in South Africa

City	RSW collection (in house)	RSW collection (outsourced)	RSW removed (weekly)
City of Cape Town	Yes	No	94.3%
eThekwini	Yes	No	86.0%
City of Johannesburg	No?	Pikitup utility outsourced	95.0%
City of Tshwane	Yes	Community contractors in some areas	80.7%
Ekurhuleni	Yes	Community contractors in some areas	88.4%
Mangaung	Yes	No	78.0%
Baffalo City	Yes	No	70.4%
Nelson Mandela Bay	Yes	Community contractors in some areas	82.0%

(Sources: STATSSA, 2011)

RSW collection rate efficiency is affected by certain aspects, the economic status of residents being one of the factors identified. Some authors report that the collection rate in developing countries in some instances is often discontinued due to non-payment of RSW tariffs by residents (Muniafu and Otiato, 2010). Moreover, inaccessible roads, and lack of bins were some of the aspects affecting collection efficiency (Henry *et al*., 2006). In some cases, government is failing due to lack of, or insufficient resources (Ragassa, Sundaraa & Seboka, 2011). Lack, or the inefficiency of the collection system, impacts on health and the environment. For example, studies have identified that in areas where RSW collection systems are rarely found, illegal dumping is the option available for residents (Ichinose & Yamamoto, 2011). Illegal dumping is a threat to the environment, for instance it degrades the aesthetical appearance of the environment. On the other

hand, it can also affect the public health and that of local livestock. Illegal dumping sites are normally breeding areas of disease-causing insects. Local livestock health may also be affected, for example domestic animals could choked on by dumped plastics. Therefore, collection of RSW must be prioritised if the successful management thereof is to be achieved.

1.6.2.5 RSW disposal

RSW disposal is the final step in waste management process. There are different methods available that are currently used for treating and disposing of waste. These include landfill-based collecting, composting, dumping (in water bodies or open spaces) and incineration. Figure 1.2 illustrate different methods that are used to dispose of waste in Africa – landfilling and dumping are the most common methods used while incineration and compost are least used. Moreover, some 0.14 million tonnes of waste are also recycled (Hoornweg and Bhada-Tata, 2012).

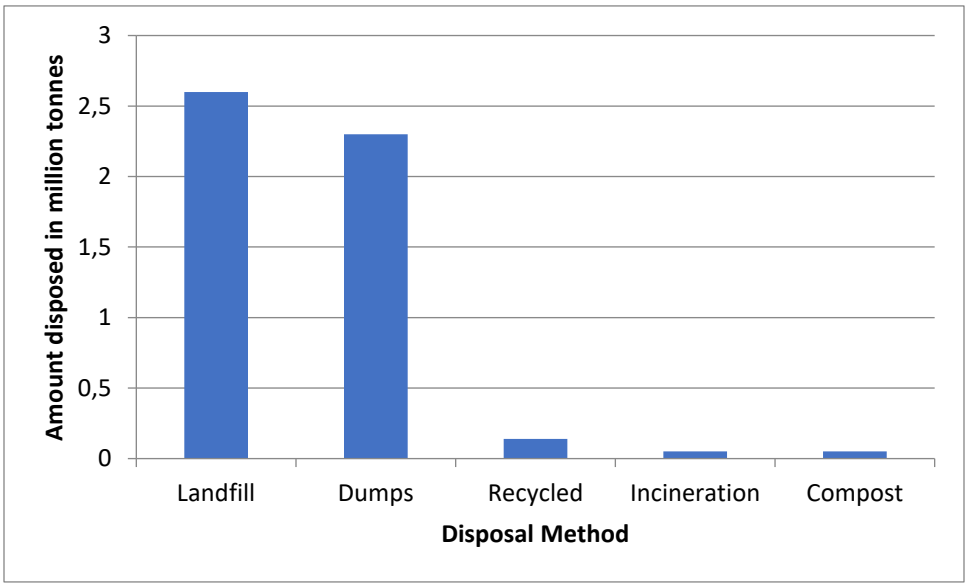


Figure 1.2: Waste disposal methods in Africa

(Source Hoornweg and Bhada-Tata, 2012)

South Africa (SA) also relies heavily on landfills. According to DEA (2012) 90% of waste in SA is disposed in landfill sites and only 10% is recycled. The waste collected is disposed to designated or licensed landfill sites. Currently, the CTMM disposes all its waste on landfill sites. The city has

some 16 landfill sites and among these, 10 have already been closed as they have reached their volume capacity (CTMM, 2020).

Landfilling of waste is cost effective but it has its limitations. At present the landfill sites in SA are reaching their maximum capacity. Figure 1.3 shows the number of years remaining for landfill sites to be full for a number of metros. As of 2018 the City of Cape Town and the City of Johannesburg have only 5 and 8 years remaining respectively while Ekurhuleni and eThekwini still have several years remaining. The CTMM has about 8 years remaining. Looking at this data, some municipalities such as the City of Cape Town and the City of Johannesburg will have to have plans in place to prolong the lifespan of the landfills as they will be full in a matter of a few years.

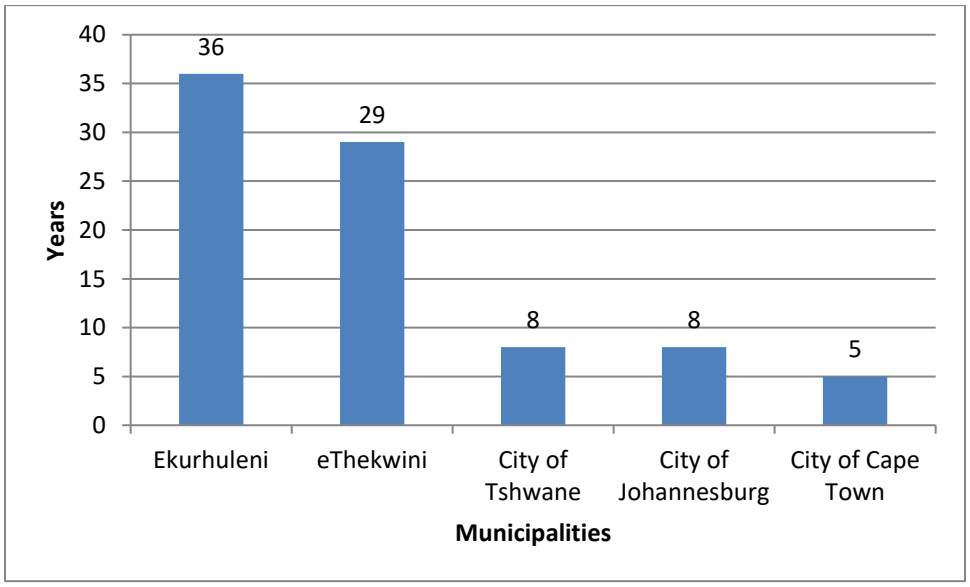


Figure 1.3: Estimated remaining years to fill landfill airspace in South Africa's major cities
(Source: Department of Environmental Affairs, State of Waste Report, 2018)

1.7 Impact of poor Residential Solid Waste (RSW) systems on the environment and human health

RSW that is collected and disposed of haphazardly has a serious impact on the environment. Adverse environmental impacts include pollution and contamination of water bodies (i.e. ground water and surface water), soil contamination and air pollution (Al-Khatib et al., 2007). Moreover, waste that is not collected and disposed of properly has a potential to spread diseases which places the general health of the public at risk (Alam and Ahmade, 2013). Thus, it is imperative for waste

authorities to study and understand the impacts of landfill sites on the environment and public health. The next sections present the impact posed by collection and disposal systems.

1.7.1 Collection systems

Waste collection is one of the key steps in RSW management. Uncollected waste, or deficiency in collection, has serious consequences on the environment and general health of people. Low income areas are characterised by poor collection (Hoornweg and Bhada-Tata, 2012; Parrot, Sotamenou & Dia, 2000). Uncollected, or inadequate collection of waste has an indirect impact on the environment and health of residents. Illegal dumping is one of the activities carried out by residents when the collection system is poor.

1.7.2 Environmental and health impact of disposal methods

Different RSW methods are currently available worldwide and each has its own limitations. Knowledge of which one is best (environmentally, social and economically sustainable) is imperative for waste managment authorities. Seeing that landfill sites as disposing method is mainly common in African countries, including South Africa, as well as the City of Tshwane and Olievenhoutbosch, this section will focus mainly on landfill sites' impacts. The impact on water, air and public health will be outlined.

a) Impacts of landfill site on water quality

RSW landfilling involves the burying waste carefully controlled conditions. Waste that is buried on the ground surface releases liquid that percolates through and produces what is known as leachate. This disposal method has been found to be a threat to groundwater sources. Studies have identified the change in quality of groundwater sources which were located nearby landfill sites. For instance, physical and chemical parameters were found to be high in concentration in New Delhi (India) groundwater sources which were located about 1.5 km from landfill sites (Mor, Ravindra, Dahiya and Chandra, 2006, p. 435-438). In Athens (Greece) as well it was found that quality of groundwater changes due to landfill site leachate and was no longer suitable for domestic and irrigation use as parameters such as colour, conductivity and hardness were exceeding the acceptable limits of the country (Fatta, Papadopoulos and Loizidou, 1999). A study conducted in

Egypt also found groundwater quality near landfill site with physical parameters that were exceeding limits stipulated by the World Health Organization (WHO).

b) Impact of landfill sites on air quality

Waste at landfill sites is buried and covered; this leads to decomposition of waste contents. According to Pitchel (2005) during decomposition gases such as methane, nitrogen and carbon dioxide are released. The aforementioned are among greenhouse gases (GHG) that were declared priority air pollutants in the Air Quality Act 39 of 2004 (Republic of South Africa, 2004a).

Table 1.2 shows the quantity of GHGs (in CO_2, CH_4, N_2O) released by landfills in different countries. China and India emit much higher amounts of GHGs from landfills compared to other listed countries. The impacts of GHGs on global warming are well known (Air Quality Act, 39 of 2004) (Republic of South Africa, 2004b) and its consequences include droughts, floods, biodiversity loss, rising temperatures, and wildfires (Ostberg et al. 2013).

Table 1.2: Greenhouse gas emissions from landfills in different countries

Country	**Greenhouse gas emission from landfills CO_2, CH_4, N_2O ($MtCO_2e$)**
South Africa	380
Brazil	659
Mexico	383
China	3 650
India	1 210

(Source: Hoornweg and Bhada-Tata, 2012)

c) Impact of landfill sites on public health

Martuzzi, Mitis and Forastiere (2010) state that environmental inequalities still exist in waste management around the world. They back this statement up by pointing out that there are people who still live near landfill sites and this situation has the potential to cause diseases. Compounds such as benzene, phenols, and others are released from landfill sites. These compounds were found to be carcinogenic (Department of Environmental Affairs, 2018; Maheshwari, Gupta & Das,

2015). Studies also point to the fact that people who live near landfill sites were found to be susceptible to skin irritations, headaches, nausea and fatigue. In Swaziland it was discovered that people who resided less than 20km from landfill sites suffered from chest pains, cholera, diarrhoea and malaria (Abul, 2010, p. 74). From these studies it is very clear that landfill sites indeed pose risks to public health.

1.8 Governance of RSW in South Africa.

(a) National regulations

There are a number of legislative documents that control RSW in South Africa (SA). National Environmental Management: Waste Act (59 of 2008) (NEMWA) (herein also referred to as NEMWA) (RSA, 2008) outlines what waste is, how it is to be managed, the standards required to comply with waste activities and actions for remediation of polluted land. It also points out that authorities responsible for waste management must have a National Waste Management Strategy (NWMS) to fulfil NEMWA objectives. This NWMS provides an approach of how waste is to be managed in SA by using a waste hierarchy as illustrated in Figure 1.4. This approach does not focus on general traditional methods which only prioritize collection, transport, treatment and disposal for waste management such as all other municipalities do, but it focuses mainly on preventing, minimising, re-using, recycling, recovery energy and disposal.

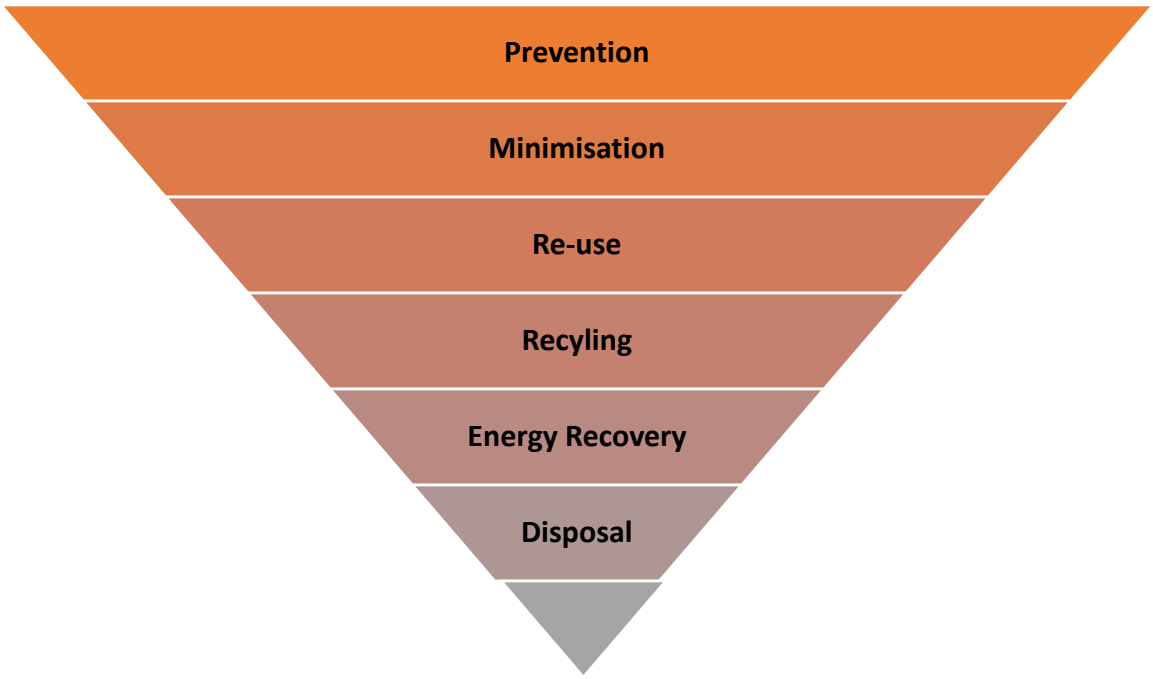


Figure 1.4: Waste Hierarchy
(Source: South African Cities Network, 2014b)

As mentioned earlier, most SA municipalities rely on landfilling for their RSW disposal. Therefore, the Department of Water and Sanitation has determined standards for landfilling which are known as minimum requirements for Waste Disposal (Department of Water Affairs and Forestry, 1998). These requirements state that a "person or organization is not allowed to establish, provide or operate any disposal site without a permit and this permit is obtained from the Minister of Water Affairs" (South Africa Department of Environmental Affairs, 1998, p. v).

1.8.1 City of Tshwane By-Laws

Apart from national regulation, cities have their own regulations known as bylaws. The City of Tshwane (CTMM) municipality by-laws about waste management protects both human health and the environment. The city by-law supports the Republic of South Africa (RSA) National Environmental Management Act: Waste Act (59 of 2008) (RSA, 2008) as it provides services such as refuse removal, collection and disposal of solid and related types of waste in order to ensure it's a clean environment. The CTMM waste management bylaws state that "to regulate and provide for waste management services including collection and disposal of solid and all other forms of

waste; to ensure that all practices concerning waste management are aligned to the Constitution of the Republic of South Africa, 1996, the National Environmental Management: Waste Act, 59 of 2008 and the Local Government: Municipal Systems Act, 32 of 2000 and in general to provide for mechanisms; forms; practices and procedures, and matters incidental are there to ensure a sustainable safe and healthy environment within the City of Tshwane jurisdictional area".

The key role of the CTMM Solid Waste Bylaws is to ensure that good service delivery is rendered and the environment and its people are in good health. Chapter two of the bylaw discusses the regular domestic waste collection. It is the municipalities responsibility to issue its residents with waste containers for the relevant type of waste; this helps to reduce the littering and pollution in the municipal environment. However, after the issuing of the waste containers, in accordance with the CTMM Solid Waste Bylaws, it is the responsibility of the premises occupier to ensure that by a stipulated time the waste containers are placed outside the yard for collection.

1.9 Research methodology designs and methods

This section discusses the research design and methodology that will be employed in this study and a description of how the collected data will be analysed.

1.9.1 Research design

An empirical study will be conducted; this is a study which derives and analyses data from direct or indirect observations (Jasti & Kodali, 2012). Mixed data collection methods will be used for collecting data. This approach involves collecting both qualitative and quantitative data (Clark & Creswell, 2014).

1.9.2 Research methodology

A multi-disciplinary approach will be used in this study to achieve research objectives. This will include desk study (literature review) and field data collection (questionnaires, site observations and interviews). Two sets of data will be collected, namely primary data and secondary data.

1.9.3 Data collection

Most social and community challenges are a concern to a large number of people; however, those who are socially and economically influential, such as government officials and politicians, are the ones who in most cases define these problems and come up with solutions without involving those who are affected.

Therefore, semi-structured interviews will be conducted with key informants; this includes people who possess unique knowledge and skills different from other people due to their position in the community or organisation. The use of key informants has been well praised for enabling researchers to obtain an in-depth insight and quality data within a short period of time (Marshall, 1996). Potential key informants for this study will include; CTMM employees involved in RSW management from different departments, namely, technical, finance, environmental officers, governance officers and Olievenhoutbosch RSW representatives.

Lastly, visual observations will be conducted. Visual observation is a form of a qualitative data collection technique as it involves in-depth observation. Pictures or peoples' actions are utilized to produce knowledge (Ritchie et al. 2013). Observations in this study will be made throughout the Olievenhoutbosch RSW systems (from point of generation to point of disposal). Illegal dumping sites around the community will also be studied.

1.9.4 Semi-structured interviews with key informants

A non-random sampling technique known as purposive sampling will be used to select key informants. According to Tongco (2007) in the purposive sampling method the researcher purposively selects participants with certain characteristics with the aim of obtaining certain knowledge or in-depth insight. Bernard (2002) clearly points out that with this technique the researcher decides what his/her aim is and then selects people who can provide information based on their skills, experience and knowledge.

The researcher will select various employees within the CTMM RSW management department. The employees will be selected purposively to represent different specialities namely, technical, finance, environmental and governance. One employee from each speciality will be

interviewed. Lists of questions will be prepared that will cover the questions about the RSW management system within the CTMM and Olievenhoutbosch in particular – this will include technical, finance, governance and environmental questions, challenges and opportunities in RSW management and also present and future plans.

(a) Interviews

An appointment will first be made and after agreeing on a date and time, the researcher will e-mail the consent form to the participant a day before the appointment date. This will allow the participant to read and sign the form, and scan and e-mail it back to the researcher upon agreeing to participate in the research. The online virtual interview method will be used whereby a computer program known as Zoom Meetings will be used to conduct the interviews as it allows for online video calls. This will enable both the participant and the researcher to conduct the interviews in the comfort of their homes or place of work. The researcher will lead the interviews by asking questions and the participant will answer while the researcher records the answers. To ensure that the participant remains anonymous, each participant will conduct interviews with the researcher at a separate time/call, not in a conference/group video call with other participants present. The copy of the virtual call/interview will also be stored and saved after the interviews. This copy will only be accessed by the researcher under password protection.

1.9.5 Visual observation

The observation method will be one of the methods used. As the desktop study provided limited information on the study area regarding RSW systems, the observation method will be used by the researcher to gather further information concerning the study area.

The researcher will visit the study area locations to identify illegal waste dumping sites and to determine if stormwater systems (drainage) and water bodies (rivers and canals) are polluted by waste. During these visits the researcher will collect data by taking photographs and notes of the aforementioned systems in order to be able to describe anything out of the ordinary.

1.9.6 Secondary data

This includes data that is already available at the municipality. As the researcher aims to measure the effectiveness of RSW management, the following data will also be collected from the CTMM Solid waste generation:

- Population
- Population served with RSW services
- Solid waste composition
- Collection rate
- Waste collection tariffs/ Non-payments
- Non-payment control measures
- Illegal dumping costs
- Awareness programmes
- Landfill sites: capacities and rehabilitation costs

1.10 Data analysis

Friese (2019) has described data analysis as a process whereby raw data is evaluated systematically using statistics and logic techniques; this process often involves describing, organising, presenting and interpreting data. Conversely, Creswell (2014) defines data analysis as a process whereby the researcher represents her/his data statistically by means of ranges, means and standard deviations. Thus, all data gathered from this research will be analysed as well. Descriptive statistics will be used to create frequencies, percentages, averages, means, standard deviations and ranges to determine a link and relationships.

In most data analysis, computer aided software involves mainly three consecutive stages namely, preparing data, creating project file, coding, sorting, structuring and querying data. To analyse data in this study, a computer program known as Microsoft Excel (MS Excel) will be used. Some of the benefits of using MS Excel is that it is free and easily accessible. Data collected will be stored in Microsoft Office (2010) spreadsheets; these data will be then be analysed using descriptive statistics. The results will be presented in the form of charts and tables and some observational data obtained will be presented in the form of pictures. MS Excel contains the spreadsheets that will be used for data entry, management and presentation of results. The advantage of using MS

Excel for data analysis is that it can manage data and present it in the form of various graphs for presentations (Rose, Spinks & Canhoto, 2015).

Microsoft Excel is one of computer programs used to analyse qualitative data. It can analyse a large quantity of data which is in different formats namely, text and graphic. During analysis the aforementioned data format is then analysed by means of codes and annotates.

This study will use three consecutive steps before data analysis and these include: organising, coding and interpreting (Creswell, 2014; Hwang, 2008).

Organising: Data collected from the field (raw data) which is from key informants and field observation notes will first be transcribed, scanned, and arranged by simply typing it in Microsoft Word.

Coding*:* According to Smit (2002, p. 69) *"*attaching keywords to text segments." This involves categorising and labelling the collected data with terms and themes (Microsoft Excel *w*ill be used).

Interpreting: Interpreting the meaning of themes coded.

1.10.1 Data validation and reliability

Validation is a process of determining data accuracy from researcher, participant and readers' viewpoint. This study adopted triangulation as validation strategy, which involved collecting data using different methods and sources for data collection.

1.11 Ethical consideration

Permission to conduct this research will be obtained from both the University (Stellenbosch University Research Ethics Committee) and the City of Tshwane. Moreover, permission to participate in this research, interviews and questionnaires will be sought from municipal staff and consent forms (**Annexure 1**) will be completed before participating in the study. Confidentiality will be exercised during the interviews and questionnaires. Participants will be afforded the right to remain anonymous and withdraw their interviews at any time.

1.12 Research Outline

The thesis consists of the following chapters:

Chapter 1: Background and introduction

This chapter contains the research background, rationale, aim, objectives and research question.

Chapter 2: Literature Review

This chapter focuses on the comprehensive review of literature on RSW management in developing countries and South Africa. Environmental and health impacts that emanate from poor RSW management are discussed. Regulations and laws that are used in waste governance are also discussed

Chapter 3: Research methodology, methods and design

Chapter 3 outlines the research design, study area and methodology that will be used to accomplish the study objectives. Additionally, it will explain how the collected data will be analysed. Lastly it will give brief details about ethical clearance.

Chapter 4: Data and results

This section will present and analyse the results obtained throughout the study. The computer program Microsoft Excel will be used. Some data management problems experienced by researchers are difficult to be solved by simple computer database. Having to deal with large amounts of qualitative data is one of the problems researchers experience (Jones & Johnson, 2000). Thus, using computer-based software is advisable by most researchers as high-quality software can improve data management by reducing analysis timeframe and human errors, provide accurate coding and analysis (Jones & Johnson, 2000; Jones, 2007)

Chapter 5 Interpretation and discussion of results

This section will report the findings of the study based on the data gathered by means of the methodology and data management applied.

Chapter 6 Conclusions and Recommendations

Findings will be elaborated on; recommendations will be made and an environmental sound RSW management system will be suggested.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

The increase in the generation of Residential Solid Waste (RSW), due to growing populations, urbanisation and improved lifestyles, have become a serious problem in most countries around the globe (Karak, Bhagat & Bhattacharyya, 2012). Managing RSW properly is necessary for building a sustainable environment and health hazard free residential areas, but it remains a challenge in countries with a low income (World Bank, 2019). These areas are characterised by a lack of technical and financial resources which consequently result in low collection rates, low coverage and improper disposal methods (Ogwueleka, 2009). Lack of adequate RSW management systems and poor governance often lead to adverse impacts on the environment (air, water and soil pollution) and it affects human health as well (Alam and Ahmade, 2013). Therefore, understanding the entire RSW system is a prerequisite for planning, designing and implementing environmentally and ecologically sustainable approaches and systems that are efficient.

In this chapter, international and national literature on RSW management and the impact of inadequate RSW on people with low incomes and the environment is reviewed. The review focuses on conceptualizing of RSW and its management specifically regarding generation, collection, disposal, environmentally sustainable RSW management paradigms, RSW impacts on human health and environment, and RSW governance which includes RSW legislation, guidelines and regulations.

2.2 Residential Solid Waste definitions and concepts

This section defines different concepts and terminologies in waste management – these include mainly waste, types of waste and waste management systems.

a) Waste

Unclear definitions of waste are placing courts worldwide under strain when waste governance issues are supposed to be resolved (Godfrey & Oelofse,2008; European Commission, 2012). Defining waste has a substantial impact on the implementation of RSW policies and regulations

as criminal charges and prosecutions for violations mostly rely on whether or not a "material" (waste) has a clear legal definition and interpretation (Oelofse & Godfrey, 2008). Explaining what waste is in this study is thus critical. Countries worldwide have various definitions of waste. As definitions of waste differ among countries, for the purpose of this research the author will therefore adopt the definition formulated in the South African National Environmental Management Waste Act (59 of 2008) (RSA, 2008) and defines waste as follows:

"Any substance, whether or not that substance can be reduced, re-used, recycled or recovered –

1. That is surplus, unwanted, rejected, discarded, abandoned or disposed of;
2. Which the generator has no further use of, for the purposes of production;
3. That must be treated or disposed of; or
4. That is defined as a waste by the Minister by notice in the Gazette; and includes waste generated by the mining, medical or other sector, but

I. a by-product is not considered to be waste; [and] or

II. any portion of waste, once re-used, recycled or recovered, ceases to be waste" (RSA, 2008).

b) Types of Waste

The Department of Environmental Affairs (DEA) states that waste in the past was captured differently by different stakeholders and role players, and this was making data collection for national waste baseline challenging. Thus, the department began to classify waste in order to standardise the reporting of waste data (DEA, 2012). According to Lamb et al. (2012) waste classification can serve as a management function; for instance, it can determine which management approach is suitable for a given waste and if waste is classified it can make sorting, collection, transportation, treatment and disposal simplistic. Additionally, classifying waste may also play a role in encouraging waste reduction, sorting at source, re-use and recycling. The DEA (2018) in its state of waste report categorised waste in two classes, namely general waste and hazardous waste.

- ***General Waste***

The National Environmental Management Waste Amendment Act (26 of 2014) (RSA, 2014) defines general waste as "waste that does not pose an immediate hazard or threat to the health or to the environment and it includes: domestic waste, building and demolition waste, business waste, inert waste or any waste classified as non-hazardous waste in terms of the regulations made under

section 69 and it includes hazardous substances, materials or objects within business, domestic, inert or building and demolition waste".

- ***Hazardous waste***

"Any waste that contains organic or inorganic elements or compounds that may, owing to the inherent physical, chemical or toxicological characteristics of that waste, have a detrimental impact on health and the environment" (Republic of South Africa, 2014).

This study focuses on general waste, mainly domestic waste which is known as "municipal solid waste" or "residential solid waste"; this study will use the term residential solid waste. This is waste from residential areas or households and it includes food leftovers, plastics, glass, paper, garden waste and metals (UNEP, 2018).

c) Residential Solid Waste Management

According to Zurbrugg (2003, p. 1): "Residential Solid Waste management includes all activities that seek to minimise the health, environmental and aesthetic impacts of solid wastes." Residential Solid Waste Management (RSWM) varies widely. Old RSWM involved only the collection of unsorted RSW and transportation of this waste to landfill sites (Jouhara et al.). This approach was a threat to the public health and environment, thus transitioning from an unsustainable to a sustainable RSWM approach was necessary (Seadon, 2010). Sustainable RSWM is based on waste hierarchy approaches which incorporate mainly reduction, reuse, recycle, recovery, treatment and disposal methods for waste management (Serge Kubanza & Simatele, 2020; Shekdar, 2009). RSWM in developing countries consists of mainly collection, transportation, minimal recycle and landfill disposal or open dumping (Hoornweg and Bhada-Tata, 2012).

d) Integrated Waste Management Concept

Integrated Waste Management (IWM) refers to solid waste management sustainable strategic approaches that cover all aspects incorporating generation, separation, collection, transportation, treatment and disposal while emphasising reduce, reuse, recycling and recovery. Additionally, integration requires involvement of all stakeholders, namely government, public and private businesses, community leaders, investors, NGOs, and environmental groups, professional and academic organisations and users (residents) (Seadon, 2006).

2.3 Waste Composition Characterisation

Waste Composition Characterisation (WCC) is one of the major steps in Residential Solid Waste (RSW) management. WCC data and information can be used for planning and designing RSW

systems. For example, it can assist during the upgrade of RSWM system to new approaches or technologies for sorting, collection, and processing and disposal of waste are to be selected. It can also be used for creating a waste composition reference for use as a baseline for evaluating and monitoring the progress of recycling objectives and alternative treatment systems (Oelofse, Muswema, & Koen, 2016). WCC also can be used to estimate RSW recovery potential (Dahlén & Lagerkvist, 2008).

Waste categorisation is therefore imperative when integrated solid waste management plans are to be designed. This will ensure that accurate and sound decisions are made in matters pertaining to regulation, planning and finance. This will not only help in decision making but it will also assist in designing, operating, controlling and monitoring sustainable RSW systems (United Nations for Sustainable Development, 1999).

Different countries have different waste categorisation approaches. The Environmental Protection Agency (EPA) (1998 (a)in the USA applies five steps to classify waste: firstly, it determines if the waste is special (i.e., medical, asbestos and waste tyres), then it determines if the waste is in liquid form. If the waste is non-special and non-liquid then it determines if the waste is hazardous (coal, lead, batteries and lead-acid), putrescible general waste (food waste, animal waste, manure, sanitary napkins and pads) or non-putrescible general waste (plastic, glass, paper, garden waste, wood and construction waste). Thereafter, if waste is not classified according to the above listed classifications then that waste is classified as hazardous (explosive, toxic, carcinogenic, corrosive and flammable). Moreover, if waste is not classified according to these four categories then it is classified according to its chemical properties (concentration of contaminant).

On the other hand, EPA (1998) states that in Ireland's classification is quite simple as their waste falls into three categories, (i) non-hazardous, (ii) hazardous and (iii) mirror (either hazardous or non-hazardous). EPA in Ireland believes that if the waste is non-hazardous, it is non-hazardous, and if it's hazardous, it's hazardous and there are no further assessments required. Like any other country around the world, African countries do classify solid waste according to sources and composition. In South Africa, the National Environmental Management Waste Act 59 of 2008 (RSA, 2008) states that waste classification is identifying if that particular waste is hazardous or

non-hazardous to public health or environment. Generally, waste is categorised based on its origin source and its composition. South Africa categorises waste in various forms namely:

a) **Domestic/Residential/Household waste:** These include waste from households or residential areas and it's non-hazardous as its composition includes mainly food leftovers, glasses, plastic and paper. Although this waste is non-hazardous, if not properly managed it could pose risks to public health and environment
b) **Commercial waste:** It is almost similar to domestic waste but originates mainly from offices and schools. It contains more paper than food leftovers.
c) **Industrial waste:** This waste can be either hazardous or non-hazardous depending on sources and composition. Hazardous waste is commonly from mines, hospitals and sewage plants – their product or waste is generally toxic, cancerous causing and harmful to human and environment.

The waste classification of Asian countries such as India, Singapore, Japan and Indonesia are almost similar to South Africa's, their classification falls into five categories, namely domestic, industrial, medical, commercial and construction (Aleluia & Ferraro 2016).

This study focuses only on solid waste, explicitly residential. Residential Solid Waste (RSW) is normally known as domestic or municipal waste. Generally, RSW is placed in five categories, namely organic, glass, paper, plastic, metal and other. Table 2.1 illustrates RSW categories and their sources.

Table 2.1: RSW categories and their origins

Category	Source
Plastic	Bottles, packaging, containers, shopping bags, cups
Paper	Newspapers, books, boxes, cardboards, magazines
Metal	Cans, tins
Organic	Food leftovers, garden waste
Other	Rubbers, textiles, leather, clothes rags

(Source: Hoornweg and Bhada-Tata, 2012)

2.3 Residential Solid Waste Management System

2.3.1 Waste Management Model

Proper planning eases the complexity that emanates from solid waste management. McDougall *et al*., (2001) cited by Rachael and Farahbakhsh (2013) believe that Integrated Solid Waste Management (ISWM) was developed to guide the RSMW flow when dealing with the entire solid waste management system. According to Najm et al. (2002) the ISWM was developed as a supporting tool in achieving a proper and sustainable solid waste management system. The author further states that the model put into consideration the following: generation, storage, sorting, collection and disposal in a manner in which there is less environmental harm. Generation, collection and disposal will be discussed further in the sections to follow. The USA Environmental Protection Agency (EPA) described the ISWM as a systematic approach to complete the solid waste management stream. Figure 2.1 below is the diagram showing the ISWM model.

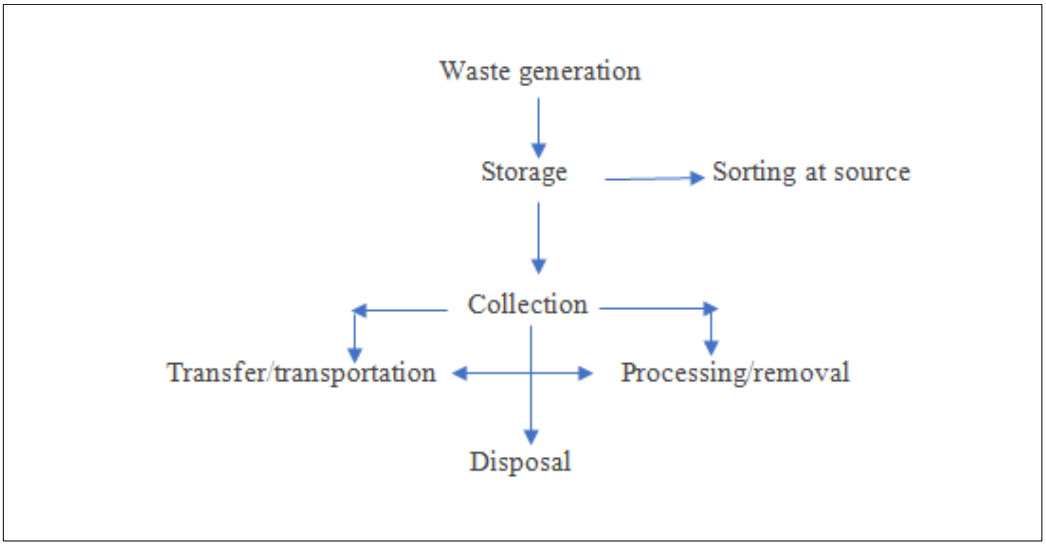


Figure 2.1: Waste Management Model

(Source: Alama and Ahmad, 2015)

2.3.2 Residential Solid Waste (RSW) generation rates

Several research studies have been conducted by universities, research institutes, NGOs, government and private sectors around the globe and in South Africa as well with regards to RSW management and these studies have directly contributed to this research (Hoornweg & Bhada-Tata, 2012; Bhat et al.2018; Godfrey et al.2018; Jouhara *et al*. 2017; UNEP, 2018; Weghmann, 2017). The City of Tshwane Metropolitan Municipality (CTMM) is responsible for providing RSW services to the Olievenhoutbosch Township. Residential Solid Waste (RSW) difficulties faced by the CTMM are like those faced by fellow authorities in developing countries. The CTMM – in its Integrated Waste Management Plan (IWMP) – points out that one of the major challenges the municipality is faced with is increasing RSW due to urbanisation and rising consumption patterns (CTMM, 2014).

Globally, increasing RSW is one major aspect attributing to other RSW issues that are placing municipalities under pressure as they are overloading the existing systems, mainly collection and disposal (Dhokhikah & Trihadiningrum, 2012; Hoornweg & Bhada-Tata, 2012; Imam et al.2008; DEA, 2018; Oyedele, 2016 & Ferronato et al.2017). For example, it is estimated that by 2050 the amount of generated waste in developing regions (such as the Middle East and South Asia) is expected to double while in Sub-Saharan Africa it is expected to triple (Hoornweg and Bhada-

Tata, 2012). This shows that the existing systems will continue to be overloaded unless zero waste paradigms are adopted.

Global RSW averages vary widely, ranging from 0.11 kg per capita per day to 4.54 kg per capita per day (as illustrated in Table 2.2). Typically, developed countries produce more waste than developing countries. North America and Europe generate relatively more RSW per capita, at 2.21 kg per day and 1.18 kg per respectively. These regions are developed and have high incomes. Developing continents with low to middle incomes generate the lowest volume of RSW per capita. On average, East Asia generates 0.56 kg per capita per day, Sub-Saharan Africa 0.46 kg per capita per day and South Asia 0.52 kg per capita per day (Karak, Bhagat & Bhattacharyya, 2012; Kaza et al. 2018).

Table 2.2: Global ranges of residential solid waste by region

	kg/capita/day		
	Minimum	**Maximum**	**Average**
Countries			
Sub-Saharan Africa	0,11	1,5	0,46
East Asia	0,14	3,57	0,56
South Asia	0,17	1,44	0,52
Middle East and North Africa	0,44	1,83	0,81
Latin America	0,41	4,46	0,99
Europe	0,27	4,45	1,18
North America	1,94	4,54	2,21

(Source: Kaza *et al.* 2018)

Africa's RSW generation rates per capita vary substantially as well. Generation rates are as low as 0.32 kg per capita per day in small cities such as Addis Ababa (Ethiopia) while in other large cities such as Lagos (Nigeria), Lusaka (Zambia), Nairobi (Kenya) and Dar es Salaam (Tanzania) they are 0.95,0.37,0.72 and 0.5 respectively (Godfrey *et al.*, 2018).

The quantity of RSW generated in South Africa is more comparable with those in developed countries than those in developing countries. About 0.7 kg per capita per day of RSW is generated in South Africa, 0.73 kg per capita per day in the UK, and in Singapore it is 0.87 kg per capita per day. Low income areas such as Nepal produce 0.3 kg per capita per day (Nkosi et al. 2013).

Available literature (Ugwuanyi & Isife, 2012; Ekeu-wei, Azuma & Ogunmuyiwa, 2018 & Bhat *et al.* 2018) points out that around the globe, growing urbanisation, improved lifestyles, economic growth and increasing population Gross Domestic Product (GDP) have triggered a rise in the rate of RSW generation. RSW increases with urbanisation; countries in North America with an 80% urbanisation rate produce more RSW waste than those with low (30- 40 %) urbanisation rates such as regions like South Asia and Sub-Saharan Africa (Kaza *et.al.* 2018).
According to Callen (2020) GDP "is composed of goods and services produced for sale in the market, as well as accounting for all of the output generated within the borders of a country. It

measures the monetary value of final goods and services." Several studies (Khajuria *et al.* 2010; Alajmi, 2016 and Gardiner & Hajek, 2017) have proven that there is positive correlation between GDP and RSW generation rate. For instance, studies by Kaza *et.al.* (2018) have demonstrated that RSW per capita in high income areas (high GDP per capita) are high (1.57 kg per capita) compared to those in middle- and low-income areas with 0.61 and 0.43 kg per capita respectively. South Africa waste reports also indicate that there is a link between RSW generation and good services generated; it states that provinces with high GDP are placing pressure on RSW systems due to high RSW per capita compared to those with low GDP (DEA, 2018).

However, Organisation for Economic Co-operation and Development (OECD) (2019) studies rather point out that there is weak correlation between GDP and RSW generation; they found that high income areas such as Finland, Sweden and Luxembourg have high RSW per capita while other high-income areas such as Norway have low RSW per capita and low-income countries like Turkey have high RSW per capita. While there are numerous factors influencing RSW generation there is no firm relationship between GDP and RSW generation as discussed earlier from OECD studies.

Therefore, for waste management authorities to achieve sustainable RSW management, it is essential that they understand the mechanisms of RSW generation and predicting RSW quantities is also essential for them. This will assist the planning and design department of RSW systems to be formulated. However, proper planning and well-designed RSW systems require accurate past, present and future RSW quantity estimates (Dyason & Chang, 2005; Daskalopoulos, Badr & Probert, 1998). Yet, lack of reliable, precise and accurate data on the quantity of waste generated remains a problem. This is generally a huge headache in poor rural regions. Unavailability of accurate data is one of the major obstacles managing authorities are facing. Dyson and Chang (2005) state that inadequate budgets and poor management capacities are a result of a lack of accurate historical data. This compels RSW authorities to make huge assumptions on RSW quantities in data poor environments.

2.4 Current Residential Solid Waste Management Systems

Proper Residential Solid Waste (RSW) management is important for both the public health and environmental sustainability. Yet, it still remains a challenge for developing regions. RSW authorities in developing regions are finding effective RSW very costly, which is a burden to their budget (Guerrero *et al.* 2013). For instance, it is estimated that the management of RSW accounts for about 30% – 50% of municipal budgets (Medina, 2010). On the other hand, lack of essential resources, such as technical skills and knowledge of RSW systems, inadequate human resources and equipment still exist in most cities (Yukalang, Clarke, & Ross, 2017).

At present Residential Solid Waste (RSW) systems in developing countries involve collecting, transporting and disposing waste on landfills, open burning and open dumps with minimal recycling, reusing and recovery (Hettiarachchi, Meegoda & Ryu, 2018; Parrot, Sotamenou & Dia, 2009and Okot-Okumu, 2002). This management mainly focuses on disposing of waste on landfills. Hoornweg and Bhada-Tata (2012) describe it as a "throwing away" approach. Studies point out that this approach is complex and its impacts on the environment and health are quickly visible (Jouhara *et al.* 2017).

The City of Tshwane Metropolitan Municipality (CTMM) uses the same "throwing away" approach described by Hoornweg and Bhada-Tata (2012) which also applies at the Olievenhoutbosch Township. For instance, its waste management services involve collection, transportation, processing, recycling and disposal (CTMM, 2014). The CTMM waste guidelines state that it is the responsibility of residents to apply for RSW containers while the CTMM is responsible for collecting (weekly) and transporting RSW to disposal sites which are the landfills (CTMM, 2016). This system is also used in Nigeria cities (Ogwueleka, 2009). RSW systems in India cities such as Kolkata, Vadodara, Shimla and Mumbai are similar to the CTMM's one. Municipalities in India provide bins from which waste is collected and dumped in landfill sites. However, the only difference is Indian municipalities provide two bins, one for organics and one for inert waste; this is to encourage separation at source (Kumar et al. 2017). Nigeria's municipalities also use this system, which includes the provision of bins, collection and then disposal in landfills (Nzeadibe & Ajaero, 2011).

RSW management systems in developed countries are different to those in developing African countries, including South Africa. For instance, in the Netherlands, the RSW management mainly involves waste composting, recycling and waste incineration (which generates electricity) (Dijkgraaf & Gradus, 2014a), and the municipalities are not only responsible for collection like other countries, but they also need to separate RSW (Milios & Reichel, 2013). Although Ethiopia's RSW system is still similar to those of other developing countries, its capital city has brought about significant improvement in managing waste. For, instance, Addis Ababa, the capital of Ethiopia, is one of the first African countries to add a waste to energy plant to their landfill site, Koshe Dump. The plant incinerates the city's waste while producing energy which is then supplied to the residents (Abebe, 2018).

The RSW system used in developing countries is often not sustainable; for instance, the disposal methods it relies on are environmentally questioned as they contribute to greenhouse gas (GHG) emission (Danthurebandara et al. 2012). Moreover, it does not only contribute to GHG, but it requires a large space (South African Cities Network, 2014b). This is what compelled the Netherlands Municipalities to reduce landfilling of RSW as they have serious shortages of suitable space (Milios & Reichel, 2013).

Regardless of the challenges facing the developing regions, there is an environmentally sustainable way to manage RSW that has been proposed internationally. This approach plays a major role in reducing the amount of waste that needs to be disposed and it uses a philosophy known as Waste Management Hierarchy (Lazarevic, Buclet & Brandt, 2010; EPA, 1998, 2017 and Hoornweg & Bhada-Tata, 2012). Waste hierarchy is an international tool used worldwide to manage waste sustainably; it encourages all waste management stakeholders to reduce, re-use, recycle, treat and dispose waste (Gertsakis, & Lewis, 2003). Throughout the world, waste hierarchy has been widely adopted as a tool that helps in management of solid waste. The value of waste hierarchy has been extensively recognised in various ways under waste management guidelines (Ferrari, Gamberini & Rimini, 2016). Lazarevic, Buclet and Brandt (2010) state that the waste hierarchy is one of the principles that helps with the management of solid waste. Van Ewijk and Stegemann (2016) defined waste hierarchy as a tool that is used to minimize the discarding of solid waste through the aim of ordering avoidance, reuse and recycling before disposing. The above definition can be

interpreted in the way that, if waste hierarchy is properly applied, residential solid waste pollution can be effortlessly reduced. To achieve the reduction in waste disposal, waste hierarchy ranks prevention, reuse and recycling as most important steps to be applied. The idea of managing waste through the hierarchy is by prioritising the approaches, with the highly favoured options being waste reduction (prevention, reuse and recycle) and the disposal option being the least favoured (Price & Joseph, 2000). The terminology used in waste hierarchy is next explained:

- **Prevention/Avoidance:** Waste hierarchy's first approach prioritises waste reduction or avoidance. South Africa first discussed the adoption of the waste hierarchy at the Polokwane Declaration during the Waste Management Seminar which aimed to come up with approaches and strategies to create a sustainable waste management system. It also aimed to reduce waste generation and disposal by 50% and 20% respectively (DEAT, 2001). This stage advocates for manufactures to try as best as possible to have alternate means, or avoid producing certain materials, that can lead to unnecessary solid waste – EPA (n.d.) suggests the avoidance option to minimise generating solid waste by the industries and other stakeholders, including the government.
- **Re-use**: The second step of waste hierarchy is waste reuse, which implies using the already used products or material again for other purposes without pre-processing them first. For instance, old furniture or clothes can be donated to charities or containers used for school projects (New Mexico State University (NMSU), 2014). The already used product/material can still be used for same or different purposes, if it is still in an intact form. Worrell and Reuter (2014) explain that this is that stage which allows the product to be reused for other various functions.
- **Recycle:** Thereafter, if waste cannot be reused it can be recycled meaning it is processed into new material which can be used as raw material for other products (Magram, 2011). This is the stage at which the material can no longer be re-used, but it can be used to re-manufacture the same and new material after processing.
- **Recovery:** Involves recovering materials and using them as fibre, plastic, metal glass and energy (Abdel-Shafy & Mansour, 2018). The material is at the stage where it is unusable; it is at an end point of its life cycle. The recovery approach is where certain materials are being recovered for reuse, recycling and used for energy recovery. David, Thangavel and Sankriti (2019) state that the recovery process helps as the already used products can be recovered,

recycled and used to make other products rather than manufacture new raw materials and make new virgin products. The author further believes that the recovered materials can save industries manufacturing cost.

- **Treatment and Disposal**: Finally, the last resort is waste treatment and disposal. Materials (RSW) are treated to separate the hazardous and to protect the environment and human health, and afterwards the useless materials will be disposed of at the landfill site as the last resort of waste management. (DEA, 2011; Van Ewijk & Stegemann, 2016).

Waste managers around the world have already taken note of the negative impacts of the conventional waste system and are increasingly opting for the waste hierarchy approach. This method has been accepted by almost the entire world (European, African, American and Asia countries) as a sustainable approach in managing waste (Ferrari, *et al.* 2016; Lazarevic *et al.* 2010and Van Ewijk & Stegemann, 2016). In adherence to international standards, South Africa adopted the waste hierarchy as well in order to boost its solid waste management systems. DEA (2013) mentioned that although the waste hierarchy was discussed beforehand, it was only adopted in 2009 after the introduction of NEMWA (RSA, 2004). Waste hierarchy is limited to reduce waste at landfill sites. Van Ewijk and Stegemann (2016) mention that waste hierarchy addresses the minimisation of solid waste to landfill sites through re-use, recycling and recovery only; it does not address the over usage of natural resources and its environmental impacts. However, waste hierarchy also plays a role in preventing environmental pollution rather than to focus only on waste disposal. In 2012, the European Commission agreed that waste hierarchy should not only be used to reduce the amount of landfill waste disposal, but can keep the environment clean as well by reducing solid waste impact (Ferrari *et al*., 2016).

2.4.1 Residential Solid Waste Collection

Existing statistics on RSW collection in developing countries show collection rates and coverages mostly for capital cities and provinces, while statistics specifically for townships, low-income and other disadvantaged areas are limited. For instance, studies by Kumar *et al.* (2017) were conducted in major states (such as Maharashtra, Tamil Nadu, Andhra and Pradesh) of India. This is the same in Africa. A case study conducted by Bello, Bin Ismail and Kabbashi, (2016) focused on African

cities such as Dar es Salaam (Tanzania), Moshi (Tanzania), Kampala (Uganda), Lira (Uganda) and Nairobi (Kenya). This is the same in South Africa where case studies and government reports often report on large cities only. They are very few case studies reporting on townships; hence with this research the aim was to select one of the townships in South Africa (SA) as its case study in order to contribute to filling the gap by shifting the focus to townships.

Collection deficiencies recognised in developing cities are almost similar to the ones reported in South Africa. High collection rates were identified mainly in high income areas while in low income areas collections rates were poor. According to Qotole, Xali and Barchiesi (2001) households without collection services in townships were more than those in the suburbs. In Diepsloot, Alexandra and Soweto, houses which did not have collection services ranged from 60-70%, 40-50% and 50-60% respectively while in suburbs it was as low as 0-10%. However, in 2011 the situation was different in some townships such as Soweto, Khayelitsha and uMlazi where collection rates were 96.5%, 80.9% and 91,4% respectively (STATSSA, 2011). In 2018, RSW collection once per week was dominant in the major cities such as Johannesburg (93%), Ekurhuleni (92%), Tshwane (83%) and minimum in Buffalo City (72,5%) and Mangaung (82,4%). On the other hand, when comparing RSW collection in South African provinces, the collections in Gauteng and the Western Cape were relatively high, ranging from 89% to 90% removals once per week, while in provinces such as Limpopo, the Eastern Cape and Mpumalanga collections ranged from 23% to 43% once per week (STATSSA, 2018).

Additionally, when comparisons are done among developing areas such as Abidjan, (Côde d´ Ivoire), Dakar (Senegal), Nairobi (Kenya), Nouakchott (Mauritania), Yaoundé (Cameroon), Dar es Salaam, (Tanzania) it is clear that collection inconsistencies still exist. The collection rates ranged between 23% to 48%, see Table 2.3 (Parrot *et al.* 2009). On the other hand, Mudzengerere and Chigwenya, (2012) report that RSW is collected once per month in Bulawayo (Zimbabwe).

Table 2.3: Collection rates in developing regions

Region	Collection rate %
Côde d´ Ivoire,	30-40
Dakar (Senegal),	30-40
Nairobi (Kenya	30-45
Nouakchott (Mauritania)	20-30
Yaoudė (Cameroon),	43
Dar es Salaam, (Tanzania)	48

(Source: Parrot *et al.*, 2009).

The Residential Solid Waste (RSW) collection system is more than just collecting waste or transporting it to disposal sites. It is a sophisticated process in the entire RSW system. Beliën, De Boeck and Van Ackere, (2011) define RSW collection as complex processes due to the multiple logistics that are required for it to be accomplished namely transportation (trucks, fuel and maintenance), human labour (human power and their occupational health), organised roads and collection points and planned collection schedules. Other factors that have a significant effect on RSW collection explained by Huang, Pan and Kao (2011) and a study by De Oliveira, Simonetto and Borenstein (2007) include the quantity and composition of RSW and the distances over which RSW is to be disposed of; it is not only sophisticated but an expensive exercise as well (Jacobsen, Buysse & Gellynck, 2013). For instance, according to Or and Curi (1993) and De Oliveira *et al*. (2007) about 75%-80% of RSW budget is spent on collection processes or services. Moreover, the situation in poor regions was reported to be worse compared to middle income regions. For example, it is estimated that 80-90% and 50-80% of RSW budget in low income and middle-income countries respectively, is spent on collection systems (Hoornweg and Bhada-Tata 2012). Knowledge, understanding and investigation of factors that affect collection waste are essential as they may assist waste authorities to plan, design and select for the most effective and suitable collection system (Abdel-Shafy and Mansour, 2018).

Residential Solid Waste (RSW) collection in several countries (Belgium, Iran, Netherlands and Ethiopia) is the responsibility of government and municipalities (UN-Habitat, 2010; Jacobsen *et al*. 2013; Moghadam, Mokhtarani and Mokhtarani, 2009; Dijkgraaf & Gradus, 2014b, p. 287;

Lema et al. 2019). This is also the case in South Africa as well; municipalities are responsible for providing RSW collection services (Africa, 2010). Yet, due to the pressure that the government and municipalities are under as a result of rising population, urbanisation and increasing RSW generation rates, coupled with deterioration of the environment's ecosystem resulting from uncollected waste and inability to cover all the residents, municipalities have been unable to respond to these challenges. Hence, a search for other possibilities was necessary (Ogu, 2000). Consequently, private companies have stepped in to assist municipalities (Kassim & Ali, 2006). In Ghana for example, the Accra Metropolitan Municipality City (AMMC), was compelled to fully privatise its RSW collection due to financial implications (Obirih-Opareh, 2002 & Oteng-Ababio, 2010). RSW collection privatisation is also practised in cities such as Dar es Salaam, Tanzania (Kassim & Ali, 2006), the Flemish region of Belgium (Jacobsen *et al.* 2013), Hyderabad in India (Post, Broekema & Obirih-Opareh 2003) and Addis Ababa in Ethiopia (Tilaye & Van Dijk, 2014). Private sector involvement in RSW collection is also available in SA; municipalities contract private companies for RSW collection and management of disposal sites (DEA, 2012).

Although there are private companies assisting with RSW collection services, developing countries are still faced with multiple challenges regarding this matter. Collection coverage and collection rates are still poor and low. This section discusses the current collection rates and collection coverage around the globe. Hoornweg and Bhada-Tata (2012) explain collection coverage as the percentage of residents with access to RSW collection services and collection rate as a fraction of waste collected from households to waste generated.

RSW collection coverage in parts of Africa varies widely; they are as low as 25% and in some African cities in Nigeria, Tunisia and Ghana are as high as 80%, 96% and 99% respectively as illustrated in Figure 2.2 (UN-Habitat 2010; Getahun et al. 2012 and Madinah, Boerhannoeddin & Rriffin, 2014).

In South Africa, according to STATSSA (2011), the collection coverage is about 66%. The proportion of households whose RSW was collected once per week increased from 56.1% in 2002 to 64.7 % in 2018 while the fraction of households that had no RSW facilities, or had to dump anyway on communal rubbish dumps decreased (STATSSA, 2018).

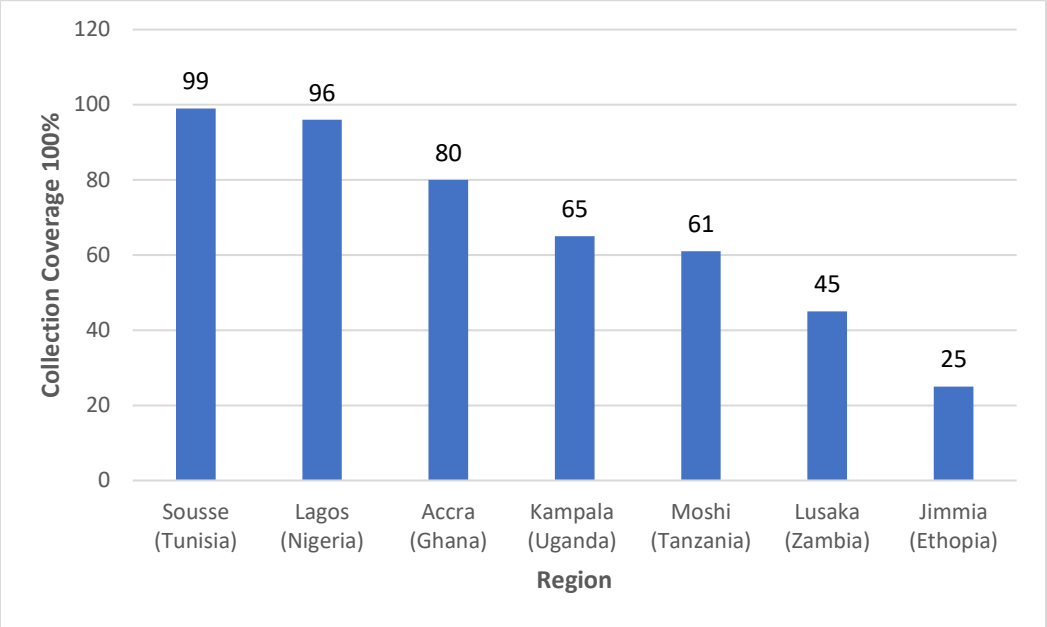


Figure 2.2: RSW collection coverage in some African cities

(Sources: Getahun *et al.* 2012)

Similar to any other developing countries, there are some areas in South Africa which are still not covered, but coverage has been improving since 1996. According to STATSSA (2011) the number of households that has RSW collection coverage by local authorities has been increasing since 1996. The collection coverage in SA has indeed been improving, households without RSW collection coverage have been declining since 1996. For instance, in 1996, 9.7% of households were without waste services, but in 2001, 2007 and 2011 the collection coverage declined from 9.7% to 8.5% to 7.1% and then to 5.4% respectively.

Figure 2.3 shows the percentage of households that has RSW collection services and where their RSW was collected by local authorities on a weekly basis, have been increasing from 52.1% to 55% to 59.9% to 62% in 1996, 2001, 2007 and 2011 respectively. Households which depend on communal waste collection decreased from 2.2% in 1996 to 1.5 in 2011.

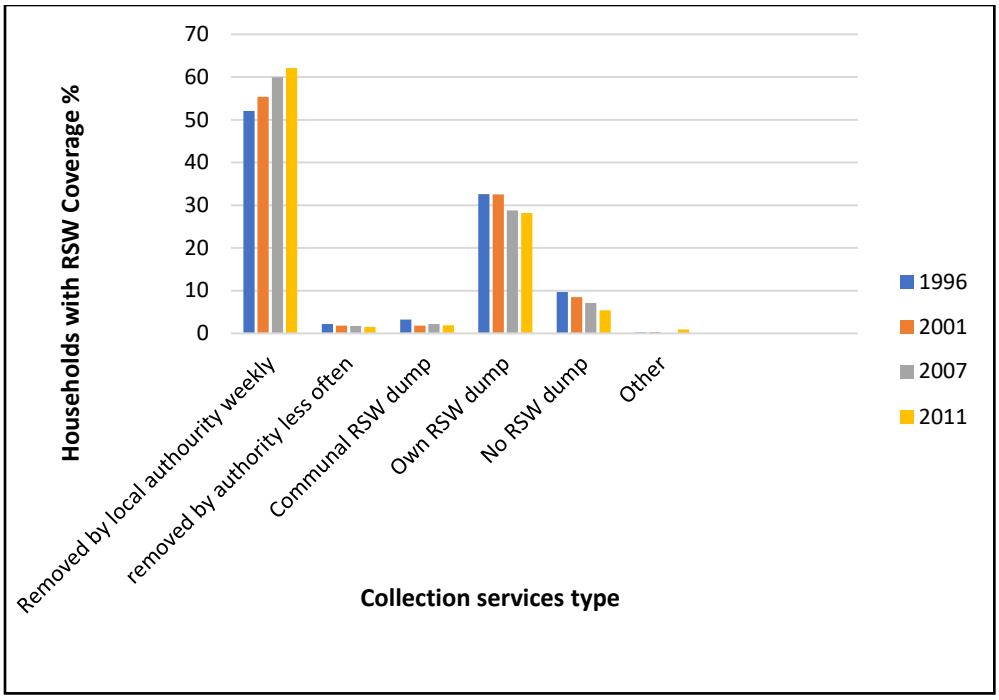


Figure 2.3: Proportion of households with RSW collection coverage in South Africa
(Source: STATSSA, 2011)

Looking at the collection coverage records in African countries, listed in Figure 2.4 and the South African (SA) collection coverage statistics in figure 2.6, it shows that SA collection coverage is low compared to some of the countries. However, this is because figure 2.3 shows the collection coverage in major African cities only, while figure 2.6 represents the entire country. Yet, collection coverage in SA major cities is quite high; it ranges from 98.7% to 94.4% as shown in figure 2.4. (STATSSA, 2011). However, collection in Tunisia is almost 100%. These records show that there is still some RSW waste that is not collected in major cities.

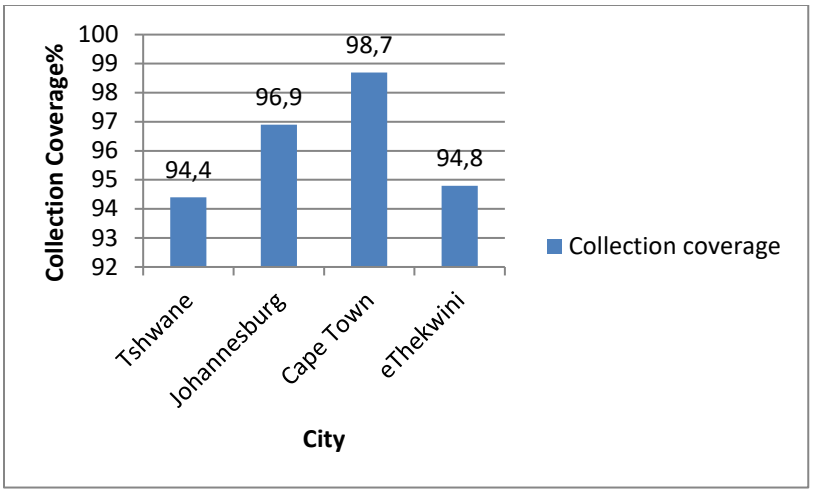


Figure 2.4: Collection coverage in South Africa's major cities
(Source: STATSSA, 2011)

In most African countries about half of the RSW generated is not collected – as illustrated in Figure 2.5. In Sub-Saharan Africa for example, collection rate ranges from 43% to 55%. However, the collection rate varies widely across Africa, for instances in some western and eastern parts of the continent the collection rate is below 42% while in some northern parts it is above 85%. There is a huge discrepancy between the collection percentages reported in South Africa's major cities (illustrated in Figure 2.4) and Africa (Figure 2.5) as continent. The reason may be that statistics shown in African context show averages of each country while figure 2.4 shows major cities in South Africa. Moreover, RSW services' inconsistencies can also be noted within South African areas; there was a huge inconsistency among metropolitan, urban and rural areas reported in a 2018 household survey. RSW was removed once per week more in metropolitan and urban areas than in rural areas. In Gauteng Province – with regard to some 90% households in metropolitan and urban areas – their RSW was removed once per week, while in rural areas only 32% had their waste removed once per week in 2018 (STATSSA, 2018).

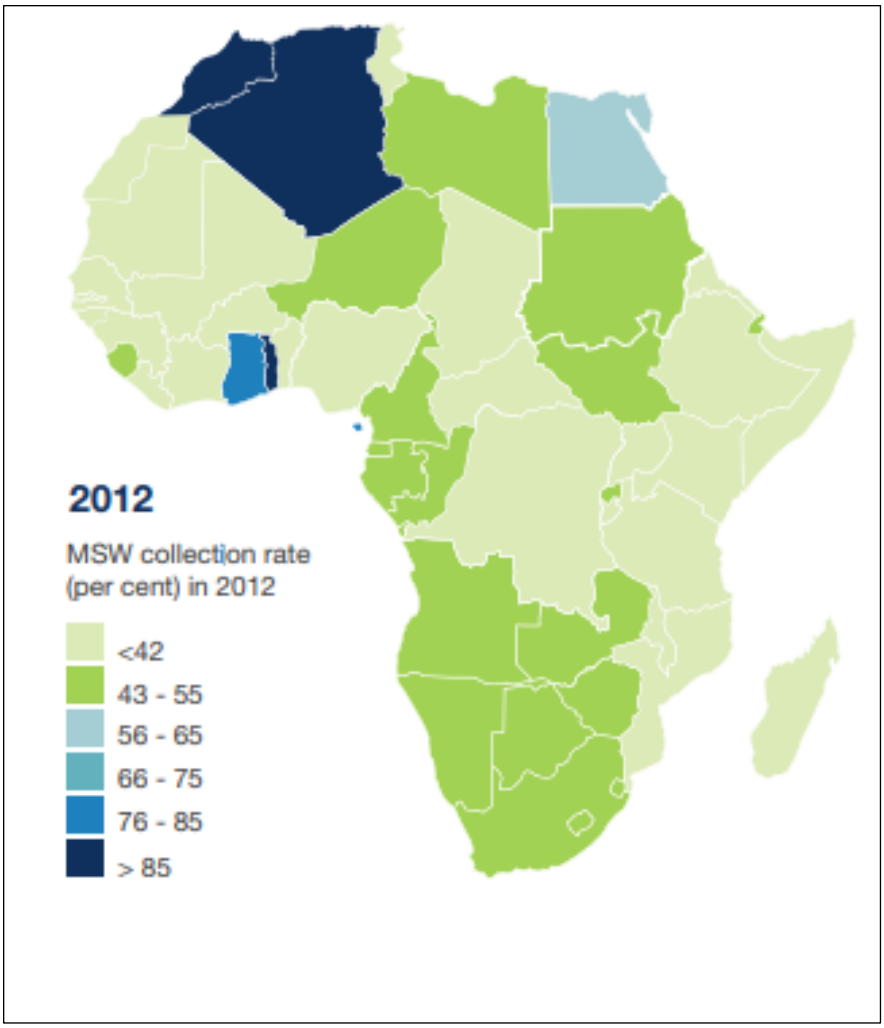


Figure 2.5: RSW collection rate in Africa

(Source: Hoornweg and Bhada-Tata, 2012)

Economic status has a huge impact on RSW collection rate. It has been reported that the collection rate in high income areas is higher than the ones in low income areas. For instance, the collection rate in low-income areas such as Yaoundé and Benin can be as low as 43% and 45% respectively, while in high income areas in Asia such as Hong Kong it is extremely high (100%) (Parrot *et al.* 2009 and Hoornweg and Bhada-Tata, 2012).

The abovementioned studies report collection rate statistics in urban cities, or capital cities in developing regions, and subsequently the question arises what the state of collection rate in townships or rural areas is if urban cities are still faced with low collection rates. This is supported

by studies by Couth and Trois (2011) that highlights that RSW is a problem in peri, or semi urban and rural areas. Boateng et al. (2016) point out that urban areas often enjoy better RSW services than other areas such as semi urban and rural areas.

2.4.2 Residential Solid Waste Disposal

Despite the huge investments made in RSW management some systems such as RSW disposal are still a threat to environmental sustainability in developing regions. The absence of, or inadequate continuous RSW collection services, are still existing problems in developing regions (Abdel & Mansour, 2018). In some areas it is even worse as uncollected waste is visible in open spaces, rivers and streets (Adeoye et al. 2016). High RSW collection tariffs, lack of accessible, convenient and cheap RSW facilities, poor waste routine collection and unenforced laws, are reported to be some of the causes of illegal dumping (EPA, 1998; Curtis & Cowee, 2010). On the other hand, if disposal systems are available, they are under stress as their capacity is being overloaded due to rising volumes of generated RSW (Yoada *et al.* 2014).

RSW disposal methods differ across the world. There are different kinds of disposal methods that are currently used around the globe namely composting, landfilling, incineration, open dumping, open burning and recycling (UNEP, 2018). The RSW disposal method used by waste authorities depends on geographical and geological conditions, financial resources and the willingness of the relevant governments. For instance, certain methods require large land or more water or energy. A lack of sufficient funding can greatly impact the type of disposal method Moreover, RSW composition plays a role in the disposal method selection. Asian regions' RSW is mainly comprised of 70-80% of organic material, therefore compositing is considered the most efficient method to handle the RSW generated as it decreases the volume of quantity of waste to be transported and disposed of (Narayana, 2009). Landfills are ineffective in countries such as the Netherlands as they require large areas (Dijkgraaf & Gradu, 2014b).

Figure 2.6 shows disposal methods throughout the world. Landfilling of waste is the most common method used across the globe: 40% of RSW in the world ends up in landfills (Kaza, *et al.* 2018). Only 18 % is recovered by means of recycling and composting and 11% is treated through incineration. On the other hand, 33 % is still disposed of in open dumps (Kaza, *et.al.*, 2018).

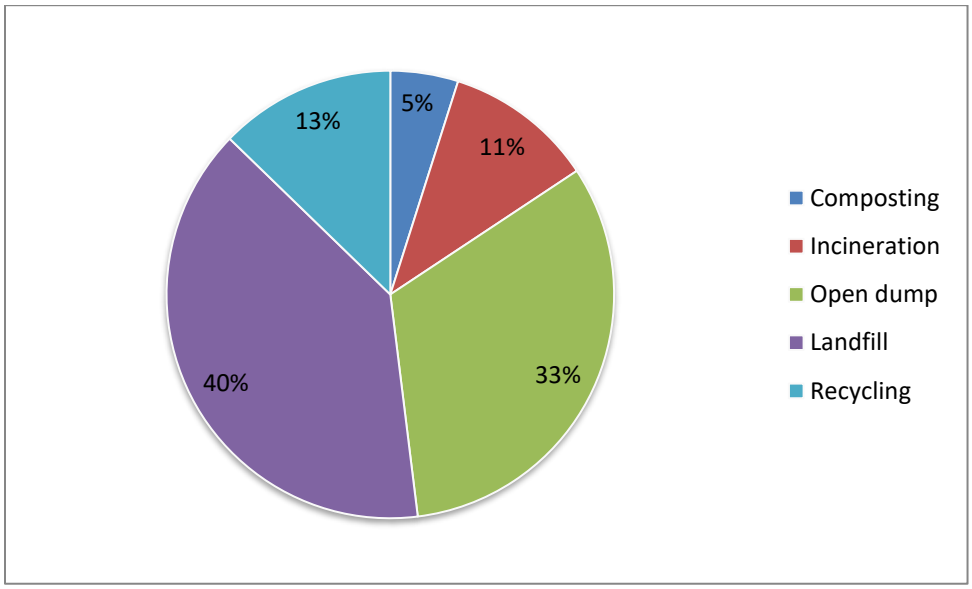


Figure 2.6: RSW disposal methods around the globe
(Source: Kaza, *et al.* 2018)

In Africa, controlled and uncontrolled landfills are a common method used for disposing of RSW. A large quantity (47%) of waste in Africa ends in open dumps, while 29% is buried in landfills. The average recycling in Africa is currently 4% while incineration stands at 2% (UNEP, 2018). The UNEP (2018) reports further state that recycling data in Africa is still a problem as it is conducted mainly by informal waste pickers which are difficult to track. Landfilling is also common in Sub-Saharan Africa countries such as Botswana, Zimbabwe and South Africa (Remigios, 2010). Figure 2.7 shows the disposal methods in Africa. About 90% of waste in SA is buried in landfills (DEA, 2018). The CTMM also disposes its RSW in landfills.

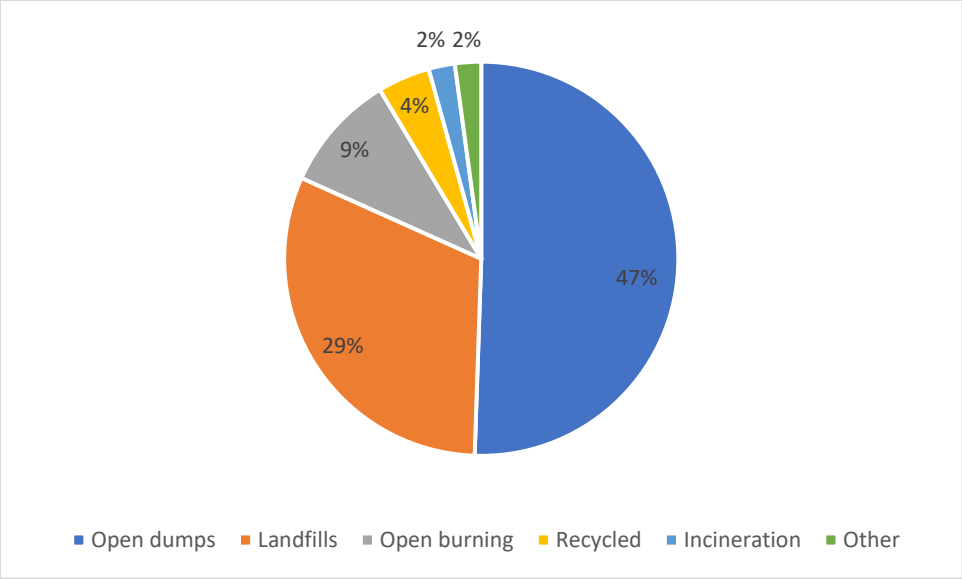


Figure 2.7: RSW disposal methods in Africa

(Source: UNEP, 2018)

The economic status of a country also plays a major role in the type of disposal method used, see Figure 2.8. Low income areas and lower middle-income areas mainly rely on open dumps (63%-93%) while high income and upper middle-income regions were found to rely primarily on landfilling. Most (54%) of the RSW in upper middle-income regions end up in landfills; this rate is lower (39%) in high income areas and some of their RSW is recycled (35%) while 22 % is incinerated. Incineration is mainly done in high income areas while in lower income areas regions, recycling, compositing and incineration are extremely limited (Kaza *et al.* 2018 and Hoornweg & Bhada-Tata, 2012).

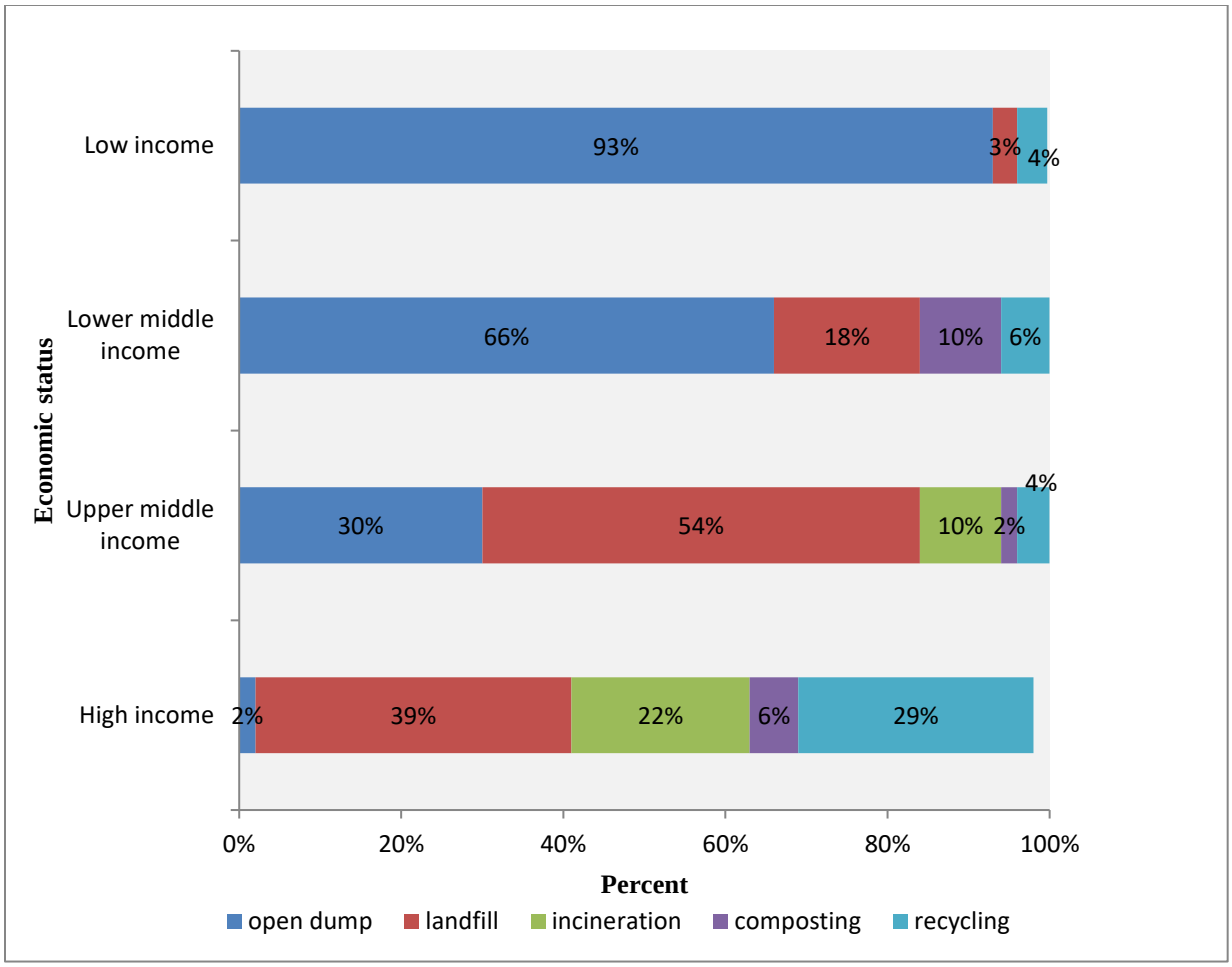


Figure 2.8: Disposal methods according to income

(Source: Kaza *et al.* 2018)

Nevertheless, countries are attempting to adopt a new paradigm which focuses on producing zero waste. Governments, Non-Governmental Organisations (NGOs), private companies and locals are involved in achieving this goal. The Netherlands government has introduced the landfill tax in order to encourage recycling and waste reduction (Parvez, Agrawal & Kumar 2019). In Nigeria a waste recycling and treatment project was initiated in 2006.

– known as the Ondo State Integrated Waste Recycling and Treatment it aims to minimise all waste (RSW, agriculture and industrial) and encourages waste separation at source and this waste is then recovered to create things like fertilizers (from organic waste) and raw materials for plastic industries. This project is effective, and the City of Ondo waste stakeholders are reaping the benefits which are employment, a clean city and reduced disposal costs (Olanrewaju & Ilemobade, 2009). Asian countries such as Sri Lanka, in a municipality known as Maharagama, have been encouraging residents to separate waste (Visvanathan & Tränkler, 2003). In China residents sell their recyclable materials to buyers known as "door to door waste buyers" and some take them to recycling industries themselves (Mian et al. 2017). South Africa, like other countries, also recognises the importance of recycling in its waste management plans. For instance, some local municipalities have drop-off recyclable centres while private companies such as Collect-a-can, Nampak, Sappi Refibre, Mondi Recycling and MPact are also playing a role in reducing waste to be disposed of by providing kerbside collection programmes and drop-off locations (DEAT, 2000). This programme's main aim is to recover, reduce, reuse and recycle waste. This paradigm protects the environment by reducing the quantity of waste that has to be buried or disposed to ground.

Moreover, it is advantageous to the economy as it creates employment for the citizens (Zaman & Lehmann, 2011). Yet, developing regions such as Africa still find it difficult to recycle, reduce and reuse their waste. For instance, the recycling rate in Africa is extremely low – only 4% of generated waste is recycled, as shown in figure 2.7.

It is reported that in most developing regions waste is recycled by Informal Waste Pickers (IWP) (Idris, Inanc & Hassan, 2004). IWP are known as people who collect and sort recyclable material which is then sold to buy back centres and recycling companies in order to earn some income for their survival (Blaauw et al. 2020). It has been established that most IWP are disadvantaged groups – such as unemployed immigrants, children and women (Medina, 2008). As unemployment rates continue to rise in developing countries, waste picking has become an employment opportunity to those with limited formal education and skills (Wilson, Velis & Cheeseman, 2006 and Schenck & Blaauw, 2011). Medina (2008) estimates that about 1% (which is some 15 million people) of the population in developing countries rely on informal recycling. Even though IWP are mostly dominant in developing countries (Gupta, 2012), they are present almost everywhere; Scheinberg

and Anschüt (2006) reports that there are informal waste pickers in Paris, Harare, New York, Bangkok, Melbourne and Tegucigalpa.

Informal Waste Pickers (IWP) are one of major stakeholders that plays a major role in the waste management hierarchy. Studies point to the fact that IWP reduce overall collection and disposal cost for waste authorities. For instance, Limo (Peru), Cairo (Egypt), Quezon City (Philippians) and Pune (India) municipalities save some $17.48 million, $16.05 million, $4.66 million and $2.44 million respectively for collection and disposal (Gupta, 2006). Their benefit is also seen in South Africa where they save municipalities about R750 million for landfill operational costs (DEA, 2019).

Informal Waste Pickers (IWP) around the globe contribute to environmental sustainability. Yet, in some countries they are still overlooked. For example, in the past South Africa's National Waste Management Strategy (NWMS) banned IWPs on municipal landfill sites (DEA, no date). However, in 2011 DEA acknowledged the importance of IWP in the recycling process in their National Waste Management Strategy by aiming to formalise IWP and to provide municipalities with guidelines that would govern waste pickers (DEA, 2011). Although IWP are not yet legally recognised in SA by other municipalities, in City of Johannesburg with the help of Pikitup[1], a service provider that provide waste management services mainly collection of RSW (Pikitup, no date) has implemented a number of projects to assist IWPs and incorporate them within the municipality`s waste management plan (Waste et al. 2020). Other countries such as India, Argentina and Colombia also have projects that attempt to incorporate IWP in formal waste picking (ILO, 2009). Brazil on the other hand, is one of the first countries that so far legally recognises IWPs – in 2001 informal waste picking was included as an occupation in Brazilian Occupation Classification (BOC). This was even supported by Presidential Decree 5940/06 which fully recognises the contribution provided by IWPs and hold the point of view that they should be remunerated (TGAWP, no date).

[1] http://www.pikitup.co.za/about-pikitup

Despite the good impact informal recycling has on the economic status of IWPs, there are also negative issues which come into play. IWPs work under harsh conditions and occupational health risks may result from sorting or picking toxic or composing waste, while on the other hand accidents may occur on roads as informal recyclers often lift or shovel their waste along on roads carrying volumes of traffic (Wilson *et al.* 2006). Additionally, it was found that IWPs receive scant remuneration from formal waste recycling centres (Nzeadibe, 2009; Fergutz, Dias & Mitlin, 2011; ILO, 2009). Considering the importance and the role of IWPs in waste management systems it is undoubtedly true that if Governments, NGOs and private concerns could collaborate to create policies and guidelines that govern IWPs and include informal waste picking in their waste management systems, the livelihoods of the disadvantaged could be improved.

2.5 Impact of poor RSW on the environment and local people

Environmental pollution due to lack of environmentally safe disposal methods poses problems in and around low-income areas. For example, landfills and open dumps are some of the widespread methods used in developing countries (Hoornweg and Bhada-Tata, 2012). South Africa and most developing countries are still relying on landfilling. Almost all the waste in South Africa is dumped at landfill sites (DEA, 2018). This can be substantiated by Rasmeni and Madyira (2019) who found that all townships around the City of Johannesburg (CoJ) rely on four landfill sites of which two have already been closed. Landfilling is also practised by other developing countries such as Cameroon (in Yaoudė) (Parrot *et al.* 2009) and Ghana (in Bawku) (Douti, Abanyie & Ampofo, 2007).

The impact of improper management of RSW is already observable in some areas. The lack of proper RSW systems has an adverse effect on both environmental sustainability and human health (Batool & Chuadhry, 2009; Misra & Pandey, 2005; Ayomoh et al. 2008). For instance, illegal open dumps on roadsides and in open spaces, as well as open air burning dumps, blocked drains and sewers, polluted water bodies (rivers, dams and streams), death of livestock due to the consumption of plastics, and unpleasant smells in residential areas are some of the visible impacts of poor RSW management (Mohammed & Elias, 2017; Ramachandra & Bachamanda, 2007; Ampofo, Soyelle & Abanyie, 2016; Ejaz et al. 2010; DEA, 2018). In addition, Hamer (2003,)

points out that uncontrolled RSW is a risk to human health as it has the potential to spread diseases. The potential impacts of poor RSW management are discussed in this section.

2.5.1 Impact of poor RSW management and systems on the environment

Proper RSW is of the outmost importance due to the risk it poses to the environment. Ejaz *et al.* (2010) state that poorly managed solid waste systems play a role in degrading the state of the natural environment. If the entire cycle (collection, transport and disposal) of RSW management systems fails, the environment will be at high risk of being degraded.

Impacts of collection inefficiency and poor collection services

A large percentage of municipal revenues is spent on collection systems (Or & Curi, 1993). Yet, RSW collection services and collection efficiencies in some areas are still low, especially in developing countries. According to Hoornweg and Bhada-Tata (2012), low income areas' collection services and efficiencies are worse when compared to high income areas. Moreover, authorities in developing countries are under pressure and unable to handle a large volume of waste which is caused by growing populations (Khajuria *et al.* 2010). All this suggests that RSW in most poor areas remains mainly uncollected. Uncollected waste is a threat to the environment. When RSW is not collected residents often opt for other methods such as disposing of their waste in open areas, along roadsides or even in rivers if they are close by. This is supported by a case study by Nazerry Rosmady and Abdul Haqi (2007) that found that all residents interviewed were of the opinion that lack of proper collection services forces them to dispose of their waste in open areas (along roadside or in rivers) as they do not wish this waste near them. This is known as illegal dumping. EPA South Australia (2018) defines illegal dumping as the discarding of waste into land or water without consent from the authorities. The impacts of illegal dumping on the environment are numerous and can compromise the health of people. For example, the study conducted in Rawalpindi City by Ejaz *et al.* (2010) found that illegal solid waste dumping was the source of flooding due to drain blockage, breeding of flies in open dumped solid waste and open burning of waste lead to hazardous gases being emitted, and many more factors that originate from illegal dumps. Poor collection services lead to illegal dumping which eventually results in water and air pollution, and land degradation. Ejaz *et al.* (2010) also mention that unsatisfactory environmental conditions are due to improper waste collection.

Impacts of disposal methods

It is not only collection services and collection efficiency that affect the environment, but the types of disposal methods also have an impact on environmental stability. As mentioned in the previous section there are different methods used to dispose of waste and these include approaches such as landfilling, open dumping, open burning, incineration and composting, and other approaches that promote zero waste such as reusing, recycling and recovery. Most of the traditional methods are a threat to our environment. For instance, greenhouse gases (methane and carbon dioxide) and leachate, are some of the landfills' by-products that pose a threat to the environment. By-products from landfills have the potential to cause groundwater pollution, air pollution, global warming, odour, fire explosions and plant degradation (El-Fadel, Findikakis, & Leckie, 1997; Chofqi *et al*. 2007; Kotovicová et al. 2011). Methane and carbon dioxide are some of the greenhouse gases that contribute to global warming. Moreover, as methane is flammable, this can be emphasised by incidents of fires and explosive resulting from landfills gases that have been reported (Emberton, & Parker, 1987; Wiwanitkit, 2016).

Leachate from landfills is hazardous to groundwater quality; if it percolates through the soil and reaches the water table the quality of groundwater will be compromised. For example, a study that was conducted in Moroccan Wells for three years (from 1999 to 2002) showed that the groundwater quality for wells that were near landfills, or located down gradient of the landfills was deteriorating and parameters such as conductivity, sulphate, chloride and cadmium were higher than that of the drinking water acceptable standards (Chofqi et al., 2004). The impact of disposing waste on open dumps and burning waste in open areas is almost similar to that caused by landfills. Water, air, vegetation and soil pollution are common in this type of disposal methods (Ali et al. 2014).

Irrespective of impacts associated with improper RSW management some developing regions are also still characterised by inefficiencies in waste collection, inadequate collection services, open dumps and uncontrolled landfills. There are some regions in Ethiopia, Nigeria, Pakistan and South Africa that are still without adequate and efficient collection services. This place the ecological state of the environment at risk. A study done in Islamabad City, Pakistan, focused on the impact of open dumping on soil and vegetation and showed that the soil and vegetation species near open

dumps were found to be contaminated by leachate which contained heavy metals such as lead and potassium (Ali *et al.* 2014). The effects of inadequate RSW collection are also experienced in cities such as Addis Ababa (Ethiopia). It is reported that due to lack of RSW collection systems, residents opt for uncontrolled open dumping and it was found that a drinking water source such as the Aba-Samuel Dam was heavily polluted with RSW (Mohammed & Elias, 2017). Also, a study conducted in Ghana has found the Korle lagoon to be one of the most polluted water bodies in the world and one of the contributors to this pollution was RSW which was disposed of into the lagoon, as well as nearby landfill leachate. For instance, it was found that the water quality was poor as its biochemical oxygen demand (which indicates the organic matter) was extremely high and was deteriorating (Boadi & Kuitunen, 2002). Groundwater qualities are also affected by landfills and open dumps, for instance an assessment of ground water quality was conducted in an area characterised by RSW uncontrolled dumps in Calabar which is situated in the east part of Nigeria. Results indicated a positive correlation between the number of waste dumps and pollutants (pollution indicators that were used) and moreover, it was established that ground waters with shallow water tables were highly polluted (Ugbaja & Edet, 2004). Moreover, studies by Nkwonta, and Ochieng (2009) found that almost 50% of residents still dispose of their waste in a township river in the area known as Shoshanguve in Tshwane, South Africa. It was further reported that South Africa's landfills emit about 43 m^3 millions of methane annually (DME, 2004). Methane is one of the greenhouse gases that contributes to global warming. The City of Tshwane, where the Olievenhoutbosch study area is located, still deposits almost all their waste at landfills as well. This means the City is also faced with the environmental hazards and risks that RSW poses that were discussed previously.

2.5.2 Health implications because of poor RSW management

Inadequate RSW facilities and poor RSW systems mainly storage, collection and disposal systems are a threat to human health. Failure to provide these systems often leads to uncollected waste scattered all over; subsequently this attracts vectors such as flies and rats which then spread diseases. The RSW content, especially food leftovers, decompose and emit unpleasant odours. If all this comes into contact with humans, especially vulnerable groups such as children, informal waste, people living near waste dumps and sick people, it will cause serious health complications (Gogoi, 2013; Alam & Ahmade, 2013; Zurbrugg, 2003; Puri, Kumar & Johal, 2008).

Cointreau (2006) points out that all RSW management activities – collecting, sorting and disposal – have health implications, which are hazardous and risky to human health. Despite the health risks associated with improper RSW handling, developing countries are still characterised by poor RSW management systems. Large amounts of waste are still not collected, and if it is collected, disposal methods are uncontrolled creating a hazard to human health. This then can affect anyone's health. Yet, most studies focus on population living near waste dumps, landfills and residents with a poor RSW system while overlooking those who work with it, which are formal and informal waste pickers. Studies state that formal waste pickers are often protected compared to informal waste pickers. Formal waste pickers are normally provided with training, hygienic tools and personal protective equipment (PPE) while informal waste pickers are not provided with any protective gear (Schenck et al. 2019). Table 2.4 lists the health and safety impacts experienced by waste pickers around the globe. This shows clearly that the health of informal waste pickers is at risk. They may sustain injuries from bottles and these cuts may become infected as hygiene is often overlooked – such infections eventually may prevent them from being able to work.

Table 2.4: Health and Safety implications for Waste Pickers around the globe

Prevalence	Seriousness
Joint pain	1. Infectious diseases
Injuries/cuts	2. Respiratory issues
Respiratory issues	3. Skin Infection
Gastrointestinal disorders	4. Gastrointestinal disorders
Fatigue	5. Injuries/cuts
Skin infection	6. Joint pain
Infectious diseases	7. Fatigue

(Source: UNEP, 2013)

2.6 Environmental governance on solid waste management

Good environmental governance can promote sustainability. Conversely, poor environmental regulation or legislation can cause serious problems, for intake, public health and environmental sustainability can be threatened. Thus, countries have designed legislatives documents that govern

waste management that requires authorities and citizens to take measures and decisions that will minimise, reduce and control waste in order to protect people, public health and promote environment sustainability. Almost all countries have laws or legislation dealing with waste management (Mohee & Simelane, 2015). According to Okot-Okumu (2012) most East Africa countries (EAC) currently have legal frameworks and policies for waste management. Zimbabwe's waste is governed by two legislations which are the Environmental Management Act 13 of 2002 Chapter 20:27 (Republic of Zimbabwe, 2002) and the Urban Council Waste Act 22 of 2015 Chapter 29:15 (Republic of Zimbabwe, 2015). Kenya has several laws that govern solid waste, including the Waste Management Bill 2019. In India waste is regulated by Article 47 of the Directive Principle of State Policy Constitution and Environment Protection Act 1986 (Karthikeyan et al. 2018). In Europe, the European Union countries drafted the waste policies to which their member countries must abide and accomplish. The policies include various ways of managing different types of waste. Some of the traditional policy targets include the Landfill Directive (European Communities (EU), 1999), Packaging and Packaging Waste Directive (EC, 1994) and Waste Framework Directive (EC, 2008) in which all work together in managing the environment. The same applies to Asian countries – they too have measures to prevent environmental degradation from improper waste management. Terazono et al. (2005) claim that some Asian countries introduced the legislation for solid waste long ago; however, Malaysia, Thailand and Indonesia only have regulations for hazardous/toxic waste.

South Africa also has numerous legislations that govern waste management, and they are listed below:

- The Constitution
- Air Quality Act (Act 39 of 2004)
- Environment Conservation Act (Act 73 of 1989)
- Health Act (Act 63 of 1977)
- Municipal Structures Act (Act 117 of 1998)
- Municipal Systems Act (Act 32 of 2000)
- National Environmental Management: Waste Act, 2008 (Act 59 of 2008)
- National Environmental Management: Waste Amendment Act, 2014 (Act 26 of 2014)
- National Water Act (Act 36 of 1998)
- Occupational Health and Safety Act (Act 85 of 1993)

- The National Environmental Management Act (Act 107 of 1998)

The South African government made sure that its people and the environment enjoy each other's benefits and protection. This is highlighted by the fact that various laws safeguarding the environment and people have been included in all three spheres of government (National, Provincial and Local). These laws include Section 24 (a) and (b) of the South African Constitution (RSA, 1996) which outlines the right for everyone to have an environment that is not harmful and also gives everyone the right to have an environment that is protected (DEA, 2016, p. 4). South African legislation regarding solid waste consists of various laws in the form of acts that guide, protect, minimise and prevent the impacts that can be triggered by waste, including residential solid waste. These acts were drafted in a way that covers a wide range of areas of the environment that can be impacted by solid waste. Meanwhile, South African waste management is guided by the Waste Act (59 of 2008) (RSA, 2008). The purpose of this Act is to achieve the reduction of waste through minimisation, reusing and recycling before disposal. Moreover, the legislation on waste management does not focus on the environment and people's health only – it also has measures that regulate and monitor private institutions to avoid polluting environmental spaces. For example, the waste legislation also includes more Acts that support each other; these include the Environmental Conservation Act 73 of 1989 National Environmental Act 107 of 1998 and the National Water Act 36 of 1998.

Chapter 7 of the Constitution (RSA, 1996) lends power to the municipalities and allows them to pass laws known as by-laws which align with the National and the Provincial government. In South Africa, the RSW is managed by the local government (municipality) – this covers transportation and landfilling of solid waste. The principles of the municipal by-laws are to encourage the residents to practice reasonable sound waste management, to protect their environment and promote sustainable environmental development through fair solid waste management. Moreover, all the by-laws have been established to help solve the challenges society faces in relation to solid waste. The National Environmental Management Act (NEMA) (RSA, 1998) is the embodiment of the entire Act that oversees the environment, and it is also part of the municipal by-laws.

NEMA 107 of 1998 (RSA, 1998) plays the role of being an "environmental lawyer" in which it guides, informs, acts on potential polluters and issues the type of remedial action to be taken. For example, the fines and type of punishment meted out to those who are found guilty of polluting are included in the NEMA ("the polluters pay" principle).

Much is being done to protect the environment. Environmental laws are some of the important government tools which decision makers and all relevant stakeholders can apply to protect public health and to promote both social and environmental sustainability. Yet, developing countries are still characterised by weak regulatory organisations, corruption, lack of political will– all factors which are hindering law enforcement (Ekhator, 2014). In addition, NEPAD (2018) stresses that environmental crime and corruption is still a huge problem in Africa. Studies point out that people involved in these environmental crimes often benefit from low penalties, or no penalties at all, fraudulent licences or agreement. The sad part is that criminologists report that most of the people involved in crimes are police officers, politicians, government and local officials (Simon, 2000; NEPAD, 2018).

Laws and regulations regarding environmental management are documented but their enforcement in many countries, especially developing countries, is still a problem as some of their environmental laws are unsatisfactory (Oyedele, 2016). Enforcement authorities and organisations in Nigeria report that current legislative aims are not being achieved as there are still some conflicts in roles and responsibilities in environmental management and acts of non- compliance still go unpunished (Ijaiya & Joseph, 2014).

These challenges include low-level constitutional provision for environmental protection, roles and conflicts in environmental management, undue adherence to legalism by the courts and absence of mandatory disclosure of information. Thus, the legislative objectives remain unachieved because enforcement is superficial; excessive time exists between non-compliance and enforcement; available punishment for non-compliance is inadequate; injured parties are not properly compensated; and some environmental crimes receive administrative instead of remedial measures or criminal punishments.

2.7 Residents' attitudes and perceptions on Residential Solid Waste Management (RSW)

Recycling is considered as a sustainable option in the solid waste management (SWM) hierarchy. Hence, countries around the globe are adopting a range of policy measures to increase their recycling rates (Nzeadibe & Adama-Ajonye, 2013). The African Union 's aim is to ensure that by 2023 African cities recycle about 50% of waste generated (Godfrey et al. 2019). South African National Domestic Waste Collection Standards encourage separation at source (i.e. households) and it further encourages municipalities to provide households with recycling opportunities such as providing kerbside collection or drop-off centres where said households can drop their recyclable waste (DEA, 2011). The Kenyan National Solid Waste Management Strategy also encourages Kenyans to recycle all their recyclable material to reduce the quantity of RSW to be disposed of in landfill sites (NEMA Kenya, 2015). Moreover, municipalities in the Netherlands are obliged to provide infrastructure for separating paper, glass and textile at source (i.e. households) (Dijkgraaf & Gradus, 2014a). From the abovementioned policies municipalities should have effective separation at source recycling programmes for residents and they must be involved to ensure that designed programmes fit their demographics and lifestyles. Hence, residents' perceptions and attitudes need to be considered.

Reviewing resident's attitudes and perceptions on Residential Solid Waste (RSW) management and the impact on environment was one of the research objectives for this thesis. Residents play a major role in RSW management systems. Studies point out that understanding residents' attitudes, behaviours and habits towards RSW is a prerequisite and essential to effective RSW management (Solomon, 2011; Zurbrugg, 2003). For this reason, RSW authorities (such as policy and decision makers) and service providers (public and private) are required to know and understand their residents (which are their customers) as this can provide them with valuable inputs that can be used in designing apt RSW management strategies. Moreover, Solomon (2011) and Ancog, Archival and Rebancos, (2012) state that improving RSW systems, such as collection or shifting to new paradigms such waste hierarchy (recycling and reusing), require residents' participation as they undoubtedly will have to change their existing habits and behaviours and adapt to new ones. Therefore, residents' attitudes and perceptions, as well as their involvement, are crucial if RSW problems in the City of Tshwane Metropolitan Municipality (CTMM), Olievenhoutbosch

Township, as well as other townships in developing regions are to be successfully solved and RSW management systems are to be improved.

Studies point out that residents' attitudes and perceptions towards RSW management is influenced by factors such as economic status, beliefs, culture, values, socio-economic, demographics, environmental attitudes, influence from friends, families and social norms – and their knowledge or lack of it (Agwu, 2012; Barr, Ford & Gilg, 2003). Educating the community on the issues of reuse and recycling helps bridge the gap of knowledge in dealing with RSW. Poor education, knowledge, age and level of income are contributors of perception towards improper RSW management (Longe, Longe & Ukbebor, 2009). However, Thomas and Sharp (2013) state that although people (residents) may have access to services and awareness campaigns or education regarding RSW management, it is not everyone who will participate in sorting, reusing and recycling of RSW. Also, Wang et al. (2018) demonstrated that awareness campaigns have no direct impact on residents' intensions regarding recycling. Consequently, they suggest that other factors that may influence recycling participation must be taken into consideration.

Several researchers have studied residents' attitude and perceptions and these include Mamady, (2016); Adogu *et al.* (2015); Suleman, Simon & Richard, *(*2015); Al-Khatib et al. (2014); Bacot, Bowen and Fitzgerald, (1994) and Wang, Guo, and Wang (2016). Al-Khatib *et al*. (2014) employed structured questionnaires to study residents' concerns and attitudes toward RSW facilities in the Hebron District of Palestine. The study investigated the residents' concerns regarding environmental impacts caused by RSW and their attitudes during the construction of new RSW systems. The results showed that most (84% of respondents) residents were more perturbed about RSW impact on their water resources; residents would prefer to have incinerators supplying energy to their houses. However, they showed a negative attitude if there were buildings erected close by their dwellings. Mamady (2016) investigated the factors influencing attitude, safety behaviour and knowledge regarding RSW in Guinea (Conakry) by using structured questionnaires. The case study looked at the effect of socio-economic and demographic factors on residents' knowledge on RSW management and poor RSW management's impact on their health and environment as well as their ways of disposal. Results showed that participants in the age group of 15-24 years and 50-59 disposed of their waste in open dumps and open burning while

participants in the age group of 30-39 years relied on private waste collectors. On the other hand, residents without formal education relied on open dumps while those with secondary and tertiary education relied on private collectors. Moreover, the type of residential area also influenced how people disposed of their waste, for example those in planned residential areas had agreements with private waste collection companies and some disposed of their waste in municipal permitted landfill sites while those in unplanned areas disposed of their waste in open areas. The study also revealed that most (96.2%) of the respondents were aware that poor RSW management was a risk to their health, yet 63% were unaware of its impact on the environment.

Adogu *et al.* (2015) studied RSW practices among residents of Owerri Municipal Imo State (Nigeria) and this was archived by use of questionnaires. The study found that 90.1% of respondents were aware of RSW management. Also, respondents with a higher education were able to explain RSW management thoroughly; they showed profound knowledge in RSW matters compared to those with no formal education. On the other hand, most (80%) respondents did not sort their waste before disposal. However, the respondents still relied on open dumps and open burning for disposing their waste and they did not sort or separate it beforehand. In addition, residents' perceptions and attitudes towards RSW management in the Brong Ahafo area of Ghana, were examined by Suleman *et al.* (2015) by way of survey questionnaires and in-depth interviews. Compared to the aforementioned studies, more than 80% respondents were aware of impacts of poor RSW, but few (about 40%) in the study indicated that RSW has an impact on their environment. Most of the respondents mentioned that they were not paying the RSW tariffs although the municipality was providing the services; this shows that residents liked free service. This may be one of the causes of financial instability municipalities in developing areas are facing.

Similar studies were also done in South Africa; Dlamini, Rampedi, and Ifegbesan (2017) studied the Residents' Opinions and Perceptions on the effectiveness of RSW and recycling potential in the Umkhanyakude area of KwaZulu-Natal Province; a random sample was used to select residents who participated in questionnaire-administered interviews. The study reflected that most (97.3%) of respondents were dissatisfied with collection services provided by the municipality. They mentioned that in most cases RSW was left unattended, both in the vicinity of their houses and around open spaces in the area, until it decayed; this increased their unwillingness to pay for the

services. Moreover, the municipality provided RSW recycling and recovery initiatives, yet respondents were not participating, and respondents were ignorant regarding the process of sorting waste before it was collected. This shows that respondents lacked knowledge of recycling. Given these problems, the authors suggested that the municipality may need to increase environmental awareness on RSW. Makhale (2016) studied the behaviour and attitudes of residents towards recycling in Olievenhoutbosch Township. The study was conducted in socio economically different areas, i.e. formal and informal settlements and questionnaires were used. The study revealed that the collection rate was high in some areas yet there were a lot of illegal dumping sites in the area. In addition, respondents indicated that they were aware that RSW could be recycled but most indicated that they were not participating in recycling or sorting RSW. Based on the results obtained the author concludes that even though RSW is provided, factors such as human behaviour, culture norms, lack of education and awareness influence how people view and treat RSW.

This study will also use survey questionnaires to explore residents' attitudes and perceptions concerning RSW management in Olievenhoutbosch Township with the aim of collecting information about residents' perceptions of RSW impact on the environment, residents' attitude on CTMM RSW management and their perception on recycling. Looking at these studies, the author concludes that if authorities wish to design and implement effective RSW management systems, policies and recovery, reuse and recycling facilities, residents' attitudes, perceptions, behaviours, socio-economic and demographic aspects must be taken into consideration.

2.8 Summary of findings

Several RSW research studies have been conducted in South Africa. Ogola, Chimuka and Tshivhase (2011) who studied the management of solid waste in Limpopo in high, medium and low-income areas, used both qualitative (interviewed municipality officials) and quantitative (weighed waste generated from residents' households) approaches. Their study focused only on generation while solid waste management includes all aspects from generation to disposal – so the results do not really give a snap shot of RSW management in Limpopo. Tsheleza et al. (2019) looked at the susceptibility of growing cities to solid waste-related environmental hazards in

Mthatha in high, medium and low-income areas and randomly selected 248 households where the waste generation was analysed. Although the abovementioned studies focused on RSW generation, researchers point out that understanding waste generation is essential as it gives authorities an indication of management practices required, especially about collection services.

Among the research conducted on RSW there was an initiative that focused on research, awareness and policies in 2001; this initiative looked at RSW management in townships such as Khayelitsha (Cape Town) and in Johannesburg like Diepsloot, Soweto and Alexandra. Researchers involved community members, municipality officials and workers representatives. The results showed specifically that collection was still an issue in townships and was clear of the fact that poor roads and piles of shacks make it difficult for trucks to collect waste (Qotole *et al.* 2001).

RSW studies were also done in other developing countries, for example Sibanda *et al.* (2017) studied the challenges of RSW in Kismu (Kenya) using interviews (for officials), and visual observation. With this methodology they were able to identify aspects that were hampering RSW management success in the study area. Moreover, in Nigeria, Abila and Kantola (2013) studied the RSW management and evolving knowledge about RSW management solutions – the authors only relied on secondary data such as policies, municipal records and literature. Their study found that RSW policies are still weak and ineffective, that there is a major lack of awareness and that recycling programmes and landfills are still used as major disposal methods.

From the abovementioned study all researchers tried to involve all RSW stakeholders in their studies using mainly interviews and questionnaires. These studies show that RSW is an increasing problem in developing regions. Challenges and problems identified in the studies thus included increasing waste generation, low collection rates and the use of landfills as disposal methods, all of which are environmentally questioned. On the other hand, it appears as if a key matter has been overlooked in the studies, namely that of informal waste pickers. Sentime (2014) emphasises that informal waste pickers play a key role in RSW management, but South Africa's legislative framework, which governs waste, does not take them into account like countries such as Brazil, Costa Rica, the Philippines and Colombia do where they are formally legalised. However, municipalities such as Johannesburg, Umgugundlovu and Ekurhuleni have programmes that

support informal waste pickers (DEA, no date). The study by Agunwamba (1998) highlights several factors that hamper the success of RSW management yet they are often overlooked – this study points out that adequate governance and stakeholder's engagement can impact how waste is treated or viewed. Therefore, this research will also study latter aspects. The root of RSW problems around the globe have been traced to increasing RSW which is overloading the current systems. Despite different approaches and solutions suggested about RSW management, the problems still continue.

2.9 Conclusion

Residential Solid Waste (RSW) management in developing countries and cities is an on-going problem. The RSW services are inadequate as they are operating on over capacity due to increasing RSW generation rates attributed to unplanned urbanisation and growing populations. The lack of adequate services results in waste authorities not following the required schedules for RSW collection which consequently forces residents to opt to illegal dumping in the environment which threatens the sustainability of the environment. On the other hand, the implementation of RSW legislation and lack of financial resources pose a challenge. Regarding RSW recovery, recycling is still done by informal waste pickers (IWP) and private companies and this brings on a challenging task of recording accurate volumes of recycled products. This study therefore aims to evaluate the existing RSW systems and the impact of inadequate systems on the environment and low-income areas. Moreover, it aims to contribute to sustainable RSW in the township of Olievenhoutbosch and other townships around the globe.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter offers a complete description of the methodology that was used in this research. An outline of the study area, research design, sampling plan, methods and instruments used to collect data and data analysis is presented. Ethical considerations and limitations of this study are also discussed.

3.2 Research study area

The study was carried out in the township known as Olievenhoutbosch, which is situated in the City of Tshwane Metropolitan Municipality (CTMM) in the Gauteng Province of South Africa. The Local Government Municipal Structures Act (117 of 1998) (RSA, 1998) section 4, classifies the CTMM as a Category A municipality. The city's natural environment encompasses protected areas, nature reserves, ridges, water catchment areas, bird sanctuaries and wetlands. Like any other metropolitan city, the CTMM ecological status continues to be threatened by growing urbanisation and inadequate management systems which are directly linked to increased quantities of waste, loss of diversity and ever-increasing pollution (CTMM, 2011).

The city is divided into 7 regions and Olievenhoutbosch Township falls under region 4, which is for administrative purposes and to improve service delivery (CTMM, 2019a). Olievenhoutbosch is located on the far south-western side of the CTMM. It borders the City of Johannesburg in the south, the Ekurhuleni Municipality in the east and the Mogale City municipality in the west. Olievenhoutbosch lies almost in between Tshwane and Johannesburg which are the two largest cities in Gauteng province and this fact is one of the attractions to residents who are flocking to reside in the township. Figure 3.1 shows the study area location.

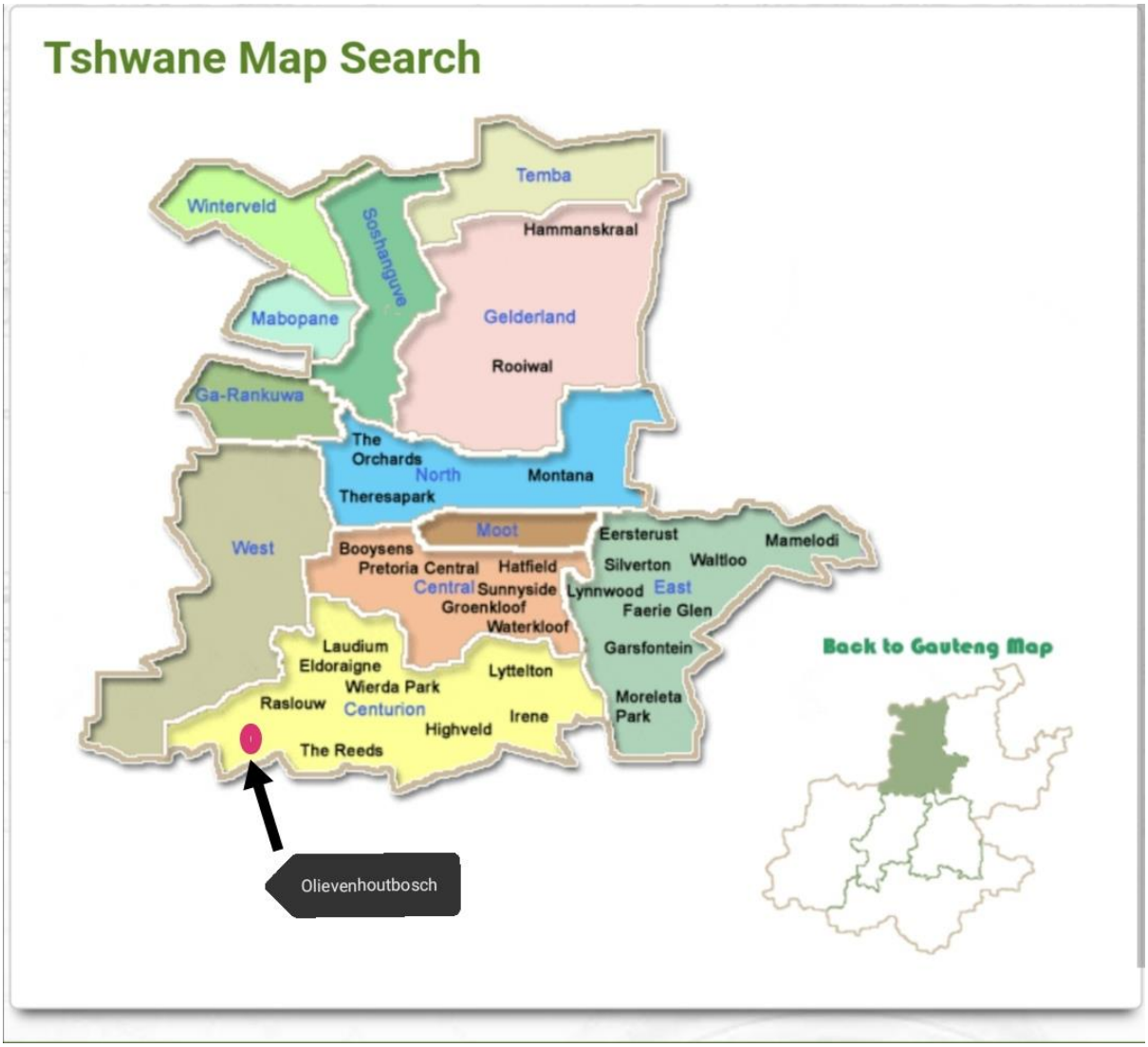


Figure 3.1: City of Tshwane Metropolitan Municipality Map
(Source: www.sleeping-out.co.za/Tshwane-map.asp, n.d.)

According to the CTMM's 2018/2019 annual report region 4 population increased from 288,000 to 468,000 between 2007 and 2017 (CTMM, 2019b). Like any other township in South Africa, Olievenhoutbosch is characterised by low or lack of community services (water, electricity, health and waste facilities, dilapidated roads), high unemployment, low incomes and poverty (Pernegger & Godehart, 2007). Olievenhoutbosch is made of three different socio-economically residential areas, namely middle income, low income and informal settlement. The physical environment of the study area consists of several wetland areas, a canal that flows through the residential area and then into the Hennops River. There is also an open area which basically consists of vegetation. In

the CTMM, the difficulty with Residential Solid Waste (RSW) is negatively affected by an ever-increasing population, and development of new residential areas, both planned and unplanned. This place a lot of stress on the existing waste management services which are already operating above capacity (CTMM, 2019c).

3.3 Research design

An empirical study was conducted – this is a study which derives and analyses data from direct or indirect observations (Jasti & Kodali, 2012). Additionally, a mixed data collection method was used for collecting data; according to Clark and Creswell (2014), both qualitative and quantitative data was gathered. This method helped the researcher collect the data that was required to understand the current Olievenhoutbosch RSW system and management, as well as challenges experienced.

3.4 Research methodology

A multi-disciplinary approach was used in this study to achieve the research objectives. This included desk study (literature review) and field data collection (observations and interviews). Two sets of data were collected, namely primary data and secondary data.

3.5 Data collection

Firstly, appointments were scheduled before the interview and dates were decided upon. Additionally, consent forms (**Annexure 1**) were e-mailed to the participant. A zoom (video) structured interview was conducted with the City of Tshwane Metropolitan (CTMM) region 4 Department of Agriculture and Environmental Management (DAEM) office which is responsible for the entire Residential Solid Waste (RSW) management in the region. DAEM is made up of five sections namely customer care, waste collection, disposal, waste separation and minimisation, and waste removal policy standards and regional support. However, the researcher was able to conduct a zoom interview with the waste collection section only as the other section's officers were in quarantine due to Covid 19 and had network challenges at their respective places of work.

With the help of the waste collection section interviews were conducted by telephone to answer questions which were specific for other sections – this was one of the limitations of the study. The participant from the waste collection section managed to answer all the questionnaires (**Annexure 2-6**) and also supplied the researcher with electronic documents for referrals.

Thereafter, visual observations were made in the Olievenhoutbosch Township. Visual observation is a form of qualitative data collection technique; it involves in-depth observation. Pictures or people actions are utilised to produce knowledge (Ritchie *et al.* 2013). Observations in this study were made throughout the Olievenhoutbosch Township. The researcher walked through the study area locations to identify illegal waste dumping sites, open dumps, water systems (drainages), water bodies (rivers and canals) and Informal Waste Pickers' (IWPs) sorting zones. During these walks, the researcher collected data by taking pictures and notes of the systems to describe anything unusual, what is typical, as well as anything that appears to be unusual.

3.6 Sampling

A non-random sampling technique, known as purposive sampling, was used to select key informants. According to Tongco (2007) with the purposive sampling method the researcher purposively selects participants with certain characteristics with the aim of obtaining certain knowledge, or an in-depth insight. Bernard (2002) clearly points out that with this technique the researcher decides what his/her aim is and then selects people who can provide the information based on their skills, experience and knowledge.

In this study the researcher selected various employees in the CTMM RSW management department (Table 4.1). Employees were purposively selected, to represent different specialities, namely technical, finance, environmental and management. However, during the interview phase some of the selected participants were unavailable due to circumstances caused by the corona virus and national lockdown, while some were struggling with network connections. This limited the study as the researcher was left with one participant available to conduct the interview. However, at a later stage the participant was able to gather required data from four other participants by telephone and responded on their behalf by means of a zoom visual interview.

The unavailability of some participants caused by Covid-19 and technical network challenges resulted in the researcher failing to interview some of the participants and was left with one available participant. However, it was agreed that the remaining participant will answer all the other questionnaires. For more referrals, supporting documents with the answers of departments in which its participants were unavailable for the interviews has been given to the researcher in case the remaining available participant do not have answers to some of those questions.

3.7 Data collection instrument

A set of questions were prepared on the RSW management system in Olievenhoutbosch Township. This comprised technical, finance and environmental questions, challenges and opportunities in RSW management, as well as present and future plans. An appointment was first made telephonically before the interviews and after a time and date were agreed on the researcher sent the participants an e-mail with the consent forms attached so that they could read and sign them. After the consent form was returned to the researcher, a zoom meeting was conducted virtually with the participant in which the researcher outlined his research objectives and read out the questions on the questionnaire while the participant answered. The answers were recorded on paper and there was a digital copy of the virtual meeting recorded as well.

During the zoom meeting, both the researcher and the participant first encountered a minor technical challenge whereby the devices were failing to record the interview and there was poor audio as well. However, this was eventually resolved, and the interview was completed successfully and recorded – on device and on hard copy (paper).

3.8 Secondary data

This includes data that are already available at the municipality. The researcher aimed to measure the effectiveness of RSW management by collecting the following data from the CTMM RSW information system: the population served with RSW services, collected solid waste composition, collection rate, waste collection tariffs, non-payments, non-payment control measures, illegal dumping costs, awareness programmes, landfill site capacities and rehabilitation costs. However,

the municipality does not have such information on the township available as they do not keep records containing such information.

3.9 Research ethics

Ethical considerations for this study were a priority due to several stakeholders being involved (one participants was eventually interviewed). The ethical clearances (**Annexure 7 & 8**) were applied as soon as the early stage of the literature review, this was done so that the researcher can have enough time to submit all the required documents and answers to the ethics committees in case there would be a need for it. The applications took between three to four weeks before the permission was granted. However, the study had to stop and new application (**Annexure 8**) for ethical clearance was submitted as there were changes to the participants which was caused by the Covid-19 lockdown. Still the application took about three weeks before the permission was granted to continue with the study. There was no interview done while the researcher was still waiting for permission to be granted. The above also applied to the permission (**Annexure 7**) application from the CTMM. Ethical clearance (**Annexure 8**) was obtained from Stellenbosch University's Research Ethics Committee. Also, permission (**Annexure 7**) to conduct the study in Olievenhoutbosch Township was obtained from the CTMM. The author was not allowed to begin with the study without the abovementioned permissions first being granted.

Permission to conduct interviews was requested from the relevant participants before they took place (although the study was later left with one participant). The consent form was e-mailed to the participant, who then completed, signed, scanned and returned it per e-mail to the researcher. Participant confidentiality was maintained throughout the study as no names and quotes were used.

3.10 Validity and reliability

Validity measures how truthful and accurate the research findings are (Golafshani, 2003) and in this study triangulation strategy was used to improve its validity and reliability. Interviews, observations, pictures and secondary data from the municipality documents were used to collect the data intended for this study in order to achieve the objectives. Moreover, interview was made

up of more open-ended questions and probes were made where questions were closed-ended to gain in-depth knowledge from the respondent. Before the zoom interview, a set of questionnaires (Annexure 1 to 5) were made available a day before the interview for the interviewee to familiarise herself/himself with the questions. Recording the zoom interview was effective for the researcher as he was able to do the recording over and over to gain more clarity on the answers. According to Ranjit (2011) reliability determines if the data collection methods used yield consistent findings when used repetitively. Reliability in this study was a challenge as only one person was interviewed. However, the researcher assumed that the interviewee was knowledgeable and well-informed to answer the questions and to provide rich data which was based on her position, capacity, reasonability and experience in the field. Therefore, the methodology used enabled the researcher to achieve the objectives. The plan was to interview all the participants (in listed in Table 4.1.). However, due to uncontrollable circumstances, the researcher ended up with one participant. The researcher further believes the data given by the participant is credible as the participant holds a management position.

3.11 Challenges and limitations of the study

The study posed various challenges to the researcher during the data collection stage. Some of these challenges resulted in delays, time loss and change in programme dates. However, it was beyond the researcher's control. For example, the surge of the corona virus that was later declared a pandemic halted the study. This occurrence cost the researcher much effort and time as the government had introduced a country wide lockdown for every person to remain indoor until further notice. This also imposed limitations on the research as the researcher could no longer interview the residents to obtain their views on RSW in Olievenhoutbosch. The inability of other stakeholders (residents, councillor and waste pickers) to participate robbed the research of insight into deeper challenges that the Olievenhoutbosch Township is experiencing regarding the management of solid waste as the residents are one of the major stakeholders in RSW.

The study proposal was later amended to continue during the lockdown. However, some of the intended participants from the CTMM could no longer be interviewed as they were infected by the virus and this resulted in them working from home – a factor which brought challenges as some

of them failed to participate in initial virtual interviews due to poor network coverage, virus isolation, etc. The waste management protest from the CTMM also impacted the research for a period of two weeks. Options of recruiting other participants from the CTMM were exhausted as well and were not fruitful. This left the researcher with one participant from the CTMM staff who participated by responding to all the questionnaires. With the aim of the study being to explore the RSW management system of the Olievenhoutbosch Township, the researcher was satisfied with the data collected from the CTMM as all the questionnaires were answered and additional information was supplied in the form of soft copies. Also, observation was done to consolidate the richness of the data needed to meet the objectives.

CHAPTER 4: RESEARCH FINDINGS AND DISCUSSIONS

4.1 Introduction

This chapter presents the research findings of this study and casts a glance on its discussions. Results originating from the primary data collected by means of questionnaires put to the City of Tshwane Metropolitan Municipality (CTMM) officer. Secondary data was also gathered, mainly from CTMM annual reports, waste integrated reports, waste data summaries and assessment of collection services reports and the municipal by-laws.

Firstly, Olievenhoutbosch township profile is discussed. This includes the current township population, Residential Solid Waste (RSW) coverage and collection rate in the area and any differences about the provision of RSW services in different areas based on income status. Secondly, the existing RSW system of the township (study area) is discussed. This includes RSW composition, generation rates, collection coverage and rates for the past five years, transportation, disposal, as well as the entire RSW management and minimization aspects that are currently in place. Thereafter, the financial and environmental management of the RSW are highlighted. Lastly, the RSW governance is explained.

4.2 Research Findings

4.2.1 The City of Tshwane Metropolitan Municipality's (CTMM) key informants

Zoom (video) structured interviews were conducted with (CTMM) region 4's Department of Agriculture and Environmental Management (DAEM) office which is responsible for the entire Residential Solid Waste (RSW) management in the region. The waste collection section (essential workers) was the only section that the researcher was able to engage as the others' officers were under Covid-19 quarantine. This was one of the limitations of this study. However, a waste collection section officer was able to complete other sections by means of a phone call and with the help of the staff that was under quarantine. Table 4.1 illustrates the CTMM waste sections, their responsibilities and how they participated in this study. The entire region 4 waste division, including those who participated in the study through telephone calls is composed of five sections

namely; customer care, waste collection, disposal site operations, waste separation and minimisation and waste removal policy standards and regional support as illustrated in Table 4.1.

Table 4.1: CTMM Key informant participants

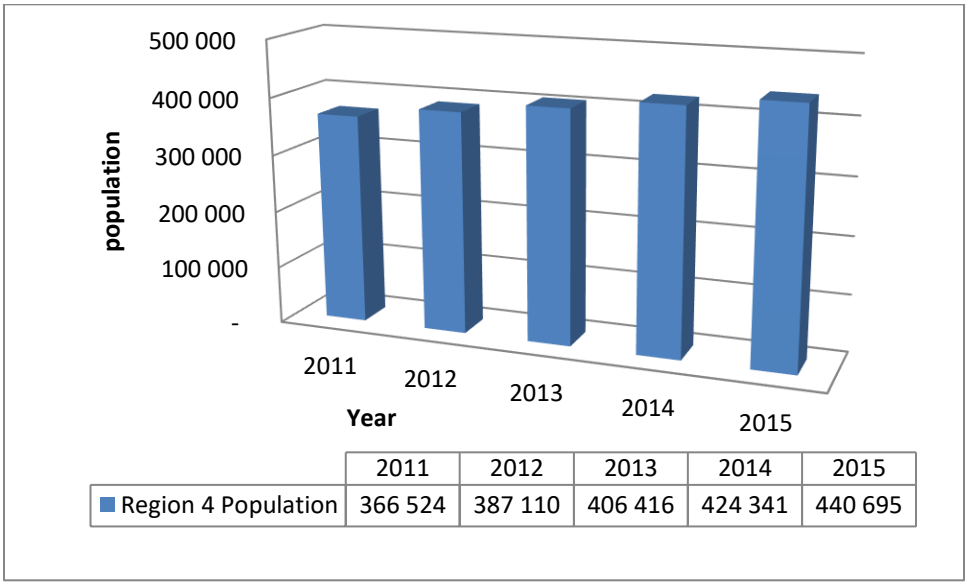
Sections	Responsibility	Mode of conduct
Section 1: Admin Officer Customer Care	Management of customer complaints and data capturing	Telephonically with the help of section 2
Section 2: Deputy director: Waste collection	Develop and implement all waste collection functions	Zoom interview
Section 3: Functional head: Disposal site operations	Management of landfill sites	Telephonically with the help of section 2
Section 4 Deputy director: Waste separation and minimization	Develop and implementation of waste minimization strategies	Telephonically with the help of section 2
Section 5: Deputy director Waste removal policy standards and regional support	Regional support on operation functions (collection and transporting RSW and clearing illegal dumps	Telephonically with the help of section 2

(Source: Author, CTTM interview)

4.2.2 Olievenhoutbosch Township's Demographics

As already mentioned, the Olievenhoutbosch Township is located in the CTMM's Region 4. Figure 4.1 shows the total population in the CTMM's Region 4 from 2011 to 2015; in 2011 the total population was 366 524 and it increased to 440 695 in 2015 (CTMM, 2015). The CTMM annual report of 2018/19 states that from 2007 to 2017 it increased from 288,000 to 468,000 repectively and it was noted that of the city's 7 regions, region 4 was the one which showed the

strongest average annual growth rate, namely 4.98 % to 5% (CTMM, 2019b). About 25% of the population is low-income earners – the low-income group includes all residents earning less than R2 000 per month while 29% and 46% are medium and high-income earners respectively, as shown in Figure 4.2 (CTMM, 2015).



	2011	2012	2013	2014	2015
Region 4 Population	366 524	387 110	406 416	424 341	440 695

Figure 4.1: Population of Region 4 between 2011 and 2015

(Source: CTMM, 2015)

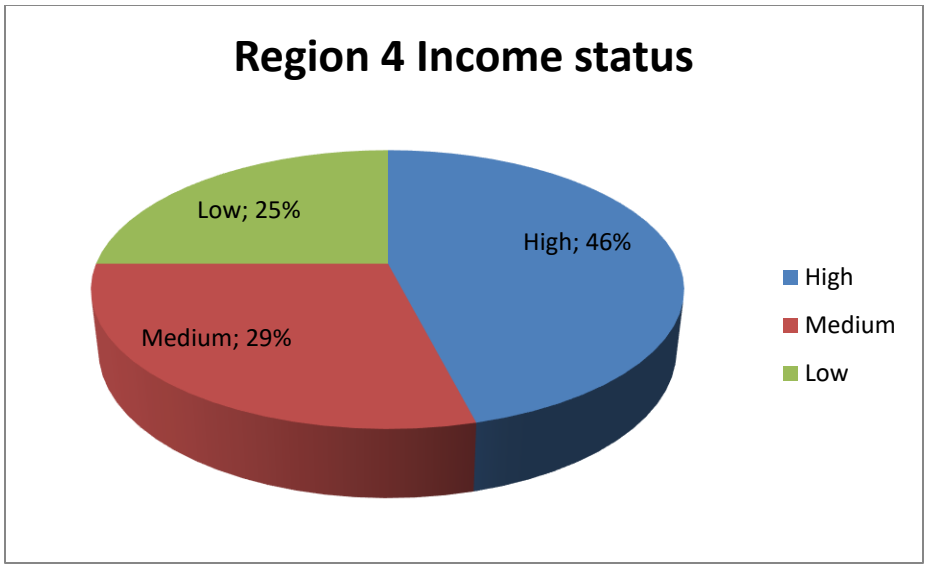


Figure 4.2: Region 4's population between 2011 and 2015

(Source: CTMM, 2015)

4.2.3 Residential Solid Waste Management in the Olievenhoutbosch Township

The interviews with the CTMM officers revealed that the Residential Solid Waste (RSW) management system in Olievenhoutbosch Township (which is in region 4) includes RSW collection services, cleaning of open dumps in informal settlements, transportation and disposal of RSW to any landfill site belonging to the CTMM as shown in Figure 4.3. It was also found that the waste minimization is solely of because informal waste pickers (IWP). The RSW management also includes tasks of clearing illegal dumping sites, recycling and cleaning of public places, such as streets and parks, managing disposal facilities (landfill sites), removal of methane gas from landfill sites, education, awareness and implementing policies, norms, by-laws standards and strategies. The municipality also mentioned that with regard to RSW services, all (100%) residents are served equally, meaning all RSW generated is collected from middle income (bonds-low to middle income houses sold by the developers), low income (RDP) and informal settlements (squatter camps) areas. Figure 4.3 depicts the existing RSW system. The CTMM allocates 240ℓ bins to each household in all formal areas – excluding informal areas – if those areas/houses have been formalized/registered by the CTMM housing department. RSW is collected on a weekly basis from all three abovementioned areas and is then disposed to one of the four landfill sites

(Soshanguve, Hartherly, Ga-Rankua and Bronkhorspruit). Collection of recyclables for further processing was conducted by IWP who collect the recyclables at generation points; on waste collection days they search through households' dustbins and at disposal points at landfill sites.

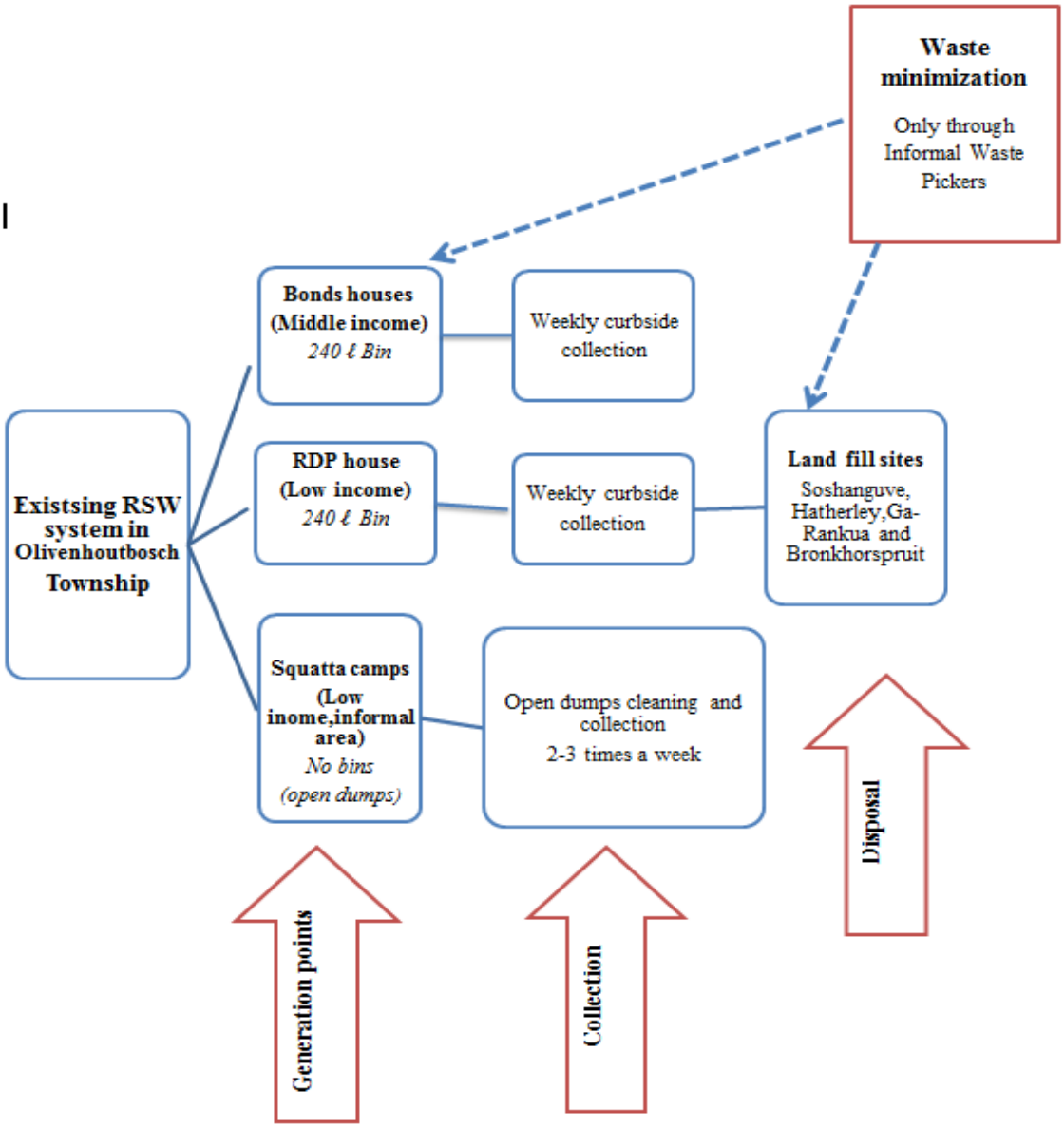


Figure 4.3: Olievenhoutbosch Township's RWS System

Source: Author (CTTM interview)

4.2.4 Residential Solid Waste (RSW) Generation

The Residential Solid Waste (RSW) generation rates for the Olievenhoutbosch Township are not quantified. Assumptions are based on the number of bins collected from each formal household (bond houses and RDPs). This is the main method that is currently used for the estimation of RSW quantities. Yet, there are no records of such estimates in their database. The interview only revealed the 2019 number of households from middle income areas and low-income areas – the number of households in informal areas is unknown.

4.2.5 Residential Solid Waste (RSW) Composition

Presently the region does not categorise RSW into plastic, paper, metal and organic, but it is categorised into larger groups such as RSW, commercial, industrial and agriculture as illustrated in Table 4.2. The volumes of these waste categories are unknown as they are not quantified.

Table 4.2: Waste Categories in the CTMM's region 4

Solid Waste category	Sources	Example
Residential Solid Waste	Residential areas Formal and informal areas	Plastics, food leftovers, paper, glass, metal
Commercial	Offices, salons, restaurants, and hotels	Paper, cardboard, glass, food leftover,
Agriculture	Farms, poultry and abattoirs;	Fertilizers, pesticides, blood and plastics
Industrial	Chemical plants, manufacturing factories, mines' waste	Hazardous by-products like oil, ashes, toxics, chemicals, hazardous weapons

Source: Source: Author (CTTM interview)

4.2.6 Collection coverage and collection rate

According to the interviews the City of Tshwane Metropolitan Municipality's (CTMM) by-laws are responsible for determining the type of services, the frequency of collection and the number of

bins in the township. The CTMM provides Residential Solid Waste (RSW) services to 99% of its residents (3,3 million) within its jurisdiction. According to the interviews RSW collection coverage in the Olievenhoutbosch Township is not recorded. However, the assumption is that all households in the township are served. This includes households in middle income areas (bond houses) and low-income areas (RDPS) which are government subsidised. The assumption is based on the idea that all the bins placed in the front of the yards during the collection day are all collected by contractors hired by the CTMM. Informal households (known as squatter camps) in the township now do not have access to RSW services. Illegal dumping spots are cleared every week in the squatter camp area.

Table 4.3 illustrates the number of households in the Olievenhoutbosch Township – there were 27,923 households between 2018 and 2019. According to the assumptions the municipality is using to quantify the number of customers served, this means that 27,485 households in the entire township receive weekly RSW collection. It was also mentioned that the number of households in squatter camps is about 438 and this area is without RSW services, but the CTMM has hired contractors who are responsible for cleaning open dumps in this area two to three times a week.

Table 4.3: Olievenhoutbosch Township households in 2019

Residential Area	**Number of households 2018/2019**
Formal residents	27,485
Informal Settlements	438
Total known /registered households	**27,923**

(Source: Author, CTTM interview)

All households with properties worth more than R150,000 (high income) are required to apply for a waste 240ℓ bin at the CTMM walk-in in centre or waste management depot or online and they are required to pay R107,19 service charge monthly for a once a week collection as part of their

rates and taxes for their properties. Middle (properties worth R150,000 or less) and low-income households (RDP, government fully subsidised houses) are exempted from paying RSW removal fee. The categories of houses (middle income) are issued with 240 ℓ bins after the CTMM formally allocate the beneficiaries with their RDP houses. Low income (informal settlements or squatter camps) in the past were allocated four waste plastics bags (one per week) per yard. However, due to budget constraints waste plastic bags are no longer provided. Residents are relying currently on communal waste dumps which are cleaned up by CTMM contractors.

Currently the RSW is collected once a week from households in middle income and low-income areas whereas in informal settlements the communal dumps are cleaned two to three times a week. These services are rendered by a contractor hired by the CTMM. If the planned collection is skipped or affected by circumstances such as strikes cover-up collections are executed within seven days to ease the challenges faced by the residents. Currently, the municipality does not have initiatives for collecting separated or recyclable waste at sources as the residents have been using the recycling bins provided for other purposes.

4.2.7 Residential Solid Waste Transportation and Disposal

CTMM region 4 has employed contractors to collect and transport waste to landfill sites. According to the interview there are 16 trucks contracted for waste collection and these are sufficient to service the entire township. RSW is collected from households' gates and transported to any CTMM owned landfill sites (Soshanguve, Hartherly, Ga-Rankua or Bronkhorspruit). The site is chosen by the truck drivers based on their preferences. The CTMM region 4 RSW officer indicated that the number of trucks were sufficient for the entire township, but the major challenge is that some areas – mainly informal areas – are not easily accessible. Also, the distance from the Olievenhoutbosch Township to landfills sites is long and this increases operational costs for the CTMM, as well as the carbon footprint.

The data collected reveals that 100% of RSW collected in the entire municipality, including the study area (Olievenhoutbosch Township) is disposed of in landfill sites. Table 4.4 presents the status of the current active and inactive landfill sites in the CTMM. There are 12 landfill sites in the CTMM however, only four are in operation – the rest are inactive. Three (Eersterus, Derdepoort

and Valhalla) are currently being rehabilitated for reduction of environmental impacts and one, Pretoria North has been rehabilitated and is currently used as a golf course.

Table 4.4: CTMM Landfill sites' status

Landfill sites	Active/Inactive	Reaming life span
1. Hartherly	Active	15-20 years
2. Soshanguve	Active	7-8 years
3. Ga-Rankua	Active	8-9 years
4. Bronkhorstspruit	Active	9-10 years
5. Eersterus	Inactive	under rehabilitation
6. Derdepoort	Inactive	under rehabilitation
7. Valhalla	Inactive	Sinkhole under rehabilitation
8. Pretoria North	Inactive	under rehabilitation (converted to golf course)
9. Temba	Inactive	Zero years, not maintained
10. Garskloof	Inactive	Zero years, not maintained
11. Kwaggasrand	Inactive	Zero years, not maintained
12. Onderstepoort	Inactive	Zero years, not maintained

(Source: Author, CTTM interview)

Figure 4.4 illustrates the volume of RSW in tons that was disposed to the Soshanguve, Hartherly, Ga-Rankua and Bronkhorstspruit landfill sites. These sites are the only four sites that are in operation in the entire CTTM. RSW disposed annually ranges from 1,650,000 to 40,941 tons. Haethley and Ga-Rankua landfill sites are two of the sites that receive more waste than the other. In 2015 Hartherly received some 1, 600 000 tons whereas the other three sites together received only about 200,000 tons.

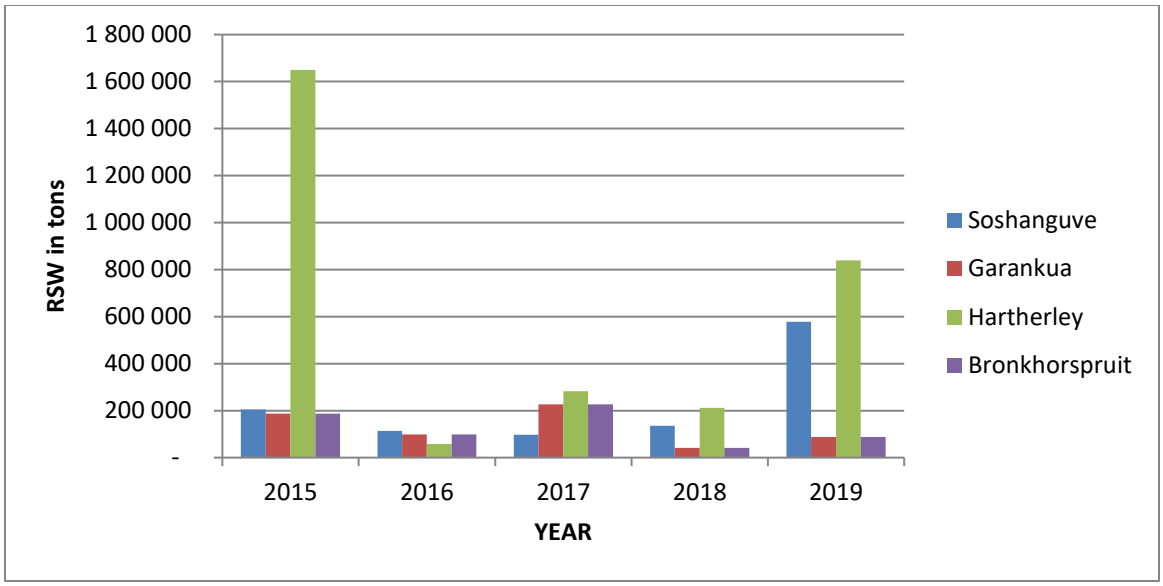


Figure 4.4: RSW disposed in CTMM landfill sites

(Source: Author, CTTM interview)

All the RSW collected from households' bins are not sorted at source or any other stage before disposal. After collection the RSW is immediately disposed to landfill site. Currently there is no waste that is recycled, composed or incinerated. The existing challenges the CTMM is facing at landfill sites is that all waste, including hazardous waste such as firearms and explosives, are found at landfill sites. It was also pointed out that the current landfill sites are in a poor condition, for instance, security access is not tight, most of the weighbridges are not working and waste pickers scatter waste all over the place. Figure 4.5 and Figure 4.6 show the IWPs busy collecting recyclables at the Soshanguve and Ga-Rankua landfill sites.

Figure 4.5: Soshanguve Landfill Site

(Source: CTMM, 2013)

Figure 4.6: Ga-Rankua Landfill Site

(Source: CTMM, 2013)

4.2.8 Waste separation, minimisation and recycling

The CTMM interview pointed to the fact that Residential Solid Waste (RSW) separation at source and other forms of solid waste recovery at the Olievenhoutbosch Township is currently not being practiced. All waste hazardous, garden, recyclable and general waste is mixed. However, three

years ago the municipality had recycling initiatives where residents were provided with separate bins which were intended for recyclable waste, but residents used them for other purposes. Moreover, the community participation or involvement was too low. The CTMM also had challenges to face such as an inadequate budget and had no external funding, poor infrastructure and lack of capacity for recyclables. The CTMM does not have any incentives to encourage residents to recycle, but they do provide education and awareness at schools and in malls to urge the community to recycle.

Regardless of weak recycling initiatives the CTMM has external stakeholders who play a major role in recovery for recycling – these include Informal Waste Pickers (IWPs). At the moment the entire municipality has some 200 IWPs. The current number of IWPs in the Olievenhoutbosch Township is unknown as there are no record or data keeping measures in place. IWPs are functioning on their own and they are not funded by the municipality due to inadequate budgets.

4.2.9 Residential Solid Waste Governance

a) Stakeholders roles and responsibilities

Residential Solid Waste governance in the Olievenhoutbosch Township and the entire CTMM includes institutions and legal framework that participate in waste management. The current stakeholders involved in RSW in the Olievenhoutbosch Township are illustrated in Table 4.5 and they include the CTMM, the Department of Environmental Affairs (national and provincial), contractors, councillors and community leaders.

b) Policies

- **Legislation Documents**

  The following are legislative documents that are in place in the CTMM and all its regions and they are regarded as crucial for RSW management

  - Constitution of South Africa
  - National Environmental Management Act, Act 59 of 2008 (NEMA)
  - National Waste Management Strategy 2011 (NWMS)
  - National Environmental Management: Air Quality Act 39 of 2004 (NEMAQ)

- **CTMM by-laws**

  The interview revealed that the CTMM has waste by-laws which were reviewed in 2016. It was also mentioned that there are two major gaps and challenges in the existing by-laws. Enforcement is still a challenge due to the absence of clear enforceable legislation and overlapping responsibilities. For instance, the CTMM's environmental inspectors do issue penalties, but offenders cannot be taken to court as the Metro Police are the ones responsible for enforcing by-laws. This often causes tensions and offenders end up not paying the fines. Moreover, the content (by-laws) does not promote waste separation and waste minimization.

- **Integrated Waste Management Plan (IWMP)**

  The municipality made mention of the fact that the development of the IWMP is a legal requirement and they have subsequently drafted the 2018/2019 IWMP, but the document has not yet received official approval.

Table 4.5: Residential Solid Waste Stakeholders and their responsibilities with regard to the Olievenhoutbosch Township

Stakeholder	Target Responsibilities
The CTMM	Collection of RSW and transportation to disposal landfill sites; operating and managing landfill sites
Department of Environmental Affairs (National)	Drafting environmental guidelines and standards, evaluating enforcement and progress
Department of Environmental Affairs (Provincial)	Adhere to environmental implementation and management plans; guidelines outlined by the national authority
Metro Police	Enforcing by-laws
Community leaders	Assist the CTMM in organising awareness campaigns
Councillor	To be a facilitator between the ward (community) and the council
Residents	Participate in decision making, being involved in recycling
Contractors	Helping the municipality in collecting RSW and clearing illegal dumps
Informal Waste Pickers	Aiding the municipality with waste minimisation by collecting recyclables

(Source: Author, CTTM interview)

c) RSW Financial Management

- **RSW revenue and budget**

It was also stated that the cost of RSW services (from collection to disposal) is covered by money from service charges. Detailed operational costs and a budget for RSW management of the Olievenhoutbosch Township were not available during the interview and from recent reports, but the operational costs for the entire municipality were located in the 2018/2019 IWMP draft.

The only available RSW costs that were located were for the 2011/2012 and 2013/2014 financial year. Figure 4.7 illustrates RSW services cost in percentage for the entire municipality. According to the report (CTMM, IWMP 2018/2019), in both years, 2011/2012 and 2013/2014 RSW collection costs were higher (64% and 89% respectively) than all the costs in the RSW budget. This was then followed by transportation costs (trucks) in 2011/2012 – 2013/2014 transportation cost (trucks) were unavailable from the report. RSW containers cost the municipality less in both the financial years.

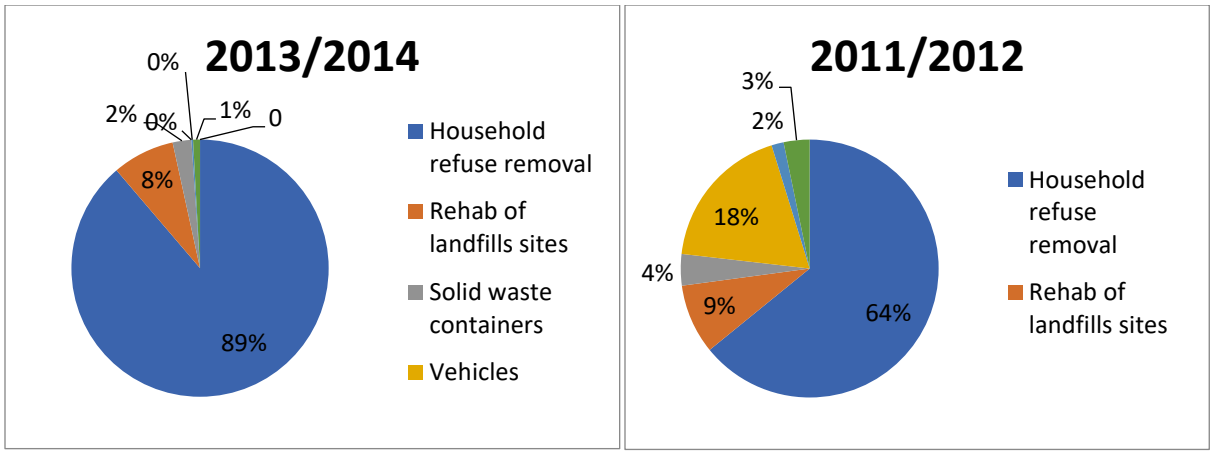


Figure 4.7: CTMM 2011/2012 and 2013/2014 RSW services costs (%)

(Source: CTMM, 2019b. IWMP 2018/2019 Report draft)

- **RSW Tariffs**

Table 4.5 illustrates the RSW tariffs with effect from July 2020. RSW services are charged based on the size of containers and the property. The collection of RSW for a 240ℓ bin once weekly is about R300,00 per month while for a 85ℓ bin it is about R110 per month. House properties costing R150,000 or less are not paying RSW services, so RSW collection is free of charge. The interview revealed that in the Olievenhoutbosch Township only the middle incomes (bond houses) pay RSW charges and low income and informal settlements are currently not paying. Illegal dumping perpetrators, if apprehended, are presently fined R7,000.

Table 4.5: CTMM RSW charges

CTMM RSW Service Type	Charge
240ℓ bin (weekly service)	R302.61
85ℓ bin	R107.19
House properties worth R150, 000 or less	Free
Fine for clearing illegal dumps	R 7,041.88

(Source: CTMM, 2020)

4.2.10 RSW Environmental impact in the Olievenhoutbosch Township

The CTMM officer for region 4 pointed to the fact that the township environment is threatened due to pollution caused by residents, and that this was not only affecting the environment but the residents' health as well. The municipality mentioned that the community's perception with regards to RSW is poor as there are still open dumps, illegal dumping being done and open burning along the streets, wetlands and water channels in the township. The CTMM does recognise that illegal dumping affects the environment's sustainability. Therefore, it is attempting to use penalties or fines as measures to control the problem, but in most instances the offenders ignore the fines so in the end it is the municipality that hires service providers to clear illegal dumps.

4.3 Researcher observations around the study area

4.3.1 Generation points

The author has observed that RSW is stored in different receptacles depending on the area. In formal residential areas (low- and middle-income residents) there are 240ℓ bins which are cleared by the municipality while in informal areas (squatter camps) maize mail sacks and plastics are used to store RSW before disposal into open dumps. Figure 4.8 shows RSW receptacles in informal areas (A) and in formal areas (B).

Figure 4.8: Informal settlements (A) RSW storage; Formal areas (B) RSW storage
(Source: Author, 2019)

4.3.2 Illegal dumps in the Olievenhoutbosch Township

The study took note of the fact that illegal dumps and open dumps were observable right throughout the township – in both formal and informal residential areas. The occurrence of open dumps in informal areas was not a surprise to the author as residents had no RSW storage facilities (see

Figure 4.7A). Open dumps and burned waste were identified in the entire squatter camp as shown in Figure 4.9 A and B. The situation was no different in the formal areas – the residents had bins as shown in Figure 4.8 B, yet they still disposed their waste in the open areas as shown in Figure 4.9.

Figure 4.9: Illegal dumps in informal residential areas

(Source: Author, 2019)

Figure 4.10: Illegal dumps in formal residential areas

(Source: Author, 2019)

4.3.3 Poor RSW management impacts

Observations revealed that the environment and public health in general in the study area was at risk due to poor RSW management and residents' perceptions concerning the RSW. Both the formal and informal areas' environment and public health were found to be problematic. The formal areas were characterised by storm water channels that were littered with RSW and children were seen playing in the midst of the waste as shown in Figure 4.11. Also, wetlands were polluted with waste although the municipality displayed notice boards to illustrate that the areas were protected wetlands, illustrated by Figure 4.11. The situation was the same in informal settlements; plastics in stagnant water were observed around communal taps (see Figure 4.13).

Figure 4.11: Polluted water channels and children playing

(Source: Author, 2019)

Figure 4.12: Protected wetland polluted by RSW

(Source: Author, 2019)

Figure 4.13: water communal tap polluted (informal settlement)

(Source: Author, 2019)

4.3.4 Waste minimisation in the township

Although the township was characterised by illegal and open dumping, sorted waste was visible at some resident's gates, as shown in Figure 4.14. Figure 4.14 also illustrates two different recyclables materials collected by IWP; glass (A) and cans (B).

Figure 4.14: Sorted RSW by informal waste pickers in the Olievenhoutbosch Township

(Source: Author, 2019)

CHAPTER 5: DISCUSSIONS OF RESULTS

5.1 Introduction

This section discusses the research findings acquired from the study. The current situation in the Olievenhoutbosch Township is discussed and then the data gathered during literature review are compared.

The results of this study have revealed that the Olievenhoutbosch Township is facing serious challenges with regards to RSW management. The current RSW systems are mainly characterized by a lack of essential historical data such as township demographic, volume of RSW generated, collection coverage and rates. This data could assist region 4 to effectively manage RSW, as it would provide an understanding of the existing RSW status. This would help the municipality plan actions that are environmentally, socially and economically sustainable.

5.2. Existing Residential Solid Waste (RSW) management

The first research objective of this study focused mainly on exploring the existing methods for Residential Solid Waste (RSW) management (collection, transport, processing, disposal and landfilling) in the Olievenhoutbosch Township. Provision of 240ℓ bins to formal residents, curbside collection on a weekly basis, clearing of open dumps two to three times a week in informal areas, and disposal of all the RSW generated to landfill sites were found to be what the current RSW management in the township consisted of. All these services were provided by the CTMM and hired contractors (especially for collection and disposal). The existing RSW management was also found to be characterized by no separation at source, minimum or lack of RSW minimization and lack of RSW historical data. Although quantitative RSW data was unavailable, the first objective has been partially met, as the picture of the existing RSW system and management is clear, and the researcher is able to suggest recommendations based on the data gathered. The following themes from the results are related to the first objective and were found to be the status quo regarding RSW management in the Olievenhoutbosch Township.

5.2.1 Residential Solid Waste (RSW) generation and composition

Understanding the RSW generation mechanism and estimating RSW quantities are essential for waste management authorities. This could assist during planning and designing of new or improved RSW systems. Dyason and Chang (2005) and Daskalopoulos *et al*. (1998) emphasize that proper planning and well-designed RSW systems require accurate past, present and future RSW quantity estimates. Generation rates and RSW composition are overlooked in the Olievenhoutbosch Township; the region does not have a RSW information and data management system. Generation rates and composition of RSW are unknown. This has led authorities to rely on assumptions and estimates. Though CTMM region 4 officers who were interviewed stated that the CTMM does not have any records in place for generation rates and composition, they mentioned that they assume that the waste generated is quantified in terms of the number of bins collected from each household. Available estimated generation rates are for the entire municipality, not per township or region within a municipality. This is because collected RSW from townships are disposed of at various landfill sites and when the disposal trucks arrive at landfill sites, the only records that are kept is of where the trucks were from or from which areas, they collected waste.

In 2007 the total population of the entire municipality was 2,345,908 and the average RSW disposed of at landfill sites in 2007 was 2,401,840 tons which means the average RSW produced was 1.02kg per capita per year. Using this estimate with the recent available data obtained from the 2018/2019 CTMM's annual report, shows that in 2017 the CTMM had 3,306,198 residents and the quantity of RSW which arrived at landfill sites was estimated at 6,454,364 tons. This means the generation can be estimated to be 1.95kg per capita, which points to an increase from the 2007 estimates. The quantity of RSW generated in the CTMM is almost equivalent to that in developed countries rather than that in developing countries. From the data collected it is not possible to estimate the amount of RSW generated using the aforementioned assumption in the Olievenhoutbosch Township, as data, like size of population and RSW disposed of, is unknown at the moment.

Other metropolitan municipalities in the country are also facing challenges in quantifying the volume of RSW generated. Latest data indicates that the City of Johannesburg (CoJ) produces

some 1,500,000 tons per year (City of Johannesburg (CoJ), 2011). However, the 2018/2019 CoJ annual report indicates that data, or records, on the quantity of RSW generated from 2016 to 2019 was not available (CoJ, 2011). Hoornweg, and Bhada-Tata (2012) in their well-known report, "What a waste," points to the fact that generation rates data in most African countries was not available and waste authorities relied on USAID estimates which claim that generation rates in urban areas is 0.5kg per capita per annum. These generation rates are based on disposal data meaning they are not a true reflection of generation rates. These estimates have limitations as they show only the quantity of RSW disposed of and not the RSW which was generated.

Lack of RSW generation rates in municipalities and townships such as the Olievenhoutbosch Township is due to challenges faced by managing authorities such as absence of working weighbridges and measures pertaining to record keeping. The CTMM does, however, recognise in its 2014/2015 Integrated Waste Management Plan (CTMM, 2014) and 2018/2019 IWMP (CTMM, 2019c) draft that it still lacks a waste information management system.

5.2.2 Collection of Residential Solid Waste (RSW)

In the Olievenhoutbosch Township the CTMM is responsible for providing RSW services. This is the same for all other metropolitan municipalities in South Africa and those in other African and European countries (UN-Habitat, 2010; Jacobsen *et al*. 2013; Moghadam *et al.* 2009; Dijkgraaf & Gradus, 2014a; Lema *et al.* 2019). Just like municipalities such as Johannesburg, Ekurhuleni, eThekwini and Cape Town and other countries like Tanzania, Belgium, India and Ethiopia, collection of RSW in the Olievenhoutbosch Township is rendered by contractors appointed by the relevant municipalities (Kassim & Ali, 2006; Post *et al*. 2003; Jacobsen *et al*. 2013; Tilaye & Van Dijk, 2014).

RSW collection in the Olievenhoutbosch Township involves curbside collections once a week, where householders place their bins on the sidewalk in the front of their yards. If a planned schedule is skipped due to unforeseen circumstances such as strikes for instance, back up collections are implemented. This weekly RSW collection is also practiced by other metropolitan municipalities such as Johannesburg (CoJ, 2019), Ekurhuleni (CoE, 2019) and eThekhwini (eThekhwini, 2016).

Interviewed CTMM region 4's RSW officers indicated that in their informal settlement in Olievenhoutbosch Township residents throw their RSW in open dumps as they are no longer provided with waste plastics due to budget constraints; however, these dumps are cleared two to three times per week.

Collection coverage in the Olievenhoutbosch Township is estimated after observation. The municipality claims that all households in all formal areas are served and during collection households place their bins outside their yards to be collected.

In South African townships the number of household dwellers living in backyards is rising faster than the proportion living in informal settlements (Lemanski, 2009). This is the same in the Olievenhoutbosch Township. Interviewed CTMM region 4's officers indicated that the volume of RSW to be collected is increasing due to the number of people moving to townships, growing informal settlers and increasing backyard dwellers (residents who erected informal houses or "shacks" adjacent existing formal houses). In the Olievenhoutbosch Township, similar to the City of Cape Town Metropolitan Municipality (CCTMM), the increase in backyard dwellers and informal settlers are found to be imposing a strain on existing municipal services such as sewage, waste, solid waste and electricity as the responsible parties cannot cope with the increased population density due to the aforementioned dwellers (Govender, Barnes, & Pieper, 2011).

5.2.3 Residential Solid Waste (RSW) transportation and disposal

Disposal methods used around the globe include composting, landfilling, incineration; open dumping, open burning and recycling – landfilling is the most used method in developing regions (UNEP, 2018). South Africa also disposes 90% of its RSW into landfills (DEA, 2018). The CTMM also dispose all Olievenhoutbosch Township's RSW at the landfill sites. The municipality presently only has four (Soshanguve, Garankuwa, Hatherly and Bronkhorstspruit) landfill sites that are in operation; the rest (eight) have reached their maximum capacities and are currently closed. RSW from the Olievenhoutbosch Township is disposed of on any of the four landfill sites that are in operation. It has been mentioned that this increases the municipality's operational cost as it has to transport waste to landfill sites that are very far from collection points. It was also revealed that none of the RSW from the Olievenhoutbosch Township is composted nor incinerated,

recycled and reused. Thus, the municipality currently focuses only on ensuring that RSW is collected and disposed of.

5.2.4 Residential Solid Waste (RSW) minimisation

The municipality is mainly focusing on ensuring that RSW is collected from the Olievenhoutbosch Township and the entire municipality. The results have shown that waste minimization and reduction are overlooked in the township. RSW is not sorted at household level before collection and disposal, but the recyclable materials are sorted and collected by Informal Waste Pickers (IWP) during collection day when households place their bins outside their yards or at landfill sites. Initially the CTMM did generate awareness and attempt to educate the residents. It also made available recycling bins to the Olievenhoutbosch Township's residents but unfortunately, they were not used for their purpose (sorting and storing waste) but for other uses such as storage for materials which are not waste. Eventually these projects failed due to lack of budgets and poor community participation in the initiatives. This supports the study of Thomas and Sharp (2013) which emphasized that residents may have access to services, education and awareness programs. However, not everyone participates.

Illegal dumping is a global environmental problem. Municipalities in South Africa and the CTMM's officials specifically are doing their best to raise awareness and educate residents regarding the impacts on environment and health, as well as the cost involved in the clearing of illegal dumping. However, illegal dumps continue to mushroom in townships. The researcher observed that illegal dumping in the township is still a challenge as RSW was seen along the streets and in water channels in formal areas where containers for RSW are provided. Some studies point to the fact that people who practice illegal dumping are aware that it is wrong, but they are just ignorant (EPA, 2017). While others point out people practice it due to minimal collection frequencies of RSW by authorities. This can be supported by Nazerry Rosmady and Abdul Haqi (2007) whose case study found that all residents they interviewed clearly voiced the same opinion namely that lack of proper collection services left them no other alternative but to dispose of their waste in open areas (by roadsides or in rivers). And this was done as they do not wish their waste near them constantly or for long periods of time.

5.3 Residential Solid Waste Governance

The second objective of this study was to explore the CTMM's guidelines, procedures and governance of RSW. The study found that the existing RSW governance included different stakeholders and legal documents. The Constitution (RSA, 1996), section 5, assigns municipalities with the task of providing RSW collection and disposal services. The CTMM does provide these services to residents of the Olievenhoutbosch Township.

The National Environmental Management Act, (59 of 2008) (RSA, 2008) outlines principles that focuses on managing waste sustainably. For example, it points out that waste must be "avoided, reduced minimised and reused or recycled where possible and otherwise disposed of in a responsible manner". This principle is currently overlooked in the Olievenhoutbosch Township and other townships within the CTMM. The findings revealed that lack of resident's participation and lack of funds are some of the obstacles hampering waste minimisation in the townships. It was also mentioned that the current CTMM waste by-laws, which govern the entire waste management regions within the municipality, do not encourage waste minimisation. The National Environmental Management Waste Act (59 of 2008) (RSA, 2008) requires metros and municipalities to have Integrated Waste Management Plans (IWMP)s and to adopt the waste management hierarchy; however, according to the research results waste management hierarchy is not adopted in the Olievenhoutbosch Township and the township does not have its IWMP, but the municipality has drafted 2018/2019 IWMP for the entire municipality. This plan may work for other regions and for some it might not as regions differ regarding demographics, type of services, culture and the number of households served.

The Municipal Systems Act, 2000 (RSA, 2000) requires municipalities to accomplish their constitutional obligation by ensuring that plans, regulations and provisions for waste collection and disposal services are in line with the Constitution (RSA, 1996). The existing CTMM waste by-laws which were approved in 2016 currently apply to the entire municipality, including the Olievenhoutbosch Township. Just like other municipalities, such as Johannesburg, eThekwini and Cape Town, CTMM waste by-laws content include definition, provision of waste services, principles outlining the promotion of waste hierarchy, residents' participation, waste minimisation

and littering. Illegal dumping is discouraged. Municipality and residents' responsibilities are outlined as well (CTMM, 2016b).

The interviewed region 4 officer mentioned that existing by-laws are effective, but there are still gaps identified by the author such as lack of enforcement and particularly to illegal dumping offenders. Currently only the municipal metro police are responsible for handling illegal dumping cases and fines. It was also mentioned that although the by-laws refer to waste minimization, waste separation at source and recycling is limited in areas such as the Olievenhoutbosch Township while in some selected high-income areas there are bins available for encouraging separation.

5.4 Residential Solid Waste (RSW) environmental impacts

Part of the main aim of this study sought to focus on the RSW impacts on the environment. This objective was achieved through interviewing the CoT official responsible for solid waste management and by way of visual observation throughout the township. **Annexure 5** (section 4) questions were used to evaluate the impact of RSW on the environment. The interview revealed that issues related to poor RSW in the Olievenhoutbosch Township are evident as there are reported pollution and health risks associated with RSW. Moreover, the author also found during his observations that illegal dumping and open dumps were a problem in the township. The results also pointed to the fact that all RSW generated in the Olievenhoutbosch Township ends up in landfill sites.

Literature in this study has shown that the impacts of landfilling are serious. Landfilling has been known to emit greenhouses gases, such as methane and carbon dioxide, that contribute to causing air pollution. On the other hand, the CTMM landfills are reaching their maximum capacities as illustrated in Table 4.4 in the previous chapter. This means that in the next 8 to 20 years a new landfill(s) may have to be developed meaning there will be loss of some species and vegetation. Landfills are also a threat to groundwater because during the rainy season organic and inorganic matter from landfills percolate into groundwater (Abd El-Salam & Abu-Zuid, 2015).

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This study collected both quantitative and qualitative primary and secondary data to explore the state of the Residential Solid Waste (RSW) management system in the Olievenhoutbosch Township. Interviews with region 4's officer, observations and reviews of municipal documents were utilized as data collection instruments. The study findings outlined in this chapter relate to the aims that were planned to be achieved. Recommendations for improving the sustainability of the management system in the Olievenhoutbosch Township are also discussed in this chapter.

The following summarized research findings are aligned to the research objectives outlined in chapter 1

Objective 1: Exploring the current methods for RSW management collection, transport, processing, disposal and landfilling in a township.

Both the primary data (interviews and observations) and secondary data (literature, municipal reports, by-laws and integrated plans) revealed that the existing RSW management in the Olievenhoutbosch Township includes provision of waste storage receptacles by the municipality to residents, collection of RSW from residential areas (generation point) on a weekly basis and transportation of collected RSW to disposal sites which are landfill sites. There is no formal sorting at source and recycling of RSW in this township, but informal sorting and recycling is present and is done by IWPs on collection days (when residents place their bins outside their yards) and at landfill sites.

Objective 2 Explore the CTMM guidelines, procedures and governance of RSW

The interview with region 4's officer and secondary data revealed that the current RSW management governance in the Olievenhoutbosch Township includes different legal framework papers which were mentioned in the previous chapter and a number of stakeholders listed in Table 4.4.

Based on the mandate outlined within the Constitution of South Africa regarding the municipality responsibility`s to provide waste services (such as collection of RSW, clearing open dumps and disposing of waste), CTMM's region 4 is executing this obligation. It was mentioned in the findings from both primary and secondary data that residents in formal areas in the Olievenhoutbosch Township are receiving collection services on a weekly basis while the open dumps of those in informal areas are cleared as well. However, other legislation such as NEMA, Act 59 of 2008, and National Environmental Management: Air Quality Act 39 of 2004 which mainly aim to encourage prevention, minimisation and reduction of pollution caused by waste, are currently not being implemented in the Olievenhoutbosch Township. Based on primary data collected, RSW minimisation initiatives are non-existent. Insufficient budgets and lack of participation from residents were pointed out as obstacles that hamper waste minimisation initiatives in the area.

6.2 Findings and conclusions

The study revealed that Residential Solid Waste (RSW) management in the Olievenhoutbosch Township is indeed a challenge and a growing environmental problem. The township's RSW management is characterized by strong policy, but weak implementation and lack of enforcement, insufficient and absence of funds, lack of RSW adequate infrastructure and poor participation from the community and other relevant stakeholders. On the other hand, rapid population growth in the township caused by backyard dwellers and informal settlers who flock to the city hoping to find better opportunities is one of the problems the municipality that have to deal with as this occurrence triggers the increase in the volume of RSW to be collected. Illegal dumping, open dumping and open burning were some of the problems identified when observations were done in the township. Even though the municipality has stated that the waste services provided are sufficient for the community of Olievenhoutbosch, there were several challenges identified during this research which showed that the entire RSW system in the Olievenhoutbosch Township still needs to be reviewed and improved in order to have a sustainable RSW system that would offer protection to the environment and the well-being of residents.

6.3 Recommendations

Based on the findings of this study, the researcher outlines some of the recommendations to address the challenges the Olievenhoutbosch Township and the CTMM are experiencing because of their existing RSW management system.

Lack of RSW information database or system

Operational and accurate RSW data collection and information systems are still absent in the CTMM's region 4, Olievenhoutbosch. The availability of these systems is essential if sustainable RSW is to be achieved. The introduction of data collection and information systems are recommended in the region. Regular recording is recommended of data such as population, households with and without RSW services, quantities of RSW generated, collected and disposed of. Record keeping must be done daily, so that monthly and annual records are easy to access. Data and information collected will assist during the planning of RSW systems (especially when IWMPs are drafted), also regarding designing new systems and in throughout the entire RSW management chain.

Rising RSW volumes to be collected

With the number of informal settlers and backyard dwellers increasing in the Olievenhoutbosch Township the volume of RSW to be collected is also increasing. Primary data has revealed that as of now the only solution for this is by increasing the number of collection trucks. However, this solution is not sustainable. At the moment the only sustainable way to solve this problem is to invest in RSW minimisation initiatives, which means encouraging residents to participate in RSW reduction, reusing and recycling in the township by providing support and creating awareness – even recycling incentives can be introduced.

Illegal dumping

Illegal dumping is a serious problem in the Olievenhoutbosch Township. The following is recommended to address this problem:

- **Stakeholders' collaboration**: involving the community by encourage them and their leaders to report illegal dumping.

- **Strengthening enforcement:** instead of clearing illegal dumps on a weekly basis the municipality could deploy a special team of metro police to inspect and oversee areas which are susceptible to illegal dumping. Visible policing in these areas could be deterrent.
- RSW management should be a cooperative effort from both the municipality and the residents. The interviews and the researcher's observations revealed that the only major stakeholder participating in Olievenhoutbosch RSW was the municipality and IWPs. Looking at the numerous spots of illegal dumps identified in the township the residents' attitude toward RSW management still needs to shift. Highlighting the adverse impact of illegal dumping through **education and awareness is recommended.** This can be done at schools, malls and by means of community meetings especially involving the IWP as stakeholders.
- The CTMM must ensure that residents in squatter camps are issued with waste bins and the collection of waste in such areas should be prioritised as there is a high number of illegal dumping and open burning in such areas.

Landfill sites

- The municipal landfill sites which were allocated to the Olievenhoutbosch Township have reached their maximum capacity and now the township RSW is disposed of in one of the four remaining landfill sites within the municipal boundary which is a long distance from the generation point. A cost effective and sustainable approach to increase the lifespan of landfill sites is recommended to reduce the volume of RSW going to such sites. This could be achieved by introducing waste minimisation strategies and recyclable material diversion strategies.

- Access to the existing landfill sites is not controlled. Improving the security of and access to landfill sites by hiring security guards, caretakers and making use of perimeter fencing to control the access of everyone coming in and out of landfill sites is recommended.

- Malfunctioning weighbridges is the current obstacle hampering the municipality to quantify accurate volumes of RSW disposed. Therefore, while weighbridges are still waiting to be repaired new methods must be established to estimate the quantities of waste disposed (i.e. volume estimation for trucks etc. can be considered). Recording and keeping the volume of

RSW disposed of on a daily basis at landfill sites is recommended as this information is important for planning.

Insufficient budgets or lack of finance to run the entire RSW system and waste hierarchy initiatives:

Funding for waste minimisation projects could be a joint venture between the CTMM and private companies where the CTMM could possibly provide recycling bins and aforesaid companies could collect at their cost. On the other hand, the CTMM could encourage the community to form recycling groups which are made up of IWPs and community members and support these groups by sorting and selling recyclables to recycling concerns.

Enforcement of by-laws:

The enforcement of waste management by-laws is absent in the township. Illegal dumping is done everywhere, and the offenders always get away with their actions and penalties are not paid. The primary data revealed that the CTMM does employ inspectors who issue fines, but at the end of the day the offenders do not go to court as it is the metro police who, by law, are the only ones that issue fines. Therefore, by-laws must be reviewed, and the roles and responsibilities of each stakeholder has to be clearly stated. For example, the CTMM must have metro police who are specifically responsible for RSW management and will oversee issues such as illegal dumping and who have the authority to issue fines.

Future research

Recommendations made in this study can be used by other townships facing the same challenges. However, a lack of the entire RSW system data and accurate data, as well as matters such as generation rates, disposed volumes, number of households served and population were the limitations of this study. Taking the aforesaid into consideration, it is strongly recommended that further research be done to fully understand and grasp the existing RSW status quo for sustainable improvement to be brought about.

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Annexure 1: RSW managing authority personnel consent form

Participant information leaflet, consent form and questions for RSW managing authority City of Tshwane

Researcher: Matodzi Mohale

Student No: 21436495

Contact details: 0835120483

Institution: Stellenbosch University

Dear Participant

My name is Matodzi Mohale and I am a student at Stellenbosch University (SU), studying towards my MPhil in Environmental Management. I would like to invite you to participate in my research project which involves the evaluation of residential solid waste management systems in low income areas and their impacts on the environment. Your community has been chosen as my study area.

Participating in this interview will not involve anything dangerous, but if you find some of the questions uncomfortable or sensitive during the discussions you are welcome to withdraw at any stage should you wish to or ask me to skip the question. In my final report your name or address will not be used, only your information about RSW, so you will remain anonymous. This interview will take not more than 30 minutes.

Permission for this study to be conducted was obtained from both your municipality (CTMM) and my university, (Stellenbosch University's Research Ethics Committee). Copies of approval are available for your reference. For more information on this study, you are welcome to contact Matodzi Mohale on 083512043 and Prof Martin de Wit (supervisor) on 0218084273. Lastly, please note that there is no remuneration in the form of money or gifts for your participation.

Thank you for participating in this research. Your insights and opinions on RSW in your area are much appreciated.

Declaration of consent by CTMM personnel to participate in research project

Declaration by CTMM personnel

I have agreed to participate in the research project titled: **Evaluating the existing residential solid waste management system and its environmental impact in low incomes areas: Case study: Olievenhoutbosch Township (City of Tshwane)**

I have been afforded the opportunity to ask questions and my questions have been answered adequately. I agree to freely provide information for this study. My name and address or any other identifying character will not be mentioned in the research report.

Initials of participant ____ Signature of participant _____ Date _____

Annexure 2: RSW managing authority personnel interview

Date: _____

Position_____

Responsibilities in Residential Solid Waste Management: _____

SECTION 1 OLIEVENHOUTBOSCH PROFILE	
Current Municipality population	
Current Olievenhoutbosch population	
Population served by Residential Solid Waste services within the municipality	
Population served by Residential Solid Waste services within the Olievenhoutbosch Township: Number of those in middle income group (bond houses) Number of those in low income group (RDPs) Number of those in informal areas (Squatter Camps)	
Is there a reason for differences (if any) in areas served? Please elaborate	

Annexure 3: RSW managing authority personnel interview

Date: _____

Position_____

Responsibilities in Residential Solid Waste Management:_____

SECTION 2: FINANCE	
How much does RSW constitute (in percentage %) in the municipal budget **Municipality as a whole:** **Olievenhoutbosch:**	
What are your financing sources (operating cost or investment capital?)	
Does reuse, recycling and recovery contribute to the RSW Budget? If yes, how much? (percentage)	
How much does the following cost for both Municipality and **Olievenhoutbosch?** ● ***Collection*** ● ***Transportation (****fuel, labour, depreciation* costs) ● ***Disposal*** ● ***Rs (reuse, recycling and recovery initiatives)***	
Number of households in the RSW tariff billing database:	

• ***Middle income areas:*** • ***Low income areas:*** • ***Informal areas:***	
What is the current Residential Solid Waste management billing method? • ***Middle income areas:*** • ***Low income areas:*** • ***Informal areas:***	
What is the monthly Residential Solid Waste tariff? • ***Middle income areas:*** • ***Low income areas:*** • ***Informal areas:***	
Is your Residential Solid Waste revenue collection stable? What is revenue collection percentage? • ***Middle income areas:*** • ***Low income areas:*** • ***Informal areas:***	

Annexure 4: RSW managing authority personnel interview

Date: _____

Position_____

Responsibilities in Residential Solid Waste Management:_____

SECTION 3 Residential Solid Waste Management System	
(a)Residential Solid Waste characterization	
Do you categorise your RSW? If yes, please give the categories and average weight per month	**Category** **Weight % or tons** Plastic Paper Metal Organic Garden waste Other
(b) Residential Solid Waste Generation rates	
How much waste was/is generated in tons/year for the past 5 years	**Municipality** 2015 2016 2017 2018 2019 **Olievenhoutbosch:** 2015 2016 2017 2018 2019

Is the annual generation rate increasing or decreasing, if it's increasing how does the municipality handle the increase?	
c) Residential Solid Waste Collection	
What was the collection coverage and rate within Olievenhoutbosch for the past 5 years? ***Middle income areas:*** ***Low income areas:*** ***Informal areas:***	Coverage Rate 2015 2016 2017 2018 2019
What is the collection frequency? ***Middle income areas:*** ***Low income areas:*** ***Informal areas:***	
Who is responsible for the RSW collection (contractor or the municipality)? ***Middle income areas:*** ***Low income areas:*** ***Informal areas:***	
Are the services sufficient for Olievenhoutbosch township?	

Are you able to serve the whole Olievenhoutbosch Township? What challenges do you experience in the collection system? How are the challenges addressed?	
(d)Residential Solid Waste Transportation	
How many RSW collection trucks are allocated for Olievenhoutbosch? Are they sufficient? If no, how is the issue addressed	
Briefly outline all the current challenges experienced with regards to RSW transportation	
(e)Residential Solid Waste Disposal	
How many landfill sites does the municipality have? Please provide details for each landfill and those that are designated for Olievenhoutbosch *Age* *Current capacity* *Those that are full* *Operation and management* *Limitations and advantages* Name(s) of the landfill sites designated for Olievenhoutbosch:	

Is there any other disposal method that the city has? If yes, what are they?	
How much waste (percentage/tons) was landfilled, composted/incinerated and recycled in the past five years	**Olievenhoutbosch:** Landfill Recycled Composted Incinerated 2015 2016 2017 2018 2019
Briefly outline all the current challenges experienced with regards to RSW disposal	
Anything you wish to add that is municipality and Olievenhoutbosch RSW related?	

Annexure 5: RSW managing authority personnel interview

Date: _____

Position_____

Responsibilities regarding Residential Solid Waste Management:_____

SECTION 4: Environmental Management	
Is waste hierarchy implemented? If yes, outline the details and statistics (quantities of RSW reused, recycled, recovered, treated, disposed)	
Do you have Rs (Reuse, Reduce and Recycle) initiatives?	
Who funds these initiatives?	
What are the challenges experienced with these initiatives?	
Recycling initiatives	
Do you have on-going initiatives/projects on public awareness development for RSW sorting, recycling, reduction and reuse?	
Do you provide households with recycling bins?	
How is sorting at source encouraged at household level?	
Are there incentives (discount in tariffs for instance) to encourage households to sort or recycle?	
Do you have recycling centres within the township? How many?	

Waste picker's initiatives	
Are waste pickers included in your RSW management plan? If no, why?	
How many waste pickers does the municipality/Olievenhoutbosch have if recorded?	2015 2016 2017 2018 2019
Are there any initiatives in place to support waste pickers? If yes outline? If no, why?	
Who funds these initiatives?	
What are the challenges experienced with these initiatives?	
What is the contribution of waste pickers in Olievenhoutbosch? Any evidence, such as quantity of waste recycled?	
How do you handle illegal dumping? (Penalties? Collection illegally dumped?)	
What are environmental impacts attributed to poor RSW management reported in the Olievenhoutbosch and municipality as a whole?	

Annexure 6: RSW managing authority personnel interview

Date: _____

Position_____

Responsibilities in Residential Solid Waste Management:_____

SECTION 5: Residential Solid Waste Governance	
List all RSW stakeholders and their responsibilities within Olievenhoutbosch	
Are the current by-laws and policies effective in managing RSW? If yes, mention examples? If no, why?	
Is the policy effective?	
How often is the policy implementation reviewed?	
Do you have a RSW management policy? If yes, may I have a copy? If no, why?	
Does the municipality/Olievenhoutbosch have an Integrated Waste Management Plan? If yes, may I have the copy?	
Do you have landfill site environmental monitoring plan? If yes, may I have the copy? How often is the monitoring done?	
How is RSW non-compliance addressed?	

Are there any initiatives in place on how illegal dumping and pollution can be prevented? If yes, what are they and how are they implemented If no, what is being done at the moment to prevent it?	
What are the remedial measures for illegal dumping or polluted areas because of the RSW?	
Do you have a RSW collection system for measuring RSW generation, collection, disposal and reduction	
Does the municipality conduct RSW management awareness to its citizens? If yes, is there RSW awareness in Olievenhoutbosch? How often is the awareness conducted?	
Does the municipality re-evaluate its RSW management system? If yes, after how long?	
Are there any challenges regarding the current RSW management system, in particular from Olievenhoutbosch?	
Anything you would wish to add?	

ANNEXURE G7

CITY OF TSHWANE
IGNITING EXCELLENCE

City Strategy and Organizational Performance

Room CSP22 | Ground Floor, West Wing, Block D | Tshwane House | 320 Madiba Street | Pretoria | 0002
PO Box 440 | Pretoria | 0001
Tel: 012 358 7423
Email: NosiphoH@tshwane.gov.za | www.tshwane.gov.za | www.facebook.com/CityOf Tshwane

My ref: **Research Permission/ Mohale**
Contact person: **Pearl Maponya**
Section/Unit: **Knowledge Management**

Tel: 012 358 4559
Email: PearlMap3@tshwane.gov.za
Date 09 September 2019

Mr Matodzi Mohale
6996 Mafumo Str
Olievenhoutbosch x36
0175

Dear Mr Mohale,

RE: EVALUATING THE EXISTING RESIDENTIAL SOLID WASTE MANAGEMENT SYSTEM AND ITS ENVIRONMENTAL IMPACT IN LOW INCOMES AREAS: CASE STUDY OLIEVENHOUTBOSCH TOWNSHIP (CITY OF TSHWANE).

Permission is hereby granted to Mr Matodzi Mohale, MPhil Degree in Environmental Management candidate at Stellenbosch University (SU), to conduct research in the City of Tshwane Metropolitan Municipality.

It is noted that the aim of this study is to explore the state of Residential Solid Waste (RSW) management system in Olievenhoutbosch Township and the impact on the environment, mainly from the collection and disposal methods, with the extended goal of improving the management system. The City of Tshwane further notes that all ethical aspects of the research will be covered within the provisions of SU Research Ethics Policy. You will be required to sign a confidentiality agreement form with the City of Tshwane prior to conducting research.

Relevant information required for the purpose of the research project will be made available as per applicable laws and regulations. The City of Tshwane is not liable to cover the costs of the research. Upon completion of the research study, it would be appreciated that the findings in the form of a report and or presentation be shared with the City of Tshwane.

Yours faithfully,

PEARL MAPONYA (Ms.)
DIRECTOR: KNOWLEDGE MANAGEMENT

City Strategy and Organisational Performance • Stadstrategie en Organisatoriese Prestasie • Lefapha la Thulaganyo ya Tiro le Togamaano ya Toropokgolo • UmNyango wezokuSebenza namaQhinga aHleliweko kaMasipala • Kgoro ya Leanopeakanyo la Toropokgolo le Bodiragatši bja Mmasepala • Muhasho wa Vhupulani ha Dorobo khulwane na Mashumele • Ndzowulo ya Maqhinga ya Dorobakulu na Matirhele ya Masipala • Umnyango Wezeqhinga Ledolobha Nokusebenza Kwesikhungo

ANNEXURE 8

UNIVERSITEIT STELLENBOSCH UNIVERSITY

NOTICE OF APPROVAL

REC: SBER - Amendment Form

19 October 2020

Project number: 10617

Project Title: Evaluating the existing residential solid waste management system and its environmental impact in low incomes areas: Case study Olievenhoutbosch Township (City of Tshwane)

Amended Project Title: Evaluating the existing residential solid waste management system and its environmental impact in low income areas. The case of Olievenhoutbosch Township, City of Tshwane.

Dear Mr Matodzi Mohale

Your response to stipulations submitted on 16 October 2020 was reviewed and approved by the REC: Social, Behavioural and Education Research (REC: SBE).

Please note below expiration date of this approved submission:

Ethics approval period:

Protocol approval date (Humanities)	Protocol expiration date (Humanities)
23 July 2019	22 July 2022

GENERAL REC COMMENTS PERTAINING TO THIS PROJECT:

INVESTIGATOR RESPONSIBILITIES

Please take note of the General Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

If the researcher deviates in any way from the proposal approved by the REC: SBE, the researcher must notify the REC of these changes.

Please use your SU project number (10617) on any documents or correspondence with the REC concerning your project.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

CONTINUATION OF PROJECTS AFTER REC APPROVAL PERIOD

You are required to submit a progress report to the REC: SBE before the approval period has expired if a continuation of ethics approval is required. The Committee will then consider the continuation of the project for a further year (if necessary).

Once you have completed your research, you are required to submit a final report to the REC: SBE for review.

Included Documents:

Document Type	File Name	Date	Version
Informed Consent Form	Consent Form	13/10/2020	v1
Research Protocol/Proposal	Proposal	16/10/2020	V2

If you have any questions or need further help, please contact the REC office at cgraham@sun.ac.za.

Sincerely,

Clarissa Graham

REC Coordinator: Research Ethics Committee: Social, Behavioral and Education Research

National Health Research Ethics Committee (NHREC) registration number: REC-050411-032.
The Research Ethics Committee: Social, Behavioural and Education Research complies with the SA National Health Act No.61 2003 as it pertains to health research. In addition, this committee abides by the ethical norms and principles for research established by the Declaration of Helsinki (2013) and the Department of Health Guidelines for Ethical Research: Principles Structures and Processes (2nd Ed.) 2015. Annually a number of projects may be selected randomly for an external audit.