An evaluation of strategic management of landfill sites: A case study of Thohoyandou Block J landfill site, Vhembe District Municipality, Limpopo Province.

By

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A thesis submitted to the Department of Ecology and Resource Management, School of Environmental Sciences, University of Venda, in fulfillment of the Master of Environmental Sciences.

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DECLARATION

I, **NEFALE ANZA** of student number **11600874,** hereby declare that this dissertation for Master of Environmental Sciences in Ecology and Resource Management has not been submitted previously for any degree at this or any other Universities. In addition, it is my own work in design and execution and all reference materials contained therein, have been duly acknowledged.

A. Nefale (student)

Signature:……………………………. Date………………………………..

ABSTRACT

The purpose of this study was to evaluate the strategic management of the Thohoyandou Block J landfill site. There are limited documented materials on strategic management of landfill sites in South Africa. As a result, this study sought to close this gap and expose new insights that it deemed to be of great importance in the management and operations of landfill sites. The capacity of a TBJ landfill site in terms of its efficiency in disposing waste, adherence to rules and procedures and the overall management of the site are the key areas of this study. The dominant types and sources of solid waste disposed at the TBJ landfill site, efficiency and effectiveness of operation of TBJ landfill site and operational challenges are the main areas covered in this study.

The study adopted the mixed methods approach, involving both qualitative and quantitative research methods. Both primary and secondary data were acquired. Primary data were obtained through a questionnaire, an interview and field observation, using an observation checklist. Secondary data were obtained from ArcGIS Desktop Help 9.2 and documented materials from the Thulamela Local Municipality and the TBJ landfill site, the Integrated Waste Management Plan, Integrated Development Plan, TBJ landfill site's monthly report, audit report and landfill site's operating plan. Basically, field observation and a questionnaire completed by the waste manager, landfill operator and supervisor, were used to collect data on the operational challenges of TBJ landfill site and to obtain data on the efficiency and effectiveness at which the TBJ landfill site is operating. Waste pickers were interviewed and field observation was undertaken, to identify the dominant types and sources of waste disposed at the TBJ landfill site. A questionnaire completed by TBJ landfill operator, ArcGIS Desktop Help 9.2 for field measurement, reports of the amount of waste recorded and the municipality's database, were utilized to elicit data regarding the determination of the capacity of TBJ landfill site.

The results obtained revealed that the TBJ landfill site's remaining capacity is 317 085 m^3, which will be exhausted in the next 4 years. Plastics were found to be the dominant waste disposed at the TBJ landfill site, at 40%, followed by card-boxes, which constituted 32%. The dominant sources of solid waste generation in the TBJ landfill site were households, at 51%, followed by commercial, at 31% and industrial, at 11%. The absence of a weighbridge, to weigh loads of waste, frequent break down of equipment, lack of equipment required to operate the TBJ landfill site efficiently and the presence of fire hazards, were some of the major challenges facing operations at the TBJ landfill site. Waste diversion and compaction, were some of the strategies used to manage the TBJ landfill site's capacity.

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ABBREVIATIONS AND ACRONYMS

CBD: Central Business District

CED: Centre for Environment and Development

DEA: Department of Environmental Affairs

DEAT: Department of Environmental Affairs and Tourism

DWAF: Department of Water Affairs and Forestry

DWA: Department of Water Affairs

ELM: Emnambithi Ladysmith Municipality

EWSWA: Essex Windsor Solid Waste Authority

EPA: Environment Protection Authority

GHG: Green House Gas

IDP: Integrated Development Plan

ISWA: International Solid Waste Association

IWMP: Integrated Waste Management Plan

MTM: Mississippi Town Mills

MSW: Municipal Solid Waste

NEM:WA: National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008)

NWMSDR: National Waste Management Strategy Draft Report

TBJ: Thulamela Block J

TCBD: Thohoyandou Central Business District

TLM: Thulamela Local Municipality

VDM: Vhembe District Municipality

GLOSSARY

Buffer zone is a separation between the registered landfill site boundary and any adjacent residential or sensitive development (DWAF, 1998).

By-product refers to a substance that is produced as part of a process that is primarily intended to produce another substance or product and that has the characteristics of an equivalent virgin product or materials (Government Gazette Republic of South Africa, 2009).

Compaction means the mechanical process of reducing the volume of municipal solid waste placed at the active face (British Columbia, 2016).

Landfill is the physical facility which is used for the disposal of solid waste and residuals on the surface of the earth (Otitoju, 2014).

Leachate production is the infiltrated water that percolates down through the waste deposit and has undergone chemical reaction (Baucom & Cedric, 2013).

Management is the organizational process that includes strategic planning, setting objectives, managing resources needs to achieve objectives and measuring results (Dwan, 2003).

Municipality means a municipality which is established in terms of the local government: Municipal Structure Act, 1998 (Act No. 117 of 1998) (Government Gazette Republic of South Africa, 2009).

Site is an area specifically set aside for the disposal of refuse and which has been approved (Ekurhuleni Metropolitan Municipality, 2001).

Solid waste is any waste that is not liquid or gaseous (Yukalang *et al*., 2017).

Strategy is an action which is designed to achieve a long-term or overall aim (Dwan, 2003).

Treatment is any method, technique, or process, designed to change the biological character or composition of waste so as to sterilize such waste (Gauteng Department of Agriculture, Conservation and Environment, 2004).

Tipping means disposing solid and semi-solid waste on the ground, compacting and covering it with suitable materials to isolate it from the environment (Gosh & Hassan, 2005).

Waste is any substance whether or not the substance can be reduced, re-used, recycled and recovered (Government Gazette Republic of South Africa, 2009).

Waste pickers are people who sift through refuse to collect items perceived to be useful (Oyiboka, 2014).

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Waste disposal has become a significant challenge, even in the most developed municipalities in the world. The world is currently experiencing unprecedented generation of waste and high waste volumes affect the capacity and operational effectiveness of landfill sites. According to Kawai & Tasaki (2016: 1) “about 1.3 billion metric tonnes of municipal solid waste (MSW) are generated annually around the world”. Apparently, the steep increase in MSW generation is influenced by factors, ranging from population growth, economic conditions, improved living standards and urbanization. Hoornweg & Bhada-Tata (2012) predict that the world’s MSW production is expected to be approximately 2.2 billion tonnes per year by 2025 and already the current systems of waste management facilities, such as landfill sites, are failing to fully cope with the huge volumes of waste which is being generated by the continuous increment of waste generating activities. The situation is worse in the global south, where waste disposal procedures, principles and protocol are commonly undermined. Beaven *et al*. (2014) state that landfill disposal remains the main destination for waste management and it is expected to remain as the main destination in the foreseeable future.

According to Mkhize (2011), South Africa is ranked amongst the major producers of waste in the world, and it is one of the biggest in Africa. This was supported Glazewski (2005), who asserted that approximately 300 million tonnes of solid waste is generated annually in South Africa, with most of this waste being disposed at landfill sites. This shows that the implementation of cleaning, collection and minimization of waste generated through various activities that generate solid waste cannot be made without considering landfill disposal (Novella, 2014). In spite of being at the bottom of the desirability hierarchy, landfill sites remain a fundamental component of effective integrated waste management, and without properly designed, managed and operated landfill sites, environmentally friendly waste management is not possible.

Solid waste has been defined by Ahmad *et al*. (2016: 120) as "solid materials arising from human activities, which has no value to people and can be categorized according to their sources, such as, domestic, industrial, commercial, construction or institutional, and also according to their type such as glass, metals, plastics and paper". Generally, solid wastes are considered useless and unwanted materials, and most of these unwanted materials end up being sent to landfill site . According to Otitoju (2014: 42): "landfill is the physical facility which is used for the disposal of solid waste and residuals on the surface of the earth and it is the most frequent MSW disposal method". Landfills remain an important component in waste management, as it deals with MSW directly and complements alternative waste management technologies, which in themselves give rise to residues that require disposal ultimately via landfill (Egun *et al*., 2016).

Chisadza (2015) states that South Africa's approach to waste management focuses on waste collection by municipalities with onward disposal in landfills, and this puts pressure on landfill sites to accommodate un-proportional amount waste to be disposed. Actually, not all solid waste disposed at (TBJ) landfill site is useless. This is because some of the discarded products could be used profitably by other end-users; for example, through recycling. The amount of solid waste which is generated in South Africa is on a steady increase and it tends to be problematic when it comes to disposing it (Glazewski, 2005). According to Kusi *et al*. (2017), while there is a steady increase in waste quantity, there is still limited information on the kind of waste that end up at landfill sites. In view of that, the steady increase in the generation of solid waste necessitates the development of waste management strategies. However, solid waste management strategies are facing an enormous challenge because waste is being generated at a disproportionally faster rate than the rate at which it is disposed. Most of MSW are disposed at landfill sites; thus, some of the recyclable waste are not recycled, and accordingly this reduces the capacity of the landfill site rapidly (Kalnatarifard & Yang, 2012).

South African's landfill sites are inundated with big volumes of waste generated, as South Africa is amongst the largest producers of solid waste materials Glazewski (2005). Within the changing environment and growing economy of the Thulamela Local Municipality (TLM), more waste is produced every day. As a result, the waste which is generated is sent to the Thohoyandou Block J (TBJ) landfill site, which is the only landfill site currently operating within the TLM, as Makwiliza landfill site is still waiting for a permit to operate (TLM IDP, 2016). The volume of waste disposed at the TBJ landfill site will never be the same due to the various activities practiced which generate solid waste within TLM. Therefore, this study was undertaken to evaluate the strategic management and the operational nature of the TBJ landfill site.

1.2 Statement of the research problem

Waste management services rely heavily on landfill sites for the disposal of waste, and these facilities end up receiving more waste than they anticipate (SAEO, 2012). Mohamad *et al*. (2017) state that landfill sites are inundated with big volumes of waste to deal with and in the global south the situation is worse because landfill facilities are not well developed; are poorly resourced, with inadequate waste treatment facilities. There is also lack of information when it comes to the operation and management of waste; lack of environmental abatement measures; absence of proper waste covering materials; co-disposal of municipal solid waste and hazardous waste; and inefficient utilization of disposal space. Most of the waste produced in TLM is collected and disposed of at the TBJ landfill site, the only landfill site which is operating in TLM. This necessitated the identification of major sources and types of waste disposed there. In addition, due to the fact that the TBJ landfill site is the only landfill site operating in TLM, this inadvertently leads to huge heaps of waste to be received, and some of the waste disposal principles, protocols and procedures end up being ignored, and the effects thereof are more problematic to the operation and management of TBJ landfill site. TBJ landfill site does not have a weighbridge of recording the waste disposed. Therefore, it is important to evaluate the strategies used to calculate the volume of waste disposed at TBJ landfill site.

The measurement of the remaining lifespan of the TBJ landfill site has not been done (TLM IWMP, 2011). Therefore, it was crucial to evaluate the capacity of TBJ landfill site in terms of the volume of disposable waste. In addition, the fence erected around the TBJ Landfill site is disintegrated, which can lead to unauthorised access to landfill site by unauthorised people, to reclaim and discard waste material illegally. This made it necessary to establish the operational management challenges of the TBJ landfill site.

1.3 Aim of the study

The aim of this study was to evaluate the strategic management and operational nature of TBJ landfill site at the Thulamela Local Municipality (TLM) in Vhembe District Municipality (VDM), Limpopo Province.

1.4 Objectives

To that end, the objectives of the study were as follows:

- To determine the capacity of the Thohoyandou Block J landfill site in terms of the volume of waste disposable.
- To identify the dominant types and sources of solid waste delivered to the Thohoyandou Block J landfill site
- To assess the efficiency and effectiveness with which the Thohoyandou Block J landfill site is operating
- To establish the main operational challenges at the Thohoyandou Block J landfill site

1.5 Research questions

The following research questions were formulated in order to help in achieving the study objectives:

- What is the capacity of the Thohoyandou Block J landfill site in terms of the volume of waste disposed?
- Which are the dominant types and sources of solid waste delivered to the Thohoyandou Block J landfill site?
- What are the operational challenges at the Thohoyandou Block J landfill site?
- How efficient and effective is the operation of the Thohoyandou Block J landfill site?

1.6 Justification of the study

The capacity of the TBJ landfill site, the effectiveness and efficiency with which the TBJ landfill site is operating, and the management and operational nature of TBJ landfill site have not been previously studied by other researchers (Thulamela Local Municipality IWMP, 2011). As a result, there was a need for this research to be undertaken, in order to find out the remaining capacity of TBJ landfill site, and how effective and efficient the TBJ landfill site is operating and managed through evaluation of operational management challenges of the landfill site, so that intervention measures can be proposed, where applicable and necessary. In addition, Eco Africa (2016) has reported that there are no landfill sites for disposal of hazardous waste in the Vhembe District Municipality (VDM) and the risks are that the hazardous waste can be disposed to landfill sites which permit general waste only. Thus, these necessitate the need for identifying major sources and types of waste disposed at the TBJ landfill site. Furthermore, limited studies have been conducted on landfill operational practices in Limpopo Province. Therefore, this study sought to bridge the existing gap (Mkhize, 2011).

1.7 Delineation of the study area

1.7.1 Geographical Location of the study site

The TBJ landfill site is located in Thohoyandou Block J, which falls under the TLM within the VDM in Limpopo Province of South Africa. The study site is surrounded by the Thohoyandou Central Business District (TCBD), Tswinga, Maniini and Shayandima. The TBJ landfill site is situated approximately 8 kilometers from the TCBD, about 401 meters (m) from the Mvudi River, along side the road leading to TCBD from Tswinga Village. The coordinates of the TBJ landfill site are 23^{0}00’11.0’’ S and 30^{0}28’01.0’’ E.

Figure 1.1: Location map of TBJ landfill site

Figure 1.1 shows the location of the study area. The study site is indicated by the red colour on the map, with a yellow line passing from the north west towards the south eastern side, representing the road used by incoming vehicles carrying waste to be disposed at the TBJ landfill site.

1.7.2 Soil type and water resources

A wide spectrum of loam and sandy soils occurs in the study area of the present research, with clay soils being least common (DWA, 2012). According to Ogunmola (2016) landfill sites must not be sited on a wetlands or less than 100m from rivers, lakes, ponds or swamps. The landfill site under study is not located on a wetland or any water resource. However, the nearest water resource is Mvudi River, which is located more than 100m from the landfill site.

1.7.3 Population

The TLM has been experiencing a population growth since 2001, as the population rose form 580 829 in 2001 to 602 819 in 2010 and the growth difference was 21 990. In 2011 the population of TLM was 618 462, meaning the population increased by 15 643 (TLM IDP, 2014). According to the TLM IWMP (2011), the population growth of TLM is 0.62%. Population growth can cause a rapid increase in waste volumes and types of waste (Mkhize, 2011). This concurs with the findings of Joshi & Ahmed (2016) who claim that there is a strong relationship between population growth and increasing waste generation.

1.7.4 Economic activities

In terms of the economic activities within the TLM, there is a host of commercial organizations, ranging from industries, banks, medical centers, educational institutions, hotels, furniture, motels, and shopping malls, that contribute in waste generation which are disposed at the TBJ landfill site. Some of the waste generated from those commercial organizations include paper, plastic and cardboard.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature that add value to this research. Documents such as books, journals, articles, government materials and any kind of report, were reviewed. The review was intended to consolidate the work that has already been done by other scholars and professionals, so that the study is based on an existing body of knowledge.

2.2 Legislative framework

Legislation is the back-bone of policy formulation and enforcement, and in order to enable an environmentally-friendly operation and management of landfill sites, comprehensive knowledge about the behaviour of the landfilling of waste is crucial and a set of completely different rules and regulations is required when one is concerned about the appropriate operation and management of landfill sites (Kubin, 2012).

2.2.1 International law on landfill disposal

Garner (2009) revealed that the basic requirements for the disposal of any kind of waste, at specified sites globally, are usually waste management licenses. The international law on waste disposal by landfill has been setout as follows: “Landfill disposal is still used because it is less expensive than recycling and waste minimization. Technological and other standards preventing contaminants from reaching the groundwater should be developed. These technological standards should make the landfill disposal a sounder waste management method”. The selection process of the landfill site and authorization of operations must incorporate an extensive Environmental Impact Assessment (EIA) and must within the approval process meet certain basic criteria. To that end, some of these criteria comprise isolation of a site via engineered barriers such as liners and other leak collection systems controlling and preventing contamination of the surrounding environment and groundwater. This therefore implies that groundwater as well as surface water must be monitored continuously. Accordingly, the structure of the landfill site is of incredibly significance. Therefore, it must make allowance for pre-and-post closure management systems (Louka, 2006).

2.2.2 South African legislations

In South Africa, there are monitoring and managing systems in place to control the process of landfilling of the waste in the form of licenses, permits, permit exemptions and directions, in terms of various acts, especially the Constitution of the Republic of South Africa, 1996 (Act No. 108 of 1996) and National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008) amongst other (Garner, 2009).

i. Constitution of the Republic of South Africa, 1996 (Act No. 108 of 1996)

The Constitution of the Republic of South Africa, 1996 (Act No. 108 of 1996) instructs and informs all other legislation and policy guideline, by setting the framework for the administration of environmental laws by national, provincial and local spheres of government (Glazewski, 2005).

Section 24 of the Bill of Rights, contained within the Constitution of the Republic South Africa, 1996 (Act No. 108 of 1996), states that everyone has the right:

(a) to an environment that is not harmful to their health or well-being; and (b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that – (i) prevent pollution and ecological degradation; (ii) promote conservation; and (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

The above section forms the legal backbone of all the legislation, policies and bills– at national, provincial and local level. The provisions set out for environmental-related rights are those which the national, provincial and municipal regulations must work to ensure they prevail. The activities undertaken by municipalities, such as landfilling, must be assessed in terms of how they are managed and operated, in order to check if these management and operational style do endorse the rights mentioned in section 24 of the Constitution of the Republic of South Africa, 1996 (Act

No. 108 of 1996), for how closely they adhere to the upholding of these rights (Garner, 2009).

ii. National Environmental Management: Waste Act, 2008, (Act No. no 59 of 2008)

National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008) (NEM:WA) has a significant impact on waste management in South Africa. Firstly, it requires the municipalities to have a comprehensive Integrated Waste Management Plan (IWMP). Secondly, it requires industries to develop an industry waste management plan, to indicate on how industries deal with their waste. Furthermore, section 26(1) paragraph (a) and (b) of NEM:WA further stipulates that no person may dispose waste in or on any land, water body or at any facility unless the disposal of such waste is authorised by a laws; or the disposal of waste is in a manner that is likely to cause pollution of the environment or harm to human health and wellbeing. Moreover, section 20 paragraph (b) of the NEM:WA states that “no person may commence, undertake or conduct a waste management activity, except in accordance with- (b) a waste management licence is issued in respect of that activity, if a licence is required”.

iii. Municipalities By-laws on waste

Most of the local municipalities around the Republic of South Africa do have by-laws, which deal with solid waste management issues within their area of jurisdiction. The following are some the municipalities By-laws of the municipalities in South Africa. Those include: the following; City of Tshwane Metropolitan Municipality: Waste Management By-law, Amathole District Municipality: Waste management By-laws, Ekurhuleni Metropolitan Municipality: Solid waste By-laws and Thulamela Local Municipality: Refuse removal, refuse dumps and solid waste disposal By-laws. A Municipality’s solid waste disposal By-laws give municipality powers to control a disposal site or to contract some other person or body to control, manage, operate a disposal site, on behalf of the municipality in accordance with the provisions of the by-laws and the provision of other legislations that may be applicable (Kidd, 2008).

2.2.3 South African guideline for waste disposal by landfill

South Africa introduced the first edition of the Minimum Requirements for Waste Disposal by Landfill in 1994, whose specific intent was to introduce the proper engineering and lining of landfill sites, so that they may not discharge polluted effluent into groundwater, thereby causing water pollution. The Minimum requirements for waste disposal by landfill (2nd edition) was introduced in 1998 by the Department of Water Affairs and Forestry, to assist in achieving compliance with regard to landfill permitting, sitting, design, operation and management, monitoring as well as rehabilitation and aftercare of the landfill site (Novella, 2014).

2.3 Landfill site operations and management

A proper operation of the landfill site involves the following: waste identification and restriction, compaction of waste, daily cover, run-on and runoff control, landfill gas monitoring and management, leachate management and treatment of special waste (EPA, 2013). This is affirmed by Riat (2010), who stated that landfill site operational practices encompass management of waste types, waste compaction, daily cover, storm water management and leachate management.

According to Kusi *et al*. (2017: 20): "the main aim of proper management of landfill site is to minimize and avoid challenges which are associated with landfill sites and to provide comprehensive documentation of the landfill and its behavior". On the other hand, Jain (2016: 99) stated that "landfill management involves strategies of waste minimisation, such as recycling and compositing at landfill site". Some of the most important operation and management practices of landfill sites include the following:

2.3.1 Signposting and road access

Suitable signs must be erected on the landfill site for showing directions and speed limits. According to the DWAF (1998: 112), "there must be enough signs which conforms to requirements of the road ordinance in the vicinity of the landfill site indicating distance to landfill site from nearest main road and roads should also be managed to meet condition of all weather period". Signage at landfill sites is of great importance, and such signage must indicate the class of the landfill site, type of waste that should be received at the landfill sites, operating hours at the entrance of the landfill, and also directing all the routes in the landfill site, as lack of signage can lead to uncontrolled dumping, in which waste is brought to the landfill site and the type of waste brought to the landfill is not taken into consideration to verify if it is appropriate to be disposed at the landfill site (Kusi *et al*., 2017). This is similar to the assertion made by Pienaar & Howard (2014), who posited that in a better managed landfill site, weatherproof notice board must be erected at an approved location, near the entrance of the landfill site, such notice board must display the operating times, the site rules, the type of waste that is accepted at the landfill site, the rates involved in disposing of waste and the contact details of the landfill site supervisor for emergencies.

2.3.2 Landfill operating plan

According to DWAF (1998: 114), "operating plan is a site specific document developed as part of the landfill permit application procedure which provides information on how landfilling must be operated". Saini *et al*. (2016) assert that it is important to have landfill operating plan in place, as it helps in directing the operation process of the landfill site, and everything relating to the operation of landfill site should be included in such operating plan. Therefore, an operating plan should always be in place to be followed when landfilling the waste. For example, a study conducted by Kumar *et al*. (2009) indicates that the unavailability of an operation plan at landfill sites may result in more environmental impacts

2.3.3 Access control

A landfill site should have effective access control, to prevent unauthorised entry into the landfill site, as effective access control prevents landfill sites from receiving all kind of wastes which are not authorised (Al-Yaqout & Hamoda, 2002). Proper security at the landfill site is important because it prevents people from dumping unauthorised waste. Therefore, landfill sites must be fenced off to prevent unauthrorised person from entering the site illegally and the condition of the fence must be inspected regularly (Rana *et al*., 2015). Pienaar & Howard (2014) have recommended that lockable gate and concrete palisade fencing must be installed around landfill site as other types of fencing can be easily vandalized and stolen.

2.3.4 Waste inspection

Regassa *et al*. (2011) state that waste must be inspected before it is disposed at a landfill site. The main reason for doing this is to verify whether such waste conforms to the landfill site permit. This practice seems quite important, as Egun (2016: 116) stated that "trucks carrying waste to be landfilled should be inspected at the gate to ensure that the waste carried is the waste that is authorised to be landfilled within such landfill site to avoid landfilling hazardous waste with municipal solid waste". A study conducted in India proved that failing to practice waste inspection in some of the landfill sites can lead to the mixing hazardous medical wastes and general waste, while landfilling waste, which is not acceptable as landfills should be authorised to accept certain types of waste (Atalia *et al*., 2015). Mixing of different types of waste due to unpracticing of waste sorting was also exposed in the West Rand District Municipality, Gauteng, South Africa, as Ginindza & Muzenda (2015) stated that waste inspection is not performed to the waste which is brought into the Luipaardsvlei landfill site as mixed types of waste (e.g. municipal solid waste and hazardous waste) are also observed at the landfill site. This also make it difficult to perform recycling. Furthermore, this practice of co-disposal of different waste in same landfill site was also exposed by Mothiba (2016: 13-14) as she stated that " most landfills in South Africa practiced co-disposal of hazardous, building and municipal solid waste".

2.3.5 Waste recording

The use of weigh bridges increases the reliability of recording data on MSW that is delivered to landfill sites (ELM, 2010). However, Egun *et al*. (2016) posited that smaller municipalities which often cannot afford weigh bridges because of budget constraints can estimate their waste based on number of trucks delivering waste to the landfill site. This shortcoming is evident in many developing countries, and many smaller municipalities have to estimate the annual MSW based on the number of trucks delivering waste (Kawai *et al*., 2012). A common way for estimating the amount of MSW sent to landfill site, based on the information available on waste transportation by trucks, is revealed in the following Equation:

$$W = c \times v \times d \times t \times I \times 365$$

Where W is the annual MSW generation amount, c is the average capacity of a waste-hauling truck, v is the average loading volume ratio of a truck, d is the average density of MSW loaded on truck, t is the average number of trips per truck, and I is the average number of operating trucks.

Unfortunately, the estimation of trucks without weigh bridge data is less reliable because of uncertainties related to the parameters (Kawai & Tasaki, 2016). The method of estimation without a weigh bridge were found to be practiced in many places, as Kumar *et al*. (2009) found that in most of the landfill sites in India, estimations of the amount of waste delivered to a landfill site are done based on the incoming vehicles carrying MSW to landfill sites, as they do not have weigh bridges for recording the waste. Similarly, Kusi *et al*. (2017) found that Abokobi and Nkanfoa landfill sites which are situated in Ghana, both did not have a weigh bridge for recording incoming waste. However, the waste load is recorded by the supervisor manually, wherein the quantity of waste is estimated using the load of the truck. At Kpone, the landfill truck load is weighed when coming in and then weighed when going out, to have a precise number of tonnes of waste sent (Kusi *et al*., 2017). Al-Yaqout & Hamoda (2002) discovered the same manner of recording waste, as they found that in Kuwait prediction of waste volume is based on the average number of incoming trucks and the optimum weight of the truck, as the landfill sites do not have weigh bridges. This method of recording incoming waste based on the tonnage of incoming trucks in the landfill is also applicable in South African landfill sites which does not have weigh bridge of recoding incoming waste. For example. Section 3 of Minimum requirements for waste disposal by landfill site states that incoming waste at landfill sites can be calculated based on average daily tonnage of on the basis of incoming volumes.

For the landfill site that have a weigh bridge, Egun *et al*. (2016) stated that the trucks carrying waste must be weighed at the weigh bridge when coming to the site and they must be then be weighed after unloading the waste, to get the total number of waste dumped without the weight of truck being included. After weighing the waste, the tonnage must be calculated and listed on the data base for record keeping. According to ELM (2010: 26) "a weigh bridge at the landfill site greatly helps or assists in quantifying the general waste volume which are disposed to the landfill site". The waste types and quantities received at the landfill site should be recorded and such recordings should be carried out using data recording system, consisting of one or more computer, this helps in finding out which type of waste is being landfilled and also to find out the amount of tonnes of waste being landfilled (International Solid Waste Association, 2010).

2.3.6 Waste compaction

Waste compaction is very important at landfill sites, because it reduces voids in the waste, which can prevent water infiltration and ultimately the amount of leachate that can be formed. In addition, waste compaction also maximizes the site life of landfills (Pienaar & Howard, 2014). Furthermore, Saini *et al*. (2016) assert that waste should be compacted and covered with soil, to reduce the risk of fires, discourage vermin, control litter and. In terms of the layer of compacted waste, Kusi *et al*. (2017) articulate that the layer of the compacted waste should not be more than 2 meter high, and the equipment which is used for compaction are bulldozers and compactors, although bulldozer has been found to be unable to offer good compaction, as compared to compactor. With regard to the type of equipments used for compaction and spreading of waste, Egun *et al*. (2016) proclaim that after loads of waste have been deposited in the working phase, bulldozers and compactors should be used to spread the waste and compact it, to reduce the volume of the waste and then a covering should be applied thereafter.

Kusi *et al*. (2017) affirm that a bulldozer and a landfill compactor are the commonly used equipment in Ghana to do compaction after waste is unloaded. The compactor was found to do 4-5 passes on the leveled waste, which is the acceptable number of passes over the spread of waste. The equipment used for compaction at Ghana's landfill sites is similar to the equipment used at landfill sites of Essex-Windsor in Canada, as they use a compactor and bulldozer for compacting waste (EWSWA, 2013). Similarly, apart from bulldozer, landfill compact was also found to be the main used equipment in South Africa to undertake compaction of waste at South African landfill sites (Bhailall, 2015).

Munawar & Fellner (2013) recommended that compaction should be practiced in every landfill, due to its importance regarding the maximizing of the landfill capacity for disposing waste, and the benefits it offers, such as reduction of odour release from the voids of waste, higher gas generation rates and reduced risk of landfill fires.

This was also supported by Egun *et al*. (2016), who stated that compaction is critical in extending the lifespan of the landfill site.

2.3.7 Covering of waste

Al-Anbari (2016) advanced that disposed wastes in the landfill sites should be covered daily, in order to reduce or prevent health hazards and to maintain a safe environment with regard to preventing fire hazards. Kusi *et al*. (2017) propose that landfill sites must use soil cover of 150mm thickness to cover the waste. Such is regarded as the acceptable thickness of the cover, as EPA (2016) clearly states that compacted waste at a landfill should be covered with at least a minimum of 150mm thickness cover. ISWA (2010) on the other hand assert that the application of a thick layer of daily cover of about 200mm could be very helpful in controlling rats and other vermin, such as feral animals. As a result, such thickness simply makes accessing the food source too difficult to be attractive to such feral animals. However the thickness of the cover also depends on the volume of waste at the landfill site, as Pienaar & Howard (2014) stated that a minimum of 100mm soil cover after 300mm waste must be placed, but the cover thickness must be increased in case the cover is of a poor quality. Even in South Africa 150 to 300mm is regarded as the appropriate soil cover thickness of the waste at landfill site (DWAF, 1998), this simply means that South African landfill site's waste cover thickness also correspond with other waste cover thickness applied in other countries, as asserted by other authors such as Kusi *et al*. (2017).

As waste covering at landfill sites is important, for instance, Jamarillo (2003) stated that uncovered waste attracted flies and vultures, due to the smell of decaying waste. Therefore, cover material should be applied on top of the waste at the end of each day, to prevent odours and fires as well as to reduce litter, insects and rodents. Soil can also be used for daily covering at landfill sites (NSWMA, 2008).

There are different types of waste covering which must be applied on compacted waste. According to the EPA (2014), an intermediate and top layer cover should be applied at landfill sites. An intermediate cover is used when the area of the landfill is not expected to receive a cap for an extended period of time, traditionally it consists of layers of soil, geo-textiles, or other materials. EPA (2016) has reported that after the application of the daily cover, intermediate cover should be done for ensuring the efficiency of landfill operation. The top layer of the final cover at landfill site must be a topsoil layer which consist of a soil horizon that will provide the moisture retention and nutrients required to support healthy vegetative growth in the long-term (British Columbia, 2016).

2.3.8 Recycling

According to Ahsan *et al*. (2014: 4), "recycling is the reprocessing of wastes, into either the same product or a different product and it is the key mechanism to recover products which are useful and reduction in waste quantity". Recycling has been viewed as a proper tool in minimizing the amount of wastes sent to landfill sites. It also provides the needed raw materials for industries, and it has been found to be the most efficient and effective method of solid waste management system (Momoh & Oladebeye, 2010).

Idris *et al*. (2004: 106) stated that "the activities of waste pickers at landfill sites in Asian countries were reported to be helpful on reducing the amount of recyclable items such as paper, plastics, glass and metals in the waste". According to Azar & Azar (2016) recycling in Lebanon was found to play an important role in reducing the amount of waste to be landfilled. They found that in landfills where recycling was not being practiced, some quickly filled up and were then shut down. Ginindza & Muzenda (2015) also reached the same conclusion that recycling plays an important role in maximizing the capacity of landfill site as they stated that recycling contributes significantly to the diversion of waste from landfill site in South Africa.

Kusi *et al.* (2017) advanced that recycling at landfill sites in Ghana, is mostly done by unregistered waste pickers who want to earn money for living. Similarly, Oelofse & Strydom (2010) asserted that most of the recycling in South African landfill site is mostly practiced by poor people in order to earn a living and typically they do so under unhealthy and unsafe conditions as they are usually not registered with the relevant authorities. Due to the important role that waste pickers play, it is necessary to register them and give them appropriate clothes to wear when they sort reclaimable materials at the landfill site. This is during the sorting of waste, they get exposed to sharp objects that can lead to cuts, and which can result in loss of blood and infection. Thus, protective clothes should be used. In addition, while waste pickers sort out recyclable waste, they are also exposed to air pollutants in the form of objectionable odours, obnoxious gas inhalation from decomposing materials, eyesores, radiation from the sun and risk of infectious diseases like cholera, malaria, typhoid fever and dysentery (Asibor & Edjere, 2017). Thus equipment to cover their noses should be used. This notion was also apparent in a study about working conditions of waste pickers, wherein Mothiba (2016) stated that that most of the South African waste pickers are unregistered with the municipalities and they are also exposed to health hazards.

2.3.9 Composting

Composting process uses microorganisms to degrade the organic content of the waste. Aerobic composting proceeds at a higher rate and converts the heterogeneous organic waste materials into homogeneous and stable humus (CED, 2003). Jain *et al*. (2016) argued that landfill sites should have a compost site for preventing landfilling waste which can be used for making compost, as this helps to reduce the volume of the waste which should be landfilled and also helps in extending the lifespan of the landfill site, as this waste can be converted to compost. According to Kadir *et al*. (2016) the benefits of composting are to divert waste from landfill, mitigate groundwater contamination, reduce air pollution and green-house gas (GHG) emissions and generate useful products.

Yasmin & Rahman (2017) stated that composting is sustainability, considering the numerous benefits, such as production of organic compost, reduction of waste quantity for final disposal, reduced air pollution and ground water leachate and others. Composting was found to be the most suitable activity, due to its low cost, less technology, less pollution effect and because it is beneficial to the environment and the economy, compared to the disposal of organic waste in landfills (Harir *et al*., 2015). Composting also reduces the need for costly waste disposal methods, such as landfilling, the quantity of waste which are supposed to be sent to the landfill, and it is probably the most attractive and sustainable alternative to waste recycling (Mlozi, 2011).

2.3.10 Ground and surface water monitoring

The monitoring of ground water must be done at each and every landfill site, in order to check the state of the quality of water: if it is contaminated or not. This can be done by sampling the ground water monitoring wells (upstream and downstream) located at the base of the landfill. The monitoring period for water quality must include a yearly monitoring of upstream and downstream groundwater wells, as recommended by Munawar & Fellner (2013). EWSWA (2013) asserted that ground water monitoring must be done twice a year, in order to be always updated about the state of ground water, if it is contaminated or not.

2.4 Challenges of operating and managing landfill sites

Landfill sites encounter different challenges when it comes to their operation and management. Therefore, it is important to identify challenges that hamper effectiveness of operating and managing landfill sites, so that strategic measures may be established, which may become useful in making sure that landfill sites are operated and managed without any challenges which might hamper the procedures of their operation and management (Saini *et al*., 2016).

2.4.1 Landfill operating equipment

Lack and frequent break down of equipment for landfill operation is a challenge when it comes to operating a landfill site. Kusi *et al*. (2017) claim that most of the frequent break-down of equipment used for landfill operation is due to the procurement of low quality equipment and poor maintenance schedules, as this tend to reduce the lifespan of the equipment. This made operation of the landfill site ineffective, as not all procedures, ranging from waste compaction and covering, will not to be practiced due to non-functioning equipment. Likewise, Al-Yaqout & Hamoda (2002) also claim that lack of equipment and tools present a significant challenge when it comes to the operation of the landfill, as it makes the operation of landfill ineffective. Therefore, equipment is important for the successful operation of landfill sites. Kusi *et al*. (2017) emphasized the importance and types of landfill operation equipment when they mentioned that landfill sites should have equipment, such as bulldozers, excavators, landfill compactors, pick-ups and tipper trucks, for effective landfill operation. Bulldozers are used for pushing and leveling the waste. Excavation of cover materials and subsequent transporting to working phase is done by an excavator and tipper trucks. Widman (2005) asserted that the landfills that receive greater than 400 tonnes per week need to have a caterpillar tractor for pushing waste, wheel loader, 2 compactors for compacting waste, 1 vehicle (all-terrain), and 1 sweeper with a water tank.

2.4.2 Waste covering material

The availability of waste covering material is essential for landfill site operation. This is because waste covering material helps to reduce diseases transmission, fire hazards, odour nuisance, atmospheric and water pollution, and aesthetic nuisance (Mohammedshum *et al*., 2014). If waste is not covered, the following can happen: invasion by vectors, wildlife and scavenging, and increased odours, litter, storm water infiltration, fugitive emissions of landfill gas emissions and risk of fire and may harbour mosquitoes which might cause disease to the nearby residents. Waste cover must thus be placed on the entire surface of the active phase at the end of each operating day, as landfill site without enough covering materials may experience many challenges, ranging from risk of fires and increased odours (British Columbia, 2016). This was also supported by Supriyadi *et al*. (2000), who stated that lack of cover materials of covering waste at landfill sites leads to a great number of rodents, insects and other disease vectors, which bred at the landfill sites. Moreover, if cover materials is not applied according to the appropriate sanitary landfill practices, it can lead to the release of odours which can become a huge challenge when it came to operating the landfill site, due to bad odours which will be emitted by the uncovered waste Vlachakis *et al*. (2010).

2.4.3 Rainy period operation

Landfill operations tend to be problematic during rainy periods if the landfill site does not have wet weather cell for operation during rainy periods. This is because soil that is high in silt or clay tends to make it impossible for trucks carrying waste to access the working phase to dispose waste. This is because during rainy period, soils become very muddy. Therefore, provision should be made for wet working cell, to enable operation to continue operation in areas of the landfill that are less susceptible to problems. The wet weather plans should include measures to reduce tracking of mud from the landfill onto the road system and provisions for cleaning the trucks (Saini *et al*., 2016). Kusi *et al*. (2017) stated that inaccessible of the road during rainy periods is one of the challenges that affects the operation of the landfill site. Therefore, access roads to the landfill operation should be accessible under all weather conditions, coupled with wet weather cell, for disposing waste during rainy periods.

2.5 Improper landfill sites' operation and management challenges

About 90% of the waste in South Africa (SA) is disposed at landfill sites. Therefore, it is important to note the potential challenges that are commonly associated with improper operation and management of landfilling in SA (DEA, 2011). According to Van Der Linde, Cillarius & Meyer (2004), landfilling at landfill sites is an acceptable method of disposing waste and it needs to be done in a proper way, and should fulfill strict codes of conduct. This is because if proper operation and management procedures are not followed, the potential for having adverse challenges can become a matter of concern. Furthermore, Van Der Linde, Cillarius & Meyer (2004) asserted that challenges emanating from poor landfill operational procedures may include bad odours, noise, flies and air pollution due to dust, smoke, windblown litter, water pollution and generation of landfill gas.

Jain (2016) stated that ground and surface water pollution, air pollution due bad odours, green house gas emission, harmful effects of rats, stray animals and insects, are some of the challenges which result from unscientific management of waste disposal. Garner (2009) asserts that the foreseeable challenges of improper management and operation of solid waste disposal in landfills comprises of gas and leachate generation primarily due to microbial decomposition, which is a serious environmental concerns. Some of the challenges which can result from poorly managed and operated landfill are fires and explosions, vegetation damage, unpleasant odours, groundwater pollution, air pollution, as well as global warming caused by methane gas generated from the landfilled waste.

2.5.1 Leachate production

According to Rafizal & Alamagir (2012), when landfill is not operated efficiently with liners at the base, and proper covering of waste is not applied, this might result in leachate generation, which leads to groundwater and surface water contamination. Adebara *et al.* (2016) also highlighted this when they reported that a landfill site's working cells which are not lined beneath prior to disposing of waste, are known to have a high chance of releasing hazardous and deleterious chemicals to ground water.

Jamarillo (2003) stated that if waste is not covered, the intake of rainwater into the garbage tends to be high, which leads to rapid establishment of leachate gases, and this tends to have negative impacts on the environment. Leachate is produced by the action of rainwater aiding bacteria in the process of decomposition. Leachate is typically composed of dissolved organic matter, inorganic macro components (such as chlorides, iron, aluminum, zinc and ammonia), heavy metals and xenobiotic organic compounds such as halogenated organics (Oyiboka, 2014). Bhalla *et al*. (2014) found soil to contain considerable amounts of dissolved organics and heavy metals, which tend to have a huge negative impact on water resources.

Al-Muzaini (2009) affirmed that different studies carried out throughout the world have shown that even small landfills have got the potential of adversely impacting the groundwater quality if landfill sites are not properly operated and managed. Therefore, protecting and preventing groundwater system from contamination has got significant importance when it comes to managing groundwater resources. One of the major tasks for protecting groundwater is the assessment of a landfill's leachate characteristics.

Contamination of groundwater by landfill leachate is recognized as a very serious challenge worldwide. This is because the contents of landfill leachate may present high risk to both human and the environment (Lin & Sah, 2002). Al-Muzaini (2009) stated that the composition of the leachate depends on the heterogeneity and composition of the waste, the degree of biodegradation, moisture content and operational procedures. Leachate from a landfill site contains considerable amounts of dissolved organics and heavy metals. It also has an intense colour, and Polycyclic Aromatic Hydrocarbons (PAH) are also present. The quantity and quality of such features could fluctuate to levels that can contaminate groundwater (Al-Yaqout *et al*., 2002).

2.5.2 Odour nuisance

According to Aderemi & Falade (2012) one of the challenges related to the improper operation of the landfill is the unpleasant odour which can be produced by bacteria or chemical process within the waste load. Furthermore, when such odour migrate to the community nearby, the landfill site can compromise the quality of life for individuals, as some of the residents may experience nausea or headache due to unpleasant smell, including the people who work at landfill sites. Ally *et al*. (2014) confirmed that odour emissions from landfill sites are due to the anaerobic degradation of putrescible substance in the waste, dependent on many factors, most of which are operational factors. Douti (2017) declared that regular cover of waste with clay or soil must always be applied at the disposed waste in landfill sites, with a view of reducing odour challenges.

Furthermore, Laister (2002) reported that the influence of weather condition, such as wind direction, wind speed, temperature and humidity, can affect the concentration of odours carried from the landfill towards residential places. Those findings concur with the findings of the study carried by Zaini *et al*. (2011) as they stated that smell from a landfill site is associated with the weather condition, as during sunny and windy period smell from landfill sites becomes more felt than during rainy period.

Similarly, bad odour which was detected at a Zanzibar landfill site by Ally *et al*. (2014) was found to be influenced by the weather, as it was mostly felt in the summer than during winter. Supriyadi *et al*. (2000) further stated that bad odour can be mitigated by applying a daily cover after landfill operations. This was found to be effective in Semarang, Indonesia. In an Abuge-Egba landfill site in Nigeria, aesthetic odours were found to be the major challenge for residents living near the landfill site (Olorufemi, 2009). Okot-Okumu (2012) also demonstrated in his seminal work that landfill sites in Uganda Kampala city have major management challenges of odour, vermin and attraction of waste pickers and poor accessibility. This was because they do not cover their waste daily after disposal at their landfill sites. Odours was also found to be a challenge in South African landfills too, for example, Roebuck *et al*. (2015) stated that odour emission in Bissar Road landfill site is problematic to the landfill workers and also the surrounding resident, and this was due to poor operation of the landfill site.

2.5.3 Landfill fires

Landfill fires are associated with improper landfill site operations waste disposal at the landfill site, mostly when waste compaction is not effectively performed, reduces the voids in the waste coupled with rarely applied soil cover (Mohammedshum *et al*., 2014). Therefore, in cases where proper operation and management of landfill site is not practiced to ameliorate nuisance, everlasting challenges will result. However, on the one hand, Kusi *et al*. (2017) findings appear to contradict with Mohammedshum's (2014) assertion, as they reported that rampant fires at landfill site are caused by waste pickers who usually set fire to the waste material while trying to obtain precious metal from waste such as electric waste.

On the other hand, Ayuba *et al*. (2013) found that due to poor operational management of landfill site, the landfill can sometimes experiences continuous combustion of fires due to the methane trapped from the buried waste as a results of ineffective compaction. These fires which comes out of landfill sites seems dangerous, as Kharlamova *et al*. (2016: 360) stated that "fire which comes out of landfill site spews out toxic smoke which is hazardous to health and the environment".

2.5.4 Air pollution

Landfills emit carbon dioxide (CO_2), methane (CH_4) and volatile organic compounds (VOCs) which have an impact on the air, and such can have health impacts to the landfill workers and the population around the landfill site through inhalation (Andrea *et al*., 2017). In 2004; SIVEST (2004) reported that in all the landfills found at uMkhanyakude District in South Africa, there is a general impact of air pollution, which were found to be caused by the uncontrolled burning of solid waste, and such had a health impact on surrounding communities and the environment in general.

2.6 Landfill site capacity

Landfill capacity is the volume between the liner and final cover with waste in between these two (BME, 2013). According to Akyen *et al*. (2017) it is important to determine the lifespan of the landfill site, in order to determine the remaining capacity of the landfill site, so that an effective plan for future usage will be known.

For example, in the Town of Mississippi Mills (TMM) (2012) it is claimed that the capacity of volume of waste disposable at landfill site and the lifespan of a landfill site can be determined by waste diversion such as recycling, composting, waste reduction programs, which must be strictly adhered to. Thus, the more the waste diversion is practiced, the more the landfill capacity and lifespan of the landfill site may increase. Calabro *et al*. (2007) recommended that pre-treating waste before they are landfilled is important, as it helps to increase the volume of disposable waste at a landfill site, thereby maximizing the lifespan of the landfill site. Furthermore, Saini *et al*. (2016) emphasized the importance of compaction at the landfill site as a means of maximizing the landfill site's capacity of disposing more waste, which will extend the lifespan of the landfill site.

Thompson (2008) established that lack of compacting waste is the main reason for ensuring that the volume of waste remains expanded, and the capacity of the landfill sites in terms of waste disposable can decrease drastically if compaction is not practiced. Therefore, compaction of waste at landfill sites plays a major role in maximizing the capacity of landfill site. A similar argument was propagated by SIVEST (2004) after a study in Dannhauser Municipality, situated in Kwa-Zulu Natal Province, South Africa, wherein it was argued that areas where compaction is not practiced landfills tend to reach their capacity faster than areas where compaction is practiced.

i. Landfill site capacity and the length of their lifespan

The remaining capacity of landfill site can be determined by comparing the amount of initial landfill site capacity and the already used landfill site capacity. It is then possible to find out the remaining net capacity of the landfill. The calculation of the remaining volume of disposable waste and remaining lifespan accounts for the air space consumed by waste and cover (British Colombia, 2016). However, DWAF (1998) mentioned that approximate landfill site life is determined by matching the available airspace to the closest cumulative airspace used, and this will also provide the remaining capacity of the landfill site in terms of waste disposable and the number of years remaining for its operation. Munawar & Fellner (2013) suggested that in order to maximize the landfill capacity, together with extending the lifespan of a landfill site, compaction should be practiced in every landfill site. This was also supported by Egun *et al*. (2016), who reported that compaction helps to extend the lifespan of the landfill site.

ii. Landfill waste height and density

The height of the landfilled waste dictates the size of the active phase and operational cover requirements. Small landfills operate more efficiently on small height, for example, 1.5m, while large tonnage landfills operate most efficiently on lifts as high as 5.0m. Compaction of solid waste is an effective way to maximize the use of available capacity. Waste should be placed at the base of the active disposal phase and should be pushed up the disposal phase to maximize compacted density. Push down operations may also be needed depending on the site operating details (British Colombia, 2016). The following lift height guidance and recommended compaction densities are provided to achieve efficient landfill operations:

- **i.** Amount of waste disposed at landfill site dictates the height of landfill site.
- **ii.** The height of the landfill site which receives less than 10,000 t/year must be 1.5m.
- **iii.** Landfill site which receives between 20,000 – 50,000 t/year the their height should be 2.5m.
- **iv.** Landfill height should comply with the required height of the landfill.
- **v.** DWAF (1998) reported that compaction density can be between 0,75 T/m^3 to 1,20 T/m^3 depending on amount of waste deposited to a landfill site and the compaction efficiency. However, 0,75 T/m^3 is the recommended compaction density in South African landfill sites DWAF (1998:179).
- **vi.** The layer of the compacted waste should not exceed 2 T/m^3 although it depend on the amount of waste received at landfill site (Kusi *et al*., 2017).

2.7. Description of types of waste

There are different types of waste, DEAT (2001) has identified the following types of waste: commercial waste; construction and demolition waste; household waste; industrial waste; institutional waste; health care waste/ medical waste; office waste". Most of the waste is generated from human activities, such as manufacturing, commercial or consumption activities. Therefore, there is no doubt that human beings are a great source of waste (Jayarama 2011). However, Yasmin & Rahman

(2017) reported that in waste can be categorized differently as follows: Household waste, commercial waste, institutional waste, industrial waste, medical waste and construction and demolition waste. For the purpose of this thesis, the following categories of waste will be discussed:

2.7.1. Household waste

According to DEAT (2001) household waste is waste which are normally produced on residential premises. Households sometimes contain small quantities of hazardous waste. Butu & Mshelia (2014) reported that household waste is collected from dwelling places and these include durable goods, non-durable goods, containers, food wastes and yard trimmings. Thus, household waste is an accumulation of rejects from residential areas (EPA, 2011). Charlotte (2009) stated that most of the household waste include unwanted and use-less materials, including plastic, card-boxes, metals, packaging, bottles and food waste.

2.7.2. Commercial waste

According to Panargyropoulou (2014:1) commercial waste "is waste from premises used for the purpose of business or trade". DEAT (2001) stated that commercial waste are waste which are generated by shops, offices and other commercial activities that do not actually make products, but trade or sell them. Nyoti *et al*. (2016) classified commercial waste as waste consisting of leftover from glasses, metals, plastics generated from stores, restaurants, market, hotels, shops, and supermarket stores, business centers, warehouses and other commercial establishments. This was also supported by Mongtoeun *et al*. (2004), who claim that the types of commercial waste include plastics, metal waste, food waste, paper and glass. It is thus clear that commercial waste forms part of the major source of solid waste which mostly found its way to landfill sites (Rana *et al*., 2015).

2.7.3. Construction and demolition waste

Construction waste exists when there are buildings, roads or any kind of infra-structures, and demolitions. Wastes therefore happen when those constructions are destroyed. This waste stream includes metals, electrical wires, concrete, pipelines, bricks and glasses, and insulation materials (Dibaba, 2017). Demolition waste is viewed as a heterogenous combination of various building materials such as aggregate, wood, paper, metal, and glass that are in most cases contaminated with paints, adhesives and wall covering. To that end, construction and demolition waste results from the demolition of existing structures, which are done intentionally, such as in renovation and remodeling works, or unintentionally due to natural catastrophes such as earthquakes, floods and hurricanes (El-Haggar, 2007). Accordingly, construction and demolition waste constitutes a huge part of solid waste stream, and it is continuing to rise because of the booming housing and building industry worldwide. As a result of fast urbanization and the booming massive construction that is happening world wide, the amount of construction and demolition waste so generated and sent to landfill site is increasingly becoming problematic due to the limited landfill space (Elgizawy *et al*., 2016).

2.7.4. Industrial waste

After the industrial revolution, an increase in industrial manufacturing has been showing great improvements. Due to increasing numbers of manufacturing industries, such as paper-producing industries, electronic companies, high-tech companies and raw materials manufacturing industries more and more waste are being generated, regardless of whether the company is a low-tech, middle-tech or high-tech (Dibaba, 2017). Omar & El-Haggar (2017) posited that industrial waste are generated from industries and this includes glass, plastics and paper used for packaging. According to Mallak *et al*. (2014 :44) the “composition and characteristics of industrial solid waste is varied and depends on the type of industrial activities. However, industrial waste can be classified into hazardous industrial waste and industrial solid non-hazardous wastes”.

2.7.5. Electronic waste

According to Jalal-Uddin (2012) electronic waste or e-waste term is used for all unwanted electrical or electronic equipment that has been disposed of by its original user, and that includes everything from large household appliances, such as microwave ovens, refrigerators, television sets, laptops, cell phones and DVD players. Because of world-wide technological and industrial advancement, the number of e-waste is on the steady increase. E-waste contains a wide range of hazardous compounds which have turned it into a global environmental issue (Swedish Environmental Protection Agency, 2011). Asari & Sakai (2011) revealed that e-waste includes batteries, fluorescent lamps, and spray cans, which are disposed by households and are usually regarded as MSW, even though they may contain hazardous materials. WHO (2015: 20) claims that “e-waste comprises a source of a variety of materials that can be recovered and brought back into the production cycle before they could be sent to landfill site”.

2.7.6. Medical waste

Kalpana *et al*. (2016: 670) state that “medical waste is a subset of hospital waste and it refers to materials generated as a result of diagnosis, treatment or immunization of patients. Medical waste is normally elaborated as waste products that cannot be considered general waste, and which are produced from healthcare premises, such as hospitals, clinics, surgeries and labs”. All types of wastes which are generated inside any healthcare facilities such as hospitals, primary health-care centre, burn units, veterinary hospitals and clinics, blood banks and medical examination and testing areas are considered as medical wastes (Charlotte 2012). According to Asante (2014: 107) “medical waste also includes a type of wastes generated by people who takes medicines in their own home like dialysis and self-taken insulin and about 85% of the hospital wastes are non-hazardous; which are not different from general household or office wastes including papers, medicines packages and kitchen wastes”.

Infectious wastes such as needles and blood, which are generated from hospitals and clinics, are designated as specially controlled wastes and are not regarded as MSW (Miyazaki & Une, 2005). However, surgical cotton containing blood and bandages generated from hospitals and clinics together with waste materials which originate from home health are managed as MSW (Myazaki *et al*., 2007) .

2.8. Types of solid waste disposed at landfill sites

Evaluating the generated types of waste that is disposed at landfill site is important because such collected information does help to determine if there is a mixture of unacceptable waste at the landfill site or not (Idris *et al*., 2004). Knowing waste composition is essential for the prediction of a future amounts of waste and to identify the generation trends, as well as to make good planning of collection, transport and treatment (Bandara *et al*., 2007). Pandey *et al*. (2016:54) asserted that “most of the types of waste delivered to landfill site in India are papers, plastics, polythene, glasses, metals, tins, bottles, used batteries, fruits and vegetables peels, food waste, and electronics waste (e-waste)”. Whereas Bello *et al*. (2016) indicated that most types of waste that are sent to landfill sites in Uganda include papers, tins, bottles, glass, and metals this are similar to types of waste reported in India. Integrated waste management plan (IWMP) of Emnambithi Ladysmith Municipality (ELM) (2010:24) revealed that papers, metals, glasses, plastics, and organic waste are types of waste that are mostly disposed at Ladysmith’s landfill sites in South Africa.

The level of urbanization affects the composition of waste. As a result of the growing incomes and new lifestyles of people living in urban areas, greater consumerism tends to generate more packaging materials. These have a higher paper and plastic content (Idris *et al*., 2004). Babayemi & Dauda (2009) declared that in developing countries solid waste types which finds its way to landfill site includes paper, wood, dust, cloth, metal scraps, electronic gadgets, bottles, food remnants, rubber and plastics. According to Kalanatarifard & Yang (2012) certain types of waste, such as plastic and metals are valuable as recoverable materials, and the resistance of these plastics to natural biodegradation process, is the reason for taking up huge amount of space in landfill as their life cycle are from one year afterwards.

Man Li, Fong & Chan (2015) indicate that food waste, metals and plastics and construction waste are the dominant types of waste that are disposed of at the landfill. The types of wastes produced around the world vary, depending on the raw materials used, per country (Bello *et al*., 2016). The types of waste found in African countries, including South Africa, was influenced by the types of industries that are present on African countries; for example, African countries were found to be more involved in industries such as food, textile, furniture, clothing, iron and steels, chemicals, printing and food industries. It was found that most of the waste come from such industries described by Nebiyeleul (2006).

2.9. Sources of solid waste disposed at landfill sites

Several scholars have investigated the dominant sources of solid waste that are delivered to different landfill sites, (Khatib, 2011; Murava & Korobeinykova, 2016; Bello *et al*., 2016; Mlozi, 2011) stated that the sources of solid waste include residential, commercial, industrial, agricultural, construction and demolition, institutional and municipal services waste. In developing countries municipal solid waste contributors comprise of refuse from households, institutions like hotels and hospitals, market places and wastes from industrial and commercial establishments (Tam & Tam, 2008). The centre for environment and development (CED, 2003) has listed residential, institutional, commercials establishment, hotels and slaughter houses, as sources of solid wastes. At Agra City, India, Sigh *et al.* (2014) found that the major sources of waste that are delivered to landfill site at Agra Municipality are residential, institutional, hotels and restaurant, commercial and industrials. Different studies indicate that a huge amount of the solid waste delivered to landfill sites in developing countries emanates from households, market areas and institutions (Nabegu, 2010; Nagabooshnam, 2011; Okot-Okumu, 2012).

Furthermore, Babayemi & Dauda (2009) posit that sources of solid waste that are disposed at landfill site in developing countries mostly includes commercial, industrial, household, agricultural and educational establishments. The residential sector, followed by commercial sector, and institutional sector, were also found to be the major sources in Dhaka City (Yasmin & Rahman, 2017). Bello *et al*. (2016) stated that sources of waste generated in African countries depend on the raw material used in such country. Murava & Korobeinykova (2016) validated such remarks after discovering that major sources of waste generation within tourist destinations of Carpathian Region in Ukraine are tourist facilities such as hotels and other accommodation facilities, food establishments, and automobile industry. Similarly, Bhailal, S (2015) also stated that sources of solid waste disposed at South African landfill site are households, restaurants, public institutions, industries and constructions sites.

2.10. Statistics of waste disposed at landfill sites

2.10.1. Global trends of solid waste disposal at landfill sites

The rate of waste generation across the world has increased over the years in different societies. This increase in waste generation has been attached to the increase in population, change in lifestyle and technological advancement (Chisadza, 2015).

San Francisco, in the United States of America, has been reported to be collecting over 508 000 tonnes of municipal solid waste per annum. However, as a result of outreach programmes on reuse, recycling and compositing its only 28% of waste is generated. This is because about 72% percent of the waste is diverted from landfills through reuse, recycling and composting, which makes the capacity of the waste disposable to diminish slowly, and also helps their landfill site to reach its lifespan slowly (UN-Habitat, 2010).

Rotterdam, in Netherlands, generates over 308 000 tonnes of waste per annum. However, due to the combination of their effective legislative environmental legislations, efficient collection systems, that facilitate diversion of waste from landfills and active participation by residents on recycling waste, they only send 30% of their generated waste to their landfills (Chisadza, 2015). The analysis clearly indicates that legislations and community participation in waste management is beneficial in Rotterdam, as not all generated of the waste generated is sent to landfill sites.

The Essex-Windsor solid waste authority (EWSWA) (2013) reported that the Essex-Windsor regional landfill site in London received a total of 188, 004 tonnes of municipal solid waste in 2013, compared to 170, 305 tonnes received in 2012. There was a 10% increase in the total waste being landfilled at the Essex-Windsor regional landfill for 2013 compared to 2012; meaning the increased tonnage of waste was being sent to landfill, which overburdened the landfill facilities (EWSWA, 2013).

Singh *et al*. (2014) classified the waste that was disposed in India's landfill sites and found that 65% of waste comes from residential areas, 18% from commercial, 13%

from institutional and the remaining 4% came from the industrial sector. In Singapore, Ahmed *et al*. (2013) asserted that in the year 2000, less than 10 % of the waste which was generated was sent to s landfill site known as Semakau landfill, which is the only landfill site in the country.

In 2000 the city of Kumasi, Ghana delivered 600 tonnes per day to their landfill site, and in 2006 they delivered 500 000 tonnes of solid waste throughout the year 2006 to its landfill site based on the 2006 projected population of 1, 610, 867, this shows the strong relationship of population growth with an increase in waste generation. In 2013 the very same city of Kumasi disposed 1, 200 tonnes of municipal solid waste per day to their landfill sites (Kumasi Metropolitan Assembly, 2013).

Khatib (2011) identified the major sources of waste delivered to the landfill site in India and found that huge tonnes of waste is generated as a by-product from industries, municipalities, agriculture, commercial and other processes. On the other hand, Bello *et al*. (2016) stated that in Uganda residential waste constitutes 50-82 % of waste landfilled and followed the commercial sector, and industrial sectors. The findings of Bello *et al*. (2016) were comparable to those observed again in Nairobi, Nakuru, Mombasa, and Kisumi by Bello *et al*. (2016), as around 61% of the waste disposed was residential waste, followed by commercial sector, industrial and other types such as hospital waste.

Rana *et al*. (2015) found that the major sources of solid waste disposed at landfill sites within Chandigarh Municipality in India are residential areas, followed by commercial areas, industrials, and lastly, offices and institutions. Table 2.1 shows sources of waste per countries, in descending order, which are mostly sent to landfill sites.

Table 2.1: Country's source of waste disposed at landfill site

No	NAMES OF THE COUNTRIES			
	UKRAINE	NDIA	UGANDA	NAIROBI
1.	Residential	Residential	Residential	Residential
2.	Commercial	Commercial	Commercial	Commercial
3.		Industrial	Industrial	Industrial
4.		Office waste	Institutional	Institutional
5.		Institutional waste		

Sources: (Sigh *et al.,* 2014; Bello *et al*., 2016; Murava & Korobeinykova, 2016; Rana *et al*., 2015)

Table 2.1 shows that residential areas are the widely reported sources of waste which is sent to landfill site in all the listed countries, followed by commercial, with institutional area the least reported source of waste. Ali (2016) reported that the major sources of waste delivered to landfill sites comprises of households, commercial, institutional, hospitals and industrial establishment. Correspondingly, Tsiko & Togarepi (2012) found similar sources of waste during their studies which are commercials, households and industrial.

2.10.2. South Africa's waste disposal trends

The South African population has increased from 48.27 million in 2006 to 55.91 million in 2016 (Statistics South Africa, 2016). This means that more waste is being generated, as population growth is associated with increased waste generation, which ends up being disposed at landfill sites (Mkhize, 2011). However, as the space for the establishment of landfill sites is becoming limited, other methods of waste management should be sought to stabilize the fast approaching full capacities of landfill sites in terms of waste disposable and reaching of the landfill sites' lifespan rapidly. This is where recycling programmes are expected to play a vital role in prolonging the lifespan of landfill sites and maximize the volume for waste disposal. Sorting and treating should thus be done before disposing waste into the landfill site (Al-Muzaini, 2009). According to DEA (2012) in 2011 South Africa generated about 59 million tonnes of waste (Table 2.3), and an estimated total of 5.9 million tonnes of this generated waste was recycled and 53.5 million tonnes of waste that remained was landfilled, (-) means no data on recycling was available.

Table 2.2: Amount of waste generated, recycled and landfilled in South Africa

General Waste 2011	**Generated Waste**	**Recycled Waste**	**Landfilled Waste**
	Tonnes		
Municipal waste (non-recyclable Portion)	8 062 934	-	8 062 934
Commercial and industrial Waste	4 233 040	3 259 441	973 599
Organic waste	3 023 600	1 058 260	1 965 340
Construction and demolition Waste	4 725 542	756 087	3 969 455
Paper	1 734 411	988 614	745 797
Plastic	1 308 637	235 555	1 073 082
Glass	959 816	307 141	652 675
Metals	3 121 203	2 496 962	624 241
Tyres	246 631	9 865	236 766
Other	36 171 127	-	36 171 127
Total general waste [T]	**59 353 901**	**5 852 484**	**53 501 417**

Source: (DEA, 2012)

According to DEA (2012) most of the waste generated in South Africa is being sent to landfill site, as the table above shows that only 5 852 484 of the 59 353 901 tonnes of waste generated were recycled, and 53 501 417 were landfilled. This was also validate in TLM IDP (2016), as it was highlighted that almost all the waste collected within Thulamela Local Municipality is disposed at TBJ landfill site, the only landfill site which is operating. Therefore, it is important to know how South African landfill sites are coping with those big volumes of waste being sent to the landfill sites.

2.11. Conclusion

In summary, chapter two highlighted the studies reviewed and indicated the need for more research into landfill site management and operational nature. The insights, questions, themes and findings that these studies prompted have given rise to the rationale for this study, and provided a rich background which had assist in evaluating the management and operation at the TBJ landfill site.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

An appropriate method was developed to collect data on the key issues being researched in this study. This chapter discusses the methods used to collect data as well as techniques for data analysis and sources which were used for this study.

3.2 Research approach

This study aimed to investigate the strategic management of the TBJ landfill site. In order for the study to achieve the set objectives, the mixed research methods were used because one method would not provide all the information required. According to Williams (2007:65): "mixed research methods is the approach meant for research questions requiring both numerical and textual data". Mixed research methods is a concurrent combination of quantitative and qualitative research approach (White, 2003). The motivation for using mixed research methods was to enable this study to provide multidimensional perspectives about the research phenomena in question. According to Johnson & Onwuegbuzie (2007) the main aim of using the mixed methods approach to research is to draw the strengths from mixed methods and minimize the weakness of the quantitative and qualitative research approach. Therefore, the two methods were used to complement each other.

In this study, the quantitative aspects of the research focused on the determination of the capacity of TBJ landfill site in terms of the volume of waste disposable. In order to determine the capacity of the landfill site, Equation 1 termed "the available airspace of landfill site formula", was applied.

Equation 1: $\text{Available volume of cover} \quad = \mathrm{L} \times \mathrm{W} \times \mathrm{H}$

Where L is the length of waste disposal place, W is the width of waste disposal place and H is the height of the waste at landfill site.

According to DWAF (1998) the potential volume or airspace of a site is calculated by quantifying the volume of cover material available and then by applying a cover to waste ratio of between 1:4 by volume, to arrive at the total airspace. Cover availability is thus a major factor which determines air space at a landfill site.

The values used to determine the available volume of cover (Equation 1) was found in the TBJ landfill documents, such as monthly reports of waste disposed and Integrated Waste Management Plan (IWMP) supplemented by the ArcGIS Desktop Help 9.2 and questionnaire completed by landfill operator. Based on the fact that waste operation would require a volumetric ratio of cover material to waste of about 1:4, the total airspace is obtained by multiplying the volume of available cover material by a factor of 5 (DWAF, 1998). Therefore, the total value of (Equation 1) is multiplied by a factor of 5 to find the total airspace of the landfill site in m^3.

After finding the available airspace of the landfill site, annual airspace utilization in m^3 was calculated using annual rate of deposition (Equation 2).

Equation 2: $\text{Annual rate of desposition } = \text{IRD } \times \text{Numbers of days/ annum}$

IRD is the volume of waste deposited at the landfill site per day.

The annual rate of deposition in m^3 is calculated by multiplying an initial rate of deposition by the operational number of days of the landfill site per year in order to determining the airspace occupied by waste in (Equation 3).

Equation 3: $\text{Airspace occupied by waste } = \frac{\text{Annual deposition rate}}{\text{Compacted density}}$

To determine airspace occupied by waste, an annual rate of deposition (Equation 2) is divided by compaction density of $0.75/\,\mathrm{m}^3$ which is the recommended compaction density for South African municipal solid waste landfill sites (DWAF, 1998).

As landfill capacity includes the volume between the liner and the final cover (BME, 2013). Therefore, airspace occupied by waste and cover is found by applying (Equation 4) termed airspace for both waste and cover.

Equation 4:

$$\text{Airspace for both waste and cover} = \text{Airspace used by waste} \times \text{Cover to waste}$$

Airspace used by waste is the value given by Equation 3, and cover to waste is given value used to calculate airspace for both waste and cover which is 5/4.

The value of airspace used by both waste and cover is then calculated by multiplying the previous year's airspace total by 1.01 for 0.62% growth of TLM because the amount of waste increases due to an ongoing growth of population and urbanization. Remaining years of landfill operation and total remaining capacity of TBJ landfill site is found by subtracting annual airspace utilization from the total airspace of landfill site until we get a negative value of the remaining capacity. Different scholars and organizations have used this method and it was proved to be effective in calculating the lifespan and remaining capacity of the landfill site (Akyen *et al*., 2017; BME, 2013; DWAF, 1998).

The reason for the use of the quantitative aspect is that data required was primarily in a numerical form. The qualitative aspect on the chosen approach was used to identify the dominant types of waste delivered to TBJ landfill site, to establish the main operational challenges at TBJ landfill site, and finally to assess the efficiency and effectiveness at which TBJ landfill site is operating. Then qualitative aspect was chosen because it deals with textual data which can be observed and which are in the form of words.

3.3 Research design

In order for the study to achieve set objectives, a descriptive research design was followed. This type of research design involves gathering data that describe situation, and it often uses visual aids such as tables, graphs, photographs and charts to aid the reader in understanding the data distribution. According to Kumar (2011) descriptive research is a type of research that seeks to describe a situation under study. The research attempted to observe situations, in order to establish what can be predicted to happen again under the same circumstances. Observation can take many forms, depending on the type of information sought. People can be interviewed, questionnaires distributed and visual records made. The significance of descriptive research is that the observations are written down or recorded in some way, in order that they can be subsequently analysed (Williman, 2011).

3.4 Sampling strategy

According to Maree (2007:79) "sampling is the process of selecting a portion of the population for study". Sampling means that the sample has the same distribution of characteristics as the population which represents it (Marlow & Boones, 2005).

TLM has two landfill sites; namely, TBJ landfill site and Makwiliza landfill site. All landfills are constructed for receiving MSW. For this study TBJ landfill site was chosen for scrutiny, as it is the only landfill site which is currently operating within the TLM, Makwiliza is still waiting for a work permit.

Three out of the fifteen waste pickers from TBJ landfill site were purposively selected and interviewed because they have a good knowledge of waste materials found at TBJ landfill site as they are the ones who sort the waste for recycling. Therefore, it was crucial to select them to validate the data which was gathered through observation by the researcher.

For TBJ landfill site officials, the researcher used purposive sampling, which falls under the broader umbrella of non-probability sample designs, in order to get necessary information. Purposive sampling may be defined as an acceptable kind of sampling for special institutions which uses the judgment of an expert. It involves assembling a sample of persons with known or demonstrated experience and expertise in landfill operation and management. The reason for using purposive sampling is that it is the best way to elicit the views of persons who have specific expertise. For the purpose of this study a TBJ landfill site supervisor and a landfill site operator, together with a manager of waste at TLM, were selected to participate in the study. This was because they are the ones who have good knowledge of the management and operation of the TBJ landfill site, as well as the effectiveness and the efficiency at which the TBJ landfill site is operating, and finally the operational and management challenges of the TBJ landfill site.

Table 3.1: Summary of participant individuals

INSTITUTION	POSITION	NUMBER OF PEOPLE
TLM	Manager: Waste Management	1
TBJ landfill site	Landfill supervisor	1
TBJ landfill site	Landfill operator	1
TBJ landfill site	Waste pickers	3

Table 3.1 shows a summary of participants who have participated in this study. Waste manager from TLM municipality, landfill supervisor, landfill operator and waste pickers were engaged in this research.

3.5 Data sources

Data sources for this study were a TBJ landfill site operational plan, ground water monitoring reports, landfill site audits reports, landfill site permit, documents and reports of the amount of waste disposed and recycled at TBJ landfill site and types of waste which is sent to the TBJ landfill site. The TLM database and reports of the TBJ landfill operation and management status from TLM together, with official publications from National institutions, were used to provide secondary data. The TBJ landfill site supervisor, the landfill operator, the manager of waste at TLM and waste pickers at TBJ landfill site were the sources of primary data. The researcher also provided primary data the in form of observation.

3.6 Methods of data collection

For the purpose of achieving the objectives of this study, the following data collection methods were utilized.

3.6.1 Observation

One of the methods that was chosen for this study was field observation, to provide the primary data. According to Kumar (2011: 138) "observation is one way to collect primary data. Observation is a purposeful, systematic and selective way of watching and listening to an interaction or phenomenon as it takes place". Observation is ideal for situations where accurate information cannot be elicited by questioning, due to unwillingness of the respondents to co-operate and provide all needed data. This method was ideal in this research because the contracted company running the TBJ landfill site would not admit their non-compliance to proper management and operation of the landfill site. Therefore, the observation was used to overcome this challenges.

During field observation, notes of what was happening at the site were documented by the researcher. For ethical reasons, permission was obtained from the municipality to observe and to take photographs of the landfill site because trespassing is an offence. Observations and recordings were made so as to assess the existing management and operational practices of the TBJ landfill site. The operation and management challenges of the TBJ landfill site were documented photographically. Another purpose of observation was to witness the effectiveness and efficiency of the operation and management of the landfill site.

An observation checklist (Apendix E) was composed of the general requirements of management and operation of landfill. Decisions were made to observe a phenomenon which takes place in a natural environment using a structured observation checklist. The elements that needed to be observed and which were to be excluded were determined before data collection. Covert observation was done, with a view of being as objective as possible. Furthermore, field trips to the landfill site were conducted from the year 2014 to 2017. Such trips were conducted three times a month for field observations.

Direct systematic observation was used as one of the most natural methods for gathering information. It was chosen because it eliminates bias. Directness also permit an observer to understand situation under study and to identify anticipated outcomes (Murgan, 2015). The TBJ landfill site was visited to observe the extent to which the municipal-contracted company adheres to the procedures of management and operation. The researcher observed aspects such as security of the landfill site, surface and ground water monitoring facilities, waste receiving, offloading, working cells, equipments used for landfill operation, capacity of landfill workers, and exit procedure. The idea was to evaluate the effectiveness and efficiency of the operation of the landfill site and the operational challenges encountered during operation of the landfill site.

3.6.2 Questionnaire

A questionnaire is a written list of questions, the answers to which are recorded by respondents. In a questionnaire respondents read the questions, interpret what is expected and then write down the answers (Kumar, 2011). A questionnaire targeting the TBJ landfill site supervisor, the operator and waste management manager for TLM was designed to gather information on the TBJ landfill site management and operation, landfill staff, landfill equipment, operational cost, landfill monitoring, landfill audit reports, nature of the operation and management practice of TBJ landfill site, as well as the challenges of operation and management of landfill (Appendix A, B, and C). Other information which had a direct or indirect impact on landfill management and operation including compaction density and ratio of cover material for waste, were also covered. The questionnaires comprised of both open-ended and close-ended questions, as they were targeting different respondents in this study.

3.6.3 Interview

An interviewing is a commonly-used method of collecting information from people. According to Burns (1997: 329) “an interview is a verbal interchange, often face to face, though the telephone may be used, in which an interviewer tries to elicit information, beliefs or opinions from another person”. Interviews were conducted with waste pickers who were sorting recyclables at the TBJ landfill site. To help elicit the data on the types of waste found at TBJ landfill site, an interview scheduled was to collect data (Appendix D).

3.7 Types of data required

In order to achieve the set objectives and the aim of this study, the following data types were required per set objective:

3.7.1 Capacity of the TBJ landfill site in terms of the volume of waste disposable

Municipal database and the TBJ landfill site’s database were reviewed to provide data about the following: number of years which the landfill has been operating; recorded amount of waste disposed and recycled; total area for waste disposal; total volume of waste disposed per year; total volume of recycled waste and population growth of TLM. The questionnaire for the TBJ landfill site operator was carried out to provide data on: depth of excavation; compaction density and ratio of cover material to waste. Field measurements using ArcGIS Desktop Help 9.2 were also made to obtain the distance of area used for waste disposal.

3.7.2 Dominant types and sources of solid waste

Field observation was done by the researcher in order to inspect, record the types of waste, which has been disposed at the TBJ landfill site from 2014 to 2017. The following data was needed: waste materials disposed at the landfill site. A questionnaire was administered to the landfill supervisor to provide data about organizations that send their waste to the TBJ landfill site and the areas that are serviced by the TLM, in order to identify the dominant sources of solid waste. Waste pickers were interviewed to provide information on the type of waste disposed at the TBJ landfill site, as they deal with the sorting of waste everyday at the TBJ landfill site. TBJ landfill site reports of the waste recorded at the entrance of landfill site were also reviewed, to check the type and sources of waste that are delivered to the TBJ landfill site by the organisations.

3.7.3 Efficiency and the effectiveness of the TBJ landfill site operation

In order to assess the effectiveness and efficiency of the operational practice of landfill site, you should have good observational skills (Garner 2009). The TBJ landfill site's database was used and field observation was carried out by the researcher to assess effectiveness and efficiency with which the TBJ landfill site is operating. The data collected included: the cost of running landfill site; availability of landfill site workers; landfill site's infrastructure: *weighbridge, site office, site security and fence*; waste identification and restriction; principles of landfill operation: *compaction, intermediate cover of putrescible*, *and daily covering*; adherence to operational plan; adherence to permit policies and environmental legislations; waste minimization: *recycling and composting*; leachate and gas management; borehole; groundwater monitoring; access control; all-weather access roads; wet working cell; and progressive rehabilitation and vegetation of completed areas.

3.7.4 Main operational challenges at the TBJ landfill site

Questionnaires were administered to the TBJ landfill site supervisor, landfill operator and the manager of waste in TLM, to help provide data on the operational challenges encountered at the TBJ landfill site. Field observation was carried out by the researcher, to assess the operational challenges of the TBJ landfill site, with a view of checking its compliance and non-compliance with the operational guidelines. An observation checklist was used to gather information about: the availability of landfill equipment: *landfill compactors, bulldozers, front-end loaders, and trucks to transport cover materials;* cover materials; nuisance: *waste burning, litter, odour, vermine & disease vectors*; special cells; and dumping.

3.8 Ethical Considerations

Ethical approval was obtained from the University of Venda, Research Ethics Committee. Research ethical clearance certificate was also issued by the research ethics committee of University of Venda (Appendix F). All respondents who participated in the study did so only after understanding the purpose of the research.

3.9 Validity and reliability

To certify that the questionnaires which were utilized for data collection gathered the relevant information, protocol for questionnaire design and administration was considered, and thus appropriate information was gathered. Some of the data collected through interviews were confirmed through direct observation. This is the consistency of the scales used to measure the observations of the study. The validity of the study centered on the establishment of the measures chosen actually to capture the essence of the variables as described for this study. Questionnaires were prepared and conducted, and responses were recorded in a standardized schedule. Observations were made with a checklist as a tool to enhance quality assurance. The researcher interviewed waste pickers, and administered the questionnaire to the landfill supervisor and operator and waste manager. Reliability was established because two independent observers (the researcher and the assistant researcher) recorded information and later they checked the extent to which they agreed on the state of the data collected observed independently, and the data collected were similar.

3.10 Data analysis and presentation

Descriptive analysis was used to analyse data. This type of analysis helped to easily draw conclusions using numbers. The analysis involved the use of frequency distribution of scores converted to percentages (White, 2003). Text, spreadsheet, tables, photographs, charts and graphs were used to describe the dominant types and sources of waste disposed at TBJ landfill site; efficiency and effectiveness of landfill operation; and the operation and management challenges of TBJ landfill site. Mathematical formulas and simple tabulation were used to determine the remaining capacity of the TBJ landfill site.

3.11 Summary

Primary and secondary data were collected for this study. Field observations, questionnaires and interviews were used to gather primary data. TLM database and TBJ landfill site database were used to gather secondary data. Data were analysed descriptively using text, spreadsheet, mathematical formulas, charts, graphs and photographs.

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSION

4.1 Location of the TBJ landfill site

The TBJ landfill site is located in Thohoyandou Block J under Thulamela Local Municipality (TLM). Most of the waste collected in TLM is disposed at TBJ landfill site, the only landfill site in TLM which is operating. TBJ landfill site is found within residential developments (Figure 4.1).

Figure 4.1: Location of the TBJ landfill site (Sourced from: Google Earth, 2016)

Figure 4.1 illustrates location of the TBJ landfill site. The distance between the boundary of the TBJ landfill site and the residential developments was found to be 80m, which does not comply with the required distance between the boundary of the landfill site and the residential developments. The minimum permitted distance between landfill site and developments and water resources must not be less than 400m, due to the significant impact it can have on the health of nearby residents (DWAF, 1998). Furthermore, the distance between TBJ landfill site and the water resource was found to be 402m, which is an acceptable distance, as it exceeded the minimum required distance of 400m.

4.2 Description of the TBJ landfill site

TLM database and field observation revealed that the TBJ landfill site is owned by the TLM. However, the TLM has contracted a private firm to operate the TBJ landfill site. Before 2004, the TBJ landfill site was operating without a permit. However, in 2004 it was granted a permit to operate as a landfill site for disposing general waste. It was classified as a G:S:B^{+} landfill site. The TBJ landfill site classification conforms with the classification of minimum requirements for waste disposal by the landfill site, as classification of a small landfill site which receives general waste and which has the potential of generating leachate, is classified as G:S:B^{+}, which can be worded as a General Waste: Small Landfill: Significant leachate producing landfill site DWAF (1998).

In terms of the volume of waste disposed to the TBJ landfill site, 116 tonnes of waste per day are disposed, the number of tonnes disposed at TBJ landfill site per day qualifies it to be classified as G:S:B^{+}. And should thus accept >25 <150 tonnes of waste per day (DWAF, 1998). Figure 4.2 displays information which describes the landfill site. It is a must for a landfill site to have a weatherproof board at the entrance gate written in all official languages spoken in TLM.

Figure 4.2: Facility description (Source: field work, 2014)

Figure 4.2 shows that TLM is the owner and holder of the operation permit of TBJ landfill site. Ingwe Waste Management is the contractor which is responsible for operating the TBJ landfill site. The TBJ landfill site operates from 07H00 to 17H00, seven days a week. Contact details in case of the emergency has been displayed on the signboard with the name of the responsible person of the landfill site. Figure 4.2 covers all the information which must be reflected at the entrance of the landfill sites as per requirements of the landfill site's permit.

4.3 Lifespan and remaining capacity

The ArcGIS Desktop Help 9.2 site revealed that the length of the TBJ landfill site used for waste disposal is 427m and the width is 259m. The TBJ landfill site report of disposed and recycled waste revealed that the TBJ landfill site disposes 116 tonnes per day. Field measurement and questionnaire carried out with the TBJ landfill site operator revealed that the height of the TBJ landfill site is 2.5m; the waste to cover ratio is 1.25 and compaction density is 0.75T/m^3, which is the recommended compaction density in South Africa (DWAF, 1998). The following calculations were made to determine the remaining lifespan and the remaining capacity of the TBJ landfill site:

- **Available airspace of the TBJ landfill site in m^3**

$$\text{Available volume of cover} = \mathrm{L} \times \mathrm{W} \times \mathrm{H}$$

$$= 427\mathrm{m}^3 \times 259\mathrm{m}^3 \times 2.5\mathrm{m}$$

$$= 276\,483\ \mathrm{m}^3$$

TBJ landfill site's cover to waste ratio is 1: 4. For a landfill site which requires a volumetric ratio of cover material to waste of about 1: 4, the total airspace is obtained by multiplying the volume of available cover material by a factor of 5 (DWA, 1998).

Therefore, the total airspace is: $276\,483\ \mathrm{m}^3 \times 5$

$$= 1\,382\,413\ \mathrm{m}^3$$

- **Annual airspace utilization in m^3**

$$\text{IRD} = 116\text{T/day}$$

$$\text{Annual rate of desposition} = \text{IRD} \times \text{Operational numbers of days/ annum}$$
$$= (116\text{T/day}) \times 365 \text{ days/annum}$$
$$= 42\,340 \text{ m}^3\text{/annum}$$

$$\text{Airspace occupied by waste} = \frac{\text{Annual deposition rate}}{\text{Compacted density}}$$
$$= \frac{42\,340 \text{ m}^3}{0.75/\text{ m}^3}$$
$$= 56\,453\text{m}^3\text{/annum}$$

Therefore:

$$\text{Airspace for both waste and cover} = \text{Airspace used by waste} \times \text{Cover to waste}$$
$$= 56\,453 \text{ m}^3 \times 1.25$$
$$= 70\,566\text{m}^3$$

The cover availability is a major factor which determines air space at a landfill site (DWAF 1998).

The annual airspace used by both waste and cover is calculated by multiplying the previous year's waste and cover airspace by 1.01 of 0.62% of population growth of TLM because the amount of waste ascend due to an ongoing growth of population and urbanization. The total remaining capacity of the TBJ landfill site is found by subtracting annual airspace utilization including cover from the total airspace of landfill site which is $1\,382\,413 \text{ m}^3$ (Equation 1) until one arrives at negative value of the remaining capacity. The method used is similar with the method used by Akyen *et al*. (2017) for determining the total remaining capacity of landfill site in Ghana, and the method yielded the same results as those found at TBJ landfill site. The estimated results of the remaining lifespan and capacity of the TBJ landfill sit is presented in Table 4.1.

Table 4.1: Approximate remaining lifespan and capacity of TBJ landfill site

Years	Annual airspace utilisation, including cover, per annum (m^3)	Annual growth rate (%)	Cumulative airspace utilisation, including cover, per annum (m^3)	Total remaining capacity (m^3)
2004	70 566	0.62%	70 566	1 382 413
2005	71 272	0.62%	141 838	1 311 141
2006	71 984	0.62%	213 822	1 239 157
2007	72 704	0.62%	286 526	1 166 453
2008	73 431	0.62%	359 957	1 093 022
2009	74 166	0.62%	434 123	1 018 856
2010	74 907	0.62%	509 030	943949
2011	75 656	0.62%	584 686	868293
2012	76 413	0.62%	661 099	791880
2013	77 177	0.62%	738 276	714703
2014	77 949	0.62%	816 225	636754
2015	78 728	0.62%	894 953	558026
2016	79 516	0.62%	974 469	478510
2017	80 311	0.62%	1 054 780	398199
2018	81 114	0.62%	1 135 894	317085
2019	81 925	0.62%	1 217 819	235160
2020	82 744	0.62%	1 300 563	152416
2021	83 572	0.62%	1 384 135	68 016
2022	84 407	0.62%	1 468 542	-16391

In Table 4.1 the annual airspace utilisation, including cover is the amount of MSW generated and actually received at TBJ landfill site in cubic meters per year. The cumulative airspace utilisation, including cover, is the amount of waste and cover which TBJ landfill site can receive within its lifetime. Cover material is included because cover is a major factor which determines air space at a landfill site (DWAF 1998). The annual growth rate is the percentage of population growth of TLM, and the total remaining capacity indicates the total amount of waste in cubic meters that the TBJ landfill site is able to accept for disposal during its lifetime.

Table 4.1 shows that between 2004 and 2017 an average of about 1 054 780 m^3 was utilized for waste and cover materials. The projected lifespan of the TBJ landfill site was found to be 18 years, which is from 2004 to 2021. The total volume of waste disposable, together with cover materials from the inception of landfill operation untill 2021, were found to be 1 382 414 m^3. Landfill capacity includes the volume of waste and daily cover between the liner and the final cover (BME, 2013). As the landfill has been operating for the past 14 years (from 2004 to 2017), Table 4.1 shows TBJ landfill site is left with 4 years of operation; that is 2018 until 2021. The remaining capacity left for TBJ landfill site is 317 085m^3 (Table 4.1). It is clear that an increase in the MSW generation in TLM will contribute to a significant decrease in the duration of the lifespan of the TBJ landfill site. This is evident from Table 4.1, where it can be deduced that an increase in MSW generation is inversely proportional to the total remaining capacity of the landfill site. Furthermore, an analysis of Table 4.1 shows that by the year 2022 the TBJ landfill will not be able to sustain the waste generated in TLM. This can be confirmed from Table 4.1, where a negative value of the total remaining capacity was obtained for the year 2022.

4.4 Dominant types of waste

The dominant types of solid waste which were found at the TBJ landfill site revealed that plastics, card-boxes and papers are the dominant types of solid waste which are delivered to TBJ landfill site, Figure 4.3.

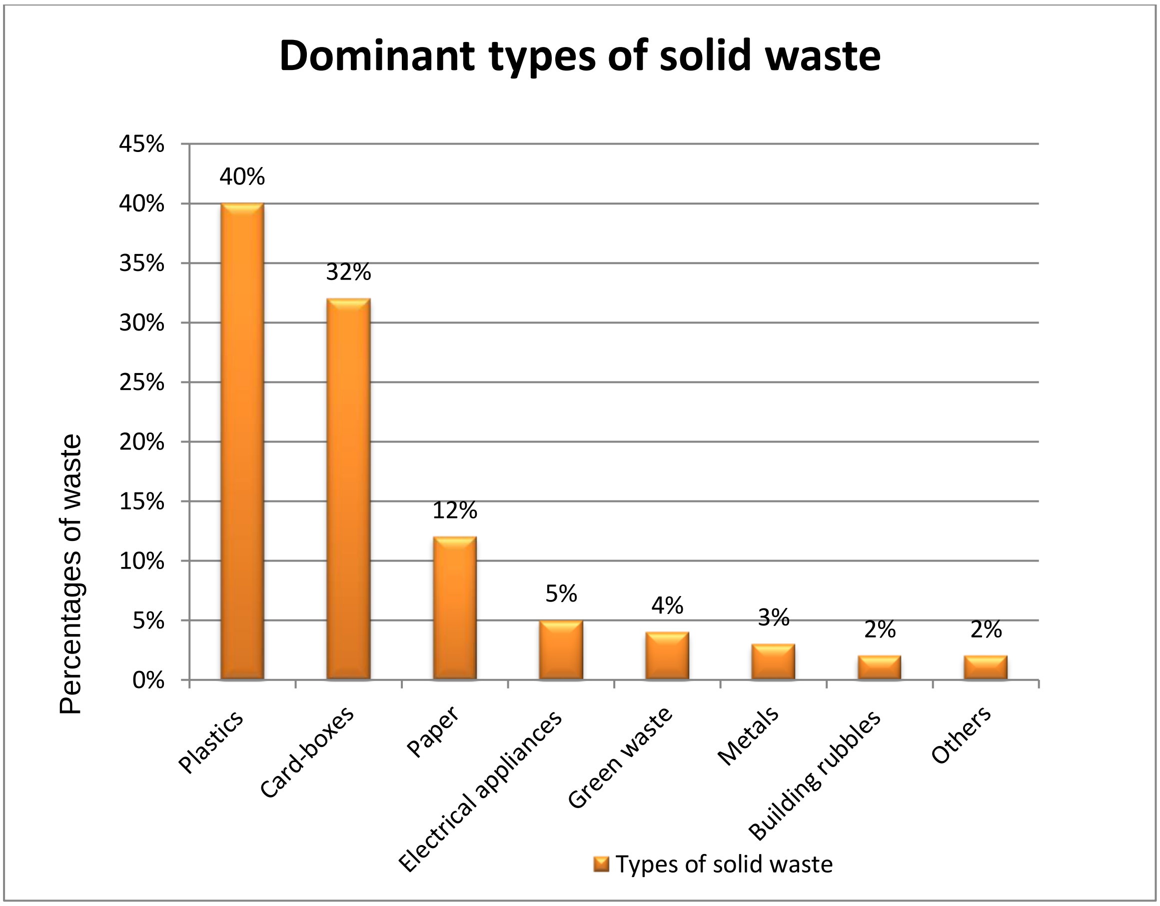

Figure 4.3: Dominant types of solid waste

Figure 4.3 shows that the dominant types of solid waste found at TBJ landfill are plastics 40%, card-boxes 32%, and paper 12%, both plastics, card-boxes, and paper constituted about 84 % of all the types of solid waste generated in the TBJ landfill site, with electrical appliances following at 5%. The least type of solid waste generated were building rumbles (2%), with the remaining other waste comprising 2%. The findings concurred with the findings by Bello *et al*. (2016), who reported that most types of waste that are sent to landfill sites in Uganda include papers, plastics, tins, bottles, glass, and metals. A considerable percentage of the plastics and card-boxes at TBJ landfill site could be explained by an increasing use of plastics and card-box products in packaging in many area ranging from households and commercial area. This further explains why the TBJ landfill site is quickly filling up as plastics waste needs approximately two hundreds of years to decompose (Miezah *et al*., 2015). Small fractions of medical packages and syringes were also identified at TBJ landfill site's working phase. However, medical packages and syringes were found to be the waste generated by people who treat themselves at home, as there were no reported companies that delivered medical waste to TBJ landfill site. Moreover, it was discovered that most of the waste disposed at TBJ landfill site are reusable products and packaging such as plastics and card-boxes, which can be diverted from the landfill Figure 4.4.

Figure 4.4: Types of solid waste (Field observation, 2017).

Figure 4.4 shows the dominant types of waste identified at the TBJ landfill site during the observation of types of solid waste disposed. Plastics, packaging materials in the form of cardboards, tins, and bottles, discarded writing materials and newspapers, glass, diapers, clothing, batteries, wooden waste, garden waste, electrical appliances, discarded paint, small fractions of syringes and medical packages, were identified. This concurs with the findings of Atalia *et al*. (2015), who found that failing to practice waste inspection in some of the Indian landfill sites, resulted in mixing medical wastes and general waste during landfilling. Identification of the types of waste which is disposed of at TBJ landfill site is very important because it will help to enlighten landfill site's management to come up with the appropriate methods to effectively deal with the various types of waste which are sent to landfill site. Methods such as source separation, recycling, and composting can be used to decrease the amount sent to TBJ landfill site depending on the dominant types of waste identified.

4.5 Dominant sources of solid waste

The bulk of the waste observed in TBJ landfill site was found to be emanating from various sources; it was found that the TBJ landfill site contains residential/ household, industrial, commercial, construction, building and electronic wastes. Based on the landfill records of the sources of waste disposed of at TBJ landfill site, coupled with areas serviced by TLM, residential, institutional, industrial and construction waste were found to be the dominant sources of wastes found at TBJ landfill site. Similar findings were made by Babayemi & Dauda (2009), as they found that the major sources of waste delivered to landfill site in developing countries are residential, institutional, hotels and restaurant, commercial and industrials. Figure 4.5 shows the percentage of dominant sources of solid waste materials disposed in the TBJ landfill site.

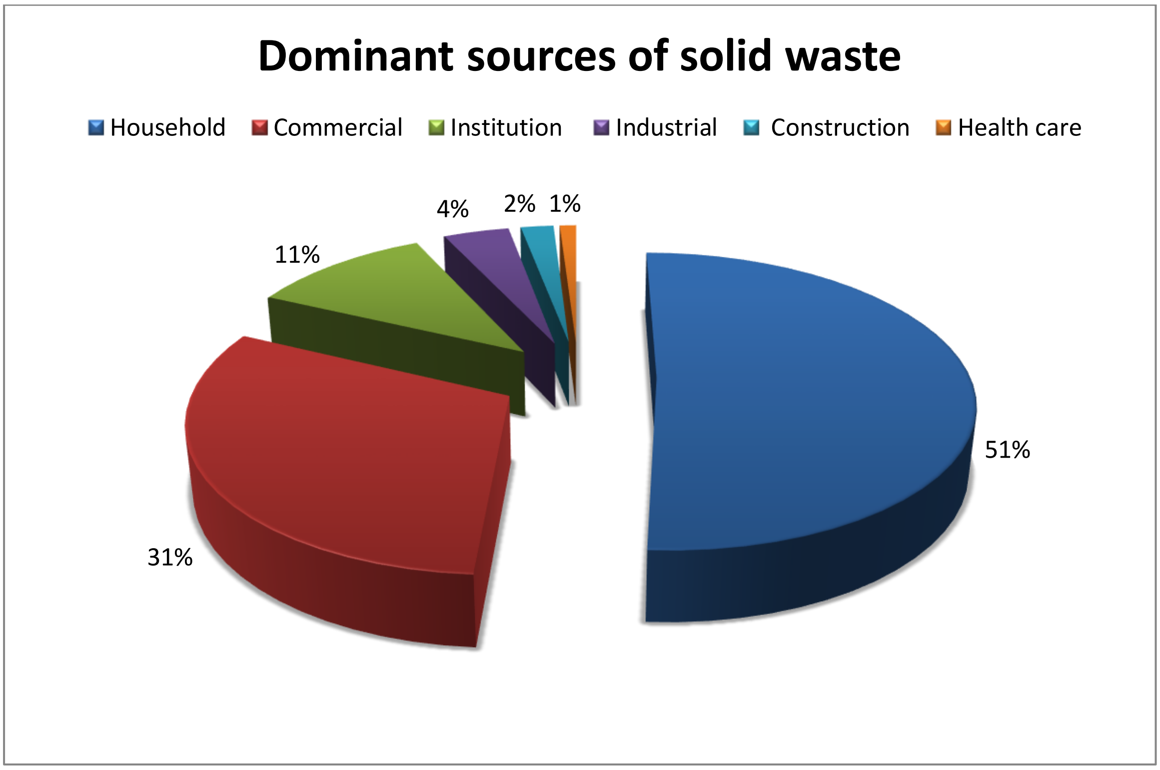

Figure 4.5: Sources of solid waste

Figure 4.5 shows that that the largest contributors of solid waste source at the TBJ landfill site are households. Households were found to be the dominant source, with 51%, followed by commercial enterprises, at 31%. Institutions were found to be the third dominant sources of waste disposed to TBJ landfill site, at 11%. Industrial areas were found to contribute just 4%, while 2% were the waste emanating from construction. Although the interview was conducted with waste pickers, the interview nevertheless revealed that health care waste, such as needles, gloves and medical packages from homes, is also found at the site, which shows that health care facilities also contribute to the waste stream in the TBJ landfill site under study at 1%. The findings correlate with the findings of Sigh *et al.* (2014), as they found that the major sources of solid waste that is frequently delivered to landfill sites around the world include residential household, commercial, institutional, industrial and construction.

4.6 Landfill site operation and management

TLM utilizes motorized trucks to collect waste at different residential and township areas, which are then transported directly to the TBJ landfill site. Dumping by private individuals is also permitted free of charge. The established system at the landfill site, as observed by the researcher, was delivery of waste, recording of the incoming waste, and recycling of recyclables by waste pickers. Waste is then spread in the working phase and compacted, then covered with soil excavated within the site. The monitoring of water quality is also practiced. Residents do have access to the facilities for dumping their refuse without paying tipping fee because they pay municipal waste services.

4.6.1 Operation and management cost

The TBJ landfill site does not generate any income from private institutions that dispose their waste at the site. However, it was revealed that the contractor responsible for running TBJ landfill site receives about R 240 000 per month to operate and manage the landfill site. It was also revealed that the municipality does not lag behind when it comes to issuing the budget of running the site, and the manager revealed that there are no delays in the disbursement of the funds for the management and operation of TBJ landfill which can not lead to lack of funds to cover operational cost.

4.6.2 Landfill staff

The TBJ landfill site database revealed that the TBJ landfill site has a supervisor who hold a Bachelor of Environmental Sciences, who manages the workers working at the landfill site. Apart from the supervisor, the landfill also has two landfill operators and litter pickers, including the securities who control access at the gate. The TBJ landfill site, in terms of staffing situation, has a total of ten (10) fulltime workers that are employed by Ingwe Waste Management, and they are all based at the TBJ landfill site (Table 4.2).

Table 4.2: Technical staff of the TBJ landfill site

Staff of the TBJ landfill site	Numbers	Qualifications
Waste manager	1	It is not disclosed
Waste management officials	3	Bachelor of environmental sciences
Landfill site supervisor	1	Bachelor of environmental sciences
Landfill operator	2	Standard 8 & 9
Security / Gate keeper	3	Security certificate
Waste recorder	1	Grade 12
General labour /Spotters and litter pickers	3	Grade 12
Tipper Truck driver	1	Grade 12
TLB Operator	1	Grade 12
Dozer Operator	1	Grade 12

(Source: The TBJ landfill site database)

Table 4.2 present profile of workers who are responsible for the running of the TBJ landfill site. In column 2 is the number of people who are employed to perform the duties of ensuring smooth running of the TBJ landfill site, and column 3 shows the qualifications held by the staff member have. Table 4.2 shows that the supervisor in charge of the TBJ landfill site is educated enough to be a supervisor of the TBJ landfill site. However, all the other workers responsible for the operation and management of TBJ landfill site only have school-leaving qualifications.

4.6.3 Equipment for landfill operation

An observation checklist which was used to assess the equipments available at the TBJ landfill site during the site visit indicated that the equipment which used during the operation of the TBJ landfill site. The landfill site should have the appropriate equipment for operating a landfill site, which includes bulldozer, excavator, landfill compactor, pick-ups and tipper trucks. Table 4.3 displays the equipment used during the operation of the TBJ landfill site.

Table 4.3: Equipment for landfill site operation

Type of equipment	**Number of items**	**Functionality**
Weighbridge	1	Not functional
Landfill compactors	None	
D6 Dozer Bulldozers	1	Functional
Excavator	1	
Front end loaders/ scrapers	1	Functional
Trucks to transport cover materials	1	Functional
Water tanker	None	
Rollers	None	
Bell TLB	1	Functional
Hino Tipper Truck	1	Functional

(Source: Field survey, 2016)

Table 4.3 shows the types and the equipment which is available for use during operation and management of the TBJ landfill site, including their functionality. Analysis of the equipments in Table 4.3 shows that the TBJ landfill is operating without a weigh bridge for recording incoming waste and the outgoing recycled materials from the landfill site. Due to the absence of a weigh bridge, the landfill worker records the volume of waste through estimation. Furthermore, if there is no weigh bridge, the average daily tonnage can be calculated on the basis of incoming volumes. This involves counting incoming vehicles and estimating the volumes carried in cubic metres. This is what is taking place at the TBJ landfill site due to the unavailability of weighbridge. A landfill compactor was another equipment which is not available at the TBJ landfill site to help reduce the volume of the waste. This is done to minimize expansion of the disposed waste, to enable the landfill to have more lifespan, due to the unavailability of landfill compactor Bell TLB and dozer which are used to spread the waste, and for compaction purposes. The lack and non-functionality of equipment and tools restrict effective operation of the landfill, as it impedes operations not to be performed effectively at landfill site.

4.6.4 Waste inspection

During the assessment of the vehicles that deliver the waste at the TBJ landfill site, it was found that vehicles carrying waste are first inspected, the gate keeper assesses the type of the waste to be disposed at the TBJ landfill site, to check if the type of waste carried is permitted at the landfill site. Thereafter, they allow the driver to go and dispose the waste. This is done to avoid landfilling hazardous waste with municipal solid waste, because if waste inspection is not practiced at landfill sites, landfilling while mixing hazardous and general waste can take place. Therefore, waste inspection is of great significance in preventing landfilling of mixed waste too.

4.6.5 Recording of waste volume

The TBJ landfill site does not have weighbridge for the purpose for recording the incoming waste volume. Therefore, the TBJ landfill site officials uses estimation to record waste volume. This is done by way of counting the capacity of the load of the vehicle which it has to deposit and thereafter they subtract the weight of the vehicle on its departure. The results obtained are identical to the findings of Al-Yaqout & Hamoda (2002), who made predictions of waste volume based on the average number of incoming truck’s tonnage.

4.6.6 Liners and nature of waste disposal

With regard to liners and nature of waste disposal, field observation showed that the TBJ landfill site does not put a liner prior to disposing their waste; they just dispose their waste on bare land until such waste makes a huge heap. Thereafter they spread the waste before they compact and cover it. The practice of disposing waste on bare land, without a liner is known to release hazardous and deleterious chemicals to ground water, and also has the potential of releasing hazardous chemicals. Even small landfills have the potential of adversely impacting the groundwater quality if they are not operated effectively (Al-Muzaini, 2009). This simply means that the manner in which waste is disposed at TBJ landfill site is not environmentally friendly.

4.6.7 Compaction, and waste covering

Waste disposal is taking place at designated areas, according to the operational plan. The spreading of waste is practiced and then compacted by the dozer, to reduces voids in the waste. After compaction the waste, a layer of soil cover of about 150mm is applied, to cover the compacted waste, using a TLB for spreading the soil to cover the waste. The compacted waste at a landfill should be covered with at least a minimum of 150mm thickness cover (DWAF, 1998), and this implies that a 150mm thick soil cover, which is applied at the TBJ landfill site, meets the acceptable requirements of cover thickness. The soil which is used to cover the waste is extracted within the site, and then transported by the tipper truck to where they are to use it to cover the waste (Figure 14.6).

Figure 4.6: Tipper truck unloading soil for covering

Figure 4.6 shows a truck unloading silt soil for the daily covering of the waste at the TBJ landfill site. The importance of daily covering landfills is meant to keep birds, insects, rats, and other animals from moving in and becoming a nuisance, as well as health hazards. Moreover, waste covering using soil which has a high clay content is advisable, as clay soil absorbs more water before they reach the buried waste quickly.

4.6.8 Re-vegetation of the already filled cells

During the site visit at the TBJ Landfill site, it was further observed that the TBJ Landfill site also does re-vegetation after closing of the already filled cell. When the landfill's operational life ceases, a final layer of soil and optimal synthetic liners are added, along with a vegetative cover to limit percolation and erosion.

Figure 4.7. Re-vegetated top part of already filled cell

4.6.9 Ground water monitoring

The field observation undertaken at the TBJ landfill site revealed that the TBJ landfill site has one borehole for monitoring ground water quality (Figure 4.8). given that, one borehole can at least provide substantially more information than when there is no borehole at all within the landfill site. However, it would be ideal to have more than two boreholes in order to provide full information about the state of water quality within the site (DWF, 1998). The monitoring of groundwater at TBJ landfill site is done twice a year, and this concurs with the findings of EWSWA (2013), who observed that monitoring of groundwater from the landfill site in Windsor Canada is made twice a year.

Figure 4.8 Groundwater monitoring borehole

Figure 4.8 shows a ground water monitoring borehole at the TBJ landfill site. It is important to assess groundwater quality at landfill sites and develop strategies to protect aquifers from contamination because leachate migration from wastes sites pose a high risk to ground resource, if not adequately monitored and adequately managed. The protection of groundwater and surface water is a major environmental issue because the importance of water quality on human health has attracted a great deal of interest. It is also a mandatory for a G:S:B$^+$ landfill site to have a borehole which is used to monitor or to check whether ground water has been contaminated by the improper operational practice of the landfill or not. G:S:B$^+$ should have at least one borehole for ground water monitoring (DWAF, 1998).

4.7 Operational challenges experienced at the TBJ landfill site

Questionnaires administered to the TBJ landfill supervisor, operator and the manager of waste management from TLM, coupled with the field observation which has been undertaken within the TBJ landfill site, revealed different operation and management challenges at the TBJ landfill site.

4.7.1 Access control

The entrance gates of the TBJ landfill site were found to be always open during the hours of operation and locked outside these hours. Therefore, access at the gate is always controlled. However, the fence of the TBJ landfill at the back of the landfill site is not in a good condition as it has been damaged at all sides of the landfill site. Figure 4.9 clearly shows that the landfill site is not properly manged and it borders on crude dumping.

Figure 4.9: The TBJ landfill site's damaged fence

Figure 4.9 shows the damaged fence of the TBJ landfill site at the back side of the site. This makes it possible for people to do illegal dumping, as unauthorised entry is no longer restricted due to the damaged fence. Furthermore, the damaged fence at the TBJ landfill site enables stray animals to enter the site and graze on the re-vegetated area.

During the field observation, cow dung was found within the fence of the TBJ landfill site, including at the top of re-vegetated area of the already closed cell (Figure. 4.10). This clearly shows that animals enter the TBJ landfill site through the broken fence in order to grace at the landfill site. This contradicts with what has been mentioned at the notice board erected at the site's entrance, as it mentioned that no animals are allowed at the landfill.

Figure 4.10: Cow dung found at the rehabilitated area (Source: Field observation, 2016)

Figure 4.10 shows the cow dung which was found at the site during the observation undertaken at the TBJ landfill site. This confirms that the damaged fence of the TBJ landfill site enables stray animals to invade the landfill site and graze there. In India, Rana *et al*. (2015) found that landfill sites without good fence tend to experience problems of stray animals, as they are found everywhere on the site during the operation of the landfill site. This was confirmed in the TBJ landfill site, as cow dung was found on the rehabilitated cell as the fence at the TBJ landfill site is damaged. This means animals have access to the site.

4.7.2 Fire hazards

It has been observed that the TBJ landfill site does not have a fire break around the site, and so possibilities for fire eruption loom large. The lack of a fire break around TBJ landfill site was confirmed and observed on the 18th of July 2017, when a fire from outside the landfill site found its way into the TBJ landfill site's working phase and burned the waste at the landfill site. Therefore, fire break is important to prevent fire at landfill sites. During field observation at the TBJ landfill site, burning of waste was observed, which implies that there is non--compliance with the landfill operation plan by the landfill staff. Burning at a landfill site is not allowed. Additionally, fire at a landfill site emits smoke that is toxic to the atmosphere and it is both a health and environmental hazard. Figure 4.11 provides evidence of the burning of waste within the landfill site.

Figure 4.11: Ashes generated from waste burning (Source: Field observation, 2015)

Figure 4.11 shows the ashes of the waste which was burned by the waste pickers in the recycling area. The outbreak of the fire in the TBJ landfill site was reported to be caused by the waste pickers who were attempting to extract precious metal from the waste. This implies that some of the principles of managing the TBJ landfill site are not strictly adhered to. Similar findings were also pointed out by Supriyadi *et al*. (2000), who posited that landfill fire in Indonesian landfills are set by waste pickers when extracting some of the valuable materials that need to be melted first.

4.7.3 Littering

The field observation undertaken within the TBJ landfill site revealed that there was significant littering on site. The littering was observed mostly around the working phase, which might have been caused by wind, refer to Figure 4.12.

Figure 4.12: Littering taking place in the TBJ landfill site

Figure 4.12 shows the litter which was observed next to the working phase of the TBJ landfill site. However, the TBJ landfill site has litter pickers who control litter in the vicinity of the TBJ landfill site. Next to the working phase it was observed that litter control is not being practiced at all, as some of the litter observed shows the picking of waste has not been done in a while. When littering is not controlled it creates a bad appearance of the site and contradicts the TBJ landfill site permit, as it states that the permit-holder must control the wind-blown waste. Littering must be controlled at all costs, as management of the landfill site is not complete if paper or other lightweight material is found anywhere within the landfill site (Senzige, 2014).

4.7.4 Difficulty of acquiring proper cover materials

The findings obtained through interviews and during field observation using an observation checklist revealed that the TBJ landfill site uses soil cover found inside the landfill site. This is due to lack of an adequate budget to secure proper clay-rich soil from outside the landfill site for covering the waste. The type of the soil used at the TBJ landfill site as cover materials is silt soil, which are excavated within the landfill site. However, it is not good for cover, because it has high permeability and a low capacity to absorb contaminants. Clay-rich soils are preferable for waste covering, as their low permeability allows more time for natural attenuation of leachate to occur (Tadros, 2009). A landfill site should preferably have abundant cover material that can be easily extracted, and which has a high clay content. This is because clay a has high capacity to absorb contaminants. If there is no clay soil at the site, it can be sourced from outside the site and transported by trucks into the site.

4.7.5 Stability of rehabilitated slope of landfill site

The embankments made of the waste and the earth cover tends to move downward, aided by the force of gravity. This can be seen by simply observing the slope (Figure 4.13). Almost all the cells at the site were filled to capacity with huge steepness of slope of the already filled cells during site visit, and such huge steepness leads to the sliding of the cover materials. Waste settles and degrades and when the slope of the landfill is too steep it is difficult to predict what will happen to the slope of the landfill (HDR Engineering, 2013). Figure 4.13, shows the huge steepness of the already filled cells, which is eroding due to improper operation.

Figure 4.13: Soil erosion on rehabilitated cell

Figure 4.13 shows some of the wastes becoming exposed due to the poor cover of waste and high steepness of the slope. The exposed waste can bring along the danger of leachate seeping out of the buried waste during heavy rains and pose a danger of fire ignition. The slope of the TBJ landfill site is not in accordance with the minimum requirements for waste disposal by the landfill, issued by the Department of Water Affairs and Forestry in 1998. The slope of the sides of the site should be constructed in such a manner that little or no erosion takes place or occurs.

4.7.6 Frequent break down of the operating equipment

Data obtained from the TBJ landfill site through observation checklist revealed several challenges at the TBJ landfill sites. Each of the challenges has a financial implication attached to it. It was found that poor-quality heavy equipment machinery is procured, and it breaks-down frequently. In addition, maintenance schedules are not always followed, thereby reducing the lifespan of the equipment. The situation is dire when the equipment breaks down with repair works mostly based on the trial and error approach. The same challenge was also found by Kusi *et al*. (2017) in Ghana, as they reported that equipment for landfill operation at Kpone landfill site break down frequently due to procured low quality equipments, and lack of following maintenance schedules which tend to reduce the lifespan of the equipment.

4.7.7 Ground water contamination

Results of ground water quality of the TBJ landfill site revealed that ground water at the TBJ landfill site has been contaminated with regard to other parameters. Even a small landfill site has the potential of adversely impacting the groundwater if it is not properly designed, operated, and properly managed. Therefore, monitoring groundwater system is significant, to prevent groundwater resources contamination. The results of ground water monitoring obtained in the report of state of water quality in the TBJ landfill site revealed the greatest value of total hardness, the Total Hardness (TH) was greater than 600mg/ l$CaCo_3$, which is not an allowable value when determining water quality, because it was above the maximum allowable limit of 400mg/ l$CaCo_3$ (Sugirtharan & Rajendran, 2015). Total hardness is high in the vicinity of the TBJ landfill site. Therefore, it can be deduced that groundwater at the TBJ landfill site has been contaminated. Total Hardness is one of the important properties of ground water from utility point of view.

4.8 Strategies of operating and managing the TBJ landfill site

4.8.1 Operating plan

During the review of the documents of the TBJ landfill site, it was also found that the TBJ landfill site has an operational plan which has been drafted with the view of operating the TBJ landfill site. The operating plan of the TBJ landfill site clearly describes the way in which the TBJ landfill site is being operated, the provision of wet weather cells, access to the site, including all the operation monitoring procedures. However, the TBJ landfill site's operating plan does not contain the plan for mitigation actions with regard to problems which would be detected through monitoring. An operating plan must have a plan for mitigation actions in response to problems detected by monitoring (DWAF, 1998). However, in terms of usage, the TBJ landfill site's operating plan was found to be more useful with regard to operating and managing the TBJ landfill site.

4.8.2 All weather access roads and wet working cell

Field observation revealed that the roads within the TBJ landfill site are in good condition and they are maintained, in order to make it suitable for driving in all weather condition when the operation of the landfill has to be done. In addition, the TBJ landfill site has a wet working cell, which enables it to be operated even during rainy period; this is undertaken to avoid difficulties when operating at the normal working cell as normal cell will be difficult to be accessible during rain period. At the TBJ landfill site, the wet working cell was found to be made up of building rubbles to enable trucks to be able to dispose the waste during wet period without challenges of slippery roads.

4.8.3 Waste minimization

- **Recycling**

Currently, there is no recycling programme which has been implemented by the TLM. However, TLM allows unregistered waste pickers to recover valuable waste at the TBJ landfill site. This concurs with the findings of Kusi *et al.* (2017), as they found that recycling at landfill sites is mostly done by the unregistered waste pickers. It has been found that 65% of solid waste disposed in the TBJ landfill site consists of wastes that are recyclable. TLM does not have a formal waste recycling system. The findings revealed that the TBJ landfill site has 15 informal waste pickers that collect recyclable wastes on a daily basis at the site. These waste pickers collect all recyclable waste, ranging from plastics, steel, card-boxes and cans Figure 4.14.

Figure 4.14 Recycled plastic bottles

Figure 4.14 shows the recycled plastic bottles which were recovered by the waste pickers, who sort out materials at the TBJ landfill site. These recycled materials are packed for recycling companies to collect and send them for processing. Waste pickers are helpful in reducing the amount of recyclable items, such as papers and plastics, which were to be landfilled. Recyclables which are recovered at the TBJ landfill site are sent to large recycling industries in Gauteng for further processing.

An interview was also conducted with the waste pickers to get data on the amount of recyclable waste collected per day. Unfortunately they never kept records of the amount of recyclables collected, although they charge the price based on a kilogram of the material. They mentioned that a 2L cold drink bottle is R1, aluminum cans R 2/ kilogram (kg), card boxes R30/kg, plastic containers 50 cents/ kg, copper R15/ kg brass R4/ kg. They were able to quantify the amount of money received at the end of the month, which was approximately R1 500 per person, depending on the rate of collection for every individual.

However, the waste pickers do not work as a team; they work independently for different stakeholders. They sort different materials received at the TBJ landfill site, and weighed for pricing.

Figure 4.15: Recycled card-boxes

Figure 4.15 shows the card-boxes which have been recovered at the TBJ landfill site. This shows that waste pickers are playing an important role when it comes to reducing the amount of waste which are to be landfilled at the TBJ landfill site, this also helps to increase the lifespan of the landfill site, because most of the waste are diverted from being landfilled.

- **Composting**

The TBJ landfill site has a compost site which is used for managing organic waste. The aim of compost site was to prevent landfilling waste, which can be used for generating compost Figure 4.16.

Figure 4.16: Composting site at the TBJ landfill site

The strategy of the TBJ landfill site to have a composting area seems to be beneficial, because composting at compost site maximizes the volume to be used for waste disposal, by diverting some of the waste to a compost site. Kadir *et al*. (2016) reported similar findings when they found that composting were beneficial for diverting waste from landfilling at Makanan Ringan Mas landfill site in Malysia. With regard to the generated compost, it was reported that those who needs fertilizers are requested to go to TLM to request compost.

4.8.4 Landfill auditing

According to the TBJ landfill site permit, internal auditing should be done quarterly, and such quarterly audit should be made available to the external auditor, as the permit requires the external audit to be conducted at the site. However, it was assumed that external audit is not being done at TBJ landfill site as there was no record of external audits document or proofs. This meaning that TBJ landfill site is not complying with the clause number 7.2 of conducting external audits, as stipulated on their landfill permit. Only internal auditing which is undertaken by the contractor responsible for running TBJ landfill site was found to be practiced at the TBJ landfill site. The internal audit of the TBJ landfill focuses on access control, infrastructure, traffic control, waste deposition, drainage & erosion, aesthetics & nuisances, safety & health, monitoring & record keeping and problematic waste. Internal audits which were performed on the 23rd of March 2016 revealed that the site is not effectively fenced to prevent unauthorised access. Although nothing has been done to date to address the challenge of damaged fence, which was shown on the internal audits which was performed on the 23rd of March 2016. This study exposed the damaged fence which was observed on the 3rd of August 2017, which is still not yet fixed.

Furthermore, in the internal audits the fire-break was reported to be unavailable. With regard to waste disposition, the internal audits revealed that residents reported that they were impacted by odours emanating from the landfill site, mostly during the rainy season, when the waste is wet as they don’t cover their waste daily during rain period. The audits also revealed that the TBJ landfill site’s staff are not given an opportunity to undergo regular medical checks, in accordance with the Occupational Health and Safety Act, 1993 (Act No. 5 of 1993). The audits further revealed that groundwater monitoring is also done to check the state of groundwater, and it is done through the use of boreholes within the landfill site. However, the sample of the groundwater, abstracted from the monitoring borehole within TBJ landfill site for sampling which was performed on the 2nd of June 2016, revealed that the groundwater within the vicinity of TBJ landfill site has been contaminated.

Lastly, the internal audit also revealed that there is no landfill committee which must be tasked for the overseeing the operation and management of the landfill site, as per the requirements of Minimum requirement for waste disposal by landfill site’s section 5 (5.2.7) of the operation and control. In addition, representatives of the affected public were found to be non-existent, meaning TBJ landfill site in terms of having monitoring committees is not complying with the minimum requirements, as it was mentioned that once the landfill is established and operating there is a need of forming a landfill monitoring committee, to monitor the operation and management style of the landfill site.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The purpose of this chapter is to summarize the findings of this research in accordance with the aim and objectives of this study. Based on these findings, recommendations will be made regarding implications concerning future decision-making and planning related to effective utilization, management and operation of the TBJ landfill site.

5.2 Summary

5.2.1 Capacity of the TBJ landfill site in terms of the volume of waste disposable.

The remaining volume of waste disposable was determined and the data collection within the TBJ landfill site revealed that the landfill site is left with $317\,085\, m^3$ of disposable waste for the next 4 years. Therefore, rehabilitation should be implemented as soon as possible. The time for identifying other sites or landfilling sites has to be considered too, in order for the municipality to undertake planning as soon possible.

5.2.2 Dominant types and sources of solid waste delivered to the TBJ landfill site

The dominant types of waste were plastics, card-boxes and papers, at 84%. The dominant sources of waste were found to be households, at 51%, followed by commercial enterprises waste, at 31%. Institutions contributed the third dominant sources of waste disposed to the TBJ landfill site at 11%. Industrial waste was found to contribute 4%, while 2% were the waste emanating from construction. Health care contributed about 1% of source of waste disposed in the TBJ landfill site.

5.2.3 Efficiency and the effectiveness of the TBJ landfill site operation

There is still a shortage of equipment to be used during landfill operation, such as a landfill compactor and weighbridge for recording waste. Apart from equipment, animals were also reported to be able to find their way into the TBJ landfill site, which is non-compliance, according to the minimum requirement for waste disposal by landfill, as animals are not allowed at landfill site. However, on other aspects, the TBJ landfill site is complying, as waste inspection, waste recording (based on the average number of incoming truck's tonnage), waste compaction and waste covering, re-vegetation on rehabilitated cell and ground water monitoring, were found to be practiced at the TBJ landfill site.

5.2.4 Main operational challenges at the TBJ landfill site

Amongst the challenges identified at the TBJ landfill site was the damaged fence, which provided free access of people to practice illegal dumping. The frequent break down of equipment used for landfill operation was also found to be another obstacle for operating TBJ landfill site. Lack of appropriate waste covering materials is problematic as it leads to the erosion of rehabilitated cell during rainy periods. Contaminated groundwater is another challenge associated with the operation of TBJ landfill site, as it shows that the landfill site is no longer environmentally friendly. Lack of a weighbridge for recording waste, encroachment by residential place and fire hazards, were some of the major challenges facing operation of TBJ landfill site.

5.3 Conclusion

Sustainable best landfill operation and management practices, such as compaction, waste covering, odour control and groundwater monitoring, not only help the TBJ landfill site, they also blend into the surrounding environment, but will also provide additional waste capacity and extend the time of existence for the landfill site. A landfill site's life is extended if its basic operation, such as compaction of the solid waste, is increased. Strong relationships were found between landfill site's space with waste diversion and compaction. An important finding for this research is that better landfill site operation and management strategies can increase the life of the landfill site.

In addition, based on the results of the study, recycling and composting are helpful in reducing the amount of waste which would have been landfilled at TBJ landfill site. Furthermore, it can be concluded that landfilled solid waste at the TBJ landfill site has adversely affected the groundwater. The average concentrations of the Total

Hardness were moderately high in the water sample within the TBJ landfill site. Therefore, there is a need to have an effective management programme for rehabilitating this landfill site to control environmental pollution.

5.4 Recommendations

In line with the findings of this research and conclusion arrived at, the following recommendations can be made:

5.4.1 Remaining landfill capacity of the TBJ landfill site

The results indicated that in the coming four years, the TBJ landfill site will not be able to sustain the waste generated in TLM. Therefore, as TLM is responsible for management of waste within TLM, it should start preparing for a new landfill site which will be used after the TBJ landfill site reaches its lifespan. Continuous diversion of recyclable and organic waste from the TBJ landfill sites should be practiced, as it will help remaining capacity to diminish slowly. Acceptance of reusable products and packaging, such as returnable bottles, should be discouraged at the TBJ landfill site. There should be a slowing down of the amount of waste at source that is disposed at the TBJ landfill site. this can be achieved through encouraging waste sorting and recovering all valuable waste to help to extend the lifespan of TBJ landfill site.

5.4.2 Types and sources of solid waste

Knowing the types and sources of waste disposed of at TBJ landfill site will help to inform management to come up with the appropriate method to effectively manage solid waste when it comes to disposal. As 51% of the waste is generated from residential households, TLM should be more serious about conducting awareness campaigns on methods such as source separation, recycling and composting to residents within TLM, because the dominant solid waste found in TBJ landfill site is from household.

5.4.3 Landfill site operation and management

i. Access control

The damaged fence around the TBJ landfill site must be fixed, to restrict access to people who practice illegal dumping; and also to prevent animals from entering the landfill site, as this alters operation and management of landfill site. Furthermore, the Municipality should perhaps draw up some terms of reference with the contractor as access control is so worrisome, taking into account the damaged fence which was observed.

ii. Landfill monitoring committee

There is a strong need to establish a monitoring committee, to assess the operation and the management style of the TBJ landfill site. Therefore, the committee should be put in place. This committee should also be responsible for the post monitoring after the landfill site has reached its lifespan.

iii. Waste picking

Waste pickers must not be considered as a nuisance, but rather a partner in achieving the reduction of waste to be landfilled at TBJ landfill site. Therefore, waste picking must be formalised and managed by the responsible authority, were in waste pickers will be taken care of in terms of their health and provided with appropriate protective clothes.

5.4.4 Operation and management challenges

i. Cover materials

The soil within the TBJ landfill site lacks clay particles. Therefore, a nearby source of cover materials that has clay particles should be found to in-source the cover material to be used at the TBJ landfill site.

ii. Control of slope stability

As erosion on the rehabilitated cell was detected, and landfilled waste is starting to be exposed. This must be remediated by removing the loose cover material, and proceed to cover and compact the slope again.

iii. Fire hazards

The burning of combustible materials, such as papers, card-boxes, metals and any other element by the waste pickers, must be discouraged. Fires should not be lit in the landfill site because decomposition of the landfilled waste produces methane, which is a combustible gas, and when a fire is made near gas vents and leachate drains, it can cause a bonfire (Ramke, 2009). In addition, to avoid a chance of outside fire getting inside the landfill site, firebreaks should be made around the TBJ landfill site.

5.4.5 Overall mitigation measures of landfill site challenges

The typical bad odour from landfill site is a consequence of unavoidable biological degradation process and can be reduced by pretreatment and daily covering of waste. A simple measure like no-open dumping of fast degradable waste can help diminish bad odour emissions (Ramke, 2009). Bortone *et al.* (2012) state that in order to minimize odour emission, the following should be done: quick assessment of the waste immediately when they arrive at the landfill and covering the waste throughout the day with the placement of a network of extraction wells in the waste layers in order to maintain the volume of waste under pressure, and the treatment of the intake air with suitable bio-filter. MSW should be pre-treated in order to render it suitable for landfilling; this is one of the possible solutions when seeking to solve environmental problem from a degradation process. Both biodegradable, organic waste components should be first removed, so that the waste masses and volumes disposed to landfill would be less, leading to a steady reduction in the number of waste landfilled (Hassan *et al*., 2006).

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APPENDIX A

QUESTIONNAIRE SCHEDULE FOR THE TBJ LANDFILL SITE'S SUPERVISOR

University of Venda

Questionnaire cover letter

Dear participant

I invite you to participate in a research study titled an **"Evaluation of strategic management of landfill sites: A case study of the Thohoyandou block J landfill site"** being supervised by Dr. T Nelwamondo and Mr. R Mulaudzi.

I am currently enrolled for the Master of Environmental Sciences degree at the University of Venda, and I am in the process of writing my master's thesis. The purpose of this study is to investigate the strategic management and the operational nature of Thohoyandou Block J landfill site at Thulamela Local Municipality in Vhembe District Municipality.

Your responses will remain confidential and anonymous. Data from this research will be kept under lock and key and reported only as collective combined total. No one other than the researchers will know your individual answers to this questionnaire.

If you agree to participate in this project, please answer the questions on the questionnaire as best as you can. It should take approximately 35 minutes to complete.

Thank you for your assistance in this important endeavour.

Sincerely yours

Nefale anza

.

This questionnaire is designed to facilitate the analysis of the operation and management of TBJ landfill site, in particular compliance with legal requirements and other requirements

1. Personal details

Name of position at Thohoyandou landfill site:
Number of years working at Thohoyandou landfill site :
Educational qualifications:
Duties at Thohoyandou landfill site:

2. Types of waste and major sources

Which areas are serviced for waste collection?
Major types of waste received at landfill site:
Major sources of waste received at landfill site:
Which institutions dispose their waste at landfill site?

3. Challenges encountered during landfill operation

Problems	Very serious. ✓	Serious ✓	Not serious ✓
Lack of financial resource			
Lack of trained personnel			
Lack of equipment			
Lack of legislation			
Difficult to obtain cover material			
Lack of control on hazardous waste			
What other specific problems do you encounter?			

Are there any challenges regarding shortage of landfill staff/ worker?	yes	No
If yes explain:		

Are there any challenges regarding functioning of landfill equipment? E.g. *Landfill compactors, Bulldozers, front end loaders, and Trucks to transport cover materials.*	Yes	No
If yes explain:		

Are there any challenges regarding obtaining cover materials?	Yes	No
Where do you obtain cover materials?		

Are there any challenges regarding nuisance? E.g *Waste burning, Litter, Odours, Vermine& disease vectors*	Yes	No
If yes explain:		

Are there any challenges regarding special cells	Yes	No
If yes explain:		

Do you experience illegal dumping?	Yes	No
If yes explain:		

What are other operational challenges experienced for running the landfill site?

APPENDIX B

QUESTIONNAIRE SCHEDULE FOR THE TBJ LANDFILL SITE'S OPERATOR

University of Venda

Questionnaire cover letter

Dear participant

I invite you to participate in a research study titled an **"Evaluation of strategic management of landfill sites: A case study of the Thohoyandou block J landfill site"** being supervised by Dr. T Nelwamondo and Mr. R Mulaudzi.

I am currently enrolled for the Master of Environmental Sciences degree at the University of Venda, and I am in the process of writing my master's thesis. The purpose of this study is to investigate the strategic management and the operational nature of Thohoyandou Block J landfill site at Thulamela Local Municipality in Vhembe District Municipality.

Your responses will remain confidential and anonymous. Data from this research will be kept under lock and key and reported only as collective combined total. No one other than the researchers will know your individual answers to this questionnaire.

If you agree to participate in this project, please answer the questions on the questionnaire as best as you can. It should take approximately 40 minutes to complete.

Thank you for your assistance in this important endeavour

Sincerely yours

Nefale anza

This questionnaire is designed to facilitate the analysis of the current situation and issues of Thohoyandou Block J landfill site, in particular compliance with legal requirements and other requirements

1. Personal details

Name of position at the Thohoyandou landfill site:
Number of years working at the Thohoyandou landfill site :
Educational qualifications:
Duties at the Thohoyandou landfill site:

2. Landfill capacity information

How long is the site been on operation?
Height of landfilled waste:
Compaction density of the TBJ landfill site:
Waste to cover ratio of the TBJ landfill site:

3. Challenges encountered during landfill operation

Problems	Very serious. ✓	Serious ✓	Not serious ✓
Lack of financial resource			
Lack of trained personnel			
Lack of equipment			
Lack of legislation			
Difficult to obtain cover material			
Lack of control on hazardous waste			
What other specific problems do you encounter?			

Are there any challenges regarding shortage of landfill staff/ worker?	yes	No
If yes explain:		

Are there any challenges regarding functioning of landfill equipment? e.g. *Landfill compactors, Bulldozers, front end loaders, and Trucks to transport cover materials.*	Yes	No

If yes explain:

Are there any challenges regarding obtaining cover materials?	Yes	No
Where do you obtain cover materials?		

Are there any challenges regarding nuisance? e.g *Waste burning, Litter, Odours, Vermine & disease vectors*	Yes	No
If yes explain:		

Are there any challenges regarding special cells	Yes	No
If yes explain:		

Do you experience illegal dumping?	Yes	No
If yes explain:		

What are other operational challenges experienced for running the landfill site?

APPENDIX C

QUESTIONNAIRE SCHEDULE FOR THE MANAGER OF WASTE MANAGEMENT AT THULAMELA LOCAL MUNICIPALITY.

University of Venda

Questionnaire cover letter

Dear participant

I invite you to participate in a research study titled an **"Evaluation of strategic management of landfill sites: A case study of Thohoyandou block J landfill site"** being supervised by Dr. T Nelwamondo and Mr. R Mulaudzi.

I am currently enrolled for the Master of Environmental Sciences degree at the University of Venda, and I am in the process of writing my master's thesis. The purpose of this study is to investigate the strategic management and the operational nature of Thohoyandou Block J landfill site at Thulamela Local Municipality in Vhembe District Municipality.

Your responses will remain confidential and anonymous. Data from this research will be kept under lock and key and reported only as collective combined total. No one other than the researchers will know your individual answers to this questionnaire.

If you agree to participate in this project, please answer the questions on the questionnaire as best as you can. It should take approximately 20 minutes to complete.

Thank you for your assistance in this important endeavour

Sincerely yours

Nefale anza

.

This questionnaire is designed to facilitate the analysis of the current situation and issues of Thohoyandou Block J landfill site.

1. Personal details

Name of position at the Thohoyandou landfill site:
Number of years working at the Thohoyandou landfill site :
Educational qualifications:
Responsibility at the Thohoyandou landfill site:

3. Landfill site budget

Do you have enough budget of running the landfill site per months and per year?	Yes	No
How much is do you spend for operating and managing the TBJ landfill site?		
Do you have a challenge with a budget of running the landfill site?	Yes	No
If yes please explain?		
How much does the municipality spend on running the landfill site per month?		

5. Operational challenges of the landfill site

What are the operational challenges of running the TBJ landfill site?

APPENDIX D

INTERVIEW SCHEDULE FOR WASTE PICKERS

1. Types of waste and major sources

1. Which types of waste are found at the TBJ landfill site?
2. Which are the dominant types of waste found in the TBJ landfill site?
3. Which are the most types of waste recycled?
4. Which institution mostly send their waste to the landfill site?
5. Where do you send the recycled materials?
6. How many years have you been recycling waste materials in the TBJ landfill site?

APPENDIX E

OBSERVATION CHECKLIST

	MARK THE RIGHT ANSWERS					
OBSERVATIONS	Mark with ✓		Mark with ✓		Mark with ✓	
1. Classification	1 = CGW		2 = SGB^-		3 = SGB^+	
2. Permit	1 = Permitted		2 = Applied		3 = No permit	
3. Ownership	1 = Local municipality		2 = Private company			
4. Site Operator	1 = Local municipality		2 = Contracted company			
5. Operation no. of days	1 = Monday to Sunday		2 = Monday to Saturday		3 = Monday to Friday	
6. Operation time	1 = 7H00-17H00		2 = 07H00-18H00		3 = 24H00	
7. Notice board with information	1 = Sufficient		2 = To some extent		3 = Not sufficient	
8. Distance from residential	1 = less than 1km		2 = 1km to 3km		3 = 4km and above	
9. Distance from source of water	1 = less than 1km		2 = 1km to 3km		3 = 4km and above	
10. State	1 = Controlled dump		2 = Partially controlled dump		3 = Not controlled dump	
11. Fencing	1 = Well fenced		2 = Fenced but damaged		3 = No fence	
12. Signposting	1 = Enough and directive		2 = Not enough		3 = No sign	
13. Access roads	1 = Good condition		2 = Poor condition			
14. Waste acceptance	1 =		2 = Use of		3 = No	

procedure	Weighbridge		security guard		weighbridge	
15. Control of vehicle access	1 = Well controlled		2= To some extent		3 = No control at all	
16. Spotter	1 = Available everyday		2 = Sometimes visit		3 = None	
17. Plant equipment	1 = Enough in good condition		2 = Not enough and not in good condition		3 = None	
18. Operation plan	1 = Operational plan is used		2 = There is no operation plan			
19. Waste compaction	1= Done		2= Not done			
20. Immediate covering of putrescibles	1 = Yes		2 = Sometimes		3 = No	
21. Daily covering	1 = Always Practiced		2 = Partially practiced		3 = Not practiced	
22. Protective clothes for workers	1 = Well dressed		2 = Some one item is not dressed		3 = Not at all	
23. Final cover	1 = Done rehabilitated		2 = Partially done		3 = Not done	
24. Uncontrolled waste salvaging prohibited	1 = Prohibited		2 = Partially prohibited		3 = Not prohibited	
25. Draining water away from the waste	1 = Well done		2 = Partially done		3 = Not done at all	
26. General site maintenance	1 = Definitely		2= To some extent		3 = Not at all	
27. Burning of waste	1 = Do burn		2 = Do not burn			
28. Animal invasion	1 = Available		2 = Not available			

29. Groundwater monitoring borehole	1 = Available		2 = Not available			
30. Illegal dumping	1 = Very serious		2 = Serious		3 = Not so serious	
31. Littering	1 = Very serious		2 = Serious		3 = Not so serious	
32. Vermin	1 = Very serious		2 = Serious		3 = Not so serious	

Types of waste delivered to TBJ landfill site **(Scale of 1-8: where 1 represent the dominant and 8 represent the least dominant)**							
Plastics		Card-boxes		Medical packages		Metals	
Metals		Electrical appliances		Garden refuse		Building rubble	
Others							

Indicate by rating the dominant types of waste found at TBJ landfill site **(Scale of 1-8: where 1 represent the dominant and 8 represent the least dominant)**							
Commercial		Institutional		Medical/HCW		Industrial	
House hold refuse		Electronic waste		Garden refuse		Construction and demolition	
Others							

University of Venda
Creating Future Leaders

RESEARCH AND INNOVATION
OFFICE OF THE DIRECTOR

NAME OF RESEARCHER/INVESTIGATOR:
Mr A Nefale

Student No:
11600874

PROJECT TITLE: **An evaluation of strategic management of landfill sites: A case study of Thohoyandou Block J Landfill site, Vhembe District Municipality, Limpopo Province.**

PROJECT NO: **SES/17/ERM/05/2108**

SUPERVISORS/ CO-RESEARCHERS/ CO-INVESTIGATORS

NAME	INSTITUTION & DEPARTMENT	ROLE
Dr TM Nelwamondo	University of Venda	Supervisor
Mr R Mulaudzi	University of Venda	Co- Supervisor
Mr A Nefale	University of Venda	Investigator – Student

ISSUED BY:
UNIVERSITY OF VENDA, RESEARCH ETHICS COMMITTEE

Date Considered: September 2017
Decision by Ethical Clearance Committee Granted
Signature of Chairperson of the Committee: ....
Name of the Chairperson of the Committee: Prof. G.E. Ekosse

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