Establishment of composting facilities on landfill sites

by

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Declaration

I hereby declare that my thesis, with the title ***Establishment of composting facilities on landfill sites***, is my own original work and that all sources used or quoted have been indicated and acknowledged in the text, as well as by means of a complete reference list.

Signed: ______________________________ (candidate)

Date: ______________________________

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ABSTRACT

Waste minimisation is implemented worldwide and has become an urgent priority in South Africa as evidenced in the promulgated National Environmental Management Waste Act (2008). The most common waste disposal method in South Africa is by landfill, which is unacceptable. Local municipalities have made little progress towards waste minimisation.

The aim of this study was to present a solution to waste minimisation for the City of Tshwane Metropolitan Municipality (CTMM) by determining the feasibility of establishing composting facilities on landfill sites. One third of all municipal waste consists of green waste, which is compostable and can be converted on landfill sites. Nine municipal landfill sites were screened. The four most feasible sites were evaluated further by applying identified parameters that address physical, social and operational requirements. It is a possible to establish composting facilities on all four sites investigated, with Hatherley ranking as the most suited.

The findings of this study clearly provided the basic parameters and requirements for constructing a composting facility and practical procedures applicable within a South African context. The evaluation method used can be applied as a model to evaluate similar studies in other municipalities to aid them in the decision-making process for waste minimisation.

Keywords: Waste minimisation; Landfill sites; Composting; Garden waste; Green waste; Composting methods; Windrows; Composting requirements; Waste management.

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LIST OF ABREVIATIONS

ABREVIATION	Description
BARC	Beltsville Aerated Rapid Composting
BATNEEC	Best Available Technology Not Entailing Excessive Cost
BOD	Biochemical Oxygen Demand
BPEO	Best Practicable Environmental Option
C:N Ratio	Carbon (C) and Nitrogen (N) ratio
CCC	Compost Council of Canada
CCQC	Compost Quality Council
CDM	Clean Development Mechanism
CJMM	City of Johannesburg Metropolitan Municipality
CO_2	Carbon dioxide
CTMM	City of Tshwane Metropolitan Municipality
DAT	Dome Aeration Technology
DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs and Tourism
DWAF	Department of Water Affairs and Forestry
ECA	Environmental Conservation Act
ECN	European Composting Network
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency, US
GDACE	Gauteng Department of Agriculture, Conservation and Environment
GDARD	Gauteng Department of Agriculture and Rural Development
IP&WM	Integrated Pollution and Waste Management
IWM	Integrated Waste Management
MSW	Municipal Solid Waste

NEM:WA	National Environmental Management: Waste Act,
NEMA	National Environmental Management Act
NIMBY	Not In My Backyard
NIST	National Institute of Standards and Technology
NWMS	National Waste Management Strategy
PAHs	Polyaromatic hydrocarbons
UNEP	United Nations Environmental Policy
VOCs	Volatile Organic Compounds
WBCSD	World Business Council for Sustainable Development

Chapter 1

STATEMENT OF THE PROBLEM

1.1 INTRODUCTION

Waste generation, linked to a growing population and excessive packaging, as well as a ‘throw-away’ culture, is a gigantic environmental concern that cannot be disputed. Waste as a management issue had been evident for over four millennia (Seadon, 2006). The responsibility for managing waste falls to governments, who generally entrust local governments with effecting national legislation. Section 5.5.1 of the Waste Act of 2008, Government Gazette No. 32000, requires the provinces and local municipalities to develop integrated waste management plans (DEAT, 2008). Municipalities therefore are legally compelled to manage the waste generated within its boundaries and have the authority to determine the method of disposal. For this purpose resources are designated to the local municipalities.

In South Africa, most of the approximately 15 million tons of Municipal Solid Waste (MSW) generated annually ends up in landfill sites and open rubbish dumps (DEAT, 1999b). However, landfills are environmentally unacceptable, therefore the focus of management of MSW is on waste minimisation (DEAT, 2008).

1.2 RESEARCH PROBLEM

This research investigated how selected resources within the municipal waste environment of the City of Tshwane Metropolitan Municipality (CTMM) could be utilised to the benefit of the physical and the socio-economic environment. It specifically concentrated on the diversion of green waste to prevent it from being land filled with the other domestic waste and to convert it into compost.

1.3 BACKGROUND

Currently most industrial countries have adopted an environmental hierarchy for handling solid waste. This is done in the form of *Integrated Waste Management* (IWM), utilising a set of management alternatives to handle *Municipal Solid Waste* (MSW) (Botkin & Keller, 2007).

In the United States of America (USA), the following hierarchy was already established more that 25 years ago (Kupchella & Hyland, 1993):

- source reduction by changing processes and products to eliminate waste;
- re-use of products for the same purpose, for example, the refill of cleaned glass bottles;
- incineration with energy recovery;
- and, as a last resort, landfill.

1.3.1 Waste reduction in world perspective

In an attempt to address waste in companies, eco-efficiency was conceived by the World Business Council for Sustainable Development (WBCSD) in 1992 (UNEP, 1992:1) based on *inter alia* the following principle:

> *"...maxim(ize)[izing] (the) use of recycled materials in production, optimising use of materials and embedded energy, minimizing waste generation, and re-evaluating 'wastes' as raw material for other processes*."

Although this principle is intended for businesses, it is clear that a new way of looking at waste needs to be adopted, not only by businesses, but more so by governmental waste management strategies. Despite the emphasis on waste reduction in this hierarchy, governments allocate more money to waste management resulting in waste disposal, than to waste management resulting in waste reduction. Studies showed that already in 1993, 75-83% of municipal solid waste in the United States was land filled, 6-12% was burned and 10-11% was recycled (Kupchella & Hyland, 1993). In European countries like Denmark, Sweden and Switzerland, half or less than half of the waste was land filled

(Kupchella & Hyland, 1993). In Japan, due to the mountainous nature of the country, only 10% of the land is available for residential use. It is therefore not surprising that incineration, with or without energy recovery, is the main route for waste here (Williams, 1998:16).

Local governments of Japan are very effective and raise enough money through local taxes to finance waste systems. In 1998 it was found that, of the 50 million tons of waste generated in a year, 74.4% was incinerated, 20.4% was land filled and 5.4% was recycled. Approximately 2.7 million tons of waste is separated by residents at the source (Williams, 1998:16). Later studies revealed that Japan, as well as Switzerland (also little space due to mountainous area), incinerate 50% of their waste and bury 15% and 12% respectively in sanitary landfills. In the United States, 54% of the MSW is land filled, compared to 90% in the United Kingdom and 80% in Canada (Miller, 2005).

These figures show that although many nations have adopted the waste minimisation strategy, land filling and incineration are worldwide still the most common ways of waste disposal. Land filling originates from dumping of waste in the open veldt, in abandoned mines and quarries, natural low areas, as well as hillside areas outside the boundaries of towns or cities. This has led to numerous health and environmental problems, which has given way to better planned and regulated sanitary landfill sites (Botkin & Keller, 2007). A sanitary landfill can be described as a "waste disposal site on land in which waste is spread in thin layers, compacted, and covered with a fresh layer of clay or foam each day" (Miller, 2005: 547).

To establish, operate and maintain a landfill site is challenging and expensive, especially after the institution of legal requirements that were developed to protect the health and safety of people, as well as the environment. Therefore, landfill space needs to be conserved at all costs. The reason for the urgent need to save landfill space is that there are numerous problems with sanitary landfill sites that will be discussed below.

It is therefore evident that the continuous reliance on landfill as the main route for disposal of waste in industrial countries leads to capacity shortages, especially in urban areas (Williams, 1998:16). Open areas within urban boundaries, where the largest volumes of waste are generated, are always under pressure because of the lack of space due to the high prices of land. High land prices have a serious effect on the establishment of sanitary landfill sites, since the landfill sites need to be within economical reach of the main waste generators, especially with the rising fuel costs. Limited landfill space in many urban regions supports the view that landfill capacity can be regarded as non-renewable resources (Chang & Davila, 2006).

The second problem lies within the "NIMBY" (*Not In My Back Yard*) syndrome (Williams, 2005). The fact that a sanitary landfill site is aesthetically unattractive creates enormous problems regarding the selection of a site within the urban area and expensive mitigation measures need to be implemented to counteract negative impacts such as aesthetics, bad odours, noise, windblown litter and dust, on the surrounding communities.

Furthermore, the sanitary landfill site has a detrimental effect on the physical environment. The leachate of waste fluid in the ground causes groundwater pollution (Botkin & Keller, 2007). Bad odours are caused by the decomposition process of organic waste and are released in the form of methane (CH_4) gas mixed with other gasses into the atmosphere. Methane is a potent greenhouse gas. When averaged over 100 years, each kg of CH_4 warms the earth 25 times more than the same mass of carbon dioxide (CO_2) (Williams, 2005). Expensive geotextile liners to prevent leachate entering the ground water, sophisticated odour control measures, where spray nozzles release a perfumed spray into the air when necessary, and methane gas harvesting systems worth millions in installation costs, have become a standard in new engineer-designed landfill sites.

Environmental management structures in most industrialised countries require that new landfill sites need to be permitted. This is an expensive, challenging and tedious process. Because of the detrimental effects mentioned, as well as this expensive design, it is imperative to prolong the life span of a landfill site as much as possible. Recent studies of the waste stream confirmed that 50-70% of the waste stream could be reduced by implementing recycling initiatives (Botkin & Keller, 2007). By the implementation of waste minimisation strategies, specifically in this case composting of green waste, something of this objective could be accomplished.

Of course, if waste could be used in some way or another, it would not be waste any longer. The composting of green waste is a well-known and reasonably easy recycling and waste reduction process, which has the added value of producing soil conditioner as a resource. Although composting as such is not likely to offer a significant income to the producer, Phillips *et al*. (2001) suggest that the hidden costs of other waste disposal methods (i.e. land filling, incineration) as well as the added benefits of a waste disposal method which can be turned into a resource, should not be ignored in decision-making.

For example, lack of space within urban areas and specified environmental criteria for the establishment of new landfill sites make it extremely difficult to find suitable landfill sites where they are needed most namely, in urban areas where the bulk of waste is generated. Extending the life of a landfill site would therefore alleviate pressure on the expensive, challenging and tedious selection and permitting process. Composting facilities could also create jobs and could, as mentioned above, produce a supplementary income for the municipality by offering valuable products at affordable prices to the public. Lastly, if other existing assets, such as waste equipment, which includes waste trucks and weighbridges, the existing roads infrastructure, municipal waste management systems and waste management expertise happen to be under-utilised, they could be put to optimal use for composting.

Green waste is, like the municipal assets mentioned above, also such a resource, and it is readily available. According to the National Solid Waste Association of India the organic fraction of solid waste already comprises 40-

85% (Zurbrügg *et al*., 2004). It is argued that green waste is a vital resource that is needed for composting facilities and refers to all types of garden waste, including dry leaves, grass clippings and branches. Diaz *et al*. (1993:3-4) states that: "Municipal waste usually contains materials which, if retrieved and suitably processed, would constitute resources that can be of great utility". This is supported in a study done by Tresler (1991:1) in Texas in the United States, where it was already established in 1991 that up to a third of generated yard wastes (grass clippings, leaves and brush) could be separated from the general "waste stream and then composted, they would become a recovered resource and extend the operating life of landfills." These two examples support the mentioned argument.

1.3.2 Waste management in South Africa

South Africa took an important step towards waste minimisation in 1999 when it adapted the US waste management hierarchy in the National Waste Management Strategy (NWMS). In the language of the document, this strategy "presents a long-term plan (up to the year 2010) for addressing key issues, needs and problems experienced with waste management in South Africa (1997/8)" (DEAT, 1999a).

Waste hierarchy	
Cleaner production	Prevention
	Minimisation
Recycling	Re-use
	Recovery
	Composting
Treatment	Physical
	Chemical
	Destruction
Disposal	Landfill

***Figure 1.1*: Steps in waste hierarchy** (DEAT, 1999a)

Figure 1.1 (DEAT, 1999a) depicts this strategy, suggesting that prevention, which goes hand-in-hand with cleaner production, is the most preferred option, and disposal by landfill the least preferred. This strategy is in line with the Bill of Rights of the Constitution of South Africa, Act 108 of 1996, Section 7-24 where it is stated 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*." (DEAT, 1999c)

In order to uphold the environmental rights of all South African citizens, several plans have been initiated. Besides the development of a National Waste Management Strategy (NWMS) for South Africa, which was initiated during 1997, the Integrated Pollution and Waste Management (IP&WM) approach was adopted. Thereafter the Polokwane declaration, also known as the Limpopo initiative, was signed to show the commitment of the province to the NWMS. The aim is to: "Reduce waste generation and disposal by 50% and 25% respectively by 2012 and develop a plan for ZERO WASTE by 2022" (DEAT, 2001). The most recent legislation (promulgated 6 June 2009) regarding Integrated Waste Management in South Africa, the *National Environmental Management Act: Waste Act*, supports waste minimisation.

Despite these developments and strict legislation, land filling is still the most common method of waste disposal, which occurs both in unsafe and environmentally unacceptable in landfill sites. According to the Action Plan for Integrated Waste Management Planning, Version C (a subsection of the

NWMS), a study prior to 1997 identified about 540 landfill sites in the country, of which only 61% had obtained permits in terms of section 20(1) of the Environment Conservation Act (Act 73 of 1989).

A later survey showed that 560 municipal landfills are registered with the regulating authority for waste disposal at that time, the Department of Environmental Affairs and Tourism (DEAT, 1999b). However, if communal and unregulated sites are included, it is estimated that there could be up to 15 000 landfills in South Africa. The amount of waste, together with the number of landfill sites, puts landfill space under tremendous pressure. In addition, a fast-growing population inevitably leads to an increase in waste generation.

The fact that strategies, plans and the necessary legislation for waste minimisation are in place in South Africa, shows that the authorities are aware of the necessity to act responsibly to nurture the environment for posterity. However, as landfills are the principal means of disposing municipal waste in the country, it is not viable to ban them altogether, as the Polokwane Declaration suggested. Moreover, almost all reduction methods result in some form of residue or other, which Fuggle and Rabie (1999) argue needs to be, and can only be, disposed of at a landfill site.

Up to now, waste management was not prioritised or addressed in a holistic manner. The main focus was on waste disposal, resulting in the detrimental impact of waste on the South African context (DEAT, 1999b). It is clear that South Africa needs to do much more to reduce the waste stream that goes into landfill sites, not only to comply with world standards regarding applicable legislation, but also to protect its citizens and its own environment.

At the very least, land filling must be regulated and managed properly. Should it be possible to minimise the waste stream to landfill sites, landfill space would be saved and the lifespan of some landfill sites could be extended. Therefore, other ways of waste reduction should be investigated vigorously. This study combines three of the goals contained in the waste hierarchy namely: improving the management of land filling through the separation of green waste, reducing waste by removing the green waste from the being land filled, and recycling the green waste through composting.

In accordance with international findings as mentioned, Snyman, (2007) found that in the City of Tshwane Metropolitan Municipality (CTMM) green waste represents approximately a third of all municipal waste. This could be separated and treated to create compost - a useful product that could be used in several ways. Slowing down the amount of waste that goes to landfill sites in this way will not only extend the lifespan of such sites, but also inevitably reduce the amount of the harmful methane gas - a principal contributor towards global warming - that is produced by the decomposition process in the landfill and released into the atmosphere. Whether the compost is sold to the public or used by municipalities to beautify parks and other open spaces under their management, it would contribute to improved soil structure and growth, which in turn would promote the release of oxygen and the absorption of CO_2. In so doing, it would contribute to South Africa's commitments to lower its green house gas emissions in the attempt to contribute towards a solution for pollution and global warming. More specifically, it could earn carbon credits, from which the income could be reinvested in the expensive operation and monitoring of operative landfill sites and the post-monitoring of closed landfill sites.

This is also in line with the objectives of the National Environmental Management Waste Act: 2008:

> "To protect health, well-being and the environment by providing reasonable measures for:
>
> a) minimising the consumption of natural resources,
> b) avoiding and minimising the generation of waste,
> c) reducing, re-using, recycling and recovering waste,
> d) treating and safely disposing of waste as a last resort,
> e) preventing pollution and ecological degradation,
> f) securing ecologically sustainable development while promoting justifiable economic and social development,

g) promoting and ensuring the effective delivery of waste services,

h) remediating land where contamination presents, or may present, a significant risk of harm to health or the environment, and

i) achieving integrated waste management reporting and planning;

To ensure that people are aware of the impact of waste on their health, well-being and the environment;

Generally, to give effect to section 24 of the Constitution in order to secure an environment that is not harmful to health and well-being." (DEAT, 2008:10).

Recognising the intentions of the National Waste Management Waste strategy, and the Polokwane Declaration, it is realised that new approaches are required to handle rapid urbanisation and MSW generation (Snyman, 2009:24).

1.4 RESEARCH AIM AND OBJECTIVES

The *aim* of this study is to determine the feasibility of the establishment of composting facilities on landfill sites. In other words, how can a waste management entity optimally use what is available to the benefit of the environment, the society and the economy to enable them to achieve the national goal of waste minimisation as imposed by the new Department of Environmental Affairs and Tourism (DEAT?

Several *objectives* to attain this aim are set out below:

a. To review the regulatory framework for waste minimisation so that the need for composting can be established;

b. To establish the value of compost as a soil conditioner;

c. To determine the amount of green waste available within the municipal solid waste stream of the CTMM to make composting a viable option and to highlight the role of garden sites;

d. To elucidate the composting process;

e. To describe and evaluate different options of composting methods to determine the best method for the CTMM;
f. To assess an existing composting facility, *Panorama*, as an example of a successful facility within a South African context to verify the suggested criteria;
g. To determine a set of criteria relating specifically to environmental, social and operational requirements of composting facilities;
h. To investigate the possibility of establishing composting facilities on landfill sites in the City of Tshwane;
i. To determine the willingness of the public to participate in a composting programme;
j. To design a recommended process for establishing composting facilities in the CTMM.

Criteria specifically for composting facilities, which do not exist for South African circumstances, are intended to evolve from this study. These criteria, further to be referred to as parameters, were used to evaluate selected landfill sites in the CTMM for the possibility of operating composting facilities on the landfill premises under the management of the municipality. This evaluation was verified at first by means of an assessment of a composting facility in Johannesburg as a successful example to confirm the feasibility of establishing composting facilities on a landfill site.

The set of parameters intended to serve as guidelines applicable to composting facilities were created against the background of the Minimum Requirements. The Minimum Requirements is a regulatory document that was compiled by the Department of Water Affairs to regulate disposal by landfill (DWAF, 1998). A process for decision-making to be designed would assist the CTMM to change current waste disposal practices by diverting green waste away from being land filled to being utilised in composting operations.

The *assumptions* underlying the study are that, if the resources currently available to municipalities in South Africa are properly exploited, an important contribution could be made towards waste reduction. Green waste, also referred to as the organic fraction in the municipal waste stream, is an essential resource that is needed for composting facilities. This vital resource refers to all types of garden waste, including dry leaves, grass clippings and branches. Diaz *et al*. (1993:3-4) is of the opinion that “Municipal waste usually contains materials which, if retrieved and suitably processed, would constitute resources that can be of great utility”.

A further assumption that underpins the study is that within the waste management structure of municipalities lie unused resources in the form of open land. Space is needed for composting facilities. By investigating the requirements for a composting facility, it would enable recommendations to be made regarding the relative size of a facility.

The third assumption, regarding municipal resources, is the current infrastructure used for waste management. If the entire waste management operations, such as waste trucks, road infrastructure, waste management structure in terms of offices, administrative staff and expertise in the waste industry that are readily available and already in use by municipalities, could be utilised for an additional function, that of a composting facility, it will contribute to the advantages composting would have.

Municipal waste disposal companies do not practise composting widely. Renkow and Rubin (1998) suggest that, as little is known about the costs of municipal solid waste (MSW), composting facilities compared to other waste disposal methods might be a limiting factor, which suggests that there is a need for more research.

With reference to the organic fraction of the municipal waste, reference is made to the threefold resource recovery of the organic fraction of the waste with the end-products as compost, methane as a combustible gas or hydrolysing the cellulose components into glucose (Diaz *et al.*, 2007). Of these, composting is the most frequently applied strategy worldwide. Braber (1995) believes that biological treatment methods such as composting offer the only route for recycling organic matter and nutrients from the organic fraction of MSW.

The *significance of this study* is that it reveals how existing municipal resources can be used for waste reduction, which is urgently needed, and how it contributes to benefiting the environment and society. This was demonstrated by the assessment of a successful municipal facility, which serves as an example for other municipalities to also achieve waste reduction objectives.

A *limitation* of this study could be that it concentrated only on the composting possibilities of green waste, and that no attempt was made to provide details of the economic benefits of this waste minimisation strategy. Another possible limitation is embodied in the fact that no attempt was made to provide a detailed evaluation of the chemical characteristic of compost, but merely to explain the composting process in broad terms.

The current study is *delimited* to the identification of criteria for the reduction of waste in South Africa through composting only by examining how feasible the establishment of composting facilities might be on selected active and closed landfill sites. It is envisaged that the state or municipalities would allocate funds for further investigation into this question, especially if composting becomes a general practice in South Africa for the reasons mentioned above. If composting does indeed have higher-level waste reduction capabilities, then in the future South Africa might actually begin to participate in such operations.

1.5 HYPOTHESIS

Green waste could be separated and treated to produce compost. This could be done on landfill sites (closed or operational), which already have the required waste management infrastructure in place.

1.6 METHODOLOGY

It is not always possible to find a single method that could provide all the information for a study (Cherubini *et al.*, 2007). Thus various methods were applied to achieve the research objectives for this study (see Appendix A). To set the background for the need and desirability of the study as proposed, a literature search was embarked upon (Chapter 2) to establish the legislatory framework and the necessity for composting in South Africa in terms of waste minimisation.

The literature review was conducted to assemble baseline information and to establish what has been done regarding municipal composting facilities in South Africa. A literature review regarding the importance of green waste recycling with the need, production and benefits of composting as the main focus, served to reflect on the international expertise available in the field of composting. Information regarding the composting process and the most suitable composting methods to apply within the confines of the available space and funds was also relevant. The value of compost, which can be used as a soil conditioner as replacement for commercially manufactured fertilisers, needed to be ascertained.

Two large municipal areas in South Africa were selected where adequate green waste is available, an established waste management system exists and the expensive available land needs to be used optimally. The purpose was to investigate the possibility of establishing composting operations on the landfill sites owned by the municipality. The intention was not to provide a detailed evaluation of the chemical characteristic of compost, but to create an understanding of the composting process. An assessment of a successful composting plant in the City of Johannesburg was made to identify the strengths and weaknesses of the operations in order to provide a suggested process for duplication on other closed landfill sites within urban areas. For the purpose of assessing the successful municipal composting plant on a closed landfill site (*Panorama*), site visits, personal interviews with the personnel and perusing articles in press and on the Internet were employed. Based on criteria for the minimum requirements of composting facilities, this closed landfill site was evaluated. This led to a set of parameters that was used to act as guidelines that were made applicable to composting facilities against the background of the Minimum Requirements.

The possibility of establishing similar composting facilities on other closed municipal landfill sites was investigated through the assessment of four landfill sites within the boundaries of the City of Tshwane Municipal area. Site visits were conducted to collect primary data by means of observation and an assessment according to a checklist (see Appendix B). The checklist is based on the classification of general waste, since green waste is a fraction of general, or domestic waste and therefore regulated according to the "Minimum Requirements for Waste Disposal by Landfill" (DWAF, 1998). Information in reports was verified by personal observation and interviews with the personnel of the CTMM.

An analysis was done by means of a questionnaire (see Appendix C) to determine the attitude of people towards composting. The study was limited to the staff and students of University of South Africa, as the latter can be regarded as a representative sample of educated people. Using all the preceding information, a synthesis was done that suggests a procedure for the CTMM to initiate change within current operations in order to commence with establishing composting facilities.

1.7 CONCLUDING COMMENTS

Compost is a useful product and has numerous advantages. It contributes to improved soil structure and improved plant growth. In this way parks and other open spaces under the management of the municipality could be beautified. This could contribute further to an increase in the release of oxygen and usage of CO_2, thereby contributing towards a global solution of pollution and global warming. It could also be used to earn carbon credits which could be a huge income to the municipally to aid with the expensive operation and monitoring of an operative landfill site and post-monitoring of closed landfill sites.

The lifespan of landfill sites could be extended, consequently the release of harmful methane gas into the atmosphere. The decomposition process of the waste in the landfill produces methane gas, which is a principal contributor towards global warming. By decreasing the amount of waste that goes to landfill inevitably could reduce the amount of methane gas that is released. It is possible that the remaining methane gas could be harvested for energy.

Lack of space within urban areas where the bulk of waste is generated, as well as specified criteria in terms of environmental considerations for the establishment of a new landfill site, make it extremely difficult to find suitable landfill sites where it is needed most. By extending the life of a landfill, the expensive, challenging and tedious selection and permitting process could be delayed.

In addition, establishing composting facilities could create jobs and could produce a supplementary income for the municipality by offering valuable products at affordable prices to the public. Other assets such as waste equipment (i.e. waste trucks, weighbridges; the existing roads infrastructure), municipal waste management systems and waste management expertise, which are in place, would be able to be put to optimal use.

Chapter 2

LITERATURE REVIEW ON COMPOSTING AS VALUABLE RESOURCE

2.1 INTRODUCTION

Waste minimisation, as established in Chapter 1, has become a necessity in municipal waste management as per the requirements of the Polokwane Declaration. Composting facilities can assist the municipality to reach this aim. It is important to provide a background to compost. In this Chapter the meaning, as well as the usefulness of specifically the ‘green’ fraction of the domestic waste stream will be explored. The definition of waste in general as well as an effective way to recycle green waste, i.e. composting will be addressed in detail.

A discussion on the following will be included:

- An understanding of the composting process;
- Composting as a valuable product with the emphasis on the benefits of composting;
- The potential of composting in South Africa specifically in CTMM and the significance of garden sites;
- Different methods used for the composting process;
- The requirements for successful municipal composting;
- A brief overview regarding international initiatives, the products and challenges of the composting process, as well as the quality of the compost as useful product.

2.2 COMPOSTING

Compost is the oldest and most natural fertilizer in the world. It is an organic fertiliser and therefore more in line with sustainable development than chemical fertilisers, which are mined and manufactured with detrimental effects on the natural environment. Many individuals are aware of the fact that it is necessary to return the nutrients to the soil (Diaz *et al*., 1993:196). It is a natural process formed continuously in nature as plants and animal decompose, and is generally known as humus. Bacteria, fungi and earthworms break down the plant and animal remains into simpler components, releasing nutrients into the soil (Collins & Maneveldt, 2001). Polprasert (1996:69) defines composting as:

> "the biological decomposition and stabilisation of organic substrates under conditions which allow development of thermophilic temperatures as a result of biologically produced heat, with a final product sufficiently stable for storage and application to land without adverse environmental effects."

2.2.1 Terms and definitions

***Solid waste*:** According to Diaz *et al*. (1993:1), municipal solid waste refers to "… a resource discarded by its possessor or user (dweller, commerce, industry, government) because apparently it is of no further use to the possessor". Botkin and Keller (2007:646) suggest that waste must be considered as a resource out of place. Diaz *et al*. (1993:3) support this definition of waste when they state, "Municipal waste usually contains many materials which, if retrieved and suitably processed, would constitute resources that can be of great utility". Waste can therefore be regarded as a 'resource', if it can be used in one-way or another. This includes green waste, which is part of the municipal waste stream.

Green waste: Green waste refers to all types of garden waste, including dry leaves, grass clippings and branches. Scragg (2005:161) adds activated sludge, excess straw and chaff, as well as agricultural wastes, which can be regarded as green waste, to the list. Most municipal green waste comes off parks and gardens and is included in the municipal waste stream. Principal components are therefore grass clippings, leaves (especially of deciduous plants), discarded herbaceous plants and trimmings, trimmings and branches of trees and of large as well as ornamental shrubs. Seasonal differences exist in the green waste due to the difference in the chemical and physical properties (i.e. autumn leaves have a higher carbon content and less nitrogen) (Diaz *et al*. 1993:92-93). Green waste is regarded as part of the general domestic waste stream, and is land filled together with the other waste collected in the suburbs and business areas. As was seen in Chapter 1, increase in disposal to landfill must be reduced. Separation and processing of the green waste from the general waste stream cannot only contribute towards this, but it can lead to a valuable product, compost.

Composting: Composting refers to the conversion of green waste into organic fertilizer with compost as end product. Diaz *et al*. (1993:122) define composting as: "the biological decomposition of wastes consisting of organic substances of plant or animal origin under controlled conditions to a state sufficiently stable for nuisance-free storage and utilisation".

Composting is derived from the Latin word *compositum*, which means 'mixture' and refers to the biodegradation process. A microbial community, composed of various populations, are responsible for the transformation of a mixture of substrates (lignin, cellulose, hemicelluloses, murien, chitien, etc.), generally known as fermentation or bio-oxidation. The composting process is stopped at a stage where more than 50% of the original mass of the organic matter is still present. If the process were allowed to continue, all the organic materials would be completely mineralised (Diaz *et al*., 2007:26-31), resulting in being soil again.

2.2.2 Benefits of composting

To initiate composting of municipal green waste, it will not only benefit the operations of the city and save landfill space, it will greatly benefit the user. Often compost is referred to as "Black Gold". The reason for this is the numerous benefits it has for the soil to which it is applied (EPA, 1997).

The success of the development of composting facilities lies in the application of the compost as product. In an article addressing composting of municipal waste, Wei *et al*. (2000) suggested that the environmental impact of the application of compost should be 'given more attention' in a statewide awareness to promote the application possibilities. It is also important to have criteria for the evaluation of the quality of compost as organic fertiliser to enhance the applicability and credibility of the compost product (Senesi, 1989).

The main benefit of composting is that it greatly influences the *condition of the soil*. It has the ability to help regenerate poor soils. During the composting process, beneficial micro-organisms like bacteria and fungi flourish. Their function is to break down organic matter with humus as the end product. Humus is a rich nutrient-filled material, which increases the nutrient content in soils and helps to retain moisture in soils. Compost is known to suppress plant diseases and pests, resulting in the reduction or complete elimination in the need for chemical fertilizers. Compost enriched soils promote higher yields of plants including agricultural crops (EPA, 1997).

Compost can be used to *remediate contaminated soil*. It has the ability to absorb odours and treat semi-volatile and volatile organic compounds (VOCs), like explosives, heating fuels and polyaromatic hydrocarbons (PAHs). Compost can bind heavy metals and prevent them from migrating into water resources or being absorbed by plants. The compost process degrades and, in some cases, completely eliminates wood preservatives, pesticides, and both chlorinated and non-chlorinated hydrocarbons in contaminated soils (EPA, 1997). Scragg (2005:199) illustrates how contaminated soil can be remediated by mixing it with composting material like straw, bark and wood chips. By piling it into windrows, the temperature can be raised higher than 60%, causing degradation of the contaminants in the soil through microbial activity (EPA, 1997).

Compost helps *prevent pollution*. Organic matter in landfills is responsible for the production of methane and leachate formulation in landfills. To divert the compostable material (organic matter) from the landfills pollution will therefore be avoided. Compost has the ability to prevent erosion and silting on embankments located parallel to streams, dams, and rivers, and prevents erosion and soil loss on roadsides, hillsides, golf courses, etc. Compost can prevent pollutants in storm water run-off from reaching the surface and underground water resources.

The use of composting makes *economic* sense, since it can reduce the need for water, fertilizers, and pesticides. Compost is a marketable product and is a low-cost alternative to standard landfill cover and artificial soil amendments (EPA, 1997). Studies have shown that, in the agricultural sector, the sustained application of compost favourably influences soil pH, is responsible for higher crop yields, increased organic matter, increased cation exchange capacity, enhanced supply of plant nutrients, and increased water retention (Diaz *et al*., 1993:176).

Throughout the world composting had been used for the stabilisation of organic residues with the emphasis on composting the organic fraction of the MSW (Diaz *et al*., 2007:3). Collection and treatment of the organic fraction of the MSW can help municipalities to meet waste reduction targets to reduce the quantities of waste reaching the landfill.

Composting can be regarded as a relatively simple and cost-effective method of treating the organic fraction of MSW. This signifies an increase in the lifespan of the landfill site. It reduces the potential for both leachate and the production of gas of a landfill site (Diaz *et al*., 2007:4). Read *et al*. (2001:623) agree with this, and, although the purpose of their study was not composting (but introducing air into a landfill called aerobic land filling), they highlighted the benefits of aerobic treatment of waste. This is therefore also applicable for the composting process. As the green waste is being diverted from the landfill, extension of the lifespan of the landfill is expected and has several additional benefits including: an increase in revenue will result through airspace recovery; leachate contaminants and volumes are reduced; the expensive treatment and monitoring of the leachate is reduced; the generation of methane gas is reduced; the expensive harvesting systems of the methane are reduced; the closure and post-closure cost of a landfill will be reduced (the landfill owner is liable for the closed landfill site 30-40 years after closure to carry the cost for mitigation of potential environmental damage (DWAF, 2005)); and finally, there will be a reduction in environmental liability.

Besides the fact that the municipality can sell the compost, it can be used to maintain and beautify parks and other open spaces within the urban boundaries, providing a range of benefits to the urban dweller. These benefits include:

> "…mitigating air and water pollution, ameliorating suburban sprawl, providing opportunities for recreation, promoting sound mental and physical health, reducing crime and fostering cohesive neighbourhoods, attracting businesses, and stabilizing property values." (Regan *et al*., 2006:169-170)

2.2.3 Composting process

A distinction is made between aerobic and anaerobic composting processes. Aerobic refers to the decomposition of organic wastes in the presence of oxygen producing end products such as carbon dioxide, nitrogen, water and heat. Anaerobic composting is the decomposition of organics in the absence of oxygen with methane, carbon dioxide, nitrate (when further oxidised), trace amounts of other gasses and low-molecular-weight organic acids (Polprasert, 1996:69). However, Williams (1998:382) is of the opinion that composting is the aerobic rather than the anaerobic biological degradation of biodegradable organic waste.

As mentioned earlier, if green waste can be taken out of the waste stream, it can be converted into a useful product, compost. In countries where waste is collected as a mixed stream, it is either disposed of in a landfill or incinerated, ignoring the potential for composting and the recycling of nutrients and organic matter. Many recycling collection programs exclude the digestible fraction, but source separation is increasingly implemented. The result is that more green waste is becoming available. Where source separation was implemented, between 50-70% of the total of the organic fraction of MSW is successfully recovered. The quality varies from reasonable to very good, enabling production of acceptable compost (Braber, 1995:366).

Composting of green waste is a well-known and reasonably easy process, and, although this valuable resource is readily available, municipal waste disposal companies do not practise it widely. The fact that little is known about the costs of MSW composting facilities compared to other waste disposal methods might be a limiting factor (Renkow & Rubin, 1998). Cunningham *et al*. (2005:465) found that the opposite is true, and that many cities have banned the green waste from the municipal waste stream. Instead of burying this valuable material in a landfill, it is turned into compost. In this way the waste stream is not only reduced significantly, but rich compost can be sold to gardeners. Although composting as such will not offer a significant income to the producer, hidden costs and added benefits cannot be ignored. In the United Kingdom waste minimisation clubs have been used since the early 1990s. This demonstrated that reducing waste generation could lead to considerable financial savings (Phillips *et al*., 2001) for the municipality.

Braber (1995:366) points out that "the composition of the organic waste is important in determining which treatment method is most appropriate". Much research has been done on composting regarding the use of different substances, methods and technologies (Körner *et al*., 2003), but little of these are implemented in municipal areas in South Africa.

2.3 COMPOSTING STATUS IN SOUTH AFRICA

Although composting is widely practised in South Africa, it is mainly done by private entrepreneurs like Conradie Organics, Cultera, Reliance Compost, Ocean Agriculture, to name a few. Selected municipalities have recently started to use the green waste disposed at garden sites to produce compost. In Durban (now eThekwini) green waste has been collected separately in blue bags since the early 1990s. Compost is produced from the organic content of their waste stream mostly at waste disposal facilities. A successful composting site is run on the Marian Hill landfill site outside eThekwini, and others are planned. The composting of general municipal waste produces inferior compost because of the presence of pieces of glass, plastic, etc. which is unattractive to the market place. Composting of the garden refuse fraction, however, should be contemplated (eThekwini Municipal Communications Department, 2008:1a).

At a composting operation near Cato Ridge abattoir wastes (paunch contents) and chicken litter is used to produce high quality compost very competitively. Few rival composting operations have been able to compete with this manufacturer who has been in business for many years (eThekwini Municipal Communications Department, 2008:1b).

Raymond Rampersad of Durban Solid Waste (DSW) stated that composting of biodegradable refuse is encouraged. In their organisation composting is seen as an important aspect in the whole process of waste minimisation and recycling, and is permitted subject to the refuse remaining on the waste disposal/recycling premises. All reasonable steps are taken to avoid a nuisance or health hazard (eThekwini Municipal Communications Department, 2008:1b).

In 1978, the municipal compost industry in the Western Cape was investigated, with specific reference to the demand structure (Lombard, 1978). Since April 2001, Cape Town has embarked on actions to divert the green waste from the landfill sites by creating collection points at conveniently located garden sites. At 11 of the 17 council drop-off facilities, the volume is reduced by four to one by chipping the incoming garden refuge at these drop-off facilities. Private partnerships collect the greens for composting at various facilities. Savings generated in this way does not only include reduced transport costs, but also saving on landfill space (Furter, 2004). In Sacks Circle in Cape Town, composting has been manufactured for the past 60 odd years from the municipal waste stream. Waste from a certain area only is allowed to this facility because of the high organic content. The waste is put through a materials recycling facility where recyclables are extracted. The organic and other putrescible material are piled into static windrows and left for six months to mature. The material in the pile is then screened to remove the remaining waste material. The compost is bagged and sold to the public.

A study titled 'Composting of Municipal Waste in South Africa – sustainability aspects' was undertaken to compare seven composting facilities in terms of the technical process, environmental impact, economical sustainability and social policy fulfilment (Ekelund & Nystrom, 2007). In another study, Khwani (2003) investigated green waste recycling in Merebank. An investigation was done amongst schools in Pietermaritzburg concluding that waste minimisation through recycling and composting is practised at 53% of the primary schools but only 10% at secondary schools. This did not incorporate any in-depth study into composting facilities (Nxumalo, 1999).

Numerous studies regarding composting as a microbial process were completed (Gouws, 1961; Van Rensburg, 1968; Issel, 1999; Harrison, 2001; Griessel, 2002; Van Staden 2006) to indicate the optimal use of different ingredients of compost mixes as well as the applicability of compost in practice (Riekert, 1991; Pieters, 1993; Van Heerden, 1998; Potgieter, 2007). In South Africa, no other studies regarding municipal composting facilities processing green waste for a soil conditioner is available in the academic literature. A successful composting facility operated by the Johannesburg waste removal company will be discussed in Chapter 3.

2.4 POTENTIAL FOR COMPOSTING IN SOUTH AFRICA

In South Africa, garden refuse is primarily disposed of in domestic landfills. Due to the large quantities generated, any form of treatment would be beneficial for volume reduction, waste stabilisation and resource recovery (Trois & Polster, 2007).

Depending on the climatic area, green waste comprises 30–45% of the municipal waste stream (Pikitup, 2007). The National Solid Waste Association of India points out that their country's organic fraction of the waste comprises 40–85% of the solid waste (Zurbrügg *et al*., 2004). According to Williams (1998:384), the compostable content of the waste stream in the United Kingdom can be as high as 60% if paper, cardboard and putrescibles are included.

Due to this high percentage contribution of green waste to landfills (e.g. 10-35%), the potential for composting in South Africa is therefore large (DEAT, 2005:38). The importance of recycling green waste is confirmed in the final report for the National Waste Management Strategy Implementation Project in which different waste streams were identified as high priority in terms of pilot investigation for recycling and include: tyres, electronic waste, building rubble, paper, glass, plastics, organics and scrap steel (DEAT, 2005:44). Thus, organics, or green waste, is a waste stream that needs urgent attention in terms of recycling.

2.5 POTENTIAL FOR COMPOSTING IN CTMM

An analysis of the waste composition of the wasteland filled by the CTMM, green waste is approximately one third of all the waste being land filled, as depicted in Table 2.1. Land filling signifies thrown away and buried together with all the other waste in the landfill.

***Table 2.1*: Types & quantities of waste disposed of at CTMM landfill sites**[a]

LANDFILL	Type of waste	Tons / Year	Building (%)	Garden (%)	House-hold (%)	Industrial (%)
Derdepoort	Garden refuse; building rubble	342 540	20	70	5	5
Hatherley	General	120 444	10	10	75	5
Ga-Rankuwa	General	153 816	10	10	60	20
Garstkloof	Garden refuse; building rubble	421 080	30	60	5	5
Kwaggasrand	General	323 856	10	15	70	5
Onderstepoort	General	336 396	10	20	50	20
Soshanguve	General	110 400	5	10	80	5
Temba	General	88 356	10	10	70	10
Valhalla	General	345 192	5	15	75	5
TOTAL		**2 242 088**				
Mean				24,4%		

[a](Felehetsa, 2004:68)

Garden waste comprises most of the waste stream only at Derdepoort (70%) and Garstkloof (60%). The percentage green waste at Onderstepoort is 20%. Kwaggasrand and Valhalla both have a garden waste fraction of 15%. The rest of the sites (Hartherly, Ga-Rankuwa, Soshanguve and Temba) all have a 10% fraction of green waste received in the landfill. Excluding Derdepoort and Garstkloof, the rest of the sites' domestic waste has the highest percentage. In the Figure 2.1 (Felehetsa, 2004:69), it is clear that green waste is the largest part of the domestic waste stream.

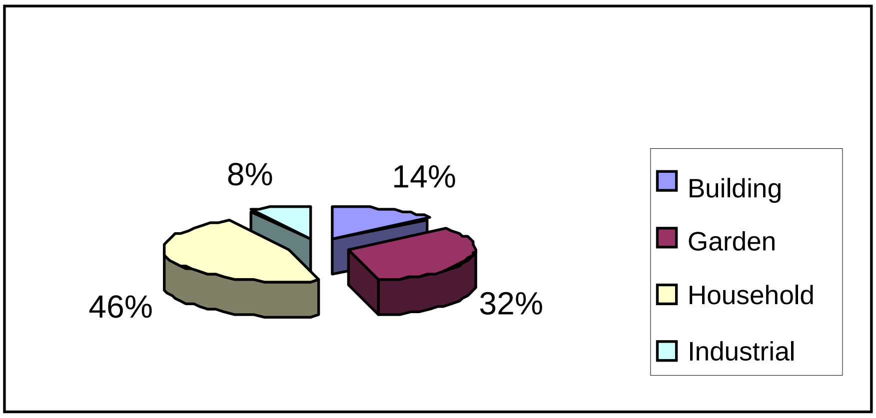


Figure 2.1: **Percentage of waste categories generated in the CTMM (Felehetsa, 2004)**

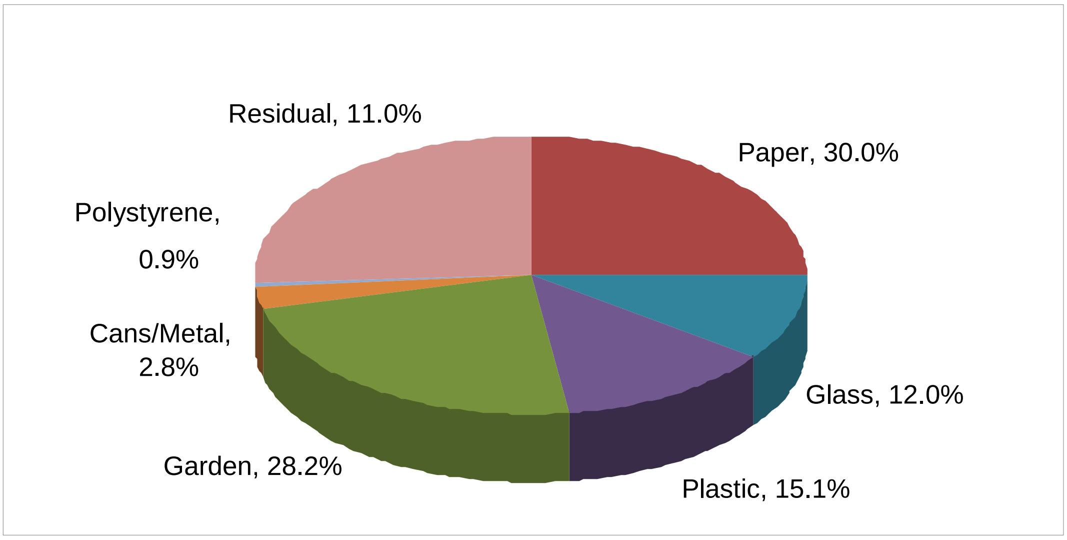


Figure 2.2**: Waste stream analysis, 2007 (Snyman, 2007)**

According to a waste stream analysis undertaken in Tshwane in July 2007, it was confirmed that approximately one third of the household waste comprises of garden waste, as illustrated in Figure 2.2 (adapted from Snyman, 2007:369). In this study a count was done of the content of wheelie bins of several representative income groups to determine the content of the bins. The content of each bin was emptied onto a canvas, then sorted into categories, and the volumes determined.

Similarly, according to the domestic waste numbers for the nine landfills of the CTMM, it was deducted that a third of the total comprises of domestic waste, leaving a foresee-able total of approximately 800 000 tons for all nine landfill sites (if the most recent 2006/7 statistics are used). This is illustrated in Figure 2.3 (Dekker, 2007).

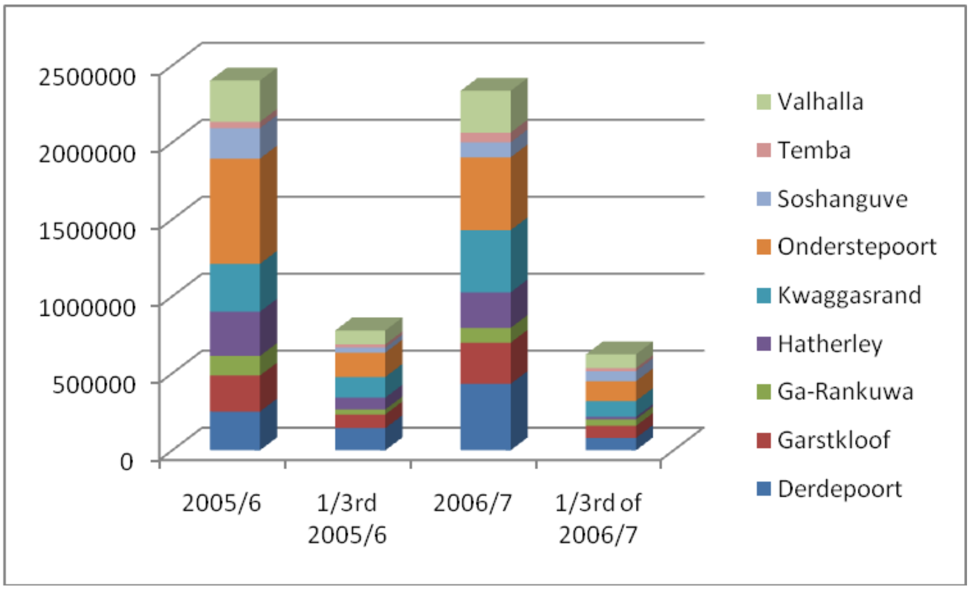


***Figure 2.3*: Waste totals for the CTMM for 2005/6 and 2006/7**

If these amounts can be taken out of the waste stream one third of the waste is prevented from being land filled and in this way the lifespan of the landfills will be extended, resulting in a decrease in methane generation. This will imply a change in the logistics of the current waste management structure, converting green waste into a valuable resource, compost.

The problem with green waste in South Africa is that it is not consistent in composition, because of the different growth seasons. In summer there will be such a large amount of nitrate rich material, and in winter there will be more carbon-rich material. An experienced operation can easily overcome these differences in seasons and run a reliable and successful composting operation.

In Figure 2.4 fluctuations in waste to landfill are shown, as recorded in 2006/7 (Dekker, 2007). The specific fraction of the green waste must be read as a ⅓ of these numbers. The rising amount of waste during June to September likely results from the landscaping program to cut open veldt areas to prevent fires.

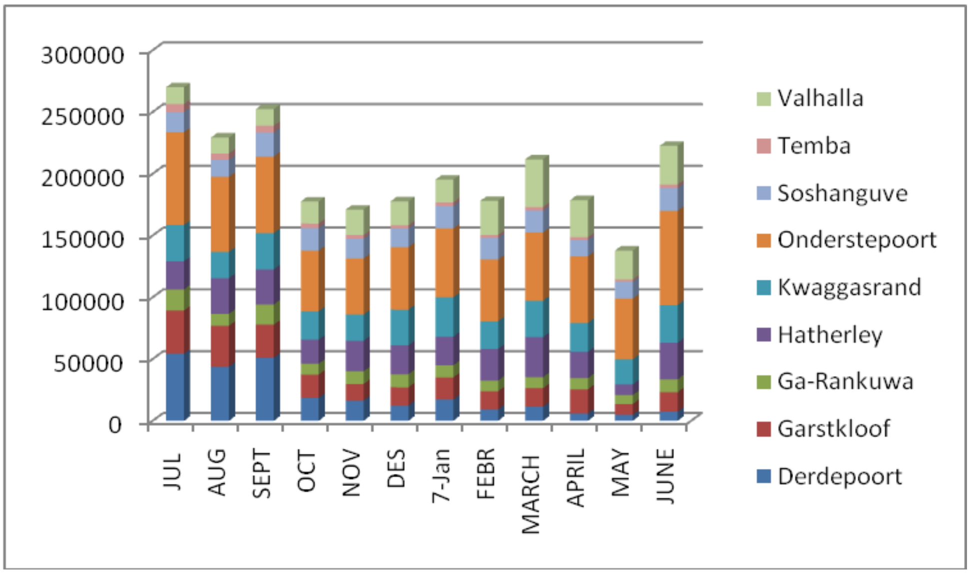


***Figure 2.4*: Fluctuations in incoming waste of CTMM for 2006/7 (Dekker, 2007)**

It is important to emphasise the effect green waste has on landfill sites. The green waste is the waste that mainly causes the 'rotting' in the landfill. It produces methane gas. Bad odours are caused by the decomposition process of the waste in the landfill and are released in the form of methane (CH_4) gas, mixed with other gasses, into the atmosphere. Methane is a potent greenhouse gas. When averaged over 100 years each kg of CH_4 warms the earth 25 times as much as the same mass of carbon dioxide (CO_2.) (Williams, 2005:215). As a greenhouse gas, methane is therefore more potent than carbon dioxide, a gas that is generally perceived as dangerous for human health. By reducing the green fraction of the domestic waste to the landfill site the amount of harmful methane gas will be reduced proportionally.

2.6 GARDEN SITES

The most important aspect, if the green waste is to be converted into compost, is the fact that it needs to be separated at the source in order to have a clean, uncontaminated product to treat (Du Plessis, 2008:4). Foreign materials reduce the quality of the compost. Therefore, cleaner green waste will contribute towards a successful and streamlined composting process. In South Africa, waste is collected in the 240 litre waste bins provided by the municipality, the responsible entity for waste management within urban areas. If separation of green waste is not done at source by residents, it is very difficult to extract the green waste, which is co-disposed into the wheelie-bin with all the other domestic waste, at the disposal facility with a composting option. Therefore, in order to have access to the green waste for composting, one must make means available for house-owners to dispose of it separately. There are different options to do this. One is the collection of green waste at Garden Refuse Sites. Garden sites are common practice in the UK, Europe, USA and also in the larger metropolitan areas of South Africa.

CTMM have four successful garden sites within its boundaries to accommodate the waste mainly generated by the parks maintenance division of the municipality. Private contractors run another six sites. The different sites operated by CTMM are shown in Table 2.2 showing the amounts of green waste collected at the garden sites (Du Plessis, 2008:4). If all of this could be made available for composting, it can make an important contribution to soil fertility. Making compost is a simple process and an opportunity for creating employment. The numerous benefits of composting will be discussed later in this chapter. Added to those benefits is that it is also useful for community parks, gardens and nurseries, which all of which create jobs within communities. The compost can then either be sold or accumulated for final rehabilitation of the landfill sites (Du Plessis, 2008:5).

***Table 2.2*: Garden refuse sites operated in the City of Tshwane Metropolitan Municipality (Felehetsa, 2004:71)**

AREA	ADDRESS	Volumes handled/day
Akasia		
Dorandia	Daan de Wet Drive, Dorandia	120 m^3
Pretoria		
Magalieskruin	Zambesi Drive, Magalieskruin	250m^3
Menlo Park	26th Street, Menlo Park	240m^3
Mountain View	Japie Peens Street, Mountain View	120m^3
Philip Nel Park	Sytze Wierda Street, Phillip Nel Park	121m^3
Waltloo	Alwyn Street, Eersterust	33m^3
Eersterust	St Joseph Street, Eersterust	33m^3
Centurion		
Kruger Avenue	Kruger Avenue, Lyttelton	300m^3
Rooihuiskraal	Rooihuiskraal Road, Rooihuiskraal	392m^3
Claudius	R55, Laudium	33m^3

In the past, composting was done in Centurion, but with the amalgamation of the different municipalities CTMM was established and the composting initiative was stopped. This was mainly due to political and financial constraints (Dekker, 2007). Therefore, large quantities of green waste to landfill consume valuable airspace and increase costs (Felehetsa, 2004). As discussed in Chapter 1, new legislation requires reduction in waste disposal to landfill. The pressure is on municipalities to abide by these prescriptions (Du Plessis, 2008:5).

New thinking is needed to change the current situation in order to meet the targets set by government. Although several factors i.e. political goodwill to support new initiatives, available infrastructure, funding for initial costs, manpower, etc., are essential to implement waste minimisation initiatives (Du Plessis, 2008:5) such as composting.

2.7 COMPOSTING ELEMENTS

The five major elements necessary to create a compost product are the *C:N Ratio*, moisture content, aeration, heat and pH, which will be discussed below.

The *C:N Ratio* refers to the proportion of carbon (C) and nitrogen (N) in the compost unit. Carbon and nitrogen are the two most important elements in the composting process. Sources of carbon include sawdust, straw, wood clippings and dry leaves and serve as an energy source for the micro-organisms. Nitrogen is found in grass clippings, plant trimmings and food waste and is needed for the microbial population growth. With too little nitrogen, microbial populations will stay small and decomposition will be slow. Too much nitrogen leads to the release of ammonia gas or other mobile nitrogen compounds and can result in bad odours. The ideal *C:N* ratios for composting of garden waste are between 25:1 and 30:1 (Diaz *et al*., 1993:168) and in some cases it can go up to 40:1, but may be altered according to the available biological activity. Since nitrogen is usually the limiting factor in municipal solid waste due to the fact that it is relatively large in size, additives such as manure, clean sewerage sludge, seepage or urea can be added to increase the nitrogen content (Du Plessis, 2006:6). According to Diaz *et al*. (1993:168), poultry manure is the most effective due to the high nitrogen content.

Moisture is an essential element since decomposition takes place in the thin liquid films around the waste particles (Du Plessis, 2006:6). If the surface of the particles glistens, it is an indication of enough moisture (Diaz *et al*., 1993:171). The amount of moisture must establish equilibrium between the microbial activity and oxygen supply (Du Plessis, 2006:6). If the moisture content is too high, the oxygen supply is reduced. Anaerobic decomposition is the result and leads to the generation of unpleasant smells and other by-products, as well as a drop in heating. Excessive moisture can be remedied by adding more absorbent material (leaves, sawdust, dry grass) or turning the compost more often (Diaz *et al*., 1993:171).

Too little moisture (40–45%) slows decomposition down and will cause the composting process not to be complete (Du Plessis, 2006:6). The moisture content can be raised by sprinkling with tap water (Diaz *et al*., 1993:171). The minimum moisture content of 50-55% is recommended for effective composting. Additional water is added to prevent premature drying and incomplete stabilisation. Garden waste compost typically begins with a moisture content of 52% and dry out to 37% before it can be utilised (Du Plessis, 2006:6).

The third fundamental element of the composting process is *aeration* of the compost pile. A layer of air surrounding each micro-organism is essential to keep the biological and chemical process functioning. Carbon dioxide (CO_2) replaces the oxygen, which is released around the cells. Anaerobic conditions will set in if the oxygen is not replaced. It is therefore essential that the aeration equipment/method be designed in such a way that there is a sufficient supply of oxygen available to sustain microbial activity. Oxygen renewal can be accomplished either by moving the particles to a new position to expose them to new air, or by displacing the gaseous envelope while the particles remain stationary (Diaz *et al*., 2007:68). Thus, aeration can be done in various ways. As the sophistication of the method increases, so will the costs. Different methods to aerate the compost will be discussed in detail under methods, and include turned windrows, forced aeration systems and sophisticated mechanical turning systems (Williams, 1998:386).

The release of CO_2 causes bad odours requiring odour control. This can be accomplished by regular aeration by, for example turning the windrows, by controlling the *C:N Ratio*, as well as the moisture content (too much water or wet material can lead to bad smells) (Du Plessis, 2006:6).

Heat is important in raising and maintaining temperatures to ensure effective decomposition. Maintaining high temperatures between 45°C and 60°C for 1-3 weeks provide the highest rate of decomposition. It reaches a plateau at about 65-70°C. Temperatures higher than 60°C cause a reduction in microbial diversity and in this way reduce the rate of decomposition until the ambient temperature is reached. This is an indication that the compost has reached maturity (Diaz *et al*., 2007:59). For effective pathogen control, temperatures higher than 55°C need to be maintained for several days. This makes the operating temperature range very narrow, and confirms that the composting procedure, although simple in principle, needs to be monitored carefully (Du Plessis, 2006:7).

An efficient composting process needs a *pH level* of as close to the neutral value of 7 as possible. Food scraps generally are below 7 and fresh leaves have a pH of approximately 7. A high pH (>8) can be remedied by the addition of acid like lemon juice and lime can be added when the pH is too low, although it is very seldom that remediating action is found to be necessary (EPA, 1994:39).

2.8 BIOLOGICAL PROCESS

During the composting process, various micro-organisms like bacteria and fungi, break down organic material into simpler substances (Compost Council of Canada, 1994a). This breakdown of organic material is very difficult to stop.

> "When the necessary components for a particular biological process are not present in adequate amounts, the microbial population will shift to favour micro-organisms capable of capitalising on existing conditions." (Compost Council of Canada, 1994b)

Oxygen will favour aerobic micro-organisms, but a lack of oxygen will cause the organisms that do not need oxygen to flourish. Both processes are required for total breakdown to ensure that most nutrients are returned to the soil, but the second process will cause unwanted odours.

Composting is a four-phase process. The first phase is called the Mesophilic Phase during which energy-rich, easily degradable compounds like sugars and proteins are abundant and are degraded by primary decomposers like fungi, actinobacteria and bacteria. Provided that mechanical influences are small, compost worms and mesofauna like mites and millipedes develop acting mainly as catalysts. The activity of these primary decomposers induces a temperature rise of 25-40°C. This introduces the next phase, the Thermophilic Phase where temperatures of 35–65°C are present. During this phase organisms adapted to higher temperatures get a competitive advantage and gradually almost replace the mesophilic flora. These thermophilic organisms continue with fast decomposition of the mesophilic flora and the remaining easily degradable substrate (Diaz *et al.*, 2007:32). The decomposition accelerates until a temperature of about 62°C is reached. Most organisms are destroyed beyond 65°C, but, in spite of that, temperatures may rise further to exceed 80°C. The final rise in temperature is not due to microbial activity, but is the effect of abiotic exothermic reactions in which temperature-stable enzymes of actinobacteria might be involved.

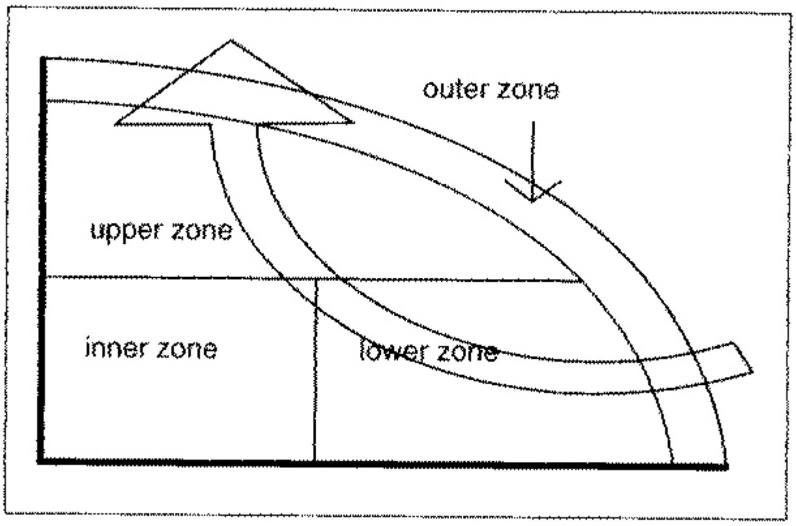


Figure 2.5: **Cross-section of a compost windrow to illustrate temperature zones (Diaz *et al*., 2007)**

The highest temperatures are in the central zone of the pile. It is therefore important to turn the pile regularly to ensure that every part of the substrate is moved to the central, hottest part of the pile. Four temperature zones can be distinguished (Figure 2.5, Diaz *et al*., 2007:33): the outer zone is the coolest and rich in oxygen; the lower zone is hot and rich in oxygen; the inner zone is hot but poorly supplied by oxygen; the upper zone is the hottest and fairly well supplied with oxygen (Diaz *et al*., 2007:33). The Thermophylic Phase is important to ensure that human and plant pathogens are destroyed and that weed seeds and insect larvae are killed.

The next phase is the cooling, or Second Mesophilic Phase, where mesophilic organisms recolonise the substrate. This can either be from surviving spores, through the spread from protected microniches, or applied externally. This stage is characterised by the breakdown of starch and cellulose by bacteria and fungi (Diaz *et al*., 2007:34). The Maturation Phase in which the composition of the microbial activity is changed completely follows the cooling phase: usually the fungi population increases while the bacterial numbers decline. Compounds that cannot degrade further, like lignin-human complexes, are formed (Diaz *et al*., 2007:34).

2.9 METHODS OF COMPOSTING

A variety of technologies are being used for composting municipal solid waste to mix, macerate, and move compost through a facility. This study will not look into the several viable options, but will discuss the most common methods being used. The purpose is to evaluate and identify the most appropriate method for municipal composting in CTMM. When a method is selected, it is important to take into account which type of material is used in the composting process: "The more problematic the waste is, the more controlled must the process be, and enclosed composting might be necessary" (Ekelund & Nystrom, 2007:15). This discussion will look mainly into open-air systems for the treatment of garden waste. A few types of enclosed systems will also be mentioned.

2.9.1 Garden composting

In order to fully understand composting, a distinction must be made between garden composting, which usually is done on a small scale, and composting of municipal green waste, which usually needs to be handled in large amounts. If garden composting is widely encouraged and implemented, there will be a reduction in the amount of greens going to landfill.

Methods of garden composting will not be discussed in detail, but it is, however, important to consider it to understand the different processes of composting, and for possible use of small municipal operations. Composting processes can be divided into cold (or slow) and hot (or fast) composting.

2.9.1.1 Cold composting

Cold composting is used when there is more carbon (brown material) than nitrogen (greens). The process is slow, a lower level of management is needed, and if the raw material contains weed seeds or plant pathogens, these might not be destroyed in the composting process (Brown & Ryan, 1999). Methods of slow composting include the following:

- Sheet composting entails spreading of organic mulch (e g leaves, wood chips) on the soil surface and allowing it to decompose over time. No further manipulation of this layer is needed, as the decomposing material will slowly filter into the soil below. This is excellent for moisture retention, but is not suitable for composting of all kinds materials (Brown & Ryan, 1999).
- Trench composting involves digging a trench of 12cm deep in the garden area, filling it halfway with kitchen scraps and backfill it with soil. The soil will be ready for use within a few months. If large amounts of material are used, the area can be tilled (Brown & Ryan, 1999). This method will not attract pests.
- Bin composting is usually an aerated bin containing layers of carbons, kitchen scraps, greens and soil left to decompose. This is a neat, clean way of composting and cannot be reached by pests.
- Heap composting is simply a pile of compostable materials placed in a designated area. The disadvantage is that it is accessible for pests (Brown & Ryan, 1999).

2.9.1.2 Hot composting

Hot composting is a more intensive method and requires a blend of greens and browns, proper moisture content, frequent aeration and particles of less than 8cm in size. This method is the best to control weed seeds and plant pathogens.

Aeration usually means active involvement in the process. Although the process is faster, expensive equipment or manual labour is required. Vermicomposting[i] is a hot composting method, but is more suitable for smaller quantities high in nitrogen (Diaz *et al*., 1993:122). The different environmental factors, *C:N Ratio*, moisture aeration, heat and pH that was discussed previously, are also needed for these composting processes.

2.9.2 Municipal composting systems

Municipal composting usually entails the treatment of large quantities of green waste using municipal structures and resources. Different technologies or systems are available from which to choose. The classification of the composting system is based on the degree of mechanisation and can be broadly classified as open (windrows) or enclosed, although these two groupings can overlap (Diaz *et al*., 1993:145). The name of the method is self-explanatory. The following are the most common methods in use:

2.9.2.1 Windrows

Since 1992 windrow composting has been gaining rapid acceptance in the United Kingdom as a means of stabilising and sanitising municipal green waste and have plant growth media (compost) as a product (Frederickson *et al*., 1997:725). Windrows can be described as elongated piles, shaped like a haystack. Windrows can be 'static' or 'turned' (Diaz *et al*., 1993:145). Both types of windrows are usually in the open, but can be covered with a roof to minimise the impact of weather and provide an opportunity for odour control (Du Plessis, 2006:8).

The windrows can be more than 100 meters long and is usually 1.5-3 meters high and 3-6 meters wide, depending on the size of the composting operation. Windrows can be constructed over a period of several days or weeks by means of a front-end loader, dump truck or a conveyor belt (Du Plessis, 2006:8). Windrow shapes can vary to help maintain moisture levels. During dry periods, windrows with concave crests are more suitable to allow precipitation to be captured more efficiently when the moisture content of the composting material is low. In order to promote excess runoff and to prevent saturation during rainy periods, peaked windrows are preferable (EPA, 1994:42).

***Static windrows*:** Turning machines do not agitate the static pile. The process can be controlled by pressure or vacuum-induced aeration, with either temperature or oxygen as the variable (Du Plessis, 2006:8). The static system ensures temperatures in the upper thermophilic range[ii] and it is therefore regarded as an efficient way to kill pathogens. It is called the Beltsville Aerated Rapid Composting (BARC) method.

The composition of the materials added is carefully selected to provide the correct *C:N Ratio* (Du Plessis, 2006:8). The piles are packed in layers to ensure that all the elements needed for the composting process are 'mixed' or the material is mixed beforehand if a bulking agent (i.e. sewerage sludge, pine bark) is used in the process. The pile remains undisturbed to decompose on its own time. In most cases air is forced upwards through the compost pile, or is pulled down and through it, and is referred to as 'forced aeration'. The composting material remains undisturbed in both cases (Diaz *et al*., 1993:145). The time for the compost to mature can take up to six months if left to mature on its own (Conradie, 2007). If forced aeration is applied, the maturing time will be reduced considerably.

The static system follows six steps of which the mixing or layering of the material is the *first step.* The *second step* entails the construction of the windrow (Figure 2.6; NIST, 2001 & Figure 2.7; Diaz *et al*., 1993:146). An impermeable composting pad is prepared where the windrow will be constructed. It will prevent moisture from the composting material to seep into the ground. A loop of perforated pipe (10–15cm in diameter) is centred in the middle of the pad, where the ridge of the windrow will be. To avoid short-circuiting of the air, the pipes are ended about 1.5-3 meters from the edge of the windrow. The perforated pipe is connected to a blower with a length of non-perforated pipe not covered by the pile, which will feed the air into the composting pile.

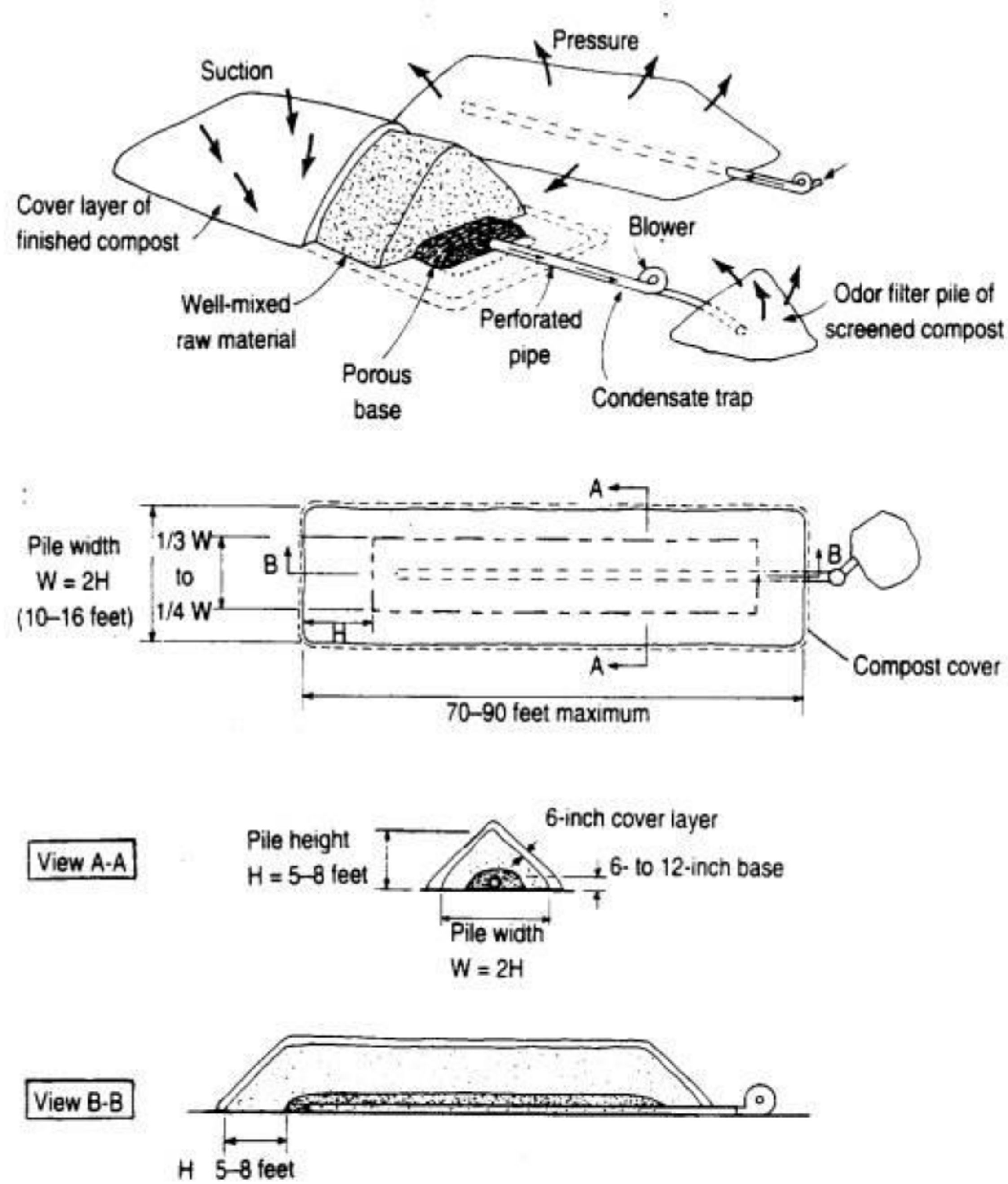


Figure 2.6 **Aerated static pile composition (NIST, 2001)**

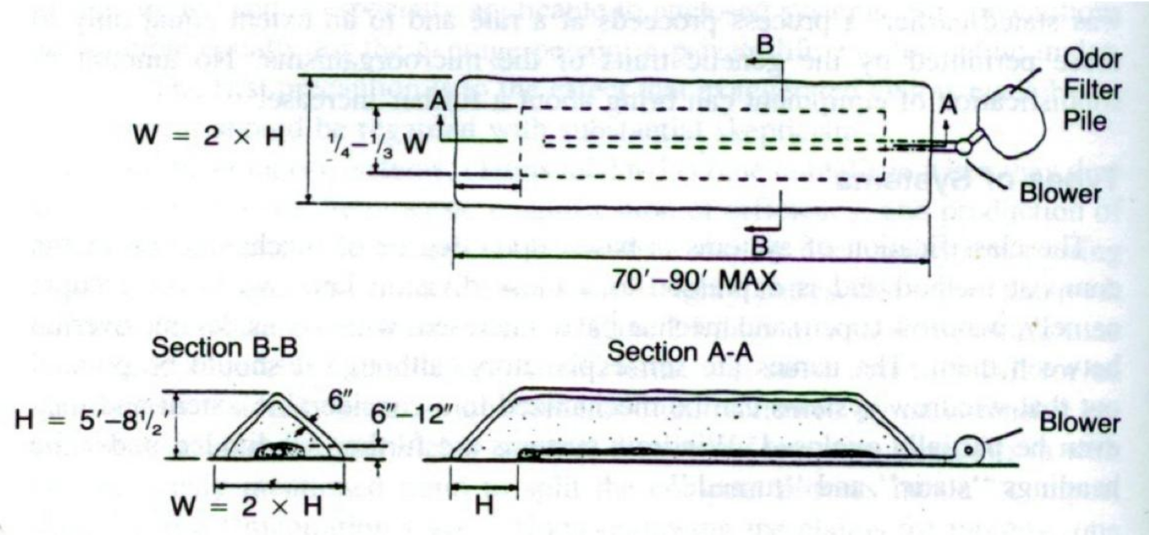


***Figure 2.7*: Approximate diameter dimensions of the windrows (Diaz *et al*., 1993)**

The piping is now covered with a layer of relatively dry material like finished compost or a bulking agent, like sawdust, over the full length of the area to be used for the windrow. Because wet material tends to block the perforated pipe, this foundational layer aims to facilitate the movement and uniform distribution of air throughout the pile during the composting process. It also absorbs excess moisture and in this manner minimises seepage from the pile. The material to be composted is then stacked into an elongated pile on the foundational layer in a triangular heap. The ideal length of the finished pile should be 20-30 meters long, 3-6 meters wide and 1.5-3 meters high (Diaz *et al*., 1993:147).

A 20cm layer of wood chips or other appropriate material or a 15cm layer of mature screened compost is used to cover the pile in order to insulate the active compost. This covering serves to absorb foul odours emanating from the composting process, ensures maintenance of high temperature levels throughout the composting material and therefore a more complete pathogen kill (Diaz *et al*., 1993:47). A cover additionally helps prevent rainwater to enter the compost pile (EPA, 1994:42). Continuous forcing of air through the pile is not necessary to sustain aerobic conditions. The required rate of air input should be determined experimentally to take all the variables, like type of composting material, size of the pile, local climatic conditions, etc. into consideration.

If large amounts of material are to be composted and a large enough area is available, an 'extended aerated' pile could be used (Figure 2.8).

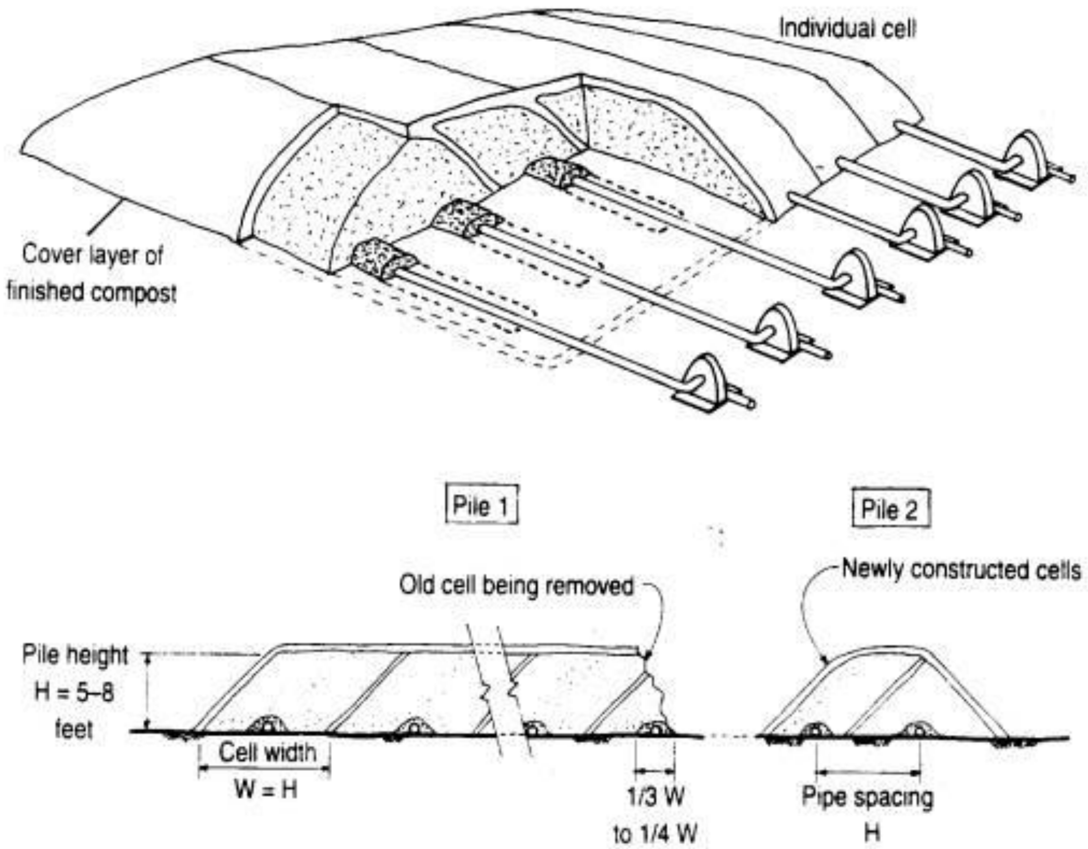


Figure 2.8: **Extended aerated pile (Diaz *et al*., 1993)**

The piles are put close to each other and are covered with a layer of mature compost on one side only, as well as the ends of the windrow. This covering layer is on the side where the next pile is to be constructed. In this way large reductions in spatial requirements are achieved. The uncovered side is covered by a thin layer of mature compost for odour control (Diaz *et al*., 1993:148).

Porosity is a key factor in forced aeration. The moisture content should therefore be between 40% and 55% (Diaz *et al*., 1993:147). The higher the moisture content, the less porous is the mix – compare sludge with bark mulch as two extremes. To remove unwanted odours, the effluent air is passed through a small cone-shaped pile of mature compost, adjacent to the static windrow. The moisture content of this pile should be less than 50%.

The *third step* is completed when the compost is ready within 2-3 weeks. As the *fourth step*, the windrow is torn down and the compost is screened. The screening depends on different factors. If the bulking material (i.e. wood chips) is to be re-used for the next windrow, the opening size of the screen should be as such that only the compost passes through. It is recommended not to do screening on a rainy day, as wet material tends to block the screen and hamper the process. The *fifth* and *sixth* steps constitute curing and storage respectively.

Of all the methods and technologies available, this is probably the least expensive, especially when labour is scarce and/or expensive. The low cost can be due to the least amount of handling of the material, and the relatively inexpensive equipment required. Additionally, this method is not suitable for all kinds of raw materials or under all conditions. It works well with material that is relatively uniform in particle size, which should not exceed 0.2–5cm in diameter (Diaz *et al*., 1993:148). Static windrows are usually in the open, but, although costs will escalate, the operations can be covered with a roof to minimise the impacts of weather and provide the opportunity for odour control (Du Plessis 2006:8).

***Dome Aeration Technology (DAT)*:** Dome Aeration Technology, which is a non-reactor open windrow composting process, has been found to be efficient for the composting of pine bark, which is low in nitrates. This method has the advantage that the input material needs no turning. A decaying time of only 3–4 months, as opposed to 6 months for the conventional static piles, indicates the high efficiency. Additionally, the low initial capital, as well as the operational costs, the low energy inputs and limited plant requirements provide potential for use in aerobic refuse stabilisation. "The innovation in the DAT process is the passive aeration achieved by thermally driven advection through open windrows caused by temperature differences between the degrading material and the outside environment" (Trois & Polster, 2007:96). This method has been tested for composting by Snyman and Du Plessis (2008) and it was confirmed that the composting time was decreased by more than double that of the conventional static rows.

***Turned windrows*:** The turned windrow method is the most common method used for municipal composting (Diaz *et al*., 1993:149). This method has been investigated widely, and a large number of studies have been done on this subject. For example, Frederickson *et al*. (1997:725) composted freshly shredded green waste (yard waste) for 16 weeks using a mechanically turned windrow system. They wanted to investigate the extent to which vermi-composting and windrow composting of green waste may be combined to enhance the potential of both processes.

The windrow is turned regularly using many variations in the method as a way to aerate the composting material and to ensure uniformity of decomposition. This is done by exposing at one time or another all of the composting material to the most active (hottest) interior zone of the pile. It also promotes further reduction of particles sizes of the material (Diaz *et al*., 1993:149). If the moisture content is too high, this will assist in moisture loss. Technologies are available to add water during the turning process, should this be necessary. The process has the same six composting phases than the previous method.

The windrow piles should be constructed on a *hard surface* for the following reasons: to make the materials handling possible (Diaz *et al*., 1993:149), especially in extreme weather conditions (Du Plessis, 2006:7); to permit the control of leachate[iii] for possible contamination of ground water and to prevent fly larvae in the material to escape into the soil (Diaz *et al*., 1993:149). The decisive factors for site preparation are therefore to preserve sanitation and to simplify materials handling. Depending on the turning method, the surface can vary from well-compacted clay with packed gravel or crushed stone on the surface to asphalt or concrete. It is important to cater for the rainy season since the large mechanical turners should have firm footing.

Another important factor in the construction of windrows is the provision of a proper *leachate collecting system* to prevent the leachate from entering the soil and polluting the ground water. It is a stipulation in the Minimum Requirements for waste disposal. In effect it implies that the area needs to be sloped, so that any leachate that are formed, are directed by means of a graded underliner to a collection point or sump (DWAF, 2005). The underliner usually is an engineered low permeability natural soil or clay liner. Collected leachate must be treated to the quality standard as prescribed by DWAF before being released into the environment. Most often, in Europe, municipalities release the leachate into a sewer system without pre-treatment (Williams, 2005:224). This will also be addressed in more detail in Chapter 3. Since this leachate, also called compost tea, is infused with useful bacteria, it is frequently used to add moisture to the composting material and to enhance microbial activity.

The most common *shape of the windrow* is conical, which mechanical turners need for operating. An alternative, if circumstances justify it, for instance windy conditions, a loaf shape is more appropriate. The determining factor is that the ratio of exposed surface area to volume is lower and the area exposed to the hot zone is greater than it will be in the conical/triangular shape. During wet weather the loaf shape will absorb too much water; instead of shedding it like the conical shape, leading to an upset in the moisture balance (Diaz *et al*., 1993:149).

The *height of the windrow* is determined by the method of turning. If manual labour is used, the windrow must be about the height of the average labourer. If mechanical equipment is used, the type of equipment will determine the height. Generally it is about 2 meters (Diaz *et al*., 1993:149). The *width of the windrow* is determined by convenience and practicality, since it is a minor element in meeting the oxygen demand of the composting mass. Windrows that are manually turned are about 2.6 meters wide, and mechanically turned windrows are about 3.3–4.3 meters wide (Diaz *et al*., 1993:149). The *length of the windrow* is undefined and depends on the size of the area available for composting. By adding new material to the one end of the windrow and removing mature compost from the other end, a continuous system can be established (Figure 2.9; Diaz et al., 1993;150).

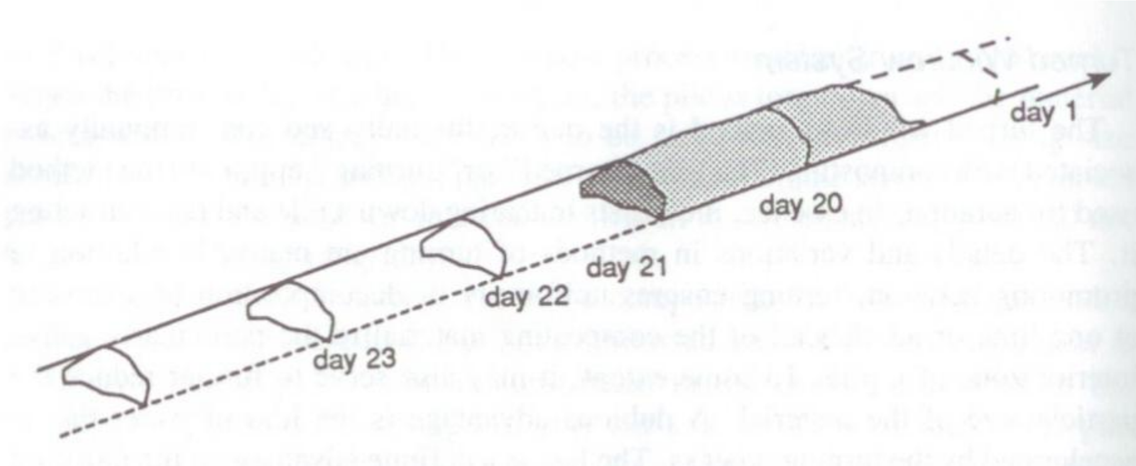


***Figure 2.9*: Construction of piles (Diaz et al., 1993)**

The type of operation determines the longitudinal arrangement of the windrows next to each other. It is important that the windrows are arranged in such a manner that turning is possible whether it be manually or mechanically. Manual turning needs at least 2–2.5 times the space of the original windrow. The windrow is placed next to the original position and returned to the original position with the second turning, as indicated in the sketch in Figure 2.10 (Diaz *et al*., 1993:150).

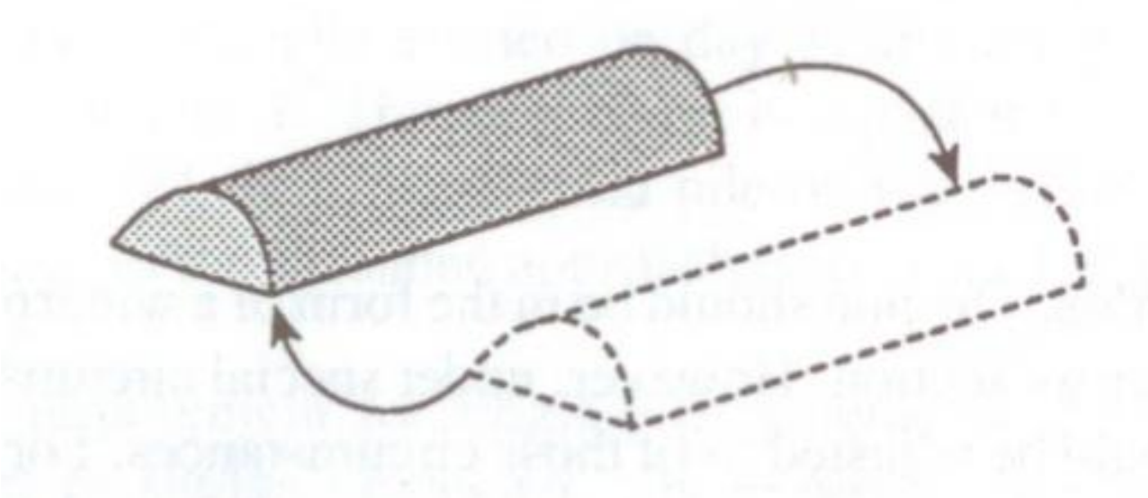


***Figure 2.10*: Logistics of turning windrows (Diaz et al., 1993)**

2.9.2.2 Windrow turning equipment

Different types of mechanical turning are available. Equipment should be chosen to fit the operations in terms of the size of the operation (area, capital available, incoming green waste, demand for compost). The equipment determines the size of the windrows.

The purpose of *turning* the windrow is to re-oxidise it to keep the process aerobic, thus preventing the build-up of bad odours. Turning windrows also increase the porosity of the pile, redistribute material to enhance process uniformity and break up clumps to improve product consistency (Du Plessis, 2006:7). Turning ensures even temperature distribution and new surfaces in the material are exposes to biological activity (Ekelund & Nystrom, 2007). After turning, the material from the inside of the pile should be outside and *vice versa* (Figure 2.11; Diaz *et al*., 1993:151). During the compost cycle every particle should, at one time or another, be in the centre of the pile to be exposed to the heat. If this is not attainable, as is the case with mechanical turning, the deficiency can be compensated by increasing the frequency of turning (Diaz *et al*., 1993:151). Windrows usually rely on natural convection and diffusion for oxygen supply (Du Plessis, 2006:7).

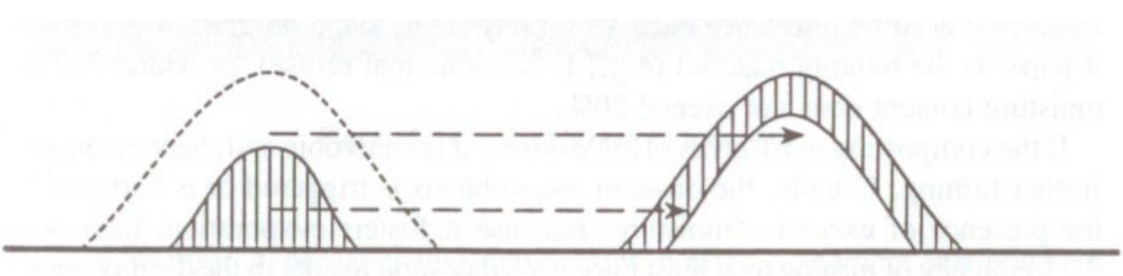


***Figure 2.11*: Rebuilding the pile (Diaz et al., 1993)**

Therefore, the size of the pile and frequency of turning times are used to balance heat loss in managing temperature control. In other words, the turning frequency is dependant on the ratio of oxygen availability to oxygen demand (Diaz *et al*., 1993:151). It is important not to compact the composting material during the turning process. Many different variables influence the process, and each operation must find its own unique recipe to manufacture compost.

Some machines move over the windrow, tearing it down as it moves and rebuilding it directly behind the machine. The aerial requirement in terms of width for this type of operation is little more than that of the original windrow. Turning space must be allowed for the machine at the two ends of the windrow. The other machines rebuild the windrow adjacent to its original position and therefore need the same space as for manual turning (Diaz *et al*., 1993:151). According to the findings of the study done by Ekelund and Nystrom (2007:15), the following turning equipment is most commonly used in South Africa.

***Photograph 2.1*: Front-end loader**

***Front-end loader*:** The front-end loader, which is used to build the piles, can also be used for turning (Du Plessis, 2006:7). Other applicable earthmoving equipment can also be used. Although it is expensive to purchase, using multipurpose equipment will aid to saving costs. This method usually does not need large extra space for turning, since it uses small turning space. However, the size of the front-end loader will determine the size of the windrows. For a small front-end loader (Photograph 2.1), larger space is needed for the windrows, which need to be smaller (1.5m) to be accessible, and *vice versa*.

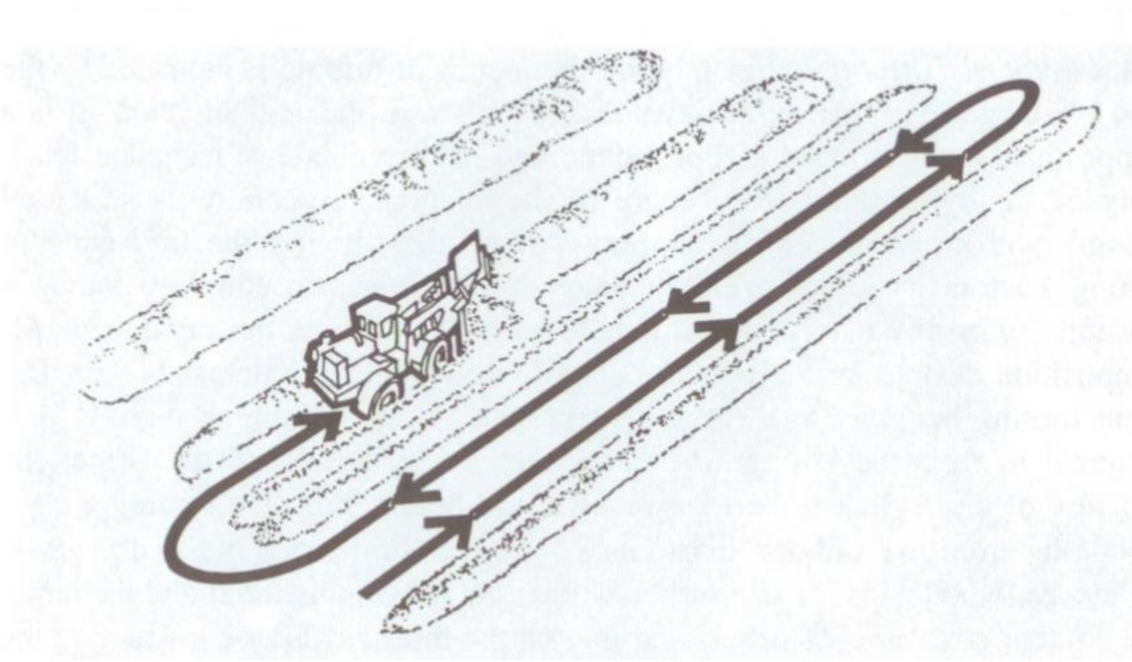


***Figure 2.12*: Mechanical turning of windrows (Diaz et al., 1993)**

***Rototiller/Straddle turner*:** A rototiller, self powered or pulled by a tractor (Figure 2.12; Diaz *et al*., 1993:151), can be used for smaller operations and large mechanical turners for larger operations as seen in Photograph 2.2 (Ekelund & Nystrom, 2007:15) and Fig. 2.13 (Diaz *et al*., 1993:154), of which there are an array available on the market. The compost pile is aerated without moving its position (Ekelund & Nystrom, 2007). Additional turning space must be allowed if the tractor is used to pull the tiller.

This system has the additional advantage that it can be fitted with a watering device, adding moisture to the compost mix while turning. A large compost turner is the most expensive equipment that can be bought and the amounts of incoming green waste must be enough to justify the capital outlay of such equipment.

***Photograph 2.2*: Small rototiller**

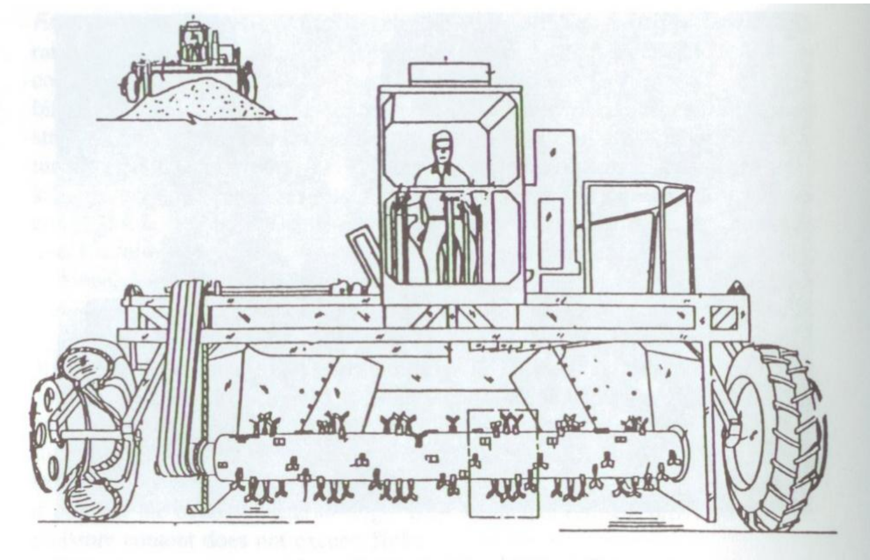


***Figure 2.13*: Large mechanical turner (Diaz et al., 1993)**

***Side cutting turners*:** The side-cutting turner operates by slicing away the sides of the composting pile and rebuilding the pile next to the old one (Figure 2.14; Ekelund & Nystrom, 2007:15 & Photograph 2.3; Recycling Product News, 1999). It is expensive to purchase and turning creates dust, which needs to be mitigated (see Chapter 3). The main advantage of this technology is that it can be used for large (3m high) windrows. Initial space is needed to re-locate the first windrow to the next position. After this, the opening left by the first windrow can be used to relocate the second windrow.

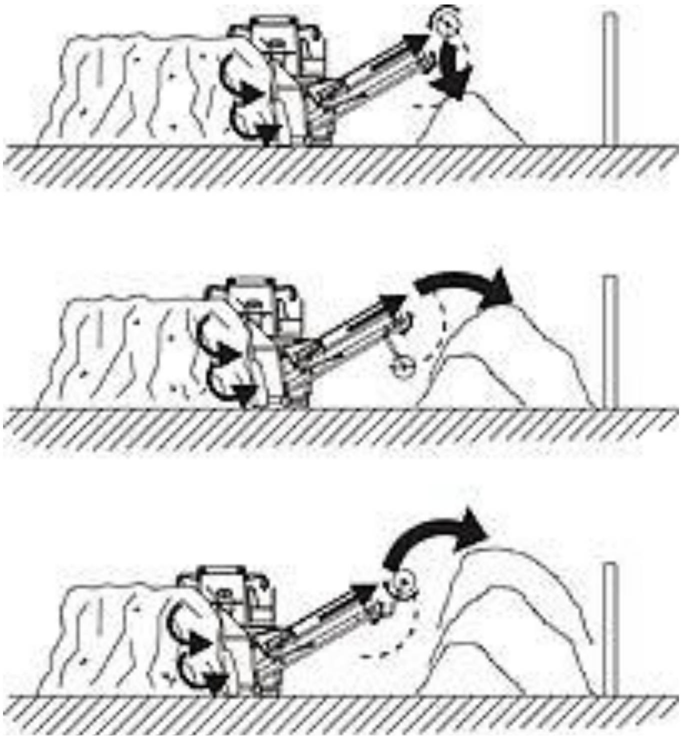


***Figure 2.14*: Side cutting turners (Ekelund & Nystrom, 2007)**

***Photograph 2.3*: Side cutting turners**

2.9.2.3 Manual turning

In small scale composting operations, manual turning can be considered as an alternative in municipal composting in developing countries. Home composting in developed countries usually make use of hand turning (Ekelund & Nystrom, 2007). This is a cheap method and in municipal composting context will provide jobs to people that would otherwise not have had a job. However, it needs to be regulated according to a scheduled program to prevent adverse effects. The windrow will be typically small to ensure easy handling. Additionally, small windrows will dry out more easily, and when it rains, it will become saturated more easily, therefore proper water management is required (Ekelund & Nystrom, 2007). For manual turning, the best tool is a four or five-tined pitchfork (Diaz *et al*., 1993:151). This is ideal when access to cheap labour is possible and large capital costs are not available to maintain a facility.

2.9.2.4 In-vessel mechanical turning

***Vertical composting reactors*:** A large, usually cylindrical, structure of over 4 meters high is needed where material is fed in from the top and is fed out at the bottom after the composting process (Photograph 2.4; WasteMINZ, 2008).

***Photograph 2.4*: A vertical composting reactor**

Pressure-induced aeration from the bottom upwards controls the process. This static vertical reactor is most successful in sludge composting, but is not so suitable for garden waste, which is this study addresses. Additionally, it has a large visual impact (Du Plessis 2006:8) and high installation costs. This technology is not widely implemented in South Africa.

***Horizontal composting reactors*:** An enclosed horizontal reactor, 2 to 3 meters high, feeds in the compost at one end and out at the other end (Photograph 2.5; WasteMINZ, 2008). It may use pressure or vacuum-induced aeration, which is set in the floor of the reactor. The control variables may be temperature or oxygen. Static or agitated systems may also be used. The agitated system uses the internal turning mechanism to move the waste through the system continually (Du Plessis 2006:8), increasing the effectiveness of the method. This method is also not widely used in South Africa.

Photograph 2.5: **A horizontal composting reactor**

***Rotating drum-composting reactors*:** The rotating drum or digester retains the waste material for only a few hours or days, where the tumbling action helps homogenise and shred the material (Figure 2.15; NIST, 2001). It is therefore more of a physical process to prepare the material for further composting by means of a biological process such as windrows (Du Plessis, 2006). This is also expensive technology more suitable for larger composting operations and must therefore be used optimally. In the South Western Cape, Ocean Agriculture uses this technology to mix compost with organic fertilisers. It is then pellitised to provide a product, which has a slow release of chemicals into the soil (Diedericks, 2007).

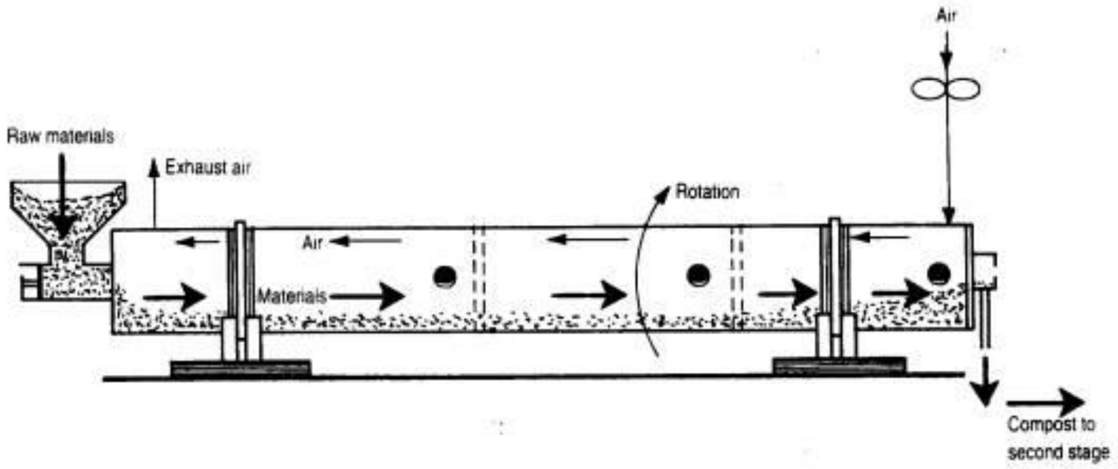


Figure 2.15**: A rotating drum composting reactor (NIST, 2001)**

2.9.3 Choosing a composting method

In Table 2.3 on the following page, the advantages and disadvantages the different technologies used commonly in South Africa are compared.

To determine the economics of the different systems will need an entire study on its own, since it varies according to circumstances, size and degree of mechanisation of the process. It is, however, certain that windrow composting is much less expensive than mechanised composting. Major expenditure lies in the machinery, the shelters for the final products and in densely populated areas for odour control (Diaz *et al*., 1993:155). To start composting operations careful planning needs to be done to ensure that it will be sustainable in the long run.

***Table 2.3*: Advantages and disadvantages with different types of turning equipment [b]**

Loaders/Turners	ADVANTAGES	DISADVANTAGES
Front end loaders	• Simple to operate • Cheap operating costs • Machinery can be used for multiple purposes	• Capital outlay for equipment • Limited mechanical mixing and break down of material • Compact the material • Gives insufficient aeration • Requires space for windrows • No watering possible
Straddle turners	• Good mixing and break down of material • Space efficient if self-powered	• Limitations in size of windrows • Requires much space if tractor pulled
Side cutting turners	• No limitations in windrow size • Space efficient	• Relatively high initial capital costs • Only large scale
Rotating conditioner drum	• Shortens the time needed in windrows • Small space required	• High capital costs • Post-treatment with turning necessary

[b]Adapted from Ekelund & Nystrom, 2007:16.

2.9.4 Composting initiatives

The composting industry has to deal with several challenges including a lack of consistent product quality due to seasonal changes, market research and planning and investment. No accepted national compost specifications and sophisticated product marketing exist in the USA (EPA, 1997). This has led to organisations that support, guide and regulate the compost industry.

In the USA, composting as a waste reduction method is widely used. California Compost Quality Council (CCQC), for example, "is a unique alliance of compost producers, scientists, farmers, landscape contractors, and recycling advocates formed to administer compost quality guidelines in California" (CalRecycle, 2010).

The CCQC runs a program through which compost producers can verify their quality and can display the CCQC registration seal on their products to provide the buyer confidence in the product. The CCQC also maintains a database of compost producers to help potential buyers locate suppliers of quality compost. This organisation also coordinates with a network of soil scientists and laboratory professionals who can answer technical questions regarding compost characteristics, applications and related issues posed by producers as well as buyers (CalRecycle, 2010).

In Europe, the European Composting Network (ECN) is a "collaboration of partners promoting sustainable practices in composting, anaerobic digestion and other treatment procedures for organic waste across Europe" (ECN, 2006). They also promote the exchange of knowledge, scientific research and development activities, provide information to decision makers on national and international level, organise workshops, seminars and establish and maintain relations with related international or national bodies.

In January 2007, the new MSW treatment plant in Vitoria-Gasteiz, the first in the Spanish Basque Country, was opened officially. This is the first of this kind of plant to make use of the organic fraction present in the municipal solid waste stream. About 50% of the waste finally sent to the landfill is reduced here. The plant treats 134,250 tonnes of waste/year, of which 120,750 tonnes are MSW and 13,500 tonnes plant waste (Hernanz, 2007). In South Africa there is not an overarching organisation for compost generators like those mentioned. The Department of Agriculture determines the South African Composting Standards, which falls under the general banner of fertilizers.

2.9.5 Products and challenges

A wide variety of composting products can be developed, depending on the need of the market. Products may include top dressing for lawns, potting soil, mulch, etc. *Ocean*, a supplier of agricultural fertilizers, produces its own compost and mixes the compost with chemical fertilizers to promote the slow release of the chemical fertilizers (Diedericks, 2007). Many composting companies market their products in home repair, garden centre, and other retail outlets (EPA, 1997). The most common market segments include landscaping, land reclamation (landfills and quarries), top dressing (i.e. golf courses, park land), erosion control, nurseries, residential gardening and agriculture (Diaz *et al*., 1993:175). Compost can also be used to control odours through new process technologies such as biofilters, while others are using compost as a filter in water treatment systems (EPA, 1997).

Compost users range from city and country landscaping to niche markets, such as soil remediation. However, new technologies allow compost companies to tailor their products to specific end-uses, thereby increasing the market value of the material. To guarantee a market, more and more compost producers are engineering multiple compost products for applications as diverse as bioremediation of contaminated soil and erosion control at construction sites (EPA, 1997).

2.9.6 Quality of compost

Composting in South Africa does not have it's own standards, but is classified according to the fertilizer standards as determined by the Department of Agriculture of South Africa. Composting may be classified as a Group 2 or 3 fertilizers, indicating the exact standards, whereas in the USA composting standards exist for the separate states.

Organic wastes contain plant nutrients, which enhance the soil fertility when applied, but the nitrogen, phosphorous and potassium content is usually insufficient for products to be legally classified as fertilizers (Diaz *at al*., 1993:103). Organic waste suitable to use as a fertilizer include the following categories: garden and crop debris; animal and human waste (provided pathogens and parasites are destroyed before used); and food processing waste (like a cannery) (Diaz *at al*., 1993:104). A major problem with green waste is that there is not control over the composition of what is being received, making it difficult to ensure a consistent quality (Soil and More Reliance South Africa, 2008).

2.10 CONCLUSION

In this chapter the value of compost as a soil conditioner was discussed. It was found to be a valuable resource with numerous benefits: it improves the condition of the soil; it can be used to remediate contaminated soil; it has the ability to absorb odours and treat semi-volatile and volatile organic compounds and thus prevents pollution; compost helps reduce the need for water, fertilizers, and pesticides; it can be used to maintain and beautify city parks; the lifespan of the landfill is extended and the absence of green waste in the landfill site reduces the generation of methane gas in landfills.

An overview of the composting process was provided, covering the aerobic and anaerobic composting processes. The essential elements of the composting process, *C:N Ratio*, moisture content, aeration, heat and pH were explained. Composting in South Africa was discussed and the focus on CTMM revealed that the required amount of green waste for successful municipal composting does exist, in fact, one third of domestic waste consists of green waste.

Selected methods that might be considered for a municipal Composting Facility in South Africa were explored. It was concluded that it would depend on the specific circumstances when the best composting method is selected. International initiatives, the products and challenges of the composting process, as well as the quality of the compost as a useful product, were also outlined.

ENDNOTES

[i] Vermicomposting refers to the introduction of macrofauna e.g. earthworms into the composting pile to enhance the composting process.

[ii] Thermophilic range refers to temperatures in the composting body of 45° and higher (Diaz *et al*., 1993:227).

[iii] Leachate is a noxious, mineralised liquid capable of transporting bacterial pollutants, produced when water infiltrates through waste material and becomes polluted and contaminated (Botkin & Keller, 2007:G-10).

Chapter 3

IDENTIFICATION OF THE MINIMUM REQUIREMENTS FOR A COMPOSTING FACILITY

3.1 INTRODUCTION

In Chapter 2, green waste as a resource was discussed, as well as the way in which green waste can be treated to be converted into a usable product, i.e. compost. In this chapter attention will be turned to another resource needed for the process of compost making, and that is available space. It is suggested that open space on landfills be used for this purpose.

To come to this conclusion, it is necessary to look at the minimum requirements landfill sites need to comply with, to ensure that waste would be handled in a responsible way. Included in the minimum requirements are the prescriptions regarding the establishment of a new landfill site, the operational requirements for the lifespan of the landfill, as well as the use of a landfill site after it reaches full capacity. It is then necessary to evaluate these requirements for a successful landfill site with a composting facility and indicate how it fits in with facility requirements for the purpose of composting.

Since the collection, transportation and disposal of waste is the responsibility of the municipality, it follows that it must become the responsibility of municipalities to initiate and oversee composting, as composting of the green fraction of municipal solid waste is a way of treating and recycling waste. A composting facility needs to be located within the municipal borders to minimise transport costs and therefore must either be undertaken by the municipality or it must be outsourced to a private enterprise, making the green waste available for this purpose.

If the green waste is available, and the best method of composting in terms of effectiveness and economics has been selected as was presented in the previous chapter, a location (i.e. available space) for the composting plant needs to be identified. The space allocated for composting needs to be large enough and compliant with rules and regulations due to the fact that it is a portion of general waste, which can have adverse effects on the environment and surrounding population if it is not regulated properly.

3.2 MINIMUM REQUIREMENTS

> *"There are only three places for waste to end up: in the ground, in the water or in the air."* (Arms, 1994:395)

When a landfill is planned, there is a lengthy process of site selection, which will not be discussed here in detail. At this point, it is sufficient to say that a landfill has to comply with strict regulations for sanitary landfill sites to protect the health of the people and the environment from pollution. Williams (1998:16) confirms that "…more stringent regulations requiring high standards of site lining, monitoring of gas and leachate and post-closure liabilities" is needed. It is therefore becoming more and more important to design and manage a landfill in such a way as to minimise impacts on the surrounding environment.

Before 1970, the bulk of domestic waste consisted of wood, paper, food and lawn clippings, which decomposed as it was exposed to air (Arms, 1994). An increase in volumes of waste, as well as the change in composition of the waste (more plastic, glass, aluminium and metal objects), resulted in the fact that the waste was no longer exposed to the air for rapid decomposition, causing a build-up of gasses in the waste body (Arms, 1994).

The change in waste composition is evident when one considers that currently nearly 7% of municipal waste is hazardous therefore needing pre-treatment. It is not always possible to control this kind of hazardous waste, as it is not dumped in bulk, but comes in the form of containers that held household insecticides, cleaning compounds, oil, hair spray and numerous other substances (Arms, 1994). The electronic age brought a new kind of waste in the form of computers, cell phones, batteries, etc. Due to the rapid development of electronic equipment, old equipment becomes outmoded, although it still functions, and is replaced with new ones, thus increasing the amount of waste. This has led to strict regulations and the establishment of sanitary landfills, as it is known today (Arms, 1994). In October 1976, the Congress of the USA prohibited open dumps and commissioned that it be changed into sanitary landfills (Kupchella & Hyland, 1993:403). In 2005, the Minimum Requirements became the prescribed legislation in South Africa to deal with the protection of the environment with regard to landfill sites. Although South Africa has many characteristics of a third world country, its environmental legislation has first world standards. This is essentially true for waste management, especially in the metropolitan areas where municipalities are regulated by strict rules, and encouraged to comply with the high standards. These standards are contained in the Minimum Requirements of 1998 prescribed by government which was a result of the acceptance of the Environmental Conservation Act of 1989 and the National Environmental Management Act of 1998.

In September 1989, the Environmental Impact Assessment Regulations was published in Government Gazette No. 18261, where waste was identified as an issue to be addressed urgently by means of guidelines (DWAF, 2005). Based on the principle of Integrated Environmental Management (IEM) and supported by the Environment Conservation Act 1989 (Act 73 of 1989) (DWAF, 2005:1-5), the Minimum Requirements for Waste Disposal was developed and accepted in 1994 as the standard for waste disposal in South Africa. This is an original document based on certain principles custom made to suit South African conditions (DWAF, 2005:1-2).

Since then, the challenges have changed significantly, and the third edition of Minimum Requirements has already seen the light. Although these Minimum Requirements regulate 'end-of-pipe', it strongly encourages waste reduction at the source (Bredenhann, 2005). It should be mentioned that the waste related activities must meet the 'Best Practicable Environmental Option' (BPEO), providing maximum benefit with the least damage to the environment. The systems and processes used to implement the waste-related activities need to be the "'Best Available Technology Not Entailing Excessive Cost' (BATNEEC), where 'excessive cost' is determined by a cost benefit analysis." (DWAF, 2005:1-2).

The Minimum Requirements therefore aims to assist the waste management environment with guidelines in order to comply with the required legislation (DWAF, 2005). Although not the aim, compliance with the Minimum Requirements increases waste disposal costs tremendously, and waste minimisation is therefore essential. Disposal cost per ton for a new landfill is between R80 and R100, as opposed to the disposal cost of R22 to R30 for 'old' landfills (Dekker, 2007).

Green waste is regulated under the same strict rules like that for general waste, as discussed above. In terms of these requirements, a composting facility has to comply with the Minimum Requirements. Environmental issues to be considered during the operational phase of the composting facility include aesthetics, bad odours, noise, windblown litter, dust and leachate, as well as social factors such as health, safety and security. Therefore, during the planning of such a facility these issues need to be taken into account.

Since composting is often regarded as 'not a viable business' as mentioned earlier, it is important to minimise operational costs including expenses for the land, transport, equipment and labour. Added to this is the process of obtaining a licence for the treatment and storage of waste. New legislation in the form of the National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008) emphasises the need for the protection of the environment with thorough environmental impact assessment to qualify for a licence. The process to purchase land at high cost and to start the lengthy and expensive Environmental Impact Assessment procedure for obtaining a waste license to establish a composting facility, can be accelerated by utilising available land owned by the municipality, like a landfill site for which a license has already been issued for waste disposal. It will, however be essential to make an amendment to the current authorisation, and to have a proper environmental management program and operational plan for the composting facility.

The findings of an inspection of an established composting facility on a closed landfill where space was available will be presented for the purpose of consolidating and expanding the criteria identified in the literature. This will culminate in a final set of criteria of the parameters that have relevance. The latter will be applied to selected sites in the City of Tshwane Metropolitan Municipality (CTMM) where the feasibility for establishing a composting facility will be evaluated and reported in Chapter 4.

3.3 END-USE

Prior to discussing an already established facility, consideration must be given to the issues behind the founding as well as final closing of a landfill site which will aid in the selection process of potential composting facilities on a closed site. Modern landfill management aims to protect three important resources (air, land and water) from contamination in the operational, as well as in the decommissioning phase of a landfill site (Arms, 1994). Resulting from this are the regulations on the closure of landfills that require sealing it off to minimise water and air pollution and therefore bad odours, which is the complaint most often voiced by communities around sanitary landfill sites in or near residential areas. South Africa’s own set of regulations in the form of Minimum Requirements will be discussed more extensively below.

Since landfill sites are permanent features, it has the potential for a long-term effect on the environment after closure. Therefore, as part of the planning process, specified closure plans are necessary, which entails remediation and aftercare to ensure sustained suitability and environmental acceptability (DWAF, 1998: Section 12). Measures to protect the environment vary with local conditions and include plastic or clay liners to protect the groundwater from pollution of leachate generated by the waste, a leachate collection system in the waste body to allow for drainage of internal moisture and a treatment plant for leachate water (Arms, 1994). These measures are implemented when the landfill is constructed and will ensure a reduced impact on the environment for the 30-40 years of aftercare. As required by law and as stipulated in the Minimum Requirements, this is the period that a landfill owner has to take responsibility for any adverse environmental effects that a landfill may have after closure.

Final closure of landfills with a cap endeavours to protect ongoing pollution of the air. Capping a landfill site has advanced into a science of its own and consists of several layers. Overlying the waste body is the gas collection layer, consisting of a porous material such as geotextile, geonet or a course sand layer. Gas permeates through this layer to the gas collection and control system (Williams, 1998). The landfill gas consists of a high percentage of toxic and flammable methane gas. Interior methane probes prevent internal combustion of the waste (Arms, 1994). The properties of the landfill gas make it viable for the generation of electricity. Gas extraction systems are often implemented to utilise this methane gas for energy recovery as part of the remediation process.

Overlying the gas collection layer a barrier layer follows which has a low permeability and can consist of a plastic polymer geomembrane, a geosynthetic clay liner of bentonite or geotextile fabric, or compacted natural clay. This barrier layer is designed to prevent the ingress of water and the egress of landfill gas (Williams, 1998). The barrier layer may have a protective geotextile layer above and below with a drainage system to prevent water from reaching the barrier layer. This drainage system consists of pipes in a porous layer of coarse sand or gravel, geotextile, geonet, etc. This protection layer is necessary to protect the underlying lining system from plant roots, burrowing animals and manmade intrusions. The protection layer usually is an extension of the restoration layer and consists of soils. The restoration layer is landscaped to enhance the run-off of surface water. This is collected in drainage canals that border the landfill site. Depending on the end-use, plants are planted in this layer (DWAF, 1998: Section 12).

Another problem with closure that needs to be considered includes differential settlement, which refers to the uneven decomposition[i] of waste, and may influence the integrity of the capping of the landfill. It also limits the uses of the area, since no permanent structures can be erected here. During the licensing process, the applicant of a proposed landfill site must identify an end-use after the landfill site has reached its full capacity. This must be an acceptable end-use taking into account the properties of the waste body and the socio-economic nature of the area. An important aspect of deciding on the end-use is the involvement of Interested and Affected Parties, as determined by the permit application process (DWAF, 1998: Section 12).

In the USA, permanent structures are allowed on the waste body, provided it has decomposed for some time, and that they use specified engineering techniques (SCS, 2009). Closed landfills have been successfully developed as sites for a variety of land uses (SCS, 2009):

- Regional malls and big box retail;
- Office and light industrial parks;
- Hotels and high rise commercial;
- Government centres, jails, animal shelters, maintenance facilities, greenhouses;
- Parks, including golf courses, ball fields, amphitheatres, firing ranges;
- Residential, including single family and multifamily housing.

Mount Trashmore in Virginia is an example that serves as an innovative approach to useful solid waste disposal. The hill of waste is 72ft high, 800ft long and 100ft wide and is composed of 85% solid waste. It is being used as a recreational area. Other uses, after capping, include parks, playgrounds, golf courses and other uses as long as it does not require heavy construction (Kupchella & Hyland, 1993:404).

In South Africa, closed landfill sites in smaller towns are used for grazing areas. In the cities of Gauteng end-uses include sports fields for schools (e.g.

Langenhoven High School), golf courses (e.g. Pretoria North), horse riding area (e.g. Linbro Park), etc. The end-use as determined in the initial permit application, often has to be revised since the environment around the landfill site usually changes during the time that the landfill was active. The establishment of composting facilities on closed municipal landfill sites as an end-use is a further option for the following reasons: open areas within urban boundaries are always under pressure due to the lack of space because of the high prices of land; the high costs resulting from the expensive licensing process; expensive mitigation measures as were mentioned in the preceding discussion. Since the end-use of closed landfill sites is highly limited, it would be to the benefit of the community and the environment if these sites could be put to functional use with the added benefit of an income from selling compost.

3.4 REQUIREMENTS FOR COMPOSTING FACILITIES

> *"Composting facilities was one of the great challenges of the past decade."* (Stephens, 2007)

The reason for this challenge is not only the process of compost making, but also to 'regulate' the composting facility. In South Africa municipal composting facilities need to comply with the same requirements as a general waste disposal facility, as it is regarded as part of the general waste stream. Composting is also a recycling facility, adding value to the 'waste' that is being treated and turning it into a useful soil conditioner. The treatment process of the green waste can have certain adverse effects influencing the natural, social and economical environment around it. These issues need to be addressed in order to make composting facilities viable, acceptable in the community, and to prevent it from having adverse effects on the environment.

In the subsequent discussions, the physical parameters mentioned above shall be discussed in more detail for the purpose of determining a set of requirements that would apply to composting facilities in particular. At present there is no designated set of rules to regulate composting facilities in South Africa. Therefore the rules for disposal of general waste must be applied as prescribed in the Minimum Requirement series. In order to focus more on waste minimisation, the then Gauteng Department of Agriculture, Conservation and Environment (GDACE), now the Gauteng Department of Agriculture and Rural Development (GDARD) started an initiative in 2008 to draft guidelines to regulate any recycling initiatives to ensure health and safety, as well as the protection of the environment. Consistent with the Final Version of the Draft of General Waste Management Facilities Standards of June 2009, facilities are classified according to the effect the facility will have on the environment. Composting Facilities are classified as follows (GDACE, 2009):

Level 1 - Chip and stockpile only,
Level 2 - Small scale windrows without screening,
Level 3 - Large scale windrows with screening,
Level 4 - Enclosed composting for food waste.

This confirms that there is an effect on the environment, which needs to be considered.

In the following discussion these, as well as international regulations will be investigated in an attempt to determine a set of guidelines for composting facilities for the City of Tshwane Metropolitan Municipality, with a possible wider application for South Africa. As was motivated earlier, through the proper management of the green waste within municipal borders and consequent establishment of composting facilities, the lifespan of a landfill can be extended by 30%.

3.4.1 Environmental factors

It follows that, according to the Minimum Requirements of DWAF (currently the Department of Water Affairs (DWA), waste disposal needs to be regulated to prevent adverse aspects to the environment (DWAF, 2005:1-2). These effects will now be considered and an evaluation will be provided as to how composting facilities on landfill sites will comply with the requirements.

3.4.1.1 Air quality

Bad odours, the creation of dust and bio-aerosols can influence air quality as a result of composting activities. The air quality has an influence on the health of people. The regulations and parameters used to determine acceptable emission standards for South Africa are included in the Atmospheric Pollution Act, (replaced by the Atmospheric Prevention Pollution Act), Act no 45 of 1965 of 11 September 2009, guidelines of the Department of Environmental Affairs and Tourism and the Occupational Health and Safety Act (Du Plessis, 2006). The requirements of these legislative prescriptions need to be taken into consideration when the method of composting, as well as operational guidelines are selected to prevent degradation of the air quality in the immediate vicinity of the composting facility. During composting a natural breakdown of organic material produces primarily carbon dioxide and water vapour, and heating takes place. When this process is unbalanced, other gasses with objectionable odours may be released. Odour management is therefore one of the key reasons why the composting process needs to be optimised.

When siting a facility, it is important to bear in mind what kind of emissions will be released by the composting process. Careful selection of the best method for composting can reduce any undesirable effects. Different harmful gasses are produced due to composting activities. These gasses occur in small quantities and are generally not an immediate threat to human health. Discussion of these gasses is needed to emphasise the importance of proper management of the composting process.

Volatile (potentially explosive) gasses producing odours and their effects include:

- Carbon dioxide is the principal greenhouse gas emitted by human activity. A high concentration can be toxic, leading to an increase in the breathing rate and ultimately unconsciousness and death (Du Plessis, 2006).
- Methane is not toxic; it is a simple asphyxiant and highly flammable (Phillips, 2002a). Asphyxiants include two types of chemicals: firstly simple asphyxiants are those that displace oxygen in the air (i.e. nitrogen, hydrogen

and carbon dioxide, methane); secondly, toxic asphyxiants are chemicals that prevent oxygen transfer, or disable the cells from absorbing oxygen (cyanide, hydrogen sulphide, carbon monoxide) (DEAT, 2007). The effect of methane as an asphyxiant is therefore that an oxygen deficit is created but it does not have any other significant physiological effects (Phillips, 2002a). Consequently, the result of inhaling too much methane is suffocation. Methane is typically formed under anaerobic conditions. If an aerobic composting process is used, methane is not likely to build up.

- Hydrogen cyanide (HCN) is a toxic asphyxiant that has a classic bitter almond odour and blocks the lungs' ability to use oxygen. It can be absorbed through inhalation, ingestion or skin absorption (DEAT, 2007). HCN is the pre-dominant form of cyanide in air, but can also occur in the soil and water (Du Plessis, 2006:13). Most animals and humans are able to detoxify and eliminate small amounts of cyanide, converting it to a less harmful compound thiocyanate (CNO). Larger quantities of cyanide can lead to weakness, headache, confusion, vertigo, fatigue, anxiety, dyspnoea and occasionally nausea and vomiting. Coma and convulsions have been recorded. Large amounts of cyanide lead to immediate death. Chronic exposure to cyanide may lead to weakness, nausea, headache and vertigo. Other symptoms like dermatitis, itching, scarlet rash, papules and severe nose irritation have been reported (Du Plessis, 2006). When material containing cyanide is used in the composting process, the air will be contaminated.

One well-known example is that the seeds and leaves of the Sago Palm, *Cycas revoluta*, are found to be toxic (Chang *et al*., 2004). Other plants that might occurs also in South Africa containing cyanide include Choke Cherry (*Prunus virginiana*), Arrow grass, White clover, Sudan grass, Johnson grass, Mountain mahogany, Velvet grass and Serviceberry (Donahue, 2002). *Nandina domestica, Phaseolus lunatus, Sorghum bicolor moench, Linum usitatissimum,* Japanese apricot (*Prunus mume*), loquat (*Eryobotrya japonica*) all contain cyanide in varying amounts (Miller & Conn, 1980).

- Hydrogen sulphate has the smell of rotten eggs (DEAT, 2007). Hydrogen sulphide (H_2S) may occur due to the presence of organic material, which is subject to rapid microbial decomposition, the reduction of sulphate and the mineralisation of organic sulphur compounds. Chronic symptoms include irritation of the eyes and respiratory organs, bronchial catarrh, nausea, malfunction of the olfactory nerves at large concentrations, spasms, numbness and ultimately death due to respiratory paralysis (Du Plessis, 2006). Olfactory fatigue (continuous exposure to a specific odour leading to a decrease in ability to detect it) may occur, blocking the ability of the lungs to use oxygen (DEAT, 2007). When H_2S dissolves in water it becomes undrinkable (Du Plessis, 2006). The danger is more acute in enclosed areas (DEAT, 2007). No build-up of H_2S will occur should an aerobic composting process be used.

It is important to assess the potential sources of odours as well as the emission rates, the detectability and the concentration. Meteorological information like wind speed, direction, temperature and inversion conditions will be needed to predict the direction and distance of the odours (EPA, 1994). Additives from chicken or beef farms, even sewerage farms may cause more odours than green waste alone. In such cases it will be wise not to have the composting facility in the residential area, but in an area zoned for industrial, or an area where a proper buffer zone can be put into effect (EPA, 1994). It will also be advisable to have a closed system to minimise the effect.

A complete list of either specifically identified or implicated compounds in composting odours is presented in Table 3.1.

Table 3.1: Possible composition of composting odours[a]

Sulphur compounds		
Hydrogen sulphide Carbon oxysulphide Carbon disulphide	Dimethyl sulphide Dimethyl disulphide Dimethyl trisulphide	Methanethiol Ethanethiol
Ammonia and Hydrogen-containing compounds		
Amminio Aminimethane	Dimethylamine Trimethylamine	3-methylindale
Volatile fatty acids		
Methanoic Ethanoic	Propanoic Butanoic	Pentanoic s-methylbutanoic
Ketones		
Propanane	Butanane	2-pentonone
Other compounds		
Benzothiozole	Ethanol	Phenol

[a] (EPA, 1994:70)

<u>Dust</u> can be generated from dry, uncontained organic materials. This will increase during screening and shredding and from vehicles driving over unkempt roads. Dust can clog equipment and can carry bacteria and fungi that can affect the health of workers at the facility (EPA, 1994). Dust is increased during the turning process. Therefore, it is important not to mix the compost on windy days and to water the piles while turning thereby reducing the amount of dust.

<u>Bio-aerosols</u> are suspensions of particles in the air consisting of micro-organisms that can be inhaled. A very common fungi is *Asperigillus fumigates*, which is not a health hazard to healthy people, but might affect persons susceptible to it, and can lead to a weakened immune system, asthma, diabetes and allergies, to name but a few. *Asperigillus fumigates* is often found in the dust of incoming material, but concentration levels decrease rapidly over a short distance (EPA, 1994). An appropriate buffer zone, as well as dust masks for the workers might be appropriate measures to minimise the effect of the bio-aerosols.

Mitigation measures can reduce odour effects to improve air quality. Firstly, the composting method and the *C:N* Ratio will play an important role in the amount of odours and emissions that will be released. This will also determine the type of material that can be accepted for composting. Secondly, should odorous material arrive, it is best to mix it quickly into high-carbon material. Thirdly, a layer of finished compost can be used to cover the outside of the pile to act as a bio-filter. Fourthly, local weather conditions need to be taken into account before turning or moving the compost. Wind direction and speed will determine dispersion of potential odorous or dusty materials to neighbouring areas. It will not be a suitable option to turn windrows on a windy day. A low barometric pressure may cause gasses to flow at ground level, and high pressure can cause it to disperse. Fifthly, ensure good drainage (Phillips, 2002b). Lastly, the location of the composting facilities with offensive odours can be placed where the influence on daily lives will be minimal (EPA, 1994), like a buffer zone to protect residents or occupants of neighbouring properties. Additionally, Personal Protective Equipment (PPE) like facemasks for the workers will minimise the effect of possible harmful bio-aerosols.

Air pollution is not a major problem when the composting facility is managed properly. In 1991, Professor Finstein emphasised the fact that no composting facility will survive politically if the odour control is not effective (Montague, 1993). Large areas are therefore needed to minimise the effect of bad odours, dust and bio-aerosols, rendering a landfill site, with the accompanying buffer, a suitable option. Alternatively, should a buffer zone not be available, an in-vessel composting method can be implemented. This is, however, far more expensive than open windrows.

3.4.1.2 Fires

High temperatures of up to 93°C in dry compost piles can lead to spontaneous combustion. This is only possible when windrows are four meters and higher. The risk of fires can be reduced by keeping the windrows three meters or lower, by good site security to prevent arson and dumping of flammable materials like diesel, as well as the prevention of the accumulation of dust (EPA, 1994). The Minimum Requirements (DWAF, 2005) makes provision for good site security on a landfill site including *inter alia*, fire-fighting equipment, emergency numbers and access on site for emergency vehicles like fire-fighting vehicles. Spontaneous fires are common on active landfill sites. Therefore it is suggested that composting facilities be established either on old cells or open, unused areas to prevent the possibility of spontaneous fires.

3.4.1.3 Water

Water management must be considered in terms of surface water, ground water and leachate. Surface water can either be run-off or storm water. Storm water refers to the water, which floods the composting facility after rain events. Standing water will create muddy conditions increasing the risk of erosion and water pollution with the subsequent rainstorm event, while also increasing operational cost and difficulties (Du Plessis, 2006). If storm water is not controlled properly, flooding can wash away the windrows, or pooling can slow down the composting process because the soil is too wet, and the windrow turner will not be able to access the site (EPA, 1994). Windrows should be constructed along the slope of the pad instead of across it to encourage effective drainage (Phillips, 2002b).

Various erosion control measures should be implemented to reduce the possibility of soil loss (EPA, 1994). One way is that storm water control needs to be installed to divert sheet flow from the surrounding areas away from the windrow and storage areas (EPA, 1994). This is done by means of storm water channels, cut-off berms, drainage ditches or interceptor drains (Phillips, 2002b). Rainwater on the windrow pad should be controlled by drainage devices to remove the water from the pad as quickly as possible through a storm water system into an evaporation pond or treatment facility. The water should be retained in this facility until it has evaporated or has been treated to acceptable standards to be released into the existing storm water system (Du Plessis, 2006). The storm water channels must be maintained to ensure it is an efficient operation. These drains must be checked regularly and plastic bags, paper and other objects accumulating in these drains must be removed (Du Plessis, 2006). Another storm water control measure is that composting facilities should not be allowed in areas located within the 1:50 and 1:100 year flood lines.

Leachate refers to "the liquid that results when water comes into contact with a solid material, either dissolved or suspended from the solid" (Phillips, 2002b:1). In the composting context, Phillips (2002b:1) describes it as a "liquid that has percolated through and drained from feedstock or compost and has extracted dissolved or suspended materials". The main concerns are the enhanced nutrient load, Biochemical Oxygen Demand (BOD) and the presence of phenols. A high BOD can be a potential threat to aquatic life because it depletes the dissolved oxygen in surface water bodies (EPA, 1994). When percolating through soil, natural phenols and BOD are reduced by the soil biota and is not considered to be a threat to ground water (EPA, 1994).

The leachate emanating from the composting process is commonly regarded as a potential pollution source of surface water due to this high nitrate content. A common source of nutrients in composting piles is grass clippings (EPA, 1994). By adding carbons to keep the *C:N Ratio* (1:3) of the compost in balance, it will help to minimise the loss of nitrogen into leachate (Phillips, 2002b:1). When too much nitrate is released in large quantities into water sources, it can lead to eutrophication. Botkin and Keller (2005:G-7) describe eutrophication as follows: "Increased nutrient loading may lead to a population explosion of photosynthetic algae and blue-green bacteria that become so thick that light cannot penetrate the water. Bacteria deprived of light beneath the surface die; as they decompose, dissolved oxygen in the lake is lowered and eventually a fish kill may result." Wetlands, floodplains and other surface water, as well as ground water should be protected from this compost water called 'leachate' (EPA, 1994).

The Minimum Requirements have strict regulations to protect the ground water. For this, an engineered designed liner is suggested, which is extremely expensive and cannot be justified by the income composting will generate (Du Plessis, 2006). This is a strong motivation to place the composting facilities on a landfill site where a liner should already have been installed. Ground water refers to water under the soil surface where saturation conditions exist (Botkin &

Keller, 2007). Leachate as mentioned above may pollute ground water if it is allowed to percolate into the soil.

To prevent the possibility of groundwater pollution, storm water must be managed well i.e. the windrows need to be operated on a compost pad. This pad must be graded in a manner to prevent ponding, flooding by storm water, and to ensure that the leachate is channelled into a leachate pond (Phillips, 2002b). The composting pad must be constructed of materials such as concrete (with sealed joints), asphalted concrete, or soil cement in order to prevent subsurface soil and ground water contamination. It is also important that the "entire surface area of the compost pad shall maintain its integrity under any machinery used for composting activities at the facility" (Washington State Legislature, 2003).

Soil type and structure have an influence on the run-on and run-off. Permeable soil is not preferred since it can lead to ponding and will limit vehicular access. The surface should ideally be an impermeable clay layer, or paved (EPA, 1994). The advantage of having a composting facility on a landfill site, is that storm water control measures in the form of a cut-off trench is a requirement of the licence conditions when the landfill site is established. It is a large capital layout, and could therefore save initial costs during the establishment of a composting facility.

3.4.1.4 Noise

International noise-emission standards are designed to control the noise emitted by specific machines, vehicles or industrial equipment and procedures. National or local authorities normally devise environmental noise exposure standards and legislation that provide an acceptable noise environment for their particular conditions. Noise emission levels depend not only on the noise emitted by specific sources, but also the distance from the source and the use of noise attenuation measures such as noise barriers to meet national or local noise emission standards at the property line (Du Plessis, 2006).

In terms of Regulation 7 of the Environmental Regulations for workplaces, promulgated under the Machinery and Occupational Safety Act 6 of 1983 (Notice R2281 of 16 October 1987), no employer may require or permit an employee to work in an environment in which he or she is exposed to a noise level equal to or exceeding 85 decibels (EPA, 1994).

To put this into context, the Gauteng Noise Regulations suggest 70 decibels for industrial use, and 55.5 decibels for residential areas (Du Plessis, 2006). Noise at a composting facility is generated by incoming and outgoing trucks, as well as by equipment like hammer mills, shredders and grinders, turners and front-end loaders. The noisiest of this equipment is about 90 decibels at the source (EPA, 1994).

Noise reduction measures include:

- Operation of the composting facility must be restricted to normal working hours (07:00 to 17:00 during weekdays, and 07:00 to 13:00 on Saturdays, no operation on Sundays);
- Equipment must have noise-reduction features such as noise hoods and mufflers;
- Noise reduction equipment must be properly maintained;
- Operators of the equipment, as well as those working in close proximity of the sound generating equipment, must be provided with hearing protection as prescribed by the Health and Safety regulations;
- A wall around the composting facility, a soil berm, trees or a buffer zone will provide effective reduction in the sound for the surrounding communities (EPA, 1994).

The required buffer zone of a landfill site will automatically reduce the noise problem, should a composting facility be established there.

3.4.1.5 Vermin and disease vectors

Composting facilities, as any waste management facility, has the potential to attract pests (Composting Council of Canada, 2006). Mice, rats, mosquitoes and flies all have the potential to carry diseases, and may be attracted by the food and shelter available at composting facilities. This may cause health hazards and needs to be controlled by proper operating procedures (EPA, 1994) in terms of the correct method of composting. Offensive odours are a sign that there is a problem with the composting process. The most common causes are inadequate aeration or excessive moisture. Turned windrows are therefore the best option, with regular turning. Static windrows, which are not turned, should be covered with a layer of mature compost to prevent odour and vermin.

Rodents can be controlled by cats on the premises or by a professional exterminator if the problem gets out of hand. The temperatures reached in the composting process can kill all life stages of a housefly, which can transmit salmonella and other food-borne diseases. Mosquitoes breed in standing water; therefore ponding of water must be prevented. By good housekeeping, maintaining proper aerobic conditions and high temperatures (up to 57°C), and appropriate grading of the land, the transmission of diseases may be prevented (EPA, 1994). Prevention of bad odours, as well as keeping the site clean, will ensure that the site stays free of rodents and other pests (Composting Council of Canada, 2006).

Most of the requirements above are in place at a landfill site. Regulations requiring that the waste needs to be land filled at the end of each day, prevents odours, flies and rodents. Although composting will not be covered daily with soil, the principle of good housekeeping is required as will be prescribed by an environmental management program.

3.4.1.6 Litter

As green waste is part of the general domestic waste stream, provision must be made to accommodate litter. Windblown litter from incoming yard trimmings, as well as rejects from the screening process, may be the cause of complaints (EPA, 1994). The best way to mitigate this is to bring in clean green waste without plastic bags, paper and other litter. If this is not possible, the litter on site must be managed by using movable fences to facilitate the collection of the litter.

Incoming vehicles must be covered to prevent litter from being blown out. Litter must be cleaned as soon as it occurs before it scatters off site (EPA, 1994). Should the composting facility be sited within the premises of a landfill site, the problem of litter from the composting facility will be minor in comparison with that of the landfill operations, if land filling and composting coexist. The composting facility will be contained to a specific area and waste management must be enforced to keep the site tidy from litter. This is one of the Minimum Requirements as stipulated by DWAF (2005).

3.4.1.7 Health, safety and security

Exposure to bio-aerosols, other potential toxic substances, excessive noise, injuries from equipment, can all pose health and safety threats (EPA, 1994). This can be overcome by proper operation of the facility, adequate training, adequate site security and complying with relevant health and safety regulations (EPA, 1994). Landfill sites are monitored regarding health, safety and security. With this already in place, it is not necessary to duplicate it where a composting facility is established.

3.4.1.8 Visual

The fact that the facilities should be made accessible to be near the source to save transport costs and to stimulate participation in the program, necessitates measures that will screen it off acceptably to reduce the visual impact. This can be done by the construction of artificial buffer zones like earth berms, trees or walls. Usually it is not possible to implement the prescribed buffer zones due to lack of space (EPA, 1994), especially within suburbs. To summarise, the environmental and physical considerations are presented in Table 3.2.

Table 3.2 Environmental and physical criteria

Aspect	Impacts	Mitigation	Influences
Air	Odours	Type of material brought in, turning schedule, buffer zone	Composting method, siting, size,
	Dust	Watering, turn on windless days	Operations, composting method
	Bio-aerosols	Buffer zone, as well as dust masks	Siting
Fires		Windrows less than 3m high, security, dust build-up.	Composting method
Water	Leachate high nutrient load and BOD, phenols	Gradient, direction of windrows, storm water channels, cut-off berms, drainage ditches, interceptor drains, outside flood lines	
	Surface	Cut-off trench, Gradient Hard surface, direction of windrows	Siting
	Ground water	Hard surface prevents ponding	Siting, slope
Noise	Rest and quiet	Buffer zone, soil berm/wall, keep to office hours, noise reduction equipment	Siting, management
Vectors	Mice, rats, mosquitoes and flies carry diseases	High temperatures in composting kills germs Aerobic method, Good housekeeping	Operations, method
Litter	Wind-blown (Visual)	Fencing, quality control, regular cleaning,	Siting, management
Health, safety and security	Lives of people		Operations, equipment
Visual		Good housekeeping	Siting

Each composting site will need its own mitigation measures according to the location and the need. Should a composting facility be established on a landfill site, the visual impact will not be an important issue to consider, since large machinery, as well as mountains of waste and land filling operations are already present on the site.

3.4.2 Operational requirements

3.4.2.1 Siting requirements

Composting must be done on suitable land large enough for the operations. The ideal is to have land available as near to the source as possible. Open land within the borders of a city is very expensive and scarce, and it is unlikely that prime land will be used for composting (Du Plessis, 2008). Typical options would be near train tracks or highways, urban periphery and industrial areas.

Siting composting facilities presents great challenges (Stephens, 2007) since a wide range of factors needs to be taken into account for finding the best location. The purpose of this study is to investigate the possibility that existing space on landfill sites be used for composting facilities in general and to provide and evaluate the guidelines as suggested for this purpose, with a further possible application to establish South African guidelines. As seen above, a landfill site should already has physical, environmental and social aspects in place. According to Polprasert (1996), a composting facility needs to be operated as a business, while paying attention to aspects such as raw material, manpower, capital, technology, a market study and political goodwill. All of this will not be addressed in this study, but the focus will be on the possible locations for composting facilities on landfill sites.

Landfill sites will be the ideal locality for the siting of composting facilities because the legal and social aspects have already been dealt with. A landfill site needs a permit and, under the new National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008), acquiring a licence to operate with is a long and expensive (in terms of consultation fees) procedure. Included in this is the process of public participation to take care of the social aspects. Since a landfill site is an unacceptable feature for any person, it is selected with great care and thorough investigation. The surrounding areas of landfill sites usually act as buffer zones to minimise the influence on the neighbouring communities (Du Plessis, 2008).

The topography of potential sites should be evaluated according to the amount of clearing and site alteration required to prepare for the windrows. Minimising groundwork is desirable to reduce expenses. Trees should be left around the perimeter or planted to act as a visual, dust and sound buffer. To avoid water from forming ponds and run-off causing erosion, the site should be appropriately graded. It was found that a gradual gradient of 2-4% is ideal (EPA, 1994).

Sufficient space is needed as land area requirement for the incoming stockpiles, shredding, windrows, storage area for products and equipment, offices, ablution facilities, etc. (EPA, 1994). If the site is too small, it can decrease the efficiency of the plant and increase the operational costs. It is important to have enough space available to be able to stockpile enough raw material for one year ahead (EPA, 1994). This will ensure continuous operation. Due to the seasonal differences of South Africa, the incoming green waste not only differs in composition but also in volume.

3.4.2.2 Site design

The design of the composting facility will be such as to minimise all the possible environmental effects. Specific information on the mitigation measures for air quality, fire control, storm water control, leachate control, noise, vectors, litter, health, safety and security and visual were discussed. The layout design of each composting facility should take into account the operational needs of the composting process. In the previous chapter, the best method for composting in Southern African circumstances was found to be open windrows for its unique circumstances. Imbedded in these are the mitigation measures to control any adverse effects. The layout design will be discussed with this method as reference.

Enough space for the following areas is essential:

- *Pre-processing area*: Incoming material is stored in the pre-processing area near the entrance to the facility. In poor weather conditions it is not possible for incoming trucks to enter into the processing area to tip the material directly into the windrows. An added advantage is that incoming material can be controlled. As the composting material comes in, the different kinds of material are shredded, stored separately, shredded and wetted if need be to prevent it from loosing too much moisture (EPA, 1994). The area needs to be accessible for front-end loaders to scoop up the material to form the windrows

(EPA, 1994). A weighbridge will enable the operator to keep track of the amounts of incoming stock and the amount of finished and distributed products (EPA, 1994). The size of the pre-processing area depends on the amount of incoming material, and therefore on the size of the operation (EPA, 1994).

- *Processing area*: The largest part of the site will be allocated to the windrow pad. As discussed earlier, the pad needs to be firm and absorbent to prevent ponding around the windrows. It is important to maintain the slope of the pads to ensure continuous gentle drainage (EPA, 1994). The composting piles are 'built' in this area in parallel rows (EPA, 1994). The Minimum Requirements (DWAF, 2005) call for the pads to be lined with specialist geotextile layers, as is prescribed for lining new landfill sites for general waste. This is unattainably expensive for the developer of a composting facility. It is suggested that the gradient and a hard clay surface be accepted as sufficient to prevent possible pollution to the ground water. It remains important to have proper drainage. Surface requirements for windrow pads differ in different states of the USA, including asphalt and concrete surfaces. The size of the windrow area will depend on the amount of incoming material (EPA, 1994), the nature of the material (density and moisture content), the type of windrows (turned or static) and the turning mechanism (mechanical or hand-turning).

  Curing is the last stage of the composting process, and needs about a quarter of the space of the windrows. Curing entails the last step for the compost to mature fully. Cured compost is stable, and does not have the same danger of ground water contamination and other siting concerns, which need mitigation (EPA, 1994).

- *Post-processing area*: In preparation for selling the compost, it can be screened, bagged and stored, preferably under a roof. This area needs to have space available for at least a three-month's supply (EPA, 1994). It is important to either cover the bulk mature compost piles or to bag it to prevent windblown seeds to grow and in this way devaluate the product (EPA, 1994).

- *Buffer zone*: Ideally every site within a built-up area needs to have a buffer zone, but this is difficult to apply due to high land prices. In South Africa there is an additional problem that vacant land, intended to be a buffer zone around the landfill site, has the risk of being occupied by informal settlers, which then defies the purpose (Du Plessis, 2008). The location of the composting facility on a landfill site should automatically include a buffer zone (Du Plessis, 2008).
- *Onsite roads*: Onsite roads for incoming and outgoing trucks, composting equipment (turners, front-end loaders) and customer vehicles, as well as parking on the property are needed (EPA, 1994).
- *Administrative facilities and ablutions*: Composting is a business and for this purpose office facilities are required. As minimum standard electricity, drinking water, telephonic connection and toilet facilities should be available, even for small operations. An area to store and maintain equipment is also essential (EPA, 1994).

Composting facilities need to be near the source of the compost feedstock to minimise transport cost of the untreated greens to the site, as well as the compost product from the site to the clients. The amount of traffic will depend on the size and collection system. Municipal facilities will have a constant flow of traffic, and a dedicated road needs to lead to the tipping and storage area (EPA, 1994). Access to the site via tarred uncrowded roads through a non-residential area will contain transport expenses. Should busy roads be the only available, off-peak times can be used for the transport of greens. A centrally located site could have the added advantage of a drop-off facility for the public. An arrangement can be made to supply free compost for every drop-off of untreated green waste. This will encourage public participation (EPA, 1994). Should a landfill site be used for the operations, access is available since the site is frequented by heavy waste collecting trucks. To overcome the accessibility for participating public, the operations at garden sites can be used for drop-off.

The composting area must be fenced off and access control will regulate traffic. Signposts, speed limit measures (speed humps) and direction signs must be clearly visible. The access road must be an all-weather road, suitable for wet and dry conditions (Du Plessis, 2006). This road needs to lead up to the composting facility to drop off green waste or collect compost for distribution.

Concerning *land ownership*, available land for a composting operation is usually expensive since it must be located near the source. A potential compost operator will not be able to buy or lease expensive land and run an economical viable operation. The municipality owns the landfill sites and it makes economic sense to use it for monetary gain. *Site security* requires access control to the site that could prevent theft, vandalism, arson or other offences. A security fence around the site is also preferred (EPA, 1994). *Permit requirements* is a legal issue and is regulated by the National Environmental Management Act (NEMA) and the National Environmental Management Waste Act (NEM:WA) of 2008. Activities listed in terms of Section 24 (2)(A) and (D) of the National Environmental Management Act (NEMA), may not commence without environmental authorisation from the competent authority. In this respect, the investigation, assessment and communication of the potential impact of activities must follow the procedure as described in regulation 22 to 26 of the Environmental Impact Assessment (EIA) Regulations, 2006, promulgated in terms of Section 24 (5) of NEMA.

Composting facilities handling more than 20 tons per day as an average over 30 days are regarded as a listed activity (GN 386, 1 (o)). This regulation was repealed and replaced by Category A of GN 718, issued on 3 July 2009 in terms of the National Environmental Management: Waste Act 2008 (Act no 59 of 2008) and requires that a Basic Assessment Report be submitted for review with the aim to authorise it. Previously section 20 of the Environmental Conservation Act (ECA), 1989 was applicable for the permit application to run a composting operation. This was repealed by section 45 of the National Environmental Management: Waste Act 2008 (Act no 59 of 2008), which came into effect on 1

July 2009 (GDARD, 2010). Since the authorisation process is so cumbersome, a composting facility on an existing landfill site would be the ideal.

3.4.3 Composting method

The aerobic method, where the raw material is placed in open windrows and turned regularly, is suggested for the composting at landfill sites that will have a minimum effect on the surrounding area. Environmental issues like odours, noise, visual aspect, etc. will all be covered by the licensing conditions.

3.4.4 Reasons for designating landfills as open spaces

The aftercare of a landfill site was discussed in Chapter 2. In South Africa this is prescribed by the Minimum Requirements. In the study by Misgav *et al*. (2001), this worldwide problem is addressed namely, the re-use of sanitary landfills. One of the main sources of concern is the negative visual impact which sanitary landfills have on the surrounding environment, usually located within the city borders for the benefit of the community (Misgav *et al*., 2001). Because of uneven settlement[ii] of the waste, it is not likely that in South Africa it will be allowed to erect buildings on closed landfill sites, but due to the shortage of land, it will be best managed when it is regarded as an asset. Various means can be applied to mitigate problematic environmental conditions (Misgav *et al*., 2001). To strengthen financial investments for this commitment, it is best to gain an income from the end-use.

As discussed earlier, landfill sites will be the ideal location for the siting of composting facilities because the legal and social aspects have already been dealt with.

3.5 ASSESSMENT OF AN ESTABLISHED COMPOSTING FACILITY - *PANORAMA*

The environmental impacts that a composting facility has, as well as the requirements of composting facilities elsewhere in the world were presented. To put this into a South African context, the findings of an inspection of a successful composting facility that was established on a closed landfill site, Panorama, will be presented to test the applicability of the identified theoretical criteria and to discover any additional criteria should they arise.

3.5.1 Background

The City of Johannesburg Metropolitan Municipality (CJMM) privatised their waste department in 2001. Based on this, *Pikitup* was founded and became the designated semi-private waste removal company to be run as a profitable business. It serves approximately 787 000 dwellings in and area of 1625km^2 (Jali, 2009). The large amounts of domestic waste that are generated put pressure on landfill sites. To find a solution to this problem, *Pikitup* had to affect waste minimisation efforts. One such an initiative was the establishment of the Panorama Composting Plant, owned and operated by *Pikitup*.

3.5.2 Location

Panorama Composting Plant is located in Little Falls, Johannesburg. The Panorama landfill site was established in 1999 to serve the rapidly expanding western residential areas of Johannesburg and was located outside the urban edge where it was opened to receive general waste (Figure 3.1).

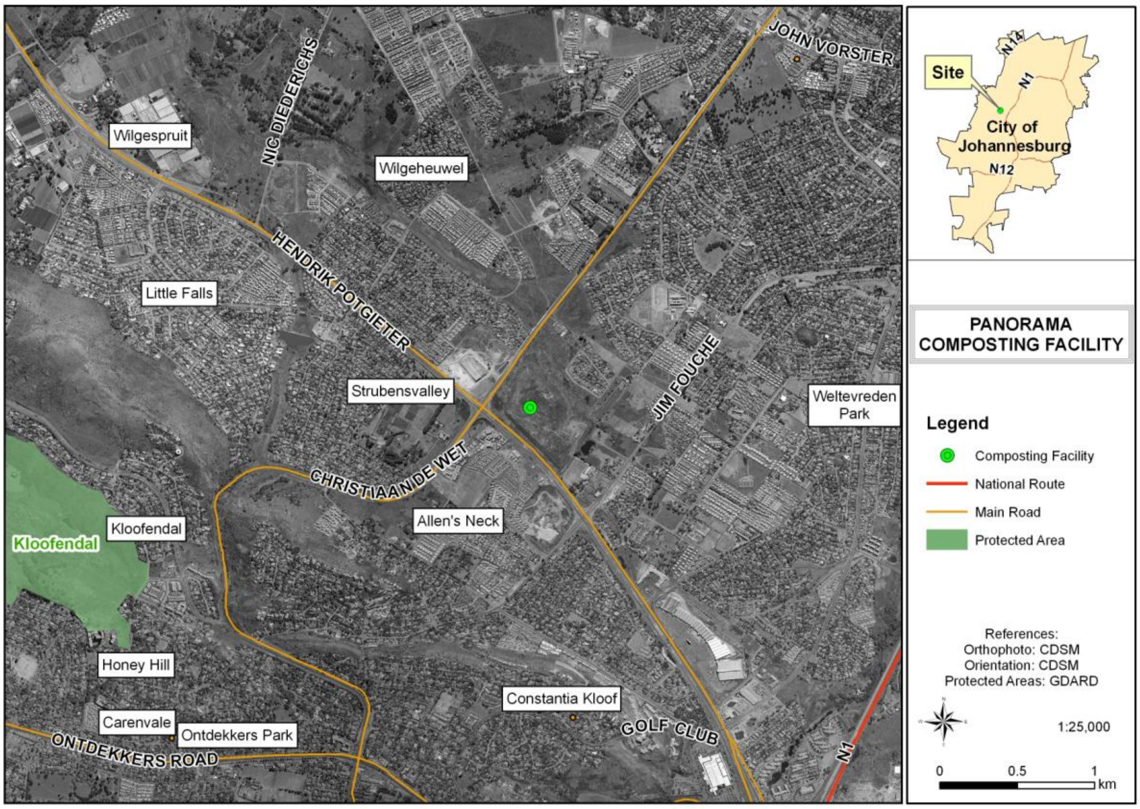


Figure 3.1 **Location of *Panorama* composting facility**

This site was engulfed by urban expansion and was prematurely closed to general waste in 2003 because the required buffer zone of 500m around a landfill site could not be maintained. The areas next to the closed site were made available for housing. The area that was originally planned for receiving waste at the Panorama waste disposal site could not be utilised to the full because of the surrounding residential areas and subsequent closure. The remainder of the site was thus used for the establishment of a garden site. This opened up an opportunity to commence with composting operations, and Panorama Composting Plant was established. In this way available space was put to good use.

Due to the fact that a landfill site was used and that residential areas surround it, it confirms the argument that a landfill site can be used for a composting facility. It is therefore not necessary to add location to the list of criteria for the establishment of composting facilities on landfill sites, since it is embedded in the concept. Landfill sites are usually within reach of the areas where waste is generated in order to save on transport costs.

3.5.3 Physical requirements

The physical properties of the site are important and include the amount of available green waste, the size of the property and the gradient. The composting method needs to be included here, since it dictates most of the physical environmental concerns.

3.5.3.1 Green waste

As discussed earlier, garden sites became part of waste management in the larger cities in South Africa and therefore also in Johannesburg. Garden waste is delivered to the site by specialised trucks from the 48 garden waste sites around Johannesburg (Deane, 2006). These sites are controlled to prevent the garden waste from contamination with other waste, like paper, plastic, etc. Acceptable waste types include garden and landscaping material consisting of grass, leaves, plants, branches, tree trunk and stumps; untreated wood waste including sawdust, shavings, wood timer cuts, pallets and wood packaging; natural fibrous material including seed hulls, straw and grape marc; processed fibrous material like paper, cardboard, paper processing sludge and mono-synthetic textiles; bio-solids and manures and food wastes. Bio-solids, manures and food waste are, however, not used for the composting process (Wiechers Environmental Consultancy, 2005).

According to the annual report of *Pikitup* (2008/9), a total of 61 140 tonnes of green waste was diverted from landfills sites for the year. This was done by rerouting green waste away from the landfill sites to garden sites from where it was taken to the Panorama Composting Plant. As garden sites are increasingly operated more efficiently, and green waste is supplied from additional sources as well, the opportunity exists to increase the utilisation of green waste as a resource, escalating composting volumes within the waste management system of Johannesburg. In the annual report of *Pikitup* it is stated that the capacity of 40 000 ton/annum which Panorama handled was exceeded in 2008/9 (Pikitup, 2008/9). It is therefore evident that there is enough incoming green waste available for continuous operation.

3.5.3.2 Space

Enough space is needed to accommodate everything that is needed to run a composting plant. A turning area is needed for the compost turner used at *Panorama* to operate, as well as a shed for the storage of equipment and the bagging process of the compost. An office building for administrative purposes and ablution facilities for the personnel and visitors are provided. Therefore, taking into consideration all the needs for a successful composting operation, the total area required for the operations must not be smaller than 1.5ha. Figure 3.2 is a representation of the layout of the Panorama Composting Plant as an example of an ideal situation.

3.5.3.3 Gradient

The slope of the *Panorama* site does not exceed 3%. This guarantees easy operation and at the same time facilitates onsite storm water flow. Since the operations at *Panorama* are in the open, it is subject to rain events. To prevent possible leachate from the compost heaps, storm water measures in the form of cut-off drains, cut-off berms, channels and an evaporation pond down-slope from the waste body, was constructed. At *Panorama* the original waste body is situated to the southern and also upstream of the composting facility. Rainwater is therefore prevented from entering the waste body.

The land slopes gently downward to the north, and, to prevent excessive run-off during rain events and also during watering of the compost windrows, the windrows are built perpendicular to the gradient. Onsite storm water control in the form of an evaporation pond near the northern boundary, serves the entire site south of the waste body and therefore also the composting operations. The leachate from the compost piles, as well as storm water from the composting area is collected in this dam.

COMPOST PANORAMA

LEGEND

1 Access control	5 Leachate Dam
2 Weighbridge	6 All weather roads
3 Office	7 Fence
4 Shed	8 Storage
	9 Windrows

Figure 3.2 ***Panorama*** **site layout**

This water is rich in nutrients and must be prevented from entering the tributary of the Wilge Spruit, a tributary of the Crocodile River, 100m south of the site. This nutrient rich 'compost tea' can be re-used to activate the composting process by watering the piles. At the time of the investigation, 'compost tea' was being collected in 2-litre plastic bottles at *Panorama* and sold to gardeners as enrichment for plants.

It must be noted that a waste disposal site usually needs to be lined if a natural liner like a clay layer does not underlie the area. Specified engineered standards need to be applied as prescribed by the Minimum Requirements. Given that *Panorama* as landfill site was established before the Minimum Requirements of DWAF came into effect, this site was not lined. As seen in the preceding discussion, effective preventative measures to protect ground and surface water are implemented at *Panorama*. In the following discussion of the composting method, other measures will be discussed to describe how air, aesthetics and noise can be mitigated.

3.5.3.4 Composting method

As it was important to select the correct composting method for *Panorama*, it was decided that an aerobic process must be used to manufacture compost using open windrows, which are turned regularly. Regular aeration of the compost prevents the release of bad odours and methane gas thereby protecting the air quality (DWAF, 1998). At *Panorama* the windrows are normally turned four times over a three-month period, which is the time needed to prepare a final compost product. Although the compost turner may cause dust when turning the windrows, this is counteracted by adding water during this process to control the moisture content of the windrow and thus prevent the creation of excessive dust.

Photograph 3.1: **Shredder**

Incoming green waste is immediately put through a shredding machine in an effort to retain as much moisture as possible (Photograph 3.1). The shredded green waste is then stockpiled into windrows of elongated piles of not more than 175m long, 3m wide and 1.5m high (Photograph 3.2). This is the preferred structure to encourage the build-up of heat, accommodate the watering system and facilitate the movement of the compost turner.

Photograph 3.2: **Windrows**

Photograph 3.3: **Mechanical compost turner**

A large mechanical compost turner is used to turn the windrows regularly so that it can be re-oxidised and to encourage the release of carbon dioxide (CO_2) to maintain an odourless, aerobic microbial process (Photograph 3.3). The temperature and CO_2 are monitored on a continual basis to determine the turning frequency of the windrow. A perforated pipe located longitudinally along the top of the pile waters the windrows. The moisture content is checked regularly to establish when water is needed. Temperatures of up to 65^{o}–70^{o}C are reached during the composting process (Wiechers Environmental Consultancy, 2005). These high temperatures are required to eliminate any potential of weed seeds thus providing a safe product to the client. When the heat build-up stops, the compost is ready.

A front-end loader is used to put the material through a drum screen where pieces of material that was not composted, are removed and disposed of as general waste. Compost sold in bulk is put through a 16mm screen while compost that is to be bagged is put through a 12mm screen (Photograph 3.4).

Photograph 3.4: **Trummel screen**

Neat concrete bunkers, protected by a roof, ensure that the compost is kept dry and uncontaminated, (Wiechers Environmental Consultancy, 2005) as depicted in the Photograph 3.5.

Photograph 3.5: **Compost in bulk storage under roof**

The equipment, like turners, the drum screen and the shredder used in the operations are high and unsightly and need to be concealed in some way. At *Panorama* this problem was solved by earth berms around the site, as well as solid walling to serve as a mitigating measure for possible noise emissions. A minimal buffer of 100m is maintained between the composting plant and the nearest houses to the south to effect noise reduction. The aspects of noise and the aesthetical value were therefore considered to address the social concerns for the prospect to have a composting plant within a residential area. Compost is bagged by clean and sophisticated technology in bags with an attractive design (Photograph 3.6).

Photograph 3.6: **Compost bagged to sell to the public**

Different mixtures are available to the customers, e.g. lawn dressing, mulch and other specialised mixes are being developed. The composting facility is open to the public for sales to enhance awareness about the composting process and to provide information about the value of compost.

3.5.4 Operations

3.5.4.1 Road network

The site is centrally located in Philallen Street, with access from Jim Fouché turning out of Hendrik Potgieter (M47). This makes the site accessible from the N1 (western bypass) lying 3km to the south, as well as areas located to the west. Other main routes include Christiaan De Wet providing access to areas located to the south (M5 and M6), and the north (Ontdekkers Road and Main Reef Road). This facilitates the transportation of green waste to the site from various parts of Johannesburg. It is also centrally located in terms of accessibility for the market including middle and high-income residential areas, as well as small holdings.

3.5.4.2 Transport equipment/waste trucks

Pikitup as waste management company has waste trucks available to bring in green waste from the garden sites. This includes roll-on-roll-off containers (Photograph 3.7), shredders compactor trucks (Photograph 3.8) and normal waste skips.

Photograph 3.7: **Shredding of waste before loading**

***Photograph 3.8*: Compactor truck**

It is important to minimise the transportation of air: the bulky green waste is therefore shredded at the garden sites before it is transported, loosing 60% of the volume of the green waste. This is an important aspect to ensure that the transport equipment is used optimally and not to waste truck space on the transportation of air. An infrastructure to accommodate the transport vehicles is available. The site has a tarred entrance and manoeuvring area for the waste trucks, as well as for the public, especially when large trucks are used to purchase compost in bulk.

3.5.4.3 All weather roads

An all-weather road network was built to ensure that operations do not come to a standstill during wet weather, and that waste trucks can access the site at all times. The windrow area is hard packed not only to prevent ingress of water into the subsoil, but also to facilitate run-off and to ensure continuous operations of composting equipment like the turner and the front-end loader, which is used to build the windrows. Parking space is provided for customers.

3.5.4.4 Waste disposal

As a landfill site, it held a permit for waste disposal according to legal requirements. According to the permit conditions as stipulated by DWAF (now DWA), the site was rehabilitated after closure, by capping and grassing it, reducing the influence on the physical and social environment. An amendment was made to the initial permit conditions to change the nature of the operations of *Panorama* from the disposal of domestic waste by landfill, to green waste disposal and the production of compost. The permit stipulates that the site be maintained according to the licence conditions as prescribed by the Minimum Requirements of DWAF, to prevent, minimise or manage any adverse effects the composting facilities might have on the environment or surrounding communities.

Compared to the *Panorama* example, if new premises for composting facilities must be identified, it will be time-consuming because of the lengthy legalities of the licensing route. Additionally, new premises within urban areas are usually scarce and expensive as will be the establishment of the required infrastructure. The closed site remains the responsibility of the waste disposal company for 30–40 years after closure to monitor groundwater quality and methane gas (DWAF, 1998). It is therefore a reasonable deduction that the site ought to be utilised, if possible, with economic benefits.

3.5.4.5 Office building for administrative purposes

Temporary offices (converted containers) offer space for administrative needs. Currently three offices are sufficient, including the sales office. Ablution facilities are available and kept clean. The municipality supplies water and electricity.

3.5.4.6 Security fencing and access control

A guard mans the gate at the Panorama Composting Plant during the day to control access to the site. At night this gate is locked, and night guards secure the site. The site is fenced off for safety reasons.

3.5.4.7 Weighbridge

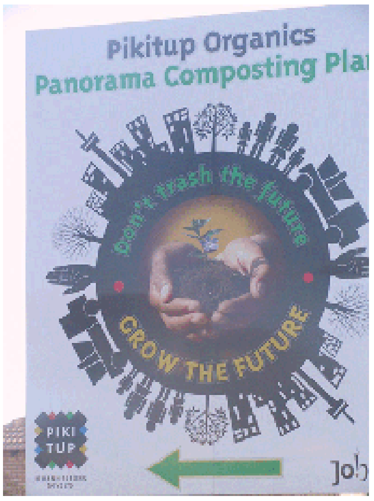
A weighbridge was installed for receiving general waste during the landfill period. Now it is used to keeping record of incoming green waste. Record of the outgoing compost is recorded in terms of what is sold.

3.5.4.8 Shed

A shed was put up for the storage of shredders, compost turners, sorters and fillers, as well as the bagging and storage of the compost.

3.5.4.9 Signposting

Clear signage for safety and directions was erected as illustrated below with the entrance sign (Photograph 3.9).



Photograph 3.9: **Entrance sign at *Panorama***

3.5.5 Social requirements

3.5.5.1 Committed management structures

Pikitup, the waste management company assigned for Johannesburg, started the composting plant. The capital layout to do this put an obligation on the management to make the facility work effectively. Besides that it is a profitable initiative in terms of income from the products, it saves precious landfill space, and most important of all, a valuable resource, green waste, is utilised. Instead of being buried in the landfill where decomposition will aid to create methane and other harmful gasses, it can be used as a soil conditioner with numerous advantages as was discussed in Chapter 2.

3.5.5.2 Trained staff

A manager and eight labourers operate the site. These trained employees have experience in waste disposal and execute various tasks like screening the green waste, operating the equipment (shredder, front-end loader, tunnel screen, turner, bagging equipment), monitoring the composting process, cleaning, selling and other general operational tasks.

3.5.5.3 Informed surrounding landowners

During closure of the landfill site and transition to the composting plant, the conditions required a public participation process to inform people of the change in operations. All residents near the composting plant were notified of the activities there. It is very important that the plant is operated according to the licensing conditions in order to consider surrounding landowners.

3.5.5.4 Concluding comments

Mitigation measures are in place to make the Panorama Composting Plant an acceptable activity within the adjacent residential area. These mitigation measures are proposed to address the physical, operational and social parameters of the site. This study recognises the potential of municipalities to incorporate composting as part of their waste minimisation strategy. *Panorama* as example demonstrated how environmental, operational and social factors of a composting facility located on a closed landfill site can be addressed. This example also reveal criteria to be added for evaluating landfill sites, whether closed or active, for establishing composting facilities or to downscale on the selected criteria.

The preceding discussions also show that the establishment of a composting plant on the premises of an existing landfill site was found to be a relatively easy and logical solution, which will greatly reduce incoming waste that would have been land filled. It would also optimise available resources (garden waste and available space) and will have valuable products, which are highly beneficial to the natural environment and are offered at affordable prices. The success experienced at an established site like P*anorama* can be used as an example to be replicated at other sites. The benefits are so significant that this example can serve as encouragement to waste disposal companies within municipal areas to institute a culture of using existing resources, in this instance closed landfill sites.

3.6 GUIDELINES FOR COMPOSTING FACILITIES

The theoretical criteria extracted from the literature and the endorsement of these criteria at a successful composting facility, *Panorama*, culminated in a set of general guidelines that could simplify the identification of possible sites for composting facilities on closed landfill sites. These guidelines address the natural, physical and social characteristics of the site to provide for the logistics of the operations.

Several factors could, however, limit the establishment of a composting facility on a closed landfill site. The first concerns the *space* available. The waste body is preferably excluded from the composting process due to the likelihood of leachate on the waste body, as well as the danger of damaging the integrity of the capping layer that seals off the waste body. The part of the premises not covered by waste must therefore be large enough to accommodate such operations. Waste cells older than 20 years will also be suitable for use.

The next concerns the input of the surrounding community. It is vital to have their consent to proceed with such an operation. This often means that additional measures must be implemented to minimise the effect of the operations on the community, e.g. screening of operations, noise management, etc. Additionally the preferred site must be near or in suburban areas, to minimise transfer costs. The guidelines identified should be applicable to other closed landfill sites.

As was mentioned, landfill sites in South Africa are strictly regulated and must comply with the Minimum Requirements as stipulated by DWAF. When a site has reached the end of its life span, a licence for closure must be obtained, indicating how the site will be looked after for the next 30–40 years until the decomposition of the waste is completed (DWAF, 1998). One of the requirements is that an end-use must be identified which will be beneficial to the surrounding community. This is an attempt to put something back into the community who have endured the inconvenience of the landfill operations for many years.

Most closed landfills are used for recreational purposes, e.g. sport grounds for schools, driving ranges, parks, soccer fields or firing ranges (examples discussed earlier under point 3.3). The composting facility can either be operated as the only end-use activity generating an income or co-exist with other end-uses planned for closure.

3.7 PARAMETERS FOR THE ESTABLISHMENT OF A COMPOSTING FACILITY

Having documented the theoretical aspects and revealing the requirements for a composting facility in relation to the Minimum Requirements, criteria specifically focussed on composting facilities can be prescribed. The parameters are focussed to mitigate any possible adverse aspects that might have an effect on man or nature. In order to make a distinction between the minimum requirements for waste disposal, and the criteria that were identified for composting facilities in the preceding chapter, the term “parameters” will be used hereafter. The parameters are also presented in a schematic format (Figure 3.3).

Physical parameters in order of importance:

- Available green waste;
- Size of the property for windrows, parking and supporting buildings and enough area for manoeuvring of the delivery and customers vehicles;
- The gradient of the area (slight downward gradient to accommodate leachate);
- Composting method.

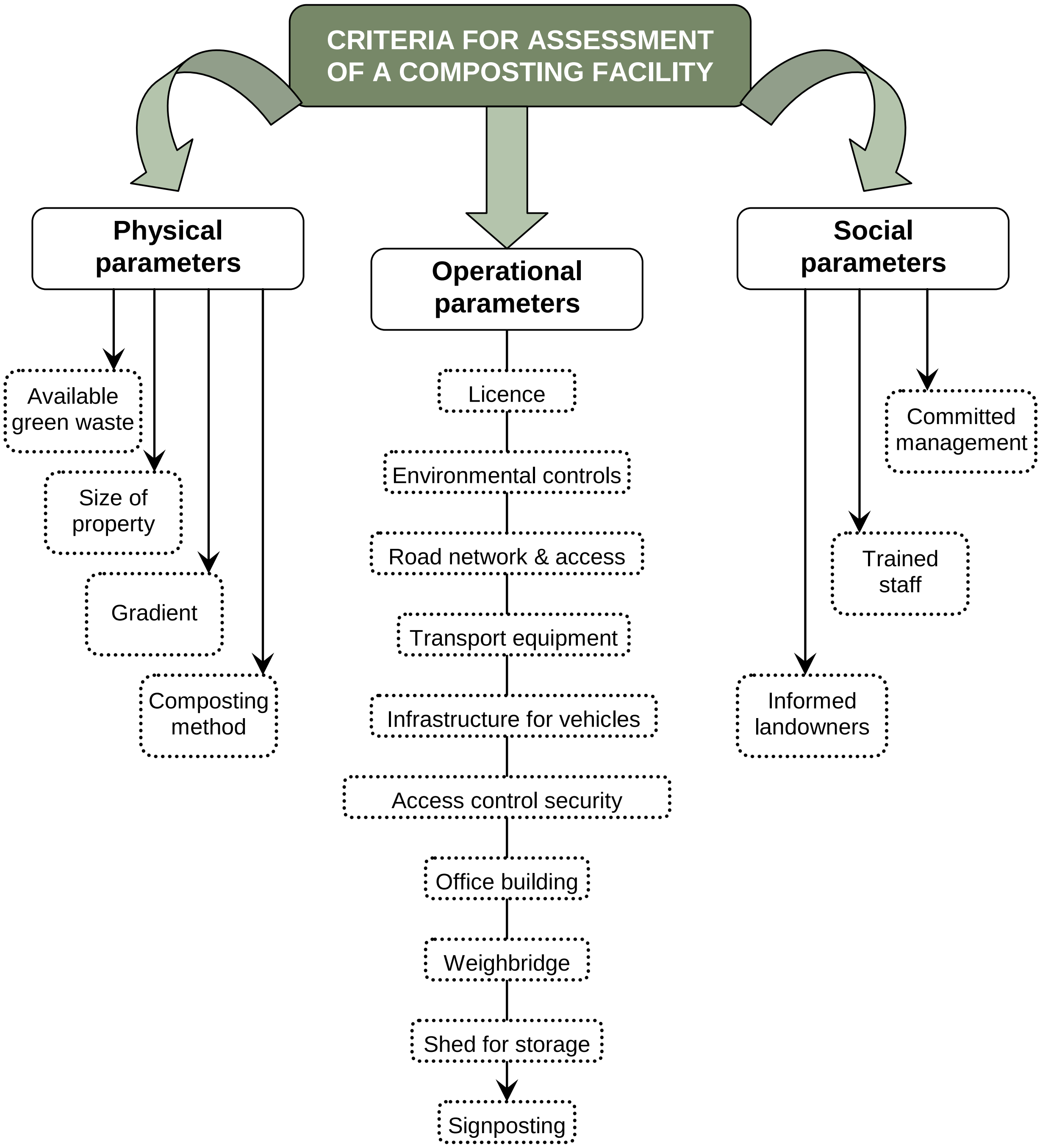


Figure 3.3: **Schematic representation of parameters for evaluation**

Operational parameters in order of importance:

- Road network;
- Transport equipment/waste trucks;
- Infrastructure to accommodate the transport vehicles (access/gate, all weather access, manoeuvring area, offloading area);

- Waste disposal licence;
- An office building for administrative purposes with ablution facilities, water and electricity, security fencing and access control, weighbridge;
- Shed for the storage of shredders, compost turners, sorters and fillers, as well as the bagging and storage of the compost;
- Signposting.

Social parameters:
- Committed management structures (CTMM);
- Trained staff;
- Informed surrounding landowners.

3.8 CONCLUSION

The identification of the parameters in the literature, as well as at a working and successful composting site, was presented. The purpose of the evaluation of an existing composting site was to determine what is already in place at a landfill site and to determine the feasibility of establishing a composting facility on such premises. However, it must be emphasised that important environmental considerations like the mitigation measures for vermin, although in place for the landfill site, will completely differ from the way it will be mitigated for a composting facility. This also applies to other important factors such as noise, smell and dust. All these environmental considerations are imbedded in the type of composting method. Should the wrong method be employed, the composting facility may impact on the surrounding community and the environment.

Municipalities are under pressure to save landfill space according to the many initiatives from government of waste minimisation. Incoming waste therefore needs to be reduced. As was seen from the waste stream analysis in Chapter 2, the green waste fraction of larger municipalities in South Africa consists of approximately one third of the municipal solid waste stream. Currently this portion is land filled. This is in spite of the fact that garden sites provide the opportunity to separate a large portion of the green waste from the rest of the waste stream. Currently it is co-disposed with the other domestic waste in the landfill. Decomposable waste, such as green waste, is the primary cause of the release of landfill gasses.

It is important to note that composting can be done even if not all the above-mentioned suggested parameters are in place, such as is the case with backyard composting. However, since the study is concerned with municipal composting, it is essential that the municipality needs to comply with legislation, provide a good service to the community, and take responsibility for protecting the natural environment; it is advisable that the parameters are in place.

It must also be emphasised how important composting is as a waste minimisation effort and not to keep on wasting green waste as a valuable resource and obvious solution to the growing waste problem.

An end-use of a closed landfill site, which can be of economic value, would contribute to the maintenance of the site. "There are many challenges to re-using a closed landfill site. Liability considerations (toxic torts) and technical problems (settlement, gas, health and safety) abound, as was discussed earlier. But just as a growing number of formerly-used industrial sites are being redeveloped for productive uses in what has become known as the 'Brownfield' movement, so too have landfill sites been increasingly developed for high-value, productive land uses." (McLaughlin, 2007:1).

Endnote

[i] Uneven settlement refers to the difference in decomposition process of the different kind of wastes in the waste body, causing some places to decompose quicker than others.

Chapter 4

AN ASSESSMENT OF THE SUITABILITY OF FOUR SITES IN TSHWANE AS COMPOSTING FACILITIES

4.1 INTRODUCTION

In the previous chapter the theoretical requirements of a composting facility, should it be established on a landfill site, were investigated. These requirements are mainly based on the protection of the environment and the safety of people. Thereafter a South African composting facility, Panorama, was appraised as an existing successful composting operation on a landfill site. This assessment led to a combined list of identified environmental and operational requirements, which include physical, operational and social parameters, needed for establishing a composting facility on a landfill site.

This chapter reports the findings of the screening of nine municipal landfill sites in the City of Tshwane Metropolitan Municipality (CTMM) with attention given to the size of the landfill property and the size of the green waste stream. These municipal sites include: Derdepoort, Hatherley, Ga-Rankuwa, Garstkloof, Kwaggasrand, Onderstepoort, Soshanguve, Temba and Valhalla. Based on the findings of the evaluation based on the requirements referred to above, four sites were selected and assessed followed by a site specific evaluation of each of these sites. The chapter culminates with a discussion of closure requirements and proposals related to waste minimisation.

The map to follow (Figure 4.1) shows the geographic location of the nine municipal landfill sites within the borders of the City of Tshwane municipal area.

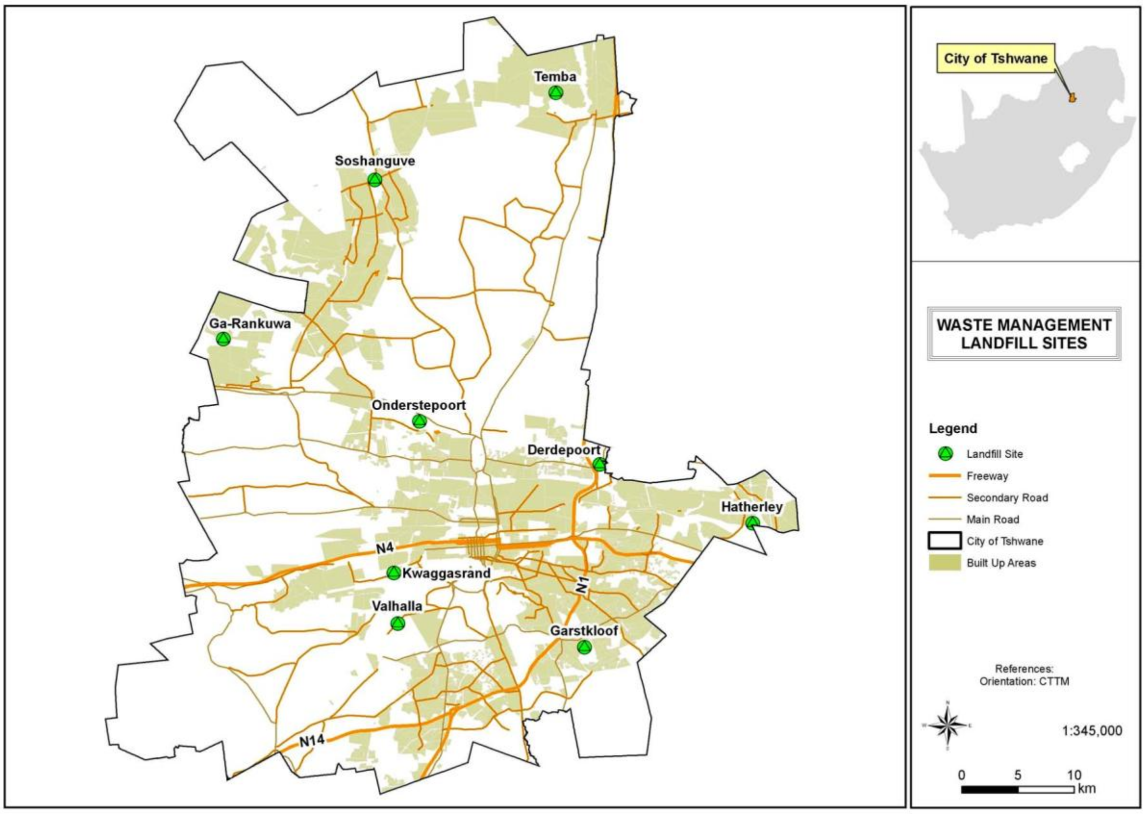


***Figure 4.1*: Nine landfill sites within the borders of the City of Tshwane municipal area**

4.2 SCREENING OF THE NINE LANDFILL SITES IN TSHWANE

To establish a composting plant on a municipal landfill site will require resources and capital outlay. This needs to be a sustainable business in order to be a continuous operation. Initially all nine municipal landfill sites within the municipal borders of Tshwane were examined to determine whether it would be feasible to operate composting facilities on their premises. This screening of the sites was undertaken to establish suitability and practicality of a composting facility on each of the sites. The screening process therefore eliminated the sites that are not suitable as a composting facility. The two screening criteria isolated and considered as essential in this selection were:

- the size of the property;
- the amount of green waste available.

The best scale of measurement to employ in the screening process was an ordinal scale. An ordinal scale is usually used to rank data where the exact measurements between the data are not known (Dwyer, 1983:31). It was not possible to use a ratio scale, since the data used does not have set intervals. However, theoretically the data is measurable, and are referred to as "ranks" (Dwyer, 1983). The data collected were arranged in order of importance. The driving question (Yin, 2003) asked was: what is essential to the success of the composting facility?

Based on the screening findings, a final selection of four sites was made. The evaluation was done according to the parameters identified previously in this study. These parameters are regarded as essential for the success of a composting facility and are in compliance with the Minimum Requirements for waste handling and disposal. To derive the information for each site, the following questions have relevance:

- Will it be viable to establish a composting facility on the premises as is?
- What else is needed to make a composting facility viable on the premises?

4.2.1 Size of the landfill property

The larger the size of the premises the greater the possibility that space will be available for composting facilities. The landfill sites within the borders of the CTMM were evaluated on a scale of 1-9 (Table 4.1).

It can be noted that Hatherley is the largest (96ha) landfill site and is nearly double the size of the site at Onderstepoort (51.82ha) that was rated the second highest. Derdepoort (12.4ha), Valhalla (11.7ha) and Temba (3.7ha) are the smallest sites.

Table 4.1: **Rating of the size of the landfill sites** [a]

Landfill sites	Size of landfill site (ha)	Rating
Derdepoort	12.40	**7**
Hatherley	96.00	**1**
Ga-Rankuwa	41.90	**4**
Garstkloof	43.60	**3**
Kwaggasrand	27.20	**6**
Onderstepoort	51.82	**2**
Soshanguve	39.17	**5**
Temba	3.70	**9**
Valhalla	11.70	**8**

[a] Adapted from Felehetsa, 2004:37

4.2.2 Size of green waste stream

It is calculated that the average waste generation of waste within the CTMM is 3.1kg/person/day (Felehetsa, 2004). Different types of waste are disposed of at the landfill sites in the CTMM and include building, garden, household and industrial waste. This study focuses mainly on the garden waste fraction (Column 3 in Table 4.2), as well as in the domestic waste of which one third is garden waste (Column 7 in Table 4.2). The amount of waste differs according to the economic circumstances and climatic season (more wet green waste in summer; dry carbons in winter; dry or wet years will have less or more amounts of green waste). Measurements are indicated in tonnage (t).

Table 4.2: **Types and quantities of waste disposed at CTMM landfill sites with green waste ratings** [b]

LANDFILL SITES	Type of waste	Tons / Year	Garden (%) and t	Household (%) and t	Garden waste in household waste as % and t	Total garden waste in t	Garden waste rating
Derdepoort	Garden Refuse; Building Rubble	342 540	70 239 778	5 17 127	1.67 5 709	245 487	**2**
Hatherley	General	120 444	10 12 044	75 90 333	25.00 30 111	42 155	**7**
Ga-Rankuwa	General	153 816	10 15 381	60 92 290	20.00 30 763	46 144	**6**
Garstkloof	Garden Refuse; Building Rubble	- 421 080	60 252 684	5 21 054	1.67 7 018	259 702	**1**
Kwaggasrand	General	323 856	15 48 578	70 226 699	23.33 75 566	124 144	**4**
Onderstepoort	General	336 396	20 67 279	50 168 198	16.67 56 066	123 345	**5**
Soshanguve	General	110 400	10 11 040	80 88 320	26.67 29 440	40 480	**8**
Temba	General	88 356	10 8 835	70 61 855	23.33 20 618	29 453	**9**
Valhalla	General	345 192	15 51 779	75 258 894	25.00 86 298	138 077	**3**
TOTAL		**2 242 080**					

[b] Adapted from: Felehetsa, 2004:63

Table 4.3: **Combined ratings**

LANDFILL SITE	Size of landfill (ha)	Site size rating	Tons / Year	Garden waste rating	Summated rating score	Final rating
Derdepoort	12.40	7	245 487	2	9	**4**
Hatherley	96.00	1	42 155	7	8	**3**
Ga-Rankuwa	41.90	4	46 144	6	10	**6**
Garstkloof	43.60	3	259 702	1	4	**1**
Kwaggasrand	27.20	6	124 144	4	10	**5**
Onderstepoort	51.82	2	123 345	5	7	**2**
Soshanguve	39.17	5	40 480	8	13	**8**
Temba	3.70	9	29 453	9	18	**9**
Valhalla	11.70	8	138 077	3	11	**7**

Column 3 of Table 4.3 represents the size rating and column 4 the garden waste rating. In column 5 the combined rating for the size of the landfill site and the amount of green waste indicate the probability. In column 6 the final rating was calculated by transferring the totals into values, with the lowest value indicating the top position i.e. Garstkloof has the lowest rating value (1).

In contrast, Temba is given the highest rating value of 9 thus assuming the bottom position. This is inversely proportional: the lower the rating, the higher the probability that a composting facility can be established on the premises. Kwaggasrand and Ga-Rankuwa have the same value, and it was necessary to distinguish between them by going back to the raw data. Although Ga-Rankuwa is larger in size, Kwaggasrand has more than double the amount of green waste available. Composting cannot be done without the green waste, and therefore Kwaggasrand was rated higher than Ga-Rankuwa.

The final outcome of the ratings of the sites is arranged below in Table 4.4 according to the most probable to the least probable to accommodate a composting facility on the premises of the landfill site.

Table 4.4: **Final rating**

Landfill	Final rating
Garstkloof	**1**
Onderstepoort	**2**
Hatherley	**3**
Derdepoort	**4**
Kwaggasrand	**5**
Ga-Rankuwa	**6**
Valhalla	**7**
Soshanguve	**8**
Temba	**9**

In order of importance, the four sites selected were therefore: Garstkloof, Onderstepoort, Hatherley, Derdepoort.

4.3 EVALUATION OF FOUR LANDFILL SITES IN TSHWANE

The criteria for evaluation included the physical, operational and social parameters, which were compiled in a checklist (see Appendix B) and applied during visits to the sites. To follow, these sites are compared with one another in terms of the criteria selected as minimum requirements for composting facilities.

4.3.1 Physical parameters

Although the physical parameters, size and available greens, were used in the selection of the four sites, it will also be included in the table for the sake of comprehensiveness (Table 4.5).

Table 4.5: Physical parameters

Parameters	Garstkloof	Onderstepoort	Hatherley	Derdepoort
Green waste	259 702 t/a	123 345 t/a	42 155 t/a	245 487 t/a
Size	43.60ha	51.82ha	96.00ha	12.40ha
Gradient	Slight slope to E	Slight slope to NW - storm water pond on premises	Slight slope to N - storm water pond on premises	Slight slope to E
Possible composting method	Open windrow – mechanical turning	Open windrow – mechanical turning	Open windrow – mechanical turning	Open windrow – manual turning

The last parameter, “possible composting method”, was added here for the sake of comparison between the four sites. It does not determine whether a composting facility can be established or not, but suggests the most suitable composting method on each site.

Except for Derdepoort, all the sites have a large enough space to accommodate composting facilities. The waste body on Derdepoort occupies the entire site. The only option will be to do the composting on an old part of the waste body. This will be visible since it is on top of the “mountain” of waste. It is recommended not to use large machinery not only due to the visual intrusion it would create, but also due to the nature of the surface, where differential settlement will still occur although reduced.

4.3.2 Operational parameters

Table 4.6 to follow is a summary of the minimum operational requirements for what is present on the landfill sites that can be used for the composting facilities.

4.3.2.1 Waste disposal licence

Except for Derdepoort (which is in the process of closing), all the sites are permitted to accept general waste. It therefore has legal authorisation for waste disposal, including the receival of green waste with the purpose of converting it into compost. It is beneficial for the sites that already have a licence. At the most, there will have to be some kind of a public participation process to communicate the change in operations from general waste to green waste. In most cases communities would accept this, provided that conditions to operate composting on the site are according to rules and regulations regarding the prevention of environmental disruption. This will be described below.

4.3.2.2 Operational-environmental controls

The operational-environmental controls are summarised in Table 4.6 at the end of this section.

In the daily operations *nuisance control* needs to be in place. This is done by means of daily coverage of the waste with a soil layer at all four of the sites to prevent bad odours and vermin. *Leachate control* is not in place at any of the sites for land filling. This is not a disqualifying parameter since implementation of leachate control will have to be specifically addressed for that area where the composting facility will be established.

Litter control is in place at all four the sites in the sense that the site is enclosed by various kinds of fencing. Daily cleaning can be done by clearing the fences of windblown litter. This is important for a composting facility, since plastics and paper are often present in the green waste. Garsfontein has concrete fencing, which is able to catch most of the windblown litter. Onderstepoort has a two-meter fence to the south, and wire fencing to the east, west and north. At Hatherly the fencing is stolen on a continual basis and it was decided to build two-meter high steep berms to fence off the site. This is also used to contain litter. However, due to the size of the site it is difficult to effectively contain litter. It will be the best option to fence off the specific area at Hatherley to contain litter that might be present in the green waste. The Derdepoort site is fenced with a wire fence. It is not recommended that additional fencing be implemented to contain litter, as it will add unnecessarily to initial capital. However, fencing has the additional asset of securing the sites from trespassers. For composting facilities this is important in order to prevent the theft of and damage to the equipment.

The influence of the current environmental controls on the proposed composting facilities on the landfill site premises will not be great, besides the fact that land filling as an activity can co-exist with a composting facility.

4.3.2.3 Road and transport controls

All weather road[i] networks are in place at all four the sites, which will benefit the proposed composting operations. Road access to all four sites is from major routes and will also be able to accommodate increased traffic, which may result from the composting operations. Waste transport and handling equipment at all four sites consists of the following: a front-end loader which can be used to build the windrows; a compactor, which will not be of use for any composting operations; and waste delivery trucks which can be used to bring in the separated green waste from the garden sites. Even if *signposting* is in place at all the sites, specific signage will have to be put up to provide directions for the composting facilities. A*ccess control* is present at all the sites. Since the incoming green waste for a composting facility needs to be controlled in terms of quality and quantity, these aspects are important, as is the availability of a weighbridge, which is not present at Onderstepoort and Derdepoort.

4.3.2.4 Administrative controls

An *office building* for administrative purposes with ablution facilities, water and electricity are present at all the sites. The composting operation needs to be run as a business. For this purpose office facilities are required. *Security fencing* is present at all the sites. *Additional facilities* i.e. a shed for the storage of shredders, compost turners, sorters and fillers, as well as the bagging and storage of the compost would have to be erected at all the sites to accommodate the composting activities. Although Hatherley has such facilities, it is being used for recycling activities.

Table 4.6: Operational parameters

Parameters	Garstkloof	Onderstepoort	Hatherley	Derdepoort
Waste disposal licence	B33/2/123/7/ P192	B33/2/123/7/P6	16/2/7/A230/ D7/Z8/P383	Not permitted – about to close
Environmental controls				
Nuisance control	Daily soil cover One active operational cell	Daily soil cover One active operational cell	Daily soil cover	Daily soil cover One active operational cell
Drainage and Leachate control	Storm water drainage is provided for. No leachate management is currently performed.	Due to land filling of pits, contamination of water occurs (no pollution control dam). No leachate control.	Drainage dam in northern corner for collection of clean run-off.	None observed. Close to stream floodplain. Leachate monitoring sumps have been covered.
Litter control devices (fencing)	Vertical concrete pallisade	N4 to the north 2m wire fencing to the south	Soil berms	Wired fence
Road and transport controls				
All weather road network	Yes	Yes	Yes	Yes
Road access	From Delmas Road	N4 west and R566	From Hans Strijdom Road (to Mamelodi) into access road	Zambezi East and Maloto Road (R573)
Waste transport equipment/trucks	Front-end loader Compactor Waste delivery trucks	Front-end loader Compactor Waste delivery trucks	Front-end loader Compactor Waste delivery trucks	Front-end loader Compactor Waste delivery trucks
Access control	Yes, Access control at weighbridge at the entrance	Yes, at entrance	Yes, access control at weighbridge at the entrance.	Yes, boom gate at entrance
Weighbridge	Yes	No	Yes	No
Signposting	Well signposted	Clearly signposted	Well signposted	Access to site via surfaced road - well signposted
Administrative controls				
An office building & ablution facilities	Yes	Yes	Yes	Yes
Water & electricity	Available	Available	Available	Available
Security fencing	Site is fenced and has lockable entrance gate	Site is fenced (1.8m wired fence), manned gates of same height at all entrances. Some areas have no fencing or have been removed.	Site is fenced with wire and soil berms	Site is fenced, a manned lockable gate.
Shed for storage	None	None	Yes for recycling	None

4.3.3 Social parameters

Table 4.7 summarises the social status of the current landfill sites and therefore also for the potential composting facilities.

***Table 4.7*: Social parameters**

Parameters	Garstkloof	Onderstepoort	Hatherley	Derdepoort
CTMM structure	Yes	Yes	Yes	Yes
Trained staff	Site supervision staff	Site supervision staff	Operations contractor	Site supervision staff
Informed surrounding landowners	Surrounded by residential development – proper buffer zone in place. No Landfill Monitoring Committee in place	No abutting residential area. No Landfill Monitoring Committee in place	No abutting residential area. No Landfill Monitoring Committee in place	Mainly residential and small businesses on agricultural holdings No Landfill Monitoring Committee in place

The most important social aspect is that surrounding landowners are used to the waste disposal activities. There should be a buffer zone to ensure that residential areas are not near the landfill. Residential areas have encroached upon the buffer zones of Garstkloof and Hatherley. If the position of the composting site is carefully selected, there will not be a significant change from the current operations.

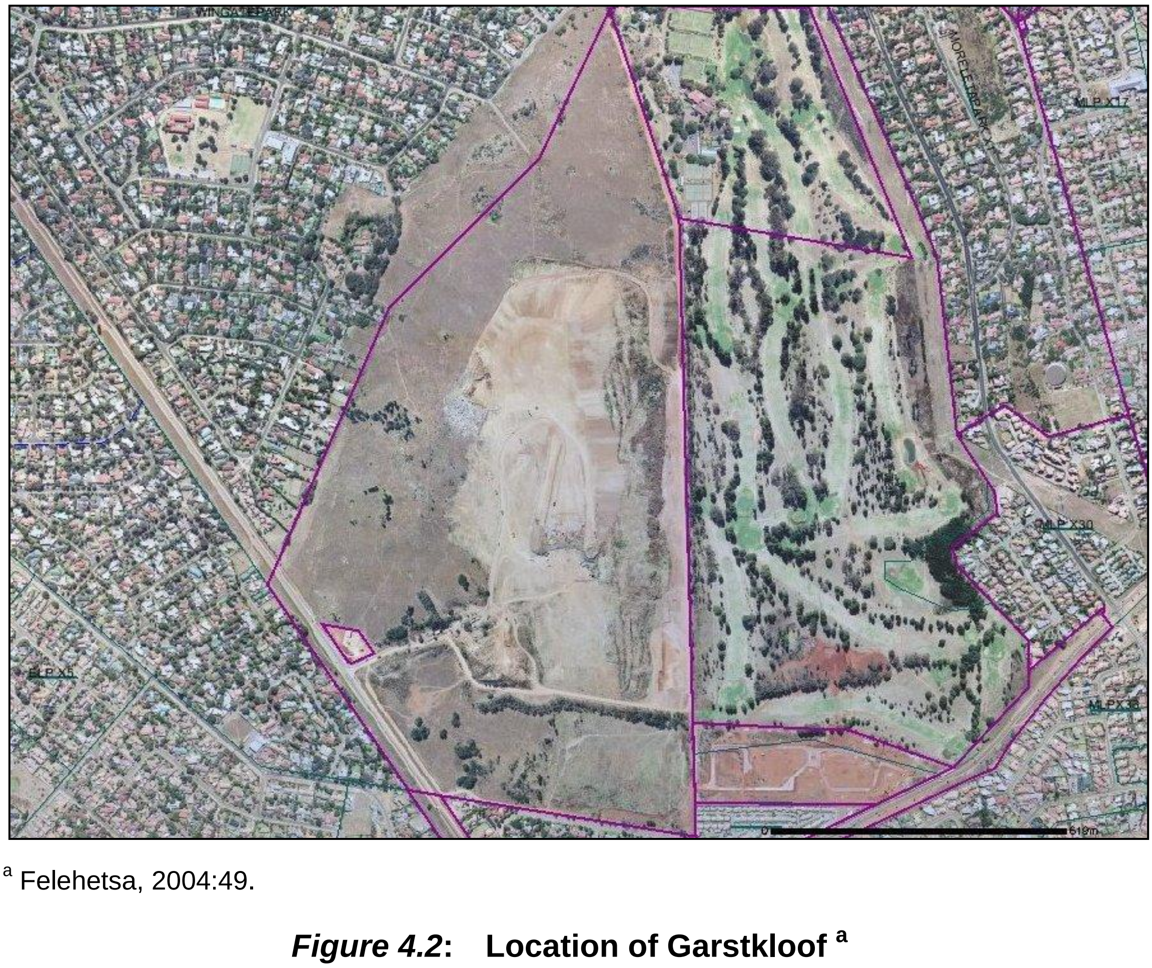
As can be seen from the discussion above, it is clear that the four selected sites are suitable for establishing a composting facility there, although there are shortcomings. To highlight the main characteristics, as well as the deficiencies of a site, each site will be analysed and discussed separately and recommendations will be made accordingly for the establishment of composting facilities.

4.4 SITE SPECIFIC EVALUATION

The evaluation of the four selected sites will be presented in the following order: Garstkloof, Onderstepoort, Hatherley and Derdepoort.

4.4.1 Garstkloof

Garstkloof is situated in the east of Pretoria, and has recently been closed for disposal of general domestic waste. Predominantly green waste and building rubble are still allowed here, given that residential areas to north (Wingate Park) and south (Elardus Park) surround it due to urban expansion. The Delmas provincial road lies to the west and provides access to the site. Wingate golf course lies to the east. Therefore, the logistical system is in place to receive large quantities of green waste. At the western side of the site a large area had been rehabilitated which could possibly be used for a composting facility (Figure 4.2).



[a] Felehetsa, 2004:49.

***Figure 4.2*: Location of Garstkloof [a]**

Dolomitic strata underlie the area. It is therefore not recommended that composting be done on the unused land east of the waste body, due to concern for ground water pollution. To counteract this pollution, a proper liner and drainage system needs to be installed which will be extremely expensive and unnecessary since the other part is available. Garstfontein has concrete fencing, which is able to catch most of the windblown litter. However, appropriate buildings, signage, grading of the site, leachate and storm water control will also be required. The site is to be closed within the next five years. This is an advantage since the Municipality still needs to maintain and monitor the site after closure and therefore could run a composting facility as end-use.

4.4.2 Onderstepoort

It is an advantage that Onderstepoort is accessible from several nearby garden sites (Dorandia, Magalieskruin, Mountain View and Philip Nel Park). Directly adjacent to the southern fence of the site lies a railway line, and provincial roads abut the northern and western boundaries. This serves as an effective buffer zone. One disadvantage is that the site is near sensitive areas, like the Onderstepoort Nature Reserve and the Magaliesberg protected natural environment area to the south. The Boeppens Spruit flows from west to east south of the site, and forms a confluence with another tributary of the Apies River (to the north) to the east of the site. To the far east of Onderstepoort lie the Bon Accord Dam and a natural wetland (Figure 4.3).

The site is filling up rapidly, and has preliminary rehabilitated areas with interim capping which could be used for composting facilities with the necessary modifications. This will include a weighbridge and storm water management, which needs to receive special attention to prevent further problems on the site due to the shallow water table and the level nature of the surrounding environment. Other requirements include appropriate buildings, signage and grading of the specific area where composting will be done. To the eastern side of the site, separate from the waste body, there is an open area that will be suitable for composting.

[a] Felehetsa, 2004:53

***Figure 4.3*:** **Location of Onderstepoort** [a]

4.4.3 Hatherley

Hatherley is a very large site and could accommodate a composting facility to the south-eastern side of the site (Figure 4.4). This is near all the relevant facilities. It is fenced and will not have a negative visual impact. Although situated on the outskirts of Pretoria, it serves a large part of the eastern suburbs, and large quantities of green waste can be made available for composting. The site is unique in that it has historical and archaeological value. By the establishment of a composting facility, an emphasis will be placed on conservation of resources and the fight against pollution and global warming, thus it is being utilised as an advantage.

Vacant land, buffers zones of 200m to the north, 500m to the south and 800m to the west and east are prescribed in the permit, which will provide a noise buffer for the composting activities. The air space is estimated to be enough for the next 50 years, making this the longest-living landfill site in CTMM. Appropriate buildings and signage needs to be erected. The composting area needs to be graded and leachate and storm water control needs to be installed. Adequate space on several locations on the site is available for a composting facility.

[a] Felehetsa, 2004:41

***Figure 4.4*: Location of Hatherly** [a]

4.4.4 Derdepoort

The major drawback of Derdepoort is that there is no open land on the property that could be utilised besides the waste body. It therefore needs to be done on top of the waste body after capping. The rehabilitation can be adapted to suit the needs of the composting facility, creating a large enough area with the required gentle slope and drainage features (Figure 4.5).

[a] Adapted from Felehetsa, 2004:39

***Figure 4.5*: Location of Derdepoort**

Large machinery, like a compost turner, will be difficult to screen off due to the high visibility of the site from the highway. However, if placed with care, composting operations can be sited in such a way as to have minimal visual impact on the surrounding area. Additionally, if small, hand turned windrows are put into operation; it will reduce the visual impact, and create jobs for the nearby semi-rural communities.

A major advantage of Derdepoort is that there is already a logistical system in place to deliver large quantities of green waste to the site. The site still needs to be permitted, but with closure so near, a composting facility can be incorporated in the closure permit as an end-use plan. Smallholdings to the west and north, and a river system to the east and south surround the site. It lies between two roads to the west and east, and besides accessibility, provides a buffer between the site and the surrounding areas. Appropriate buildings and signage will be needed. To prevent leachate, the site needs to be graded to provide a slight slope for run-off of rainwater and water from the windrows. This can be accommodated in the closure planning and will not require extra resources, since earth working machinery are available.

4.5 CLOSURE REQUIREMENTS

To avail an area on the landfill site, one has to take into consideration the unique requirements with which the landfill has to comply. According to the minimum requirements an expensive capping layer is prescribed (DWAF, 1998). This entails a 0.5m thick formation layer, comprising of 50% imported G7[ii] material and 50% selected *in situ* material compacted in layers of 250mm. On top of this formation layer, a clay layer of 300mm must be placed. A third layer, 0.75m thick, comprising of imported G7 materials compacted to 90% MOD AASHTO[iii], needs to be placed on top of the clay layer. This third layer is the platform on which the windrows might be constructed, with paving done with 60mm segmented paving on top of a 150mm stabilised G4[iv] layer (Du Plessis, 2006).

As a capping is extremely expensive, it is recommended that the composting be done on a part of the landfill site that does not receive waste. If proper storm water control measures are implemented, and the area graded (a gradient of 3% is prescribed in the Minimum Requirements of DWAF to optimally use the available air space, and simultaneously ensure stable sides), it is highly probable that a composting facility could be established. None of the landfill sites within the borders of the CTMM were closed at the time this investigation was done, providing the opportunity for custom made rehabilitation to specifically suit a composting facility.

Besides capping a landfill site, several other requirements need to be addressed prior to establishing a composting plant on a landfill site. Primarily, according to South African legislation, the permit conditions need to be adjusted to reflect the coordinates for the disposal of garden waste (Du Plessis, 2008). This would require additional consultations with surrounding landowners to obtain their comments and permissions or even possible objections. The fact that the landfill site as unwanted element is already established will support this process, since the composting facility does not have the same detrimental effect on its surroundings. None of the selected landfill sites have the required Monitoring Committee (driven by the surrounding landowners) in place, which could mean that there is not an active opposing community adjacent to the landfill site (Du Plessis, 2008).

The information that was available to predict the lifespan of the landfill sites in 2004 has changed drastically over the past few years leaving waste management in an alarming predicament. All the landfill sites have the same governmental structure. This placed them under the same waste minimisations efforts, and under the same political will to bring about changes to municipal waste disposal (Du Plessis, 2008).

A major limiting factor for the establishment of a composting facility on the premises of a waste disposal site is the visual impact that such a facility will have. This could be overcome by selecting a screened part of the premises or the construction of berms to screen off operations. This will also assist in mitigating noise that may be generated by the machinery used in the composting process (Du Plessis, 2008:8).

All the parameters, as identified in Chapter 3, are essential to operate a composting facility, but can be adapted to suit the specific needs of a specific site. The environmental parameters as suggested do not have set requirements and can be adapted to the specific circumstances at each landfill. The size of the property may vary, and where a site is very small, the composting method needs to be adapted i.e. in-vessel composting or hand-turned windrows could be used. The gradient of the area can be rectified with earthworks by means of the landfill machinery. To grade the site slightly will not require a large capital layout.

Although operational parameters should be in place, other measures could be used to continue with composting, i.e. green waste can be brought in by private contractors and during rain events the waste can be moved by hand or left until the surface has dried off. A waste disposal licence, although required by law, should not, according to current legislation, detain the process to establish a composting facility. An office building and ablution facilities are needed and it may vary in size, convenience and construction material. Water and electricity is required for running a business. Should insufficient water be available for the composting operations, it could be brought in with a water cart. Security fencing, access controls, a weighbridge, signposting, and a shed for storage purposes could all be adapted to suit the *in situ* needs. Current landfill staff could be trained to run the composting facility successfully.

4.6 A SOLUTION FOR WASTE MINIMISATION

4.6.1 Landfill avoidance

The preceding analysis showed that the four selected sites comply with the determined criteria. As was discussed in Chapter 2, the green waste fraction of larger municipalities of South Africa consists of approximately one third of the municipal solid waste stream. Currently this portion is being land filled, although garden sites provide the opportunity to separate the green waste from the rest of the waste stream.

The green waste is transported to the landfill site and, notwithstanding their value, disposed of in the landfill together with the other domestic waste. At Garstkloof, for example, when it was fully operational and where large volumes of green waste came in, it was the custom to have separate cells for the incoming green waste than for the general domestic waste. The expertise of the landfill staff to distinguish between the two is therefore already available. It is consequently suggested that the disposal process be adapted to start a composting process on the premises of the landfill site.

Economic and ethical pressure is put on municipalities to save landfill space. The only way to do this is to reduce incoming waste. Recycling initiatives, of which composting is one, is therefore essential.

4.6.2 Composting facilities on existing landfill sites

It is important to emphasise that the garden sites, as discussed in Chapter 2, be incorporated into the waste minimisation planning, since a 60% reduction in volume is possible if the green waste is shredded at the garden site. The garden sites also provide the opportunity to ensure that only clean green waste reaches the composting facility. During the shredding process all other waste contaminating the greens can be removed. The greens will then be transported to the landfill site as soon as the waste skip is full and diverted towards the composting facilities, ready to be piled into windrows. Figure 4.6 indicates the close proximity of the garden sites to the selected four landfill sites to support this suggestion.

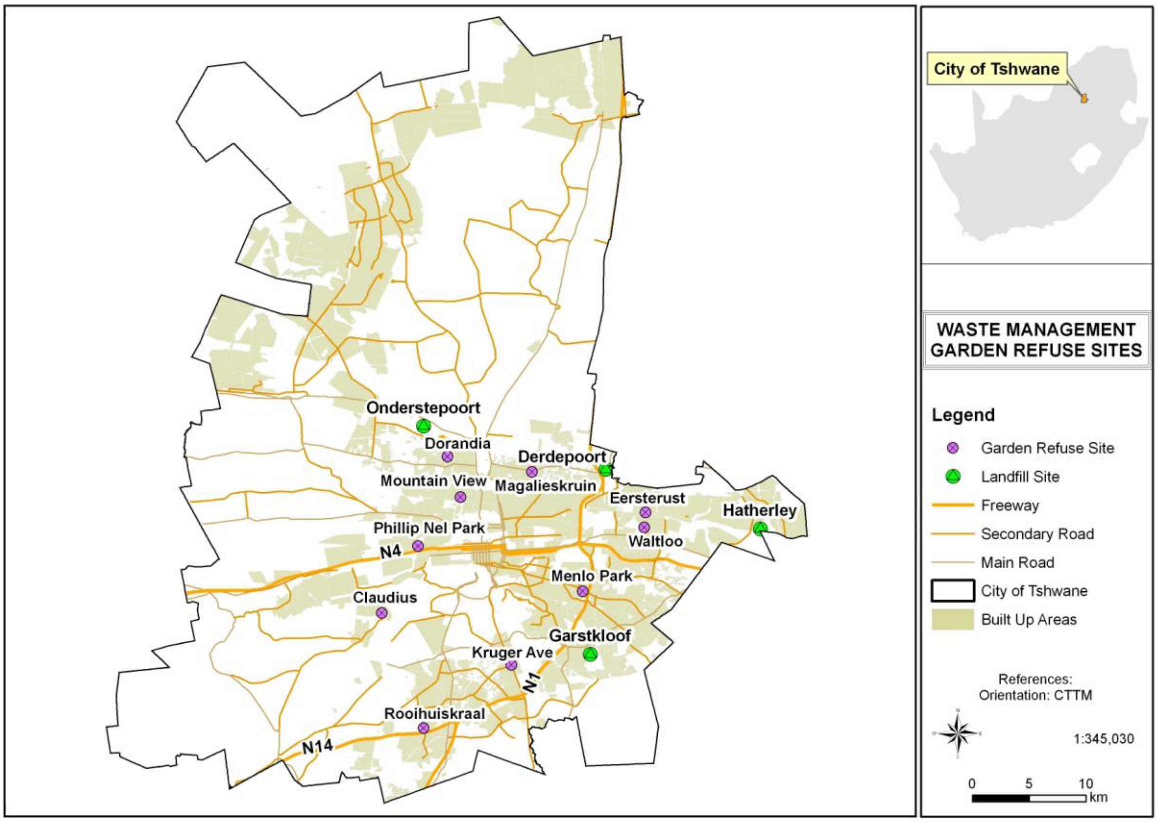


***Figure 4.6*: Proximity of garden sites to selected four landfill sites**

The operations therefore do not change dramatically, but will be more effective. The operation at the garden site will change in terms of improved supervision and the availability of a shredder for the incoming green waste. The reduction on transport costs will be significant. For every five trips to the landfill site with the unshredded green waste, three trips will be saved for the same amount of shredded green waste. This should make enough funding available to improve the operations at the garden site in terms of acquiring a shredder, and higher salaries because of more responsibility being taken by the garden site operators. The operations at the landfill sites will also change in terms of running a composting plant, but it is recommended that a dedicated team of officials with knowledge of composting and business management be appointed to run the plant. This is being done successfully at the Panorama Composting Facility.

The compost can be used by the municipality for municipal open spaces and gardens, thus saving on commercial fertilisers, or for rehabilitation of landfill sites. Alternatively the composting “business” can be leased out to a private company, making the green and the landfill space available to them. This supports Snyman (2009) who suggested that the green waste be made available to private enterprises specialising in composting.

In Cape Town approximately 14% of the total general waste designated for land filling are diverted by various waste minimisation methods, of which composting is one. Public-Private Partnerships is key to the success of the composting operations: the greens are shredded at the garden sites, and through a tender process it is allocated to private composting companies. In this way green waste is diverted from the landfill sites (City of Cape Town Council, 2008).

Saving landfill airspace *per se* is not the only advantage, the concurrent operational costs are also saved, and, as was seen earlier, it is the biodegradable portion of the MSW, which causes most of the greenhouse gasses. Composting can reduce the release of carbon dioxide and methane gas into the atmosphere, and financial gain can be obtained by means of carbon credits under the principles of Clean Development Mechanism (CDM) (Snyman, 2009). It can be argued that a composting plant as suggested, which will involve major changes in operations, logistics and allocation of financial resources, cannot be successful within the current municipal structure. If saving in landfill space is considered, substantial reduction in costs can be made, offsetting the increase in cost to establish the composting facility.

According to the State of Environment Report of the City of Tshwane, approximately 2.2 x 10_6 m^3 MSW was generated and disposed of at the nine landfill sites during 2002 (CTMM, 2004). Cover material needed for daily management amounted to about 559 $000m^3$. A total amount of R42 million was approved for the 2002/03 financial year for the operation and maintenance of the nine landfill sites. When converted to a cost per ton, the operational cost was approximately R35 per ton (CTMM, 2004). Currently the cost to dispose one ton of municipal waste is R29 per ton (Dekker, 2009). The reason for the low costs is that the landfill sites were in operation for many years and were not developed according to new engineering requirements with expensive liners, gas management, odour management, etc. Should a new landfill be established, the cost will increase to about R95 per ton (Du Plessis, 2007). This will be an incentive for the Municipality to carefully consider what is sent to the landfill, and waste minimisation, including composting, would be a more viable option.

4.6.3 Feasibility of municipal composting

In order to support the feasibility of composting municipal green waste, a survey was conducted with UNISA staff regarding the current level of awareness and participation in waste recycling in general, but also specifically in green waste recycling, i.e. composting (Joubert & Du Plessis, 2008). UNISA as a tertiary education institution was considered to be the ideal environment to do this research and to initiate recycling projects due to the high level of education of the respondents. More than 50% of the respondents held higher degrees in education. This survey was conducted by means of a structured questionnaire (see Appendix C), which was distributed by hand to 200 individuals and was also placed on the staff internal notice system for voluntary participation. A total of 125 hard copies (62.5%) and 142 electronic responses were “returned”. To put the survey into the context of the fact that educated people participated, it is necessary to give a wider background of the results and not refer to the green waste questions only. All questions are independent from each other and reflect a result expressed as a percentage. Of those interviewed it was revealed that 86.6% knew what recycling meant and that 78.8% knew what can be recycled and what can not. A percentage of 74.6 participated in recycling initiatives available within the community.

Of the respondents, 47.1% indicated a willingness to travel less than 3km to utilise recycling facilities and 35.2% indicated that they would travel between 3-5km to drop off their recyclables. However, most respondents indicated that they would prefer to drop off recyclables at shopping centres (30.2%) or at the workplace (28.1%). This is clearly an indication that this comprises of recyclables other than green waste, which will not be suitable for drop-off at those places. However, it was established that the willingness to put in some effort to promote recycling does exist.

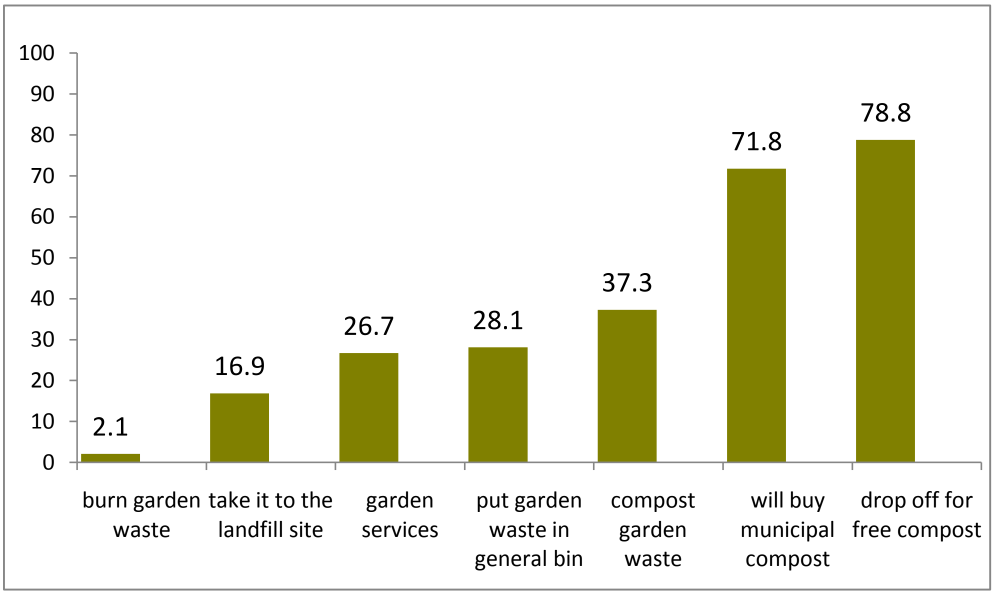


Figure 4.7: **Results of questionnaire on garden waste (%)**

Specific questions on the recycling of garden waste is depicted in Figure 4.7 revealed the following: a small percentage (2.1%) burn their garden waste; 16.9% take it to the landfill site; 26.7% have it taken away by garden services; 28.1% put it in the general municipal garbage bin; and the largest percentage, 37.3%, compost the garden waste themselves. Should high quality, certified municipal compost be sold at market-related prices, 71.8% indicated that they would buy such compost. The response to the question, should high quality, certified compost be given for free in exchange for dropping off clean green waste, 78.8% indicated that they would utilise this opportunity. This is a clear indication that participating communities would support a composting initiative.

4.6.4 Proposed procedures

Procedures for producing compost are intended to be practical and economically viable within the confines of existing practices of municipalities. A flow chart for decision-making is presented in Figure 4.8, to follow, as a proposed sequence of procedures for waste minimisation and composting. These procedures could assist the CTMM to change current waste disposal practices by diverting green waste away from being land filled to being utilised in composting operations. It provides a natural flow of events that should culminate in a product that has a multiple market to the benefit of the municipality, the public and the environment.

It is recommended that the separation of waste be implemented at the source. The separated garden waste would be directed to various recyclers who would compost the garden waste to optimally utilise available resources, and in this way promote conservation of natural resources. The extracted green fraction would be taken to garden sites where it can be chipped into waste skips to reduce the volume. From the garden sites, it would be transported to the landfill site to the area designated for composting where it is processed. The mature, certified compost would be ready to be sold to the public, dispatched for use in municipal gardens or to rehabilitate landfills or other brownfield areas[v].

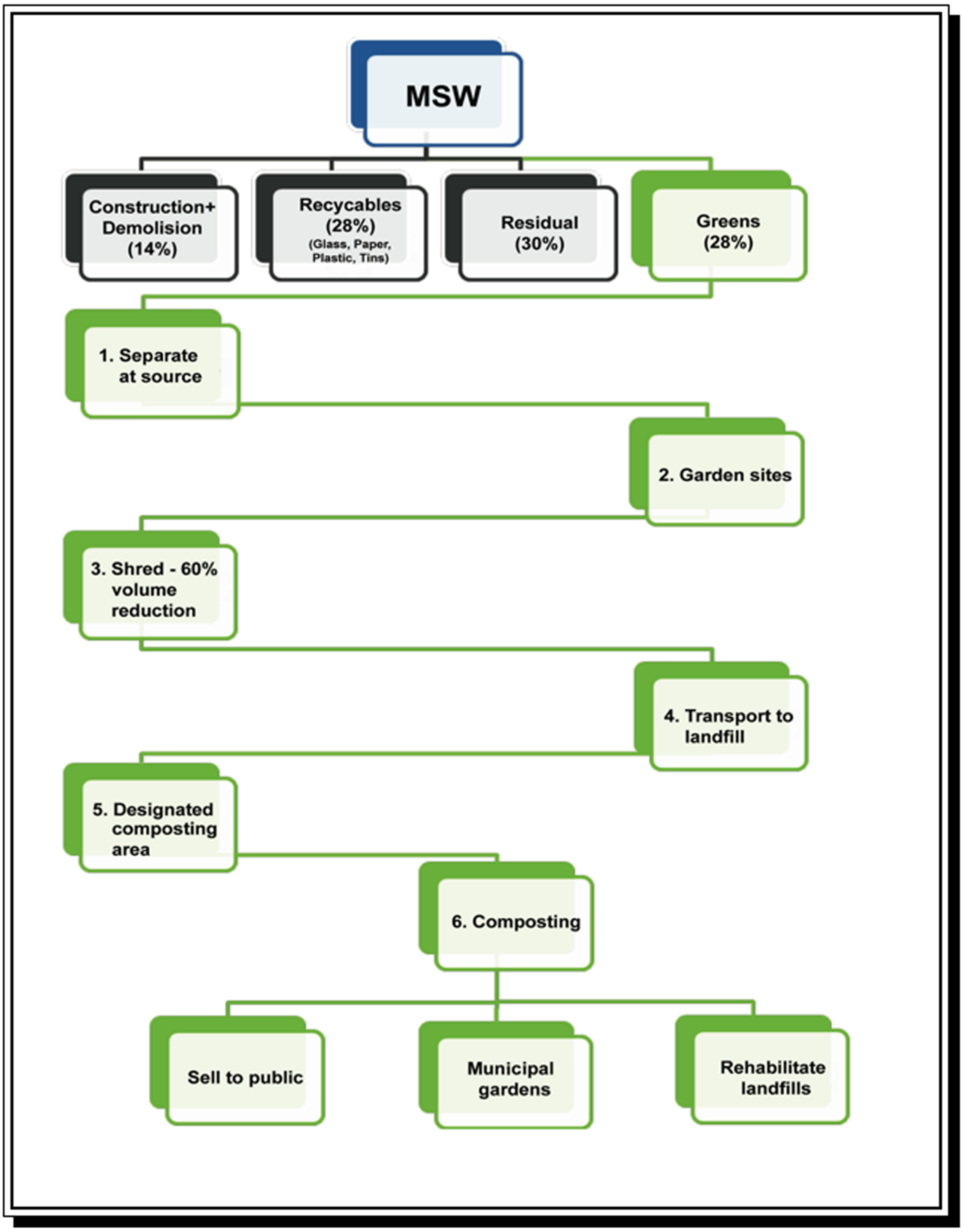


Figure 4.8: **Proposed sequence of procedures for waste minimisation and composting**

4.7 CONCLUDING COMMENTS

The assessment as completed in the preceding chapter provided a recommendation on how the current waste management system of the CTMM can be adapted to align itself with the national waste minimisation strategy to reduce waste to landfill. The screening of the sites was undertaken as an essential step to eliminate those sites that will be less suitable for a composting facility. This narrowed down the subsequent assessment to four sites and afforded a focused evaluation omitting unnecessary considerations. The selection of the physical, social and operational issues for the evaluation highlighted the essential elements to ultimately come to the realisation that most of the elements for the establishment of a composting facility are already in place. The information and recommendations presented in this dissertation should be useful for the implementation by the municipality of Tshwane's waste management operators.

The site-specific evaluation provided a description of each of the four sites to practically demonstrate how the application of the selected parameters could influence a decision on the suitability or unsuitability of the site for a composting facility. It provided information of what is already in place, what is still needed for a composting facility and where on the site a suitable location can be recommended. The evaluation has a practical value and is considered viable.

The chapter concluded with proposals to the CTMM on how to achieve their targets of waste minimisation without unattainable changes in their operations or excessive additional operating cost. In actual fact it implied a change in the mindset of the decision-makers to adapt current operations towards an environmentally friendly approach which they are not only encouraged to apply according to governing legislation, but are obliged to do. The recommendations have a wider application to any municipality in South Africa to enable them to manage waste minimisation adequately and with which they can easily cope in an economically thrifty fashion.

The completed evaluation of the selected landfill sites provided convincing evidence that the a change in the operations as suggested offers a logical incentive to save landfill space, as well as natural resources, since the use of compost denotes that the City of Tshwane would need less chemical fertilisers. Additionally it will contribute towards a reduction in the pollution landfills could cause. Instead of expensive mitigation measures at landfills to counteract the pollution, that which causes the pollution can be used as a valuable resource to add value to soils, produce healthier plants and have numerous other advantages as was discussed in Chapter 2. It is important to have the political will to approve of such changes and to revisit the waste management structure of the CTMM to suit this process. The waste minimisation focus of the government of South Africa, strongly driven by the Polokwane Declaration, could aid in positive decision-making to and encourage positive change of current practices.

Endnotes

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[i] *All weather roads* are roads that can handle the heavy waste trucks and other vehicles during muddy conditions, which are necessary to allow operations to proceed even during heavy rainfall events.

[ii] *G7* material refers to soil/fill with a particle size of 100–150mm.

[iii] MOD AASHTO is a soil/aggregate classification system developed for road building.

[iv] *G4* refers to natural base material, used for fill.

[v] *Brownfield areas* refers to those abandoned areas previously subjected to pollution and being rehabilitated for economic use.

Chapter 5

SYNTHESIS, RECOMMENDATIONS AND CONCLUSION

5.1 INTRODUCTION

The purpose of this chapter is to summarise the most important 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 waste minimisation intended for the CTMM area. Proposals for further and future research will also be suggested.

This study was based on the current waste management situation in South Africa. All waste generated within the boundaries of local municipalities is their responsibility and is in most cases managed by municipalities. The most common waste disposal method in South Africa is by landfill, which is an unacceptable facility and which have a detrimental effect on its surroundings. Because of this, landfill sites became the least preferred option of waste disposal and municipalities are encouraged to minimise waste disposal. Although waste minimisation was made mandatory by several national initiatives, very little progress had been made to curb rising waste generation, and subsequent disposal into landfill sites.

The ultimate aim of this study was to present a solution to waste minimisation by determining the feasibility of the establishment of composting facilities on landfill sites to advance waste minimisation by the CTMM. According to the findings of this study, one third of all municipal waste consists of green waste, which is compostable. Composting this fraction of the waste would immediately put the Municipality in a position to meet the reduction in waste disposal target of 25%, as proposed in the Polokwane Declaration, by 2012.

5.2 SYNTHESIS

Should available resources, which are accessible to municipalities, be utilised, a contribution could be made towards waste minimisation in the form of composting. Green waste could be removed and treated separately to produce compost. This will have multiple advantages of which saving landfill space and the production of compost, a valuable soil conditioner and fertiliser, are the most important. This research has shown that the CTMM can indeed accomplish this goal, although changes to the current waste management plan would need to be implemented. The hypothesis can therefore be accepted. The major findings of the research will be presented below according to the objectives formulated in Chapter 1.

a. To review the regulatory framework for waste minimisation to establish the need for composting.

By means of a literature study, the background to the research problem was successfully established, including the legislatory framework and the need for composting in South Africa (Chapter 2). Worldwide waste minimisation has been established in countries like the USA, Canada, Japan, European countries and United Kingdom. South Africa joined this trend through several legislatory measures:

- *Constitution of South Africa* promote that "Everyone has a right to an environment that is not harmful to their health and well-being";
- *National Waste Management Strategy (NWMS)* adopted the waste minimisation hierarchy of waste prevention the most preferred option, and waste disposal by land filling the least preferred;
- *Integrated Pollution and Waste Management (IP&WM)* promoting pollution prevention;
- *Polokwane Declaration* has the aim to reduce waste generation and disposal by 50% and 25% respectively by 2012 and develop a plan for ZERO WASTE by 2022;

- *National Environmental Management Waste Act: 2008* envisages the protection of health, well-being and the environment by providing reasonable measures for waste minimisation.

Composting will be key to waste minimisation, which is the most important focus of the current waste management in South Africa.

b. To establish the value of compost as a soil conditioner.

According to the literature, composting is a valuable soil conditioner and can be used as a fertilizer with the following main benefits:

- It greatly influences the condition of the soil.
- It helps to retain moisture in soils.
- It suppresses plant diseases and pests and reduces the need for chemical fertilizers.
- It enriches soils and promotes higher yields of plants and crops.
- It can be used to remediate contaminated soil.
- It helps prevent pollution.
- It has the ability to prevent erosion and silting.
- It makes economic sense reducing the need for water, fertilizers and pesticides.

c. To determine the amount of green waste available within the municipal solid waste stream of the CTMM to make composting a viable option and to highlight the role of garden sites.

It was established that there is sufficient green waste available within the municipal solid waste stream of the CTMM to make composting a viable option. One third of the domestic waste within the borders of the CTMM is green waste. The origin of this is not only residential gardens, but also sport fields, municipal parks and open areas. Garden sites are conveniently situated and accessible for most garden-owners. Garden sites could play a key role in the separation of green waste from the rest of the waste stream in order to provide enough greens for composting operations on landfill sites.

d. To elucidate the composting process.

Information on the composting process was presented to serve as a background for the study. Composting is a basic and easy process if understood correctly. Five basic elements are required:

- a ratio of *carbon* (C) to *nitrogen* (N) of 1:3 (Carbons include sawdust, straw, wood clippings and dry leaves; Nitrogen include grass clippings, plant trimmings and food waste);
- *moisture content* (50-55% is recommended for effective composting; compost must dry out to 37% moisture content before it can be utilised);
- *aeration* by means of turning (essential to keep the biological and chemical process functioning; prevents the release of CO_2 which causes bad odours);
- *heat* (high temperatures between 45°C and 60°C for 1-3 weeks is recommended; temperatures of higher than 55° is needed for effective pathogen control; temperatures higher than 60°C indicate reduction in microbial activity and therefore the end of the composting process);
- *pH level* (A neutral value of 7 is required).

Composting is a four-phase process namely, the *Mesophilic Phase* (decomposing by fungi, action-bacteria and bacteria); the *Thermophilic Phase* (heating to destroy pathogens, kill weed seeds and insect larvae); the *Second Mesophilic Phase* (cooling); and the *Maturation Phase* (an increase in the fungi population and a decrease in bacterial numbers).

e. To describe and evaluate different options of composting methods to determine the best method for the CTMM.

A distinction was made between aerobic and anaerobic composting processes. In order to motivate for the different options of municipal composting, different composting methods were presented:

- *garden composting* (<u>cold composting</u> – small scale with high carbon content; <u>hot composting</u> – a faster method and requires turning);
- *municipal composting systems* (<u>static windrows</u> - green waste is piled in rows of 3m high and 6m wide; large space needed; premixing of material needed; takes 6 months to mature; forced aeration could be used to

quicken the process; dome aeration method - no turning needed, 3-4 weeks to maturation, inexpensive; turned windrows - most common method; 16 weeks to maturation; expensive turning equipment; composting reactors - unsightly technology, high installation costs, ideal for sludge composting, require small space).

If there is sufficient space available, windrows will be suitable for composting by the CTMM. Static windrows do not need expensive turning equipment, but it takes longer (6 months) for the compost to mature, whereas turned windrows is a faster process (3 months), but it needs expensive turning equipment. Hand-turned windrows will be suitable for community projects or where job opportunities are needed. When a very small space is available, mechanical turning equipment will be the best option, although more expensive. This has the added benefit that the composting process will be quick (4-6 weeks). Unique circumstances will determine the method to be applied.

f. To evaluate the Panorama Composting Facility as a successful example in the South African context.

The Minimum Requirements as the South African guideline for general waste (including green waste) disposal was used to establish the influence, which a composting facility will have on the receiving environment (Chapter 3). Potential adverse effects include aspects of air, water, noise and visual pollution, fire hazard, the presence of vermin and disease vectors and windblown litter, health safety and security.

Panorama Composting Facility owned and operated by *Pikitup*, was presented as an example of a successful composting facility effectively addressing these issues:

- Panorama receives enough green waste from garden sites.
- Adequate space is available for turned open windrows.
- A gradient of 3% presents the ideal slope for composting to accommodate on-site run-off and leachate from the compost piles in a small leachate dam.

- Panorama effectively uses the infrastructure, which already exists for waste management (waste trucks, road infrastructure, waste management structure in terms of offices, administrative staff and expertise in the waste industry).

Pikitup is committed to address waste minimisation through composting using existing municipal resources for urgently needed waste reduction thus contributing to the benefit of the environment and society. A composting facility on a closed landfill as an additional attribute is successful in the neighbouring city, Johannesburg, and it can also be so in the CTMM.

g. To determine a set of criteria relating specifically to the environmental, social and operational requirements of composting facilities.

Based on the minimum requirements as well as Panorama as example, criteria relating specifically to the physical (environmental), social and operational parameters of composting facilities were determined in order to distinguish it from the criteria regulating general waste (Chapter 3). These parameters specifically for composting facilities, which do not exist for South African circumstances, were isolated:

- *Physical parameters* include available green waste, size of the property (for windrows, parking and supporting buildings and enough area for manoeuvring of the delivery and customers vehicles), the gradient of the area (slight downward gradient of 3% to accommodate leachate) and the composting method (type of windrows/mechanical turner specific to each site according to the size of the area).
- *Social parameters* refer to committed management structures (a decision to minimise waste through composting), trained staff and informed surrounding landowners (through a process of consultation).
- *Operational parameters* include road networks, transport equipment/waste trucks and infrastructure to accommodate the transport vehicles, waste disposal licence, office building for administrative purposes (with ablution facilities, water and electricity), security fencing and access control, (with

weighbridge), a shed (storage of shredders, compost turners, sorters and fillers, bagging and storage of the compost), signposting.

Reasons to motivate for the open land on landfill sites as locations for composting facilities were offered:

- Composting as end-use of a landfill can contribute financially to the expensive aftercare.
- Available space on landfill sites can be used optimally.
- A buffer zone and licensing conditions address adverse impacts.
- Uneven settlement of the waste limits the use of the large open area after landfill closure.
- Municipal resources are available and utilised.

A relative size of 1.5ha was recommended as a minimum for a composting facility with turned windrows as method.

h. To evaluate the possibility to establish composting facilities on landfill sites in the City of Tshwane.

A selection process through screening all the landfill sites managed by the CTMM was conducted (Chapter 4). The two determining criteria applied were size of the property and the amount of green waste using an ordinal scale to rank the nine sites. The four of the nine landfill sites within the borders of the CTMM that ranked the highest were finally selected and investigated further according to the physical, social and operational criteria established earlier in the study. The evaluation established the following important facts in favour of the sites:

- Garstkloof: *Positive aspects* are that enough green waste, accessible, logistical system is in place to receive large quantities of green waste, a rehabilitated area is present, concrete fence and closure is near. The major *negative aspect* is the presence of dolomite. Appropriate buildings, signage, grading of the site and leachate and storm water control are *still needed*.

- Hatherley: *Positive aspects* include enough space, large quantities of green waste, no visual impact, buffer zone in place and the landfill is to operate for the next 50 years. A *negative aspect* is that it is historically and archaeologically sensitive. S*till needed* are appropriate buildings and signage, grading of the specific area and leachate and storm water control.
- Onderstepoort: *Positive aspects* are that it is accessible, has effective buffer zones, the site is filling up rapidly and preliminary rehabilitated areas as well as an open area suitable for composting is available. The *negative aspects* are that it is near sensitive areas and has a shallow water table. However, interim capping, a weighbridge, storm water management, appropriate buildings, signage and grading of the site are *still needed*.
- Derdepoort: *Positive aspects* include that it is accessible, closure is near, rehabilitation can be adapted to suit the needs of a composting facility, hand turned windrows will create jobs and the logistical system is in place for green waste. The negative aspects are that the site has no open land, resulting in composting be done on the waste body creating a visual impact. Derdepoort will *still need* appropriate buildings, signage, a leachate system, a waste licence (no permit) and it has to consider the neighbouring communities and a nearby stream.

It is a feasible option to establish composting facilities on all four sites that were investigated, especially if end-use of a landfill site is taken into account. Suggested solutions for waste minimisation include the reduction of waste to landfill by separating the green waste from the rest of the waste stream, and the establishment of a composting facility on one/all four landfill sites to process this green waste into a valuable product, compost.

i. To determine the willingness of the public to participate in a composting programme.

Members of UNISA staff were interviewed by means of a structured questionnaire (50% of the respondents held higher degrees in education). The respondents' knowledge of recycling indicated that the majority knew what recycling meant and knew what can be recycled and what not, including green waste. Their response to their willingness to participate in recycling revealed that most do participate in recycling initiatives, some are willing to travel less than 3km to utilise recycling facilities while others are willing to travel between 3-5km to drop off their recyclables or prefer to drop off recyclables at shopping centres or the work place. On the question of recycling garden waste, more respondents indicated that they compost garden waste themselves, others place it in the general municipal garbage bin or others use garden services. The majority of the respondents would buy high quality certified municipal compost or exchange their clean green waste for free high quality compost. All these findings seem to point to a high probability that the public would be willing to participate in composting activities, should it be made available to residents.

j. To design a set of procedures for establishing composting facilities in the CTMM.

Composting facilities are feasible using a suggested procedure to help change current waste management operations of the CTMM. A flow chart indicating practical procedures for decision-making was presented that should assist the CTMM to change current waste disposal practices by diverting green waste away from being land filled to being utilised in composting operations.

5.3 RECOMMENDATIONS INTENDED FOR COMPOSTING FOR THE CTMM

The findings reported clearly demonstrate that each of the four selected sites comply with the determined criteria. It is therefore recommended that the CTMM proceed immediately to implement composting facilities on all four sites that were evaluated, or as a minimum, on one site. Should only one site be considered, Hatherly is recommended since it attained the highest rating and is well suited for such an operation to be successful and an economical asset. It is therefore suggested that the infrastructure on the landfill site, the disposal process, as well as the management process be adapted to start a composting process on the premises:

- *Landfill infrastructure*: The shortcomings identified at the sites and suggestions made in the previous section could be addressed to put everything in place for a composting facility on site. Finances for this could be acquired through the projected savings on transport costs and landfill operating costs.
- *Disposal process*: Apply a change in operations at the garden sites and the landfill sites: screen incoming green waste for quality (clean green waste); implement a shredder to reduce the volume of the waste; transport the shredded waste to the nearest composting facility; pile incoming waste into windrows.
- Implement a *change of operations* on the landfill site so that it could function as a composting facility by directing all incoming green waste to the on-site composting facility, depositing the green waste in and through a shredder and piling the shredded green waste into windrows.
- *Management process*: Several arrangements could be implemented to utilise the compost: for own use in parks, street gardens, and open areas within the CTMM boundaries; to sell compost to the public at reasonable prices in bags or bulk; to trade free compost for delivered green waste from home-owners or garden services; to provide a collection mechanism through Public Private Partnerships to collect separated green waste from home-owners to avoid it landing in the general waste disposal process.

The operations therefore do not have to change dramatically, but would need to be more effective. The operation at the garden site would change in terms of improved supervision and the availability of a shredder for the incoming green waste. The reduction on transport costs should be significant. For every five trips to the landfill site with the unshredded green waste, three trips will be saved for the same amount of shredded green waste. This should make enough funding available to improve the operations at the garden site in terms of acquiring a shredder and providing higher salaries because of more responsibility being taken by the garden site operators. The operations at the landfill sites will also change in terms of running a composting plant, but it is recommended that a dedicated team of officials with knowledge of composting and business management be appointed to run the plant. This is currently applied successfully at the *Panorama* composting facility.

The compost can be used by the Municipality for municipal open spaces and gardens, thus saving on commercial fertilisers, or for rehabilitation of landfill sites. Alternatively the composting “business” could be leased to a private company by making the green and the landfill space available to them. This proposal supports that of Snyman (2009) who suggested that the green waste be made available to private enterprises specialising in composting.

5.4 RECOMMENDATIONS FOR FURTHER STUDY

Very few municipal waste companies in South Africa practise composting. The costs of municipal solid waste (MSW) composting facilities are not widely known (Renkow & Rubin, 1998), and no in-depth studies regarding this are available for South African circumstances. This opens an opportunity for more research to establish the economic benefits of a municipal composting facility to motivate the establishment thereof.

With reference to the organic fraction of the municipal waste, mention is made to the threefold resource recovery of the organic fraction of the waste with the end products as compost, methane as a combustible gas or hydrolysing the cellulose components into glucose (Diaz *et al.*, 2007). Of these, composting is the most frequently applied worldwide. Braber (1995) believes that biological treatment methods such as composting offer the only route for recycling organic matter and nutrients from the organic fraction of MSW. However, the other two components of resource recovery that were not investigated provide an opportunity for further research within the South African context and circumstances.

Another area of study that needs to be investigated, is that by composting carbon credits could be earned, from which the income could be reinvested in the expensive operation and monitoring of operative landfill sites and the post-monitoring of closed landfill sites.

5.5 CONCLUSION

The hypothesis that green waste could be separated and treated to produce compost was proofed in this study. The production of compost could take place on landfill sites (closed or operational), which already have the required resources and waste management infrastructure in place. The findings of this study clearly provided the basic parameters and requirements for constructing a composting facility and practical procedures applicable within a South African context. The outcome of the evaluation of the landfill sites within the boundaries of the CTMM is in order of suitability: Garstkloof, Onderstepoort, Hatherley and lastly Derdepoort.

By applying the recommendations made, the CTMM should be inspired and empowered to reach their goals of waste minimisation within a very short period, with limited effort and expenses, with the benefit of producing a valuable product, which can be applied for own use or sold to the public. Not only will a positive contribution be made to the aspiration of conserving and beautifying the environment, but also minimising related health problems within nearby communities.

REFERENCES

Arms K. 1994. *Environmental science*. Orlando, FL: Saunders College Publishing.

Botkin DB & Keller EA. 2007. *Environmental Science: earth as a living plane* (3rd ed.). Danvers, IL: John Wiley.

Braber K. 1995. Anaerobic digestion of municipal solid waste: a modern waste disposal option on the verge of breakthrough. *Biomass and Bioenergy,* 9(1-5):365-376.

Bredenhann l. 2005. Introducing the draft third edition of minimum requirements for waste disposal by land filling, for hazardous waste handling, classification and disposal and for water monitoring at waste disposal facilities. Unpublished paper presented at a Seminar of the Landfill Interest Group, 20 & 21 October 2005, Durban. Durban: Landfill Interest Group.

Brown SP & Ryan P. 1999. *Master composter handbook.* Hillsborough: Hillsborough Cooperative Extension Service.

CalRecycle (California Department of Resources Recycling and Recovery). 2010. California Compost Quality Council. http://www.ciwmb.ca.gov/lglibrary/innovations/organics/Summary.htm Accessed: 01-04-2010.

Chang N-B & Davila, E. 2006. Minimax regret optimization analysis for a regional solid waste management system. *Waste Management,* 27(6):820-832.

Chang S, Cha Y, Wu M, Chiu T, Che J, Wang F & Tseng C. 2004. Acute *Cycas* seed poisoning in Taiwan. *Clinical Toxicology*, 42(1):49-54. http://informahealthcare.com/doi/abs/10.1081/CLT-120028744 Accessed 04-05-2010.

Cherubini F, Bargigli S & Ulgiati S. 2007. Life cycle assessment of urban waste management: energy performance and environmental impacts. The case of Rome, Italy. *Waste Management,* 28(12):2552-2564.

City of Cape Town Council (Solid Waste Management [SWM] Department). 2008. Solid Waste Management Department Integrated Waste Management and Service Delivery Sector Plan. http://www.capetown.gov.za/en/IDP/Documents/Statutory%20compliance%20plans/I%20Waste%20Plan%20SWM%2017_01_08%20(final).pdf Accessed 04-03-2009.

Collins J & Maneveldt G. 2001. Compost. http://www.botany.uwc.ac.za/Envfacts/facts/compost.htm Accessed 16-06-2007.

Compost Council of Canada. 1994a. What is Composting? Compost Council of Canada website: http://www.compost.org/qna.html#section5 Accessed 26-06-2008.

Compost Council of Canada. 1994b. The composting process: odour management. Compost Council of Canada website: http://www.compost.org/pdf/sheet 3 PDF Accessed 26-06-2008.

Composting Council of Canada. 2006. *Questions and answers about composting*. http//www.compost.org//qna.html#section14 Accessed 26-06-2008.

Conradie J. 2007. Personal visit 5 February 2007 at Conradie Organics on the Delmas Road.

CTMM (City of Tshwane Metropolitan Municipality). 2004. *State of the Environment Report for the City of Tshwane 2001–2002*. Pretoria: CTMM, Department of Housing, City Planning and Environmental Management section, Environmental Resource Management.

Cunningham WP, Cunningham MA & Saigo BW. 2005. *Environmental Science, a global concern* (8^{th} ed.). Boston, MA: McGraw-Hill.

Deane C. 2006. *Waste management firm shifts focus to recycling.* http://www.engineeringnews.co.za/searchquick.php?searchString=pikitup&imageField.x=10&imageField.y=1 Accessed 20-10-2007.

DEAT (Department of Environmental Affairs and Tourism). 1999a. Action Plan for Integrated Waste Management Planning Version C. DEAT website: http://www.environment.gov.za/ProjProg/WasteMgmt/planning/index.html Accessed 01-05-2009.

DEAT (Department of Environmental Affairs and Tourism). 1999b. *National Waste Management Strategy of South Africa*. Pretoria: Government Printer.

DEAT (Department of Environmental Affairs and Tourism). 1999c. The Constitution: Bill of rights. DEAT website: http://www.info.gov.za/documents/constitution/1996/96cons2.htm#7 Accessed 15-01-2010.

DEAT (Department of Environmental Affairs and Tourism). 2001. The Polokwane Declaration on Waste Management. DEAT website: http://www.environment.gov.za/ProjProg/WasteMgmt/Polokwane_declare.htm Accessed 08/05/2010.

DEAT (Department of Environmental Affairs and Tourism). 2005. *National Waste Management Strategy Implementation Project*. Pretoria: Government Printer.

DEAT (Department of Environmental Affairs and Tourism). 2007. Environmental management compliance inspection and investigation – biodiversity. Advanced short course. Pretoria: Department of Environmental Affairs and Tourism.

DEAT (Department of Environmental Affairs and Tourism). 2008. National Environmental Management: Waste Act 2008 (Act no 59 of 2008). *Government Gazette* (No. 32000) Vol. 525:10, Cape Town.

Dekker F. 2007. Interview with CTMM Landfill Manager, Hatherley, 05-10-2007.

Dekker F. 2009. Personal communication with landfill manager: CTMM, Pretoria, 19 June 2009.

Diaz LF, Bertoldi deM, Bidlingmaier W & Stentiford E. 2007. *Compost science and technology* (Waste Management Series, No. 8). Amsterdam: Elsevier.

Diaz LF, Savage GM, Eggebert LL & Golueke CG. 1993. *Composting and recycling municipal solid waste*. London: Lewis Publishers.

Diedericks B. 2007. Personal visit 15 October 2007 at Ocean fertilizers, Cape Town.

Donahue M. 2002. Ingestion of toxic plants by herbivores. Utah State University. http://extension.usu.edu/files/publications/factsheet/3_2_1.pdf Accessed 04-05-2010.

Du Plessis R. 2006. Scoping Report with a view to closure for the Linbro Park landfill site for waste disposal by landfill. Unpublished report. Johannesburg: Pikitup.

Du Plessis R. 2007. A feasibility study into the establishment of composting facilities on closed municipal landfill sites. The 2nd International Conference of the Egyptian Society for Environmental Sciences, Ismailia, 9-10 July 2007. Ismailia (Egypt): ESES.

Du Plessis R. 2008. Municipal composting facilities on selected sites in the Tshwane municipal area in South Africa. IWMSA 19th Waste Management Conference proceedings, WasteCon 2008, 6-10 October 2008. Durban: IWMSA.

DWAF (Department of Water Affairs and Forestry), 1998. *Minimum requirements for waste disposal by landfill* (Waste Management Series, 2nd ed.). Pretoria: Government Printer.

DWAF (Department of Water Affairs and Forestry). 2005. *Minimum requirements for waste disposal by landfill* (Waste Management Series, 3rd ed.). Pretoria: Government Printer.

Dwyer J H. 1983. Statistical models for the social and behavioral sciences. New York: Oxford University Press.

ECN (European Composting Network). 2006. About ECN: About the network. http://www.compostnetwork.info/ Accessed 26-06-2008.

Ekelund L & Nystrom K. 2007. Composting of municipal waste in South Africa – sustainability aspects. Uppsala (Sweden): Uppsala University.

EPA (Environmental Protection Agency, US). 1994. Composting of yard trimmings and municipal solid waste. http://www.epa.gov/epawaste/conserve/rrr/composting/pubs/cytmsw.pdf Accessed 02-03-2009.

EPA (Environmental Protection Agency, US). 1997. Environmental benefits of composting. EPA530-F-97-042. Washington, DC. http://www.epa.gov/epawaste/conserve/rrr/composting/benefits.htm Accessed 03-03-2009.

eThekwini Municipal Communications Department (1a). 2008. http://www.durban.gov.za/durban/services/services/dsw/refuse_sites/new_landfills/landfill7 Accessed 20-05-2008.

eThekwini Municipal Communications Department (1b). 2008. http://www.ethekwini.gov.za/durban/government/munadmin/media/press/325 Accessed 20-05-2008.

Felehetsa (Environmental). 2004. *Draft for comment: Development of an integrated waste management plan for the City of Tshwane Metropolitan Municipality*. Report. Pretoria: City of Tshwane Metropolitan Municipality.

Frederickson J, Butt KR, Morris RM & Daniel C. 1997. Combining vermiculture with traditional green waste composting systems. *Soil Biology and Biochemistry*, 29(3-4):725-730.

Fuggle RF & Rabie MA. 1999. *Environmental Management in South Africa*. Cape Town: Juta.

Furter L. 2004. Green waste should not end up in large holes in land. *Resource*, 6:1. http://search.sabinet.co.za/images/ejour/resource/resource_v6_n1_a17.pdf Accessed 10-05-2008.

GDACE (Gauteng Department of Agriculture, Conservation and Environment). 2009. General waste management facilities standards. Final version. Johannesburg: GDACE.

GDARD (Gauteng Department of Agriculture and Rural Development). 2010. Communication received in response to an enquiry with regard to the establishment of a waste composting facility dated 14-04-2010.

Gouws L. 1961. Laboratory studies of the breakdown of plant waste products in composting. Unpublished MSc thesis. Bloemfontein: University of Orange Free State.

Griessel W. 2002. Anaerobic bioconversion of the organic fraction from the fruit processing industry. Unpublished MSc thesis. Stellenbosch: University of Stellenbosch.

Harrison JA. 2001. Turning compost. Unpublished MA thesis. Cape Town: University of Cape Town.

Hernanz S. 2007. MSW Treatment Plant with biomethanisation and composting in Vitoria-Gasteiz. Infoenviro Plant Report. http://www.ows.be/pub/Vitoria_InfoEnviro.mei07.pdf Accessed 06-11-2010.

Issel LJ. 1999. Bioprocessing of grape pomace. Unpublished MSc (Microbiology) thesis. Stellenboch: University of Stellenbosch.

Jali P. 2009. History. www.pikitup.co.za/default.asp?id=665 Accessed 31-05-2010.

Joubert ED & Du Plessis R. 2008. Minimising waste through education: A case study of awareness levels and practices at Unisa, Pretoria. IWMSA 19th Waste Management Conference proceedings, WasteCon 2008, 6-10 October 2008. Durban: IWMSA.

Khwani CB. 2003. The green waste recycling in Merebank. Unpublished MSc(Eng.) thesis. Durban: University of Kwa-Zulu Natal.

Körner I, Braukmeier J, Herrenklage J, Leikam K, Ritzkowski M, Schlegelmilch M & Stegmann R. 2003. Investigation and optimization of composting processes – test systems and practical examples. *Waste Management*, 23(1):17-26.

Kupchella CE & Hyland MC. 1993. *Environmental science living within the system of nature*. New York: Prentice-Hall.

Lombard JP. 1978. Investigation into the municipal compost industry in the Western Cape, with specific reference to the demand structure. Unpublished MSc thesis. Stellenbosch: University of Stellenbosch.

McLaughlin M. 2007. *Closed landfills: assets in disguise*. http/:www.scsengineers.com/Papers/McLaughlin_Closed_Landfill-Assets_in_Disguise.pdf Accessed 10-12-2007.

Miller GT (Jr.). 2005. *Living in the environment*. Pacific Grove: Brooks/Cole-Thompson Learning.

Miller JM & Conn EE. 1980. Metabolism of hydrogen cyanide by higher plants1. *Plant Physiology*, 65:1199-1202. http://www.plantphysiol.org/cgi/reprint/65/6/1199 Accessed 04-05-2010.

Misgav A, Perl N & Avnimelech Y. 2001. Selecting a compatible open space use for a closed landfill site. *Landscape and Urban Planning*, 55(2):95-111.

Montague P. 1993. Rachel's Hazardous Waste News #352: News and resources for environmental justice. . erf@igc.apc.org Accessed 28-05-2007.

NIST (National Institute of Standards and Technology, Washington and the U.S. Commerce Department) 2001. Will composting work for us? A decision guide for managers of businesses, institutions, campuses, and other facilities. cwc.org/organics/organic_htms/cm976rpt.htm Accessed 26-06-2008.

Nxumalo FT. 1999. Waste management through recycling and composting: a case study of some schools in Great Edendale, Pietermaritzburg. Unpublished MEnvDev thesis. Pietermaritzburg: University of Natal, School of Environment and Development.

Phillips C. 2002a. The Composting process: Odour management. Composting Council of Canada. http//www.compost.org/pdf/sheet_3PDF Accessed 26-06-2008.

Phillips C. 2002b. The Composting process: Leachate management. Composting Council of Canada. http//www.compost.org/pdf/sheet_3PDF Accessed 26-06-2008.

Phillips PS, Pratt RM & Pike K. 2001. An analysis of UK waste minimization clubs: key requirements for future cost effective developments. *Waste Management*, 21(4):389-404.

Pieters R. 1993. Reproduction strategy in the vermin-composting oligochaete Species Perionix Excavatus. Unpublished MSc thesis. Potchefstroom: Potchefstroom University for Christian Higher Education.

Pikitup. 2007. Pikitup launches the first fully organic potting soil. http://www.pikitup.co.za/default.asp?id=860 Accessed 20-10-2007.

Pikitup. 2008/9. Pikitup annual report. http://www.pikitup.co.za/upload/files/Pikitup_annual_report%2008_09_LATEST_VERSION_v1.pdf Accessed 31-05-2009.

Polprasert C. 1996. *Organic waste recycling: technology and management*. New York: John Wiley.

Potgieter JJC. 2007. Compostability and compost quality of certain municipal and industrial biosolids. Unpublished MscAgric thesis. Pretoria: University of Pretoria.

Read AD, Hudgins M & Phillips, P. 2001. Perpetual landfilling through aeration of the waste mass: lessons from test cells in Georgia (USA). *Waste Management*, 21(7):617-629.

Recycling Product News. 1999. Drum versus elevating-face compost turners. Recycling Product News website: http://rpn.baumpub.com/products/10066/drum-versus-elevating-face-compost-turners Accessed 28-06-2008.

Regan HM, Colyvan M & Markovchick-Nicholls, L. 2006. A formal model for consensus and negotiation in environmental management. *Journal of Environmental Management,* 80(2):167-176.

Renkow M & Rubin AR. 1998. Does municipal waste composting make sense? *Journal of Environmental Mana*gement, 53(4):339-347.

Riekert HF. 1991. The utilisation of Eisenia fetida (oligochaeta) in vermin-composting abattoir waste. Potchefstroom: Potchefstroom University for Christian Higher Education.

Scragg A. 2005. *Environmental biotechnology*. Oxford: Oxford University Press.

SCS (Engineers). 2009. Landfill closure, post-closure care and site re-use. http://www.scsengineers.com/closure%20and%20site%20reuse.html. Accessed 02-05-2009.

Seadon JK. 2006. Integrated waste management – Looking beyond the solid waste horizon. *Waste Management*, 26(12):1336-1327.

Senesi N. 1989. Composted materials as organic fertilizers. *Science of the Total Environment*, 81-82:521-542.

Snyman NJ & Du Plessis R. 2008. No greens, to waste. IWMSA Conference proceedings, IWMSA 19th Waste Management Conference proceedings, WasteCon 2008, 6-10 October 2008. Durban: IWMSA.

Snyman NJ. 2007. Waste stream analysis for the City of Tshwane Metropolitan Municipality. Unpublished raw data. Pretoria: Tshwane: Metropolitan Municipality.

Snyman NJ. 2009. A zero waste model for the City of Tshwane Metropolitan Municipality. Doctor Technologiae. Pretoria: Tshwane University of Technology.

Soil and More Reliance South Africa. 2008. http://www.soilandmore.com/sites/partnersouthafrica.html Accessed 06-03-2009.

Stephens LN. 2007. *Locating and attracting composting facilities*. http://www.ciwmb.ca.gov/LgLibrary/Innovations/Organics/Compost.htm Accessed 08-05-2008.

Tresler NL. 1991. Technical and implementational considerations in designing a municipal yard waste composting facility for the city of Garland, Texas. Unpublished doctoral dissertation. Arlington, TX: University of Texas.

Trois C & Polster A. 2007. Effective pine bark composting with the dome aeration technology. *Waste Management,* 1(27):96-105.

UNEP (United Nations Environment Programme). 1992. Sustainable Consumption and Production Branch, Division of Technology, Industry, and Economics. http://www.unep.fr/scp/cp/understanding/concept.htm Accessed 12-11-2010.

Van Heerden I. 1998. Compost from citrus waste for control of Phytophthora root rot. Unpublished MScAgric thesis. Pretoria: University of Pretoria.

Van Rensburg CAJ. 1968. Population studies on the mesofauna of compost, with special reference to the parasitoid mesostigmata (Acari). Unpublished MSc thesis. Potchefstroom: Potchefstroom University for Christian Higher Education.

Van Staden, F. 2006. Monitoring microbial community structure during the composting process using genetic fingerprinting techniques. Unpublished MEnvSci thesis. Potchefstroom: North-West University.

Washington State Legislature. 2003. *Composting facilities* (WAC 173-350-220). http://apps.leg.wa.gov/WAC/default.aspx?cite=173-350-220 Accessed 05-06-2009.

WasteMINZ (The Waste Management Institute of New Zealand). 2008. Operations: A guide to commercial and industrial composting facilities. WasteMINZ website:

http://wasteminz.org.nz/sectorgroups/compost/composting-nz_new/operations.htm Accessed 03-06-2010.

Wei Y, Fan Y, Wang M & Wang, J. 2000. Composting and compost application in China. *Resources, Conservation & Recycling*, 30(4):277-300.

Wiechers Environmental Consultancy. 2005. Scoping study for the proposed construction of a new Garden Green Composting Facility at the existing Robinson Deep landfill site in Johannesburg. Unpublished report. Johannesburg: Pikitup.

Williams PT. 1998. *Waste treatment and disposal* (1st ed.). West Sussex [England]: John Wiley.

Williams PT. 2005. *Waste treatment and disposal* (2nd ed.). West Sussex [England]: John Wiley.

Yin RK. (2003). *Case study research: Design and methods* (3rd ed.). London: Sage.

Zurbrügg C, Drescher S, Patel A & Sharatchandra, HC. 2004. Decentralised composting of urban waste: an overview of community and private initiatives in Indian cities. *Waste Management,* 24(7):655-662.

APPENDIX A
Research design

RESEARCH OBJECTIVES	METHODS & PROCEDURES **Case study, qualitative** Analysis of implementation process	PLANNING OF CHAPTERS
• To review the regulatory framework for waste minimisation and establish the need for composting	Literature search	Chapter 1 Establish the legislature framework and the need for composting in South Africa in terms of waste minimisation
• To establish the value of compost as a soil conditioner	Literature search	Chapter 2 Facts of composting as a valuable soil conditioner and fertilizer
• To determine the amount of green waste available within the municipal solid waste stream of the CTMM to make composting a viable option and the role of garden sites	Perusal of reports, articles, interpretation of data, quantitative analysis of green waste amounts	Chapter 2 Availability of enough green waste and key role of garden sites
• To provide an understanding of the composting process	Literature search	Chapter 2 A clarification of the composting process
• To describe and evaluate different options of composting methods to determine the best method for the CTMM	Literature search for critical valuation	Chapter 2 Describe and evaluate different composting methods

RESEARCH OBJECTIVES	METHODS & PROCEDURES **Case study, qualitative evaluation** Analysis of implementation process	PLANNING OF CHAPTERS
• To determine a set of criteria relating specifically to the environmental requirements of composting facilities	Description and evaluation of environmental factors, deductions	Chapter 3 Determine criteria specifically for composting facilities
• To evaluate a South Africa composting facility as a successful example – Panorama case study	Case study: Description, assessment, personal observations during site visits, personal interviews with the personnel and perusing reports, articles in press and on the Internet	Chapter 3 Panorama investigated as a successful composting facility on a landfill site
• To evaluate the possibility to establish composting facilities on landfill sites in the City of Tshwane	Ordinal scale for selection Checklist drafted for evaluation site visits to evaluate using observation, photographs and the checklist	Chapter 4 Evaluation of the 4 selected sites in Tshwane
• To determine the willingness of the public to participate in a composting program	Questionnaire – quantitative analysis	Chapter 4 Report responses of public willingness to participate
• To design a set of recommended procedures in the operations in the CTMM (flow chart)	Synthesis of all previous information	Chapter 4 Propose procedures within the municipal context in the form of a flow chart

APPENDIX B
Site checklist

PARAMETERS	ONDERSTE/P	DERDE/P	HATHERLY	GARST/K	COMMENTS
Physical parameters					
Available green waste					
Size of the property					
Gradient					
Operational parameters					
Road network (all weather)					
Transport equipment/waste trucks					
Infrastructure to accommodate the transport vehicles access/gate manoeuvring area offloading area					
Waste disposal licence					
Office building					
Ablution facilities					
Water and electricity					
Security fencing and access control					
Weigh bridge					

PARAMETERS	ONDERSTE/P	DERDE/P	HATHERLY	GARST/K	COMMENTS
Operational parameters (*cont.*)					
Shed					
Signposting					
Operating plan: nuisance control Leachate control					
Social parameters					
Committed Management structures (CTMM)					
Trained staff					
Informed surrounding landowners					

APPENDIX C
Waste questionnaire

Dear Participant

Unisa is positioning itself as a leader in education on the African continent. This places us in the limelight, and we need to be an example to be followed. Looking after the environment is a worldwide trend, trying to find solutions to environmental issues. One of the serious problems we are faced with is uncontrollable amounts of waste.

The primary objective of this questionnaire is to determine the level of awareness of waste recycling within the Unisa community and to determine to what extent they participate in waste recycling. A secondary objective is to assess the possibility in the change of attitude and increased participation of Unisa employees in waste recycling initiatives.

Please take 4 minutes to fill in the questionnaire. All personal information will be treated as strictly confidential and will be used solely for the purposes of this survey. The results can assist us in developing strategies to use waste as a resource by means of the three R's (see the logo below). Your participation in this baseline survey is greatly appreciated.

Kind regards

Roelien du Plessis Esther D. Joubert

________________ ________________

Department of Environmental Sciences

REDUCE

RECYCLE REUSE

WASTE RECYCLING SURVEY
Please indicate the relevant option by means of a tick (✓).

GENERAL WASTE

1 Do you know what recycling of waste means?
- ♲ Yes
- ♲ No

2 Can you distinguish between what can be recycled and what cannot?
- ♲ Yes
- ♲ No

3 Do you recycle any of your non-garden (non-green) waste at home?
- ♲ Yes
- ♲ No

4 If yes, indicate what types of recyclable waste (indicate all applicable options).
- ♲ Glass
- ♲ Paper
- ♲ Plastics
- ♲ Cans
- ♲ Metal
- ♲ E-waste (refers to electronic and electrical waste such as stoves, fridges, computer equipment, cellular phones, etc.)

5 Do you recycle any of your waste at work?
- ♲ Yes
- ♲ No

6 If yes, indicate what types of waste (mark all applicable options):
- ♲ Glass
- ♲ Paper
- ♲ Plastics
- ♲ Cans
- ♲ Metal
- ♲ E-waste

7 Are you aware of any recycling facilities / bins in your community?
- ♲ Yes
- ♲ No

8 If yes, indicate what type of waste is catered for (mark all applicable options):
- ♲ Glass
- ♲ Paper
- ♲ Plastics
- ♲ Cans
- ♲ E-waste
- ♲ Metal

9 Do you use any of the above facilities?
- ♲ Yes
- ♲ No

10 If yes, indicate how often.

- Weekly
- Monthly
- Bi-annually
- When there is a need

11 If not, indicate which of the following reasons prevent you from using these facilities.

- Do not recycle at home
- Too inconvenient
- Too far
- Unaware of recycling initiatives.

14 What distance would you consider convenient to travel to drop off your recyclables?

- Less than 3 km
- 3 to 5 km
- More than 5 km

15 Indicate which one of the following places is most convenient for you to drop off your recyclables.

__ Recycling centre at landfill site
__ Transfer station or garden refuse site
__ Shopping Centre
__ Filling station
__ School
__ Workplace

GARDEN/GREEN WASTE

16 What do you do with your garden / green waste? (tick all applicable options)

- Have it taken away by garden services
- Burn it
- Put it in the general garbage bin
- Compost it
- Take it to a landfill
- Other, please specify ______________________

17 If garden refuse sites sold high quality, certified compost at a market-related price, would you purchase compost from them?

- Yes
- No

18 If you are given free high quality, certified compost in exchange for dropping off clean green waste, would you to utilise this opportunity?

- Yes
- No

AWARENESS

19 Do you feel that you have been sufficiently made aware of recycling facilities?

- Yes
- No

20 Will increased awareness regarding the benefits of waste recycling would you start to implement it at home and work?

- Yes
- No
- Dedicated recycler

21 If you were provided with information and advice that would help you to implement simple lifestyle changes in your household to recycle waste, would you consider doing this?

- Yes
- No

22 In general, do you feel there is a need for greater awareness and education about waste management and the role that communities can play?

- Yes
- No
- Dedicated recycler.

PERSONAL INFO

23 Level of Education:

Grade 12 and below
- Degree / diploma
- Honours degree
- Masters degree
- Doctoral degree

26 In which sector are you working in Unisa?:

- Academic
- Professional
- Administative

25 Gender:

- Male
- Female

26 Age group:

- Younger than 20 years
- 20 to 29 years
- 30 to 39 years
- 40 to 49 years
- 50 years and older

27 Name the city/town and suburb that you reside in.

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Thank you for your participation. Keep an eye out for recycling opportunities near you!