



IMPROVING SOLID WASTE MANAGEMENT IN A COAL MINING ORGANIZATION: A CASE OF MAFUBE COAL

Research Report submitted in partial completion of the degree MSc in
Environmental Science

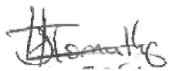
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2024

Declaration

I declare that this research report is my own, unaided work. It is being submitted for the Degree of Master of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



(Signature of candidate)

6 day of June 20 25 at Mafube Coal

Abstract

Waste can be any substance that is unwanted and discarded. In most definitions, all waste is harmful unless treated (Nyika et al, 2019). Waste, and the management thereof, is a global issue and depending on how it is managed, it tends to be very harmful to the environment (Chen et al., 2019). It is acknowledged that including waste management in the legislature of a country is the best tool to enforce waste management. South Africa only has four decades of such an experience. This has made it slow for industries, such as coal mining, to implement lucrative waste initiatives. This study seeks to determine key issues associated with non-mineral waste management and to assess if a waste transfer station can be used as a tool to improve waste management. The key findings were that waste management at Mafube Coal is not standardized and a waste storage facility with a similar design of a waste transfer station can be used by the operation to improve non-mineral waste management.

Acknowledgements

Words cannot express my gratitude to my supervisor Mary Evans and co-supervisor Duduzile Modiba for their consistent patience and great support throughout the research period, through their provision of their knowledge and expertise this journey would not have taken place.

I would also like to acknowledge Lytton Malele and Ingrid Sithole for their belief in the research and for providing their expertise on the subject matter.

I am also appreciative of my colleagues at Mafube Coal and Steve Tshwete Local Municipality who took their time to participate in the research.

Lastly, I would be remiss in not mentioning Nomfundo Nala (partner) and Patience Gcinile Hlomuka (mother) for their unswerving support and belief in me which has kept my motivation in this research report.

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Chapter 1: Introduction

1.1 Background to the study

The management of waste has become a fundamental challenge because waste has multiple related impacts on the environmental and social space (Namgay & Norbu, 2020). With the increasing economic activities from developed and developing countries and its population (Aryampa et al, 2023), waste generation has increased exponentially. Using 2016 as a baseline, it is estimated that global waste generation will double by the year 2050 and triple by the year 2100 (Ferdous et al., 2021). An enormous amount of this waste goes to landfills, which are currently being pressured to expand (Aryampa et al., 2023). Disposing of waste in landfills remains the primary method of managing waste, which has caused significant degradation of land along with related impacts such as surface and groundwater pollution from the leachate as seen in the Kiteezi landfill in Uganda (Aryampa et al., 2023).

Waste management is mainly the strategies that are used to handle waste from generation to its treatment or disposal (Mubaslat, 2021). The global perspective of waste management stems from the waste hierarchy originating from the European Region which indicates the most favourable to the least favourable option, the tool has been adopted and modified to include a life cycle of a product (Zhang et al., 2022). In Africa, urbanization has gradually increased after the colonial era, and even though some countries have defined management options for waste, the prevailing waste management issues are from storage, collection to disposal to landfills and illegal dumps due to lack of capacity creation, technological and infrastructural limitations (Bello et al., 2016).

South Africa is one of the developing countries that have stringent waste management strategies and frameworks that have incorporated the lifecycle perspective of waste management, such as the National Waste Management Strategy (NWMS), which was created over six years under the National Environmental Management Waste Act (Nyika et al., 2019). The strategy advocates, amongst other things, that all waste generators and holders in all sectors work towards reducing waste to landfill by at least forty-five percent in

five years, fifty-five percent in ten years, and seventy percent in the next 15 years (Parliamentary Monitoring Group, 2022). However, even with the development of this strategy, all sectors still dispose of the waste mainly in landfills.

Since private sectors contribute massively to waste generation, Bello (2016) recommends that they should partner with government bodies to tackle waste issues. The mining sector, for example, contributes significantly to the country's economy but still, large quantities of mineral and non-mineral waste are disposed of (Krishna et al., 2020). Mafube Coal Mining, for example is a coal mine entity formed from a joint venture between two large coal mining companies in Mpumalanga, between Middelburg and Belfast (Exxaro limited, 2024). The mine has been gradually increasing their waste to landfill for the past three years (Malele, 2024). Even though they aim for sustainable mining, there were several issues related to waste management identified in the 2024 audit report published by Thungela Resources (2024). These issues have led to the disposal of majority of non-mineral waste to the landfill. To address this gap, waste streams need to be identified, managed using best practice using tools or facilities that will work for the operation.

To develop sustainably, such sectors need to strategically manage the waste by looking into greener solutions, such as recycling using a waste transfer/sorting station as opposed to disposing of the waste. This will efficiently improve financial performance in parallel with sustainable production (Al-Sakkari et al., 2022). Thus, this research used the Mafube Coal mine as a research site to bridge the gap by investigating an effective waste management alternative for its non-mineral waste, with a specific focus on waste transfer stations.

1.2 Aim and Objectives

This study aimed to investigate how a waste transfer station can be used as an alternative to improve non-mineral waste management at Mafube Coal and achieve its goal of reducing waste to landfills.

The objectives of the study are:

- To determine the waste streams generated in the coal mining operation.

- To examine alternative waste management options, if any, for each waste stream.
- To evaluate using a waste station as one of the mechanisms for zero waste to landfill.
- To recommend a best practice model for the waste transfer station for the mine.

1.3 Rationale

This study is important because waste generation in the operation is increasing. The measures in place to divert waste from the landfill are currently inadequate. The site has identified waste management as one of the key objectives and the reduction of waste to landfill is being targeted for the next decade, indicating that the mine shows a potential to implement the required actions. The research will thus examine how a waste transfer station can improve management.

1.4 Study Area

Mafube Coal is a 50/50 joint venture between Exxaro and Thungela Resources. It is situated approximately 30 km from Middelburg and 20 km north of Arnot Power Station. (Exxaro Limited, 2024) (see Figure 1.1). It covers three coal reserve blocks situated in the Witbank Coalfields with approved mining rights for each of them with other land uses such as grazing (Golder Associates Africa, 2019). The operation is a well-established coal mine producing approximately five million tons per annum for export, with an annual rainfall of 680mm (Golder Associates Africa, 2019). It has two sites currently operating, one of which is where the coal is mined through truck and shovel, and the second site is where coal beneficiation takes place (Geovicon Environmental, 2022). The operation consists of an average of 1200 employees and several contractors. The infrastructure found in both operations includes two office and security areas, four workshops, three salvage yards, and four overland conveyor areas. (Golder Associates Africa, 2019).

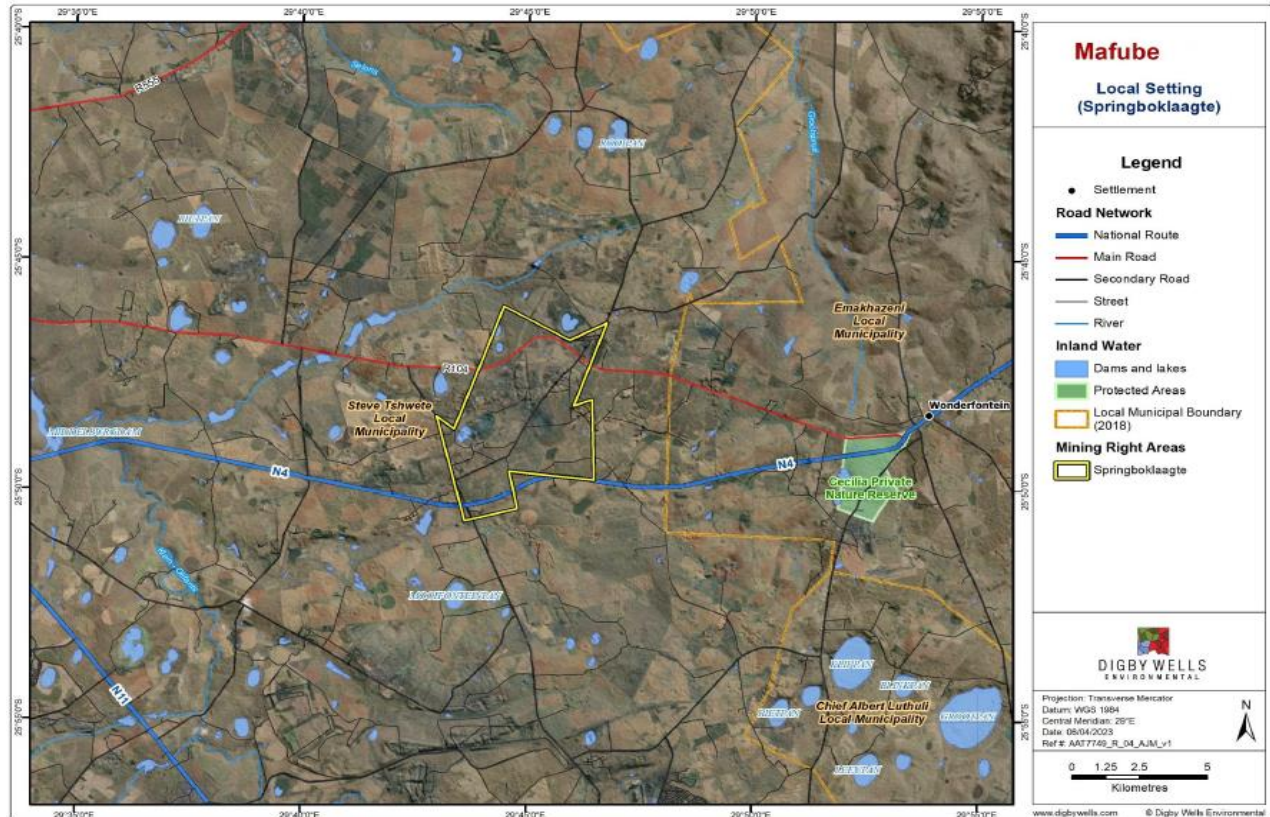


Figure 1.1: Map showing the locality of the research site (Kganedi et al., 2023 p.6).

The site manages its waste through a procedure that determines some of the waste that it generates and where that waste is taken (Geovicon Environmental, 2022). The waste is placed in colour-coded six m³ skip bins; yellow is used for general waste, red is used for hazardous, and blue is for scrap (Malele, 2024). These skips are put in different locations for ease of placement depending on operational requirements (Malele, 2024). For example, there will be more general waste skips than scrap and hazardous skips in office areas than in workshop areas. A contractor is scheduled to collect and dispose of general and hazardous waste in approved landfill sites and scrap metal is recycled (Kganedi et al., 2023).

The joint companies' business strategy has objectives to reduce waste going to landfills using the waste disposal recorded tonnages in 2021 as a baseline (Thungela Resources, 2023). However, most of the waste (both hazardous and general) is currently sent to the landfill site with only a few recycling activities such as scrap metal, plastic bottles, and bottle tops (Malele, 2024). There is also a reuse trial for oily rags at one workshop

whereby the rags are collected from the generators, washed using existing facilities and finally sent back to users. Partly due to this initiative, hazardous waste has decreased for the past three years (see Figure 1.2) (Malele, 2024).



Figure 1.2: Graph showing hazardous waste disposed from 2021 – 2023 (Hlomuka, 2024).

However, the general waste disposed of is increasing (see Figure 1.3), mainly due to the increase in the number of employees and contractors as well as the increase in the mine footprint (Malele, 2024). It also means that the current alternatives for general waste are not sufficiently implemented, and separation of waste is not adequate (Malele, 2024).

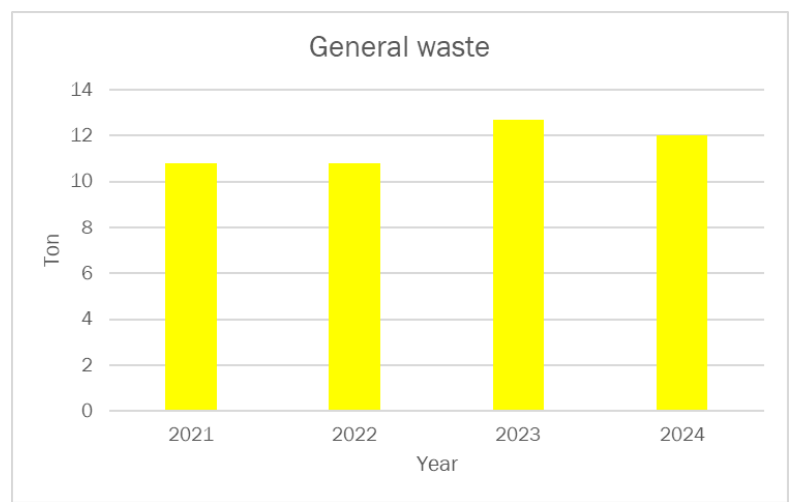


Figure 1.3: General waste disposed from 2021 – 2023 (Hlomuka, 2024)

Although hazardous waste is decreasing, the South African Petroleum Industry Association (2023) indicates that the cost of diesel increased from 1792.48 cents per Liter to 2181.49 cents per Liter from 2021 to 2023 respectively. This ultimately affects the cost of

waste collection and transportation. The site requires a standardized waste management strategy that will manage general and hazardous non-mineral waste that it generates using best practices and processes.

1.4 Structure of the Report

- Chapter 1 focused on the background of waste management along with the aims and objectives of the study and more information regarding the study site.
- Chapter 2 is a literature review which looks at relevant themes related to waste management, the issues associated with waste, and how it is managed internationally, nationally as well as within the coal mining industry. A brief overview of the Zero Waste to Landfill to build an understanding of the concern and the possible solutions.
- Chapter 3 discussed the tools and processes that were used to conduct the research and how the qualitative data assisted in achieving the study's objective.
- Chapter 4 determined the outcomes of the study from the methods used.
- Chapter 5 discussed the results and possible recommendations associated with the construction of a waste transfer station at Mafube Coal.
- Chapter 6 discusses the research conclusion and proposes recommendations for future work.

Chapter 2: Literature Review

2.1 Introduction

The study undertakes a conceptual framework that seeks to define different concepts related to waste management on a global and national scale and the relationships of the concepts. The review briefly discusses the findings from the desktop and the implications thereof. The aspects or themes of this chapter briefly defines waste and its environmental and socio-economic impacts. It also touches on the history of waste management and what it entails and highlights how other countries apply waste management. Moreover, it reviews waste management in South Africa in terms of its development in the legislature and the current frameworks and strategies it uses. The chapter also briefly discusses the concept of Zero Waste to Landfill and waste transfer stations. Management of waste in the coal mining industry in South Africa as well as a look into how the major mining companies are currently managing non-mineral waste for the past three years is also discussed.

2.2 Waste and its impacts on landfills

Waste has been largely defined in many studies. The general definition of waste in most studies is described as a by-product of human activities that is not of use to the producer (Amasuomo & Baird, 2016). It can be any substance that is unwanted and discarded. In most definitions, all waste is harmful unless treated (Nyika et al, 2019). Waste comes in all physical states of matter: solid, liquid, and gas. The six main sources of waste are household or municipal, industrial, demolition and construction, agricultural, and commercial and mining (Al-Sakkari et al., 2022). Studies have shown that the most produced waste differs from one country to another based on economic and development activities (Amasuomo & Baird, 2016). Construction and demolition waste, for example, is the primary waste generated in large economies such as China, the US, and the European Union (Kabirifar et al., 2020). In 2010, the total waste generated globally was 7 to 10 billion tonnes of waste, and two billion comes from solid municipal waste. Half of the total waste is generated by developed countries such as Canada, Europe, United States of America etc (Wilson & Velis, 2015).

Solid waste can impact the environment and health differently depending on how it is managed (Chen et al., 2020), several studies have covered waste streams that have significantly impact. Plastic, for example, waste is a concern that is gradually increasing due to its longevity when disposed of since it gets ingested by organisms and possibly causes health issues throughout the food chain (Borelle et al., 2017). Waste impacts the air through the leachates from landfills, which produce nitrogen, dust, and open waste burning, all contributing to greenhouse gases (Vaverkova, 2019). Looking at the global waste generation stipulated in Figure 2.1, the impact will likely increase. Waste that is not collected correctly can allow for air and water-borne diseases, insects, and scavengers to thrive (World Bank, 2012). This information indicates that there is a need for waste to be managed

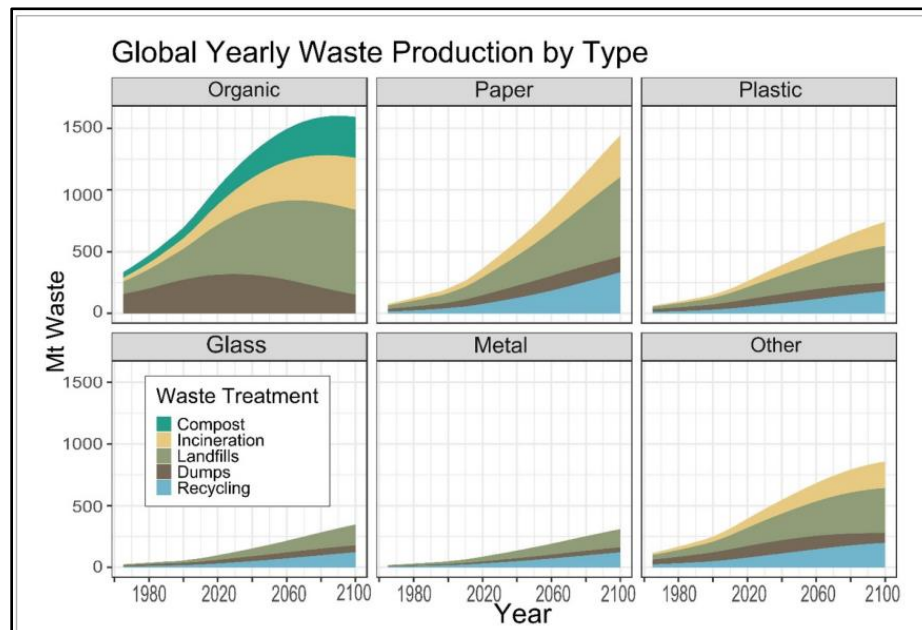


Figure 2.1: The global waste production by type per year (Chen et al., 2020 p.7)

2.3 The fundamentals of waste management

Waste management is the utilisation of different approaches and procedures that are designed and executed to identify, control as well as handle several types of waste from a life cycle perspective (Mubaslat, 2021). Ikizoglu and Kiyan (2020) concur by alluding to it as an international philosophy whereby a systematic approach involving the product, its

process design and management thereof to preserve natural resources and prevent incineration and burial of the waste, the product itself must be designed to be managed effectively (Kiyan & Ikizoglu, 2020). Implementing these processes is important in reducing or avoiding environmental impacts considering resource availability (Abubakar et al., 2022).

To develop policies, frameworks and strategies, a waste hierarchy is one of the key tools used to establish the most preferable option to the least waste management option, which then prompts technical and innovative initiatives (Eguez, 2021). The history of a waste hierarchy in research stems back to 1979 when a Dutch politician named Ad Lansink submitted a schematic presentation showing a ladder of preferred options for waste management with the most preferred at the top and the least at the bottom, and this was eventually known as the Ladder of Lansink (Recycling.com, 2019). It was not until 2008 that the European Commission adopted and gradually modified the concept to what is known as the Waste Hierarchy, which had a clear vision of the prevention of waste and ultimately evolved by factoring the cyclic economy, which focused on the product life cycle perspective (Zhang et al., 2022). Figure 2.2 shows the development of the waste hierarchy that continues to include other industries such as the food industry (Food waste Hierarchy) or a shift in which waste is or is not allowed into the Landfill (Zero waste Hierarchy).

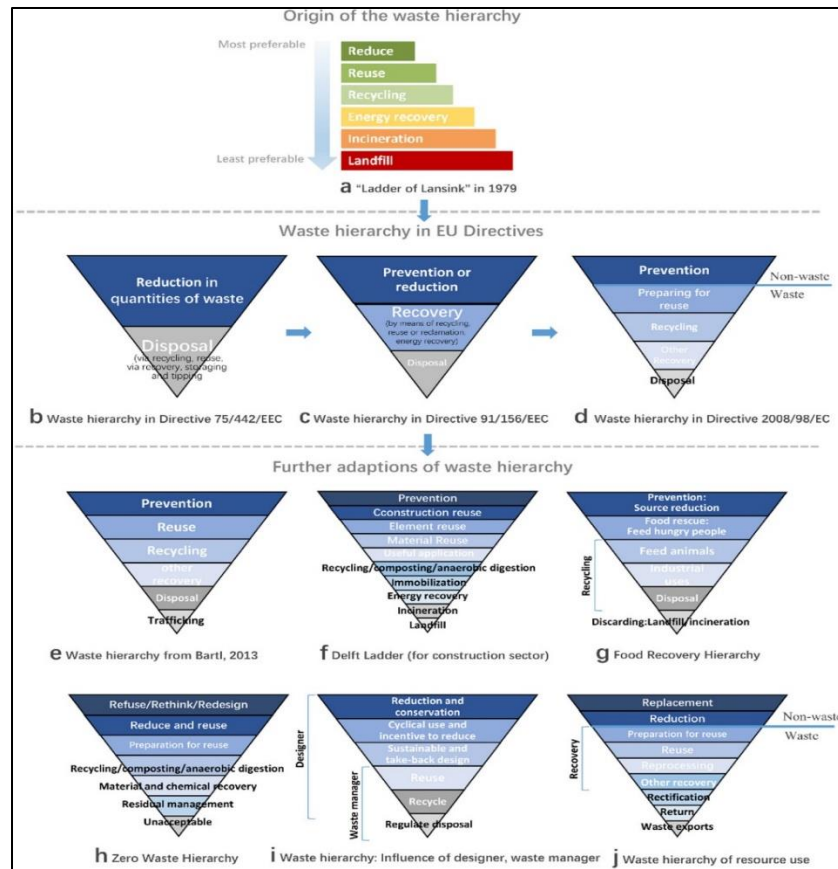


Figure 2.2 The evolution of the Waste Hierarchy (Zhang et al., 2022 p5)

The most common hierarchy is the Waste Hierarchy (D), as seen in Figure 2.2, which was found in Directive 2008 and adopted in other countries and policies. The first recommendation is waste prevention or avoidance as the most preferred option to prevent additions to an existing waste stream (Van Ewijk & Stegemann, 2016). Prevention is the most difficult to execute as it depends on economic development aspects that must be endorsed by incentives and depends on producer responsibility (Department of Environmental Affairs, 2019). Reusing, recycling, and recovering are part of physical processes that reclaim substances deemed as waste and redirect the stream from landfills. Recycling entails refurbishing or repairing waste to a reusable form (Price & Joseph, 2000). It is typically done by non-governmental organisations, some of which work in partnership with the government, e.g., collect-a-can initiatives. Other recovery methods involve biological, chemical, and heat processes that are used as alternatives, and they avoid the least favourable option of disposal in landfills (Nyika et al., 2019).

A study compared waste management in the Umbria Region based in Italy and the West Bank in Palestine. Due to the strict inclusion of the waste hierarchy into the legislation and the economy, the Umbria Region was able to reach about fifty percent of its recycling rate through the separated collection and treated disposal, whereas the West Bank region in Palestine had a recycling rate of six percent due to political instability and inadequate awareness (Di Maria et al., 2017). Other countries, such as Mozambique, do not define a waste hierarchy in their legislation clearly, and even though local frameworks and economic issues should be considered, most African countries generally struggle with waste management due to a lack of coordinated initiatives and inadequately structured institutions (Ferrari et al., 2016).

2.4 Waste Management in South Africa

South Africa uses the National Environmental Management: Waste Act to regulate and manage waste (Department of Environmental Affairs, 2019). However, like other countries, the Integrated National Waste Strategy was drafted so that the waste hierarchy is the backbone of the strategy, with preferable management options in descending order (Dlamini et al., 2019).

To understand waste management in South Africa, it is imperative to look at the stages of waste policy and legislation development because they can indicate the maturity of waste management. In Figure 2.3, Godfrey and Oelofse (2017) summarise the development of the waste sector in four stages, the first stage being the age of landfilling that began in 1989 when the Environmental Conservation Act determined how landfills should be managed to prevent pollution prevention from poorly built and maintained landfills. This stage saw the development of the first NWMS that set the tone for the following stages. The second stage, named the emergence of recycling policies, began in 2001 with the establishment of the White Paper, followed by the wave of regulations in the third stage after the enactment of the National Waste Management Act in 2008. The current stage is the drive for producers to take responsibility for the end of life of the products they distribute; this was seen with the development of the waste tyre plan in 2012. Implementing better management options is driven by stringent policies and regulations. With

the established and existing policies being just a little over three decades, researchers argue that options other than disposal are far from significant progression (Department of Science and Technology, 2012).

One of the Sustainable Development Goals (SDGs) related to waste management is improving life on land through the restoration of degraded land and aiming to neutralise land degradation (Elsheekh et al., 2021). Even though South Africa is one of the countries that are committed to SDGs, waste generation is growing in direct proportion to the rise in economic activities and increased population (Department of Environmental Affairs, 2011). Waste management in South Africa relies heavily on landfilling, dumping and incineration in open spaces (Dlamini et al., 2019). In 2012, South Africa produced 108 million tonnes of general and hazardous solid waste, ninety-eight million tonnes were disposed of in landfills and less than ten percent was recycled (Adeleke et al., 2021). Large cities that contribute significantly to the country's economy, such as Johannesburg, which is 1646 square kilometres in size, are running out of air space (Dlamini et al., 2019). Like other regions, South Africa needs to investigate improving their strategies, with the starting point being how a collection of separated waste (which can exponentially increase effective reuse, reduction and recycling rates) can be incorporated into the current waste management processes.

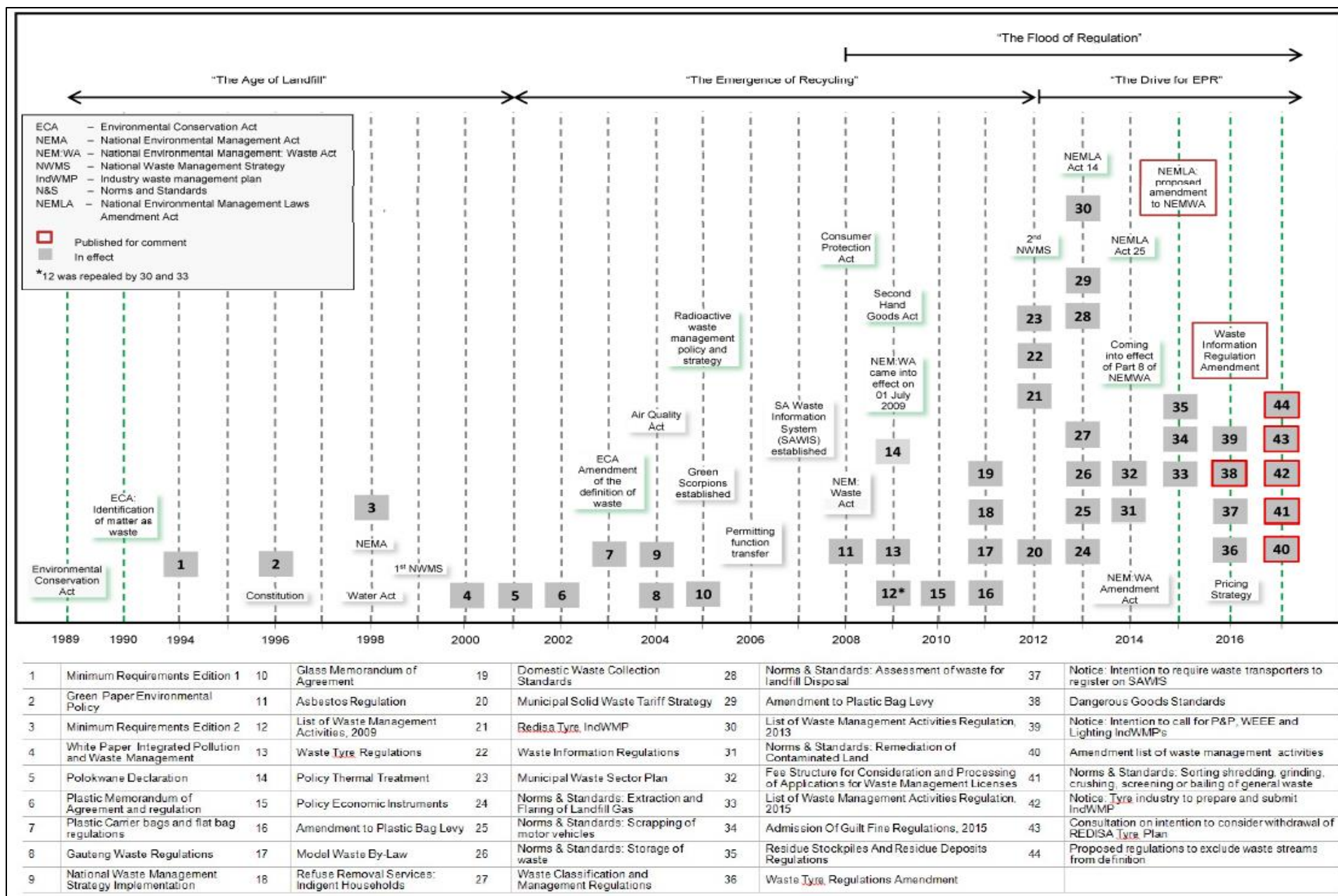


Figure 2.3: Timeline of waste management policies, legislations, and regulations in South Africa (Godfrey and Oelofse, 2017 p3)

2.5 Overview of the Zero Waste to Landfill and Waste Transfer Stations

Waste is a clear sign of inefficiency and misallocation of resources. When waste is created, a strain is placed on land, natural resources, energy, water, and the economy (Zaman & Lehman, 2013). Solutions to this issue require a shift towards transformation and not generation. Consequently, concepts such as zero waste to landfill have gained momentum globally (Hamid et al., 2020). Zero waste to landfill is the culture of adopting daily practices that involve diverting as much waste as possible from the landfill through reducing, reusing, and recycling waste (Hamid et al., 2020). Zero waste calls for responsible production and consumption with proper measures for re-using and recovering resources without burning or discharging them to the environment (Almansour & Akrami, 2024). This can be practised in municipalities and industries such as the coal mining industry.

Some international case studies supporting Zero Waste initiatives are the German Closed Cycle Management Act which aims to turn waste into a useful source of raw materials and put the responsibility of disposal on the producer of the products (Nelles et al., 2016). The Chinese government created policies that will firstly transform the economy from being linear to cyclic and shift industries from using non-renewable to renewable resources along with increasing to reduce carbon footprint and using waste as a secondary feed to energy resources (Lee et al., 2020). Other cities such as Adelaide, located in Australia, aspire to be one of the first cities in the country to reach Zero Waste to landfill with a clear action plan that aligns with its government objectives, one of those actions amongst others was to divert 90percent of the waste generated by the city from landfills (City of Adelaide, 2020).

In South Africa, the first milestones for Zero Waste to Landfill and entrenchment of a cyclic economy were introduced in 2020 when the updated National Waste Management Strategy was released (Olatayo et al., 2024). According to the strategy, zero waste to landfill can be reached through three pillars. The first pillar is waste minimization, which focuses on plastic packaging in some industries and implementing the waste hierarchy (Department of Environment, Forest and Fisheries, 2020). The outcomes for this pillar are shown in Figure 2.4. The second and third pillars are effective waste management services and

compliance enforcement. The key stakeholders for all pillars are the government sector and the private sector (Department of Environment, Forest and Fisheries, 2020).

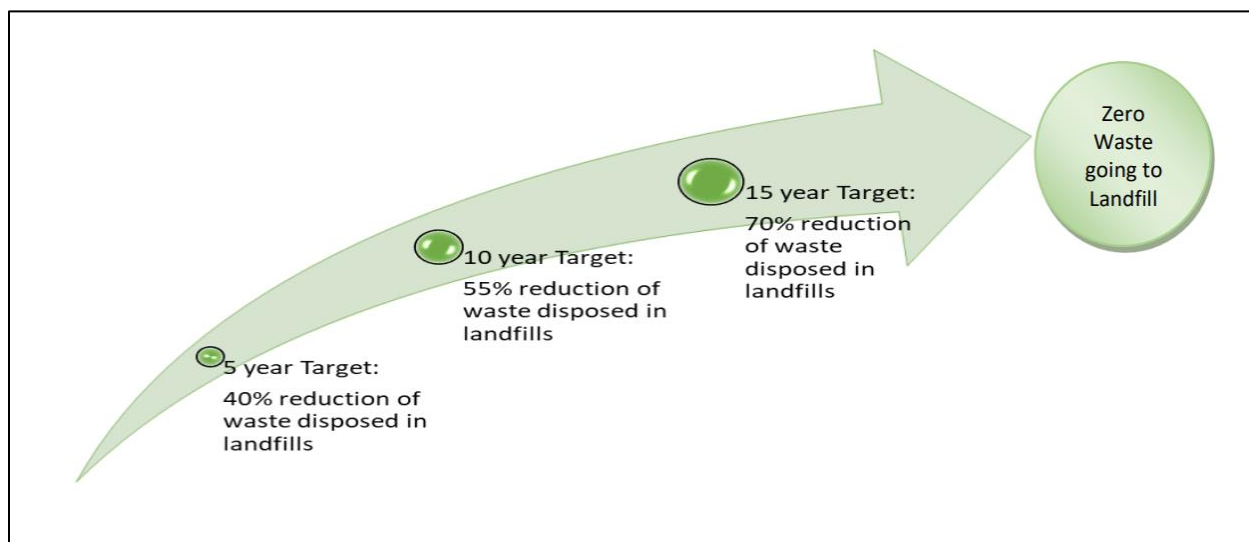


Figure 2.4: Milestones for waste minimization (Department of Environment, Forest and Fisheries, 2020 pg33)

As observed in other countries, reaching these milestones requires efficient separation collection methods. The traditional method of municipal solid waste collection is a door-to-door system whereby wheelie bins are placed outside the household, and a garbage truck is allocated to collect the waste and transport it to the disposal site (Gl'aser & Stücken, 2021). The main issues associated with this system are that the trucks are subjected to congested areas, which can prolong collection times, and the residential areas are subject to environmental impacts such as waste leakage (Han et al., 2024). Thus, trucks' collecting waste at each household becomes inefficient and costly (Gultekin et al., 2020).

A waste transfer station is a facility that receives waste coming from different sources and offers a centralised collection for waste collectors (Ramachandra, 2006). Transfer stations are used mostly by municipalities by smaller vehicles can be used to collect and transport waste to a collection point and large vehicles can collect accumulated waste from those stations to the disposal facilities (Everett & Applegate, 1995). They form a link between the disposal facilities and waste generators while reducing travelling time and cost (Shechter et al., 2007). There are different forms of transfer facilities, such as collec-

tion sites and underground garbage collection sites and the most common form is garbage accumulation points (GAPs) (see Figure 2.5), whereby the dustbins are collected by smaller vehicles to the transfer stations and the larger vehicles transport the waste to disposal sites (Han et al., 2024). Such collection concepts done by mostly municipalities can be adopted and moderated by waste generators such as the coal mining industries.

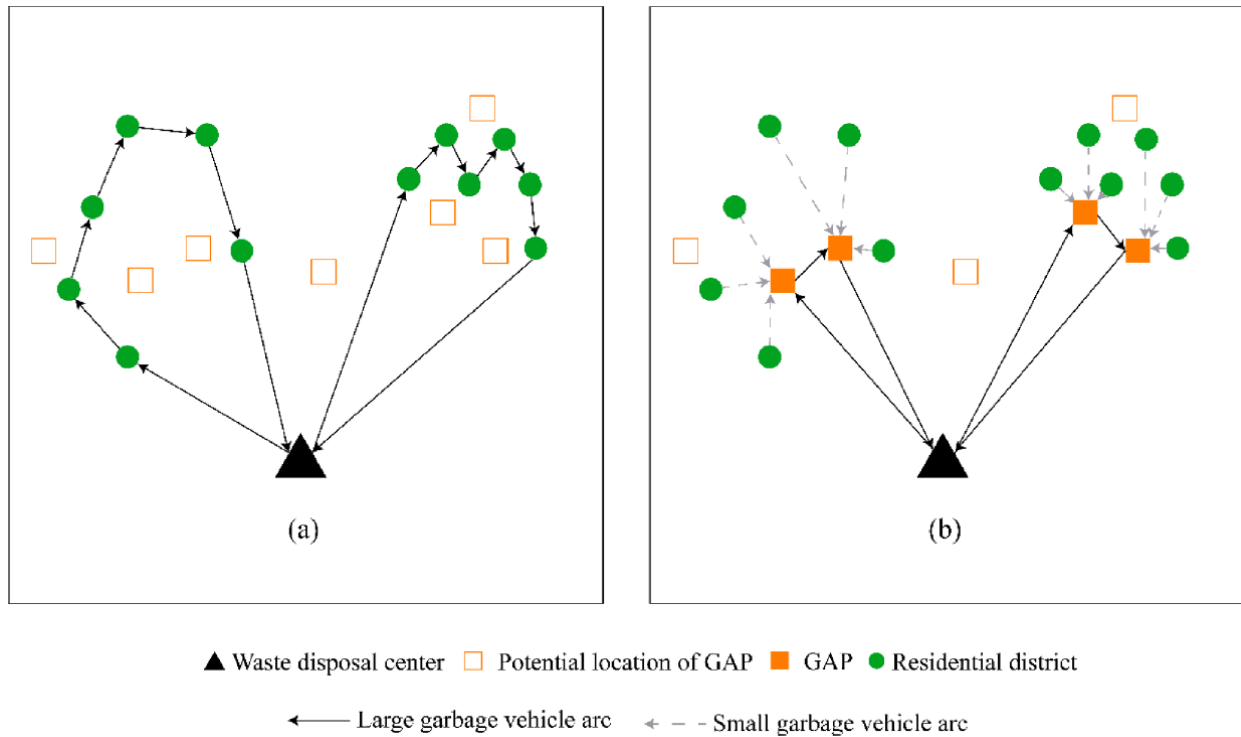


Figure 2.5: Traditional collection system versus GAP system (Han et al., 2024 p959).

2.6 Waste management in the South African coal mining industry

Research has covered coal extensively in South Africa in terms of its history and the socio-economic impacts it has. Coal in South Africa was discovered in Mpumalanga, Kwa-Zulu Natal and Eastern Cape provinces as early as the 1860s. With the discovery of other minerals such as gold and diamonds, coal demand increased (Jeffrey et al., 2014). The economic development of the country after the Second World War was forged majorly through coal mining (Hancox and Gotz, 2014). Coal is one of the largest energy sources in the world, with a gradual consumption increase annually, with South Africa being one of the top five coal producers, employing over 92000 people (Made et al., 2023) coupled with over 50 billion tonnes of reserves and 200 years' worth of coal left to supply (Jeffrey, 2005), it is likely that this cheap source of energy will still be used for a long time. Although there are alternatives to energy generation such as renewable energy (wind, water and biofuels) and countless studies are being done on the gradual transition away from coal, many of these lessons and transitions thrive better in developed countries rather than developing countries like South Africa (Strambo et al., 2019). Since studies indicate that coal will still be thriving, the waste from the mining processes will be generated.

Coal mining activities in South Africa also continue to have significant environmental impacts, such as water, air, and land pollution (Mbhedzi et al., 2018). As seen in other countries, waste is one of the key contributors to pollution. As mentioned earlier, mine waste is one of the 6 main types of waste generated worldwide. Most of the waste produced by a coal mine is waste rock, which is discarded on land. However, other types of waste are generated by a typical mine. Looking at a coal mines waste management strategy, it can illustrate the type of waste that can potentially be generated as well as its management options. an example, the Carmichael Coal mine and rail project by Adani Mining (2013) published its possible solid and liquid non-mineral waste streams. During the construction, operational and decommissioning phases, the following waste is produced:

- Green waste that comes from the clearing of land
- Spoils that will come from civil earthworks.
- Construction waste from the building of mine houses, offices, workshops

- General waste such as food, paper, plastic, cardboard, and glasses generated by the workforce.
- Hazardous waste from maintenance of equipment such as oils, drums, lubricants, paints, spill kits, air filters, oil filters, electrical waste such as fluorescent tubes or any other contaminated waste
- Sewage effluent waste and sludge from the treatment plants (both water and sewage)
- Medical wastes from injuries

It is therefore important to review how the current large mining companies are managing their waste, specifically non-mineral waste, as it contributes to approved landfill sites. Table 2.7.1 summarises the non-mineral waste generated and disposed of/recycled by these large companies. This information is shared through the company's sustainability report. According to the latest Environmental, Social and Governance (ESG) report by Exxaro Limited (2023), the company generates general waste such as recyclable waste (paper, plastic, polyethylene, cardboard and papers), non-hazardous recyclable waste (scrap metal, rubber products, conveyor belts) and non-recyclable waste. As shown in the Table below, the company has recycled four waste streams for the past 3 years from their business units, with a 2percent decrease from 2022 due to one of the operations not producing one of the recyclables. The hazardous waste generated, such as used oil, contaminated soil, etc, is also either recycled or disposed of in landfill. Exxaro disposed of 3186 tons of hazardous waste in landfills in 2023 compared to 520 tons in 2021. The general waste generated by Exxaro is not disclosed.

Thungela Resources generates the same type of non-mineral waste as Exxaro Resources, and it has also seen an increase in waste sent to landfills compared to the past years (2021-2023). Their ESG report indicated that general waste sent to landfills increased to 886 tons in 2023 from 776 tons in 2022, and the hazardous waste increased to 1442 tons from 1103 tons in the previous year, even with the recycling initiatives taking place, as shown in the table below. Other mining companies, such as MC Mining Limited (2023) have increased their waste to landfill due to the transition of management from

incineration to disposal to landfill; companies such as Seriti and Glencore have not disclosed the amount of waste generated. However, they have indicated that waste is sent to the landfill site.

One of the limitations of this theme is that there are more studies related to mineral waste management than non-mineral waste management in coal mines both internationally and nationally which what this study intends to contribute towards. Information regarding non-mineral waste is largely found in the sustainability of companies and has limited information regarding challenges and detailed solutions. This means that researchers and the private sector that mining industry fall under know very little about the current state of non-mineral waste and potential improvement methods that can be implemented. Further research of non-mineral waste management in coal mines can push companies a step further towards zero waste to landfill.

Table 2.1: South African coal mining companies and their waste management.

South African Largest coal mining companies and contributions to Landfills													
ROM (Mt)				General waste to landfill (t)					Hazardous waste to landfill (t)				
Mine ESG report	2021	2022	2023	2021	WTL 2022	WTL 2023	Management option	per-cent	WTL 2021	WTL 2022	WTL 2023	Management option	percent
Thungela Resources (Thungela Resources, 2023)	27.4	25.2	24.1	1416	1103	1442	Four streams are re-cycled; rest is dis-posed	2	916	776	889	Used oil recycling, other streams are dis-posed	
Exxaro Resources (Exxaro Resources. 2023)	42.5	43.1	42.5	ND	ND	ND	Four streams are re-cycled; rest is dis-posed	ND	520	1624	3186	Disposal	84
Glencore				ND	ND	ND	Disposal	ND	ND	ND	ND	Disposal	ND
MC Mining (MC Min-ing, 2023)	0.47	0.2	0.23	11	42	241	Disposal	95	0	0	124	Disposal	124per-cent
Seriti (Seriti. 2023)	ND	40	41	ND	ND	ND	One stream is recy-cled, rest is Disposal	ND	ND	ND	ND	One stream is recy-cled, rest is disposed	ND

Chapter 3: Methodology

3.1 Introduction

This chapter covers the steps that were taken to achieve the objectives of the study, including the importance of a waste stream list, what it will contain, and how it will be populated. It consists of a brief description of the study approach. It determines how the interviews of mine officials, and the waste site observations were used as information on the waste opportunities that the mine can practice. The chapter also determined how the study evaluated other stations to identify learnings and opportunities that the mine can consider when constructing and operating a waste transfer station.

3.2 Qualitative and quantitative research approach

It is essential to understand the research approach of this study and its dynamics to ensure clarity on why certain methods were chosen. A research approach can either be qualitative, quantitative or both. Quantitative research uses numerical data to test a theory, determine patterns or statistically determine trends and inter-relationships between variables, whereas qualitative research gathers non-mathematical data in the form of narratives to determine opinions and experiences of phenomena (Henline-Hall, 2024). There are three standard methods of qualitative research, namely interviews, which involves pre-set and open-ended questions for participants; focus groups which consists of group discussions conducted by the researcher with focused guidelines; and lastly observations, which come in the form of photographs, recordings and videos (Denny & Weckesser, 2022). Quantitative data comes from reliable measurements that stem from validated and organized collection methods (Abuhamda et al., 2021).

Instead of utilizing a quantitative approach which deduces a broad view that can be generalized to the population, qualitative research seeks to describe a current situation in a certain setting for a particular group of people, thus it requires fieldwork (Lowhorn, 2007). This study largely used a qualitative approach because the inputs are experiences coming from a particular group and the outcomes and recommendations needs to be specific

for that group. Individual interviews, questionnaires and visual observations served as the preferred research methods for this study.

3.3 Mining non-mineral waste inventory list

Knowing the tonnages of the waste generated as well as the composition of the disposed waste is the first step towards developing an efficient waste management strategy (Namgay & Norbu, 2020). A waste inventory list contains basic information on the waste that the operation generates (Namgay & Norbu, 2020), which assists the operation in identifying which stream can be managed using best practices. To record the company's waste streams, a waste inventory list was populated in an Excel Spreadsheet because it is a more effective capturing data tool that was used to identify the waste stream, the classification of the waste stream (whether it is general, hazardous or scrap), where the waste stream had been stored as well as how it was managed i.e., had the waste being disposed of, recycled, reused as shown in Figure 3.2. The data collected was also be analysed more digitally than manually using the spreadsheet to save time. All waste generating department were visited and different spreadsheets were populated for each department, the output was a stream list for each department as shown in the results chapter.



Waste Name	Waste classification (Hazardous, general etc)	Where is the waste stored on site	Waste discarded or recycled?	Contractor disposing or recycling waste
Air Filters	Hazardous	waste skips	Discarded	TL IDEAS
Oily rags	Hazardous	waste skips	Discarded	TL IDEAS
Oil and diesel filters	Hazardous	waste skips	Discarded	TL IDEAS
Diesel pumps or hydraulic	Hazardous	waste skips	Discarded	TL IDEAS

Figure 3.1: Waste stream list to be used.

3.4 Mafube waste generators perspective of waste management

The mine personnel in all relevant departments were given questionnaires to complete the waste stream list. The questionnaires also included questions related to issues concerning waste management and their view of how it can be treated. The questionnaires will be analysed quantitatively through tallying the number of respondents who answered the questions to understand the current experiences within the mine even though there

will be limit of detailed responses associated with questionnaires. This method was chosen based on its time efficiency and accessibility of the operational personnel. The generators from each department participated in the questionnaires through face-to-face meetings in their offices to gain an insight into their overall understanding of waste management and which waste they dispose of in the skip bins. The permission to conduct research at Mafube Coal was given by the General Manager using the participation information sheet that was signed. The questionnaires are listed in Appendix A with a total of forty participants. Each foreman was approached from their offices whereby participation was requested. Upon agreement the questionnaire was scheduled and thereafter took place at any place of their convenience within the mine, this was either during their routine inspection, lunch time or their offices. This approach was taken to avoid any limitations of hindering questionnaire to take place. Table 3.1 shows the departments as well as the designation and number of the people that participated. One site visit per area was conducted over a period of two days

Table 3.1: List of team members

Department	Designation	Number
Mining team	Mining assistants	10
Plant team	Plant operators	3
	Plant Foreman	4
	Plant engineering	3
Stores	Stores supervisor	1
	Stores assistant	4
	Stores Forklift operator	1
Admin block	General workers	4
Section heads	Supervisors	10

Over and above the questionnaires with the generators, a site visit of the operation was conducted. This validated the generator's inputs in terms of the types of waste generated and the management thereof. The site observations covered other streams not identified in the questionnaires and determined the general waste management practice in each area. The observations took place once with the assistance of a waste manager. A judgment-based approach was used for each waste storage area to assess its conditions. Photographic images were also taken at each site as additional visual information. The

focus was mainly on general and hazardous waste as scrap waste was already being sent for recycling. The observations also played a significant role in populating the waste stream list.

3.5 Waste transfer stations site visits

To conduct the study at the waste transfer stations, the municipality's waste department was contacted telephonically whereby the waste officers' contacts were obtained. An approval to conduct the study was received from the municipal manager for interviews with the workers and site observations to take place at the stations, the approval is shown in Appendix C. The interviews and site observations were chosen as an evaluation tool to gain more insight regarding issues that occur during the operation of the station, what informed their design of the station, and concerns that are being addressed by the stations (such as travel times of the truck). Furthermore, these visits were also used to determine the flow of waste from the source to recycling or disposal, what gets to the transfer station and what does not, and the benefits and challenges associated with waste transfer stations. The combination of interviews and site observations during the visit allowed for photographic evidence to be taken simultaneously as the interview took place.

There are 12 waste transfer stations approved in the Steve Tshwete Local Municipality; however, only four site visits were conducted with the permission that was received from the municipality to gather information on waste transfer stations as an alternative. The questions are indicated in Appendix B.

Legal frameworks such as the National Environmental Management Waste Act Norms and Standards for sorting, shredding, bailing, binding, crushing, and screening of general waste were considered to make recommendations towards the design and construction of a waste sorting station. A gap analysis of current and potential new permits took place thereafter, which advised the operation on which permits to apply for or conditions to consider in case of exemptions. Internal and external safety and health standards were also factored into the recommendations. A waste transfer station simulation model was created to determine the ideal area that considers relevant aspects associated with a waste transfer station. The combination of the information will then guide establishing a

best practice waste management strategy and, ultimately, for a waste transfer station at Mafube Coal mine.

3.6 Ethical considerations

This study was conducted after the attendance of the ethics training served by the University of the Witwatersrand on the 17th of April 2024 after which a certification of competence was obtained. An application for ethics clearance was submitted on the 28th of June 2024 along with the interview questions and relevant documents. The application was accepted on the 5th of July 2024 with a protocol number (GAES-2024-65) provided by the school. Interviewees were given consent forms for quoting of statements, photographs which were signed before the interviews were conducted to ensure confidentiality of the responses is understood as per the ethical requirements. They were also given participation information sheets to go through when they were approached or a day before the interview took place. Power dynamics and employment status of the participants were considered ruled out as limitations since there were no supervisory relations between the researcher and site employees.

Chapter 4: Results

4.1 Introduction

This chapter focuses on the results obtained through the stages stated in the methodology. The results comprise waste stream lists gathered from the waste observations and interviews with the mine officials. Each department had its own stream list showing the various streams generated. The next results were the outcomes of the interview questions from the mine officials that aimed to give a better knowledge of how the officials understand the waste and how it can be improved. The last set of results were from the waste transfer stations that were visited, which shed light on how waste flows, the purpose of the station, and the opportunities it has that can be implemented in the study site.

4.2 Waste Stream List

Tables 4.1 – 4.6 are the waste stream lists for each department around the operation. The table names and classifies the stream, and it determines how the waste is currently stored and managed. Moreover, it determines which service provider manages the waste and the potential best practice management thereof. This information allowed the study to develop strategic ways to separate and divert waste from landfills by determining what is generated. The waste stream list was populated using two forms of information: individual interviews and waste observations conducted with a waste manager. The observations also included photos that show the condition or state of a few waste skip areas of major departments.

Table 4.1: Pit Engineering Waste Stream List

Waste Name	Waste classification (Hazardous, general etc)	Current storage	Current Waste management practice	Name of the company	Recommended best practice management
Air Filters	Hazardous	Waste Skips	Discarded	TL IDEAS	Recycling
Oily rags	Hazardous	Waste Skips	Discarded	TL IDEAS	Re-Use
Oil and diesel filters	Hazardous	Waste Skips	Discarded	TL IDEAS	To be investigated
Diesel pumps or hydraulics	Hazardous	Waste Skips	Discarded	TL IDEAS	To be investigated
Twenty-litre oil containers	Hazardous	Oil drums bay	Recycled	Ikhwezi Lomso	Recycling
Used oil	Hazardous	Used oil tanks	Recycled	Ikhwezi Lomso	Recycling
Contaminated soil	Hazardous	Waste Skips	Discarded	TL IDEAS	Remediation
Cardboard boxes	General	Waste Skips	Discarded	TL IDEAS	Recycling
Food waste	General	Waste Skips	Discarded	TL IDEAS	Recycling
Paper	General	Waste Skips	Discarded	TL IDEAS	Recycling
Plastic bottles/ or general plastics	General	Waste Skips	Discarded	TL IDEAS	Recycling
Bolts and nuts	Scrap	Waste Skips	Recycling	TL IDEAS	Recycling
Offcuts metal/steel waste	Scrap	Waste Skips	Recycling	TL IDEAS	Recycling
Pumps	Scrap	Waste Skips	Recycling	TL IDEAS	Recycling

As shown in Table 4.1, thirteen streams were identified at the pit engineering department: forty-six percent were classified as hazardous waste, thirty-one percent were general, and twenty-three percent were scrap waste. Eighty-five percent was being stored in waste skips, and the current waste management practice is sixty-two percent was disposed of, and the rest was recycled. The potential increase for best practice can go from thirty-nine percent to eighty-five percent. Figure 4.1 indicates the waste management area where waste separation and collection are done. The observation is that there is an overflow of waste.



Figure 4.1: Waste management area at the pit engineering workshop showing the storage areas and designated oil drum storage area.

Table 4.2: Mining Engineering Waste Stream List

Waste Name	Waste classification (Hazardous, general etc)	Current storage	Current Waste management practice	Name of the company	Recommended best practice management
Cardboard boxes	General	Waste Skips	Discarded	TL IDEAS	Recycling
Food waste	General	Waste Skips	Discarded	TL IDEAS	Recycling
Paper	General	Waste Skips	Discarded	TL IDEAS	Recycling
Plastic bottles	General	Waste Skips	Discarded	TL IDEAS	Recycling
Old explosives boxes	Hazardous	Destruction Bay	Destroyed as per standard	Done by mine officials	None needed
Pipeline scraps	General	Back to supplier	Returned to supplier for repurposing	Water-zone	Separation
Damaged demarcation poles	General	Waste Skips	Discarded	TL IDEAS	Recycling
Dust mask	General	Waste Skips	Discarded	TL IDEAS	Separated and disposed of as biowaste

Table 4.2 shows that eight streams were identified at the mining department. All the waste was classified as general waste except for old explosive boxes. Currently, a contractor discards all the waste apart from what is being destroyed (explosive boxes) and what is re-used. There is potential for a sixty-three percent increase in best practices from twenty-five percent of what is currently being done.

Table 4.3: Plant Process Waste Stream List

Waste Name	Waste classification (Hazardous, general etc)	Current storage	Current Waste management practice	Name of the company	Recommended best practice management
Cardboard boxes	General	Waste Skips	Discarded	TL IDEAS	Recycling
Food waste	General	Waste Skips	Discarded	TL IDEAS	Recycling
Paper	General	Waste Skips	Discarded	TL IDEAS	Recycling
Plastic bottles/general	General	Waste Skips	Discarded	TL IDEAS	Recycling
Flocculent bags	Hazardous	Waste Skips	Discarded	TL IDEAS	Recycling
Oily rags	Hazardous	Waste Skips	Discarded	TL IDEAS	Re-use
Coal spillages	Hazardous	Discard dump or back to the belt	Discarded	Done by plant official	None
Old hosepipes	Hazardous	Waste Skips	Discarded	TL IDEAS	Still to be investigated
Empty coagulant containers	Hazardous	Waste Skips	Discarded	TL IDEAS	Still to be investigated
Polyurethane	General	DRA Yard	None	None	Still to be investigated
Old shovels and wheelbarrows	Scrap	Waste Skips	Recycled	TL IDEAS	Recycling
Metal from metal detectors	Scrap	Waste Skips	Recycled	TL IDEAS	Recycling

Table 4.3 indicates that there were twelve streams identified at the plant process department; forty-two percent was classified as hazardous waste, forty-two percent was general, and fifteen percent was scrap waste. The other places where waste was stored apart from waste skips are the discard dump and the salvage yard. The current waste management practice is

that seventy-five percent of waste is discarded, and the rest is recycled, except for the Polyurethane screens, which currently do not have a management method. The potential increase for best practice can go from twenty-five percent to fifty-eight percent. Figure 4.2 indicates the plant waste management area and illustrates an overflow of waste.



Figure 4.2: Waste management area for the plant process department with colour-coded skips

Table 4.4: Plant Engineering Waste Stream List

Waste Name	Waste classification (Hazardous, general etc)	Current storage	Current Waste management practice	Name of the company	Recommended best practice management
Cardboard boxes	General	waste skips	Discarded	TL IDEAS	Recycling
Food waste	General	waste skips	Discarded	TL IDEAS	Recycling
Paper	General	waste skips	Discarded	TL IDEAS	Recycling
Plastic bottles	General	waste skips	Discarded	TL IDEAS	Recycling
Wooden pallets	General	waste skips	Discarded	TL IDEAS	Re-use
Idlers	Scrap	waste skips	Recycling	TL IDEAS	Recycling
Steel offcuts	Scrap	waste skips	Recycling	TL IDEAS	Recycling
wires from cables	Scrap	waste skips	Recycling	TL IDEAS	Recycling
Scrap Segments	Scrap	waste skips	Recycling	TL IDEAS	Recycling
Scrap Screen mesh	Scrap	waste skips	Recycling	TL IDEAS	Recycling
General Scrap	Scrap	waste skips	Recycling	TL IDEAS	Recycling
Oily rags	Hazardous	waste skips	Discarded	TL IDEAS	Re-use
Conveyor offcuts after splicing (joining of a conveyor belt) vulcanizing, rubber	Hazardous	waste skips	Discarded	TL IDEAS	Recycling
Chemical containers (solvents and glue)	Hazardous	waste skips	Discarded	TL IDEAS	To be investigated
Twenty litre oil containers	Hazardous	waste skips	Discarded	TL IDEAS	Recycling
Epoxy containers	Hazardous	waste skips	Discarded	TL IDEAS	To be investigated
Grease containers	Hazardous	waste skips	Discarded	TL IDEAS	Recycling
Old paint	Hazardous	waste skips	Discarded	TL IDEAS	To be investigated
Fluorescent Tubes	Hazardous	Designated bags	Recycling	Hazco green	Recycling

Table 4.4 shows that there was a total of nineteen streams identified at the plant engineering department. Forty – two percent were classified as hazardous waste, twenty-six percent were general waste, and thirty-two percent were scrap waste. All the waste was stored in skips apart from fluorescent tubes, which were separated. The current waste management practice was that sixty-three percent of the waste was discarded, and the rest was recycled. The potential increase

for best practice can go from thirty-six percent to eighty-four percent. The observation on the area shown in Figure 4.3 was that there were other streams, such as wooden pallets, that did not have a collection point.



Figure 4.3: Waste management storage area used by the plant engineering department.

Table 4.5: Admin Waste Stream List

Waste Name	Waste classification (Hazardous, general etc)	Current storage	Current Waste management practice	Name of the company	Recommended best practice management
Cardboard boxes	General	waste skips	Discarded	TL IDEAS	Recycling
Food waste	General	waste skips	Discarded	TL IDEAS	Recycling
Paper	General	waste skips	Discarded	TL IDEAS	Recycling
Plastic bottles	General	waste skips	Discarded	TL IDEAS	Recycling
Electronics (e-waste)	Hazardous	Storage room	Recycled	Whalerock	Recycling

Table 4.5 shows that only five streams were identified at the admin block, and only one stream was classified as hazardous waste. The rest was general waste. All the waste is stored in skips except for electronic waste, which is separated and recycled. The rest of the waste was discarded, and all have the potential to be recycled.

Table 4.6: Stores Waste Stream List

Waste Name	Waste classification (Hazardous, general etc)	Current storage	Current Waste management practice	Name of the company	Recommended best practice. management
Cardboard boxes	General	waste skips	Discarded	TL IDEAS	Recycling
Food waste	General	waste skips	Discarded	TL IDEAS	Recycling
Paper	General	waste skips	Discarded	TL IDEAS	Recycling
Plastic bottles	General	waste skips	Discarded	TL IDEAS	Recycling
Wooden pallets	General	waste skips	Discarded	TL IDEAS	Recycling
Old PPE	General	waste skips	Discarded	TL IDEAS	Recycling

Table 4.6 observed only six streams identified at the store's block; only one stream was classified as hazardous waste, and the rest were general waste. All the waste was stored in skips. The waste was discarded and has the potential to be recycled. Figure 4.4 also shows full skips in the waste area, with the white bin meant for paper recycling that has not been collected.



Figure 4.4: Waste management area used by the stores department.

4.3. Mining officials' interviews

The interview questions involved officials stating which area they fall under to get a broad spectrum of experiences around waste management. It also involved understanding their knowledge regarding waste management and how it is treated to determine if the current management system is being used correctly. The questions further provide insights into how mine officials think waste management can improve and if a waste transfer station can be one of the tools that the mine can use. The questionnaires are shared under Appendix A of the study.

Mining officials ranged from general workers to supervisors (Figure 4.5), and a total of five departments were interviewed. The first question involved the personnel's role, and

the major departments are the majority generators. This means that more waste streams will be found in those departments. The total number of people interviewed was forty.

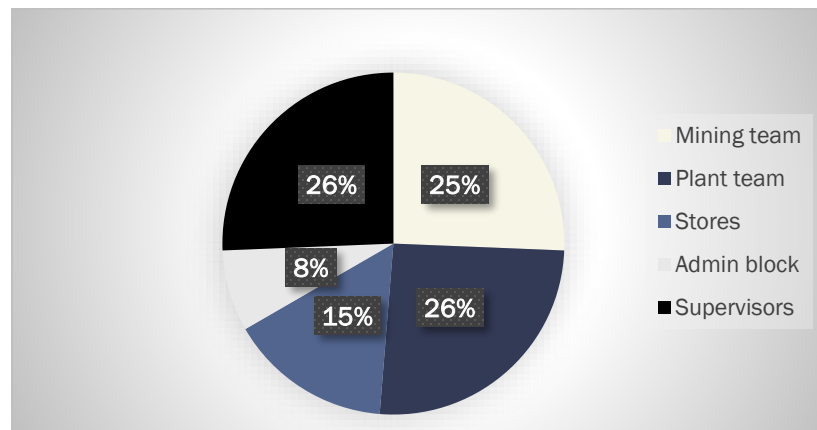


Figure 4.5: The role of the interviewee.

When asked what the understanding of waste management is, eighty-nine percent of the respondents that it is the use of different approaches and procedures designed and executed to identify, control, and handle several types of waste from a life cycle perspective (Figure 4.6).

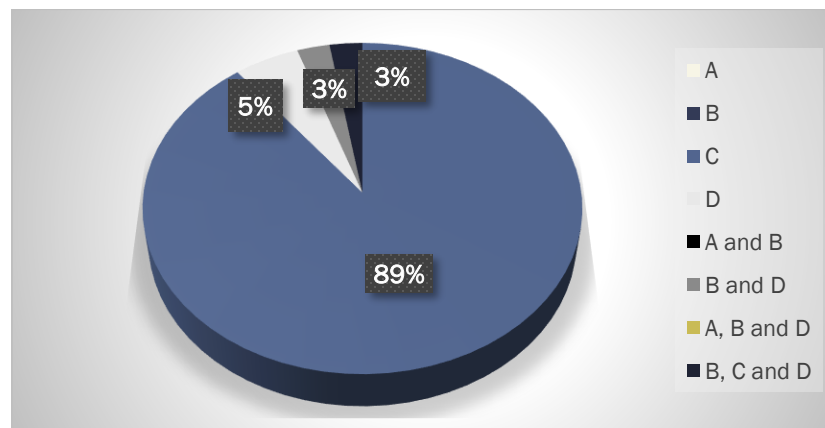


Figure 4.6: The understanding of the term waste management. A= A Political Strategy; B= A Legal framework; C= The use of different approaches and procedures designed and executed to identify, control, and handle several types of waste from a life cycle perspective; D= A standard of safety.

Figure 4.7 illustrates how participants think most of the waste is being treated or managed. Forty-four percent of people indicated that the waste is collected by a contractor

and disposed of in a landfill site, recycled, or re-used (B, C, and D). Thirty-five percent stated that the waste is collected. Other respondents either chose both or all results.

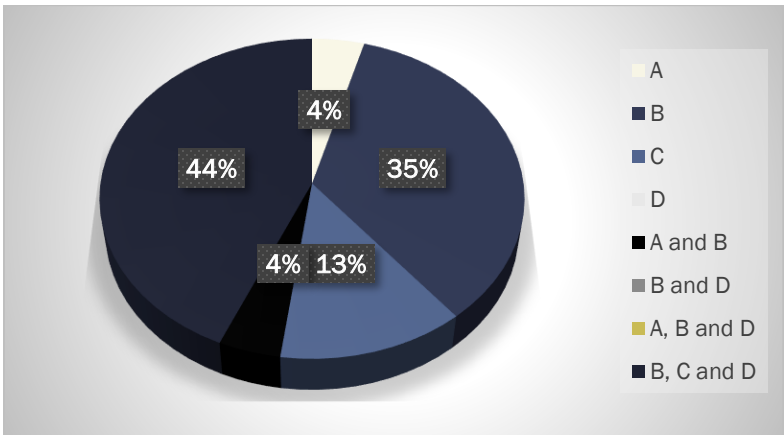


Figure 4.7: Opinion on how waste is treated in the work area. A= The waste is burnt; B= The waste is collected by a contractor and disposed of in a landfill site; C= The waste is recycled; D= The waste is re-used.

The results presented in Figure 4.8 indicate what the interviewees think the mine should do to solve some of the waste management concerns on the mine. Thirty-three percent indicated that the mine should standardize recycling and re-use initiatives followed by the frequent collection of waste by the service provider and the third highest was to separate the waste. Some also touched on suggestions such as extra storage, monitoring, training, and awareness as well as new technologies that can reduce the generation of waste.

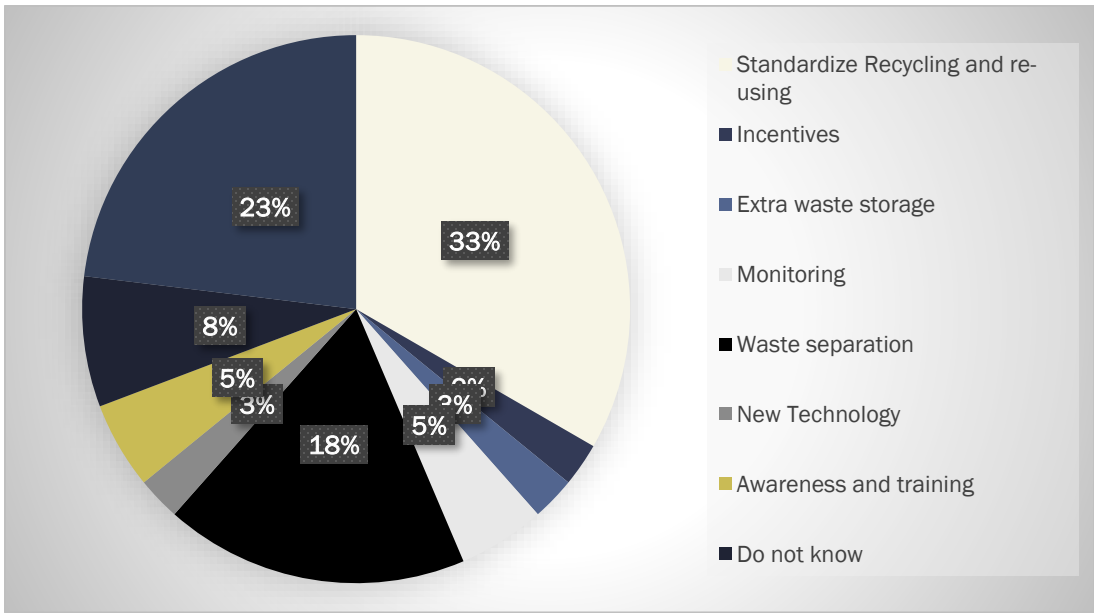


Figure 4.8: Suggestions for improving waste management

When questioned on their understanding of a waste transfer station, fifty-four percent of the respondents answered C, which is a facility that receives waste coming from different sources and offers a centralized site for a waste collector (Figure 4.9). Then, thirteen percent selected the dumping site option, and ten percent selected all the options.

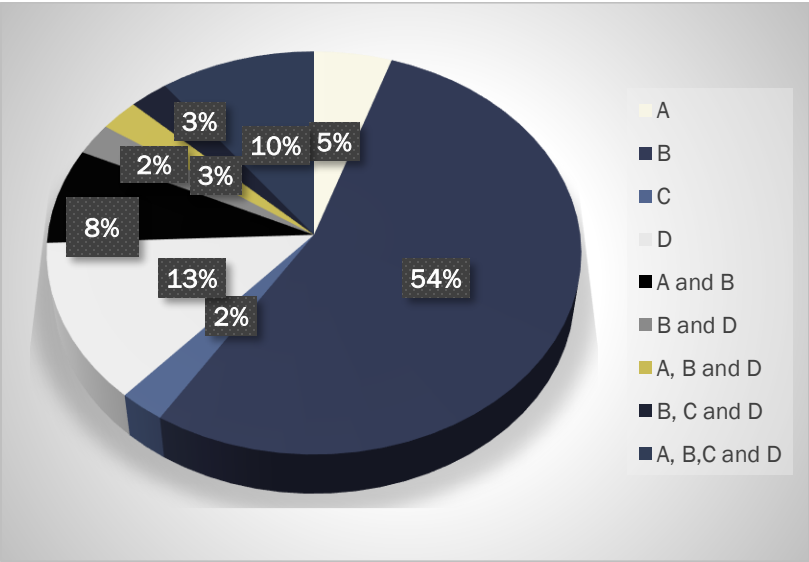


Figure 4.9: Understanding of a waste transfer station. A= A recycling station; B= A facility that receives waste coming from different sources and offers a centralised collection for waste collectors; C= A hazardous storage facility; D= A dumping site.

The respondents were asked whether a transfer station could improve the mine's overall waste management, and ninety-five percent indicated that this would be beneficial for the mine, and five percent said it would not (Figure 4.10).

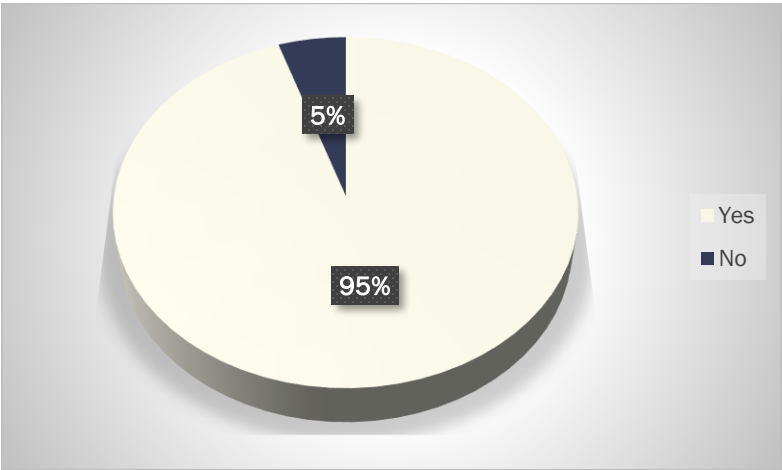


Figure 4.10: Would a waste transfer station benefit the mine?

4.4. Interview with Steve Tshwete Local Municipality.

The following results are the outcomes of the visits to the Steve Tshwete Local Municipality waste transfer stations. Although there are total of twelve stations around the municipality, there were only three stations, namely, Dennisig Waste Transfer Station, Mhluzi Waste Transfer Station, and the Extension 49 Waste Transfer Station, that were available for a visit at the time of the study. A fourth station, the Sikhululiwe Village Waste Transfer Station, was also approached; however, it could not be accessed. The results indicate the flow of waste from local members to large trucks and highlight some of the key issues stated by the operators that stations are faced with, which can be learnings that will assist in giving recommendations on how the mine can best implement the concept.

Figure 4.11(A and B) are the notice boards that were observed immediately outside the stations. These are meant to give clear information of the type of waste acceptable at the station, the operating hours and contact details for the station. Information regarding where the local landfill site is located is also given.



Figure 4.11a) Dennisig Waste Transfer Station Notice Board b) Extension 49 Waste Transfer Station Notice Board

During the site visit, it was noted that the municipality uses waste transfer stations to transfer general waste in bulk to the landfill site. The process starts with local community members bringing their general waste (less than a ton) with smaller vehicles to the station,

(Figure 4.12a). The vehicles then ramp up the platform (Figure 4.12b) and offload the waste on the waste skips. Once the skips are full (Figure 4.12c), the municipality will then remove the skips (Figure 4.12d) and dispose to the landfill.



Figure 4.12a) Vehicle entering the Dennisig Waste Transfer Station to dispose of waste b) The pathway for the vehicles going to the platform c) Vehicles offloading the waste onto the large skips d) Waste collection done by the municipality.

As seen in Figure 4.13a and b, the stations are secluded and surrounded by a concrete fence containing a security guard at the gate who will monitor the process. It also has a waste sorting station (Figure 4.13b) where recycling activities occur. Apart from the guard, two or three operators are hired by the municipality to ensure the process continues. Waste pickers recycle minimal waste (cans and wooden pallets).



Figure 4.13a) Concrete fence surrounding the Sikhululiwe Village Waste Transfer Station b) Waste sorting station and security guard house at Extension 49 Waste Transfer Station.

According to the waste officer, the main concern was that private companies tend to bring their waste to the stations (see Figure 4.14a), whereas they are supposed to go straight to the landfill site and pay the fee, which they are avoiding. The risk is that the bins tend to fill up quickly which forces security at the station to close the gates and local communities tend to lose interest in using the station. Another risk that was observed was the dumping of hazardous waste in the general bins which further depletes the landfill (see Figure 4.14b).



Figure 4.14a) Private companies bringing waste at Extension 49 Waste Transfer Station b) Overflowing Mixture of hazardous and general waste at Extension 49 Waste Transfer Station

Stations are placed in remote areas surrounded by fields. Over time, the collection activities also damage the platforms (Figure 4.15b).



Figure 4.15a) Waste observed around the edges of the Extension 49 Waste Transfer Station b) Damage on the concrete platforms on the Extension Waste Transfer Station

With the learnings from the older transfer stations, some stations are in good condition and have minor upgrades. The Mhluzi Waste Transfer Station (see Figures 4.16a and b) was one of the new stations built. The site has compartmentalised its area for sorted waste for ease of collection; it has general good housekeeping with a steel fence, paving, and good concrete conditions.



Figure 4.16a) Waste sorting station for the Mhluzi Waste Transfer Station b) Waste disposal section of the Mhluzi Waste Transfer Station.

Chapter 5: Discussion

5.1 Introduction

This chapter provides analyses and evaluates the results in line with the objectives, which were to identify and classify waste streams that are generated by Mafube Coal mine; determine the best practice for its management; analyse how a waste transfer station is currently being used and suggest how it can be applied in the mine's operations. It focuses on the current state of waste management at the operation, the findings from mine site visits and mine interviewees, and what they mean for the mine. It also provides information on how the mine can avoid landfill disposal through other management forms such as recycling. From the site visits to the waste stations, the recommendations on how the mine can implement the waste station on site are stated. The discussion also connects the literature with the results to substantiate the study.

5.2 Mafube waste streams and insight from the workers

The waste stream list generated shows that the site creates various types of waste streams from different departments because of the multiple activities that take place in each of them, this is consistent with the Carmichael mine and railway project mentioned in section 2.6. The most well managed type of waste stream is scrap waste because the flow of scrap waste streams as well as its collection is simple. This is also true in the sustainability reports from the coal mines reviewed. As seen in the waste stream tables, scrap waste consists of multiple types of waste streams of all shapes and sizes. All the scrap streams can be placed onto the blue skips which are at a closer proximity to the generators. The service provider then collects the scrap waste directly from the blue waste skips using a grab truck and sells it to buyers, after which the mine receives a rebate; the employees noted that the service provider is more consistent with this type of waste since the mine generates heavy scrap that attracts more income.

With general waste, there are five main waste streams throughout the mine: food, paper, plastic, wooden pallets, and cardboard boxes. Apart from food waste, these streams have different colour-coded wheelie bins at the source for separation and collection. However, the waste still ends up in the yellow general waste skip, which is collected and discarded

in the landfill. This indicates a disconnection with the flow of the waste streams from one point to another to reach the intended recycling. In chapter one, it was highlighted that general waste has been increasing for the past three years even though there are efforts from the mine to decrease it.

Paper, for example, is separated using the 140-litre white wheelie bin placed outside of-fices and beside printers; the mine relies on the office cleaners to take this waste to a bigger wheelie bin where the service provider can collect it. However, this collection has not taken place for some time, causing an accumulation of paper waste and forcing the cleaners to place the waste in the general skip bin as it was becoming a housekeeping issue for the mine. The bigger wheelie bin was also placed in one of the two operations, meaning that there was no separation in the other site.

The mine also generates plastic waste from the bottled water procured by the mine. There were a few initiatives to reduce this waste; one of them was to procure water-filtered dispensers and 1.5-litre PBA-free water bottles for employees and contractors, which they can use to refill for water. This did not work because the workforce did not trust the frequency of filter maintenance, thus forcing the mine to revert to procuring bottled water. The current initiative involves the workforce bringing over six kilograms of plastic waste and receiving a gift. At the same time, a local recycler collects the bottles and takes them to a recycling facility.

This initiative has been ongoing and not without its challenges. The main issue was obtaining a storage area for the separated waste as there was no permanent designated area where the recycler could collect the waste, which meant that the recycler needed to be in the mine on the days when the workforce brought in their plastic bottles, and this could not always be the case. This is the same with the study that Di Maria (2017) conducted in Palestine whereby inadequate infrastructures strained recycling initiatives. The internal resources to cross-check for the legitimacy of the waste received were also not sufficient, as there were instances where workers added heavy materials such as bricks and water-filled plastic bottles to increase the weight of their waste. Moreover, the recycler only wants the bottle and not the cap, and the separation between the two hardly takes

place. These issues run parallel with Dong's (2024) statement that there is a lack of balance between production (or procuring in this case) and recycling of plastics which lead to environmental issues (Dong et al., 2024).

As noted initially, the continuous rise of general waste in the operation is also caused by the increase in the mine's footprint, as Aryampa (2023) has stated that an increase in the economic activities and population, an exponential waste increase will be seen. This means that more workers (whether permanent or not) will be appointed, and more food waste is generated, leading to higher the production targets resulting in the acquiring of more products that come either wrapped in plastic, cardboard boxes or wooden pallets depending on what it is. There are other streams which do not have management methods which lead them being discarded as general waste from time to time such as construction rubble, some are left pile up on the mine on salvage yards or open areas such as polyurethane panels and old conveyor belts.

Hazardous waste streams on site are generated by production-related departments. The most common hazardous waste are oily rags, oil and grease drums, chemical containers and bags such as paint, air and oil filters, and contaminated soil. As Saleh (2024) has indicated, that the measures to treatment or disposal of such waste need to be airtight as it can cause serious harm to the environment (Saleh et al., 2024). Since hazardous waste is the most complex type of waste to manage (Malele, 2024), disposal has been the easiest option regardless of the shift in the cost implications. However, the mine has taken up an initiative that is at trial stages, such as the oily rags project.

The oily rags project originated from the environmental department of the mine; through their environmental inspections, they observed that contaminated rags were a consistent waste throughout the workshop areas since that's where mechanics usually work. When discarded, the rags are mostly heavier than their initial weight due to the thickness of the grease and oil that is wiped from the machines, increasing the weight of the rag and, ultimately, the skip bin with accumulating the bulk of rags. A process was then adopted whereby the rags could be rewashed and sent back to mechanics to reduce the amount sent to landfill. This project was trialled at one site to assess the feasibility of it and from

an engineering and safety perspective, there were a few concerns including the fumes from the rags when they were being washed and possible damage from the grease on the washing machines and tumble driers. There is little to no viable information about such processes in the literature.

Although mining officials from various departments show a good understanding of waste management, it is evident that the mine needs to implement sound waste separation at source and collection facilities for the streams that can be easily recycled or reused. This is validated by the study in the Umbria region located in Europe that used separation collection facilities to increase their recycling rate (Di Maria et al., 2017). The flow of each waste that needs to be recycled and re-used is currently not clear and thus a lack of standardization leads to confusion and a lack of interest from the generators to participate in any waste management initiative. The officials have expressed that the current service providers need to improve its collection times and with majority of the interviewees suggesting that recycling activities could improve waste management, this indicates that the mine should rather shift from seeking a collection and disposal service provider to a waste management service provider that will assist the mine with implementing best practices for handling the operations' waste streams. This shift will shape the initiatives to incorporate the product life cycle perspective of waste management from Mubaslat (2021).

5.3 Alternative management options for the waste streams

The results have stipulated that most sections can reach an average of eighty percent when it comes to best practice management options. For the waste discarded (general or hazardous), there are multiple options that can be implemented so that the site can reach the recommended best practice management method. There are better industrial practices that the mine can adopt with general waste, such as converting food waste to fertiliser and supplying it to composting facilities. The mine also has a nursery which they could utilize the compost to establish a food garden. Paper, plastics, and cardboard boxes can be taken to recyclers to produce a new product as indicated by Malele (2024). Wooden pallets can also be converted to other products, such as wooden outdoor furniture as suggested by Bush (1996) when looking at pallets as a source for wood. The site

can also collaborate with various energy projects that can take contaminated boxes and wooden pallets.

Although a few best practices are already taking place or gaining momentum, such as recycling used oil, old oil and grease drums, the trial for washing oily rags has a lot of potential. The mine can engage other stakeholders that can assist with some of the hurdles that they have come across, such as seeking and continuously testing a chemical that can completely remove the grease and oil to eliminate the potential damage on the machines and the hydrocarbon odour from the rags.

There are opportunities for other hazardous streams to be sent to other facilities other than a landfill site. Streams such as polyurethane panels and chemical containers can be recycled or taken to alternative licensed facilities. Used PPE can be taken as part of a renewable energy resource to facilities such as a Refuse-Derived Facility (RDF) that converts left over solid waste to energy (Department of Environment, Forestry and Fisheries, 2020). Air filters can be sent to licensed facilities where mechanical recycling can take place (Wilke, 2024). Disposal of contaminated soil can be avoided through bioremediation processes, whereby a biochemical solution is used to breakdown hydrocarbons (Wilson & Jones, 1992). It is important to understand that hazardous waste has a more complex approach when it comes to practices other than discarding. Thus, the operation must engage with stakeholders to ensure that the stream is handled accordingly. The recycling and re-using will not materialize to its fullest potential if waste is not separated, stored and collected from a designated area.

5.4 Conceptual model of an ideal transfer station

After the visits to the waste transfer station located in the Steve Tshwete Local Municipality and results from the operation whereby majority of the participants indicated that a Waste Transfer Station is facility that would be beneficial to the mine, it is evident that Mafube can use the concept of a transfer station as a collection facility for separated waste to increase recycling rate. For the mine to obtain the station, just as the Municipality has done, an application needs to be done with the Regulatory Authority and adhere to the National Environmental Management: Waste Act: National norms and standards for

sorting, shredding, grinding, crushing, screening, or baling of general waste. This will give the mine full insight into application conditions, where to register, conditions for the construction and design of the station, and the general management of the station.

The mine should also consider the Integrated Waste Management Plan By-Laws for Steve Tshwete Local Municipality (Local Authority Notice 193 of 2022) Section 23. This is where the conduct in the waste transfer facilities is discussed. Hence, an internal risk assessment should be done concurrently with the development of the conceptual design. This can take into consideration the Safety, Environmental and Health concerns within projected activities that were identified during the waste transfer site visits. It is important to adhere to regulations involving construction of waste facilities to avoid stoppages as experienced in the Butler Recycling and Transfer Facility located in Pennsylvania due non-compliance to land zoning regulations (Singleton, 2019).

It would be beneficial for the site to place the first waste station at the Springboklaagte operation opposite the Light Duty Vehicle (LDV) workshop (shown in Figure 5.1). This is ideal because it would be located away from heavy machinery whereby waste collectors do not have to go in the more active side of the operation as well as reducing the traveling time as per the intentions of the facility observed in the findings.



Figure 5.1: Potential location of the station.

Figure 5.2 is a simulation of the proposed waste transfer station for the sole purpose of recycling with the consideration of site-specific needs. Looking into components of the proposed waste transfer station shown in the model, it is recommended that it does not contain concrete ramps since waste skip areas are already constructed as shown by the photographic evidence of the site, the skip areas are important for scrap (since it is heavier) and for hazardous waste collection. However, general waste should be separated at the source, collected, and sorted at the station for baling and removal. From what the waste stream list has identified, it is suggested that only cardboard boxes, plastic, wooden pallets, and paper can be recycled using the transfer station since these streams form part of the bulk of the general waste in all areas generated by the mine. At closure, this station can also be donated to the surrounding communities, which can use this facility for recycling.

As noted in section 2.7 of the literature review as well as the observations at the waste transfer sites, a well-organized waste flow is important. The flow of the waste, with consideration of the results, can be implemented as follows: separated general waste must be collected from the source i.e., offices, greenrooms, tea rooms, printing machine areas, and is taken to the waste transfer station security entrance. A record book will be kept by the security having all details required for reporting as seen with the Mhluzi Waste Transfer Station. The recyclables are then taken to the sorting station to ensure that the waste has been separated correctly, if there are any unwanted materials they will be discarded into a skip bin at the station. The sorted material gets baled or grouped and placed in their designated place where collection will be done. The recycling truck that comes for collection first reports to security and the weighs the recyclables which are then loaded onto the truck and gets taken to recycling facilities. It is important that the recyclables are weighed separately on the scale at the station weighbridge and not when it is on the truck to record the waste being recycled, this is to eliminate traveling to and from the existing mine weighing bridge which will increase energy usage.

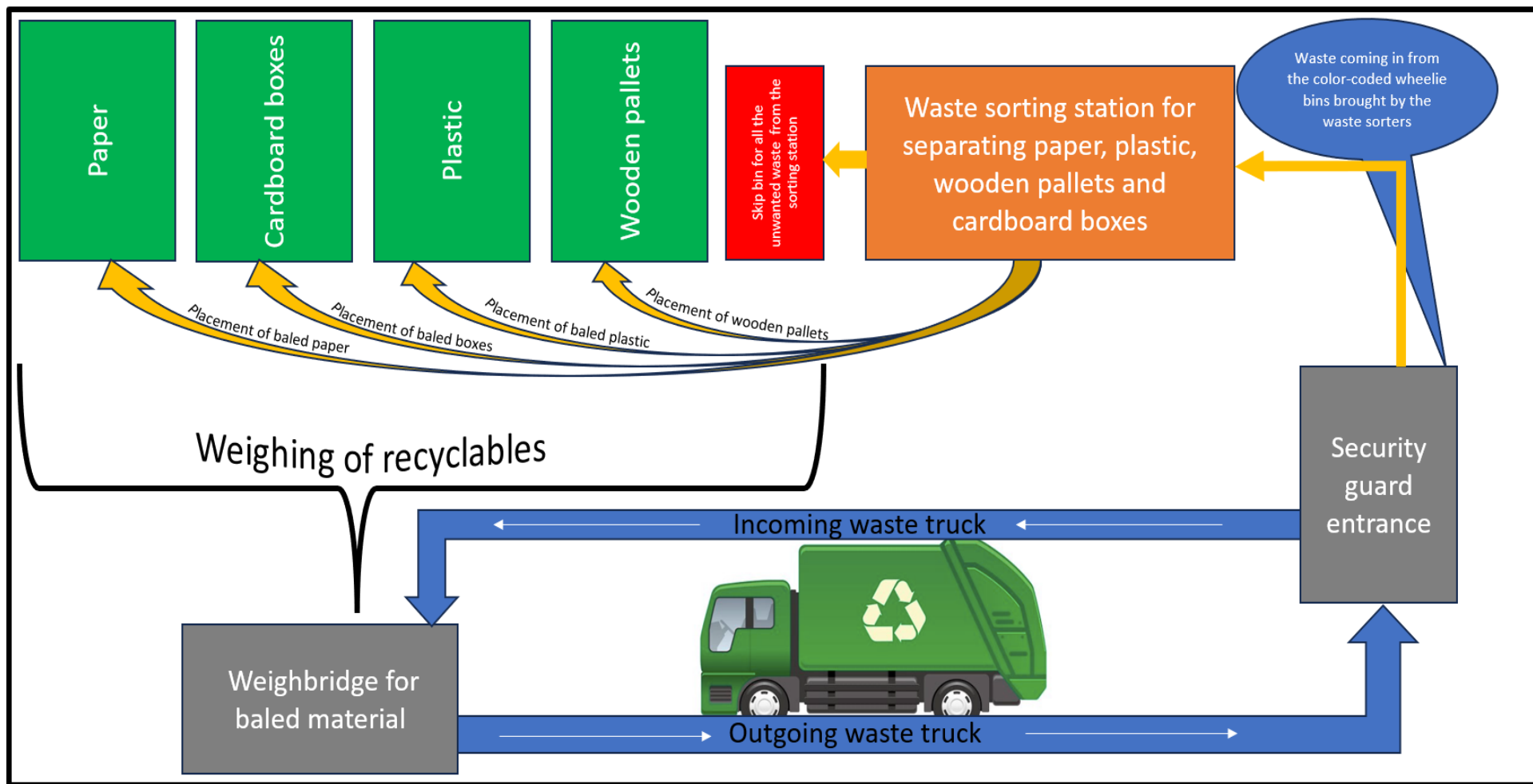


Figure 5.2: Model of a waste station for mines.

Other recommendations for the mine waste transfer station include: The mine needs to carefully draft a scope of work that will ensure that key performance indicators for the service provider are linked to reducing waste to landfill and shifting from rewarding disposal to landfill. The service provider should be the middleman that will ensure waste cradle-to-cradle with enough labour capacity. The operation should also tighten its monitoring of waste going in and out of the mine to ensure data integrity. The mine also needs to include a waste management recycling programme in the mine closure plan to address the livelihood post-mining as part of responsible mining. The mine should also standardize their initiated projects (oily rags project) as it can serve as a learning for other operations discarding their rags.

Chapter 6: Conclusion and Recommendations

This section concludes the research by emphasizing the study's importance and capturing the main ideas, findings, and suggested recommendations regarding the aims and objectives.

6.1 Conclusion

Waste has proven to be a global issue that adds to the existing socio-economic and environmental impacts. It was seen that waste management has thus been evolving over the years, moving from cradle-to-grave to cradle-to-cradle, i.e. a life cycle perspective. With the shift in perspective, there was also gradual changes to the Waste Hierarchy which forces industries to establish different designs, processes, technologies, or initiatives that will divert waste from landfills. The application and implementation of waste management practices in developing countries proves to be more challenging than in developed countries due to a lack of standardization of waste management practices in legal frameworks and institutions, which is the first firewall that can prevent any kind of impact.

Even though it is a developing country, South Africa has also grown in the waste management space in terms of legislation for the past four decades. With the implementation of concepts such as Zero Waste to Landfill, it is evident that before re-using, reducing, and recycling initiatives can happen, separation of waste and designated collection facilities such as waste transfer stations must be the starting point of any waste management practice. Separation collection can also be implemented in coal mining industries that seek to be Zero Waste to Landfill stewards, such as Mafube Coal.

Through the methods of this study, a waste inventory list has been established, which gave rise to learning that it is impossible to manage the unknown. For the mine to manage the waste to its fullest potential, it needed to know exactly what it is. With the stream list, the study achieved the second objective by identifying the best practice management methods for some of the streams even though the others needed more research. The most significant outcome was that almost all general waste generated could be diverted from landfills, greatly improving waste management.

With the observations revealing that various waste streams are being generated, and collection being categorised into three different types of waste, namely general, hazardous and scrap waste, the recycling rate will likely increase if the streams are separated at source and placed in a collection facility where that stream can be collected separately. With the site observations from other transfer stations, constructing a station on the mine can greatly assist the mine with improving their waste. A waste transfer station that is properly designed with the intention of recycling purposes can improve the status of waste management in operation.

6.2 Research Recommendations

It is recommended that the mine construct a trial waste transfer station to study the viability of the model. Further to this, an economic evaluation including but not limited to a cost-benefit analysis for the implementation of the station at Mafube as well as how this model can extend to other operations should also be researched.

6.3 Limitations

The study could not research all the municipalities' waste transfer stations due to some of them not being utilized as much as they should. This could have given the study more validation of the results for the site recommendations. Since the operation runs for a full twenty-four hours, the study only focused on day activities, the night activities could not be observed.

7. References

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8. Appendices

Appendix A: Mine Stakeholder interviews questions

1. What is your role in your designated area?

2. What do you understand by the term waste management? Select whichever applies.

a) A Political strategy

b) A Legal framework

c) The use of different approaches and procedures designed and executed to identify, control, and handle several types of waste from a life cycle perspective.

d) A standard of safety

3. How is the majority of the waste generated in your area of work treated? Select as many as apply.

a) The waste is burnt.

b) The waste is collected by a contractor and disposed of in a landfill site.

c) The waste is recycled.

d) The waste is re-used.

4. List the waste generated in your department and indicate whether it is general, hazardous or scrap waste.

Waste stream	Gen	Haz	Scrap	Waste stream	Gen	Haz	Scrap

5. What do you think can be done to improve waste management in your area?

6. What is your understanding of a waste transfer station?

- a) A recycling station.
- b) A facility that receives waste coming from different sources and offers a centralised collection for waste collectors.
- c) A hazardous storage facility
- d) A dumping site

7. A waste transfer station can also sort and recycle waste generated by the mine. Would such a station benefit the mine? Explain.

- a) Yes
- b) No

Appendix B: Steve Tshwete Municipality Stakeholder interviews questions

1. What is your role in your designation?

2. What is your understanding of a waste transfer station?

3. What was the reason for the construction of the waste station?

4. What type of waste does this station handle?

5. What informed the design of the station?

6. How does waste flow from the generators through the waste station to the end?

7. Give a list of the factors (e.g., legal permits, SHE aspects) you had to consider and obtain for the site?

8. What were the lessons learnt from the operational phase of the waste station?

Appendix C: Steve Tshwete Local Municipality study approval



Steve Tshwete
Local Municipality

PO Box 14 | Middelburg | 1050
Cnr Walter Sisulu Str & Wanderers Ave
Middelburg | Mpumalanga
T: +27 (0)13 249 7000 | F: +27 (0)13 243 2550
council@stlm.gov.za

Your reference:

Our reference: M Lekondeni

Attention: Jackie Hlomuka
University of the Witwatersrand,

The School of Geography, Archaeology and Environmental Studies, Faculty of Science.

Dear Sir/Madam

REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT STEVE TSHWETE LOCAL MUNICIPALITY WASTE DISPOSAL FACILITIES (WASTE TRANSFER STATIONS)

This letter serves as an approval for Jackie Hlomuka student no:787218 of the University of the Witwatersrand, to conduct research on improving Solid Waste Management through the utilization of waste transfer stations, subject to the following conditions:

That the researcher notify the Environmental and Solid Waste Management department prior to visiting the waste disposal facilities during the research period to enable the department to make necessary arrangements.

That the outcomes, results and reports of the research study be communicated with the municipality before any publication can be made.

Yours faithfully,

A stylized, jagged signature in black ink, appearing to be 'S.M. MNGUNI'.

MUNICIPAL MANAGER

S.M MNGUNI

02 July 2024