



Assessment of hazardous waste management practices of SAPS Forensic Department, North West Province

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PREFACE AND ACKNOWLEDGEMENTS

Hazardous waste continues to be a complex matter, globally, due to its adverse health, environmental, economic, and social impacts. It then becomes crucial for this waste to be adequately categorised, segregated and handled systematically. This necessitates a need for people to have satisfactory knowledge on proper management of hazardous waste. South Africa produced nearly 67 million tonnes of hazardous waste in 2017, whereby over 93% of the waste was landfilled.

The National Waste Management Strategy (NWMS) offers government strategy for the waste sector which is aligned to the Sustainable Development Goals (SDGs) of Agenda 2030. Both SDG 3 and the NWMS prioritise mechanisms towards the minimisation of waste-related environmental factors that contribute to ill-health. These considerations are applicable to the management of hazardous waste, which may have physical-, health- and environmental hazards.

The main aim of this research is to assess the hazardous waste management practices of the South African Police Service (SAPS), Forensic Department in the North West Province. I was motivated to carry out this research to identify areas which require improvement and recommend actions necessary for improved practices.

I would like to extend my special thanks and sincere gratitude to the following;

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ABSTRACT

Hazardous waste demands meticulous handling and management due to the potential harm or threat it poses. This type of waste may contain chemical and biological contaminants, which must be handled, stored, collected and disposed of with procedural care. The management of chemical and biological wastes must adhere to applicable institutional guidelines and legislative requirements. Failure to comply with these regulations can result in harm to the environment, human health, and other living organisms.

Any institution dealing with or managing hazardous substances, such as chemical and biological wastes, bears the responsibility of doing so in a manner that promotes occupational health and safety, as well as environmental protection. The South African Police Service (SAPS), Forensic Department involved in activities generating various hazardous waste streams, has not been extensively researched regarding the management of hazardous waste and compliance with South African legislation.

This research aimed to assess hazardous waste management at the SAPS Forensic Department in North West. The assessment involved investigating current waste management practices, including generated quantities, and aspects such as waste separation, storage, collection, and transportation. To achieve this, a mixed methods approach was employed, encompassing both quantitative and qualitative data collection methods. Data were collected through the review of documents and records from eleven Local Criminal Record Centres over a three-year period. Fifty (50) SAPS employees participated in survey questionnaires and on-site observations were also conducted.

Findings indicate that Local Criminal Record Centres need to improve waste segregation and handling practices, as well as recordkeeping of waste generated and disposed of. Additionally, waste storage facilities were found to be inadequate, and the Department faced challenges with delays in hazardous waste collection for disposal purposes. Limited awareness and training regarding hazardous waste management was also identified, with survey participants expressing general dissatisfaction with current waste management practices.

These findings underscore the need for improvement in hazardous waste management systems through enhanced recordkeeping, improved hazardous waste infrastructure, and increased training and awareness. Recommendations include the adoption of a formalised hazardous waste management system, informed by the principles of ISO 14001: 2015.

Keywords: *hazardous waste, waste management, forensic services, South African Police Service, SAPS*

ABBREVIATIONS AND ACRONYMS

Cd	Cadmium
CSI	Crime Scene Investigation
CSL	Crime Scene Laboratory
DEA	Department of Environmental Affairs (now DFFE)
DEAT	Department of Environmental Affairs and Tourism (now DFFE)
DEFF	Department of Environment, Forestry and Fisheries (now DFFE)
DEFRA	Department for Environment, Food and Rural Affairs
DFFE	Department of Forestry, Fisheries and the Environment
DFO	1,8-Diazafluoren-9-one
DOEL	Department of Employment and Labour
DWAF	Department of Water Affairs and Forestry
EMS	Environmental Management Systems
EU	European Union
FNAS-REC	Faculty of Natural and Agricultural Sciences - Research Ethics Committee
GEO	Global Environmental Outlook
GHG	Greenhouse Gas
GHS	Globally Harmonised System
GNR	Government Notice Regulation
HBA	Hazardous Biological Agents
HCS	Hazardous Chemical Substances
HCRW	Health Care Risk Waste
HFE	Hydrofluoroether

Hg	Mercury
ISO	International Organisation for Standardization
LCRC	Local Criminal Record Centre
NEMA	National Environmental Management Act 107 of 1998
NEMWA	National Environmental Management Waste Act 59 of 2008
NEMWAA	National Environmental Management Waste Amendment Act 26 of 2014
NHA	National Health Act 61 of 2003
NWMS	National Waste Management Strategy
NWU	North West University
OHSA	Occupational Health and Safety Act 85 of 1993
PDCA	Plan Do Check Act
Pb	Lead
PPE	Personal Protective Equipment
R6G	Rhodamine6g
RCRA	Resource Conservation and Recovery Act
SA	South Africa
SABS	South African Bureau of Standards
SANS	South African National Standards
SAPS	South African Police Service
SAWIS	South African Waste Information System
SDG	Sustainable Development Goals
SDS	Safety Data Sheets
SHE	Safety Health and Environmental

SOP	Standard Operating Procedure
SWM	Solid Waste Management
TREMcard	Transport Emergency Card
TSDF	Treatment Storage and Disposal Facility
U.S. EPA	United States Environmental Protection Agency
UN	United Nations
UNEP	United Nations Environmental Programme
UNODC	United Nations Office on Drugs and Crime
WCMS	Waste Classification and Management Systems
WHO	World Health Organization
WTE	Waste to Energy

DEFINITIONS

Biological waste: Waste materials that contain or have been contaminated by biohazardous agents e.g., waste contaminated with blood and other bodily fluids, swabs, surgical gloves and Personal Protective Equipment (WHO, 2021).

Chemical waste: Waste that contains solvents and reagents used in the laboratory (WHO, 2021).

Colour coding: The use of colour on a container or bag or the label attached to such that it serves to identify the category of waste it contains (National Norms and Standards for the Storage of Waste GNR. 926 of 2013).

Container: Re-usable container(s) in which waste is placed for the purposes of storing, accumulating, handling, transporting, treating or disposing of that waste e.g., skips, bins and drums (National Environmental Management: Waste Act 59 of 2008).

Hazardous Chemical Substances: Substances that are toxic, corrosive, irritant, strongly sensitising, and flammable and pressure generating under certain circumstances and may injure, cause ill-health or even death in humans (Hazardous Substances Act 15 of 1973).

Hazardous waste: Waste that contains organic or inorganic elements or compounds that may, owing to the inherent physical, chemical or toxicological characteristics of that waste, have a harmful impact on health and environment (National Environmental Management: Waste Act 59 of 2008).

Storage: The accumulation of waste in a manner that does not constitute treatment or disposal of that waste (National Environmental Management: Waste Act 59 of 2008).

Temporary storage: Once off storage of waste for a period not exceeding 90 days (List of Waste Management Activities that have, or likely to have a detrimental effect on the environment GNR. 921 of 2013).

Thermal treatment: Incineration, co-processing and other high temperature treatment of general and hazardous waste (List of Activities which result in atmospheric emissions which have or may have a significant detrimental effect on the environment including health, social conditions, economic conditions, ecological conditions or cultural heritage GN. 893 of 2013).

Waste generator: Any person whose actions, production processes or activities results in the generation of waste (Waste Classification and Management Regulations GNR. 634 of 2013).

Waste manifest system: A system of control documentation, which accompanies a load of hazardous waste transported from the point of generation to the waste management facility (Waste Classification and Management Regulations GNR. 634 of 2013).

Waste recovery: The controlled extraction of a material or the retrieval of energy from waste to produce a product (National Environmental Management: Waste Act 59 of 2008).

Waste treatment: A process designed to change the physical, biological or chemical characteristics of a waste and ultimately reduce the toxicity of a waste (National Environmental Management: Waste Act 59 of 2008).

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CHAPTER 1: INTRODUCTION

1.1 Introduction

This introductory chapter presents the background to the research, problem statement, research aim and objectives, scope of the study, and its limitations.

1.2 Background

Globally, the term "hazardous waste" refers to waste that is potentially harmful to human health and safety and the environment, which may also cause damage to property. Hazardous waste may include various waste types such as explosive-, corrosive-, infectious-, biological-, pathological-, pharmaceutical-, cytotoxic-, chemical-, and radioactive wastes (WHO, 2021). Hazardous wastes encompass liquids, solids, gases, sludges, discarded commercial products, or residues from industrial processes (Kanagamani *et al.*, 2021). Hazardous waste is categorised according to their hazard properties, such as corrosiveness, flammability, toxicity, carcinogenicity, infectiousness, and radioactivity (Akpan & Olukanni, 2020).

Managing hazardous waste is challenging due to the potential release of harmful substances like reactive agents, heavy metals, and harmful emissions, posing risks to the environment and public health (Monteiro *et al.*, 2013). Infectious waste carries pathogens that can spread illnesses, increasing the risk of disease transmission through unsafe handling and disposal practices (Bdour *et al.*, 2007). To prevent and mitigate these risks, hazardous waste demands meticulous handling, storage, treatment, and disposal (Hossain *et al.*, 2011). The classification and overall management of hazardous waste become crucial factors for an effective waste management system (Pyssa, 2019).

A hazardous waste management system encompasses control from "cradle to grave", focusing on the entire waste management life cycle, which includes generation, segregation, storage, collection, transportation and final disposal (Amadi *et al.*, 2017). Clear requirements, informed by legislation, should advise how each step of the waste life cycle should be managed (Makgae, 2011). Adequate waste management systems, supported by appropriate waste management infrastructure and sufficient training and awareness play a key role towards achieving sound and legally compliant hazardous waste management (Mmereki *et al.*, 2015).

This research focuses on hazardous waste management by the Forensic Department of the South African Police Service (SAPS). Forensic science, relying on scientific principles and techniques, investigates and processes evidence related to various crimes, serving the justice system (UNODC, 2010). Both biological and chemical wastes, with various harmful properties, are

generated in the process. According to Vinod *et al.* (2009), waste generated during forensic laboratory activities, particularly biological waste, has a higher potential for causing illnesses than other waste types.

1.3 Problem statement

The problem at hand, which forms the basis for this research, revolves around the assessment of hazardous waste management practices originating from the SAPS Forensic Department, North West. Global studies, as highlighted by the United Nations Environment Programme (UNEP), as well as Akpan and Olukanni (2020), indicate an alarming annual generation of approximately 400 million tonnes of hazardous waste. The mismanagement of such waste has become a critical global concern, leading to adverse environmental impacts, including air, soil, and water pollution (Ruoyan *et al.*, 2010). This mismanagement has also been linked to an increase in waste-related infectious diseases (Olaniyi *et al.*, 2018). Hazardous waste, characterised by its high toxicity and infectious nature, therefore, necessitates specialised handling, storage, treatment, and disposal (Hossain *et al.*, 2011).

In the South African context, the National Waste Management Strategy (NWMS) reveals that the country produced around 67 million tonnes of hazardous waste in 2017, with a staggering 93% of this waste ending up in landfills (DEFF, 2020). The NWMS aligns with the Sustainable Development Goals (SDGs) of Agenda 2030, particularly SDG3, focusing on minimising waste-related environmental factors contributing to ill-health, and SDG13, emphasising the reduction of greenhouse gas emissions and promotion of climate resilience and renewable energy (DEFF, 2020).

Effective hazardous waste management involves proper handling, segregation, storage, and processing from the point of generation. Inadequate waste management practices, characterised by irregular collection and disposal, lack of waste segregation, insufficient resources, and a lack of knowledge among key role players are common challenges related to hazardous waste management – especially in public institutions (Cheru, 2011).

Building on Maqutu's (2017) research on "*Life Cycle Assessment (LCA) of hazardous waste generated by Crime Scene Laboratories (CSL) in Mpumalanga, South Africa*", this research aims to investigate the current waste management practices of SAPS Forensic Department in North West, South Africa, encompassing eleven Local Criminal Record Centres. The Department faces challenges related to the generation and handling of hazardous waste during their crime scene examination and evidence processing activities. This waste includes disposable Personal Protective Clothing (PPE) potentially contaminated with infectious materials, infectious body fluids, fingerprint powders and other chemicals used for evidence processing. The research

delves into understanding current waste management practices, including waste types and quantities generated, separation, storage, collection, and transportation, as proposed by Ali *et al.* (2017). Additionally, the research aims to gauge the level of knowledge and awareness among key role players regarding hazardous waste management, as suggested by Omar *et al.* (2012).

1.4 Research aims and objectives

The study aims to assess the hazardous waste management practices of the SAPS Forensic Department, North West Province.

In line with the research aim, the following objectives are set out:

- **Research objective 1:** Determine the types and quantities of hazardous waste generated by the SAPS Forensic Department, North West Province;
- **Research objective 2:** Evaluate the current hazardous waste management practices of SAPS Forensic Department, North West Province against legal requirements; and
- **Research objective 3:** Assess the level of knowledge and awareness of personnel with regards to the management of hazardous waste.

1.5 Scope of the research

The study focused solely on waste management practices related to *hazardous waste* generated and managed by SAPS Forensic Department in the North West Province, South Africa. The research specifically focuses on *biological and chemical* wastes. No other hazardous waste types and/or general waste were included.

The case study area includes the SAPS Forensic Department in the North West Province only. No other SAPS departments from any other provinces were involved in the research. The facilities included in the research were eleven *Local Criminal Record Centres* (LCRC) as well seven *Crime laboratories* which are attached to the LCRCs located in the North West Province. No other facilities from other provinces were included in the research. Data gathering was conducted between 2020 and 2022.

1.6 Assumptions and limitations of the study

In the context of this study, the research was conducted focusing on particularly human behaviour towards hazardous waste management practices and overall hazardous waste management. Most of the literature available does not directly relate to crime laboratories or on waste generated by forensic departments during the execution of their duties. The majority of existing literature focuses on hazardous waste which includes waste types such explosives, radioactive waste and

electronic waste which did not form part of the study. This means that the scope and quantities investigated in other studies may not be directly comparable with the findings from the study.

The findings of this research were based on results from seven laboratories and eleven Local Criminal Record Centres of the Forensic Department of SAPS in the North West Province only, concentrating on biological and chemical waste streams. Data was gathered from the review of waste collection records, audit and inspection reports, application of observation checklist and a structured survey questionnaire. No additional waste characterisation studies were performed to confirm the hazardous waste types and quantities.

1.7 Possible contribution and significance of the research

The results of this study contribute towards understanding the challenges in the management of hazardous waste by SAPS Forensic Department and make recommendations towards improving hazardous waste management practices. Dissemination of the findings across South Africa will assist forensic departments at other provinces to establish enhanced systems on the handling of hazardous waste.

1.8 Structure of the study

The dissertation is structured in five chapters:

Chapter 1 - Introduction: The chapter gives an overview of the problem statement, and the research aims and objectives. Chapter 1 also delineates the research scope and outlines assumptions and limitations related to the delineated scope.

Chapter 2 - Literature Review: Chapter 2 entails providing an overview of the literature background on the research problem to be investigated. The literature review covers legislative requirements, the different studies conducted on the hazardous waste management with focus on the handling, storage, transportation and disposal. The review also looks at the impacts associated with poor management of waste as well as the recommendations based on lessons learnt.

Chapter 3 - Methodology: This chapter gives a description of the research design, study area and the research method to be utilised. Data collection and analysis methods are also explained.

Chapter 4 – Results and Discussions: This chapter gives a representation of the data collected in form of descriptive and graphic illustrations. A discussion of the results is also given.

Chapter 5 - Conclusions and Recommendations: This chapter gives a conclusion and recommendation based on the study conducted.

1.9 Chapter conclusion

Chapter 1 presented an overview of the introduction and background information on hazardous waste management. It further outlined the problem statement; research aim and objectives as well as the scope of the research. The limitations of the study are also discussed in this chapter. Chapter 2 will contextualise the research in terms of a literature review.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Ramdhani *et al.* (2014) define a literature review as an examination of scholarly articles, books, and other sources relevant to a specified research area. This involves integrating results and perspectives from various empirical findings (Snyder, 2019). This chapter provides a review of literature related to the research topic – namely hazardous waste management practices by the Forensic Department of the South African Police Service (SAPS), with the case study context being the North West Province.

In this chapter, the researcher delves into general regulatory requirements for hazardous waste and reviews studies conducted in similar context both globally and in South Africa. The chapter further explores legislative requirements, effects, challenges, and provides a profile of different studies on hazardous waste management practices as well as highlight key findings and lessons.

Reviewed literature comes from published journals, government reports, books, and web search databases such as Science Direct, Research Gate, Google Scholar, and Boloka NWU Institutional Repository. Website content from international organisations like the World Health Organization (WHO) is also accessed. The researcher used the following keywords individually and in combinations to search for literature including: *"hazardous waste," "hazardous waste management," "hazardous waste management practices," "chemical waste," "biological waste," "infectious waste," "Health Care Risk waste," "non-anatomical waste,"* and *"forensic laboratories."* While research and published literature on global hazardous waste management is readily available, literature specifically addressing hazardous waste management in forensic departments is limited.

Legislation reviewed within the South African context included the National Environmental Management Act, 107 of 1998 (NEMA), National Environmental Management Waste Act, 59 of 2008 (NEMWA) and related norms and standards, and regulations, as well as the Hazardous Substances Act, 15 of 1973, and the Occupational Health and Safety Act, 85 of 1993, as amended.

2.2 Defining hazardous waste

Amasuomo and Baird (2016) have argued the need to clearly define what constitute waste as these forms the basis for its regulation. Numerous definitions of hazardous waste exist in the literature, with Kaur and Arora (2021) noting the absence of a clear worldwide definition. According to Vallero (2019) the distinction between hazardous and non-hazardous waste

depends on circumstances, either technical or legal. From a technical standpoint, a substance is deemed harmful based on examination, which means a waste material may contain hazardous substances without itself being hazardous (Exposto & Sujaya, 2021).

Legally, a constituent of a waste stream is considered harmful if it poses various types of harm. Kanagamani *et al.* (2021) define hazardous waste as liquids, solids, gases, sludge, and discarded commercial products potentially harmful to human health and the environment. Hazardous waste includes biological, radioactive, toxic, explosive, or harmful materials, categorized by characteristics, sources, and constituents, considering leaching, acute toxicity, and corrosiveness (Exposto & Sujaya, 2021; Li *et al.*, 2018). Furthermore, hazardous waste should exhibit properties like explosiveness, oxidising, flammability, carcinogenicity, infectiousness, and mutagenicity (Akpan & Olukanni, 2020; DWAF, 2005).

For this research, the definition of hazardous waste aligns with the National Environmental Management Waste Act (59 of 2008) (as amended) and means *“any waste that contains organic or inorganic elements or compounds that may, owing to the inherent physical, chemical or toxicological characteristics of that waste, have a detrimental impact on health and the environment”*.

The study focuses on chemical and biological wastes from facilities and activities of SAPS Forensic Departments. Chemical waste includes organics, inorganic metals, salts, acids, bases and flammables, while biological waste can be explained as a type of waste material with potential to infect living organisms and produce contaminants (WHO, 2021).

2.3 Steps involved in hazardous waste management

The handling and disposal of hazardous waste present a significant global challenge, as waste that is improperly discarded directly into the environment can pose severe health and environmental risks (Kanagamani *et al.*, 2021; Maowei *et al.*, 2021). Managing hazardous waste is complex due to its composition of harmful substances such as heavy metals and dioxins (Monteiro *et al.*, 2013). Effective hazardous waste management necessitates the implementation of procedures and policies aimed at minimising potential threats to both human health and the environment (Kanagamani *et al.*, 2021). Governments and international organisations are continually developing processes to regulate the escalating issue of hazardous waste (Li *et al.*, 2018).

The concept of integrated sustainable waste management is pivotal for promoting health, safeguarding the environment, and managing resources effectively (Jan *et al.*, 2022). A sustainable hazardous waste management system entails controlling waste from its generation to its final disposal, along with comprehensive pollution monitoring (Amadi *et al.*, 2017) (refer to

Figure 2-1). The waste generator bears a 'duty of care' to the wider community to manage waste in an environmentally responsible manner. This obligation is often referred to as 'cradle-to-grave' responsibility, signifying its continuous application throughout the hazardous waste management process (Maowei *et al.*, 2021; Olaniyi *et al.*, 2018).

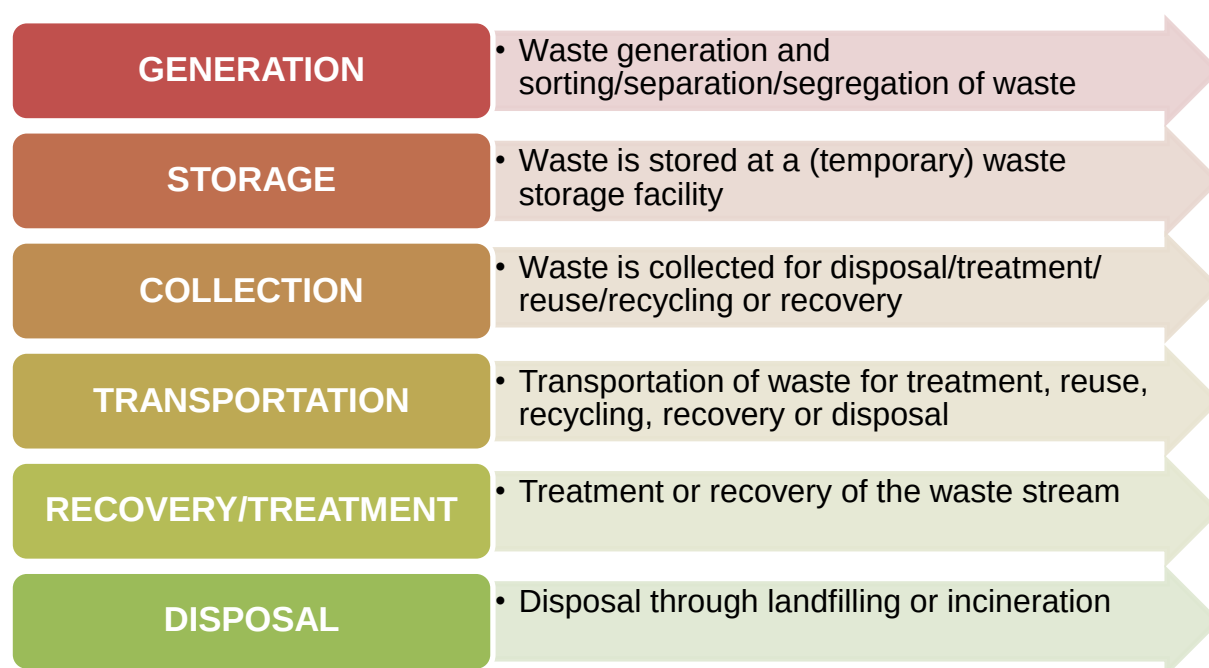


Figure 2-1: Steps involved in hazardous waste management (adapted from Olaniyi *et al.*, 2018).

The essential steps for managing hazardous waste encompass several stages, including waste generation, source separation, waste classification, storage, transportation, waste treatment, disposal, and ongoing monitoring of waste disposal sites (Bansod & Deshmukh, 2023; Expoto & Sujaya, 2021; Kanagamani *et al.*, 2021; Maowei *et al.*, 2021; Monteiro *et al.*, 2013). These distinct stages, as illustrated in Figure 2-1, are integral to ensuring effective hazardous waste management. Subsections 2.3.1 to 2.3.5 further elaborate on these stages, delineating the process from waste generation through to disposal.

2.3.1 Generation of hazardous waste

Jan and Shafi (2021) emphasise the crucial need for all the hazardous waste management steps to be followed in a systematic manner. While Figure 2-1 provides overview of the steps necessary for hazardous waste management, the sub-sections below discuss considerations for the generation of hazardous waste focusing on waste identification, segregation, and classification (Kumar *et al.*, 2023).

2.3.1.1 Identification of hazardous waste

Correctly identifying hazardous waste can present challenges and uncertainties, demanding a thorough grasp of the regulatory definition of "hazardous waste." Effectively managing waste requires meticulous planning and control to minimise its negative effects on the environment. Identifying hazardous waste serves as a pivotal starting point in waste management systems, guiding the determination of necessary management protocols (Akpan & Olukanni, 2020). The process of identifying hazardous waste entails evaluating whether the waste in question presents any chemical or physical hazards (US EPA, 2023). This identification process requires an understanding of the physico-chemical properties of hazardous waste, together with associated documents, such as Safety Data Sheets (SDSs) and/or records of waste classification.

2.3.1.2 Classification of hazardous waste

The key to correctly identifying waste as being "hazardous" lies in its proper classification. Waste generation occurs through various activities, resulting in hazardous waste manifesting in diverse forms. Common characteristics used in waste classification encompass physical states (liquid, solid, and gaseous), physical properties, reusable potentials, biodegradable potentials, source of production, and the degree of environmental impact (Demirbas, 2011; Dixon & Jones, 2005; White *et al.*, 1995 cited by Amasuomo & Baird 2016). According to the United States Environmental Protection Agency (USEPA, 2023), solid waste is declared to be hazardous when it is explicitly categorised into the listed four (4) categories as per the code of Federal Regulations (F, K, P, and U).

In South Africa, the classification of hazardous waste is governed by the *Waste Classification and Management Regulations* of 2013 (GNR. 634 of 2013). These regulations require that waste is analysed and classified in accordance with SANS 10234 to determine its physical-, health- and environmental hazards. The classification of waste informs the development of a SDS and information to be included in labelling and waste manifest documentation.

Proper classification is crucial to ensure appropriate handling, storage, and disposal methods are employed, preventing potential dangers to human health and the environment.

2.3.1.3 Quantification and recordkeeping of hazardous waste generated

The quantity of hazardous waste generated is determined by several factors, such as the size of the facility, the frequency of activities, and the nature of activities carried out (Jang *et al.*, 2006). Chartier (2014) highlights that knowing the types and quantities of hazardous waste produced is a crucial step in ensuring safe handling and disposal. Slutzman *et al.* (2023) also emphasise that robust quantitative data is necessary for the implementation of waste reduction strategies. Failure

to accurately quantify the hazardous waste generated is one of the encountered difficulties during its management (Abah & Ohimain, 2011; Mmereki *et al.*, 2016).

Waste streams may be quantified by direct measurement (volume or weight) or by estimation. Direct measurement is the most preferred method, however, facilities generating hazardous waste may not have the necessary equipment (scales, weigh bridges) to correctly quantify waste, or equipment may be inaccurate (not calibrated correctly, for example) (Slutzman *et al.*, 2023). Accurate and up-to-date records of the quantity of waste generated should be kept. This will allow for mass-balances and checking when waste is collected for treatment or disposal. Being in a position to indicate that all of the waste that was generated, was collected, and then safely disposed of contributes to the “duty of care from cradle to grave” principle (Mmereki *et al.*, 2016).

A waste manifest document, indicating the quantity of each category of waste generated and taken for treatment and disposal, should be kept by the hazardous waste generator. The generator is also responsible to safekeeping of the safe disposal certificate issued by the waste management company. Institutions should delegate persons and implement systems to ensure safekeeping of these records (Olaniyi *et al.*, 2019).

Study conducted by Slutzman *et al.* (2023) on *Waste audits and description of best practices* recommends a greater emphasis on the improvement of waste recordkeeping and reporting standards in order to advance the comparison of waste data across different settings. Regular monitoring of stored waste is necessary to maintain comprehensive records, including quantities and information on waste reception and dispatch (Vinod *et al.*, 2009).

2.3.1.4 Separation and segregation of hazardous waste

Separating and segregating waste according to its hazard properties or compatibility are crucial steps in mitigating risks associated with the mishandling of hazardous waste. At the point of generation, different streams of hazardous waste are initially sorted and allocated to appropriately numbered and color-coded bags and containers, facilitating safer and more effective management (Kaur & Arora, 2021).

Waste should be categorised based on its type, ensuring that each category is handled and disposed of according to specific guidelines (Bansod & Deshmukh, 2023). These categories may include sharps, infectious materials, non-anatomical waste, recyclable contaminated waste, chemicals, and laboratory waste, among others. The international color-coding system for waste classification includes yellow for sharps; red for anatomical and infectious materials; dark green for chemicals; and black for domestic waste (WHO, 2021). Additionally, infectious waste should be disposed of in bins or cardboard boxes lined with red heavy-duty plastic (with a thickness of 80 microns or more) and marked with a biohazard symbol.

Challenges in effective segregation at the source may arise from a lack of sufficient containers, inadequate color-coding, and negligence. However, segregating waste at its origin not only enhances the calorific value for waste-to-energy processes but also leads to reduced operating costs by simplifying the management of different waste types compared to mixed waste (Moshood *et al.*, 2022).

2.3.2 Storage of hazardous waste

Storage facilities for hazardous waste must have adequate capacity to accommodate the generated waste. The maximum duration for temporary storage varies globally, with Europe allowing between 28 to 90 days, and the United States permitting up to 90 days for large quantities and 180 days for smaller ones (Lakhuit, 2020). In South Africa, according to the *Waste Classification and Management Regulations* (GNR. 634 of 2013) (DEA, 2013a), waste must be reused, recovered, treated, or disposed of within 18 months of generation. Additionally, for health care risk waste, such as infectious and pharmaceutical waste, South African Health Care Risk Waste Regulations stipulate a temporary storage limit of 90-days from the date the container is sealed to final disposal (Du Toit & Bodenstein, 2014). However, Jan and Shafi (2021) suggest that the 90-day period should commence from the date of initial waste accumulation.

Hazardous waste storage areas must adhere to specific specifications, including protection from flooding, placement away from regular employee movements, proper ventilation, a drainage system, and the provision of absorbent kits for spillages (Maowei *et al.*, 2021; Vinod *et al.*, 2009). In South Africa, the *Norms and Standards for the Storage of Waste* (GNR. 926 of 2013) (DEA, 2013c) outline additional requirements for the storage of hazardous waste (in capacities exceeding 80 m³), such as proper access control, warning signs and notice boards, training and awareness, as well as emergency preparedness, monitoring and auditing.

Chemical liquid wastes should be stored in sealed containers or tanks, while hazardous solid wastes are typically stored in skips. These containers must be compatible with the waste they secure to prevent adverse consequences. They should be inert, resistant to reactions with hazardous waste, capable of withstanding impact, robust, leak-free, and devoid of physical defects (Lakhuit, 2020; Maowei *et al.*, 2021). Proper labelling of containers, specifying waste content and hazard type, is essential within storage areas (DEA, 2013c).

Additionally, the storage area should display cautionary signs, such as the biohazard symbol, to indicate the risks of entering the specific zone (Bansod & Deshmukh, 2023).

2.3.3 Collection and transportation of hazardous waste

The transportation of hazardous waste is tightly regulated due to the potential risks and environmental consequences associated with accidents during transit (Kanagamani *et al.*, 2021). Despite the stringent regulations in place, the transportation process can still raise safety concerns, leading to accidents resulting in serious injuries and environmental pollution (Kaur and Arora, 2021). Fulga *et al.* (2020) stress the importance of regular collection of hazardous waste from temporary storage areas to manage waste generation rates, storage capacity, and control odours emanating from waste.

Vehicles transporting hazardous waste must be registered as dangerous goods operators, display appropriate placards and warning diamonds, and carry relevant documentation such as Transport Emergency Cards (TREM cards) and waste manifest documentation. In the United States, for instance, the Resource Conservation and Recovery Act (RCRA) mandate the provision of documentation, known as a manifest, to inform key stakeholders about the safe handling of waste. The United Nations (UN) refers to this documentation as a consignment note (Kaur & Arora, 2021).

The waste manifest system is integral to the "cradle-to-grave" waste management process, tracking hazardous waste from its origin to final disposal (Nathanson, 2023). This system makes provision for a "chain of custody" and helps prevent issues related to haphazard or illegal dumping by detailing the type and quantity of hazardous waste generated and providing recommended emergency procedures for accidental spills (Nathanson, 2023). In some developed countries like South Korea, advanced technological surveillance systems are utilised to track the transportation of hazardous waste online (Kaur & Arora, 2021).

In South Africa, the transportation of dangerous goods, including hazardous waste, is governed by the National Road Traffic Act (93 of 1996) (Chapter 8) and the National Road Traffic Regulations, and Section 25 of the National Environmental Management Waste Act (59 of 2008). Typically, hazardous waste is transported to an approved Treatment, Storage, and Disposal Facility (TSDF). The TSDF may either have its own landfill, or the waste may need further transportation to another location for final disposal (Kaur & Arora, 2021).

SANS 10228 (SABS, 2012), the *South African National Standard for the Identification and Classification of Dangerous Goods for Transport by Road and Rail*, is incorporated into the National Road Traffic Regulations. To determine whether transported waste is hazardous, its properties are assessed against the nine categories outlined in SANS 10228, establishing the relevant minimum requirements for treatment, incineration, or destruction. These categories

represent classes of hazardous substances present in various waste streams, including infectious substances, flammable liquids, organics, and oxidising substances (Machete & Shale, 2015).

2.3.4 Treatment of hazardous waste

While the waste management hierarchy promotes the re-use, recycling and recovery of waste to its treatment and disposal (DEFF, 2020), the potential to re-use, recycle and recover biological and mixed chemical wastes is relatively limited. Hazardous waste is, generally, treated to render it less harmful or less toxic prior to disposal. Treatment may include chemical-, physical-, biological- or other treatment.

The treatment of waste may, however, require an environmental authorisation. The GNR. 921, the *List of Waste Management Activities* (DEA, 2013d) in terms of NEMWA, regulate the treatment of waste (thermal, physical, chemical, biological or any other treatment). The thermal treatment of waste may also be regulated through other legislation, such as the National Environment Management: Air Quality Act (39 of 2004). It is, therefore, important to understand the required treatment processes in line with legislative requirements.

2.3.5 Disposal of hazardous waste

Landfilling is a prevalent waste management method employed globally; encompassing municipal solid waste, industrial waste, and hazardous waste landfills (Yang *et al.*, 2018 cited by Abubakar *et al.*, 2022). Effective landfill management necessitates compliance with legislative requirements and structural engineering (Siddiqua *et al.*, 2022). Landfills are designed to receive concentrated waste in compressed layers, minimising volume. Technologically advanced landfills incorporate barrier or liner systems, leachate management, underground water monitoring, and gas extraction systems whereby the extracted gas is repurposed for energy production.

In South Africa, the *Norms and Standards for the Disposal of Waste to Landfill* (GNR. 636 of 2013) (DEA, 2013e) prohibits the disposal of certain types of waste to landfill. The norms and standards further provide the requirements for landfilling and the considerations for the design of landfill sites. Furthermore, the *Norms and Standards for Assessment of Waste for Landfill Disposal* (GNR. 635 of 2013) (DEA, 2013d) provide the requirements for the assessment of waste (Type 0 to 4) before it may be disposed to landfill. For instance, Type 1 waste may only be disposed of at a Class A landfill designed in accordance with required engineering specifications (see Figure 2-2).

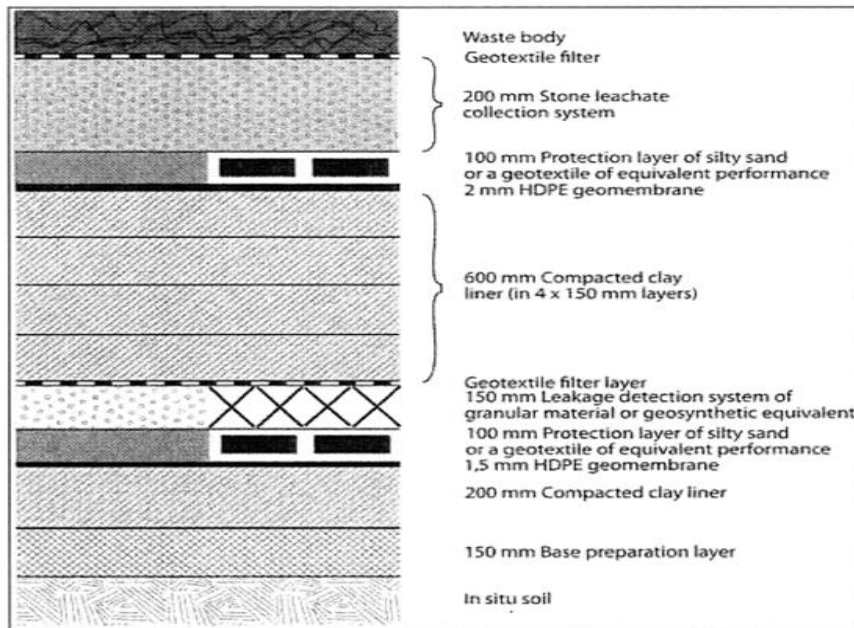


Figure 2-2: Design of Class A landfill (Norms and Standards for the Disposal of Waste to Landfill, GNR. 636 of 2013)

Hazardous waste landfills demand stringent monitoring and control. Specific structural enhancements are integrated to contain hazardous waste securely, mitigating the risk of environmental leakage (Siddiqua *et al.*, 2022). These additions encompass double liners, enhanced leachate collection systems, leak detection mechanisms, dispersion controls, and quality assurance inspections, which may add to the costs of constructing and managing these hazardous waste landfill sites.

The management of certain biological waste types, such as anatomical and infectious waste, requires special treatment processes due to its potential to cause environmental pollution and public health risks. In line with their inherent hazards, incineration is considered the preferred method for disposing of these biological waste types. The high temperatures involved during the incineration process bring about significant volume reduction of the waste material, disinfection, and sterilisation (Huang & Lin, 2008). In South Africa, the thermal treatment of hazardous waste (amongst others through incineration) is regulated through the *National Environmental Management Air Quality Act* (GNR. 893 of 2013) to manage and mitigate the potential impacts of emissions on air quality (Jang *et al.*, 2006).

2.4 Consequences and impacts of hazardous waste

According to Jan and Shafi (2021), in most developing countries hazardous wastes is handled without consideration of their negative effects on human health as well as the environment. Due diligence in hazardous waste management is crucial, as improper practices pose risks to workers, waste handlers, and the broader community. Risks of possible exposure heighten during waste collection and transportation (Maowei *et al.*, 2021). The subsections below explain the consequences and impacts of hazardous waste on the environment, on human health, and on property.

2.4.1 Impacts of hazardous waste to the environment (land, air and water)

Unsatisfactory storage, handling, treatment and disposal of chemical waste may affect the environment by releasing contaminants into groundwater, soil, and atmosphere (Wood, 2021). Open dumping and illegal dumping of hazardous waste is widely carried out in many developing countries because it is inexpensive and easily accessible. Uncontrolled or illegal burning of waste may lead to emissions of toxic materials, endangering public health and the environment (Olaniyi *et al.*, 2018). Unregulated incineration contributes to smog, fine particle emissions, and significant air pollution and greenhouse gas emissions.

Siddiqua *et al.*'s (2022) literature study identified various pollution concerns linked to landfilling, including underground water pollution from leaching, air pollution from particle suspension, odour pollution from waste accumulation, and marine pollution from run-offs. Landfilling of hazardous waste can also pose unexpected combustion hazards, contamination of drinking water and increasing infection risks (Koop & Van Leeuwen, 2016). Olaniyi *et al.* (2018) add that a substandard landfill resulting in erosion, may cause the washing of the waste into water bodies, thus contaminating the water.

2.4.2 Impacts of hazardous waste on human health

The improper handling of hazardous waste causes exposure to occupational health hazards to the any individual handling the waste from the point of generation to the entire hazardous waste life cycle. The consequences of mishandling hazardous waste, whether through skin contact, inhalation, or ingestion, can be severe (Oli *et al.*, 2016). The surrounding community may be negatively affected if toxic waste escapes through water supplies, air pollution and soil pollution and thus infiltrating the human food chain either directly or indirectly. The possible health effects of hazardous waste vary from minor discomforts, such as headaches and nausea to severe health problems, such as cancers, birth defects and tragedies that result in immediate injury or death (Jan & Shafi, 2021). These risks arise from the presence of sharp objects, chemicals, human tissue, and other infectious materials in the waste (Olaniyi *et al.*, 2018).

Human contact with chemical waste can also cause a number of health issues, including skin irritation, impairments, breathing problems and other diseases (Hasan *et al.*, 2020). Exposure to toxic substances in infectious waste can weaken the immune system (Kaur & Arora, 2021). Microorganisms present in biological waste have the potential to cause infectious diseases, such as Hepatitis B and C, and Human Immune Virus (HIV) (Prajapati & Kaur, 2021).

Environmental pollution, in turn, has been linked to health challenges such as the spread of diseases like typhoid and cholera, as well as non-communicable diseases like cancer and asthma in affected local communities (Hossain *et al.*, 2011). Incineration has been linked to the disruption of human hormonal, immune, and reproductive systems, along with cancer risks (Olaniyi *et al.*, 2018).

2.4.3 Impacts of hazardous waste on property

Hazardous waste could exhibit properties such as explosiveness, oxidising, flammability, carcinogenicity, infectiousness, and mutagenicity, amongst others (Akpan & Olukanni, 2020; DWAF, 2005). Biological waste can consist of pathogens namely bacteria, viruses, fungi, or parasites, while the liquid chemical waste could display toxic, corrosive, inflammable, or reactive properties (Saleh, 2016).

Hazardous waste spills can affect sewer systems resulting in explosions in pipes and thus polluting the entire water management system (Gu *et al.*, 2014). Chemical reactions and examinations carried out in the laboratory can cause fire, and explosion. There are also risks associated with semi volatile and volatile gases produced due to landfilling. For instance, a flammable gas such as methane can lead to explosions and fire when exposed to air under certain conditions (Diaz & Savage, 2003). The presence of such risks can be minimised through adequate safety management procedures, supervision and awareness (Cimera *et al.*, 2020).

2.5 Hazardous waste management in the African context

The African Waste Management Outlook (UNEP, 2018) and the Global Environmental Outlook Report (GEO-6) for Africa (UNEP, 2019) underscore hazardous waste management as a significant concern in the African region. Nigeria reportedly produces the highest amount of hazardous waste in Africa, at 2,469,000 tonnes annually, followed by Egypt at about 1,440,000 tonnes per year (Akpan & Olukanni, 2020). Nigeria faces challenges in establishing a distinct system for the separation, storage, collection, transportation, and disposal of hazardous waste materials (Akpan & Olukanni, 2020). In Ethiopia, reported waste data indicates that the composition of hazardous waste (as a proportion of total amount of waste generated) ranges between 21 and 75% (Yazie *et al.*, 2019 cited by Ibrahim *et al.*, 2023). The inconsistency in the

proportion of the hazardous waste generation rate can be attributed to poor segregation practices and lack of enforcement legislation and policies.

While many African countries have enacted laws and regulations for effective hazardous waste management, challenges persist, including weak law enforcement, lack of waste data, inadequate waste management infrastructure, and illegal disposal of hazardous waste. Unregulated landfill sites and poor segregation of hazardous waste at source are critical issues requiring attention in African countries (Akpan & Olukanni, 2020).

Awareness regarding hazardous waste management is reported to be lacking in developing African countries. In West Africa, Ghana, for instance, manages hazardous waste, including biomedical waste, through disposal in landfills. Challenges in Ghana, include a lack of information on hazardous waste generated, leading to the presence of hazardous waste in landfill sites (Akpan & Olukanni, 2020). These issues emphasise the need for increased awareness and improved waste management practices in the region.

The African Waste Management Outlook (UNEP, 2018) highlights the concern around the unlawful transboundary movement and transportation of hazardous waste amongst African countries. This unlawful movement of waste destabilises international relations and enforcement efforts (Carroso *et al.*, 2012). African nations, which are signatories of the Basel Convention, need to align themselves with international standards for the handling and transboundary movement of hazardous waste. Additionally, the Bamako Convention within the African continent aims to prohibit the import and incineration of hazardous waste and thus ensures environmentally sound waste disposal (UNEP, 2023).

2.6 Hazardous Waste Management in South Africa

Section 2.6.1 provides an overview of hazardous waste management in South Africa, while Section 2.6.2 and its subsections provide an overview of the key legislation for hazardous waste management in the country.

2.6.1 Overview of hazardous waste management in South Africa

In South Africa, hazardous waste management is regulated by the National Department of Forestry, Fisheries and Environment (DFFE). The National Waste Management Strategy (NWMS) reports that nearly 67 million tonnes of hazardous waste generated was generated in 2017, of which 93% of that was landfilled (DEFF, 2020). According to the 2018 State of Waste Report, released by Department of Environmental Affairs (DEA), only 0.1% of the hazardous waste was treated, 0.6 % of the waste was stockpiled, 6.6% was recovered and 92.7% was disposed to landfill (DEA, 2018).

The reported figures highlight the need for waste minimisation in order to give focus on the reduction of hazardous waste through implementing an integrated approach to pollution and waste management (Makgae, 2011). This means that South Africa has a duty to align with international commitments and to be a globally responsible country.

The strategies required for adequate handling of hazardous waste entail the implementation of systematic plans, commitment, change in behaviour as well as capital investment (DEFF, 2020). The management of hazardous waste in South Africa is aligned with NWMS which supports working towards sustainable development goals (SDG) by means of using advanced systems to progress from a linear economy to a circular model (Makgae, 2011).

2.6.2 Legal framework for managing hazardous waste in South Africa

Hazardous waste management in South Africa is regulated through various pieces of legislation, such as National Environment Management Act, National Environmental Management Waste Act, National Environmental Management Air Quality Act, Environment Conservation Act, National Water Act, Health Act, Hazardous Substances Act and the Occupational Health and Safety Act (Chauke *et al.*, 2017). The sub-sections below provide a brief overview of the legal framework applicable to the management of chemical and biological wastes, which forms part of the scope of this research. The intent of the section is not to provide a comprehensive legal overview of all of the legislation applicable to hazardous waste in the country, but rather to contextualise the legal framework applicable to the types of hazardous waste, and activities in which the SAPS Forensic Department in North West is involved. For instance, none of the hazardous waste generated by SAPS Forensic Department is exported. Therefore, the legal framework applicable to the export of hazardous waste is not discussed below.

2.6.2.1 The Constitution of the Republic of South Africa Act 108 of 1996

South Africa is guided by its post-democracy Constitution, promulgated in 1996, which oversees the constitutional rights and responsibilities of its citizens. Section 24 of the Constitution (1996) asserts the right of every South African citizen to an environment that is not harmful to their health and well-being.

The enactment of the Constitution laid the foundation for the development of relevant legislation essential for the efficient management of waste. As noted by Makgae (2011), hazardous waste, given its harmful nature, necessitates stringent regulatory and technical controls. South Africa has implemented a range of legislative measures to enhance environmental quality. However, effective regulation of hazardous waste demands robust compliance and enforcement capabilities.

In South Africa, the management of hazardous waste, which forms part of the scope of this research, is currently governed by several pieces of legislation, which will be detailed in the following subsections.

2.6.2.2 Hazardous Substances Act 15 of 1973

According to the Hazardous Substances Act 15 of 1973, a substance is classified as general or hazardous waste depending to the risk it carries. General waste is defined as waste which does not pose a significant threat to public health or the environment while hazardous waste, however, can pose adverse effect on public health and on the environment, even in lower concentrations.

The Act regulates the production, import, utilisation, handling and discarding of hazardous substances in South Africa. The hazardous substances listed within the Act are classified into Group I up to Group IV, whereby Group II comprises of nine classes of wastes which excludes explosives and radioactive substances (Du Toit & Bodenstein, 2014).

2.6.2.3 The National Environmental Management Act 107 of 1998

The foundational framework for environmental laws in South Africa is established by the National Environmental Management Act (107 of 1998), commonly referred to as NEMA. NEMA (1998) delineates strategies for environmental laws, encompassing a life-cycle approach to waste management (Zhakata *et al.*, 2016). Section 2 of the NEMA (1998) incorporates internationally recognised environmental management principles, including the precautionary principle; the polluter pays principle, duty of care, sustainable development, and more. The polluter pays principle holds organisations or generators accountable for pollution resulting from their practices.

The precautionary principle advises individuals to presume that generated waste is hazardous until sufficient evidence proves otherwise. This ensures the safety of workers, contractors, and the overall environment (Zhakata *et al.*, 2016). NEMA principles also emphasise considering alternatives and selecting the Best Practicable Environmental Option in situations where certain pollution practices cannot be avoided (King *et al.*, 2018).

Section 24 of the NEMA makes provision for environmental authorisation of activities which may have a detrimental impact on the environment, through an environmental impact assessment process.

2.6.2.4 The National Environmental Management Waste Act 59 of 2008

The primary legislation in South Africa addressing waste management, including hazardous waste, is the National Environmental Management Waste Act (59 of 2008) (NEMWA in short).

Section 16 of the NEMWA (2008) underscores the general duty in respect of waste management, obliging waste custodians to take prudent steps for the safe handling of waste. Additionally, the NEMWA requires that waste be transferred to an authorised recipient capable of transporting, recycling, and disposing of the waste safely (Zhakata *et al.*, 2016).

The sub-sections below focus on the strategies, norms and standards, and regulations in terms of the NEMWA.

2.6.2.4.1 National Waste Management Strategy (NWMS)

The primary objective of the National Waste Management Strategy (NWMS) is to operationalise the goals outlined in the National Environmental Management Waste Act (NEMWA) of 2008, particularly by implementing the waste management hierarchy.

The NWMS (2020) aligns with the Sustainable Development Goals (SDGs) of Agenda 2030, providing a strategic framework for the waste sector in South Africa. The NWMS underscores the importance of integrated waste management, emphasising coordination within the waste management hierarchy (DEFF, 2020). Both the NWMS (2020) and the NEMWA recognise the significance of moving waste management up the hierarchy, with a specific focus on the prevention of hazardous waste in terms of quantity and toxicity.

Sustainable development features prominently in various international agendas and agreements. Goals associated with the NWMS and hazardous waste management align with SDG3, aiming to minimize environmental factors contributing to ill-health. Additionally, SDG13 emphasises the implementation of activities to reduce greenhouse gas emissions, enhance climate resilience, and promote renewable energy (DEFF, 2020).

The 2020 NWMS identifies waste prevention in terms of amount and toxicity as the main priority in relation to hazardous waste. Pillar 1 of the NWMS, which focuses on “*Waste Minimisation*” has a specific focus area - “*Minimise hazardous waste in terms of their volume, toxicity and streams the environmental risks associated with their treatment and disposal streams*” (DEFF, 2020:38). Furthermore, Pillar 2 of the NWMS, aiming towards “*Effective and sustainable waste services*” has a focus area on “*Safe Management of hazardous wastes*” (DEFF, 2020:41).

2.6.2.4.2 Waste Classification and Management Regulations (GNR. 634 of August 2013)

Prior to 2013, waste classification in South Africa adhered to the *Minimum Requirements for the Handling, Classification, and Disposal of Hazardous Waste* (DWAF, 2005). In August 2013, new regulations known as the *Waste Classification and Management Regulations* of 2013 (GNR. 634

of 2013) were enacted (DEA, 2013a). These regulations provide a framework for classifying waste based on its characteristics, including its chemical and physical properties.

The primary purpose of waste classification is to assess the risks associated with waste, distinguishing between extremely hazardous waste requiring precautionary disposal and less hazardous waste (Nyika *et al.*, 2019). The *Waste Classification and Management Regulations* outlined in GNR. 634 of 2013 delineate the responsibilities of waste generators, transporters, and management executives (DEA, 2013a).

Aligned with the Globally Harmonised System of Classification and Labelling of Chemicals (GHS) specified by the South African National Standard (SANS) 10234, GNR. 634 provide conditions for classifying hazardous substances, including waste. The GHS standard also incorporates communication elements for labelling and information required for Safety Data Sheets (SDS). Requirements of GNR. 634 include recordkeeping, and the requirements for information included as part of the waste manifest document (DEA, 2013a).

2.6.2.4.3 The Norms and Standards for assessment of waste for landfill disposal (GN. R 635 of August 2013)

GNR 635, the *Norms and Standards for the Assessment of Waste for Landfill Disposal* (DEA, 2013b), play a crucial role in regulating the disposal of waste in landfills in South Africa. Specifically, this regulation provides norms and standards for assessing waste before it is disposed of in landfills. For adequate hazardous waste management, GNR. 635 is relevant as it establishes the criteria and procedures for evaluating the characteristics of waste, ensuring that hazardous waste is appropriately identified and treated. The regulation addresses parameters such as leachate potential, chemical composition, and other factors that can impact the environment and public health. The output of the assessment process is waste types (Type 0 to Type 4, of which Type 0 is the most hazardous and Type 4 the least hazardous) (DEA, 2013b).

GNR. 635 contributes to the responsible and safe disposal of waste to landfill, preventing potential environmental contamination and adverse effects on human health.

2.6.2.4.4 The Norms and Standards for the disposal of waste to landfill (GNR. 636 of August 2013)

The GNR. 636 of 2013 which is the *Norms and Standards for Disposal of Waste to Landfill*, (DEA, 2013e) provide prohibitions, restrictions and requirements for the disposal of waste to land (Nyika *et al.*, 2019).

Hazardous landfill classification is determined by the landfill class, with a well-constructed hazardous waste landfill mandated to have two impermeable liners and leachate collection systems (Nathanson, 2023). The requirements for the design, operation, and monitoring of hazardous waste landfill sites (i.e. Class A landfills) are more rigorous compared to those for general waste landfills (DWAF, 2005).

In the regulations, landfills are classified into four classes as per their waste containment barriers and engineering designs. Class A has the most superior engineering with a geotextile barrier layer while class D is the least advanced. Type 0 waste is not suitable for landfilling and requires to be it is treated and re-classified to a category that allows for disposal, while Type 1 to Type 4 waste can be disposed in classes A to D landfills (DEA, 2013e), respectively.

2.6.2.4.5 The National Norms and Standards for the Storage of Waste GNR. 926 of 2013

The *Norms and Standards for the Storage of Waste*, as outlined in GNR. 926 of 2013 (DEA, 2013c), establish the essential criteria for waste storage facilities. These norms and standards are particularly relevant to waste facilities with a capacity to store 80 m³ or more of hazardous waste.

The specifications include the use of containers that must be clearly marked and structurally robust to resist leaks and perforations. The norms and standards further require access control, regular monitoring and inspections, emergency preparedness measures and training/awareness measures. This ensures a standardised and secure storage environment, with special consideration for hazardous waste, enhancing the overall safety and effectiveness of waste management practices (DEA, 2013c).

2.6.2.4.6 The National Waste Information Regulations GNR. 625 of 2012

The waste information is essential in making known the identity of waste types that need to be prioritised. GNR. 625 of 2012 outline the *National Waste Information Regulations* (DEA, 2012). These regulations impose a duty on entities involved in the waste management process, such as generators, transporters, and facilities, to provide accurate and detailed information regarding the generation, transportation, and disposal of waste. Within these regulations, distinct categories of waste, encompassing hazardous waste, general waste and specific waste types, are outlined. Each category is associated with specific reporting requirements, ensuring that the submitted information captures essential details relevant to the nature, origin, and management of the waste. Khan *et al.* (2019) report that unsatisfactory data collection and record keeping gives indication that many more activities go undocumented within an entity. Furthermore, the regulations emphasise the significance of recordkeeping, requiring entities to maintain

comprehensive records related to their waste management activities. This practice ensures traceability, accountability, and a holistic approach to managing waste information.

In South Africa, waste data is monitored through the South African Waste Information System (SAWIS). According to Mmereki *et al.* (2016), in developing countries, the quantities of hazardous wastes have not been documented because the waste streams are incorrectly managed and therefore presenting greater risks to the environment. Entities involved in waste management are required to adhere to designated reporting intervals, ensuring that information is submitted regularly and in a timely manner. This periodic reporting contributes to the establishment of a robust waste information system, allowing for continuous monitoring and assessment of waste-related activities.

2.6.2.4.7 Draft Regulations on Health Care Risk Waste

In South Africa, only Gauteng and the Western Cape have legislative directives in terms of the management of Health Care Risk Waste. According to Jansen *et al.* (2017), *'there is a lack of development and adherence to directives and laws in developing countries such as South Africa'*. Ramodipa *et al.* (2023) declare that Eastern Cape Province does not have clear strategic document from any national authorities that provides guidance on the guides the management of Health Care Risk Waste. According to the Draft Health Care Risk Waste Management Regulations of 2012, regulations HCRW include infectious waste, chemical waste, sharps and expired and unused medicines (Du Toit & Bodenstein, 2014).

These regulations are, however, not applicable to the North West Province. It could, however, inform best practice with regards to the handling, storage, segregation, separation, labelling and disposal of biological and chemical waste.

2.6.2.5 Occupational Health and Safety Act 85 of 1993

According to Kaur and Arora (2021), it is crucial for employees to undergo regular testing and screening to ensure they have not been contaminated by any chemicals and toxins in the waste. The Occupational Health and Safety Act 85 of 1993 serves as a regulatory legislation that offers a practical approach to preventing and minimising work-related injuries and illnesses. Employers must ensure a safe working environment for employees and provide adequate PPE and training before exposing workers to hazards. The necessary PPE for employees handling waste include respiratory protection, hand and skin protection, eye protection and protective clothing to reduce the effect of contact with hazardous substances (Amadi *et al.*, 2017).

Khan *et al.* (2019) mention that the lack of regular medical screening can result in encountered difficulties when determining the cause-effect correlation. Occupational Health and Safety Act

includes pertinent guidelines through the regulations for Hazardous Chemical Agents (HCA, 2021) and Hazardous Biological Agents (HBA, 2002) which provide a standardised approach for managing hazards. These regulations outline requirements for air monitoring, medical surveillance, risk assessment, recordkeeping, training, handling, labelling, packaging, transportation, and storage, among other aspects.

2.7 Studies conducted in a similar context

The assessment of hazardous waste practices requires an investigation of waste activities from generation until final disposal. The management also includes the possible application of engineering controls in order to reduce or eliminate exposures. This section investigates other literature studies related to waste management practices within different or similar discipline in order to establish similarity of contexts and determine any corroborations and arguments (Maalej *et al.*, 2017).

The study by Hossain *et al.* (2011), which focused on *the management of clinical solid waste and its impact on human health and the environment*, indicates that clinical and non-clinical waste materials are often mixed before proper disposal due to insufficient financial investment and a lack of awareness. This lack of segregation at the source not only increases adverse health effects but also leads to higher disposal costs (Hossain *et al.*, 2011). Insufficient waste management training programmes lead to a lack of knowledge among the general workforce and waste handlers, resulting in unsafe waste handling and various health risks (Hossain *et al.*, 2011; Khan *et al.*, 2019). To improve occupational safety for cleaning staff, there is a need for regular training programmes and the provision of adequate protective measures. The study emphasises that financial support and administrative monitoring by local authorities are essential for enhancing hazardous waste management practices.

Ikau *et al.*'s study (2016) on *factors influencing waste generation* concludes that the lack of regulations, enforcement, and guidelines contributes to increased hazardous waste generation. Inadequate hazardous waste management practices also result in an increasing burden of illegally dumped and burned waste, foul odours, and poor aesthetics (Ferronato & Torretta, 2019).

Mmereki *et al.* (2016) in their research focusing on *the management of hazardous waste in developing countries* indicate that, especially in developing countries, the lack of efficient approaches to systematically regulate hazardous waste is a major issue (Mmereki *et al.*, 2016). According to Akpan and Olukanni (2020), the absence of financing and an integrated programme for monitoring and controlling hazardous waste has led to substantial weaknesses in the efficient management of hazardous waste materials. The study by Mmereki *et al.* (2016) reveals shortfalls

in the implementation of existing regulations due to disintegrated responsibilities in government departments and local authorities.

Addressing inadequate hazardous waste segregation in industrialised countries requires that factors such as poor separation at source, colour coding, insufficient recording, and workers negligence attended to (Kaur & Arora, 2021). African countries, such as Nigeria, face challenges due to low awareness of hazardous waste management, lack of information on quantities produced, low incentives or penalties, unclear roles and responsibilities for stakeholders, and limited infrastructure (Akpan & Olukanni, 2020). Portugal has implemented hazardous waste management through political alterations, changing legislation frameworks, and implementing new energy conversion infrastructure (Monteiro *et al.*, 2013).

Proper separation at the source is crucial to handle both hazardous and non-hazardous waste types appropriately and thus preventing the entire waste stream from becoming harmful (Vinod *et al.*, 2009). In a study on chemical waste generated from teaching laboratories, Rodriguez-Rodriguez *et al.* (2020) in their research on *physical, chemical, and biological treatment of chemical waste from teaching laboratories* report variations in wastewater properties due to the laboratory's chemical waste. The study identified 55 chemical substances in the laboratory's wastewater samples, including fatty acids, aromatic organic substances, reducing agents, strong oxidants, and amides.

Vinod *et al.* (2009) in their research focusing on *biomedical waste hazards and their management in forensic laboratories - An overview in Indian context* have mentioned inconsistent recordkeeping as a concern for biomedical waste from forensic laboratories in India. The authors state that: "*Forensic science laboratories being not a part of health care establishment, these rules [recordkeeping requirements related to health care facilities] are hardly applied to them.*" The lack of recordkeeping on waste quantities generated and collected for disposal is cause for concern.

Maqutu's study on *Life Cycle Assessment (LCA) of hazardous waste generated by Crime Scene Laboratories (CSL) in Mpumalanga (2017)* highlights that compliance with waste management practices at Crime Scene Laboratories is far from ideal due to a lack of training and awareness among staff. Elements which were investigated comprised of; suitability of temporary waste storage area, use of waste registers, regular inspection of waste bins as well as the competency of people managing waste. The findings suggest that alongside developing better waste management practices and empowering staff with knowledge, attention should be given to management facilities, especially storage facilities, to ensure an economically sustainable and environmentally friendly waste management system.

2.8 Recommendations towards improvement of hazardous waste management based on lessons learned

The collective findings from studies conducted in a similar context (See Section 2.7 above) underscore critical lessons for effective hazardous waste management. One recurring theme is the imperative of proper waste segregation at its source. The studies reveal that inadequate segregation, whether in clinical settings or industrial contexts, leads to a myriad of challenges. Not only does it contribute to increased health risks for workers and the general public, but it also results in higher disposal costs (Ibrahim *et al.*, 2023). The importance of regular training programmes and the provision of protective measures for workers to enhance occupational safety are highlighted across these studies.

Financial investment and awareness emerge as pivotal factors influencing waste management practices (Akpan & Olukanni, 2020). In several instances, insufficient financial resources and a lack of awareness lead to suboptimal waste management, including the mixing of hazardous and non-hazardous waste (Olaniyi *et al.*, 2018; Prasetya *et al.*, 2023; Sawalem *et al.*, 2009;). Study conducted by Padmanabhan and Barik (2019) highlighted that lack of awareness, inadequate training in proper waste management, absence of waste management and disposal systems, insufficient financial and human resources, and the non-prioritisation of waste management contribute to existing challenges.

Effective waste management practices are contingent on robust regulatory frameworks, enforcement, and guidelines (Fazzo *et al.*, 2017; Kumar *et al.*, 2023; Li *et al.*, 2018). The absence of clear regulations and guidelines, coupled with weak law enforcement, contributes to increased waste generation, further emphasising the need for comprehensive regulatory measures. A study conducted in Malaysia by Zainu (2020) revealed that there is a need for improvement in terms of renewal of policies and regulations in order to adapt to current time and technologies associated with hazardous waste. Developing countries in Africa need a practical system with stringent laws, policies, and regulations to ensure compliance and enforcement (Moshood *et al.*, 2022).

The challenge of waste management is not limited to African countries, as even in European countries, such as Portugal, political alterations and new infrastructure are deemed necessary to control hazardous waste effectively. A study conducted in Portugal achieved enhanced waste management by revising legislative frameworks and employing advanced energy conversion technologies (Monteiro *et al.*, 2013).

The reviewed literature also shed light on the importance of administrative monitoring and financial support from local authorities (Kanagamani *et al.*, 2021). In particular, the management

of hazardous waste materials requires integrated programs and adequate funding to address weaknesses in current practices (Li *et al.*, 2018).

Kaur and Arora (2021) emphasise the significance of knowledge in waste disposal, yet Siddiqua *et al.* (2022) argues that knowledge alone is insufficient to induce behavioural change in waste management. Despite strict regulations against illegal dumping, it is found that individuals continue to engage in this prohibited activity. The environmental and health impacts of inadequate waste management practices, such as illegal dumping and burning, are consistently highlighted. These impacts include pollution, foul odours, and aesthetic degradation (Kanagamani *et al.*, 2021). Additionally, the studies stress the importance of considering the improvement of the entire waste management system, including storage facilities, to ensure economic sustainability and environmental friendliness (Mmereki *et al.*, 2016).

The lessons learned from these studies emphasise the need for comprehensive and integrated approaches to hazardous waste management (Farooqi *et al.*, 2021). This includes proper waste segregation, robust regulatory frameworks, continuous training and awareness programs, *and adequate financial support for effective and sustainable waste management practices* (Tudor *et al.*, 2008). Akpan and Olukanni (2020) emphasise that effective hazardous waste management in Africa must integrate economic development and environmental sustainability. They propose a lifecycle approach (see Figure 2-3) involving policy planning, a robust legal system, strict enforcement, stakeholder coordination, training, public awareness, resource supply, and investment to address non-compliance effectively.



Figure 2-3: Lifecycle approach designed to manage hazardous waste in an integrated manner (adapted from Akpan & Olukanni, 2020)

ISO 14001 implementation entails the use of a formalised set of procedures for planning, implementation, monitoring and review of an organisation's activities (Deyassa, 2019). The essential elements of the ISO 14001 standard are environmental policy, planning, implementation, checking and executing corrective action for improvement (Franchetti, 2011). The voluntary international standard has been established to incorporate environmental aspects into organisation processes and products whereby environmentally unsafe inputs are replaced with less harmful inputs and thus preventing pollution and consequently avoiding high generation of waste (Chauke *et al.*, 2017). The ISO 14001 audits enable the identification of existing irregularities and are an excellent tool for organisation advancement. The environmental management system foundation is built on the basis of the Plan-Do-Check-Act (PDCA) model (see Figure 2-4).



Figure 2-4: EMS PDCA Cycle (Adapted from Tariq *et al.*, 2023)

This model drives the practice necessary to achieve continuous improvements in an environmental program (Tariq *et al.*, 2023). The implementation of Environmental Management System standard (EMS), ISO 14001 is achieved through the use of a systematic approach to environmental management that consequently aims to improve the environmental performance of an organisation. In a study conducted by Deyassa (2019), it was found that the implementation of ISO 14001 provides added value for environmental management through improvement in terms of compliance to environmental legal requirements, waste minimisation, and overall environmental performance.

2.9 Chapter conclusion

The literature review has provided a comprehensive overview in terms of hazardous waste management on a global scale, African context, in South Africa and briefly at forensic laboratories. There is still limited research focusing only on waste generated by crime laboratories. The literature review has created a foundation to support the objectives of this study, to assess hazardous waste management practices. Chapter 3 outlines the methodology that was employed in the study.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter describes the research approach and design, case study selection, sampling design, data collection and analysis, as well as ethical considerations and methodological limitations applicable to this research.

3.2 Research approach

The research approach encompasses the systematic and methodical plan or strategy employed to investigate a particular topic, guiding the researcher in collecting, analysing, and interpreting data to gain meaningful insights and contribute to the advancement of knowledge in a specific field (Grover, 2015). Mixed methods research is popular as it employs both quantitative and qualitative data in a single study, which may provide a stronger interpretation to the overall research (Creswell & Creswell, 2017; Grover, 2015). The general objective of the mixed-methods research approach is to present an improved, meaningful comprehensive depiction that can enhance the description and understanding of the findings (Creswell & Creswell, 2017). For instance, a survey questionnaire includes some open-ended descriptive questions, serving as qualitative method to capture aspects of the research topic that may be significant to the research problem, may aid in the interpretation of quantitative data.

For this research, a mixed methods approach was utilised whereby both qualitative and quantitative data were collected. The research followed an explorative case study design in which the management of chemical and biological wastes within the SAPS Forensic Department in North West was looked at.

3.3 Research design

The research design serves as a comprehensive plan for data collection in a research study. For research to be conducted effectively, it requires the researcher to have a suitable research plan before the commencement of data collection in order to ensure that the research objectives are realised (Asenahabi, 2019). The key principle of research design is to translate a research problem into data for analysis related to specific research questions or objectives.

The research design implemented for this research involved the collection of both primary and secondary data. Primary data was gathered through the use of questionnaires and observation checklists, while secondary data included information from previous audit reports and the review of documents. Table 3-1 provides an overview of each research objective, illustrating the data collection methods used and providing justifications for adopting each method.

Table 3-1: Research design

Research objective	Data collection	Justification
Research objective 1: Determine the types and quantities of hazardous waste generated by the SAPS Forensic Department, North West Province	Document Analysis: Available waste manifest collection records were used to determine waste quantities and waste types generated.	The types and quantities of hazardous waste generated are recorded (when it is collected) through waste manifest documentation. These documents were used (in the absence of any other systems implemented by SAPS Forensic Department, North West) to determine waste types and quantities generated.
Research objective 2: Evaluate the current hazardous waste management practices of SAPS Forensic Department, North West against legal requirements.	Observations: Observations were conducted across each facility to identify the waste collection, handling and disposal practices at the different facilities. Observation checklists focused on the on-site management of chemical and biological wastes. Photographs were used to supplement data obtained from the observation checklist. Document review: A review of previous audit reports and internal organisational procedures (SOPs) was done as means of justification and enhancement to the obtained data from the observation checklist	Observation entails the recording of interactions, processes, or behaviours as they occur. The observation of the storage, handling practices and records generated during the handling process is valuable during the evaluation of waste practices (Ruoyan <i>et al.</i> , 2010).
Research objective 3: Assess the level of knowledge and awareness of personnel with regard to the management of biological and chemical waste.	Survey questionnaire: A semi-structured survey questionnaire (Annexure B) was used to evaluate the level of knowledge and awareness among the personnel responsible for waste management.	Surveys are appropriate methods of gathering perceptions on knowledge and/or awareness of a particular topic (Asenahabi, 2019).

3.4 Case study description

The sections below provide a description of the selection criteria for the case study, and the selected facilities included in the case study.

3.4.1 Selection of the SAPS North West province as a case study area

This research was conducted at facilities of SAPS Forensic Department in North West. The researcher is an employee of SAPS Forensic Department, and the case study area was purposively selected because hazardous waste management has been (internally) highlighted as one of the main areas of concern within the department. The Department was willing to make information available to the researcher, because of her current role within the organisation. The limited research conducted on the topic, the challenges faced with specifically hazardous waste management within the Department, and the willingness to participate in the research, served as justification for selecting the SAPS Forensic Department in North West as a case study.

3.4.2 Description of the case study area

The North West Province is bordered by Botswana to the northwest, Limpopo province to the northeast, Gauteng province to the east, Free State province to the southeast, and Northern Cape province to the southwest. Mahikeng is the capital of the province, while Potchefstroom, Klerksdorp and Rustenburg are part of the bigger towns in the province. Other main towns are Brits, Vryburg and Lichtenburg.

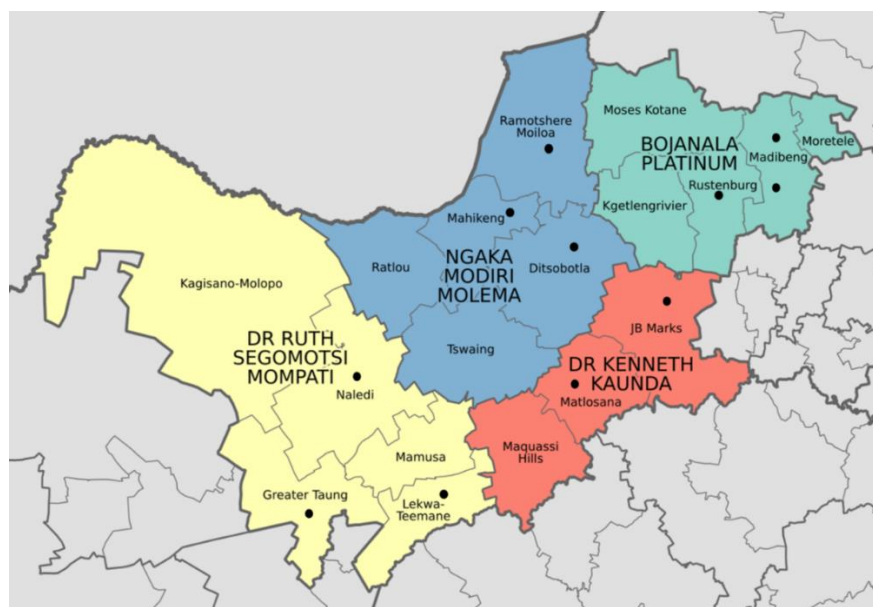


Figure 3-1: The district- and local municipalities of the North West Province with the 11 sites (see Section 3.4.3) included in the research scope indicated with black dots (Mogogana *et al.*, 2018).

3.4.3 Selection criteria and sampling

SAPS Forensic Department in North West comprises of seventeen sites which are responsible for the examination of crime scenes and the processing of evidence in North West. Among the seventeen sites, six sites were excluded from the research for the following reasons:

- The activities at these six sites are not representative of hazardous waste activities typically conducted by SAPS Forensic Department.
- The sites mainly consist of office blocks with minimal laboratory and processing work taking place. Due to their small office structure, minimal hazardous waste related activities are carried out.
- The sites are not a representative size of an average office in the North West Forensic Department.

Eleven Local Criminal Record Centres (LCRC) were included in this research. From the eleven selected sites, only seven have Crime Scene Laboratories generating chemical waste (Table 3-2). This means that all eleven (sites) generate biological waste, however, only seven with laboratories will generate both biological and chemical wastes.

Table 3-2: Selected facilities included in the research

Site location	Local Municipality	Facility type	Classification ¹	Total number of staff members	Frequency of crime scenes
Brits	Madibeng	Local Criminal Record Centre (LCRC) and Crime Scene Laboratory (CSL)	Large	36	High ²
Bloemhof	Lekwa-Teemane	LCRC	Small	4	Low ³
Klerksdorp	Matlosana	LCR and CSL	Large	44	High
Klipgat	Madibeng	LCRC	Small	11	Low
Lichtenburg	Ditsobotla	LCRC and CSL	Medium	21	Medium ⁴
Mmabatho	Mahikeng	LCRC and CSL	Large	40	High
Potchefstroom	JB Marks	LCRC and CSL	Large	27	Medium

¹ The classification of the facility (small/medium/large) (Table 3-2) is not based on surface area of the facility, but is rather based on the number of staff members of the LCRC, and the frequency of crime cases/crime scenes dealt with by the LCRC, since these are the factors which would have an impact on hazardous waste generation.

² High frequency of crime scenes: More than 300 cases per month.

³ Low frequency of crime scenes: Less than 150 cases per month.

⁴ Medium frequency of crime scenes: 151 to 299 cases per month.

Site location	Local Municipality	Facility type	Classification ¹	Total number of staff members	Frequency of crime scenes
Pudimoe	Greater Taung	LCRC	Medium	22	Medium
Rustenburg	Rustenburg	LCRC and CSL	Large	40	High
Vryburg	Naledi	LCRC and CSL	Small	19	Low
Zeerust	Ramotshere Moiloa	LCRC	Small	9	Low

3.5 Selection of participants

To gather information on hazardous waste management and related knowledge and awareness, purposive sampling was used to select personnel who are directly involved with hazardous waste activities as participants for this research. These included Supervisors, Safety Health and Environment (SHE) Representatives, Crime Scene Examiners, Laboratory Analysts, as well as workers who are directly responsible for handling of the hazardous waste streams at individual facilities. Based on the number of staff typically employed for these functions, at least six personnel members were targeted per facility/site, which provided for a total targeted sample size of 66 respondents⁵.

3.6 Data collection

Data was collected between February 2020 and November 2022 through document review and analysis, observations and survey questionnaires (as explained in Table 3-1).

3.6.1 Document review and analysis

The review and analysis of documents and records were used to determine the hazardous waste types and quantities (with a specific focus on biological and chemical waste) generated by each of the facilities (RO1). Document review was also used to evaluate the extent to which hazardous waste practices are provided for in internal organisational procedures (RO2).

For the purposes of this research, the following documents and records were reviewed to understand the waste types generated by the Local Criminal Record Centres (LCRC) and Crime Scene Laboratories (CSL) in North West. The permission to access information was granted by the internal Research Division of the SAPS:

- Records of waste collection, such as waste manifest documents;

⁵ Note: Table 3-2 provides the total number of staff members per facility and not those directly involved in hazardous waste management (which would be approximately four to eight staff members per facility).

- Previous audit reports; and
- Internal organisational waste management procedures (SOP)

The documents were reviewed against the following criteria:

- Availability of information on waste types and quantities generated and collected per site;
- The extent to which the internal SOP addresses safe handling, storage, transportation and disposal of hazardous waste;
- The extent to which the internal SOP makes provision for the recording of waste quantities;
- The extent to which the internal document addresses compliance to legislative requirements for hazardous waste management; and
- Issues or aspects raised in internal audit reports.

3.6.2 Observations

The aim of the observations was to evaluate hazardous waste management practices (RO2) at the different facilities included in the research. As mentioned earlier, areas with Local Criminal Record Centre (LCRC) only are expected to generate mainly biological waste, while facilities that also has a Crime Scene Laboratory (CSL) will generate chemical waste from laboratories as well as biological waste.

The process of conducting observations, from developing the observations checklist to **executing the observations is outlined in the sub-sections below.**

3.6.3 Developing observation checklists

A checklist was developed (see **Annexure A**), which addressed the following aspects to guide observations:

- Do the waste types generated require classification in terms of SANS 10234?
- Is there evidence of classification and a Safety Data Sheet for the products from which the waste is generated?
- Are the containers holding the waste labelled or are records kept indicating the: waste information, first disposal of waste as well as the last disposal before the container can be sealed off?
- Are there records (daily/weekly/monthly) of waste quantities generated for each waste type?
- Are waste manifest documents available?
- Are storage conditions, generally, adequate?
- Are access control arrangements in place?

- Are there adequate measures to ensure that the different waste types generated are not mixed in one bag or container?
- Are the containers compatible with their contents?
- Are there adequate measures taken to ensure that the waste does not accumulate such that it poses a risk to the public, workers and the environment?

Disposal of hazardous waste occurred off-site and was not included as part of the observation checklist.

Photographs were taken in order to depict the hazardous waste management practices, where deviation from legal requirements was anticipated.

3.6.4 Selecting areas to conduct observations

In order to obtain data on waste management practices related to biological waste, observations were conducted at all eleven Local Criminal Record Centres (LCRCs) included in the research scope (see Table 3-2). Observations related to chemical waste management was conducted at the seven Crime Scene Laboratories (CSLs) located at the LCRCs (see Table 3-2).

The investigation of hazardous waste management practices through observations covered areas/locations where waste is generated, separated, stored, and collected (Ali *et al.*, 2017).

3.6.5 Conducting observations

Observations were conducted at all of the facilities included in Table 3-2 through scheduled on-site visits. An observational checklist (containing the elements outlined in Section 3.6.1.1) was utilised to evaluate the hazardous waste management practices on site (Ibrahim *et al.*, 2023). Approximately two to three hours was spent at each site to complete observations in line with the observation checklist. All observations were recorded, and supplementary photographs were taken, where necessary.

3.6.6 Survey questionnaires

Survey questionnaires were used to investigate current hazardous waste management practices (RO2) as well as assessing knowledge and awareness of personnel where hazardous waste management is concerned (RO3).

3.6.7 Selecting survey participants

The selection of survey participants is described in Section 3.5 above. A total of 66 respondents were targeted for participation in the survey.

3.6.8 Developing the survey questionnaire

A semi-structured questionnaire, with ten questions (**Annexure B**) was developed to gather information on current hazardous waste management practices (RO2) and the knowledge and awareness of personnel responsible for waste management (RO3). The questions were designed for participants to respond “yes” or “no” on questions, and they were encouraged to add comments (space for comments were provided). The questionnaire presented questions in relation to the handling of hazardous waste management, and included the following questions:

- Do you understand why chemical and biological wastes are managed differently from general waste?
- In terms of law, do you know what legislations/regulations regulate the efficient management of waste? If yes, please name them
- Do you understand what is meant by waste segregation or separation at source? If yes, please give a brief explanation
- Were you ever trained on the adequate handling of hazardous waste?
- Are you aware of the health, safety and environmental risks relating to chemical and biological wastes?
- Are you satisfied with the current waste management practices in your office specifically looking at chemical and biological wastes? Please elaborate.
- In your opinion, are there any areas which require improvement with regard to the handling of chemical and biological wastes in your office?
- Are you satisfied with the services rendered by the waste removal contractor? If no, what do you think can be changed?
- In a case of accidental spillage of waste, are you aware of the emergency response procedures to be followed?
- Are you aware of the organisation’s policy and procedure on waste management?
- Do you have a good understanding of the different labelling, international bio hazard signs and colour coding used for waste storage and marking?

No personal information of respondents was gathered, as it was a condition of the Department.

3.6.9 Piloting the survey questionnaire

The questionnaire was piloted to establish whether participants would understand the questionnaire and provide the researcher with the outcome required. The questionnaires were administered to two (2) colleagues. Feedback from the colleagues was obtained and, where necessary, the questionnaire was adjusted. These responses were not included as part of the research findings.

3.6.10 Distributing the survey questionnaire

The survey questionnaire was distributed face-to-face whereby the researcher and the participants were provided an opportunity to complete the survey questionnaire. All survey questionnaires were completed in English.

No personal information from participants was captured due to the SAPS provisions in terms of the Protection of Personal Information Act (4 of 2013).

Surveys were conducted from February 2020 to November 2020. A total of fifty (50) respondents participated in the survey. This is a 76% response rate, based on the targeted sample of 66 respondents.

3.7 Data analysis

Qualitative and quantitative data from document evaluation is presented in tables and graphs. Findings made during observations are provided in a descriptive narrative.

The data from surveys was analysed using descriptive statistics to describe level of knowledge and awareness of biological and chemical waste management practices. The researcher also reviewed previous compliance audit and inspection reports to gather information that determines which areas of waste management were audited and findings of the reports were verified through data collected from observation checklist. The results were also analysed using data from the internal organisational SOP in order to highlight gaps and challenges as well as identify areas which require improvement.

3.8 Ethical considerations

Ethical clearance was obtained from the North-West University Research and Ethics Committee and the permission to conduct the study was obtained from the SAPS Research Department. Ethical permission to proceed with surveys was provided by the North-West University Faculty of Natural and Agricultural Sciences Ethics Committee (FNAS-REC), ethics number NWU-01414-20-A9. The study does not include animals or vulnerable groups. The issue of confidentiality and the right of participants to withdraw or participate in the study was designed in order to conform to university ethical research requirements. All participants were required to provide informed consent before participating in the research. No personal information from participants was captured due to the SAPS provisions in terms of the Protection of Personal Information Act (4 of 2013).

3.9 Methodological limitations

This research is mainly based on data obtained from document review, observations and self-reported data gathered during surveys. The limitations that were encountered were mainly that area of hazardous waste management by Forensic Departments is not well-researched, and consequently resulting in difficulties when comparing the results of this study to what other authors have found and provide context (Mmolai, 2021).

Records of quantities and types of waste generated were not available at the time of conducting this research. The researcher had to rely on records of waste collection (waste manifest documents), rather than records of waste generation, to gather information related to RO1. Due to lack of satisfactory recordkeeping, waste manifest documents or collection records were not available at all of the sites. The unavailability of the documents contributed to limitations on part of the research scope. Information on generated and collected chemical waste was only available for the year 2022.

As part of the agreement to participate in the research, it was agreed upon that specific waste management practices at specific facilities of the SAPS Forensic Departments would not be disclosed. Therefore, results related to waste management practices provide a generic reflection on practices, and general compliance/non-compliance with legislation, rather than mentioning the specific facilities and their practices.

Personal information from respondents, such as age, gender, highest qualification was omitted from the research due to the SAPS requirements for protection of personal information in terms of the Protection of Personal Information Act (4 of 2013).

The targeted sample size was 66 participants; however, only fifty (50) respondents participated in the survey. This was mainly due to the unavailability of some staff members during the site visits. These participants also did not respond to the request to electronically complete the survey questionnaire. However, the 76% response rate is considered to be appropriate for this research.

Although survey respondents were urged to add comments or areas for improvement to the survey questionnaire, none of the respondents opted to add any open-ended comments to their responses (only “yes” or “no” were indicated). This has limited the results in terms of seeking opportunities for improvement for the management of chemical and biological wastes in terms of the perspectives of SAPS LCRC employees.

3.10 Chapter conclusion

This chapter presented an outline of the research design and methodology used to conduct the study. This study adopted a mixed-method research approach. Data was collected through document review, observations and a survey questionnaire. The next chapter will focus on data presentation and discussion of the findings. The findings are presented from data collected from observations, document review and semi-structured survey questionnaires. Chapter 4 presents the research findings.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Introduction

Chapter 4 provides the findings of this research based on the three research objectives:

- **Research objective 1:** Determine the types and quantities of hazardous waste generated by the SAPS Forensic Department, North West Province
- **Research objective 2:** Evaluate the current hazardous waste management practices of SAPS Forensic Department, North West Province against legal requirements; and
- **Research objective 3:** Assess the level of knowledge and awareness of personnel with regards to the management of biological and chemical waste.

The sub-sections below provide the research findings and discussions of the data collected through a document analysis, observation checklist as well as semi-structured questionnaire (as explained in Section 3.6 of this dissertation).

Section 4.2 presents results and discussions of the types and quantities of hazardous waste generated by SAPS Forensic Department, North West (RO1), Section 4.3 presents the evaluation of current hazardous waste management practices (RO2), and, lastly, Section 4.4 discusses the assessment of the level of knowledge and awareness of personnel with regards to the management of biological and chemical waste generated (RO3).

4.2 Results related to RO1: Determine the types and quantities of hazardous waste generated by the SAPS Forensic Department, North West Province

The hazardous waste generated by SAPS Forensic Department in North West largely consists of biological and chemical waste. Eleven Local Criminal Record Centres (LCRC) were included in this research. From the eleven selected sites, only seven have Crime Scene Laboratories generating chemical waste (Table 3-2). This means that all eleven (sites) generate biological waste; however, only seven with laboratories will generate both biological and chemical waste.

Section 4.2.1 outlines the types and quantities of biological waste generated, while Section 4.2.2 outlines the types and quantities of chemical waste generated. These results must be interpreted against the limitations outlined in Section 3.9 of this dissertation. Upon performing this research, it was established that records of waste generation are not kept. Therefore, records of waste collection and disposal were used instead. It should be noted that these records were not consistently available at all facilities. Although there should not be discrepancies between the quantities of waste generated, and the quantities of waste disposed of, there may be instances where discrepancies occur.

4.2.1 Types and quantities of biological waste generated

Understanding the types and quantities of hazardous waste generated plays a key role in the procedures of handling, storage, transportation, treatment, and disposal of hazardous wastes (Mmereki *et al.*, 2015; Saleh, 2016). According to Makgae (2011) effective management of waste requires knowledge on the characteristics of waste, including waste types and quantities. The type and quantity of hazardous waste would determine the level of potential hazards, chemical and physical stability, waste compatibilities, storage capacity requirements, etc.

4.2.2 Biological waste types

During the execution of the Forensic Department's mandate, biological waste is generated by the crime scene investigators during crime scene attendance and processing. Crime scene evidence handled by crime scene investigators in the department consist of small quantities of biological exhibits such as blood samples, saliva, semen, viscera, human tissue, bone, hair and nails. This type of waste can be classified as infectious, non-anatomical waste, which is waste that is known to be at risk of being contaminated with microorganisms (Raphela, 2014). Microorganisms present in biological waste have the potential to cause infectious diseases, such as Hepatitis B and C, and Human Immune Virus (HIV) (Prajapati & Kaur, 2021), and prolonged storage under the incorrect conditions may also lead to the release of offensive odours (Vinod *et al.*, 2009).

Furthermore, disposable Personal Protective Clothing (PPE) worn by the crime scene investigators is collected in biohazardous bags (red bags) as it may possibly be contaminated with infectious materials, infectious body fluids, powders, chemicals etc. PPE contaminated with biological waste has the same potential infectious nature and hazards as the biological waste itself.

Limited research exists on waste generated by forensic departments of law enforcement agencies. Research by Vinod *et al.* (2009) on *Biomedical Waste Hazards and Their Management in Forensic Laboratories* also highlights that biomedical and biological wastes are the main waste types generated by forensic laboratories. The authors also highlight that samples and evidence from forensic laboratories, as well as contaminated PPE, which is generally not correctly disposed of, are cause for concern.

4.2.3 Biological waste quantities

This section provides an overview of the quantities of waste collected for disposal from the Forensic Department in North West Province from 2020 to 2022. The unavailability of waste generated records, and inconsistent recordkeeping of waste manifest documents for waste collection and disposal, were limitations to this part of the research (also refer to Section 3.9 of this dissertation). The most complete waste collection records were available for the year 2020. However, given the fact that no published research exists on the quantities of hazardous waste generated by SAPS Forensic Departments in the country, this information (albeit with limitations) contributes to knowledge on the research topic.

Figures 4-1 to 4-3 outline the quantity of biological waste generated and collected per month for each site from the years 2020 to 2022, respectively. As mentioned above, biological waste quantities are based on figures extracted from waste collection records (see example in Figure 4-4) and not records of actual quantities of biological waste generated.

Figure 4-1 depicts the quantities of biological waste collected from the eleven Local Criminal Record Centres (LCRC) between January and December 2020.

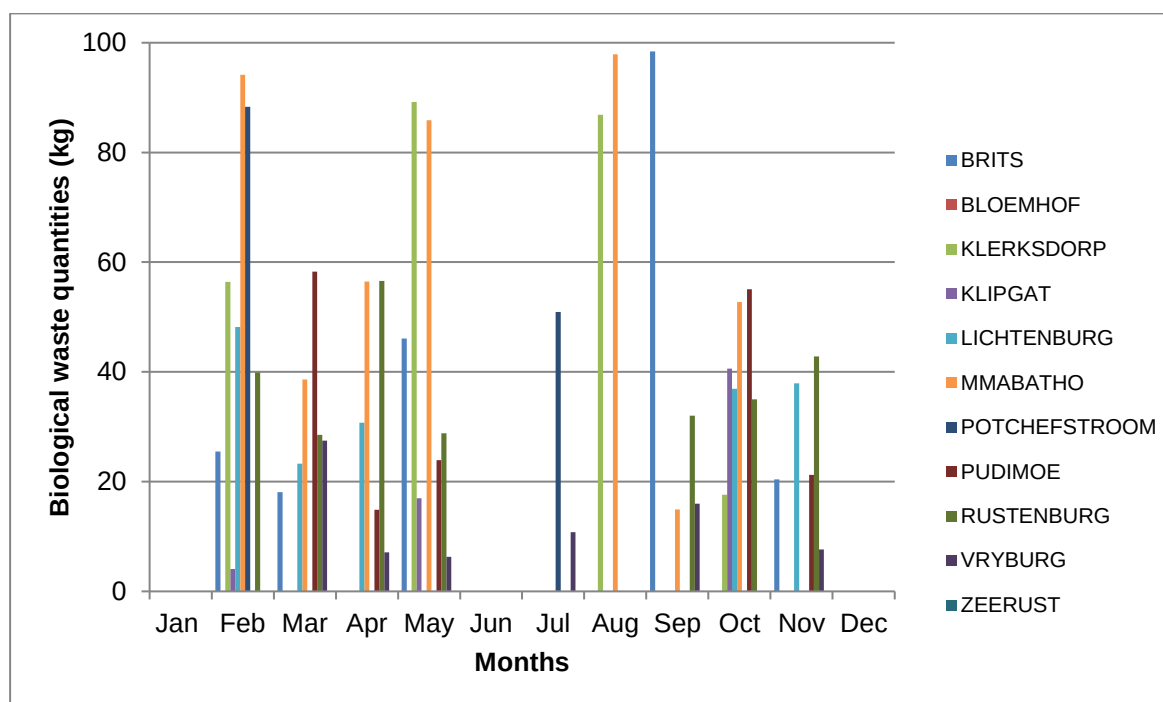


Figure 4-1: Quantities biological waste (kg) collected for disposal between January 2020 and December 2020 at each of the SAPS Forensic Department facilities included in the research.

The quantity of biological waste collected varied between 3 and 100 kg per month from the various sized facilities. The total amount of biological waste collected for the 2020 calendar year ranged between 61.7 kg and 440.7 kg at the different facilities. The results indicated that Mmabatho, Rustenburg, Klerksdorp and Brits LCRCs were the highest generators of biological waste in 2020, while Klipgat, Vryburg and Zeerust are the lowest generators of biological waste in 2020.

The quantity of hazardous waste is determined by several factors such as the size of the facility, and the activities carried out (Jang *et al.*, 2006). There was an observed relationship between the sizes of the offices whereby Mmabatho, Rustenburg, Klerksdorp and Brits LCRCs are classified as larger LCRC offices, while Klipgat, Vryburg and Zeerust are smaller (see Table 3-2). The classification (i.e. small, medium or large) is depicted from the number of personnel, as well as number of crime cases attended by these offices. This means that LCRCs dealing with a higher number of crime scenes would generate larger quantities of waste than LCRCs dealing with less crime scenes.

No biological waste was collected in the months of January, June and December at any of the facilities. The non-collection of waste may be due to delayed acquisition of waste removal services during these periods. At the time of the research, no comparative literature was available on the quantities of biological waste generated by forensic services laboratories from law enforcement or other entities.

Figure 4-2 depicts the quantities of biological waste collected from the eleven Local Criminal Record Centres (LCRC) between January and December 2021.



Figure 4-2: Quantities biological waste (kg) collected for disposal between January 2021 and December 2021 at each of the SAPS Forensic Department facilities included in the research.

The unavailability of waste collection data in 2021 is a limitation of the research (also see Section 3.9). Waste manifest documents were only available for five of the eleven sites (Brits, Mmabatho, Rustenburg, Vryburg and Zeerust). For these facilities, manifest documents were also only available for January and February 2021. It is uncertain whether the absence of waste manifest documents for other months in 2021 was due to the fact that biological waste was only collected during January and February, or due to poor recordkeeping.

Vinod *et al.* (2009) have also mentioned inconsistent recordkeeping as a concern for biomedical waste from forensic laboratories in India. The authors state that: *“Forensic science laboratories being not a part of health care establishment, these rules [recordkeeping requirements related to health care facilities] are hardly applied to them.”* The lack of recordkeeping on waste quantities generated and collected for disposal is cause for concern.

Based on these limited records of waste collection (Figure 4-2), between 8.1 and 62.5 kg of biological waste were collected between January and February 2021 from the five facilities, where the highest quantities of biological waste were collected from Rustenburg, and the lowest quantities were collected from Vryburg.

Figure 4-3 depicts the quantities of biological waste collected from eleven Local Criminal Record Centres (LCRC) between January and December 2022.

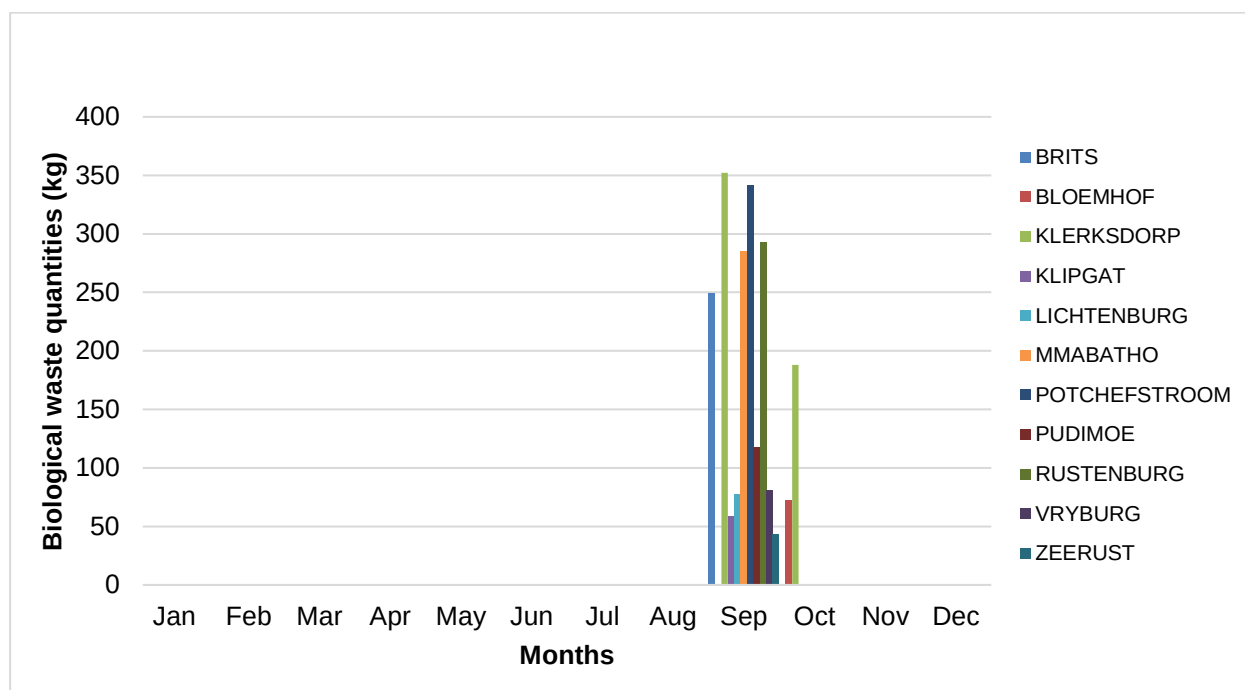


Figure 4-3: Quantities biological waste (kg) collected for disposal between January 2022 and December 2022 at each of the SAPS Forensic Department facilities included in the research.

Result for biological waste generated in 2022 showed that records of waste collection were only available for September and October 2022. Again, these results could be due to poor recordkeeping. Staff members did, however, mention that “*slow procurement processes were an issue in 2022, and waste removal services were only acquired late in 2022*”.

Biological waste collected between September and October 2022 ranged between 30 kg and 370 kg per facility. Based on the results depicted in Figure 4-3, the highest quantities of biological waste were collected from the medium to large LCRCs in Klerksdorp, Potchefstroom, Rustenburg, Mmabatho and Brits, while the lowest quantities of biological waste were collected from the smaller LCRCs in Zeerust and Klipgat. The total amount of biological waste collected in 2022 ranged between 43 and 540 kg at the different facilities. As mentioned above, these differences in quantities may be due to high waste generating offices attending to more crime scenes than the lower waste generating offices.

The quantities of waste collected for disposal in 2022 are relatively high when compared to the quantities of waste collected in 2020 (Figure 4-1) and 2021 (Figure 4-2). However, comparison of the quantities of waste generated among the different years would not be scientifically sound, because of the absence in waste generation records, and the inconsistency in waste collection records.

A trend that is concerning, is the low frequency of waste collection in 2021 and 2022, with records of waste collection only being available for January and February 2021, and for September and October in 2022. This low frequency of collection could lead to the undesirable accumulation of biological waste. According to Chisholm *et al.* (2021) in the paper ‘*Sustainable waste management of medical waste in African developing countries: A narrative review*’, the general guideline for the management of biological waste is to restrict the storage duration to ninety (90) days from the day it was sealed to the date of disposal. Jan and Shafi (2021) added that the 90-day period should commence from the date that the initial accumulation of the waste begins.

Figure 4-4 provides an example of a waste manifest document, also referred to as a “waste collection slip”.

GENERATOR'S CERTIFICATION: I hereby declare that the contents, as described, are contained, marked and labelled prior to transportation according to all relevant legislation. Generator's Name: <u>RUSTENBURG LCRC</u> WIS Number: _____ Contact Person: <u>Leseteng Mawaz</u> Contact Details: Tel: <u>05240419</u> Fax: _____ E-mail: _____ Date: <u>2021/01/13</u> Signature: <u>[Signature]</u>	TIRELO YA MAPODISI A AFFIKA BORWA RUSTENBURG 2021-01-13 LOCAL CRIMINAL RECORD CENTRE SUID AFRIKAANSE POLISIEDIENS SOUTH AFRICAN POLICE SERVICE	TRANSPORTER'S ACKNOWLEDGEMENT OF RECEIPT OF MATERIALS: I hereby declare that the contents, as described, are contained, marked and labelled according to all relevant legislation and can be safely collected for transportation. Transporter Name: <u>BUHLE WASTE (PTY) LTD</u> WIS Number: <u>GPT-00-520</u> Driver Name: <u>SIBUSISO MBAMALI</u> Vehicle Registration: <u>DS 31 FM 92</u> Date: <u>13 / 01 / 2021</u> Time: <u>09H31</u> Signature: <u>[Signature]</u>																																																																																																																																																																																																																																																																																																																																																																				
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Figure 4-4: Example of a waste manifest document.

4.2.4 Types and quantities of chemical waste generated

Chemical waste can be referred to as waste that contains solvents and reagents used in the laboratory (WHO, 2021). As mentioned earlier, of the eleven LCRCs, only seven have Crime Scene Laboratories (CSLs) generating chemical waste (refer to Table 3-2).

4.2.5 Chemical waste types

Laboratory activities undertaken by the Crime Scene Laboratories entail the chemical processing of exhibits collected in order to identify whether there is sufficient evidence that can be presented in court. The different chemicals utilised in the Crime Scene Laboratories include ninhydrin, 8-Diazafluoren-9-one (DFO), various solvents such as methanol, ethanol, ethyl acetate, acetic acid and Hydrofluoroether 7100 (HFE); as well as dyes such as rhodamine 6G (R6G) and basic yellow.

Ninhydrin (triketohydrindene hydrate) is a chemical compound widely known for its use in detecting amino acids and amines, making it particularly valuable in biochemistry and forensic science. Ninhydrin is best known for its ability to turn purple (Ruhemann's purple) upon reacting with amino acids, producing a deep blue or purple colour. This colour change is utilised for visualising fingerprints on porous surfaces, as sweat from fingerprints contains trace amounts of amino acids. It is a relatively stable compound, but it requires careful handling due to its potential

irritant properties and the possibility of causing allergic reactions upon contact with skin or inhalation of its dust (Friedman, 2004).

The chemical 8-Diazafluoren-9-one (DFO) also reacts with amino acids present in fingerprint residues to develop fluorescent marks on porous surfaces. DFO differs from ninhydrin in that it reacts with amino acids to form a red-coloured product, which is highly fluorescent under green light (Jelly *et al.*, 2009). The fingerprint development procedure requires exhibits to be treated with ninhydrin after initial DFO processing, since DFO has proven to be more sensitive to amino acids than ninhydrin thus additional fingerprints can often be found (Wilkinson, 2000). DFO is not classified as hazardous according to the Globally Harmonised System (GHS). However, repeated exposure may cause temporary irritation of the skin (Jelly *et al.*, 2009). According to Lewkowicz *et al.* (2022) proposals have been made for replacement of toxic solutions containing the molecule DFO and modify the procedure and solutions with ones which are non-toxic. Jelly *et al.* (2009) suggests research to investigate natural products as a means of targeting the amino acids development of latent fingerprints, due to an essential advantage of reduced toxicity.

Solvents such as acetic acid, HFE, ethyl acetate, methanol and ethanol are used during reagent preparation for the development of fingerprints. Acetic acid is added to acidify the solution whereby the absence of the acidification process will result in virtually no finger marks being developed (Zygadlo & Lewkowicz, 2021). Acetic acid is one of the ordinary carboxylic acids which is presented as a clear colourless liquid that has a strong smell. Acetic acid can irritate the skin and mucous membranes and long-term inhalation of its fumes can result in breathing difficulties (Pravasi, 2014).

HFE 7100 is used as the main carrier solvent for DFO and ninhydrin. An ideal carrier solvent is required to be volatile, non-toxic, non-flammable and nonpolar, so as to avoid the running of inks on the porous exhibits e.g. paper (Jelly *et al.*, 2009). Other benefits of HFE-7100 include its low toxicity, low environmental impact, and no flammability (Stimac, 2003a cited by Pregent, 2021).

In addition to the non-polar reagents, polar reagents such as ethyl acetate, methanol and ethanol may be required to ensure that active ingredients remain in solution (Jelly *et al.*, 2009). These carrier solvents are flammable and can cause damage to the environment. High concentrations of ethyl acetate can accumulate in poorly ventilated spaces and thus causing eye, nose, and respiratory tract irritations (Marino, 2005). Methanol is a highly flammable solvent with low vapour pressure. Methanol-based solutions are toxic when ingested and absorbed through the skin, and can also destroy surfaces such as paints and some plastics. The release of methanol into on soil can result in environment degradation and leaching (Sherperd, 2005).

Development of latent fingerprints on plastics, metal, and other non-porous surfaces is done through a process known as cyanoacrylate fuming, which uses fumes created by either methyl or ethyl cyanoacrylate esters. Subsequent to the fuming process, dye staining of the exhibit material is done to give a high fluorescent yield. The different dyes used include rhodamine 6G (R6G) and basic yellow 40. R6G is notorious for its acute toxicity, capable of causing respiratory, dermal, and ocular irritation upon exposure, along with potential carcinogenic effects suggested by laboratory studies. Furthermore, its presence in water bodies poses a threat to aquatic life due to its high toxicity and persistence, leading to disruptions in ecosystems. Similarly, basic yellow 40 raises concerns over skin and eye irritation, making it a hazard in industries involving direct human contact. Moreover, it may act as an allergen for some individuals. Environmentally, basic yellow 40 exhibits aquatic toxicity, and it is also suspected to persist in the environment, potentially leading to long-term ecological risks (Bandey *et al.*, 2017).

The products mentioned above produce liquid chemical waste, which is collected in 25-litre containers during reagent preparations, dye staining and exhibit processing. The safety data sheets (SDSs) comprising of information with regards to hazards associated with the chemicals used within the laboratories were consistently available at all Crime Scene Laboratories. However, not all of the SDSs contained all of the necessary information as required by SANS 10234.

4.2.6 Chemical waste quantities

As with the biological waste quantities mentioned above (Section 4.2.3), the availability of records for chemical waste quantities generated and disposed of was also a limitation. No records of chemical waste generated between 2020 and 2021 were available for any of the Crime Scene Laboratories. Records of chemical waste collected and disposed of were only available for the year 2022.

Figure 4-5 indicate the chemical waste collected from the seven crime scene laboratories in 2022.

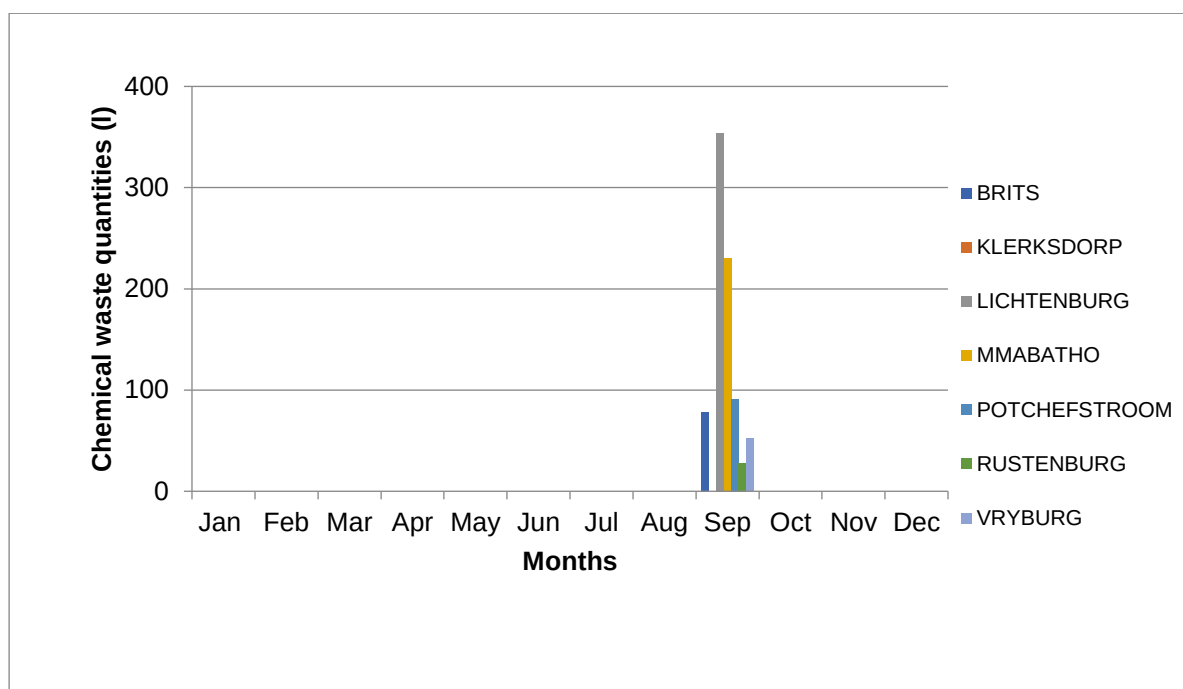


Figure 4-5: Quantities chemical waste (litres) collected for disposal between January 2022 and December 2022 at each of the SAPS Forensic Department facilities included in the research.

Similar to biological waste (see Figure 4-3), chemical waste was only collected in September 2022. The quantities of chemical waste collected ranged from 28.1 to 354.3 litres from the different facilities. As indicated in Figure 4-5, Crime Scene Laboratories in Lichtenburg and Mmabatho were the highest generators of chemical waste, while the lowest quantities of chemical waste were collected from Crime Scene Laboratories in Rustenburg and Klerksdorp. The correlation in terms of (Table 3-2) could not be made with reference to chemical waste. This is mainly due to insufficient data which does not allow for conclusive findings.

In summary, the results obtained in relation to Research Objective 1 indicate inconsistency in terms of the frequency of waste collection, which resulted in both biological and chemical waste being accumulated and stored for longer periods. The long term storage of hazardous waste is undesirable, due to the risks related to the accumulation of the waste and potential exposure (Torkashvand *et al.*, 2021).

The unavailability of records of waste generated and disposed of can also be attributed to poor recordkeeping. Moshood *et al.* (2022) highlight that record management is an important element of hazardous waste management which can be used to ensure safe and effective management of hazardous waste. The book “*Hazardous Waste Management: An Overview of Advanced and Cost-Effective Solution*”, by Yadav *et al.* (2022), recommends that facilities create a systematised recordkeeping system for waste management that offers the simplicity and transparency. The

Waste Classification and Management Regulations (WCMR) (GNR. 634 of 2013) also require that waste generators should keep up to date records of the quantity of each waste generated per month. Additionally, the National Waste Information Regulations (GNR. 625 of 2012) requires recordkeeping of waste manifest documents, and reporting of waste quantities and types by generators of hazardous waste in excess of 20 kg per day.

4.3 Results related to RO2: Current hazardous waste management practices at SAPS Forensic Department, North West

Research Objective 2 investigated the hazardous waste management practices at SAPS Forensic Department facilities. As indicated in Chapter 3, data related to this research objective were gathered through on-site observations and document review and analysis.

4.3.1 Results from the observation checklist

Ali *et al.* (2017) report that it is important to investigate hazardous waste management practices, such as separation, storage, collection, and transportation, since these are areas of non-compliance with legal requirements. The management of hazardous waste requires the application of various legislative requirements depending on hazardous waste type (Akpan & Olukanni, 2020) (also refer to Section 2.6.2 of this dissertation).

On-site observations were conducted at all eleven of the sites included in the research scope (See Table 3-2), which included eleven Local Criminal Record Centres and seven Crime Scene Laboratories of SAPS Forensic Department, North West (also refer to Section 3.6.1). As part of the agreement to participate in the research, it was agreed upon that specific waste management practices at specific facilities of the SAPS Forensic Departments would not be disclosed. Therefore, the results reflected in the sub-sections to Section 4.3.1 will not make reference to specific facilities, but rather provide a general, overall indication of practices and compliance/non-compliance to legal requirements.

An observation checklist (see Section 3.6.1.1 and Annexure A), which was developed in line with legal requirements and internal procedures for the categorisation, classification, storage, handling and collection of waste, was used to guide on-site observations. Tables 4-1 to 4-4 outline the results related to observation of waste practices of the Local Criminal Record Centres and Crime Scene Laboratories of SAPS Forensic Department, North West focusing on classification, segregation and packaging, storage, as well as collection and transportation of waste. As mentioned above, the results below (Table 4-1 to 4-4) are general observations made at all of the facilities visited, and specific facilities that were non-compliant to legislation are not named.

The results of observations were supplemented by photographs, as suggested by Muzzio (2023).

4.3.2 Waste classification and categorisation

Table 4-1 below indicates the results from the observation checklist relating to waste classification and management.

Table 4-1: Observation results based on waste classification and categorisation

Requirements	Compliance status	Summary of observed practices
Waste Classification and Management Regulations, No. R. 634		
Does the waste types (biological and chemical) generated require classification in terms of SANS 10234?	N/A	The waste generated by SAPS Forensic Department facilities and activities does not require classification in accordance with SANS 10234, within one hundred and eighty (180) days of generation. Annexure 1 of the Waste Classification and Management Regulations (WCMR) exclude the need to classify mixed, hazardous chemical waste from analytical laboratories in containers less than 100 litres.
Is there a Safety Data Sheet for waste generated?	Partial	There was only specific SDS for the different chemicals used in the laboratory. Not all of the SDSs included the requirements of SANS 10234: - Source and composition of waste - Hazard Identification - Physical and chemical properties - Toxicological and ecological effects - Disposal options - First aid/ firefighting measures - Handling and storage requirements
Are the containers holding the waste clearly labelled to indicate the type of waste as well information indicating the first disposal of waste as well as the last disposal before the container can be sealed off	Partial	Generally, only biological waste was clearly labelled to indicate the waste class and specific category of waste in the container. Not all chemical waste containers were clearly labelled. The information on the containers did not include: - The date on which container was first placed/used; - The date on which waste was placed in the container for last time when the container was full, closed or sealed.
Are there monthly records of waste quantities generated for each waste type?	No	During the study period (2020 – 2022), the sites were not able to produce monthly reports of waste quantities generated.
Is the waste manifest document available?	Partial	Waste manifests were available for waste that was collected, however poor recordkeeping of waste records was observed. Refer to discussions in Section 4.2 above

The results obtained indicate that the waste generated by the forensic department in North West does not require classification as accordance with SANS 10234. This is because the waste generated is exempted as per Annexure 1 of the Waste Classification and Management Regulations (GNR. 634 of 2013).

The findings of the study indicate that Safety Data Sheet (SDS) for the chemical products from which the waste is generated were mostly available at all laboratories. However, not all of the SDSs contained the minimum information as required by SANS 10234. The information required on the SDS includes composition, first-aid measures, firefighting measures, accidental release measures, physical and chemical properties, exposure controls and personal protection etc. (Gilbert, 2008). The unavailability of minimum information in SDSs indicates that the facilities are not well-equipped to manage accidental spills, mishandling and emergencies (Ramos-Peralonso, 2014).

The results from the study also indicate partial compliance with regards to the labelling of the waste containers, with not all of the sites consistently labelling chemical waste containers. Containers with biological waste were generally labelled correctly.

Monthly reports for waste quantities generated were also not available for the sites on which the observation checklist was completed (also see Section 4.2 and related sub-sections above). According to Mmereki *et al.* (2015) the inability to quantify hazardous waste generated in reliable records is one of the key challenges relating to the management of hazardous waste. This is because the availability of waste data provides a positive impact on the way organisations manage waste generated (Godfrey *et al.*, 2012).

Some of the waste manifest documents (for waste collection and disposal) were available upon request, however, poor recordkeeping was observed at virtually all of the sites (refer to Section 4.2 above). Moshood *et al.* (2022) advice hazardous waste generators to formulate an efficient recordkeeping system that offers and most logical way to achieve certain objectives. The absence of proper recordkeeping on waste types and quantities generated are highlighted as a concern for the management of hazardous waste in South Africa by Maqutu (2017).

4.3.3 Waste segregation and packaging

Table 4-2 below provides an outline on the waste segregation and packaging practices of the facilities of the Forensic Department of North West.

Table 4-2: Observation results based on waste segregation and packaging

Requirements	Compliance status	Summary of observed practices
SANS 10248, SANS 10234, Norms and Standards for the Storage of Waste (GNR. 926)		
Are there adequate measures to ensure that the different waste types generated are not mixed in one bag or container?	Partial	The separation of waste was not satisfactory. Chemical waste (Figure 4-6) is mixed in one container. There were also sites (Figure 4-7) where general waste was mixed with biological waste.
Are the containers compatible with their contents?	Partial	There were prescribed containers for both biological and chemical waste. However, it was observed at some of the sites, that biological waste was not stored in the prescribed containers.
Is there an indication that the waste is segregated correctly at the point of generation and the correct liners used?	No	Red liner bags were used to store biological waste at the point of generation. It was observed that there are instances where general waste is mixed with biological waste. Furthermore, mixed chemical waste with different properties was collected in single chemical waste containers.
Is liquid chemical waste filled only to $\frac{3}{4}$ capacities to prevent excessive vapour pressure?	Yes	Liquid chemical waste was generally filled to the correct capacity in order to avoid excessive vapour pressure.
Is the biological and chemical waste securely and efficiently packaged for storage, and transportation to prevent any leakages?	Partial	The observed practices at the investigated sites indicate that adequate measures of waste handling are not carried out. The biological waste at four of the sites was filled to full capacity which resulted in spillages. In appropriate stacking practices were observed at one of the sites (Figure 4-12). Chemical waste generated at one of the sites had no lid which could lead to loss of containment.
Is the biological waste and chemical waste labelled with appropriate international hazard signs and signs as prescribed in SANS 10234?	Partial	Only biological waste was correctly labelled. Chemical waste was not consistently labelled.
Are there adequate measures taken to ensure that the waste does not accumulate such that it poses a risk to the public, workers and the environment?	No	There were high levels of biological waste that has accumulated at five of the sites. Waste collection records also indicate the infrequent collection of waste in 2021 and 2022, which would lead to the accumulation of waste.

Aljamali *et al.* (2020) argue that different types of waste can be collected inside one container on condition that they share the same chemical compatibility to make certain that no other reaction occurs. Common practice at the laboratories investigated is to mix all chemical wastes into one waste container. This subsequently means the generated chemical waste composition may contain non-chlorinated waste and other organic acids used by the laboratory (see Figure 4-6). Muzzio *et al.* (2016) also highlight that waste container should not contain more than two types of hazardous wastes of different properties or categories at the same time. The separation of the waste becomes necessary because of the risks involved during storage, collection and disposal of the waste. This means that the same chemical container cannot be used for more than two types of hazardous wastes of different properties (Maowei *et al.*, 2021). The results also aligned with the findings of Maqutu (2017) whereby chemical waste was discarded in one drum despite their incompatibility. Furthermore, chemical containers were not clearly labelled as per the requirements of SANS 10234 (Figure 4-6).



Figure 4-6: Example of unlabelled mixed chemical waste.

Observations indicated the mixing of biological waste with general waste. A few sweet packages and other packing materials were observed inside the waste box which indicates that there is no adequate separation of the waste (see Figure 4-7). Research by Hossain *et al.* (2011) indicates that hazardous and non-hazardous waste materials are often mixed before proper disposal due to insufficient financial investment and a lack of awareness. This lack of segregation at the source not only increases adverse health effects but also leads to higher disposal costs (Hossain *et al.*, 2011). There are numerous studies indicating that 50% to 90% of non-hazardous waste is disposed of together with hazardous waste stream Zafar and Butler (2000); AoDM, (2003), Woolridge *et al.* (2005); Tudor *et al.* (2005); Tudor, (2007) cited by Tudor *et al.* (2008) which is an undesirable practice.



Figure 4-7: Example of biological waste mixed with general waste.

Some instances of unsealed/uncovered chemical waste were observed (see Figure 4-8). Suitable chemical waste containers should be intact and free from corrosion, leaks, damage or other defects that can reduce the efficiency of the packaging material. Maowei *et al.* (2021) emphasise that chemical waste containers should be adequately secured and sealed. The unsealed chemical containers can cause accidental spillages and thus pose as health and environment hazards.



Figure 4-8: Example of unlabelled chemical waste without a lid.

4.3.4 Storage of waste

Table 4-3 below provides an outline on the waste storage practices of the facilities of the Forensic Departments of North West.

Table 4-3: Observation results based on waste storage practices

Requirements	Compliance status	Summary of observed practices
SANS 10248, SANS 10234, Norms and Standards for the Storage of Waste (GNR. 926)		
Is the temporary waste storage facility adequately illuminated and ventilated.	Partial	The temporary storage areas were not adequately ventilated (Figure 4-9, Figure 4-11).
Is the storage area rodent-proofed in accordance with the best available method?	No	There was no sufficient evidence to indicate that the temporary storage areas are rodent proof. The wastes at three of the sites (Figure 4-10) were stored in an area which can be easily infiltrated by rodents.
Is the floor surface free from cracks and have a firm waterproof base to prevent permeation of storm water and constructed of a fire proof and theft resistant materials?	No	The floor surface from the temporary storage areas at two of the sites did not meet the prescribed standards. The waste was stored at the basement area and the floor areas were observed to have cracks.
Is the temporary storage area enclosed and secured to prevent unauthorised entry?	Partial	The temporary storage areas at three of the sites were not access controlled.
Is the storage area marked / labelled with the relevant hazard symbols of the waste streams and a written warning statement?	No	The temporary storage areas did not have adequate marking and warning statements.
Is the hazardous waste stored away from the door and areas with excessive pedestrian traffic?	Partial	There were sites which ensure that waste is stored away from areas to ensure excessive traffic. This was, however, not observed at all of the sites. See Figure 4-9, Figure 4-10, and Figure 4-11 whereby the waste was stored in areas where it is accessible.
Is safe and convenient height storage maintained to avoid accidental tip over?	Partial	The manner in which waste was packed at four of the sites was unsafe and could lead to accidental tip over.
Is the storage area kept clean and dry at all times?	Partial	The storage areas of three of the sites were exposed to possible rainfall.

Security issues and loss of containment of hazardous waste are challenges when it is stored in unsound waste management facilities (Maqutu, 2017). According to the Occupational Health and Safety Act 85 of 1993, it is the responsibility of an employer to provide a conducive working

environment that is safe and without risk to the health of employees. The absence of basic infrastructure poses serious consequences to human and environmental health. The design of a temporary waste storage facility should be in a sound manner to minimise health, environment and safety risks.

Waste storage areas are required to have adequate ventilation, proper drainage systems and the waste should be stored out of direct exposure to sunlight. This has proven to be main challenge with the waste storage areas in the study. The following main areas of concern were noted:

- Biological waste was kept outside near the laboratory due to lack of suitable temporary storage area at one of the sites;
- Biological and chemical waste were stored in an office space and along the passage area within the building; and
- Biological and chemical waste was stored in areas where it is exposed to rain and rodents.



Figure 4-9: Biological waste stored within the office passage at one of the sites.

Some of the areas where hazardous waste was kept did not have shelter to protect from sunlight and seasonal rainfall. Additionally, many of the allocated storage areas were not enclosed nor secured to prevent unauthorised entry (see Figure 4-10). Maqutu (2017) highlights challenges related to vandalism and theft of hazardous and biological waste, and the risk of being accidentally released to the environment.



Figure 4-10: Biological waste stored at the allocated area outside the office at one of the sites.

Another shortcoming observed at the waste storage sites, was a lack of warning signs and/or placarding, as required by the Norms and Standards for the Storage of Waste (GNR. 926 of 2013). This can expose the personnel and others to risks of entering these places (by mistake) and becoming exposed to potential risks. Findings from the study showed that biological waste at one of the sites is kept at the office occupied by three crime scene investigators (Figure 4-11). This practice was observed as a health hazard to the personnel occupying the office. This is because biological waste contaminated with body fluids from humans can cause highly communicable diseases (Siddiqua *et al.*, 2022).



Figure 4-11: Biological waste stored inside an office at one of the sites.

Furthermore, one of the Local Criminal Record Centres stored biological waste at a storage area for office consumables and the waste is also not adequately demarcated. The waste is stored only inside red liner bags and not placed inside a rigid container or box (See Figure 4-12). Similar practices were observed at two of the other LCRCs. Some of the storage areas were unsafe and a suitable stacking height was not maintained in order to avoid an accidental tip over (See Figure 4-12).



Figure 4-12: Biological waste stored within the basement area at one of the sites.

Many of the storage areas had issues in terms of ensuring permeability of floor surfaces. The floor surfaces were not free from cracks and did not have a firm waterproof base to prevent infiltration of storm water. In addition, the waste was not packed in an orderly manner and some of the waste is dropped on the basement floor and not adequately stored in the supplied waste containers or boxes.

4.3.5 Collection and transportation of waste

Table 4-4 below provides an outline on the waste collection and transportation practices of the facilities of the Forensic Department of North West.

Table 4-4: Observation results based on waste collection and transportation practices

Requirements	Compliance status	Summary of observed practices
NEMWA Sections 23 – 25, Draft Health Care Risk Waste Management Regulations		
Are there a licenced waste management services who is contracted to render treatment and disposal services for the organisations?	Partial	Waste was collected infrequently. Some of the LCRCs could not provide records of licenced waste collection and transportation contractors.
Is there a record of the disposal certificate from the services?	No	Waste manifest documents were only sporadically available. Disposal Certificates were not available upon request.
Is there adequate stock available in terms of boxes, red liner bags, liquid waste drums and cable ties?	Yes	There was sufficient stock of waste accessories for all the sites.

The majority of the facilities could not provide evidence that waste is collected by authorised service providers.

The study findings indicate substantial amount of both chemical and biological wastes kept for prolonged periods (also refer to Section 4.2 above). This is because collection of hazardous waste from the various sites is not done in time as per the prescribed frequency. This non-collection resulted in the accumulation of high levels of waste at four of the large Forensic Department facilities. Observation results indicated that there no adequate measures taken to ensure that the waste does not accumulate such that it poses a risk to the public, workers and the environment (Hossain *et al.*, 2011).

The delay in waste removal or collection resulted in one of the laboratories having seven full chemical waste drums which were kept in the laboratory for longer than six months (Figure 4-13). Although waste manifest documents were sporadically available, disposal certificates for hazardous waste generated at all the eleven sites were not available (also refer to discussions in Section 4.2 above).



Figure 4-13: Accumulated chemical waste at one of the sites.

In summary, the results of observations have highlighted several instances of poor waste management practices as it relates to the management of both chemical and biological wastes.

4.3.6 Results from document analysis

Current waste management practices were also determined by reflecting on documents, such as audit reports, standard operating procedures (SOPs) and records of waste disposal.

Audits, as highlighted by Maruszewska and Bialy (2013), provide techniques for organisations to identify current irregularities and opportunities for improvement. The audit process involves obtaining evidence and objectively evaluating it to determine the degree to which audit criteria

are fulfilled. Safety, Health and Environmental (SHE) audit can be described as an instrument used to identify hazards in the workplace and also to evaluate the risk of incidents. An audit is conducted through the evaluation of records and activities whereby implemented policies and procedures are used to evaluate compliance (Arifin *et al.*, 2010).

In the context of this research, document analysis involved reviewing available audit and inspection reports, internal standard operating procedures (SOP) as well as waste manifest documents. The internal Waste Management SOP is implemented within Division Forensic Services Waste and applicable to all the Forensic Departments within the SAPS. The researcher evaluated previous legal compliance audit reports from 2019 to 2022. The audit reports were available for all the eleven facilities; however, aspects related to hazardous waste management were not covered in every report. Only five reports addressing hazardous waste aspects were available and were examined. The scope of the audit reports was limited to issues of health, safety and environmental legislation. Table 4-5 indicates the results from document analysis.

Table 4-5: Results of document review and analysis.

Criteria	Records of waste collection	Previous audit reports	Waste Management SOP
The extent to which the document makes provision for the recording of waste quantities	Partial. Waste quantities collected are indicated	No. Previous audit reports have not highlighted recordkeeping as a concern	No. The SOP makes no reference to recordkeeping of waste generated
The extent to which the document addresses safe handling, storage, transportation and disposal of hazardous waste	N/A	An inspection conducted on 2019-11-20 indicated that the temporary storage area is non-compliant as it does not have waterproof base to ensure that there is no escape of contaminants into the environment. This was also corroborated by internal SHE inspection report for 2019-12-19 which indicated that there is no Temporary demarcated waste storage area.	Yes. The SOP addresses measures for safe handling, storage, transportation and disposal of hazardous waste

Criteria	Records of waste collection	Previous audit reports	Waste Management SOP
The extent to which the document address compliance to legislative requirements for hazardous waste management	Partial. Waste collection records that were available complied with the requirements for waste manifest documents as outlined in Annex 2 of the Waste Classification and Management Regulations. However, waste manifest documents were not consistently available	An audit report conducted in February 2022 indicated that the one of the facilities is not to in full compliant of the Hazardous Chemical Agents Regulation due to hazardous waste stored for prolonged periods. A similar finding from inspection conducted on 2022-06-24 also indicated that has not been removed since 2021-01-13	Yes. The Waste Management SOP provide an outline of legal requirements and requires compliance to these requirements.

Kumar *et al.* (2023) suggest that ‘a sustainable hazardous waste management needs effective policies and regulations and their implementation’. The internal standard operating procedure on Waste Management, stipulates that facilities which are generating waste should ensure that the container holding waste is labelled and details of waste stored should be recorded in the register. The internal procedure on waste management is not clear in terms of recording of the generated quantities per month, and the SOP has no requirements in terms of which register should be used by the personnel to record the generated quantities. Therefore, the criterion in terms whether the document makes provision for the recording of waste quantities is not met.

Although the internal Waste Management procedure provides for the safe handling, storage, transportation and disposal of hazardous waste, the results from the audit reports indicated that the LCRC facilities were in non-compliance with the procedure, especially as far as waste storage infrastructure is concerned. Akpan and Olukanni (2020) also highlight inadequate data and infrastructure as part of main challenges contributing to management of hazardous waste materials. This indicates that more emphasis should be assigned to the data collection and storage facilitates in order to better manage hazardous waste (Akpan & Olukanni, 2020)

Kumar *et al.* (2023) mention that limitations in terms of regulations can be a possible factor for ineffective management of hazardous waste. The internal Waste Management SOP indicates six months as the period limit for waste storage, while the Health Care Risk Waste regulations stipulates ninety (90) days as a best practice. The SOP should be reviewed and revised to reflect best practice, as far as possible.

A study by Mmereki *et al.* (2015) mentions that *‘there are inadequacies in the implementation of regulations associated with hazardous waste management due to fragmented responsibilities among government departments and local authorities’*. These inadequacies result in departments not having clear guidance in terms of legislative requirements for their specific waste types. The implemented policies and organisational procedures should be inclusive and in addition, address responsibilities of various key stakeholders as well as ensure proper systems to control and monitor the hazardous waste generated (Exposto & Sujaya, 2021). Although the SOP did address safe handling, storage, transportation and disposal of hazardous waste, specific roles and responsibilities were not assigned. This is an area for potential improvement.

In summary, similar to the observations, the document review indicated several poor waste management practices at the LCRC facilities, which were applicable to both biological and chemical waste.

4.4 Results related to RO3: Assessment of the level of knowledge and awareness of personnel

Section 4.4 discusses the results obtained from the structured questionnaire as it relates to the different questions related to knowledge and awareness of hazardous waste (See Annexure B). The discussion of results also incorporated aspects observed during on-site observations. Table 4-6 below shows the results from the survey questionnaire. Apart from answering “yes” or “no” to questions posed, participants were also required to provide comments and elaborate on the reasons for giving a specific answer.

The questionnaire was completed by fifty (50) respondents. The personal information of the respondents was not gathered (as explained in Section 3.6.2.4).

Table 4-6: Summary of results from the questionnaire (n=50)

No.	Question	Yes	No
1.	Do you understand why chemical and biological wastes are managed differently from general waste?	97%	3%
2.	In terms of law, do you know what legislations/regulations regulate the efficient management of waste? If yes, please name them.	23%	77%
3.	Do you understand what is meant by waste segregation or separation at source? If yes, please give a brief explanation.	63%	37%
4.	Were you ever trained on the adequate handling of hazardous waste?	30%	70%
5.	Are you aware of the health, safety and environmental risks relating to chemical and biological wastes?	97%	3%
6.	Are you satisfied with the current waste management practices in your office specifically looking at chemical and biological wastes? If no, please elaborate.	23%	77%
7.	Are you satisfied with the services rendered by the waste removal services? If no, what do you think can be changed?	20%	80%
8.	In a case of accidental spillage of waste, are you aware of the emergency response procedures to be followed?	47%	53%
9.	Are you aware of the organisation's policy and procedure on waste management?	30%	70%
10	Do you have a good understanding of the different labelling, international bio hazard signs and colour coding used for waste storage and marking?	50%	50%

4.4.1 Respondents' awareness on waste legislation and procedures

The results from the questionnaire indicate lack of awareness with regard to governing legislation on waste management (Q2). As indicated in Table 4-6, only 23% of the respondents indicated that they were aware of the relevant legislation regarding waste management.

Furthermore, waste management practices such as separation and/or segregation at source is not a practice that was prevalent and understood amongst all of the respondents (Q3). While 63% of the respondents indicated that they were familiar with the practice, 37% indicated that they were not. The results also indicated that only half of the respondents (50%) were aware of the different labelling signs and colour coding requirements for hazardous waste (Q10).

Only 30% of the respondents were aware of the internal waste policies within the organisation (Q9). The observed findings were indicative of these low levels of awareness of the internal standard operating procedures for waste (see Section 4.3.1) where various instances of non-compliance in relation to hazardous waste management were observed. These findings are in

line with Maqutu's study in Mpumalanga (2017) who highlighted that compliance with waste management practices at Crime Scene Laboratories is far from ideal due to a lack of training and awareness among staff.

4.4.2 Respondents' awareness on hazardous waste handling and health and safety risks

Lack of awareness, poor infrastructure, limited finances as well as poor enforcement are the main challenges cited for improper hazardous waste management (Cheru, 2011; Hossain *et al.*, 2011; Maqutu, 2017; Abubakar *et al.*, 2022). This research, therefore, aimed at evaluating respondents' awareness of hazardous waste handling and related health and safety risks, amongst others.

The obtained results from the survey questionnaire indicate that there is general understanding from 97% of the respondents in terms of why the biological and chemical waste should be handled differently from general waste (Q1) (Table 4-6). Similar results were obtained when respondents were asked about whether they are aware of health, safety and environmental risks which the waste may pose to the environment and humans (Q5), with 97% responding positively.

These findings are, however, in contradiction with observed practices from the data collected with relation to RO2 (See Section 4.3), where the practices observed are not indicative of understanding that chemical and biological wastes should be handled in a specific way to prevent health safety and environmental risks. Research has, however, shown that there are many times a gap between knowledge and actual behaviour. The results are in agreement with Siddiqua *et al.* (2022) who argue that knowledge alone is insufficient to induce behavioural change in waste management. Other studies conducted by Akulume and Kiwanuka (2016) indicated that workers who had knowledge on the use of colour coded bins reported that they did not segregate clinical waste which necessitates for additional measures to be implemented to improve knowledge through providing the resources required for waste separation, particularly the colour coded bins.

4.4.3 Training and Emergency Preparedness

Accidental or leakages of hazardous waste material can be avoided through ensuring that waste is stored in adequate waste management facilities. According to Donalson *et al.* (2013), surface spills and their harmful effects can be minimised through:

- Provision of adequate training for the personnel handling hazardous material;
- Use chemicals that are not toxic to the environment and are biodegradable;
- Use using appropriate liners to contain spills;
- having site-specific spill prevention control;

- Adequate spillage kits to neutralise any spill; and
- Maintaining good housekeeping.

The results (Table 4-6) indicate that only 30% of the respondents who have received training on hazardous waste, while 70% have not been trained on the adequate handling of the waste (Q4). In terms of emergency preparedness (Q3), only 53% of the respondents indicated that they know what to do in the event of a spillage, while 47% indicated that they were not aware. Appropriate records to indicate that training sessions were conducted were not available.

4.4.4 Satisfaction rate on current practices and services rendered

The transportation of hazardous waste requires a systematic approach due to the potential risks and environmental consequences associated with the activity (Kanagamani *et al.*, 2021). Question 6 required respondents to reflect on: *Are you satisfied with the current waste management practices in your office specifically looking at chemical and biological wastes? If no, please elaborate.* Furthermore, Question 7 asked *Are you satisfied with the services rendered by the waste removal services? If no, what do you think can be changed?*

The findings (Table 4-6) indicated that there are challenges relating to the collection of hazardous waste from the sites to an approved disposal facility. The results from the questionnaire (Q6) indicated that only 23% of the respondents were satisfied with the current waste practices in their offices, while 77% indicated that they were not satisfied. This indicated that personnel observe and acknowledge that current challenges and there's adequate space for improvement.

The satisfaction rate focusing on the hazardous waste removal services received (Q7), 80% of the respondents were not satisfied with the services rendered by the waste removal services.

Although it is clear that the majority of respondents were not satisfied with how waste is managed and collected, and they were urged to provide responses on what should be changed – none of the respondents made any recommendations for improvement.

4.5 Chapter conclusion

In general, hazardous waste management practices at the LCRC facilities included in the research were unsatisfactory and therefore require improvement. The results indicate the insufficient waste infrastructure, partial compliance to existing regulations, failure to quantify waste generated in reliable records, poor handling of waste which can be attributed to lack of personnel training on hazardous waste management.

Document review revealed that previous SHE audits conducted at the different Forensic Department sites in North West also highlighted challenges where hazardous waste management is concerned.

Results related to the survey questionnaire completed by 50 respondents indicated that staff was generally unaware of the requirements for the management of biological and chemical waste. Training on waste management and emergency response has not been properly implemented. Satisfaction levels of respondents as far as waste management and collection are concerned, were also generally low.

Chapter 5 concludes on the research findings and provides recommendations for improving the management of hazardous waste.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter provides the conclusion of this research which aimed to assess the hazardous waste management practices of SAPS Forensic Department, North West Province. Hazardous waste included both chemical and biological wastes from Local Criminal Record Centres (LCRCs) and Crim Scene Laboratories (CSLs).

The findings of this study are based on the document analysis, observations and survey responses of 50 SAPS Forensic Department employees. The delineated research scope (see Section 1.5 and 1.6) and methodological assumptions and limitations (as outlined in Section 3.9) of this research should be taken into account when considering these results.

The three research objectives related to the research aim included:

Research objective 1: Determine the types and quantities of hazardous waste generated by the SAPS Forensic Department, North West Province;

Research objective 2: Evaluate the current hazardous waste management practices of SAPS Forensic Department, North West Province against legal requirements; and

Research objective 3: Assess the level of knowledge and awareness of personnel with regards to the management of biological and chemical waste.

5.2 Conclusions

The sub-sections below provide the conclusion related to each research objective.

5.2.1 Conclusions related to RO1: Determine the types and quantities of hazardous waste generated by the SAPS Forensic Department, North West Province

Generators of hazardous waste are entrusted with a 'cradle to grave' duty of care to ensure the environmentally sound handling, storage, transportation, and disposal of generated waste (Du Toit & Bodenstein, 2014). Understanding the types and quantities of waste generated is pivotal to fulfilling these responsibilities and ensuring safe disposal practices.

Biological waste from LCRC facilities encompassed infectious, non-anatomical waste and contaminated personal protective equipment (PPE), while chemical waste included various substances such as ninhydrin, 8-Diazafluoren-9-one (DFO), and alcohol solvents like methanol,

ethanol, ethyl acetate, acetic acid, and Hydrofluoroether 7100 (HFE), along with dyes like rhodamine 6G (R6G) and basic yellow.

Both biological and chemical waste streams generated could pose considerable risks to human health and the environment. Occupational exposure to biological waste can lead to infectious diseases such as Hepatitis B and C, and Human Immunodeficiency Virus (HIV) (Prajapati & Kaur, 2021), while exposure to chemical waste can cause skin irritation and respiratory issues (Hasan *et al.*, 2020). Release of hazardous waste into water resources, air, and the terrestrial environment may cause adverse effects.

The availability of waste generation and waste collection records was a limitation of this research. Waste collection records show regular collection of biological waste in 2020, with decreasing frequency in 2021 and 2022, while records for chemical waste were only available for 2022. Larger LCRCs, such as Mmabatho, Potchefstroom, Klerksdorp and Rustenburg, typically, generated larger quantities of waste when compared to smaller LCRCs, such as Zeerust, Bloemhof and Klipgat.

Effective recordkeeping of waste quantities and types is crucial for traceability, yet it was observed during the study that records of waste generation were not kept by any of the facilities, and there was poor recordkeeping of waste manifest documents of waste collection and disposal, indicating inadequate monitoring of waste generation (Maqutu, 2017). Additionally, slow procurement processes in 2022 resulted in delayed and infrequent waste removal services, potentially leading to prolonged storage of hazardous waste.

5.2.2 Conclusions related to RO2: Evaluate the current hazardous waste management practices of SAPS Forensic Department, North West Province against legal requirements

The improper handling of hazardous waste may cause adverse environmental effects, damage to property, as well as occupational health and safety risks to any individual handling the waste from the point of generation to the entire hazardous waste life cycle (Mmereki *et al.*, 2016; Kaur & Arora, 2021; Saleh, 2016). Furthermore, non-compliance with legislative requirements may incur civil and/or criminal liability.

For this research, hazardous waste management practices of SAPS Forensic Departments in North-West were evaluated through observations, and document review and analysis. The evaluation of hazardous waste management practices within SAPS Forensic Department in North West revealed several deficiencies.

Firstly, hazardous waste segregation was lacking, leading to the mixing of biological and general waste. Additionally, chemical waste was not categorised or separated according to toxicity and hazardous properties, with all chemical wastes being combined into one container. This practice could result in a mixture containing non-chlorinated waste and other organic acids used in the laboratory, contrary to recommended practices (Muzzio *et al.*, 2016).

Furthermore, partial compliance was observed regarding the labelling of waste containers, with inconsistent labelling of chemical waste containers across sites.

Biological waste was often stored in red liner bags without being placed inside rigid containers, and instances of unsealed chemical waste containers were noted, posing risks of accidental spillage (Maowei *et al.*, 2021).

Inadequate waste storage infrastructure further exacerbated the problem, with storage areas lacking proper ventilation, drainage systems, and protection from direct sunlight, contrary to recommended standards (Wagnes and Bilitewski, 2009). Additionally, a lack of notice boards, warning signs and/or placarding was observed at the majority of the hazardous waste storage sites.

Discrepancies identified in document reviews and observation checklists highlighted further deficiencies in hazardous waste management practices, potentially exacerbated by regulatory limitations. Notably, the internal Waste Management SOP stipulates a six-month storage limit, while industry best practices and regulations recommend a maximum of ninety days for waste storage.

Lastly, the timely collection and disposal of hazardous waste were found to be lacking. This issue was compounded by the absence of waste generation records at all of the facilities, and the inconsistent availability of waste manifest documentation and safe disposal certificates at most of the facilities. This highlights the overall inadequacy of recordkeeping by the SAPS Forensic Department in North West.

These findings underscore the urgent need for comprehensive improvements in hazardous waste management practices within the SAPS Forensic Department to mitigate risks to human health and the environment.

5.2.3 Conclusions related to RO3: Assess the level of knowledge and awareness of personnel with regards to the management of biological and chemical waste

Results pertaining to the third research objective were obtained through a survey questionnaire, which gathered self-reported responses from 50 participants.

The findings indicated a general understanding among respondents (97%) regarding the necessity of handling biological and chemical waste differently from general waste, as well as awareness (by 97% of respondents) of the health, safety, and environmental risks associated with hazardous waste. These findings are, however, in contradiction with results of observations (refer to Section 5.2.2 above), where observed practices were not indicative of understanding that chemical and biological wastes should be handled in a specific way to prevent health safety and environmental risks.

The study revealed a lack of awareness among many employees regarding existing waste management regulations and recommended practices (Du Toit & Bodenstein, 2014). While respondents were able to express insights into hazardous waste within their workplace, they lacked knowledge concerning correct handling procedures and legislative requirements for such waste types.

Only 63% of respondents indicated that they were familiar with separation and/or segregation at the source, while only 50% were aware of labelling and colour-coding requirements for hazardous waste. Additionally, a mere 30% reported that they were knowledgeable about internal waste management policies and procedures. These findings indicate a low level of awareness regarding waste management procedures, aligning with Maqutu's study in Mpumalanga (2017), which emphasised inadequate training and awareness among staff in Crime Scene Laboratories. It is known that limited knowledge and awareness may contribute to poor waste segregation, improper handling, and disposal practices (Khan *et al.*, 2019; Oli *et al.*, 2016).

Adequate training programmes are essential to equip employees with the necessary knowledge to handle hazardous waste effectively (Akpan & Olukanni, 2020). Survey responses, however, underscored a shortage of hazardous waste management training provided to employees, with only 30% of respondents reporting having received such training. In terms of emergency preparedness, only 53% of respondents indicated that they were aware of how to react to spillages.

Additionally, the survey results shed light on challenges related to the handling of hazardous waste, and collection of hazardous waste from sites to approved disposal facilities, with 77% of respondents expressing dissatisfaction with on-site hazardous waste management practices, and an alarming 80% of respondents expressing dissatisfaction with hazardous waste removal services.

Addressing these challenges and knowledge gaps through comprehensive training and improved waste management practices is imperative to ensure the safe handling and disposal of hazardous waste within SAPS Forensic Services, North West.

5.3 Recommendations

Effective implementation of suitable waste management practices is determined by the implementation of the national regulations, occupational health and safety legislation, internal policies and procedures, as well as the competence of all those managing waste (Ramodipa *et al.*, 2023).

The study was conducted with the aim of providing recommendations towards improvement of hazardous waste management practices of SAPS, Forensic Department North West Province. Awareness of waste management issues and legal non-compliances the first step towards taking action to improve waste management practices (Vinod *et al.*, 2009). The sections below provide recommendations for improvement of waste management by SAPS Forensic Department, as well as recommendations for future research.

5.3.1 Recommendations for improvement of hazardous waste management practices

The study reveals a significant need to determine and implement a suitable hazardous waste management strategy to improve the current hazardous waste management practices of the SAPS Forensic Department in North West.

Based on the findings and conclusions of the study, the following recommendations are made:

5.3.1.1 Development of improved Hazardous Waste Management Systems

Kanagamani *et al.* (2021) emphasise the significance of integrating sustainable waste management systems, employing acceptable procedures, equipment, and management approaches to achieve predefined objectives. It is recommended that an integrated hazardous waste management system is developed for SAPS Forensic Department, North West. The system should, as a minimum, take cognisance of the aspects outlined below.

Effective hazardous waste management necessitates heightened precautionary measures to mitigate potential adverse impacts associated with poor practices. Core principles of effective waste management, as outlined by Padmanabhan & Barik (2019), include developing a comprehensive system, delineating responsibilities, allocating resources, and ensuring proper handling and disposal.

Alignment with the waste management hierarchy, which prioritises prevention, reduction, reuse, recycling, and recovery over disposal (Monteiro *et al.*, 2013), emphasises the need for hazardous waste prevention in terms of both quantity and toxicity (NWMS, 2020). Source separation is essential for effective hazardous waste management.

Suggested behavioural solutions, as proposed by Kaur and Arora (2021), can encourage better waste disposal practices, aiming to change the behaviour of hazardous waste generators to consistently store, transport, treat, and dispose of waste safely (Amadi *et al.*, 2017).

Audit results regarding hazardous waste management can inform organisational improvements (Maruszewska & Bialy, 2013). Effective management necessitates regular monitoring of systems and reporting programs, with corrective actions implemented for identified non-compliances (Mmereki *et al.*, 2015).

As advocated by Deyassa (2019), hazardous waste management systems can benefit from the Plan-Do-Check-Act (PDCA) cycle incorporated into ISO 14001: 2015 Environmental Management Systems. While Environmental Management Systems certification entails cost and resource implications, adopting the system as a voluntary standard can inform the development of more appropriate waste management systems without mandating certification.

5.3.1.2 Increased awareness

The research findings underscore the need for enhanced training and awareness in hazardous waste management practices. Ibrahim *et al.* (2023) suggest implementing guidelines, providing training on Standard Operating Procedures (SOPs), and utilising informative posters to disseminate information on hazardous waste management.

All staff members responsible for the handling of waste should receive training on proper waste identification, classification, segregation, containerisation, and storage, as recommended by the World Health Organization (WHO, 2015, as cited by Ramodipa *et al.*, 2023). Along with the colour coding for waste segregation, it is also important for the staff to be trained in record keeping (Bansod & Deshmukh, 2023).

Every member involved in hazardous waste management process must be made aware of the dangers to avoid accidents that harm the environment and humans. Effective training and awareness initiatives can ensure that individuals handling hazardous waste are well-informed and equipped to use personal protective equipment (PPE) as necessary precautions against adverse health effects such as skin dermatitis, asthma from prolonged exposure, and eye irritation (Kanagamani *et al.*, 2021).

5.3.1.3 Improved infrastructure

Maqutu (2017) highlights challenges related to vandalism and theft of hazardous waste, and the risk of the waste being accidentally released to the environment, especially in instances where infrastructure is inadequate.

Findings from the study showed that waste storage infrastructure was generally inadequate. Instances were noted where biological waste was kept outside and along passage areas and in offices, due to a lack of suitable temporary storage facilities. Both biological and chemical waste streams were, typically, stored in areas where they were exposed to rain, sunlight and rodents. Furthermore, many of the allocated storage areas were not enclosed nor secured to prevent unauthorised entry.

An improvement of especially waste storage infrastructure is necessary for managing hazardous waste (Monteiro *et al.*, 2013). The SAPS Forensic Department should ensure that each facility has an adequate waste storage area, which is access controlled, weather-proof, rodent-proof, has adequate ventilation and visible warning signs (Maowei *et al.*, 2021).

5.3.2 Recommendations for future research

This section proposes critical areas for future research aimed at advancing our understanding of hazardous waste generated by SAPS, Forensic Departments. The following areas can be explored for future research:

- Investigating hazardous waste management practices which covers the entire waste life cycle, including off-site practices, such as transportation and disposal;
- Exploring staff members' perceptions on the opportunities and challenges related to hazardous waste management by SAPS Forensic Departments; and
- Replicating this research for SAPS Forensic Departments from other provinces in South Africa.

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ANNEXURE A: OBSERVATION CHECKLIST

**ASSESSMENT OF HAZARDOUS WASTE MANAGEMENT PRACTICES IN
SAPS- NORTH WEST FORENSIC DEPARTMENT-
OBSERVATION CHECKLIST
PREMISES DETAILS**

Name of Local Criminal Record Centre (LCRC)	
Physical address	
Town	
Date	

REQUIREMENTS	COMPLIANCE STATUS	COMMENTS
Waste Classification and Management Regulations, No. R. 634		
Do the waste types generated require classification in terms of SANS 10234?		
Is there Safety Data Sheet for the products from which the waste type is generated?		
Are the containers holding the waste labelled and if not are records kept indicating the first disposal of waste as well as the last disposal before the container can be sealed off?		
Are there monthly records of waste quantities generated for each waste type?		
Is the waste manifest document available?		
Waste Segregation and Packaging		

Are there adequate measures to ensure that the different waste types generated are not mixed in one bag or container?		
Are the containers compatible with their contents?		
Is there an indication that the waste is segregated correctly at the point of generation and the correct liners used?		
Is liquid waste filled only to $\frac{3}{4}$ capacities to prevent excessive vapour pressure?		
Is the biological and chemical waste securely and efficiently packaged for storage, and transportation to prevent any leakages?		
Is the biological waste and chemical waste labelled with appropriate international hazard signs and signs as prescribed in SANS 10234- Globally Harmonized System of Classification and Labelling of Chemicals?		
Are there adequate measures taken to ensure that the waste does not accumulate such that it poses a risk to the public, workers and the environment?		

Are there records of such training conducted in the past five years?		
Does the organisation make provision for vaccinations to prevent the spread of any communicable disease?		
Temporary Storage Facility		
Is the temporary waste storage facility adequately illuminated and ventilated in accordance with the National Building Regulations and National Building Standards Act, 1977 (Act No. 103 of 1977)?		
Is the storage area rodent-proofed in accordance with the best available method?		
Is the floor surface free from cracks and have a firm waterproof base to prevent Permeation of storm water and constructed of a fire proof and theft resistant materials?		
Is the temporary storage area enclosed and secured to prevent unauthorized entry?		
Is the storage area marked / labelled with the relevant hazard symbols of the waste streams and a written warning statement?		

Is the hazardous waste stored away from the door and areas with excessive pedestrian traffic?		
Is safe and convenient height storage maintained to avoid accidental tip over?		
Is overcrowding of hazardous waste containers avoided?		
Is the storage area kept clean and dry at all times?		
Is there an emergency response policy to deal with accidental spills of hazardous waste?		
Waste Removal/Transportation		
Is there a licenced waste management contractor who is contracted to render treatment and disposal services for the organisations?		
Is there proof of the certificate on site?		
Does the office keep a record of waste collection certificate and also record of the waste quantities generated for both biological and chemical waste?		
Is there a record of the disposal certificate from the contractor?		

Is there adequate stock available in terms of boxes, red liner bags, liquid waste drums and cable ties?		
Records for Proof of collection		

ANNEXURE B: SURVEY QUESTIONNAIRE

RESEARCH TOPIC: ASSESSMENT OF HAZARDOUS WASTE MANAGEMENT PRACTICES GENERATED AT SAPS- NORTH WEST FORENSIC DEPARTMENT

Rank	
Designation	
Address	
Date	

This questionnaire aims to assess the hazardous waste management practices at SAPS, Forensic Service North West

Instructions

1. Please complete all sections of the questionnaire.
2. This research was approved by the North-West University Faculty of Natural and Agricultural Ethics Committee (NWU-01414-20-A9) and regarded as a minimal-risk application.
3. Confidentiality is ensured and your details will not be disclosed.
4. Your answer should be honest, and based on your experiences.
5. You are welcome to withdraw from this research at any time.
6. Please provide informed consent to participate in this research.

No.	Question	Yes	No	Comment
1	Do you understand why chemical and biological wastes are managed differently from general waste?			
2.	In terms of law, do you know what legislations /regulations regulate the			

	efficient management of waste? If yes, please name them			
2	Do you understand what is meant by waste segregation or separation at source? If yes, please give a brief explanation			
3	Were you ever trained on the adequate handling of hazardous waste?			
4	Are you aware of the health, safety and environmental risks relating to chemical and biological wastes?			
5	Are you satisfied with the current waste management practices in your office specifically looking at chemical and biological wastes? If no, please elaborate			
6	In your opinion, are there any areas which require improvement with regard to the handling of chemical and biological wastes in your office?			
7	Are you satisfied with the services rendered by the waste removal contractor? If no, what do you think can be changed?			
8	In a case of accidental spillage of waste, are you aware of the emergency response procedures to be followed?			
9.	Are you aware of the organisation's policy and procedure on waste management?			
10.	Do you have a good understanding of the different labelling, international bio hazard signs and colour coding used for waste storage and marking?			