A critical review of the challenges with classifying sludge within the South African petroleum industry

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Abstract

In South Africa, The Waste Classification and Management Regulations (2013) stipulate that applicable waste streams need to be classified according to SANS 10234; the South African National Standard for the Globally Harmonised System of Classification and Labelling of Chemicals (GHS). One of these waste streams is petroleum sludge, which exists as a complex mixture of petroleum hydrocarbons, water, salts and solid particles. The primary focus of the GHS however is first and foremost on chemicals, secondly the consistent classification and labelling of petroleum substances in line with the GHS is not straightforward due to their complex nature and chemistry.

The aim of this research is to critically identify what the challenges are related to the classification of sludge within the South African petroleum industry. The research methodology included a legislative review, a literature review and the conducting of semi-structured interviews. 21 interviews were conducted in total with various role-players including waste generators, waste management consultants and waste related government authorities.

The results from the semi-structured interviews indicated that the challenges related to the classification of sludge within the South African petroleum industry include the lack of data from the waste generator, no standardisation when conducting the classification process, limited analytical resources, high expenditure, the variable composition of the sludge, an absence of regulatory guidance and an inefficiency with regards to SANS 10234.

Recommendations were also identified including a revision of the current waste classification system, more capacity building, further published guidelines related to the classification process, more guidance from regulators and lastly standardisation with regards to the classification of industry related waste streams including petroleum sludge.

The identified challenges and recommendations can allow future measures to be put in place to ensure the effective management and compliance of petroleum sludge.

Key words: Classification, petroleum sludge, chemicals, challenges, recommendations

Opsomming

Die Afval Klassifikasie en Regulasies in Suid-Afrika (2013) stipuleer dat toepaslike afvalstrome geklassifiseer moet word volgens SANS 10234; die Suid-Afrikaanse Nasionale Standaard vir die Globally Harmonised System of Classification and Labelling of Chemicals (GHS). Een van hierdie afvalstrome is petroleum slyk wat opgemaak is van 'n komplekse mengsel van petroleum waterkoolstowwe, water, soute en soliede deeltjies. Die primêre fokus van die GHS is egter eerstens gerig op die chemikalieë, tweedens op die konstante formaat en etikettering van petroleum stowwe in lyn met die GHS. Dit is nie vereenvoudig as gevolg van hul komplekse aard en chemie nie.

Die doel van hierdie navorsing is om krities te identifiseer wat die uitdagings is wat verband hou met die klassifikasie van slyk binne die Suid-Afrikaanse petroleum-industrie. Die navorsingsmetodologie sluit in 'n literatuuroorsig sowel as die uitvoer van semi-gestruktureerde onderhoude. Een-en-twintig (21) onderhoude was in total gevoer met verskeie rolspelers, insluitende afval kragopwekkers, afvalbestuur konsultante asook afval verwante owerhede.

Die resultate van die semi-gestruktureerde onderhoude dui aan dat die uitdagings wat verband hou met die klassifikasie van slyk binne die Suid-Afrikaanse petroleum-industrie sluit in die gebrek aan data van die afvalgenereerder; geen standaardisering by die afsluiting van die klassifikasieproses; beperkte analitiese hulpbronne; hoë uitgawes; die veranderlike samestelling van die slyk; ‘n afwesigheid van regulerende leiding en die ondoeltreffendheid met betrekking tot SANS 10234.

Aanbevelings is ook geïdentifiseer, insluitend 'n hersiening van die huidige afval klassifikasie stelsel, meer kapasiteitsbou, verdere gepubliseerde riglyne wat verband hou met die klassifikasie proses, meer leiding van reguleerders en laastens standaardisering ten opsigte van die klassifikasie van die industrie verwante afvalstrome, insluitend petroleum slyk.

Die geidentifiseerde uitdagings en aanbevelings kan verseker dat toekomstige maatreëls in plek geplaas word om die effektiewe bestuur en nakoming van petroleum slyk te verseker.

Sleutelwoorde: Klassifikasie, petroleum slyk, chemikalieë, uitdagings, aanbevelings

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List of Abbreviations

CDU	Crude distillation unit
CG/HCCS	Coordinating Group for the Harmonization of Chemical Classification Systems
DEA	Department of Environmental Affairs
DWAF	Department of Water Affairs and Forestry
ECA	Environmental Conservation Act No. 73 of 1989
EINECS	European Inventory of Existing Commercial Chemical Substances

FCC	Fluid Catalytic Cracking
GHS	Globally Harmonised System of classification and labelling of Chemicals
IMDG	International Maritime Organisation's Dangerous Goods
IPIECA	International Petroleum Industry Environmental Conservation Association
MSDS	Material Safety Data Sheet
MTBE	Methyl tertiary butyl ether
NEMA	National Environmental Management Act No. 107 of 1998
NEMWA	National Environmental Management: Waste Act No. 59 of 2008
NWMS	National Waste Management Strategy
OECD	Organisation for Economic Cooperation and Development
OHSA	United States Occupational Health and Safety Act
PHCs	Petroleum hydrocarbons
SABS	South African Burea of Standards
SANS	South African National Standard
SDS	Safety Data Sheets
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCETDG/GHS	United Nations Committee on Experts on the Transport of Dangerous Goods and the GHS
UNDES	United Nations Department of Economic and Social Development

UNEP	United Nations Environmental Programme
U.S. EPA	United States Environmental Protection Agency
UVCB	Unknown or variable composition, complex reaction products or biological materials

CHAPTER 1

Introduction

This chapter begins by providing insight into the background of the research including the problem statement and research aim. The research objectives are further defined as they will aid in achieving the research aim. The chapter then looks at providing insight into the motivation for the research from an International, South African and Management perspective, before ending with a provision of the chapter layout of the research.

1.1 Problem Statement

The initial focus on waste management in South Africa was on basic principles that included the storage, collection, transport and disposal of waste in line with an environmentally acceptable standard (Muzenda *et al*. 2012). However, over the last decade with the focus on service delivery being emphasised, together with local economic development (Fiehn & Ball, 2005); integrated waste management has come into the spotlight. This included the accountability of local municipalities to their communities through ensuring that they have an integrated waste management plan in place to adequately provide an equitable service to all stakeholders (Fiehn & Ball, 2005).

An increase in economic growth has led to an increase in commercial, industrial, hazardous, mining, power generation and radioactive waste (Fiehn & Ball, 2005). Furthermore prevailing production and consumption patterns have resulted in waste that could adversely affect human health and the environment (Garner, 2009).

Fiehn and Ball (2005) state that some of the key waste management challenges which face South Africa include the lack of waste information from various sectors, illegal dumping, unregulated salvaging at waste disposal sites, use of unpermitted landfills, limited environmentally acceptable landfill space, large sections of the population not receiving an adequate waste collection service, lack of recycling, waste minimisation which is almost exclusively industry driven, government department lack of waste databases', and a lack of the enforcement of waste legislation. The National Waste Management Strategy (2012) provides a plan to address the numerous waste challenges in South Africa which include amongst other goals, a waste classification and management system (South Africa, 2012).

This waste classification and management system formed the precursor to the National Environmental Management Act No. 107 of 1998 Waste Classification and Management Regulations, which were promulgated in August 2013. The regulations stipulate that applicable waste streams referred to in the regulation need to be classified according to SANS 10234 (South Africa, 2013), which is the South African National Standard for the Globally Harmonised System (GHS) of classification and labelling of chemicals. One of these waste streams requiring classification under the GHS, is petroleum, petrochemical, hydrocarbon or oily sludge. A considerable amount of this form of sludge is produced from the petroleum industry during processes that include crude oil exploration, production, transportation, storage, and refining (Hu *et al.* 2014). This specific form of sludge usually exists as a complex mixture of various petroleum hydrocarbons (PHCs), as well as other inputs that include water, salts and solid particles (Hu *et al.* 2014). The primary focus of the GHS however, is first and foremost on chemicals. This was highlighted by the United Nations Department of Economic and Social Development where it was indicated that the “system not only endeavours to harmonise existing hazard classification and labelling of chemicals, it also attempts to strengthen and promote national capacities for the management of chemicals in line with Chapter 19 of Agenda 21” (UNDES, 1992). Furthermore the consistent classification and labelling of petroleum substances is not a straightforward process due to the complex nature and chemistry of these substances (IPIECA, 2010).

The main aim of this research is to critically identify what are the challenges related to the classification of sludge within the South African petroleum industry. In order to achieve this research aim, the following research objectives will be addressed:

I. To review the legal framework for the classification of waste in South Africa.
II. To investigate the generation and composition of sludge within the South African petroleum industry.
III. To review what was the Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste in terms of previous environmental legislation.
IV. To review what is the Globally Harmonised System of Classification and Labelling of Chemicals in terms of current environmental legislation.

V. To investigate what the challenges are related to the current methodology of waste classification for sludge within the South African petroleum industry.

1.2 Motivation for the research from an International perspective

The global economy is generating increasing amounts of hazardous waste that pose serious risks to people and the environment if not adequately controlled. Chapter 19 of Agenda 21 (UNDES, 1992) makes reference to "the environmentally sound management of toxic chemicals, including the prevention of illegal international traffic in toxic and dangerous products" (including waste). One of the programmes developed to achieve the objectives of Chapter 19 is the harmonization of classification and labelling of chemicals through the GHS (UNDES, 1992).

GHS research from an international perspective has provided some insight into its implementation (Blainey & Holmqvist, 2008; Peterson *et al*. 2010) as well as an indication of some of the challenges and impacts related to specific industries (Canter, 2013) and laboratory protocol (Hill, 2010). There is also evidence of research that addresses the challenge in classifying petroleum substances in line with the GHS (IPIECA, 2010 & Clark *et al*. 2013). However it is the implementation, challenges and impacts related to the classification of waste in line with the GHS that is not well researched and documented.

It is important to note that in order to effectively implement the objectives of Chapter 19 of Agenda 21, there is a need to critically assess and evaluate the challenges related to classifying waste in line with the GHS for applicable waste streams and not only those waste streams containing petroleum substances; such as petroleum sludge. An understanding of the challenges will enable correct measures to be put in place to ensure that there is a continued environmentally sound management of toxic chemicals, including waste.

1.3 Motivation for the research from a South African perspective

Muzenda *et al*. (2012) states that "the waste management philosophy in South Africa is based on the White Paper on Integrated Pollution and Waste Management , the National Waste Management Strategy (NWMS) and the National Environmental Management: Waste Act No.59 of 2008 (NEMWA)". The Legislative framework for waste management in South Africa is extensive, however this legislation will not be effective if there are challenges related to its implementation. In saying that, the aspiration to implement good waste management practice does not always result in actual behaviour and good waste management practice is not always under the volitional control of those tasked with its implementation (Godfrey *et al*. 2013). “Within both the public and the private sector, waste needs to be managed according to the following principles – accountability; affordability; cradle to grave management; polluter pays; equity; sustainable development; integration; open information; subsidiarity; waste avoidance and minimisation; co-operative governance; and environmental protection and justice” (Fiehn & Ball, 2005).

The GHS was designed specifically for chemicals and although it has been applied to waste streams, there still remains challenges related to the classification of specific waste streams, such as those containing petroleum substances. This research aims to highlight some of these challenges within a South African context.

1.4 Motivation for the research from a Management perspective

According to Davie *et al.* (2014), “the GHS was approved by the United Nations Committee on Experts on the Transport of Dangerous Goods and the GHS (UNCETDG/GHS) in 2002, and focuses on four main sectors, namely Transport, Industrial/Workplace, Consumer Products and Agricultural/Pesticides”. The purpose of classifying and labelling dangerous chemicals was to systematically identify the hazards of these chemicals, to draw the attention of the user to those hazards, and to enable them to put in place the correct measures to protect themselves as may be required (Pratt, 2002). However if challenges are experienced in classifying the applicable waste, there could potentially be management implications and these could vary in the different sectors of GHS application. Furthermore, inconsistencies and the inaccurate classification of waste could have extensive financial implications for the waste generator.

The challenges identified by this research will assist in identifying possible ways forward to ensure that the correct management protocol in the South African petroleum industry can be implemented for sludge classified in line with the GHS.

1.5 Chapter Layout

Chapter 1 details the problem statement, research aim as well as the five research objectives that will aid in achieving the research aim. Chapter 1 also provides insight into the motivation for the research from an International, South African and Management perspective. Chapter 2 describes the methodology utilised for the research. The research methodology includes a legislative review, literature review and the conducting of semi-structured interviews. Chapter 3 addresses research objective I and aims to review the legal framework for the classification of waste in South Africa. Chapter 4 addresses research objective II and aims to focus on the generation and composition of sludge within the South African petroleum industry. Chapter 5 addresses research objective III and IV by reviewing the waste classification methodologies that have been utilised in South Africa. Chapter 5 will firstly review the Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste in terms of previous environmental legislation, and secondly review what the Globally Harmonised System of classification and labelling of chemicals (GHS) is. Chapter 6 will address research objective V by presenting and evaluating the data obtained from the semi-structured interviews. Chapter 7 will evaluate the success of the results obtained in line with the overall research aim and the research objectives. Recommendations for future research are also made in this Chapter. Table 1 provides a view of the chapter layout relative to the objectives for this research

Table 1: Chapter layout of the research.

Chapters (see chapter 1, section 1.5)	**Research objectives** (see chapter 1, section 1.1)	**Research Methodology** (see Chapter 2)
Chapter 3	To review the legal framework for the classification of waste in South Africa?	Legislative Review
Chapter 4	To investigate the generation and composition of sludge within the South African petroleum industry?	Literature Review
Chapter 5	To review what was the Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste in terms of previous environmental legislation?	
	To review what is the Globally Harmonised System of classification and labelling of chemicals (GHS) is in terms of current environmental legislation?	
Chapter 6	To investigate what the challenges are related to the current methodology of waste classification for sludge within the South African petroleum industry?	Semi-structured Interviews
Chapter 7	Conclusion	

CHAPTER 2

Research Methodology

This chapter provides both a description and justification of the research methodology in order to achieve the research objectives and aim.

2.1 Background

The methodology for this research was divided into three sections. The first section consisted of a legislative review for the classification of waste in South Africa (Chapter 3). The second section consisted of a literature review that was further divided into two additional parts. The first part reviewed the generation and composition of sludge within the South African petroleum industry (Chapter 4), while the second part included a review of the Minimum requirements for the Handling, Classification and Disposal of Hazardous Waste in terms of previous environmental legislation, as well as a review of the GHS in terms of current environmental legislation (Chapter 5). The first two sections were supplemented by section three. This section consisted of a qualitative study in order to determine the challenges related to the classification of sludge within the South African petroleum industry under the current legislated methodology. Information was gathered through conducting semi-structured interviews with individuals working directly with waste management and particularly waste classification. The study was limited to South Africa and specifically petroleum sludge as a waste stream.

2.2 Description of research methodology

This section deals with the methodology that was used in the research to obtain the required data. The methods that were used included a legislative review, a literature review and a qualitative study that included the conducting of semi-structured interviews.

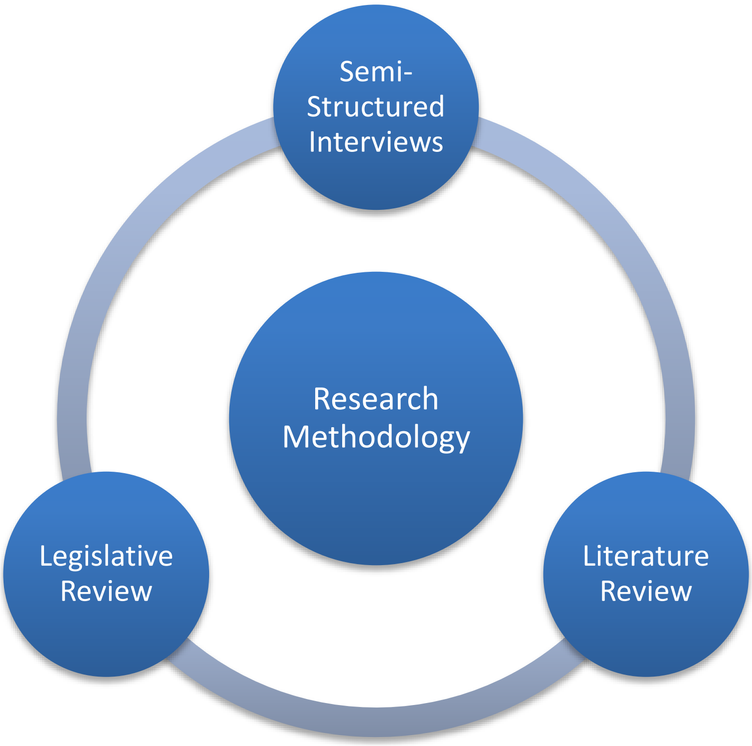

Figure 1: Research Methodology

2.2.1 Legislative Review

A review of South African legislation, related guidelines and South African National Standard (SANS) codes dealing with waste management and more specifically waste classification was undertaken. The legislative review provided an overview of the legislative history as well as an overview of the current legal requirements pertaining to the classification of waste in South Africa.

The legislative review included the following legislation, guidelines and SANS codes:

- The Environmental Conservation Act No. 73 of 1989
- The Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste (2005)
- The National Environmental Management Act No. 107 of 1998 (NEMA)
- The National Environmental Management: Waste Act No. 59 of 2008 (NEMWA)
- NEMWA: The National Waste Management Strategy (2012)
- NEMWA: The Waste Classification and Management Regulations (2013)
- NEMA: Environmental Impact Assessment Regulations (2010)

- NEMA: Environmental Impact Assessment Regulations (2014)
- SANS 10234: Globally Harmonized System of classification and labelling of Chemicals (2008)

2.2.2 Literature Review

A literature review was conducted for three reasons. Firstly, literature reviews can be a source of ideas and research questions, secondly literature reviews assist scholars to avoid "reinventing the wheel" by enabling to build on what others have discovered, and lastly because literature reviews assists researchers in developing an argument for their study by demonstrating that they are extending existing knowledge-building on what is already out there, as well as by filling the gaps (Zorn, 2006).

The literature review firstly consisted of a review of the generation and composition of sludge within the South African petroleum industry. Secondly the literature review included a look at the two waste classification methods that have been used in South Africa thus far; the previously utilised Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste and the current GHS.

The literature review included the following sources:

- Relevant publications from electronic, internet and library sources
- SANS codes
- Applicable documentation from the United Nations
- Various local and international guidelines

The literature review aimed to provide the background regarding generation, composition and the classification of sludge within the South African petroleum industry, prior to determining the challenges faced when classifying this waste stream.

2.2.3 Qualitative Research

Anderson (2010) states that "qualitative research involves the collection, analysis, and interpretation of data that is not easily reduced to numbers".

Qualitative research was selected due to its numerous benefits when correctly conducted (Anderson, 2010), including:

- Issues can be examined in detail and in depth.
- Interviews are not restricted to specific questions and can be guided or redirected by the researcher in real time.
- The research framework and direction can be quickly revised as new information emerges.
- The data that based on human experiences obtained is powerful and sometimes more compelling than quantitative data.
- Subtleties and complexities about the research subjects and/or topic are discovered that are often missed by more positivistic enquiries.
- Data usually is collected from a few cases or individuals so findings cannot be generalised to a larger population. Findings can however be transferable to another setting.

Within qualitative data techniques there are a number of ways that data can be obtained, such as the use of workshops, field notes, observation notes, structured interviews and case study notes. For this research, audio recordings and transcripts from semi-structured interviews were utilised. A pre-determined questionnaire was used to gather information from the various participants.

2.2.3.1 Semi-Structured Interviews

According to Galletta (2013), "semi-structured interviews are sufficiently structured to address specific dimensions of a research question while also leaving space for study participants to offer new meanings to the topic of study". Furthermore Schmidt (2004) states that "in a semi-structured interview the important text passages are not always found in the direct context of the question that was asked; the aspects that the interviewer introduces are frequently only taken up later in more explicit form, or else they turn up (again) in response to a different question within a quite different context". While conducting the interview, interviewees were encouraged to express their opinions and elaborate on issues related to their personal experience within the context of the interview questions.

Twenty-one interviews were conducted and the list of interviewees can be found in Table 2. The interviewees comprised those individuals that would be directly involved in the classification of petroleum sludge as a waste stream. The interviewees include Waste Generators, Waste Management Consultants and Waste Related Government

Authorities. Twenty-five individuals were initially approached for an interview. An interview could not be obtained from SAPREF (joint venture between Shell SA refining and BP Southern Africa) due to their legal department indicating that the research is not specific to the core business and the information can be sourced from other companies. Chevron Refinery also indicated that they utilise a waste management consultant for the GHS classification and therefore do not have anything to add. Two additional interviews were also conducted with individuals from Shell and Sasol respectively. However the results from these interviews were not considered as the results obtained from the other two interviewees from these two companies listed in Table 2 was considered sufficient.

Table 2: Research interviewees including Waste Generators, Waste Management Consultants and Waste Related Government Authorities.

Name	Company	Position
Waste Generators		
Thendo Nethengwe	BP	Environment and Compliance Manager
Alison Osborn	FFS Refiners	Environmental, Health, Safety, Compliance Manager
Lynette van Rookhuyzen	Total	Environmental Specialist
Khosi Zondi	Transnet Pipelines	Environmental Manager
Mac Sewruttan	Engen	Environmental Scientist
Dipitseng Phaleng	Shell	Corporate Environmental Advisor
Patrick Cebekhulu	NATREF Refiners	Specialist SHE
Christina Moraal	Sasol	Specialist SHE for product risk management
Leon van Dyk	Oil Separation Solutions	Director and Co-owner
Waste Management Consultants		
Neville Chetty	Wasteman	Waste Specialist

Nancy Oosthuizen	Nancy Oosthuizen Consulting CC	Owner of company
Bradley Thorpe	Interwaste	Environmental Compliance and Waste Classification Specialist
Adam Sanderson	WSP Environmental	Senior Associate at WSP and business unit manager
Liz Anderson	Responsible, Packaging, Management Association of South Africa	Executive Director
Dr. David Baldwin	EN-chem consultants CC	Owner of company
Raj Lochan	Rose Foundation	Chief Executive Officer
Dr. Johan Schoonraad	Enviroserv	Technical Director
Kyle Gaffar	Dolphin Coast Environmental and Laboratory Solutions	Managing Director
Dr. Willie van Niekerk	Infotox	Managing Director, Toxicologist
Waste Related Government Authorities		
Zama Mtembu	Department of Environmental Affairs	Deputy Director Hazardous Waste Management
Heather Sheard	KZN Dept. of Economic Development, Tourism and Environmental Affairs	Control Environmental Officer

Waste generators were selected as they are responsible for the waste they generate and would therefore be responsible for ensuring that classification takes places according to the legislative requirements. The majority of the waste generators comprised the larger petroleum companies while the remainder included the “smaller” refining companies (FFS Refiners and Oil Separation Solutions) as well as a parastatal (Transnet Pipelines) that transports petroleum products.

Waste generators in South Africa in most cases outsource the classification of their waste to waste management consultants due to the technical requirements and knowledge needed to conduct the process. The waste management consultants interviewed played various roles, however their ultimate goal was to ensure that the classification of waste was conducted according to legislative requirements on behalf of the waste generator. For example some of the service providers did not have their own laboratory facilities and this service would therefore be outsourced. However the appointed waste management consultant would manage the classification process to completion.

Waste related government authorities were also selected as interviewees. These included a representative from the national sphere of government (Department of Environmental Affairs) as well as a representative from the provincial sphere of government (Kwa-Zulu Natal Department of Economic Development, Tourism and Environmental Affairs).

Where possible, interviews were conducted face to face. Due to the geographical distribution of the interviewees, some of the interviews were conducted telephonically in order to obtain the required information. All interviews were recorded and each one ranged on average from between 30 to 45 minutes.

2.2.3.2 Questionnaire Design

A pre-determined questionnaire was used to gather information from the various participants. The questionnaire was designed to gain open-ended opinions by respondents in their own words through the use of content mapping and content mining questions. Legard *et al*. (2003) indicates that “content mapping questions are designed to open up the research territory and to identify the dimensions or issues that are relevant to the participant” while “content mining questions are designed to explore the detail which lies within each dimension, to access the meaning it holds for the interviewee and to generate an in-depth understanding from the interviewee's point of view".

The questionnaire aimed to gather information in respect to:

- What role does the interviewee play in ensuring that the classification of petroleum sludge takes place in terms of the GHS and what challenges have they experienced in fulfilling the role?
- What financial implications has the interviewee experienced or foreseen with regards to the classification of petroleum sludge in line with the GHS?
- What institutional implications has the interviewee experienced or foreseen with regards to the classification of petroleum sludge in line with the GHS?
- Does the interviewee have any recommendations that would allow them to better fulfil their role in ensuring that the classification of petroleum sludge takes place in line with the GHS?

The complete questionnaire is listed in Appendix A and it comprises a total of 16 questions.

2.2.4 Challenges for the research

The following challenges experienced may also be applicable to future research along a similar theme.

Access to interviewees

Interviewees were distributed throughout South Africa from the provinces of Kwa-Zulu Natal, Gauteng and the Western Cape. Where possible face-to-face interviews were conducted and during these interviews communication between the interviewer and the interviewee was more effective. This was favourable and complimented the semi-structured nature of the interview. However, due to the geographical distribution of the interviewees, the majority of interviews were conducted telephonically.

Scope of the research

The scope of the research being related to the classification of sludge within the South African petroleum industry, resulted in the potential interviewees being limited for two reasons. Firstly it is mainly the petroleum and related industries that generate petroleum sludge as a waste stream in South Africa and this mainly includes the major petroleum companies such as Engen, Sasol, BP and Shell. Secondly the classification of waste in line with the GHS is a technical process and is often assigned to specialists or managers in higher positions. These reasons make it challenging to obtain a wider sample of interviewees and to gain a broader perspective on the extent of impact of the GHS at different scales of employment (i.e. officers and general workers are often excluded from the classification process).

2.2.5 Data Analysis

The unprocessed qualitative data consisted of audio recordings that were converted to verbatim transcripts. Regardless of form, Ritchie *et al.* (2013) states that qualitative data is "highly rich in detail but unwieldy and intertwined in content", and therefore the use of coding and categorisation was chosen to be the method of data analysis.

According to Bohm (2004), "coding may be described as the deciphering or interpretation of data and includes the naming of concepts and also explaining and discussing them in more detail". A code in qualitative research is according to Saldana (2009), "most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data". Coding can either be done manually or electronically and for this research, manual coding was considered sufficient due to the interview sampling pool. Each transcript was reviewed in detail and possible codes were highlighted and acknowledged.

In larger data sets, it is evident that several of the same codes will be used repeatedly throughout (Saldana, 2009). Saldana (2009) states that "this is both natural and deliberate –natural because there are mostly repetitive patterns of action and consistencies in human affairs, and deliberate because one of the coder's primary goals is to find these repetitive patterns of action and consistencies in human affairs as documented in the data". Each transcript was reviewed more than once in order for efficient coding to take place. Coding patterns throughout the transcript were acknowledged and noted.

Grouping of the data is done through the development of a set of categories, with each category expressing criterion (or a set of criteria) for distinguishing some observations from others (Dey, 2005). When the review of the transcripts was completed and effective coding had been completed, the various codes were grouped according to their similarities into data sets called categories. These categories trigger the construction of a conceptual scheme that suits the data (Basit, 2003). Dey (2005) states that “categories must be grounded conceptually and empirically in that they must relate to an appropriate analytic context and be rooted in relevant empirical material”. In other words the categories must relate to the data obtained through the semi-structured interviews and they must also relate to the other categories. The development of codes and categories provides a means of directing and deciphering the data from the original unprocessed data captured, while the development of a theme presents a high level assessment of the data. The theme for this research is in line with the research aim which is the challenges with classifying sludge within the South African Petroleum Industry. Figure 2 is modified from Saldana (2009) and it provides the process from coding to categorisation and the relevant theme for this specific research.

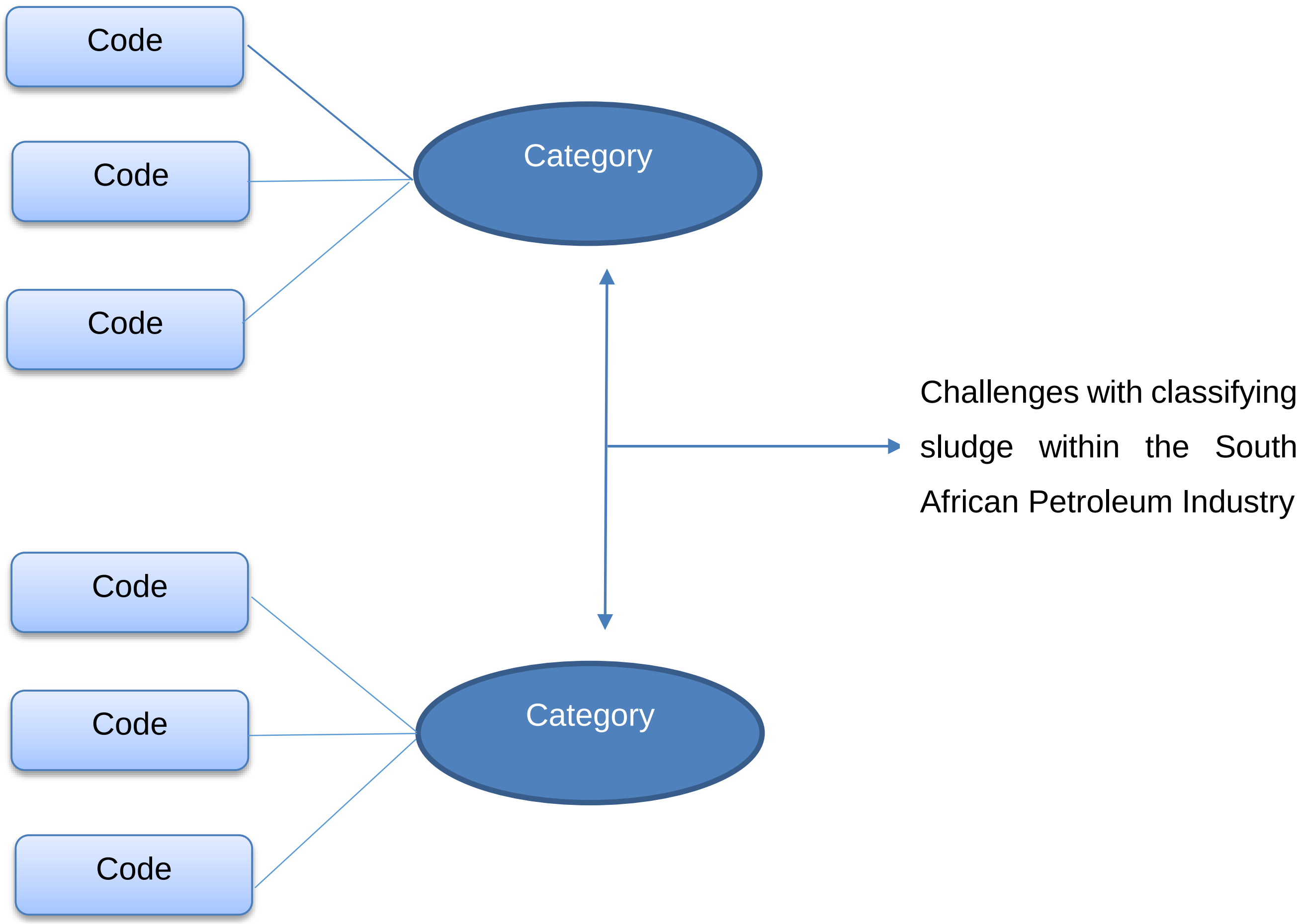

Figure 2: Process from coding to categorisation in relation to a relevant theme (Saldana, 2009)

It is not necessary to include the entire data set in the data analysis process, rather the researcher needs to ensure careful selection of the data to be reviewed (Ritchie *et al.* 2003). While undergoing this data analysis, it is important to review the proposal on which the research is originally based, as well as the stated objectives of the research (Ritchie *et al.* 2003). The research aim was utilised as a guide when deciding what data will be coded and categorised and the data analysis focused on the challenges related to the classifying of sludge within the South African petroleum industry.

CHAPTER 3

Legislative Review

This chapter details the historical and current legislative framework with regards to the classification of waste in South Africa. The legislative review includes past and current Acts, Regulations and Guidelines.

3.1 The Environment Conservation Act No. 73 of 1989

Prior to 1990, environmental protection in South Africa was mainly regulated in an uncoordinated and reactive manner (van der Linde, 2009). This is evident through the existence of almost a hundred laws at national level dealing directly or indirectly with environmental protection (van der Linde, 2009). However it was in 1989 that the South African Government enacted the Environment Conservation Act No. 73 of 1989 (ECA), which was South Africa's framework environmental legislation (van der Linde, 2009).

Besides providing a definition for the term "waste", the ECA also provided definitions for the terms "litter" and "disposal site", thus indicating the beginning of waste management regulation in South Africa. The ECA, defines waste as meaning:

"Any matter, whether gaseous, liquid or solid or any combination thereof, which is from time to time designated by the Minister by notice in the Gazette as an undesirable or superfluous by-product, emission, residue or remainder of any process or activity."

Section 20 of the ECA further highlighted waste management provisions as mandated by the Act. Section 20(1) states that:

"No person shall establish, provide or operate any disposal site without a permit issued by the Minister of Water Affairs"

While Section 20(6) states that:

"Subject to the provisions of any other law no person shall discard waste or dispose of it in any manner, except:

(a) at a disposal site for which a permit has been issued in terms of subsection (1); or

(b) in a manner or by means of a facility or method and subject to such conditions as the Minister may prescribe"

It is therefore evident that the ECA focused mainly on the waste disposal related aspects of waste management instead of integrated waste management as a holistic approach.

Section 1 of the ECA goes on to define the word "prescribe" as meaning to prescribe by regulation or notice in the Gazette, whilst Section 20(5) of the ECA indicates that:

"The Minister of Water Affairs may from time to time by notice in the Gazette issue directions with regard to:

(a) the control and management of disposal sites in general;
(b) the control and management of certain disposal sites or disposal sites handling particular types of waste; and
(c) the procedure to be followed before any disposal site may be withdrawn from use or utilised for another purpose."

The definition of the term "prescribe" highlighted in Section 1 and the ability of the Minister of Water Affairs to issue directions in terms of disposal sites (Section 20(5)) indicates that a provision has been made available for further regulations pertaining to waste management. This is further verified in Section 24(c) of the ECA where it is indicated that the "Minister may make regulations with regards to waste management, concerning the classification of different types of waste and the handling, storage, transport and disposal of such waste."

In terms of the ECA, a disposal site was defined as a "site used for the accumulation of waste with the purpose of disposing or treatment of such waste". No definitions are however provided for disposing or treatment of waste in the ECA. Furthermore, in terms of the ECA, no reference is made to temporary storage sites where waste would be stored for purposes other than treatment. This created problems for the government simply because as landfills across South Africa continued to fill, sites deemed more acceptable for new landfills became more difficult to find, especially in populated areas (South Africa, 2000). South Africa (2000) states that "waste managers therefore needed to become more resourceful in their search for space, to limit the amount of landfills and to also follow the cleaner technology route by establishing facilities such as waste recycling plants, treatment plant transfer stations, storage areas and vacuum pyrolysis plants". The guideline titled “Interpretation of the definition of disposal sites with regard to the issuing of permits for waste incinerators, waste management facilities and other alternative waste disposal technologies and related guidelines” aimed to address this pending issue (South Africa, 2000).

The guideline (South Africa, 2000) goes on to state that “vacuum pyrolysis plants, incinerators, compost plants, transfer stations, storage facilities and recycling plants are all seen as waste disposal sites according to the definition of a disposal site highlighted in section 1 of the ECA”. Furthermore the guideline (South Africa, 2000) indicates that “the facilities mentioned are considered disposal sites because of the continuous storage of waste on the premises of these plants or sites before the disposal, removal or handling thereof”.

3.2 Waste Management Series

The previous Department of Water Affairs and Forestry (DWAF) developed the Waste Management Series during 1998 and this included the Minimum Requirements Series. The series was developed in order to align with the development and permitting of facilities highlighted in the previously discussed guideline (Interpretation of the definition of disposal sites with regard to the issuing of permits for waste incinerators, waste management facilities and other alternative waste disposal technologies and related guidelines).

With regards to the Minimum Requirement Series, South Africa (2005) states that “the approach adopted is the Integrated Waste Management Approach. The aim is to curtail the risks associated with the handling and disposal of waste to the point where they are acceptable to humans and the environment”. Waste management must therefore be carefully planned in advance and take place in the following order (South Africa, 2005):

- Waste prevention: the prevention and avoidance of the production of a waste.
- Waste minimization: the reduction of the volume or toxicity of waste during production through the use of different processes or cleaner technology.
- Resource recovery: recycling of waste materials, the reuse of waste articles, or the recovery of energy through the use of incineration and biodegradation technologies.
- Treatment: the treatment of waste to reduce volume or hazardousness.

- Disposal: the safe disposal of waste so that it will not pollute the environment or cause human health hazards.

At the inception of the Minimum Requirements Series, the measures that were put in place for the management of hazardous waste in South Africa were not on equal footing with international legislation (South Africa, 2005). According to South Africa (2005), “DWAF initiated the development of the Waste Management Series with the aim of ensuring the sustained fitness for use of South Africa’s water resources and to protect both the public and the environment from the harmful effects of incorrect waste management without impairing the essential economic development of South Africa”.

The series itself comprises three documents and these include “The Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste, The Minimum Requirements for Waste Disposal by Landfill and The Minimum Requirements for the Monitoring of Water Quality at Waste Management Facilities” (South Africa, 2005).

A brief description on each document can be found in Table 3.

Table 3: Documents comprising the Minimum Requirements Series (South Africa, 2005).

Document	Name	Description
1	Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste	This document provides guidance on the waste classification system by placing waste in two classes, namely General or Hazardous, depending on their intrinsic toxicological characteristics. Hazardous wastes are further subdivided according to the risk that they may pose at disposal, through the use of a hazard rating. Wastes with a hazard rating of 1 or 2 are very or extremely hazardous, while wastes with a hazard rating of 3 or 4 are moderate or low hazard. The waste classification process also provides requirements for pre-treatment and disposal. Hazardous waste prevention, minimisation, handling, transportation and storage are also addressed due to their importance.
2.	Minimum Requirements for Waste Disposal by Landfill	This document addresses landfill classification; including the siting, investigation, design, operation and monitoring of landfill sites. According to the document a landfill is classified in terms of waste class, the size of the operation and the potential for significant leachate generation, all of which influences the risk posed to the environment. Graded requirements are then established for all aspects of landfilling, including public participation. Although the primary focus of this document is landfills, the classification system is also applied to disposal sites other than landfills.
3.	Minimum Requirements for the Monitoring of Water Quality at Waste Management Facilities	This document addresses the monitoring of water quality at and around waste disposal facilities.

The Minimum Requirements Series was aimed at enforcing the permit system highlighted in Section 20(6) of the ECA as well as to improve waste management practice in South Africa including the classification of waste which is in line with section 24(c) of the ECA.

It is important to the note that the minimum requirements were not issued as directions as provided for in section 20(5) of the ECA and were therefore not legally binding unless indicated specifically such as being part of an authorisation or directive from the relevant authority.

Chapter 5 will further highlight the details of the Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste in line with this research.

3.3 The National Environmental Management Act No. 107 of 1998

In South Africa the National Environmental Management Act No. 107 of 1998 (NEMA) is an example where framework legislation serves as both enabling legislation for a constitutional right and as a vehicle to realise the constitutional protection afforded to the environment (van der Linde, 2009). With this being said, NEMA did not regulate waste management in South Africa explicitly and this is indicated by the absence for a definition of waste. Reference was therefore still made to the ECA in terms of a waste definition prior to the promulgation of The National Environmental Management: Waste Act No. 59 of 2008 (NEMWA).

3.4 The National Environmental Management: Waste Act No. 59 of 2008

Under the NEMWA a more extensive definition for waste is provided and defined as meaning:

"any substance, whether or not that substance can be reduced, re-used, recycled and recovered-

(a) that is surplus, unwanted, rejected, discarded, abandoned or disposed of;
(b) which the generator has no further use of for the purpose of production;
(c) that must be treated or disposed of; or
(d) that is identified as a waste by the Minister by notice in the Gazette, and includes waste generated by the mining, medical or other sector, but-
(i) a by-product is not considered waste; and

(ii) any portion of waste, once re-used, recycled and recovered, ceases to be waste”.

Furthermore a definition is provided for hazardous waste as being:

“any waste that contains organic or inorganic elements or compounds that may, owing to the inherent physical, chemical or toxilogical characteristics of that waste, have a detrimental impact on health and the environment”.

While general waste is defined as meaning any:

“waste that does not pose an immediate hazard or threat to health or to the environment, and includes-

(a) domestic waste;
(b) building and demolition waste;
(c) business waste; and
(d) inert waste” (DEA, 2008).

The NEMWA fundamentally reformed the law regulating waste management in South Africa by providing a coherent and integrated legislative framework (South Africa, 2012). NEMWA addresses all steps in the waste management hierarchy by providing “a systematic and hierarchical approach to integrated waste management, addressing in turn waste avoidance, reduction, re-use, recycling, recovery, treatment, and safe disposal as a last resort” (South Africa, 2012). More precisely the preamble of the NEMWA goes on to state “that sustainable development requires that the generation of waste is avoided, or where it cannot be avoided, that it is reduced, re-used, recycled or recovered and only as a last resort treated and safely disposed of” (Figure 3).

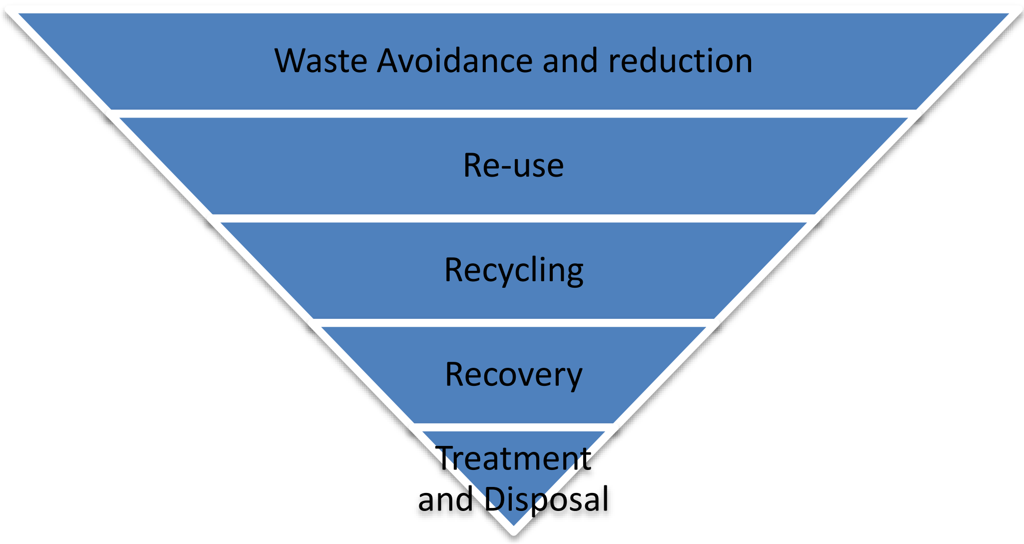

Figure 3: The Waste Management Hierarchy (South Africa, 2012).

Chapter 2, Part 2 of the NEMWA details national norms and standards, provincial norms and standards and waste service standards. More specifically section 7(1) indicates that the Minister must, by notice in the Gazette, set national norms and standards for the classification of waste. Furthermore Chapter 6 which addresses the establishment of a national waste information systems; indicates in section 60(1) that “the Minister must establish a national waste information system for the recording, collection, management and analysis of data and information that must include data on the quantity and type or classification of waste generated”.

Chapter 2, Part 1 of the NEMWA makes provision for the establishment of a national waste management strategy (South Africa, 2012) (NWMS). The NWMS was legislated in May 2012 with the overall purpose being to give effect to the objects of the NEMWA, which are to protect health, well-being and the environment through responsible waste management through the application of the waste management hierarchy. The NWMS is structured around a framework of eight goals as indicated in Figure 4.

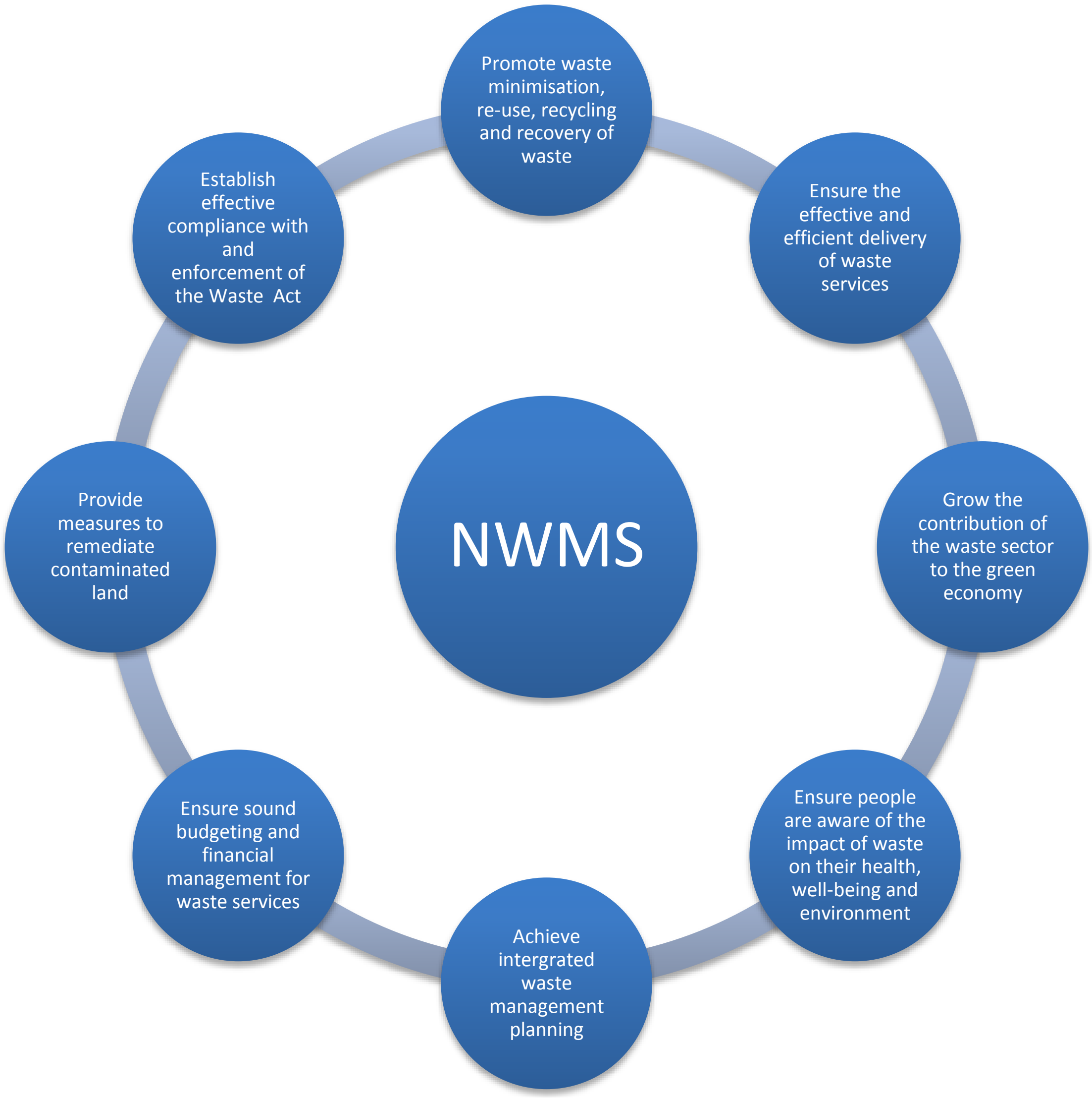

Figure 4: The eight Goals of the NWMS (South Africa, 2012).

In order to achieve these eight goals, the NEMWA provides a toolbox of waste management measures including the provision of a Waste Classification and Management System (Chapter 2, Part 2 of the NEMWA). This Waste Classification and Management System formed a precursor to the Waste Classification and Management Regulations (2013) which would go on to replace the DWAF Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste (South Africa, 2012).

The Waste Classification and Management Regulations were legislated in August 2013 thereby ensuring that the classification and management of waste is regulated in a manner that supports and implements the provisions of the NEMWA (South Africa, 2013).

Annexure 1 of the regulation provides a list of pre-classified waste that do not require classification. Section 4(2) of the regulation however indicates that for all other waste streams not listed in Annexure 1 of the regulation; the required classification needs to take place in accordance with SANS 10234 within one hundred and eighty days of generation. One such waste stream is petroleum sludge.

3.5 SANS 10234

SANS 10234 is the South African National Standard for the Globally Harmonised System for the Classification and Labelling of chemicals (GHS). Generators of hazardous waste subjected to classification in terms of SANS 10234, must furthermore ensure that a safety data sheet for the hazardous waste is prepared in accordance with SANS 10234. Although not requiring classification in terms of SANS 10234; specific waste streams listed in Annexure 1 of the regulation do however require a safety data sheet to be prepared in line with SANS 10234 in terms of the product the waste originates from (waste listed in item (2)(b)(i) of Annexure 1) or in terms of reflecting the details of the specific hazardous waste/s or hazardous chemicals in the waste (waste listed in item (2)(b)(ii) of Annexure 1). Generators of waste listed in item (2)(b)(iii) of Annexure 1 of the regulation do not have to prepare a SDS for the waste. A list of the pre-classified waste as listed in Annexure 1 of the Waste Classification and Management Regulations (South Africa, 2013) can be found in Appendix B of this research.

Besides dealing with waste classification, the regulation also makes provision for (South Africa, 2013):

- Waste management
- Waste management activities that do not require a waste management licence
- Record keeping and the waste manifest system

Reference is made to SANS 10234 once more in both the 2010 and 2014 NEMA Environmental Impact Assessment Regulations where dangerous goods are defined as meaning:

“Goods containing any of the substances as contemplated in South African National Standard No. 10234, supplement 2008 1.00: designated “ List of classification and labelling of chemicals in accordance with the Globally Harmonized System (GHS)” published by Standards South Africa, and where the presence of such goods, regardless of quantity, in a blend or mixture, causes such blend or mixture to have one or more of the characteristics listed in the Hazard Statements in section 4.2.3, namely physical hazards, health hazards or environmental hazards".

Unlike the Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste, the GHS was not a guideline but a regulation to the NEMWA and therefore a legal requirement. More information regarding the GHS will be discussed in Chapter 5.

CHAPTER 4

The generation and composition of petroleum sludge

This chapter highlights the generation and composition of petroleum sludge as means of indicating its variability. The chapter starts off by describing what crude oil is and highlights that variability starts at the earliest stages. The chapter then describes the various processes within a petroleum refinery followed by a description of what UVCB substances are. The chapter ends by describing what petroleum sludge is and how it is related to the other sections highlighted in this chapter.

4.1 Crude oil

Fahim *et al.* (2010) states that "crude oil is a complex, liquid mixture made up of a vast number of hydrocarbon compounds that consist mainly of carbon and hydrogen in differing proportions". In addition to this, small amounts of organic compounds that contain sulphur, oxygen, nitrogen and metals such as vanadium, nickel, iron and copper are also present at various quantities within crude oil samples (Fahim *et al*. 2010). These additional constituents are mainly impurities and despite their low concentrations, they are undesirable (Fahim *et al*. 2010). The reason for this is because they cause concerns in the ability of crude feedstocks to be processed and also because they affect the quality of the produced petroleum products (Fahim *et al*. 2010). The variability within crude oil means that there are many different types and that no two crude oils are compositionally the same (IPIECA, 2010).

4.2 Petroleum refining

A petroleum refinery is a collection of unit operations that includes fractionation towers, pumps and heat exchangers (Fahim *et al*. 2010). The petroleum refinery activities commence with the receipt of crude for storage, followed by all petroleum handling and refining operations, as well as storage before shipping the refined products from the refinery (U.S. EPA, 1995). The petroleum refining industry utilises a wide variety of processes and the arrangement and availability of these processes will vary among refineries (U.S. EPA, 1995). Figure 4 provides an example of a refinery flow scheme that is typical to the processing arrangement used by refineries in the United States (U.S. EPA, 1995).

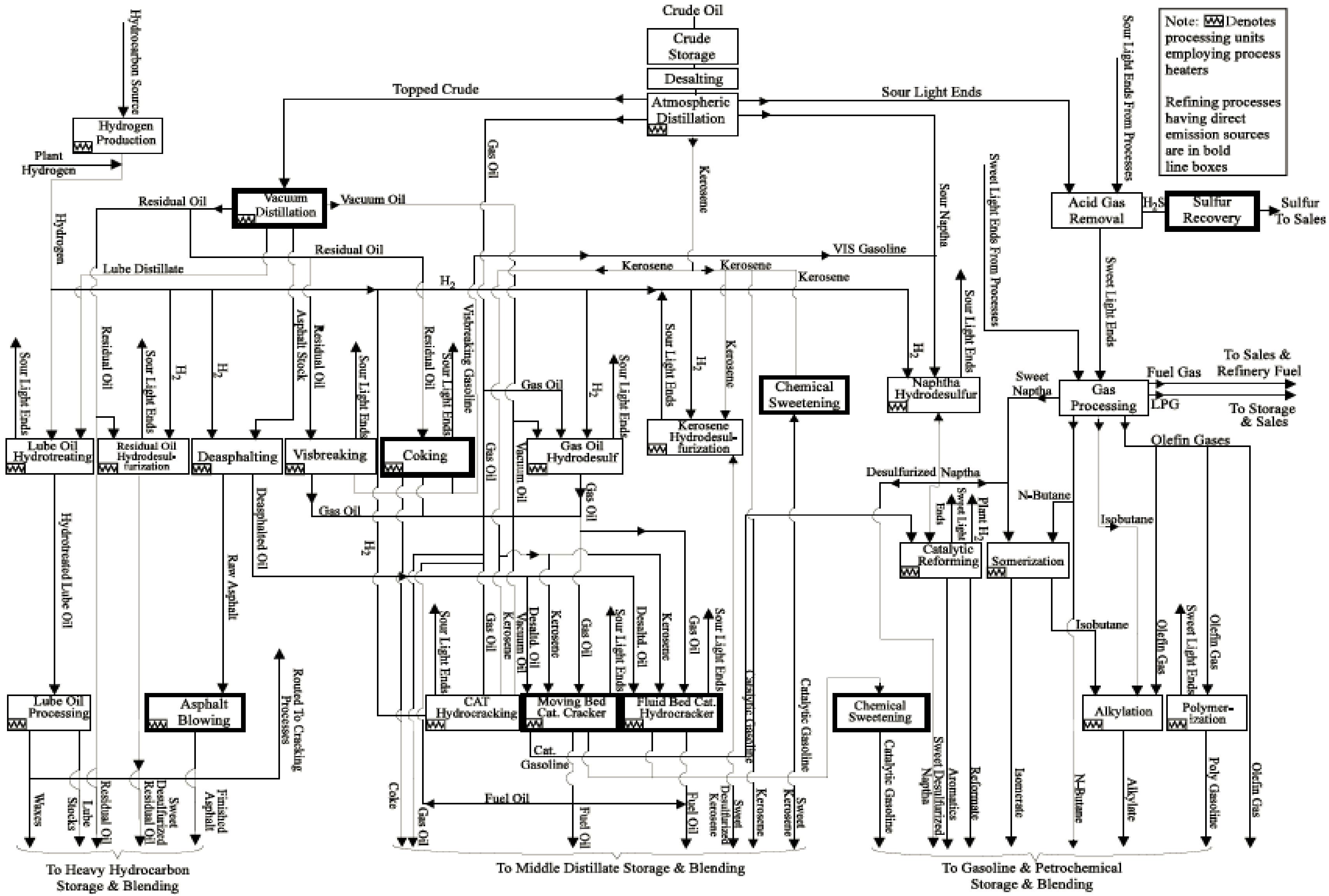

Figure 5: A petroleum refinery flow scheme (U.S. EPA, 1995).

There are 5 categories of general refinery processes. These include The Separation Processes, The Petroleum Conversion Processes, The Petroleum Treating Processes, Feedstock and Product Handling, and lastly Auxiliary Facilities. These 5 categories will be discussed in more detail below.

4.2.1 The Separation Processes

U.S. EPA (1995) indicates that "the first phase in petroleum refining operations is the separation of crude oil into its major constituents using 3 petroleum separation processes; namely atmospheric distillation, vacuum distillation and lights ends recovery (gas processing)". The crude distillation unit (CDU) or atmospheric distillation unit is part of the atmospheric distillation process and is situated at the front-end of the refinery where the highest flow rate is received (Fahim *et al*. 2010). The unit produces raw products that have to be processed downstream, including (Fahim et al. 2010):

- Gases
- Light straight run naptha
- Heavy gasoline (military jet fuel)
- Kerosene (light distillate or jet fuel)
- Middle distillates (diesel or light gas oil)
- Heavy distillates (atmospheric gas oil or heavy gas oil
- Crude column bottoms (atmospheric residue or topped crude)

4.2.2 The Petroleum Conversion Processes

According to U.S. EPA (1995), "to meet the demands for high-octane gasoline, jet fuel and diesel fuel; components such as residual oils, fuel oils, and light ends are converted to gasolines and other light fractions". "Catalytic reforming is the process of transforming C7-C10 hydrocarbons with low octane numbers to aromatics and iso-paraffins which have high octane numbers" as stated by Fahim *et al*. (2010). Highly aromatic liquid products can also be produced from heavy petroleum residues through severe thermal conditions known as thermal cracking (Fahim *et al*. 2010). Polymerization and alkylation processes are utilised to combine small petroleum molecules into larger ones, while isomerization and reforming processes are applied to rearrange the structure of petroleum molecules to produce higher-value molecules of a similar molecular size (U.S. EPA, 1995).

4.2.3 Petroleum Treating Processes

According to U.S EPA (1995), ”Petroleum treating processes stabilize and upgrade petroleum products by separating them from less desirable products and by removing objectionable elements”. Examples of petroleum treating processes include hydrotreating, hydrocracking and hydrogenation. Hydrotreating is the process of removing sulphur, nitrogen and metal impurities in the feedstock by hydrogen through the use of a catalyst (Fahim *et al*. 2010). Hydrocracking is described as the process of catalytic cracking of feedstocks to products with lower boiling points by reacting them with hydrogen (Fahim *et al*. 2010). Hydrogenation is used when aromatics are saturated with hydrogen to the corresponding naphthenes (Fahim *et al*. 2010). Treating processes employed primarily for the separation of petroleum products, include processes such as deasphalting, while desalting is utilised to remove undesirable substances that include salt, minerals, grit, and water from crude oil feedstocks before refining can take place (U.S. EPA, 1995).

4.2.4 Feedstock and Product Handling

The refinery feedstock and product handling operations consist of storage, blending, and transfer operations (U.S. EPA, 1995). All petroleum refineries have a product storage area known as a “tank farm”, which ensures uninterrupted refinery operations (U.S. EPA, 1995). Fahim *et al,* (2010) indicates that “refining processes do not generally produce commercially usable products directly, but rather semi-finished products which must be blended in order to meet the specifications of the demanded products”. An example of this is gasoline, which is produced by blending a number of components, such as alkylate, reformate and Fluid Catalytic Cracking (FCC) gasoline, as well as an oxygenated additive such as methyl tertiary butyl ether (MTBE) to increase the octane number (Fahim *et al*. 2010). Refinery feedstocks and products can be transported by pipeline, trucks, rail cars and marine vessels (U.S. EPA, 1995). The feedstocks and products are transferred to and from these transport vehicles in the refinery tank farm area by specially designed and constructed pumps and piping systems (U.S. EPA, 1995). Feedstock and Product Handling operations are not only limited to petroleum refineries, but may also include companies dealing only with the handling and transportation of petroleum products.

4.2.5 Auxiliary Facilities

A variety of processes and equipment not directly involved in the refining of crude oil are utilised in functions that are vital to the operation of the refinery (U.S. EPA, 1995). U.S. EPA (1995) indicates that some examples of these auxiliary facilities include “boilers, waste water treatment facilities, hydrogen plants, cooling towers and sulphur recovery units”.

Industrial effluent treatment plants in refineries include neutralizers, oil/water separators, settling chambers, clarifiers, dissolved air flotation systems, coagulators, aerated lagoons and activated sludge ponds (U.S. EPA, 1995). The design of the industrial effluent treatment plant is determined by the spectrum of refinery pollutants; that may include oil, phenols, sulphides, dissolved solids and toxic chemicals (U.S. EPA, 1995).

4.3 UVCB Substances

It is stated by IPIECA (2010) that “there are many different types of crude oil and each consists of many thousands of chemicals, predominantly hydrocarbons”. Petroleum substances are chemicals derived from these different crude oils through the process of physical separation (i.e. distillation), which may be followed by chemical modification (e.g., hydrogenation, cracking, etc.) (IPIECA, 2010). As a result the European Inventory of Existing Commercial Chemical Substances (EINECS) has identified petroleum refinery streams as a complex combination of hydrocarbons that may also include other additions such as sulphur and nitrogen compounds which may influence their toxicological characteristics (Lyne *et al*. 1996). Clark *et al*. (2013) therefore states that most petroleum products and the streams produced in petroleum refineries have been defined as substances with unknown or variable composition; more precisely they have been designated by the United States Environmental Protection Agency (U.S. EPA), the federal agency responsible for registration of chemicals, as UVCB substances (those with either unknown or variable composition, complex reaction products or biological materials).

4.4 Petroleum Sludge

Bush and Levine (cited by Petroleum HPV Testing Group, 2010) indicate that hydrocarbon waste form a component of refinery waste and can be further broken down into the following waste streams:

- American Petroleum Institute separator sludge
- Dissolved air flotation float
- Slop oil emission solids
- Tank bottoms
- Other separator sludge's
- Pond sediment
- Flotation –Flocculation Unit sediment
- Desalter bottoms
- Waste oils/solvents
- Miscellaneous oil sludge's

A substantial amount of oily sludge is generated from petroleum refineries during their storage operations and through on-going operations (El Naggar *et al*. 2010). Guangji & Jianbing (2014) states that the sludge can exist "as a complex mixture of various petroleum hydrocarbons, water, salts and solid particles", while El Naggar *et al*. (2010) indicates that industrial sludge from refineries "could contain not only organic and inorganic matter, but also bacteria and viruses, oil and grease, nutrients such as nitrogen and phosphorous, heavy metals and organochlorine compounds". A portion of the sludge generated in petroleum refinery activities is therefore comprised of UVCB substances as well as other variable substances with undefined quantities.

Both the upstream (processes of extracting, transporting and crude oil storage) and downstream (crude oil refining processes) operations in a petroleum industry can result in large amounts of oily wastes being generated (Hu *et al*. 2013). Hu *et al*. (2013) states that the "sludge quantity generated from petroleum refining processes depends on several factors such as crude oil properties, refinery processing scheme, oil storage method and most importantly the refining capacity". van Oudenhoven et al. (cited by Hu *et al*. 2013) estimates that one ton of oily sludge waste is generated for every 500 tons of crude oil processed.

This type of sludge generated through petroleum refinery activities may be referred to as oily, hydrocarbon, petrochemical or petroleum sludge. The term petroleum sludge has been selected to ensure consistency within this research.

CHAPTER 5

The Classification of Hazardous Waste in South Africa

This Chapter will provide a review of the two waste classification methods utilised in South Africa. The previous Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste and the current legislated Globally Harmonized System of classification and labelling of chemicals.

5.1 The Minimum Requirements

The first part of this chapter will include a review of the previous Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste. A short background will be provided regarding this methodology including is objectives. This will be followed by a greater focus on the actual classification process as well as additional requirements related to the waste handling, storage and transportation.

5.1.1 Background

South Africa (2005) states that “the Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste (referred to as The Minimum Requirements) sets out a systematic framework for identifying a Hazardous Waste and classifying it in accordance with the degree of risk that it poses”. From the classification process, requirements are set that will ensure hazardous waste is treated and safely disposed of (South Africa, 2005).

The Minimum Requirements was first published in 1994. This was followed by a Second Edition in 1998 and a Third Edition in 2005. The Third Edition includes a number of new protocols for evaluating downstream uses of waste; sampling to ensure uniformity; risk-based modelling for site-specific design and operation to achieve acceptable environmental exposure; co-disposal of sewage sludge; risk assessment based on eco- and human health toxicity and lastly an extension of the hazardous waste classification tables to include acceptable human health exposure (South Africa, 2005).

DWAF (South Africa, 2005) states that the objectives of The Minimum Requirements are to:

- Encourage the avoidance, re-use, recycling and treatment of waste;
- Develop a waste classification system which will ensure that waste is to be classified in accordance with the risk it poses;
- Provide the relevant authorities, generators, transporters and managers of waste with guidelines and graded Minimum Requirements in order to ensure that waste, and in particular Hazardous Waste, can be effectively managed from generation to disposal;
- Prevent Hazardous Waste from impacting the environment;
- Effectively manage and administer the issuing of waste disposal site permits.

5.1.2 Hazardous Waste Classification

In line with the second objective, DWAF (South Africa, 2005) has provided four steps for the Hazardous Waste Classification System. These are depicted in Figure 5 and will be discussed in more detail.

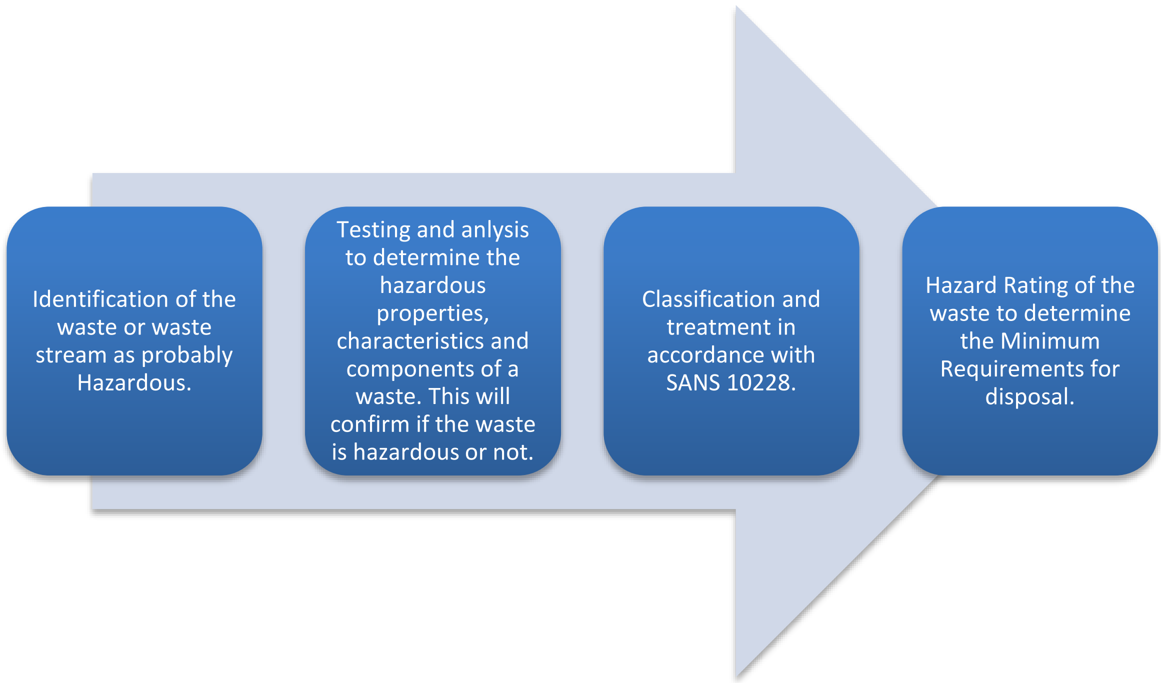

Figure 6: The four steps of the Hazardous Waste Classification System (South Africa, 2005).

1. Identification of a Probably Hazardous Waste

The identification of a Probably Hazardous Waste is the first step in the classification process, and it includes the identification of relevant industries and processes which from past practices are known to generate Hazardous Waste (South Africa, 2005).

South Africa (2005) indicates that the objectives of the identification of a waste as being probably hazardous are to:

- identify industrial clusters, processes or waste streams that are possibly expected to produce Hazardous Waste, for registration purposes (when required to be mandatory)
- alert the generator of the earliest possible opportunity of the possible generation of Hazardous Waste so that applicable legislation can be adhered to and possible legal implications avoided.

Figure 7 provides wastes or waste streams that could potentially be classified as hazardous.

Select Industrial Group	
A	**Agriculture, Forestry and Food Products**
B	**Mineral Extraction and upgrading** ***(Excluding hydrocarbons)***
C	**Energy**
D	**Metal Manufacture**
E	**Manufacture of Non-Metal Mineral Products**
F	**Chemical and Related Industries**
G	**Metal Goods, Engineering and Vehicle Industries**
H	**Textile, Leather, Timber and Wood Industries**
J	**Manufacture of Paper and Products, Printing and Publishing**
K	**Medical, Sanitary and other Health Services**
L	**Commercial and Personal Services**

Identify Process:	Key
A - Agriculture, Forest Management, Fisheries - Animal and Vegetable Products from the Food Sector - Drink Industry - Manufacture of Animal Feed	A1 A2 A3 A4
B: - Mining and Quarrying of Non-metallic Minerals - Mining and Quarrying of Metallic Minerals	B1 B2
C: - Coal Industry including Gas Works and Coking - Petroleum and Gas Industry including Extraction and Refined Products - Production of Electricity	C1 C2 C3
D: - Ferrous Metallurgy - Non-ferrous Metallurgy - Foundry and Metal Working Operations	D1 D2 D3
E: - Construction Materials, Ceramics and Glass - Salt Recovery and Refining - Asbestos Goods - Abrasive Products	E1 E2 E3 E4
F: - Petrochemicals - Production of Primary Chemicals and Feedstocks - Production of Fine Chemicals - Production of Inks, Varnish, Paint and Glue - Fabrication of Photographic Products - Production of Pharmaceuticals - Rubber and Plastic Materials - Production of Explosives - Production of Biocides - Waste and Water Treatment	F1 F2 F3 F4 F5 F6 F7 F8 F9 F10
G: - Mechanical Engineering - Electronic and Electrical Engineering - Manufacture of Motor Vehicles and parts	G1 G2 G3
H: - Textile, Clothing and Footwear Industry - Hide and Leather Industry - Timber, Wood and Furniture Industry	H1 H2 H3
J: - Paper and Cardboard Industry - Printing, Publishing and Photographic Laboratories	J1 J2
K: - Health, Hospitals, Medical Centers and Laboratories - Veterinary Services	K1 K2
L: - Laundries, Dyers and Dry Cleaners - Domestic Services - Cosmetic Institutions	L1 L2 L3

Identify Waste Stream:
A - **Inorganic Wastes** ▪ Acids and alkalis ▪ Cyanide Wastes ▪ Heavy metal sludges and solutions ▪ Asbestos wastes ▪ Other solid residues
B - **Oily Wastes** ▪ Primarily from the processing, storage and use of mineral oils
C: - **Organic Wastes** ▪ Halogenated solvents residues ▪ Non-halogenated solvent residues ▪ PCB wastes ▪ Paint and resin wastes
D - **Putrescible Organic Wastes** ▪ Wastes from production of edible oils, slaughter houses, tanneries and other animal based products.
E - **High Volume / Low Hazard Wastes** ▪ Those wastes which, based on their instrinsic properties, present relatively low hazards, but may pose problem because of their high volumes. *(e.g. drilling mud, fly-ash from power plants, mine tailings, etc.)*
F - **Miscellaneous Wastes** ▪ Infectious waste from diseased human/animal tissue ▪ Redundant chemicals ▪ Laboratory wastes ▪ Explosive wastes from manufacturing operations or redundant munitions.

Figure 7: Identification of Hazardous Waste (South Africa, 2005).

2. Tests and analysis

If it was determined that the waste is probably hazardous, then the second step will be to test and analyse the waste (South Africa, 2005) in order to:

- correctly identify any hazardous substance in the waste;
- provide the information needed for classification and Hazard Rating to take place;
- assess the effectiveness of any treatment, disposal or remediation programme; and
- determine whether a waste generator, transporter, or treatment and disposal site is conforming to the legislative requirements.

3. Waste Classification

South Africa (2005) indicates that "once the substances, compounds, properties and characteristics of a waste have been determined, usually by tests and analyses, it can then be classified". The objectives of the classification system are to (South Africa, 2005):

- differentiate between Hazardous Waste and General Waste
- identify the single most hazardous property of the waste and, hence;
- determine the degree of hazard posed by the Hazardous Waste;
- rate Hazardous Wastes, based on the properties and degree of hazard, and set requirements for pre-treatment and disposal;
- provide a hierarchical approach, which ensures that unnecessary preventive measures and expenses are avoided

Once the substances and characteristics of a waste have been determined, whether the waste is hazardous or not will have to be confirmed. This is done by comparing the waste with SANS 10228, the Basel Convention and the Waste Classification Tables included in The Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste (South Africa, 2005).

The Basil Convention, which came into the fore on the 5 May 1992, includes the Control of Transboundary Movements of Hazardous Waste and Their Disposal as well as providing a list of hazardous substances (UNEP, 1992). The Waste Classification Tables are an extension of SANS 10228 in order to take into account the possible hazardous impacts to ecosystems and especially groundwater (South Africa, 2005).

SANS 10228 (2012) is the South African National Standard for The identification and classification of dangerous goods for transport by road and rail modes. The SABS has incorporated the International Maritime Code for the Transportation of Dangerous Goods (IMDG) into SANS 10228 (Bosman, 2009). The scope of SANS 10228 takes into account that the dangerous goods are capable of posing a significant risk to health and safety or to property and the environment (SABS, 2012).

When confirming that the waste is hazardous, the properties of the waste are tested against the nine SANS 10228 classes in order to determine the relevant minimum requirements i.e. treatment, incineration or destruction. Figure 7 and Table 4 provides further details regarding SANS 10228 and the related minimum requirements that need to be complied with. In determining the minimum requirements according to Figure 7, the user moves from Class 1 through to Class 9 by responding to the Yes or No choices. The waste must be classified according to its most dangerous substances (South Africa, 2005).

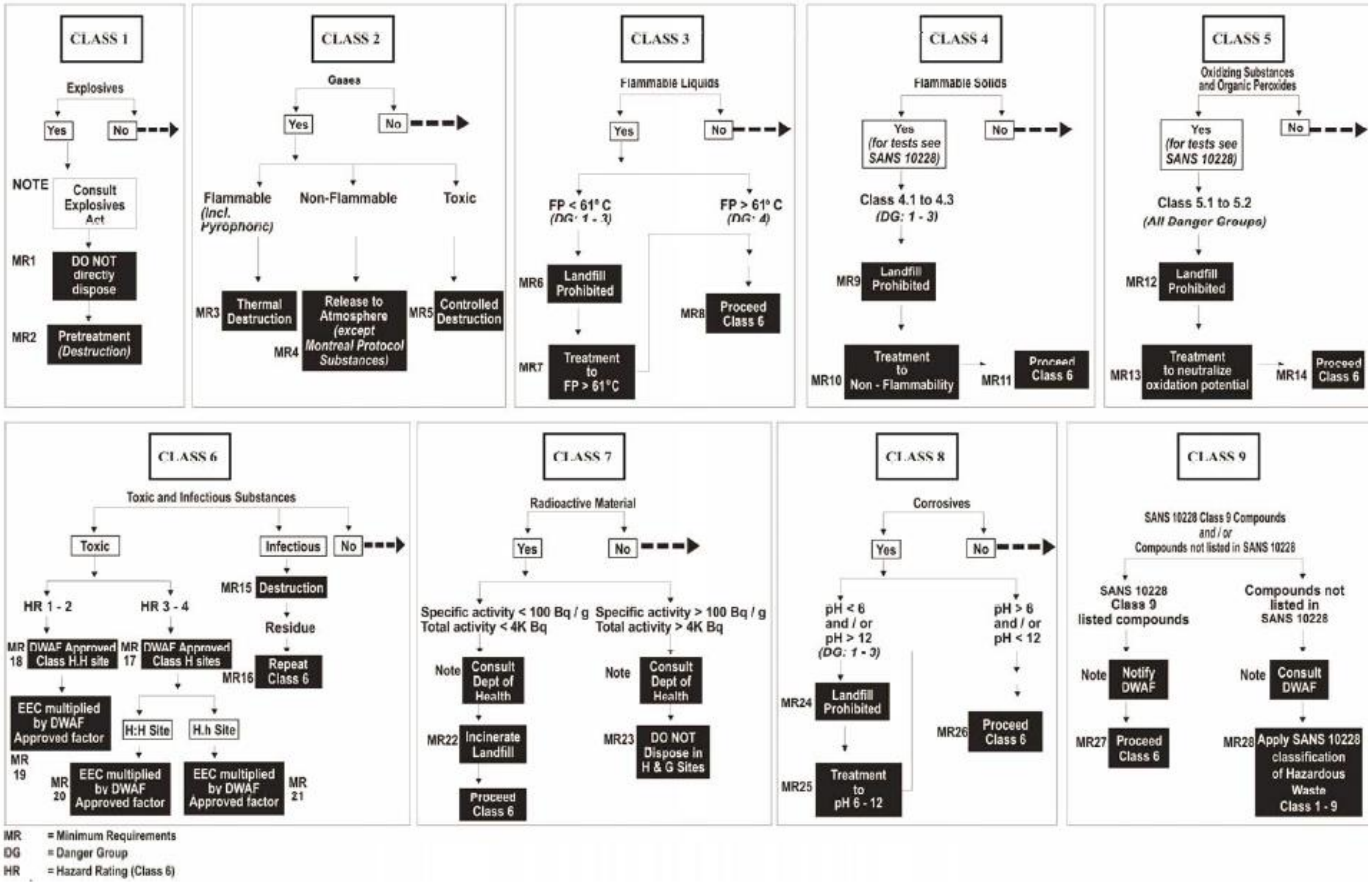

Figure 8: SANS 10228 Hazard Classes indicating the Minimum Requirements for the Treatment and Disposal of Hazardous Waste (South Africa, 2005).

Table 4: SANS 10228 Hazard Class descriptions and the applicable Minimum Requirements for the Treatment and Disposal of Hazardous Waste (South Africa, 2005).

Hazard Class	Description	Minimum Requirement
Unlisted compounds	Should a Hazardous Waste contain compounds not listed in SANS 10228, the Competent Authority must be consulted before classification is attempted.	
1	Explosives	Direct Disposal of Class 1 wastes is prohibited. Class 1 wastes is to be pre-treated (destroyed)
2	Gases: compressed, liquefied or dissolved under pressure	Flammable gases to be thermally destroyed. Non-flammable gases to be released to atmosphere, unless in contravention with the National Environmental Management: Air Quality Act (Act 39 of 2004) and the Montreal Protocol. Controlled destruction of poisonous gases.
2.1	Flammable gases	
2.2	Non-flammable, non-toxic gases	
2.3	Toxic gases	
3	Flammable liquids	Landfilling of flammable liquids, flashpoint <61ºC is Prohibited. Flammable solids to be treated to non-flammability.
3.1	Low flashpoint group of liquids; flashpoint below - 18oC	
3.2	Intermediate flashpoint group of liquids; flashpoint of -18oC up to, but not	
3.3	High flashpoint group of liquids flashpoint of 230C up to, and including, 61oC	
4	Flammable solids or substances	Landfilling of flammable solids is Prohibited. Flammable solids to be treated to non-flammability.
4.1	Flammable solids	
4.2	Flammable solids liable to spontaneous combustion	
4.3	Flammable solids which emit flammable gases when in contact with water	
5	Oxidising substances and organic peroxides	Landfill of Oxidising Substances and Organic Peroxides is Prohibited. Treatment to neutralise oxidation potential.
5.1	Oxidising substances	
5.2	Organic peroxides	
6	Toxic and infectious substances	Infectious Substances to be sterilised. Residue of Infectious Substances to be Hazard Rated. Toxic Substances, Hazard Rating 3 or 4, to be disposed of at H:H or H:h sites, to have EEC multiplied factor approved by the Competent Authority.
6.1	Toxic substances	
6.2	Infectious material	
7	Radioactive substances	Radioactive Substances with specific activity <100Bq/g, total activity < 4kBq, to be incinerated or landfilled. Disposal of Radioactive Substance with specific activity >100 Bq/g, total activity >4 kBq, is Prohibited. Consult Department of Health.
8	Corrosive substances	Disposal of Corrosive Substances, pH <6 and/or pH> 12, by landfill is prohibited. Corrosive substance to be treated to pH 6 – 12.
9	Other miscellaneous dangerous substances	Competent Authority to be notified if a compound contains substances listed in Class 9 and written approval must be obtained before disposal. Competent Authority to be notified if a compound contains substances not listed in Class 9.

4. Hazard Rating

Once the Hazardous Waste has been treated to comply with the minimum requirements for the applicable SANS 10228 class, its residues must then be tested against Class 6 of SANS 10228 in order to allocate a hazard rating. The objectives of Hazard Rating are to indicate (South Africa, 2005):

- the risk posed by a Hazardous Waste and therefore the degree of care required for its disposal;
- the class of Hazardous Waste landfill at which the waste may be disposed;
- the amount of a Hazardous substance or compound that can be disposed of at a particular Hazardous Waste landfill site before it begins to pose a risk (South Africa, 2005).

Figure 8 provides further guidance regarding the process of hazard rating by responding to Yes or No choices. Table 5 highlights the Hazard Rating, Hazard Description and the corresponding class of landfill that a particular type of waste can be disposed at. If a waste is indicated as “no risk” or “non-toxic”, the waste can then be disposed of at a General Waste landfill (G:B+). The requirements for the siting, investigation, design, operation and monitoring of a Hazardous Waste Landfill (H:H and H:h) are more stringent than those for a General Waste landfill. In turn, the requirements for an H:H landfill are more stringent than those for an H:h landfill (South Africa, 2005).

Table 5: Hazard Ratings and corresponding landfill class (South Africa, 2005).

Hazard Rating	Description	Landfill Class
1	Extreme Hazard	H:H
2	High Hazard	H:H
3	Moderate Hazards	H:H or H:h
4	Low Hazard	H:H or H:h

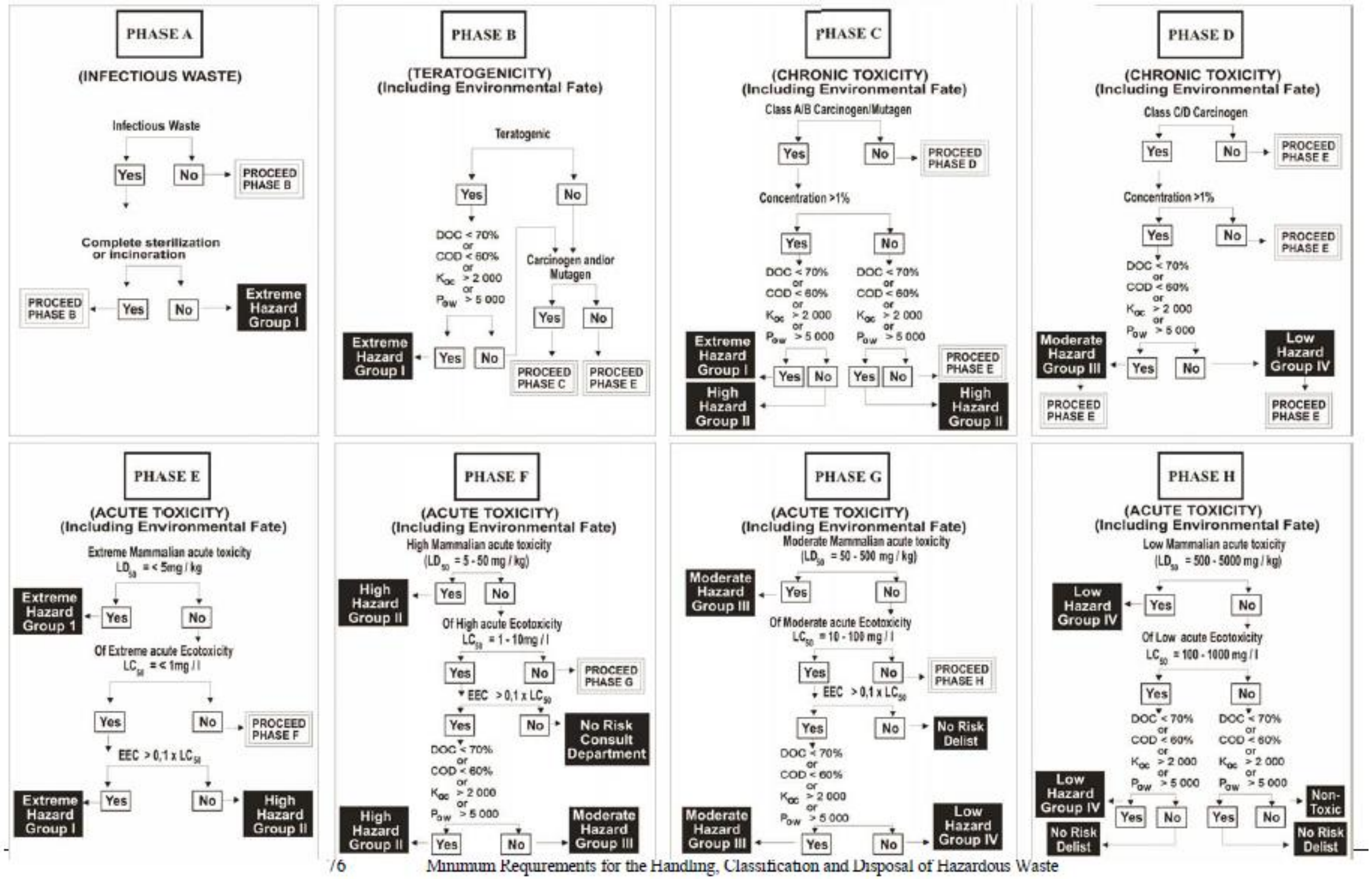

Figure 9: Determining of Hazard Ratings (South Africa, 2005).

5.1.3 Waste Handling, Storage and Transportation

According to South Africa (2005), “the handling, temporary storage and transportation of Hazardous Wastes follows the same principles and requirements as those, which relate to dangerous goods in general”, furthermore “South Africa accepts the United Nations Recommendations for the transport of dangerous goods as incorporated in the International Maritime Organisation’s Dangerous Goods (IMDG) code and the International Civil Aviation Organisation’s Regulations as given in their Technical Notes”. Both of these requirements have been implemented as legislation through The Department of Transport’s Merchant Shipping Act No. 57 of 1951 and The Aviation Act No. 72 of 1962 (South Africa, 2005).

Packaging

South Africa (2005) states that “hazardous waste must be securely contained during handling, storage and transport to prevent risk to the environment, and the type of packaging to be used is determined by a series of practical tests, related to the degree of hazard posed by the material to be contained”. SANS 10229-1, the South African National Standard for the Transport of dangerous goods – Packaging and large packaging of dangerous goods for road and rail transport (Part 1: Packaging) is the guide used to provide conformance to packaging requirements (South Africa, 2005).

Labelling

Labelling of containers with the correct Name and Description of the content is essential to correctly identify the material in question, to facilitate the appropriate action in case of an emergency and to ensure that the required treatment and disposal methods are being adhered to (South Africa, 2005).

The labelling of hazardous substances must be undertaken in accordance with SANS 10233, the South African National Standard for the Transport of dangerous goods – Intermediate bulk containers (South Africa, 2005).

5.2 The Globally Harmonized System of classification and labelling of chemicals

The second part of this chapter will include a review of the Globally Harmonized System of Classification and labelling of chemicals (GHS). This section will start with a review of the background of the GHS, followed by a review of the implementation of the GHS, which will include the two types of hazard communication. The chapter will then look at the focus of GHS in South Africa and lastly a short review of the challenges with classifying UVCB substances in line with the GHS.

5.2.1 Background

Over the last 30 years a number of different systems for the classification of chemicals have been developed by different countries with varying approaches and degrees of similarities and difference (Blainey & Holmqvist, 2008). Furthermore, many countries in the world have laws since the mid-1980s requiring warning labels on packages or containers or to provide material safety and health information of a specific chemical (Lee *et al.* 2013). The purpose of classifying and labelling dangerous chemicals was to systematically identify the hazards of these chemicals, to draw the attention of the user to those hazards and to enable them to take action to protect themselves as required (Pratt, 2002). The variety of systems utilised however resulted in many inconsistencies in the classification and labelling of the same chemical between the different countries, or within different sectors in the same country or manufacturers (Winder *et al*. 2005). The UN (2013) states that “through variations in definitions of hazards, a chemical may be considered flammable in one country, but not in another, or it may be considered to cause cancer in one country, but not in another”. Due to the reality of the global trade in chemicals, and the requirement to develop national plans to ensure their safe use, transport and disposal; it was recognised that an internationally harmonised approach to classification and labelling would provide the basis for such programs (UN, 2013).

A Globally harmonised system would therefore (UN, 2013):

- Enhance the protection of human health and the environment by providing an internationally comprehensible system for hazard communication;
- Provide a recognized framework for those countries without an existing system;
- Reduce the need for testing and evaluation of chemicals; and

- Facilitate international trade in chemicals whose hazards have been properly assessed and identified on an international basis.

According to Winder *et al.* (2005) "in 1992, the United Nations Conference on Environment and Development (UNCED) gave rise to the Agenda 21 report. The report outlined the responsibilities of States towards the achievement of sustainable development, and was adopted by heads of government in over 150 countries". Chapter 19 of Agenda 21 addresses the environmentally sound management of toxic chemicals, including basic programs for (UNDES, 1992):

- Adequate legislation
- Information gathering and dissemination
- Capacity for risk assessment and interpretation
- Establishment for implementation and enforcement
- Capacity for rehabilitation of contaminated sites and poisoned persons
- Effective education programs
- Capacity to respond to emergencies.

Paragraph 26 and 27 of Chapter 19 of Agenda 21 (UNDES, 1992) also went onto state that:

"26. Globally harmonized hazard classification and labelling systems are not yet available to promote the safe use of chemicals, inter alia, at the workplace or in home. Classification of chemicals can be made for different purposes and is a particularly important tool in establishing labelling systems. There is a need to develop harmonized hazard classification and labelling systems, building on ongoing work";

"27. A globally harmonized hazard classification and compatible labelling system, including material safety data sheets and easily understandable symbols, should be available, if feasible, by year 2000".

A globally harmonized approach no doubt raised some concerns from the global community. Some of these concerns related to the exemption of certain sectors and products or whether or not the system would be applied at all stages of the life cycle of a chemical (UN, 2013). As a result The Coordinating Group for the Harmonization of Chemical Classification Systems (CG/HCCS) agreed on three parameters that are critical to the application of the Globally Harmonized System of classification and labelling of chemicals (GHS) in a country or a region (UN, 2013).

These three parameters include (UN, 2013):

1. The GHS covers all hazardous chemicals. The mode of application of the hazard communication elements of the GHS (e.g. labels, safety data sheets) may vary by product category or stage in the life cycle. Target audiences for the GHS include consumers, workers, transport workers, and emergency responders.
2. The mandate for development of a GHS does not include establishment of uniform test methods or promotion of further testing to address adverse health outcomes.
3. In addition to animal data and valid in vitro testing, human experience, epidemiological data, and clinical testing provide important information that should be considered in application of the GHS.

The system would therefore not only endeavour to harmonise existing hazard classification and labelling of chemical, but also attempt to strengthen and promote (especially in developing countries) national capacities for the management of chemicals in line with Chapter 19 of Agenda 21 (Dalvie *et al.* 2014).

The GHS was approved by the United Nations Committee on Experts on the Transport of Dangerous Goods and the GHS in 2002, and would focus on four main sectors, namely Transport, Industrial/Workplace, Consumer Products and Agricultural/Pesticides (Dalvie *et al.* 2014). Winder *et al.* (2005) states that “this new system, the outcome of collaborative efforts of the World Health Organisation, the International Labour Organisation, the Organisation for Economic Cooperation and Development (OECD), and the United Nations, as well as member countries of the above mentioned organisations, was broadly supported from the chemical industry because of its promise to harmonize at international level the manner in which chemicals are classified according to their hazards and labels using universally understandable pictograms, as well as a uniform system of safety data sheets”.

The United Nations published the “Purple Book” in July 2002 outlying the GHS, particularly the classification criteria and hazard communication elements (UN, 2013).

The originally published version was followed by five revised editions (1st version: 2005, 2nd version: 2007, 3rd version: 2009, 4th version: 2011, 5th version: 2013).

5.2.2 Implementation of the GHS

The goal of the GHS is to identify the inherent hazards found in substances and mixtures and to communicate this hazard information to all relevant stakeholders.

According to the GHS (UN, 2013), a substance:

“means chemical elements and their compounds in the natural state or obtained by any production process, including any additive necessary to preserve the stability of the product and any impurities deriving from the process used, but excluding any solvent which may be separated without affecting the stability of the substance or changing its composition”.

The GHS (UN, 2013) also provides for the definition of a mixture as meaning:

“a mixture or a solution composed of two or more substances in which they do not react”.

UN (2013) states that “the criteria for hazard classification are harmonised with hazard statements, symbols and signal words being standardised and harmonised in order to form an integrated hazard communication system”.

The purpose of classification and labelling of dangerous chemicals is to systematically identify the hazards of chemicals, to draw the attention of the user to those hazards and to enable them to take action to protect themselves as appropriate (Pratt, 2002).

Hazard classification

Hazard classification incorporates only three steps (UN, 2013):

1. Identification of relevant information regarding the hazards of a substance or mixture.
2. Subsequent review of relevant information to ascertain the hazards associated with the substance or mixture.
3. Decide on whether the substance or mixture will be classified as hazardous and the degree of hazard where appropriate, utilising the data with agreed hazard classification criteria.

Depending on the classification outcome, the substance or mixture can be either defined as a Physical, Health or Environmental Hazard. Substances and mixtures are further classified not only in terms of a Hazard Class, but also a Hazard Category. A more detailed layout of the hazard types, classes and categories of the GHS can be found in Appendix C.

Hazard Communication

According to the UN (2013), “one of the objectives of the GHS has been the development of a harmonised hazard communication system, including labelling, safety data sheets and easily understandable symbols, based on the classification criteria developed for the GHS”.

- Labelling

The needs of the primary end-users of the harmonised hazard communication scheme include those in the workplace, consumers, emergency responders as well as those involved in the transport of dangerous goods (UN, 2013). As mentioned previously, the GHS is based on a standard method in order to ensure that numerous companies comply with the same standard as well as to facilitate trade. This standard approach also includes the standardisation of labels as part of the GHS. In terms of these labels, hazard symbols, signal words and hazard statements have all been standardised and assigned to each of the hazard categories (UN, 2013).

SANS 10234 (SABS, 2008) indicates that the intention of the label is to:

- Draw the attention of persons who handle or use the product to its inherent hazard(s),
- Provide essential data on the hazardous substances(s) present in the product, and
- Present the safety measures to be taken into account.

The GHS label elements comprise the product identifier signal words, hazard statements, precautionary statements and pictograms and as well as the supplier identification (Figure 9). The pictograms prescribed in SANS 10229-1 shall be used for transport purposes (SABS, 2008).

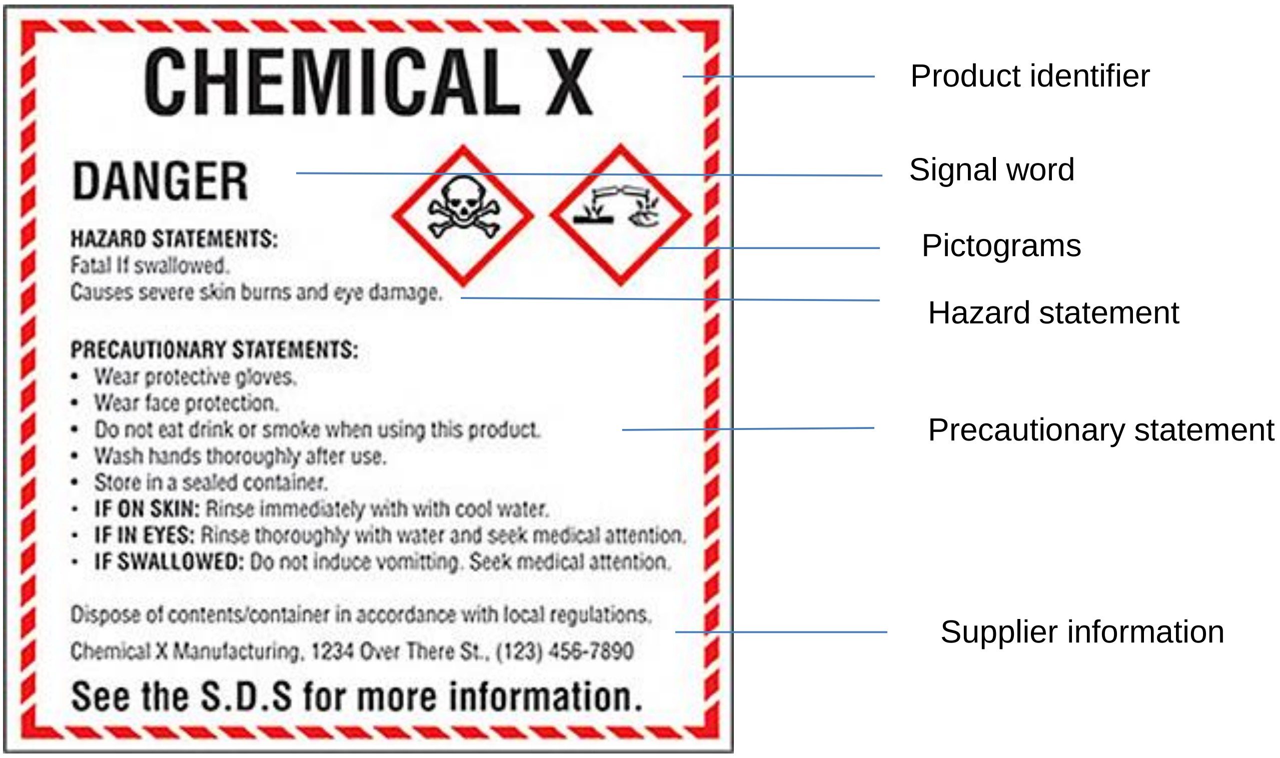

Figure 10: Label requirements in line with the GHS.

- Safety Data Sheets (SDS)

The Safety Data Sheet or SDS should provide comprehensive data about a substance or mixture for use in workplace chemical regulatory frameworks (UN, 2013). Winder *et al.* (2005) states that the SDS will allow “employers and workers to obtain concise, relevant and accurate information that can be put in perspective with regard to the hazards, uses and risk management of the chemical product in the workplace”. Every supplier, manufacturer, importer or distributor of a hazardous substance or mixture intended for use at a workplace shall ensure that the entity receiving such a substance or mixture is provided with an SDS, free of charge (SABS, 2008). SABS (2008) also states that the competent authority may request SDSs for mixtures not meeting the criteria for classification as hazardous but which contain hazardous substances in certain concentrations.

The information in the SDS should be presented using the following 16 headings in the order below (UN, 2013):

1. Identification
2. Hazard(s) identification
3. Composition/information on ingredients
4. First-aid measures
5. Fire-fighting measures
6. Accidental release measures
7. Handling and storage
8. Exposure controls/ personal protection
9. Physical and chemical properties
10. Stability and reactivity
11. Toxicological information
12. Ecological information
13. Disposal considerations
14. Transport information
15. Regulatory information
16. Other information

Over the past years significant progress has been made in many countries, especially developed countries towards adoption of the GHS (Peterson *et al*. 2010). While many developing and transition countries have recognised the value of developing and strengthening a basic system for the classification and labelling of chemicals according to the GHS as a fundamental component of sound management and as a contribution to facilitate safe trade (Peterson *et al*. 2010).

5.2.3 GHS in South Africa

Research by Dalvie *et al*. (2014) had indicated that the GHS had not yet been implemented in South Africa, although a GHS standard for use in local legislature was published and new legislation on classification and labelling of chemical substances in line with the GHS was drafted by the Department of Labour with the overall aim to strengthen national capacities for safe management of chemicals. The reason for this being was that at the time the United States Occupational Health and Safety Act (OHSA), which is a reference for South African legislation was still under review and going through major changes, furthermore the GHS was found to be out of line with the South African constitution (Dalvie, *et al.* 2014)

It was only in August 2013 that the GHS came into effect as a legislative requirement. However this was through the Department of Environmental Affairs and not the Department of Labour. The promulgation of The Waste Classification and Management Regulations (2013) provided a new means of classifying waste that would supersede the previous Minimum Requirements regime, amongst other things. Applicable waste streams would require classification in accordance with SANS 10234, the South African National Standard for the GHS. SABS (2008) states that the scope of the "standard covers the harmonized criteria for the classification of hazardous substances and mixtures, including waste, for their safe transport, use at the workplace or in the home according to their health, environmental and physical hazards". The scope of the standard also provides the harmonized communication elements for labelling and safety data sheets that have previously been discussed (SABS, 2008).

In the process of evaluating the possibility of replacing SANS 10228 with SANS 10234 (GHS) as basis for waste classification in South Africa, to ensure alignment with other systems and apply the most appropriate system, it was concluded that (DEAs, 2010):

- It would not be efficient or practical to have different systems for hazardous substances (products) and wastes.
- The GHS was not developed to focus on transport as is the case with SANS 10228. The additional/expanded hazard criteria related to human health and the environment in the GHS are appropriate considerations for waste handling, treatment and disposal.
- At first glance the difference between SANS 10228 and the GHS hazard classes and criteria seem extensive, however if the whole waste classification system of the Minimum Requirements is considered, the differences are not significant.
- Approach and methodology to hazard classification is similar in the GHS and SANS 10228.

5.2.4 Classifying UVCB substances under the GHS

Chapter 4 of this research provided insight into a group of substances with either unknown or variable composition, complex reaction products or biological materials; otherwise known as UVCB substances. Petroleum substances are one such group that fall into this category of UVCB substances due to their complex chemical make-up.

IPIECA (2010) states that the "consistent classification and labelling of petroleum substances is not straightforward due to the complex nature and chemistry of the substances". While the intent of the GHS is to cover all hazardous chemicals, the GHS does not define UVCBs or offer specific guidance on how the GHS should be applied to these specific substances (Clark *et al.* 2013). It was previously highlighted in this chapter how the GHS distinguishes between substances and mixtures and how the process for classification differs between the two. The process for evaluating mixtures is generally based on the hazards of their individual constituents and requires knowledge of the identity and toxicity of the individual components (Clark *et al*. 2013). In contrast, the constituents of UVCB substances are often undefined and no guidance is available under the GHS for evaluating their hazards (Clark *et al*. 2013). Classifying sludge from petroleum industries presents a further challenge due to the content of the sludge being comprised of these UVCB substances as well as other types of solvents, oils, greases additives and environmentally distributed waste material such as grit, dust and sand.

CHAPTER 6

Results and evaluation

This chapter presents the results obtained from the semi-structured interviews conducted. The results firstly indicate the challenges related to the classification of sludge within the South African petroleum industry and this is followed by an assessment of the possibility of a hierarchy amongst the challenges. The Chapter ends off by reviewing what is required in order to be compliant and this includes possible recommendations.

6.1 Interpretation of data

All data obtained from the semi-structured interviews was interpreted and analysed for this research. No distinctions were made between data gathered from Waste Generators, Waste Management Consultants and Waste Related Government Authorities

Figure 10 provides the results from the data analysed and indicates the challenges associated with the classification of sludge within the South African petroleum industry. These challenges are displayed in the form of categories developed from the coded data, and include a Lack of data from the waste generator, No classification standardisation, Limited analytical resources, High expenditure, Variable composition of the petroleum sludge, an Absence of regulatory guidance and lastly the insufficiency of SANS 10234. These challenges will be discussed in more detail.

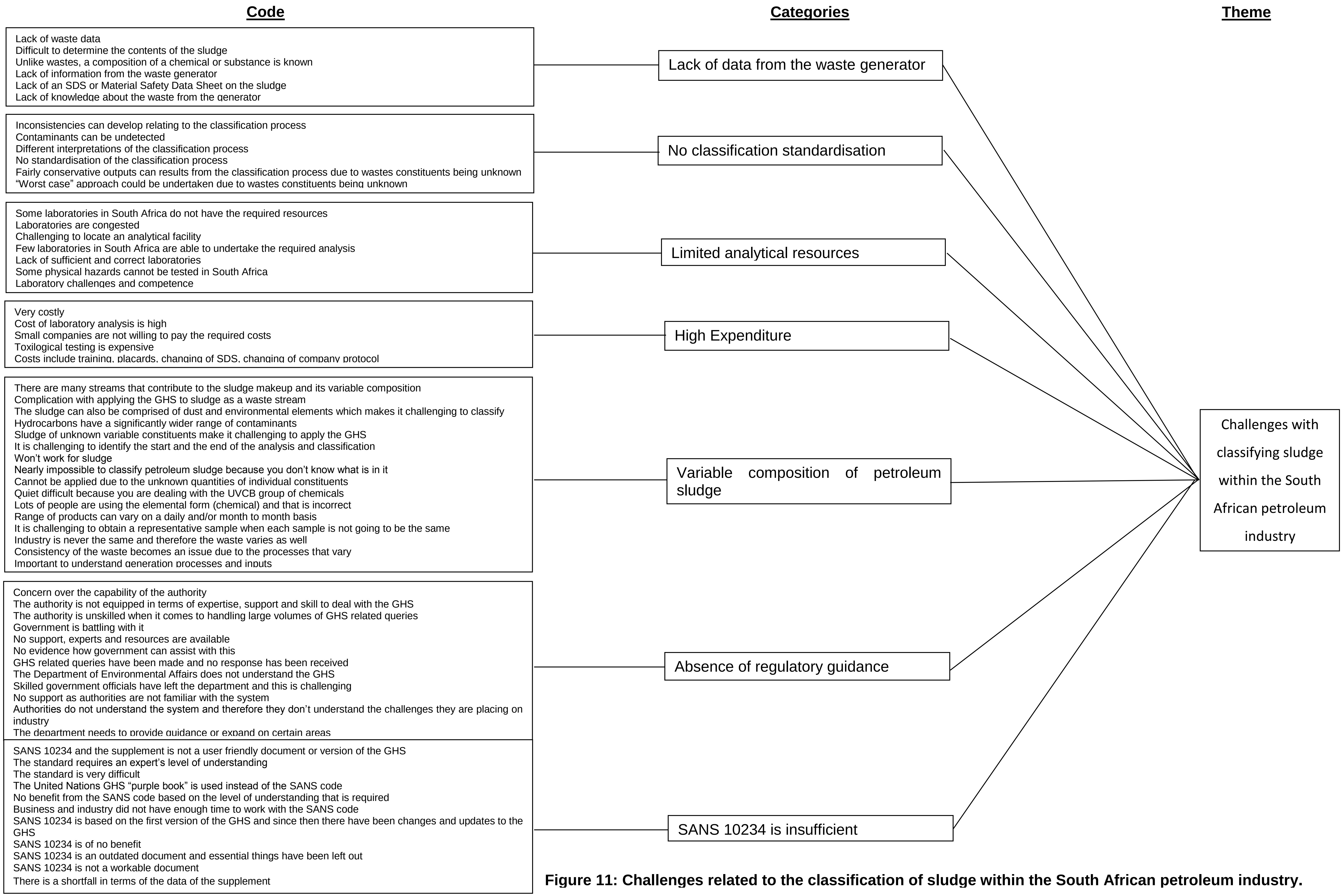

Figure 11: Challenges related to the classification of sludge within the South African petroleum industry.

6.1.1 Lack of data from the Waste Generator

Waste contains a variable amount of chemicals of unknown quantities. This is particularly true for petroleum based sludge that may contain anything from petroleum products (lead, unleaded petrol, crude), degreasers and various other solvents as well as environmentally distributed waste (grit, sand and debris). For chemicals that have been formulated, a material safety data sheet (MSDS) or safety data sheet (SDS) is provided by the supplier to the purchaser. However with petroleum sludge as well as other waste streams, an SDS is generated as part of the classification process. This however requires that information is provided by the waste generator regarding the composition of that particular waste stream. This is also identified as the first step in the GHS where it is referred to as the "identification of relevant data regarding the hazards of a substance or mixture" by the UN (2013). The challenge though, is that there is a lack of data and knowledge about not only petroleum sludge, but waste streams in general. Information is not readily made available from the generator and this includes applicable MSDS and SDS of the various constituents in the sludge. This has a greater impact on the waste management consultant tasked with the classification of the petroleum sludge as the lack of information makes the classification process challenging. It is of benefit to all parties (including the waste generator) if as much information as possible can be provided about the sludge as this will ensure that adequate information is made available about the waste and this will lead to a more effective and accurate classification of the sludge.

6.1.2 Variable composition of petroleum sludge

Some of the feedback from the interviews regarding the classification of petroleum sludge is that it is complicated, challenging, does not work or is impossible. This is due to the nature of petroleum sludge being comprised of various constituents in various quantities. Petroleum sludge may contain anything from petroleum products (lead, unleaded petrol, crude), degreasers, various other solvents as well as environmentally distributed waste (grit, sand and debris). It was previously highlighted in Chapter 4 by Clark *et al*. 2013 that "most petroleum products and the streams produced in petroleum refineries have been defined as substances with unknown or variable composition, complex reaction products or biological materials (UVCB substances)". The consistent classification and labelling of petroleum substances is not straightforward due to the complex nature and chemistry of the substances (IPIECA, 2010) and the GHS does not define UVCBs or offer specific guidance on how the GHS framework should be applied to these substances (Clark *et al.* 2013). Further to the UVCB content of petroleum sludge is that it may also contain other waste streams such as other organic and inorganic material and this will further complicate the classification process in line with the GHS. The petroleum sludge constituents can also often vary over a period of time as well as due to a result of change in business processes and activities.

6.1.3 No classification Standardisation

It was stated above that the variable composition of petroleum sludge makes the classification process more challenging. As a result of this variable composition, there is a possible chance that inconsistencies between waste management consultants classifying this particular waste stream could develop. Due to the GHS not providing guidance on the classification of UVCB substances which form a part of petroleum sludge, there is a chance that those conducting the classification process may either not take into account all possible contaminants or fairly conservative output results from the classification process could result. The different interpretation from various consultants and the lack of standardisation presents a challenge for the classification of petroleum sludge.

6.1.4 Limited analytical resources

There are challenges related to the laboratories that can conduct testing in line with the GHS requirements. The availability of the laboratories is a concern. Within South Africa it has been indicated that there are not enough laboratories that are able to conduct the required testing in line with the GHS. The result of this is that the available laboratories in South Africa are congested as companies aim for compliance within the required timeframe. Furthermore some of the laboratories that are available do not provide analysis for all the GHS requirements. For example some laboratories can only focus on certain organic analysis and some physical hazards cannot be tested in South Africa. Questions have also been raised with regards to the competence of laboratory staff in dealing with something as new as analysis in line with the GHS requirements.

6.1.5 High Expenditure

The classification of petroleum sludge in line with the GHS has been described as a very costly process. GHS related costs can be attributed to various sources such as training, the formulation of hazard communication such as placards and SDS as well as changes with regards to business activities and protocol. However the most significant cost can be attributed to laboratory analysis. The cost of analysis has been described as very high, particularly any testing that requires the appointment of a Toxicologist. Companies that are larger and more established may be able to absorb the significant costs related to the classification in line with the GHS, however smaller companies may not and therefore whether compliance is achieved amongst these smaller companies' remains to be seen.

6.1.6 Absence of regulatory guidance

There is a concern over the capability of the authority to provide any form of guidance or direction related to the classification in line with the GHS. The GHS is a relatively new form of classification in South Africa, hence concerns and challenges can be expected (as highlighted in this Chapter). Those providing the waste classification service might seek to gain guidance from the authorities to ensure that classification is done effectively and accurately, particularly for challenging waste streams such as petroleum sludge. Companies seeking to comply with the applicable regulations might also seek guidance from the regulator to ensure that what those waste management consultants are advising is correct (inconsistencies in the classification process). It has been suggested however that the authorities are not equipped in terms of the expertise, support and skill to deal with the GHS. Those providing the waste classification service have indicated that queries have not been attended to. Furthermore due to the authorities' limited understanding of the GHS, there is a limited understanding with regards to the challenges that are being placed on industry. The authorities have also acknowledged that more can be done to improve capacity.

6.1.7 SANS 10234 is insufficient

SANS 10234 is the South Africa National Standard for the GHS. The scope of the standard covers the harmonized criteria for the classification of hazardous substances and mixtures, and the standard also includes a supplement that provides the GHS classification and label elements of the most commonly used chemicals. All waste requiring classification in line with the GHS, needs to be done so according to SANS 10234. The standard itself is technical and is primarily utilised by those conducting the classification process. Many waste generators do not understand the standard and admit that it requires an expert's level of understanding. An accompanying guideline could perhaps bridge the knowledge gap between those conducing the classification process and the waste generators, therefore ensuring that the classification process is understood by all parties.

Although SANS 10234 is mostly used by those conducting the classification process, they themselves have indicated shortfalls with regards to the standard. SANS 10234 has been based on an earlier version of the GHS and therefore it is an outdated standard. Some interviewees have also indicated that they do not entirely make use of SANS 10234 but instead choose to use the GHS as published by the United Nations as a reference. Another challenge related to SANS 10234 includes the supplement falling short in terms of available data.

6.2 Hierarchy of challenges

Having discussed the challenges above which are a result from the categorisation of coded unstructured interview data, it is possible to identify a common link amongst the various challenges.

It was highlighted that petroleum sludge is comprised of varying constituents in different quantities. Petroleum products and the streams produced in petroleum refineries form a component of petroleum sludge and have also been referred to as UVCB substances. It has been indicated that the GHS does not provide guidance with regards to the classification of these UVCB substances. The variable composition of petroleum sludge may therefore be regarded as a key challenge related to the classification of petroleum sludge and as a result this challenge may influence the extent of the other challenges highlighted in Figure 11. The relationship between these challenges is indicated in Figure 12.

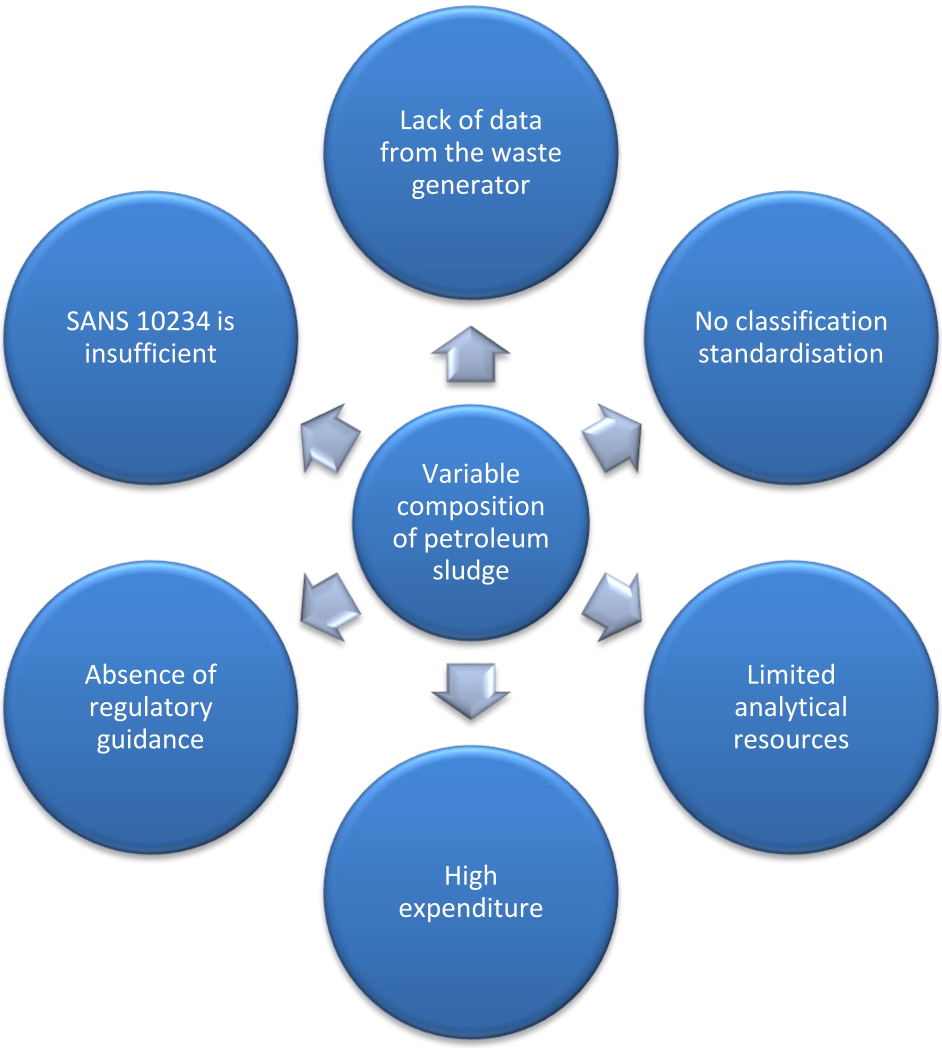

Figure 12: The influence of variable composition on the challenges related to the classification of petroleum sludge

Due to the variable composition of petroleum sludge, waste generators might not be familiar with the constituents that comprise the sludge and therefore may not have the required information regarding the composition of the sludge, such as SDS and MSDS. The variable composition of petroleum sludge may also play a role in the possibility that inconsistencies between companies could develop when classifying this particular waste stream. The absence of guidance from the GHS on UVCB substances plays a deciding factor in this and consultants conducting the classification process may either not take into account all possible contaminants or fairly conservative outputs resulting from the classification process may be presented.

The variability of petroleum sludge presents a further complication with regards to the use of laboratories for analysis. The variable nature of this waste stream means that applicable testing such as those for organic analysis and those related to the physical hazards of the waste may not be able to be undertaken as the laboratories in South Africa are not equipped to deal with this. Having to conduct this laboratory analysis for this variable waste stream will furthermore results in significant costs that the waste generator has to cover.

It was been mentioned that the variable composition of petroleum sludge has resulted in inconsistencies in the classification process between various consultants. Furthermore this variable composition has resulted in cases where those conducting the classification process as well as those seeking guidance to ensure that the correct level of compliance has been achieved have made queries with the applicable authority. However minimal feedback has been received and the opinion is that the authority is not capacitated to deal with the GHS as a requirement.

SANS 10234 is based on the GHS. It has been indicated in this research that the GHS does not provide guidance on the classification of UVCB substances, which form a component of petroleum sludge. Furthermore it has been indicated that SANS 10234 is based on an earlier version of the GHS and that the supplement falls short in terms of GHS classification and label elements of the most commonly used chemicals that could assist in the classification of challenging waste streams.

6.3 Recommendations

As part of the interview process, interviewees were further questioned on any possible recommendations that would assist them in ensuring that petroleum sludge is classified more effectively and accurately. Possible recommendations were then coded and grouped into categories in a similar manner as to what was done with the challenges. The categories represent the possible recommendations. Figure 13 provides an insight as to what recommendations have been provided. The results have indicated that the recommendations do not necessarily focus on each challenge as highlighted in Figure 11, but rather that they seek to address the key challenge of the variable composition of petroleum sludge in order to ensure effective classification takes place. For example, although limited analytical resources was highlighted as a challenge in Figure 11, a possible recommendation was not to increase the analytical resource capacity. These recommendations will be addressed in more detail. The recommendations and challenges highlighted in Figure 13 are important determinant factors when aiming to manage waste within the required “sphere” or level of compliance.

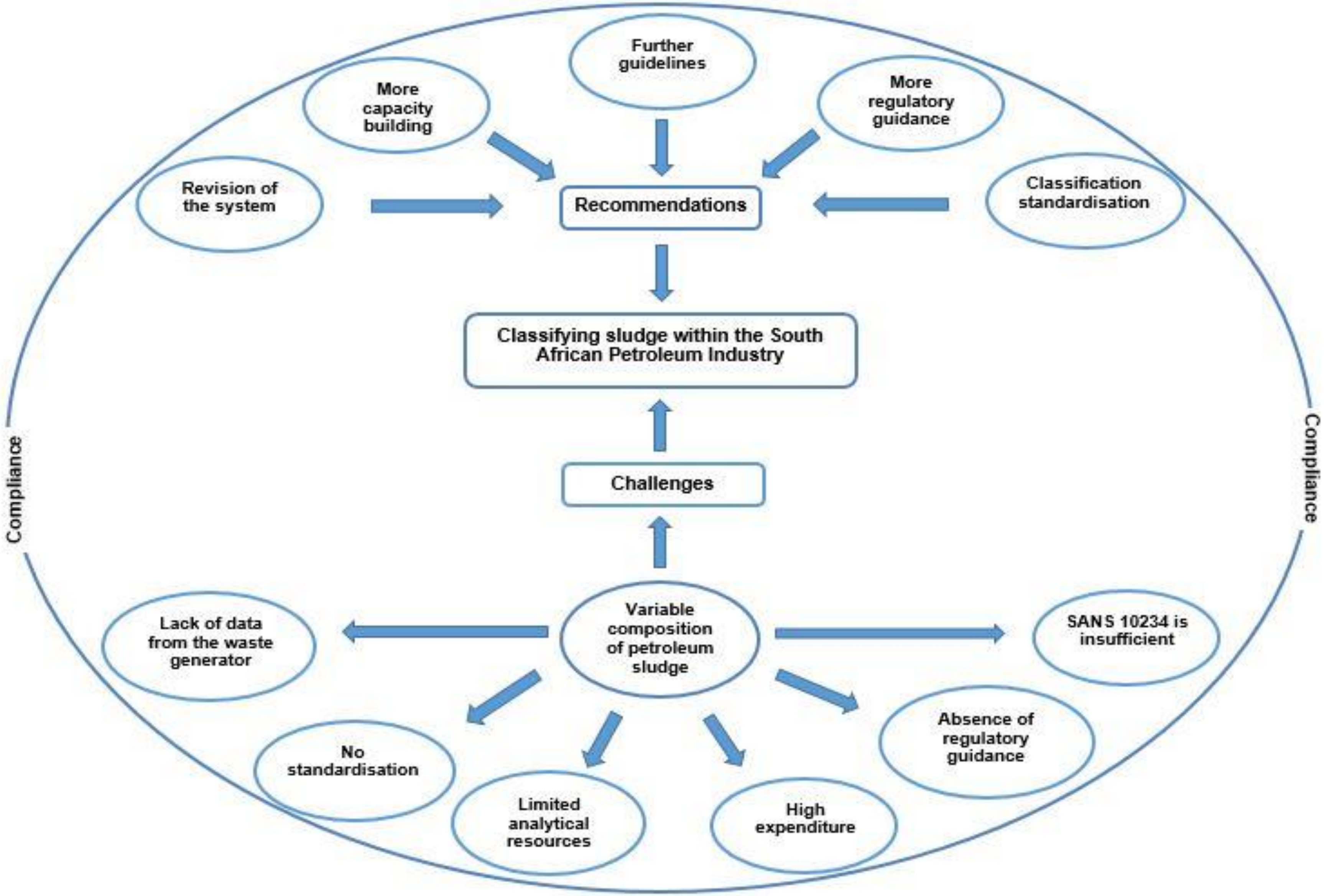

Figure 13: Compliant classification of sludge within the South African petroleum industry.

6.3.1 Revision of the system

A revision of the current waste classification system was suggested as a possible recommendation to improve the classification of petroleum based sludge. There was suggestions that the previous method for waste classification should be considered (The Minimum Requirements). A more common suggestion was that the current SANS 10234 should be revised and updated. This recommendation is not surprising considering that the inefficiencies of the SANS 10234 was considered a challenge as it was not based on one of the more recent versions of the GHS and because there were shortfalls in terms of the supplement data.

6.3.2 More capacity building

A recommendation that featured quiet frequently throughout the interview process was the need to build capacity related to the GHS. It was recommended that this be done through greater exposure, training and understanding of the GHS as well as more accessibility to forums for different stakeholders. The capacity building also needs to be broad based and address all stakeholders including waste generators, waste management consultants (service providers, legal representatives, laboratories) as well as authorities (national, provincial, municipal). Capacity building is especially important because the GHS is a relatively new concept in South Africa, it was initially introduced globally for the classification of chemicals (not waste) and also because feedback received from the interviews indicates that it is a technical process. A good recommendation was to get industry involved in capacity building for GHS implementation. This will ensure that those currently conducting the classification process can assist other stakeholders in ensuring that there is bridging of the required level of understanding, as well as also to provide an opportunity for standardisation of the classification process within industry.

6.3.3 Further Guidelines

Feedback from the interviews indicated that most waste generators found that SANS 10234 and the GHS was quiet a technical document and that little benefit was achieved from reviewing these related documents. A recommendation was that further guidelines should be developed that could bridge the gap between those wanting to achieve compliance (waste generator) and those waste management consultants conducting the classification process. This would ensure that waste generators are able to question the classification process and ensure that there is consensus for more challenging waste streams such as petroleum sludge. Furthermore a guideline could ensure that there is consistencies when classifying these challenging waste streams among various waste management consultants.

6.3.4 More regulatory guidance

A challenge that was raised was that there was an absence of regulatory guidance. Regulatory guidance was seen as beneficial because those providing the waste classification service might seek to gain guidance from the regulator to ensure that classification is done effectively and accurately particularly for challenging waste streams (petroleum sludge) while companies seeking to comply with the applicable regulations might seek guidance from the regulator to ensure that what those consultants are advising is correct.

It was therefore recommended that more guidance from applicable regulators would ensure the effective classification of challenging waste streams such as petroleum sludge. Suggestions relating to this recommendation include the provision of more resources to create awareness of the GHS as well as the attendance to various outstanding queries related to the GHS. Furthermore the DEA currently runs a quarterly forum for waste related issues and this platform can be used more effectively to address queries related to the GHS when dealing with issues such as classifying challenging waste streams. The improved guidance from authorities as a recommendation will need to be aligned to the previous recommendation relating to the increased training, workshops and seminars applicable to the GHS. Authorities were also identified as needing capacity building and this will need to be done to ensure that they can address the challenges and concerns raised by industry.

6.3.5 Classification standardisation

The need for a standardisation of the classification process in line with the GHS is of the utmost importance particularly for challenging waste streams such as petroleum sludge. From the interview data obtained, the lack of standardisation among those classifying petroleum sludge was raised as a challenge. It was suggested that industry waste classification plans should be developed for cross cutting applicable waste streams. These plans can also be presented to the relevant authority for approval. For example oil and petroleum companies could develop waste classification plans for addressing petroleum sludge and its variable constituents and this can be presented to the DEA as a proposal for implementation throughout industry. It was also suggested that a centralised system be created for waste classification in line with the GHS. This centralised system could comprise a database generated by the DEA in order to compare classification outputs and methodologies and to determine if there is continuity between various waste management consultants. Another centralised system could include a referral or centralised committee of skilled individuals to address concerns related to the GHS. Both these centralised systems could ensure that there is standardisation related to the classification of petroleum sludge.

Chapter 7

Conclusion

This chapter will conclude the research with an evaluation of the success of the objectives and the main research aim stated in chapter 1. The chapter will also focus on areas of possible future research.

7.1 Evaluation of research objectives

The success of the research is dependent on whether or not the research objectives stated in Chapter 1 have been achieved as well as the achievement of the overall research aim. The indication of recommendations or a way forward is also testament to the success of the research.

7.1.1 To review the legal framework for the classification of waste in South Africa.

The review of the legal framework was successfully completed and entailed historical as well as current legislative requirements related to the classification of waste in South Africa. The review highlighted the requirements of The Environmental Conservation Act no. 73 of 1989, The National Environmental Management Act No. 107 of 1998, The National Environmental Management: Waste Act No. 59 of 2008, The National Waste Management Strategy (2012) and The Waste Classification and Management Regulations (2013). The review also highlighted the legislative requirements of The Waste Management Series and more specifically The Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste, as well as the requirements of SANS 10234, the South African National Standard for the GHS.

7.1.2 To investigate the generation and composition of sludge within the South African petroleum industry.

The investigation relating to the generation and composition of sludge within the South African petroleum industry was completed successfully. This type of sludge can be referred to as oily, hydrocarbon or petrochemical sludge, however for this research the term petroleum sludge was considered. The variability in crude oil was firstly highlighted and this was followed by a brief assessment of the petroleum refining process. Insight was provided with regards to the term UVCB substances; a group which includes petroleum substances as they are either unknown or variable composition, complex reaction products or biological materials. The complex composition of petroleum sludge was highlighted as including both UVCB substances as well as other organic and inorganic material.

7.1.3 To review what was the Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste in terms of previous environmental legislation.

The Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste was successfully reviewed. The review included an analysis of the four steps for the Hazardous Waste Classification System including the use of SANS 10228 (The South African National Standard for the identification and classification of dangerous goods for transport by rail and road modes), the treatment and disposal of Hazardous Waste and the landfill class allocation. The review in terms of the Minimum Requirements also highlighted waste handling, storage and transportation in terms of packaging and labelling requirements.

7.1.4 To Review what is the Globally Harmonised System of classification and labelling of chemicals (GHS) in terms of current environmental legislation.

The review of the GHS was successful and included a look at the background and need for a globally harmonised system. The review then highlighted the implementation requirements of the GHS in terms of Hazard Classification and Hazard Communication. Lastly the application of the GHS in South Africa was highlighted as well as the challenges related to the classification of UVCB substances.

7.1.5 To investigate what the challenges are related to the current methodology of waste classification for sludge within the South African petroleum industry.

This objective was successfully reached though the conducting of semi-structured interviews. The challenges related to the current methodology of waste classification for sludge within the South African petroleum industry was determined to be:

- Lack of data from the waste generator
- No classification standardisation
- Limited analytical resources
- High expenditure
- Variable composition of petroleum sludge
- Absence of regulatory guidance
- SANS 10234 is insufficient

It was further determined that the variable composition of petroleum sludge was a key challenge and influenced the extent of the other challenges.

Recommendations were also successfully determined through the semi-structure interview process as being:

- Revision of the system
- More capacity building
- Further guidelines
- More regulatory guidance
- Classification standardisation

It was determined that both the challenges and recommendations related to the current methodology of waste classification for sludge within the South African petroleum industry were important factors to consider when aiming to comply with the applicable environmental legislation.

7.2 Areas of future research

The research focused specifically on the challenges related to the classification of waste within the South African petroleum industry. It was determined that the key challenge was due to the variable composition of petroleum sludge. There are however other waste streams that due to their variable composition could also present challenges in terms of classification. These waste streams include fly ash from coal burning and slags from smelting or ore refining operations. It would be of value to determine if the challenges vary between these waste streams for comparative purposes and whether possible recommendations can also be determined as a way forward to assist the applicable industries with the relevant compliance.

The research focused on the overall challenges experienced by different role players with regards to the classification. Although the results from the semi-structured interviews did indicate that some challenges were more prevalent amongst some role players more than others (for example the technical aspects of the GHS was raised as a concern more amongst waste generators), the research did not specifically aim to look at whether the challenges varied amongst the role players (waste generator, waste management consultants and waste related regulators). Investigating this possible variance could be of benefit and this could also be expanded to other possible challenging waste streams.

The research focused primarily on the management implications related to the classification of sludge within the South African petroleum industry. The GHS is a technical and chemically analytical process and throughout the interviews reference was made to some of these more analytical challenges. It would be of value if further research could focus on these more analytical challenges not only for petroleum sludge, but also other more challenging waste streams. Input from those conducting the chemical analysis such as the relevant laboratories as well as Toxicologists would be of great benefit for the research.

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Appendix A: Semi-structured interview questions

- What is your name, title and company that you work for?
- Can you provide a brief description of the work you do?
- Are you familiar with the GHS (SANS 10234) as part of the Waste Classification and Management Regulations (August, 2013)?
- How did you come about knowing about the GHS as a requirement?
- What is your general opinion on the GHS as a system for the classification of waste?
- Do you know what is meant by petroleum sludge as a waste stream?
- What is your opinion on the GHS as a system for the classification of petroleum sludge?
- What role do you play in ensuring that the classification of petroleum sludge takes place in terms of the GHS?
- What challenges have you experience in fulfilling your role?
- What financial implications have you experienced or foreseen, with regards to the classification of petroleum sludge in line with the GHS?
- What institutional implications have you experienced or foreseen, with regards to the classification of petroleum sludge in line with the GHS?
- Is the SANS 10234 standard and the related supplement on the GHS of any benefit to you fulfilling your role, and if not, why?
- Do you make use of the SANS 10234 standard and the related supplement on the GHS in order for you to fulfil your role, and if not, why?
- Which parts of SANS 10234 standard and the related supplement on the GHS are not clear in terms of you fulfilling your role?

- Which parts of the SANS 10234 standard and the supplement on the GHS are of the most beneficial in terms of you fulfilling your role?

- Do you have any recommendations that would allow you to better fulfil your role in ensuring that the classification of petroleum sludge takes place in terms of the GHS?

Appendix B: Pre-classified wastes as listed in Annexure 1 of the Waste Classification and Management Regulations (South Africa, 2013)

Annexure 1: Wastes that do not require Classification or Assessment

(1) The wastes specified in item 2 of this Annexure do not require classification in terms of Regulation 4(1), nor assessment in terms of Regulation 8(1)(a).

(2) (a) General waste—

(i) Domestic waste;

(ii) Business waste not containing hazardous waste or hazardous chemicals;

(iii) Non-infectious animal carcasses;

(iv) Garden waste;

(v) Waste packaging;

(vi) Waste tyres;

(vii) Building and demolition waste not containing hazardous waste or hazardous chemicals; and

(viii) Excavated earth material not containing hazardous waste or hazardous chemicals.

(2) (b) Hazardous waste—

(i) Waste Products:

- Asbestos Waste;
- PCB waste or PCB containing waste (> 50 mg/kg or 50 ppm); and
- Expired, spoilt or unusable hazardous products.

(ii) Mixed Waste:

- General waste, excluding domestic waste, which contains hazardous waste or
- Mixed, hazardous chemical wastes from analytical laboratories and laboratories from academic institutions in containers less than 100 litres.

(iii) Other:

- Health Care Risk Waste (HCRW).

Appendix C: Hazard types, classes and categories of the GHS

Physical Hazards

Hazard Class	Hazard Category	Hazard Statement (Characteristics)
Explosives	Unstable Explosive	Unstable explosive
	Division 1.1	Explosive; mass explosion hazard
	Division 1.2	Explosive; severe projection hazard
	Division 1.3	Explosive; fire, blast or projection
	Division 1.4	Fire or projection hazard
	Division 1.5	May explode in fire
	Division 1.6	No hazard statement
Flammable Gases	1	Extremely flammable gas
	2	Flammable gas
	A (Chemically unstable gases)	May react explosively even in the absence of air
	B (Chemically unstable gases)	May react explosively even in the absence of air at elevated pressure and/or temperature
Aerosols	1	Extremely flammable aerosol
	2	Flammable aerosol
	3	Pressurised container
Oxidizing gases	1	May cause or intensify fire, oxidizer
Gases under pressure	Compressed gas	Contains gas under pressure; may explode if heated
	Liquefied gas	Contains gas under pressure; may explode if heated
	Refrigerated liquefied gas	Contains refrigerated gas; may cause cryogenic burns or injury
	Dissolved gas	Contains gas under pressure; may explode if heated
Flammable liquids	1	Extremely flammable liquid and vapour
	2	Highly flammable liquid and vapour
	3	Flammable liquid and vapour
	4	Combustible liquid
Flammable solids	1	Flammable solid
	2	Flammable solid

Health Hazards

Hazard Class	Hazard Category	Hazard Statement (Characteristics)
Acute toxicity	1 Oral Dermal Inhalation	Fatal if swallowed
		Fatal in contact with skin
		Fatal if inhaled
	2 Oral Dermal Inhalation	Fatal if swallowed
		Fatal in contact with skin
		Fatal if inhaled
	3 Oral Dermal Inhalation	Toxic if swallowed
		Toxic in contact with skin
		Toxic if inhaled
	4 Oral Dermal Inhalation	Harmful if swallowed
		Harmful in contact with skin
		Harmful if inhaled
	5 Oral Dermal Inhalation	May be harmful if swallowed
		May be harmful in contact with skin
		May be harmful if inhaled
Skin corrosion / irritation	1	Causes severe skin burns and eye damage
	2	Causes skin irritation
	3	Causes mild skin irritation
Serious eye damage / eye irritation	1	Causes serious eye damage
	2/2A	Causes serious eye damage
	2B	Causes eye irritation
Respiratory sensitization	1	May cause allergy or asthma symptoms or breathing difficulties if inhaled
	1A	May cause allergy or asthma symptoms or breathing difficulties if inhaled
	1B	May cause allergy or asthma symptoms or breathing difficulties if inhaled
Skin sensitization	1	May cause an allergic skin reaction
	1A	May cause an allergic skin reaction
	1B	May cause an allergic skin reaction

Environmental Hazards

Hazard Class	Hazard Category	Hazard Statement (Characteristics)
Hazardous to the aquatic environment, short-term (acute)	Acute 1	Very toxic to aquatic life
	Acute 2	Toxic to aquatic life
	Acute 3	Harmful to aquatic life
Hazardous to the aquatic environment, long-term (chronic)	Chronic 1	Very toxic to aquatic life with long lasting effects
	Chronic 2	Toxic to aquatic life with long lasting effects
	Chronic 3	Harmful to aquatic life with long lasting effects
	Chronic 4	May cause long lasting harmful effects to aquatic life
Hazardous to the ozone layer	1	Harms public health and the environment by destroying ozone in the upper atmosphere

Self-reactive substances and mixtures	Type A	Heating may cause an explosion
	Type B	Heating may cause a fire or explosion
	Types C and D	Heating may cause a fire
	Types E and F	Heating may cause a fire
	Type G	-
Pyrophoric liquids and solids	1	Catches fire spontaneously if exposed to air
Self-heating substances and mixtures	1	Self-heating; may catch fire
	2	Self-heating in large quantities; may catch fire
Substances and mixtures, which in contact with water, emit flammable gases	1	In contact with water releases flammable gases which may ignite spontaneously
	2	in contact with water releases flammable gases
	3	In contact with water releases flammable gases
Oxidizing liquids and solids	1	May cause fire or explosion; strong oxidiser
	2	May intensify fire; oxidiser
	3	May intensify fire; oxidiser
Organic peroxides	Type A	Heating may cause an explosion
	Type B	Heating may cause a fire or explosion
	Type C and D	Heating may cause a fire
	Types E and F	Heating may cause a fire
	Type G	-
Corrosive to metals	1	May be corrosive to metals

Germ cell mutagenicity	1A and 1B	May cause genetic defect
	2	Suspected of causing genetic defects
Carcinogenicity	1A and 1B	May cause cancer
	2	Suspected of causing cancer
Reproductive toxicity	1A and 1B	May damage fertility or the unborn child
	2	Suspected of damaging fertility or the unborn child
	Additional Category for effects on or via lactation	May cause harm to breast-fed children
Specific target organ toxicity-single exposure	1	Causes damage to organs
	2	May cause damage to organs
	3	May cause respiratory irritation or May cause drowsiness or dizziness
Specific target organ toxicity-repeated exposure	1	Causes damage to organs
	2	May cause damage to organs
Aspiration hazard	1	May be fatal if swallowed and enters airways
	2	May be fatal if swallowed and enters airways