# Legal compliance challenges for the management of waste from the explosives sector: A South African case study

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# PREFACE AND ACKNOWLEDGMENTS

Conducting research on ***"Legal compliance challenges for the management of waste from the explosive sector: A South African case study"*** is considered useful to the explosives industry. The research aimed to identify the current legislative framework applicable to explosives waste management, to identify areas of non-compliance and challenges with achieving compliance, and to, ultimately, provide recommendations for improved compliance. Although the research was conducted on a specific case study, the findings of the research may be useful to other explosives manufacturers or other sectors dealing with explosives wastes in South Africa.

I am thankful to all my departed family who could not physically witness this journey but were always there in spirit. To my husband Matlhomola Mmolai and our three beautiful children Reneilwe, Atlegang and Reatlegile for providing constant support, love and motivating me.

I am grateful to all my colleagues who took their time to respond to the questionnaire and Mr Tami Mudau for his support, time and knowledge in the subject matter.

Lastly, I would like to thank my supervisor, Dr Claudine Roos, who was very patient with me, allocated time to listen and provided guidance. This study could only be done under the guidance of my mentor and supervisor.

# ABSTRACT

Explosives waste generation is a universal problem because of its complex and hazardous nature. Despite the well-known negative impacts of explosive waste on the environment, there has been very little research on the governance of these waste streams, especially in the evaluation of the legislative framework and legislative compliance.

This study aimed to determine the legal framework applicable to the management of explosives wastes in South Africa, and to examine legal compliance challenges in the explosives sector. This was done by using a South African explosives manufacturer as a case study, focusing on the life cycle of explosives waste management – from generation, including the explosive destruction process to final disposal.

To achieve the aim of this study, three research objectives were researched through the collection of primary and secondary data. The methodology of data collection included literature review, the review of previous audit reports, conducting interviews, performing on-site observations, as well as a legal verification on selected legislation applicable to the scope of this study.

The findings of the research revealed that legal compliance status of the explosives manufacturer has improved over the past five years, and that the manufacturer was generally in compliance with applicable legislation at the time of the research study being conducted. There were, however, some areas of non-compliance, where these non-compliances may cause negative environmental impacts. Non-compliances related to explosives waste management were related to the storage of explosives waste exceeding the storage capacity, transportation of uncovered explosives waste, which can be easily blown away by the wind and result in contamination of the exposed area. The outcomes of the interviews indicated that employees did not receive appropriate training from local authorities on the requirements for the handling and disposal of explosives wastes, and interviewees perceived a lack of emphasis on explosives waste recycling.

The study has provided different recommendations to appropriately manage legal compliance challenges by the explosive sectors. From lessons learned from the developed world, this research recommends that government officials should take the lead in ensuring that explosives manufacturing sectors level of legal compliance is enforced and continuously monitored.

***Key terms:*** Explosive Waste, Open burning, Waste disposal, Legal compliance and Waste management.

# ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ACOP | Approved Code of Practice |
| AEL | Atmospheric Emission License |
| AITG | International Ammunition Technical Guidelines |
| CIE | Chief Inspector of Explosives |
| CWC | Chemical Weapon Conventions |
| DoD | Department of Defence |
| EPA | Environmental Protection Agency |
| EIA | Environmental Impact Assessment |
| FFCA | Federal Facilities Compliance Act |
| IRP | Installation Restoration Program |
| NAAQS | National Ambient Air Quality Standards |
| NAEIS | National Atmospheric Emission Inventory System |
| NEMA | National Environmental Management Act No 107 of 1998 |
| NEMAQA | National Environmental Management Air Quality Act No 39 of 2004 |
| NEMWA | National Environmental Management Waste Act No 59 of 2008 |
| NEPA | National Environmental Policy Act |
| OBOD | Open Burning Open Destruction |
| OHSAct | Occupational Health and Safety Act No 85 of 1993 and Regulations |
| PEP | Propellant Explosive Pyrotechnic |
| RCRA | Resource Conservation and Recovery Act of 1976 |
| RSA | Republic of South Africa |
| SAWIS | South African Waste Information System |

# KEY DEFINITIONS

**Air pollution**

Means any change in the composition of the air caused by smoke, soot, dust (including fly ash), cinders, solid particles of any kind, gases, fumes, aerosols and odorous substances

**NEMAQA RSA (2004)**

**Atmospheric emission**

Means any emission or entrainment process emanating from a point, non-point or mobile source that results in air pollution

**NEMAQA (RSA, 2004)**

**Burning grounds**

A fenced-in area with controlled entrance where explosives may be exposed to a naked flame under safe controlled conditions

**Explosives Regulations GNR.109 of 17 (RSA, 2003c)**

**Disposal**

The removal of ammunition and explosives from a stockpile utilising a variety of methods, (that might not necessarily involve destruction). Logistic disposal may or may not require the use of RSP **Wilkinson (2006)**

**Disposal**

Means the burial, deposit, discharge, abandoning, dumping, placing or release of any waste into, or onto, any land

**NEMWA (RSA, 2008)**

**Destruction**

The process of final conversion of ammunition and explosives into an inert state that can no longer function as designed. **Wilkinson (2006)**

**Explosives**

Means a substance or a mixture of substances, in a solid or liquid state, which is capable of producing an explosion; (b) a pyrotechnic substance in a solid or liquid state, or a mixture of such substances, designed to produce an effect by heat, light, sound, gas or smoke, or a combination of these, as the result of non-detonative self-sustaining exothermic chemical reaction, including pyrotechnic substances which do not evolve gases; (c) any article or device

containing one or more substances contemplated in paragraph (a); (d) any plastic explosive; or (e) any other substance or article which the Minister may from time to time by notice in the Gazette declare to be explosive.

**Explosives Act (15 of 2003)(RSA, 2003b)**

**Explosives manufacture**

The making or processing of any explosive including the division of any explosive from its component parts by any process, and the conversion of any explosive of one kind into an explosive of another kind, including the alteration, fitting for use, testing, on-site manufacture, repair or destruction of any explosive

**Explosives Regulations GNR.109 of 17 (RSA, 2003c)**

**Point source**

Means a single identifiable source and fixed location of atmospheric emission, and includes smoke stacks and residential chimneys

**NEMAQA (RSA, 2004)**

**Waste**

Means any substance, material or object, that is unwanted, rejected, abandoned, discarded or disposed of, or that is intended or required to be discarded or disposed of, by the holder of that substance, material or object, whether or not such substance, material or object can be re-used, recycled or recovered and includes all wastes as defined in Schedule 3 to this Act but it excludes explosives waste.

**NEMWA (RSA, 2008)**

**Waste**

Includes any solid material or material bat that is suspended, dissolved or transported in water (including sediment) and which is spilled or deposited on land or into a water resource in such volume composition or manner as to cause, or to be reasonably likely to cause the water resource to be polluted

**NWA(RSA, 1998b)**

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# CHAPTER 1 INTRODUCTION

## 1.1 Background

The South African explosives industry has developed significantly since the discovery of gold in 1886 in Witwatersrand, with Johannesburg emerging as the most engaging markets for dynamite, globally. This industry has grown exponentially over the past few decades (Agrawal, 2010). The explosives industry, being an integral component of modern society, conducts activities leading to the production of waste as a consequence of explosives production and destruction (Astratov *et al*., 1997).

Explosives manufacturing comprises chemical processes involving organic compounds' nitration, and associated activities involving recovery and manufacture of acids (Akhavan, 2011). The manufacturing and eventual destruction of explosives and explosive compounds result in the generation of liquid, solid and gaseous wastes.

*Explosive wastes* mainly refer to products of poor-quality and explosives wastes generated during the production, marketing, storage and use of explosives, as well as the end-products of the explosive destruction process (Duijm and Markert, 2002). Considerable volumes of explosive wastes are produced in South Africa each year, containing potentially toxic or dangerous elements such as high levels of nitrogen, polychlorinated dibenzo-dioxins, polychlorinated dibenzo-furans and rotary kiln (Noyes, 1996). The negative impacts of wastes related to the production, handling and disposal of explosives to the environment and human health have received significant research attention and are well-known (Cairns and Dickson, 1973, Ryon *et al*., 1984, Steuckart *et al*., 1994, Simini *et al*., 1995, Brannon and Pennington, 2002, Letzel *et al*., 2003, Ana *et al*., 2012).

The generation of explosives wastes may result in environmental impacts through manufacturing processes involving nitrates and acids, emission of hazardous gases, and the disposal of solid wastes in the form of sludge due to incineration residues. These activities may result in adverse impacts on the surface and groundwater quality, air pollution, and human health (Carrol *et al*., 1979, Hudak and Parsons, 1977, Shen *et al*., 2009, Barreto-Rodrigues *et al*., 2009). These impacts may also lead to global effects such as ozone depletion and global warming (Duijm and Markert, 2002, Zhou and Schoenung, 2009).

The environmental impacts of activities, products and services are fast-moving up the priority level of industries today. The Johannesburg and Beyond: 2002 World Environment Summit United Nations (2002) and the Sustainable Development Goals (United Nations, 2015) emphasise the importance of sustainable development and its relationship to environmental protection. These requirements are equally applicable to the explosives sector. This implies that the activities related to the sourcing of the unprocessed materials, manufacturing, utilisation and disposing of explosives;

need to be managed sustainably. According to the South African Constitution RSA (1996a), in particular Section 24, provision is given to everyone with the right to an "*environment that is not harmful to their health and well-being, and the right to have the environment protected through reasonable legislative and other measures"*.

The type of impacts expected from the destruction and disposal of explosives may differ, based on the type of technology or activity used (Poulin, 2010); Duijm and Markert (2002), and each technology or activity may present its own set of legal requirements, which could be challenging to implement.

### 1.2 Problem statement and rationale for the study

There is an understanding for the need to minimise the environmental impacts from all affected stakeholders, and the explosive sector is no exception (Alverbro *et al*., *2009)*. The manufacturing of explosive materials for use in military or commercial product applications results in the generation of complex hazardous waste streams (Doel, 2016), which are unsafe to treat with conventional methods of hazardous waste management.

In ensuring the regulation of explosives management and resultant waste, numerous pieces of legislation have been gazetted – some focusing on the protection of health and wellbeing, and others on the environmental protection. Internationally, the Environmental Protection Authority (EPA)-developed the *Resource Conservation and Recovery Act* (RCRA) which is a public law providing the guidelines for the proper management of hazardous and non-hazardous solid waste (EPA, 2017), and provides for the regulation of military munition (King, 1998).

The fragmented nature and the multiple requirements of the legislation applicable to the management of explosives wastes may create an environment where the compliance and enforcement of these requirements are problematic.

Limited studies focusing on compliance with legislation regarding the disposal of explosives have been done in relation to the country's (RSA) context. This study aims to understand the legal framework applicable to the disposal of explosives, and to understand possible challenges or obstacles to compliance, by focusing on a selected South African explosives manufacturing plant.

### 1.3 Research aim / objective / question

In the context of the complex legislative environment created by numerous pieces of legislation applicable to the management of waste from the explosives sector, the aim of the research is to critically evaluate the challenges of legal compliance for the management of waste by the explosives sector.

The objectives of the study are to:

- ***Research objective 1:*** Determine the legal framework applicable to the management of waste by the explosive sector;
- ***Research objective 2:*** Evaluate compliance of a specific explosives manufacturer to the legal requirements for the management of explosives waste, as a case study; and
- ***Research objective 3:*** Identify challenges and opportunities for achieving legal compliance.

## 1.4 Delineating the scope of the study

The sections below delineate the scope of the study in terms of its content (or focus), the study area and time (and duration) during which the research was conducted.

### 1.4.1 Content

The explosives waste life cycle consists of five major stages indicated in Figure 1-1, starting with the generation of explosives waste and moving on to the handling and storage of these explosives wastes as the second stage. From there, these wastes are destroyed through technological methods in the third stage, known as the destruction of explosives waste. Next, the waste residue classification, storage and handling are conducted in the fourth stage when it finally moves to the fifth stage where the waste residue is transported for final disposal. However, due to the major focus of the study on the challenges of legal compliance from explosives waste disposal, its scope ranges from the second to the fourth stage consisting of four key stages. Each stage is discussed in detail in Chapter 3 (Literature Review) to provide an understanding of the effect that each of these stages may have on the environment.

### 1.4.2 Study area

The study is based on a South African explosive manufacturer as a case study. The site is a manufacturer of propellant, explosive and pyrotechnic (PEP) materials for use in military or commercial product applications, which results in the generation of a complex hazardous waste stream that includes waste PEP compositions, reject components and munitions, and a diverse range of packaging materials and equipment contaminated with explosive materials. The site is located in the North-West Province, but site-specific details have been excluded for the sake of confidentiality.

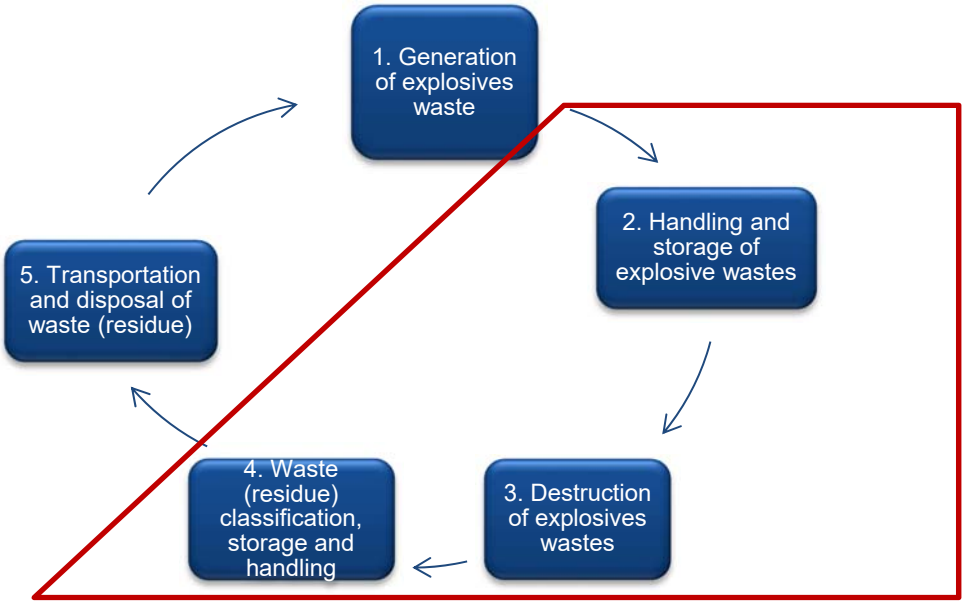


**Figure 1-1: The stages of the explosives waste life cycle, indicating the scope of this research**

### 1.4.3 Time

The study was based on activities conducted and audits conducted between 2010 and 2019. The time has been selected focusing on the number of legal compliance audits conducted at the said site. In providing a clear high level view of an organisation's legal compliance at a particular time, it will be required to undertake a legal compliance audit (Baer, 2009). The objective of the legal compliance audit is to ensure that any possible evidence of non-compliance, unauthorised deviations and legal compliance risk factors impacting negatively on the organisation and its entire operations are brought forward. There is no legal requirement prescribing the frequency of the legal compliance audits for the explosives manufacturing sector, however, for the chosen case study the legal compliance audit is conducted every two years (biennially).

## 1.5 Assumptions and limitations of the research

Despite the comprehensive and detailed information included in the research study, there are some limitations of the research that need to be taken into consideration. Although the dissertation focuses on the major environmental implications and associated issues of explosive waste disposal, the research is mostly based on the literary and scholarly work conducted by other authors in the past. For this reason, the environmental implications are based on the previously available data and fail to include the current impact. With the various technological advancements in explosives waste disposal, the current effects might have changed and the report fails to conduct a study or analysis of its own. The information on the impacts of the environment are however, provided for contextual background purposes and is excluded from the main objectives of this study.

The evaluation of legal compliance for the disposal of explosive wastes was conducted according to South African legal requirements, more specifically focusing on the *Manufacture and Storage of Explosive Regulations 2005* under the Approved Code of Practice (ACOP). The dissertation provides an overview of compliance of the selected case study of the requirements of Regulation 6 of the ACOP, which provides the four most effective ways to dispose of or destroy explosives. This regulation, however, fails to consider the updated environmental consequences mentioned in the Earth Summit.

### 1.6 The possible contribution of the research

The research examines the generation of explosives wastes, its handling and storage, destruction and residue classification for a selected case study within the South African context, where limited research has been done on legal compliance by the explosives sector. The contribution of the research is in creating an understanding of the application of the legal frameworks for explosives waste management and understanding challenges with legal compliance in the country. The results of the research may assist other explosives manufacturing organisations in identifying applicable legislation and address gaps in legal compliance. Limited research has been done in South Africa on the challenges faced by the explosive sector concerning legal compliance when handling and destructing explosive waste. This research intends to develop knowledge of the requirements for the handling, storage and destruction of the explosive wastes.

### 1.7 Structure and outline of the dissertation

The structure of the dissertation is outlined as follows:

***Chapter 1: Introduction***

This chapter presents the background to the research problem statement, research aim, objectives of the research, research questions, problem statement and the outline of the rest of the study.

***Chapter 2: Methodology***

The chapter focuses on data collection that is essential in the study. The appropriate design, relevant to answer the questions related to the research will be identified, defined and motivated to provide a clear understanding. The research population and its sampling size will be clearly described in the study. The specific and appropriate measuring instruments, will be chosen and applied for each of the identified variables. The credibility, reliability and validity of the measuring instruments will also be taken into account.

***Chapter 3: Literature review***

The research overview of the international and national legislation and the role that legislation plays in business with a special emphasis in creating competitive advantage and fair broad knowledge of

the topic will be outlined in this chapter. All variables and their contestation among different theories involved in the study, will be clearly defined and described from literature. The results of the most pertinent studies in the field (both internationally and nationally) will be consolidated into a coherent discussion.

***Chapter 4: Results/ Data analysis and discussion***

The chapter will present the outcomes of the data analysis based on the respondents' feedback in relation to the variables identified, in an attempt to test the literature studied. Specific and appropriate data analysis techniques will be described to address each of the three objectives of the study. A clear motivation of the technique, relevance will be clarified and explained. Presentation of results will be in graphic form, table illustrations and charts to simplifying the findings.

***Chapter 5: Conclusion and Recommendation***

The chapter will provide a conclusive view of the fundamental common or/and deferential factors between the literature theories and the actual results presented in chapter four and their impact on the current and prospective studies. This chapter will also necessitate for providing of recommendations based on the findings both progressively and correctively.

## 1.8 Chapter summary

The evaluation of the legal requirements applicable to explosives waste, its storage, handling, destruction and other associated activities, and compliance to these requirements may provide an understanding of the current challenges that the sector are facing. This research aims to assess and examine the applicable legal frameworks for explosive wastes within the South African context. This chapter provided the background, problem statement, as well as the aim and objectives of the research. Chapter two elaborates on the methods followed to conduct the research.

# CHAPTER 2 METHODOLOGY

## 2.1 Introduction

According to Kumar (2019), there are several methodologies that can be considered by the researcher and the intention of the research would dictate the choice of the research methodologies to address specific research questions. This chapter focuses on the research design, methods of data collection as well as data analysis procedures.

## 2.2 Research design

Creswell and Creswell (2017) state that the design of the research should be considerate of the intended outcomes, as well as the factors which may influence data collection and integrity. The research design intends to establish the means of data collection to, ultimately, reach conclusions and make recommendation (Yin, 2003).

This study was based on exploratory research using a case study and a qualitative data collection method. The main purpose for using a case study was to gain insight into real-life situations and to provide a comprehensive description and analysis of a single, bounded unit situated in a specific environment (Pickard, 2013). According to Stake (2005), a case study can also focus on outlining the processes, group behaviour or individual in its entire location, and/or the sequence of events in which the behaviour occurs.

The objectives of the study (as indicated in Table 2-1) generally attempt to explore the challenges faced by explosives manufacturing industries, when handling explosives waste, as well as to evaluate the legal compliance of those industries when handling explosives waste. The researcher used primary data obtained from interviews and observations, secondary data obtained from the results of previous audits, as well as the review of national and international literature.

A South African explosive manufacturing site was used as a case study to obtain particular information intended to assess factors affecting legal compliance of explosive waste management. The research objectives and associated research design are outlined Table 2-1.

**Table 2-1: Research design: Objectives and methods used**

| Research objective | Methodology used | Justification |
|---|---|---|
| 1. Determine the legislative framework applicable to the management of waste | *Literature and legal requirements review* | To understand the mandatory requirements for waste management by explosive industries, focusing on the handing and storage of explosives wastes, the destruction of explosives wastes, and |

| Research objective | Methodology used | Justification |
|---|---|---|
| by the explosive sector | | the final disposal of associated waste from the destruction process. |
| 2. Evaluate compliance of a specific explosives manufacturer to the legislative requirements for the management of explosives waste, as a case study | Review *previous audit reports and evaluate the current compliance of the explosives* manufacturer to selected legal requirements to verify whether the audit reports addressed the necessary legal requirements applicable to the scope of the study. | To establish trends in compliance with the applicable laws and regulations that apply to explosive's waste the results of legal compliance audit reports for the period 2010 – 2019 were reviewed.<br>To verify whether the audit reports adequately addressed legal requirements applicable to the scope of this study, an evaluation of compliance to selected legal requirements were performed. The evaluation focused on selected requirements of the Explosives Act, the NEMAQA and the NEMWA. The purpose of the evaluation was not to conduct a full legal compliance evaluation, but rather to verify the completeness of the audit reports (i.e. Whether the audits adequately addressed legal requirements applicable to the storage of explosives wastes, the destruction of explosives, and the management of related wastes). |
| | *Interviews* (using semi-structured questionnaires) with employees at the explosives manufacturing site and *observations* of the manufacturing process | To obtain an understanding of attitudes, experiences and behaviours of employees managing the explosive waste interviews were conducted with selected employees. According to Cozby (2009) interviews are appropriate to provide an understanding of human behaviour in a manner that is interactive, inductive, flexible, complete and reflexive method of data collection and analysis. |

| Research objective | Methodology used | Justification |
|---|---|---|
| 3. Identify challenges and opportunities for achieving legal compliance | *Review* areas of non-compliance with the legal requirements | To establish areas of non-compliance and identify possible actions to address the non-compliance, as well as associated opportunities and challenges. |

As outlined in Table 2-1, four data collection methods were used, namely literature review, interviews, observation of the explosive waste handling process, evaluation of previous and current audit reports, as well as verification of legal compliance to certain legal requirements.

## 2.3 Data collection

The sub-sections to Section 2.3 provide an overview of the methods of data collection referred to in Table 2-1.

### 2.3.1 Literature review

Some research has been conducted on explosive waste and its effects to the environment *(Ryon et al*., 1984), as well the best practices and technologies for treating explosive wasted (Duijm and Markert, 2002). There is, however, limited published research on the regulation of explosives wastes, and the associated challenges of achieving legal compliance, especially within the South African context. The literature review focused on exploring the international and national legislative frameworks for the management of explosives wastes (as explained in Figure 2-1).

### 2.3.2 Evaluation of previous audit reports

To evaluate the level of compliance of the explosives manufacturer to legislative requirements applicable to explosives waste management, the results of previous audit reports were assessed. The main objective of an audit is to collect evidence that is reliable and verifiable, which then allows for conformity with particular requirements (Ebimobowei, 2010). Audits are an excellent tool which makes it possible for organisations to identify the existing irregularities and opportunities for improvement (Maruszewska and Bialy, 2013).

The researcher evaluated previous legal compliance audit reports from 2010 to 2019. The scope of the audit reports was limited to issues of health, safety and environmental legislation. The main objective of the audits was to assess the legal risks faced by the organisation as it relates to the Occupational Health and Safety Act (85 of 1993) (OHSA), the National Environmental Management Act (107 of 1998) (NEMA), the National Environmental Management: Waste Act (59 of 2008) (NEMWA), the National Water Act (36 of 1998) (NWA), the National Environmental Management: Air Quality Act (39 of 2004) (NEMAQA), as well as the ISO 45001:2018 and ISO 14001:2015

Management Systems standards. The findings related to ISO systems conformance is, however, excluded from the scope of this research.

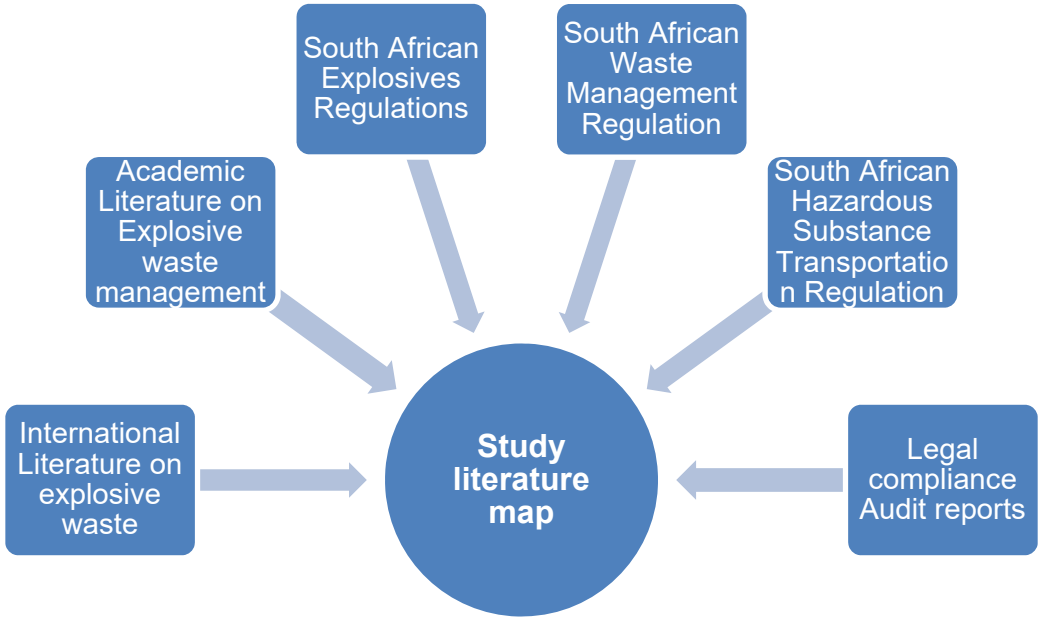


**Figure 2-1: Outline of literature review**

The main objective of the evaluation of previous audit reports (as part of the research objectives) was to evaluate areas of non-compliance to applicable legislation, determine challenges and trends in non-compliances, and to provide recommendations for improvement. The sample included five audit reports, over a nine-year period, since audits were conducted every two years (biennially).

### 2.3.3 Evaluation of current compliance to selected legal requirements

To verify whether the scope of the audit reports adequately addressed the legal requirements applicable to the scope of this study, an evaluation of the current compliance of the explosives manufactures to selected legal requirements were performed. The evaluation focused on selected requirements of the Explosives Act, the NEMAQA, the NWA and the NEMWA, as it relates to the scope of this study (refer to Section 1.4.1of this dissertation). The evaluation also focused on the previous site assessment conducted by external auditors (including certification bodies) focusing on water and air pollution, soil contamination, recording and reporting of environmental incidents and follow-up on the ISO 14001 and OHSAS status of conformance.

The purpose of the evaluation was not to conduct a full legal compliance evaluation, but rather to verify the completeness of the audit reports (i.e. whether the audits adequately addressed legal requirements applicable to the storage of explosives wastes, the destruction of explosives, and the management of related wastes), with the aim of identifying any areas of non-compliance which were not identified in the audit reports.

### 2.3.4 Interviews

Interviews were used to gather the opinions and perceptions of respondents on the challenges and areas for improvement, as it relates to explosives waste management.

#### 2.3.4.1 Developing semi-structured questionnaires

A semi-structured questionnaire with a list of questions was prepared by the researcher to cover the explosive waste management lifecycle and the challenges within the system and legal compliance (Table 2-2). The researcher used both closed and open-ended questions to understand the causes of non-compliance and suggestion to prevent recurrence of the non-complying areas. The questionnaire is appended in ***Annexure A*** together with the informed consent form. The structure of the interview questions also focused on the level of legal compliance awareness and day-to-day practices to ensure compliance of the manufacturing site. The interviews were conducted anonymously.

**Table 2-2: Structure of the questionnaires**

| | Question | Focus | Motivation |
|---|---|---|---|
| Q1 | Designation | Level of responsibility and accountability | According to De Hoogh and Den Hartog (2008) the level of learning and socialisation experiences are critical in developing a sense of responsibility and accountability |
| Q2 | Designated area for collection of explosive waste | Practice | Zhao and Ke (2017) emphasise the importance of sorting explosives waste as hazardous waste, during the process of collection, transportation, and temporary storage because it poses immense threats to the environment and human health |
| Q3 | Type of equipment used for collection of explosives waste | Practice | |
| Q4 | Transportation method (explosives waste) | Practice | |
| Q5 | Disposal method used at manufacturing site | Practice | |
| Q6 | Types of waste generated at the manufacturing plant | Practice | |
| Q7 | Potential environmental impacts from explosives wastes | Awareness | Schubert (2004) says throughout the whole munition life cycle, the environment is threatened by the munition and its components because of its energetic content, which may cause detrimental chemical pollution. |
| Q8 | Initiatives taken to reduce explosives waste | Awareness | According to Samiha (2013) awareness/knowledge of waste influences recycling behaviour |
| Q9 | Level of implementation of policy | Awareness | The National solid waste management policy aims are:<br>(1) to establish a solid waste management system that is integrated, sustainable, cost effective, and acceptable to the |
| Q10 | Effectiveness of policies in reducing impacts in real-life situation | Awareness | |

| | Question | Focus | Motivation |
|---|---|---|---|
| Q11 | Employee awareness of policy and legislation | Awareness | community which emphasises environmental conservation, selection of economical technology while ensuring safe public health,<br>(2) to efficiently implement a solid waste minimisation strategy which is based on the waste hierarchy emphasised through the 3R (reduce, reuse and recycle) |
| Q12 | Training of employees by government representatives | Awareness | |
| Q13 | Training of employees by site representative (SHE Dept.) | Awareness | According to the manufacture's special safety rules, it is important for employees to demonstrate or provide proof of adequate training or experience in the duties when handling explosives. |
| Q14 | Involvement of employees in legal compliance audits | Practice | As iterated by Perinel and Adham (2020), Measuring compliance is essential to analyse the success of policy and procedure implementation into daily practice |
| Q15 | Challenges with regards to legal compliance | Practice | |
| Q16 | Opportunities for improvement with regards to explosives waste management | Awareness | According to (Stratta *et al*., 1998) the explosives industry should start considering alternatives to open burning for destruction of production-related explosives waste |

#### 2.3.4.2 Selection of respondents

The choice of the respondents for the collection of the required data was done with consideration of the validity and accuracy of the information that was being gathered. Purposive sampling was used to select the key respondents (Leedy and Ormrod, 2013). In this technique, the researcher chose only those respondents, which were considered to provide the required information (Sharma, 2017). The major sampling criteria for inclusion in the respondent sample required that a person needs to be an expert or experienced with the problem under investigation. The advantage of this method was that it provided an efficient, cost-effective and relatively quick means of selecting the sample of respondents. Only experienced employees who deal directly with the study subject at the explosive manufacturing site were interviewed and sampled as indicated in Table 2-2. Employees who were not working within the scope and focus of the research were excluded.

The respondents represented staff from the explosives manufacturer (case study) with expertise in explosives management (Table 2-3). Because of the size of the explosives manufacturer (which is relatively small), and relevant staff members working within the focus area (explosives waste management) of this research, a representative sample of thirty (30) participants were selected (as indicated in Table 2-3) from a total of eighty (80) staff members (population size, n = 80). The sample size was representative of 38% of the entire population size, but represented 100% of the staff directly engaged in explosives waste management.

The three key groups of respondents included the plant managers responsible for the manufacturing of the products and development of waste management policies; the SHE-Representative as key personnel responsible to enforce compliance during operations; and finally the waste area manager as the responsible person to manage waste data and implement legal requirements.

**Table 2-3: Selection of interview respondents**

| No | Types of respondents | Role of respondent | Number |
|---|---|---|---|
| 1 | Plant Managers | Policy developers and response to legislation | 10 |
| 2 | Plant Operators | Implementation of legislation | 10 |
| 3 | Waste Area Manager | Response to legislation | 01 |
| 4 | Waste Area Operator | Implementation of legislation | 02 |
| 5 | Logistics Manager | Response to legislation | 01 |
| 6 | SHE-Representatives | Enforce compliance to legislation | 06 |
| **TOTAL** | | | **30** |

#### 2.3.4.3 Conducting the interviews

The researcher made an appointment prior to the interviews with the participants. Two different strategies were employed depending on the participants involved. The managers were issued with the leaflet and the consent form prior to the interview for them to go through it and sign. Whereas, the researcher decided to read the research information leaflet and consent form to the plant operators and SHE-representatives to provide additional clarification, where necessary to ensure that everyone understood the research undertakings and contents. The researcher captured the responses during the interviews anonymously. Approximately one hour was spent per interview.

### 2.3.5 Observation of the system and manufacturing process

To supplement the data gathered during the audit report assessment, evaluation of current compliance, and interviews, a site visit was conducted where the researcher performed comprehensive observations of the explosives manufacturing process (Figure 2-2).

**Life cycle of explosive waste:** The researcher observed the operation process from the manufacturing of the ammunitions, generation of explosives waste and finally the management and disposal of the explosive waste. Explosive waste residue is generated from the destruction of waste by open burning; an appointed service provider does removal of the explosive residue on a monthly basis. The Logistics Department administers the collection of the explosives waste residue for final disposal.

**Data collection tool:** The researcher took comprehensive notes of the process and any non-compliances or areas of concern. Photographs were taken of the activities throughout the process in order to keep records of the typical range of activities from waste generation to final disposal.

**Process:** The researcher made prior arrangements with the plant managers to observe the manufacturing process. The researcher observed the implementation of the system from the point of product manufacturing, waste generation, waste storage and transportation to the destruction facility where the waste was burnt and finally the waste residue is removed from the site transported by the appointed service provider to final disposal at the landfill (Figure 2-2). The researcher compiled the noted findings of the process against the requirements of the explosive manufacture's standard operating procedure (SOP) and Planned Task Observations (PTO) checklists. This gave the researcher insight into the overall explosive waste management process implemented at the manufacturers' site.

## 2.4 Data analysis

Quinlan *et al*. (2019) iterated that the data analysis process employed by the researcher predicts the accuracy of the results and outcomes of the research. This research employed primary and secondary qualitative data, which enhanced the knowledge base and were complementary to the exploratory research design.

### 2.4.1 Analysis of primary data

Primary data collected from interviews and observations were evaluated to ensure completeness accuracy, clarity and uniformity. This was facilitated by proper recording, and enabled the researcher to discover whether the data collected align with research objectives and research questions.

The results of the legal compliance evaluation were gathered in checklists and areas of non-compliance were grouped together.

Data from the interviews was transcribed into a Microsoft Word document, including the responses of the interviewer and interviewee. The responses were categorised using Altas.ti to group responses and determine trends.

During the observation process a flow chart describing the process from the point of explosive waste generation to the final disposal of waste residues was developed. The data collected was summarised and displayed on the process flow diagram to identify areas of concern.

### 2.4.1 Analysis of secondary data

Secondary data analysis just as any research method similar is a practical exercise applying the same basic research principles as studies utilising primary data and has essential steps that must

be followed (Johnston, 2017). The researcher reviewed the legal compliance audit reports and the results from the literature review following the steps as iterated by Johnston (2017).

The researcher reviewed the legal compliance audit reports to gather information that determines which areas were audited, what the findings were and which corrective action measures were implemented. Areas of non-conformance were coded and categorised to determine trends in legal non-compliance. The researcher then evaluated the dataset to ensure the suitability of the research topic.

Through the literature review, the researcher identified other researchers that have conducted related studies and summarised their findings and recommendations, focusing on challenges to achieve legal compliance, as well as opportunities for improvement, where relevant.

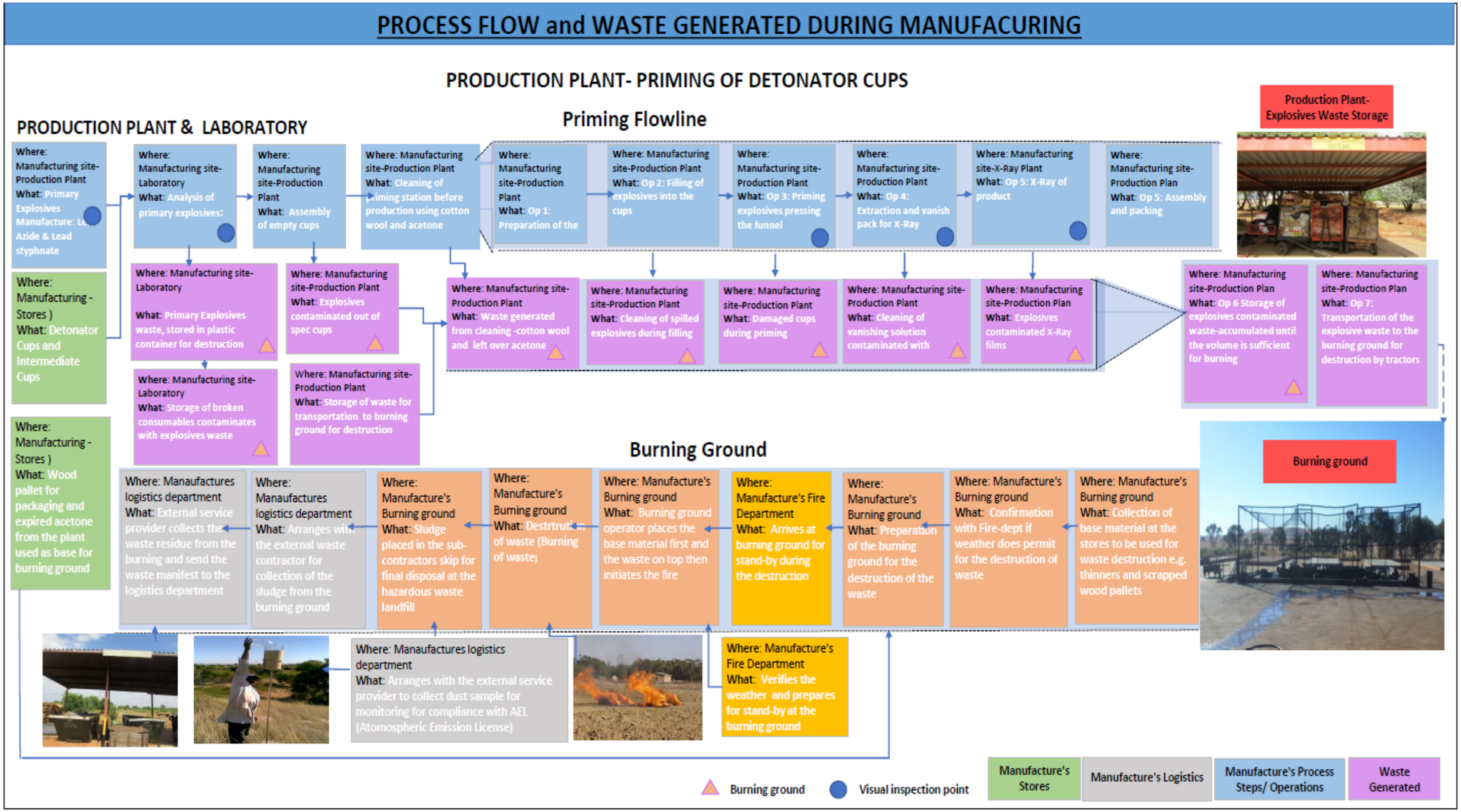


**Figure 2-2: Process flow diagram of the explosives manufacturing process, focusing on the generation and destruction of explosives waste**

## 2.5 Ethical considerations

According to the North West University (2018), ethical considerations should be acknowledged and taken into consideration during research. The study was conducted based on secondary data gleaned from the literature, and evaluation of compliance to legislation, supported by interviews (limited human interaction). The study involved human participants, but did not include any sensitive respondents (i.e. children, persons with disabilities, etc.). The research proposal was submitted to the Scientific Committee of the Environmental Management Research Group (EMRG) in the Unit for Environmental Sciences and Management of the North-West University, Potchefstroom Campus for consideration. The scientific committee has found that the research proposal was in accordance with the scientific method and adhered to the required standards as set out in the Academic Rules for Master's and Doctoral Students at North-West University (Ethics number: NWU-01197-20-A9). The Scientific Committee concluded that the proposed methodology posed a low ethical risk, hence exemption from further ethical approval was recommended for the study. Another dimension of the ethical consideration of the project was the legal implications of the explosive wastes generated in the country. The safeguards and the accessibility of the Government information were also duly gained from the proper authorities. The permissions and necessary documents were also stored in a secure location for future references.

## 2.6 Methodological limitations

The main limitation of the study was the availability of data from explosives manufacturers in South Africa. Only one explosives manufacturer was willing to participate in the research and to provide documentation of its legal compliance related to explosives waste management, with the condition that their name should be kept confidential.

Since the area of explosives waste management is not well-researched, it was difficult to compare the results of this study to what other authors have found to provide context. Some good practices could, however, be included based on explosives guideline documents and other best practices.

## 2.7 Chapter summary

This chapter of the description of the methodologies that are being provided here provides the reader with an overview of the process for conducting the research. The methods that were adopted were done so after careful consideration of the several factors like availability of resources for interviews and time allocated for observation of the process. Chapter 3 provides the literature review that aims to provide context to the research and endeavours to address research question 3.

# CHAPTER 3 LITERATURE REVIEW

## 3.1 Introduction

As per the views of Rigby *et al*. (2019), explosion refers to a chemical reaction which involves the production of various gases which involves speed temperature pressure and might cause severe damage to the environment. The *explosive*, on the other hand, is considered to be a mixture of various solid and liquid substances that might later on become capable of creating an explosion. The explosive substance is either in a liquid or in a solid state, and the mixture of such substances is designed to create heat, light and sound (RSA, 2003a).This results in a non-denoted, self-sustaining chemical reaction which includes evolving gases and pyrotechnic substances.

The explosive industry of South Africa is growing and the waste generated is increasing at a consistent rate (Lèbre *et al*., 2017). Market Watch (2020) has predicted that the market of the explosives industry in South Africa is predicted to increase to $ 15650 million by 2022. The waste generated by the sector is increasing, as the demand and generation of explosives increase. Therefore, the development of waste management measures to address explosives waste in the country is essential.

Explosives wastes may be harmful to the environment and to the health and safety of humans (Akhavan, 2011). Therefore, the storage and disposal of explosives waste need to be well managed. Explosives are categorised as Class 1 dangerous goods in accordance with SANS 10228: 2012 (Table 3-1). The level of hazard associated with the different divisions of explosives are outlined in Table 3-1, with Division 1.1 presenting mass explosion hazards, while Division 5.1 explosives are very insensitive (and less hazardous in terms of risk of explosion).

**Table 3-1: Explosives divisions according to SANS 10228:2012**

| **Class 1: Explosives** | |
|---|---|
| Division 1.1 | Mass explosion hazard from the explosives |
| Division 1.2 | Projection hazard from the explosives |
| Division 1.3 | Fire hazard and either a minor blast hazard or a minor projection hazard or both from the explosives |
| Division 1.4 | No significant blast hazard from the explosives |
| Division 1.5 | Explosives with a mass explosion hazard and a very insensitive |

*Source SANS 10228:2012 Edition 6 (SANS, 2012)*

### 3.2 Waste generated by the explosives sector

Explosives manufacturing comprises of complex chemical processes, involving a number of hazardous chemical substances (such as nitrates and acids). The waste generated as part of the manufacturing process is in solid, liquid and gaseous form (Barreto-Rodrigues *et al.*, 2009) and may, therefor, interact with the environment and human beings through different routes of exposure.

Chemicals such as nitric acids, water-based nitration effluent (WNE), water-based amination affluent (WAE), toluene-based amination effluent (TAE) are some of the most common types of waste generated by the explosive sector in South Africa (Letzel *et al*., 2003).

The volumes of waste generated by the explosives manufacturing sector depended on the production volume. Limited information is publically available on the amounts of explosives wastes generated in South Africa, and explosives manufacturers are reluctant to make this information available. Approximately 31 tonnes of waste was generated by the explosives manufacturer included in this study (in 2019) (Table 3-2), which is quite significant when compared to the total amount of hazardous waste being generated in the North-West Province in 2019 (being 934 tonnes) (SAWIC, 2019).

**Table 3-2: Quantities of explosives waste generated by the explosives manufacturer included in the study in 2019**

| Month | Quantity (kg) |
|---|---|
| January | 400 |
| February | 1200 |
| March | 2300 |
| April | 11030 |
| May | 300 |
| June | 780 |
| July | 800 |
| August | 860 |
| September | 2980 |
| October | 3540 |
| November | 6500 |
| December | 500 |
| **Total** | **31,190 kg** |

### 3.3 Negative impacts of explosives waste

According to Eom *et al.* (2019), the most significant negative impacts of explosive wastes is pollution of the environment (soil, water and land), which may cause environmental degradation. These negative impacts are further elaborated on in Sections 3.3.1 to 3.3.3. Health effects may be directly or indirectly related to exposure to explosives. Direct exposure to TNT can, for example, induce blood disorders such as anaemia, abnormal function of the liver, enlargement of the spleen, immunological deficiency and other health-related problems. Indirect exposure to explosives may include exposure through soil, water and air that may contaminated by by-products or wastes from the explosives industry (Letzel *et al*., 2003). The adverse health impacts of explosives waste are further discussed in Section 3.3.4.

#### 3.3.1 Impact of explosives wastes on water quality

Manufacturing sites contaminated with explosives waste, particularly those situated in sensitive areas (for instance, within 100 metres of a water course) may be subjected to surface water and groundwater contamination from over 200 chemical munitions constituents. The Department of Defence (DoD, Fiscal Year 2002 Defence Environmental Restoration Program Annual Report to Congress) has indicated that there are twenty specific types of explosive constituents (listed in Table 3-3) that are of greatest concern due to their extensive use and potential impacts on the environment, especially water quality.

**Table 3-3: Explosives constituents of great concern**

| # No | Type of explosive constituents |
|---|---|
| 1 | Trinitrotoluene (TNT) |
| 2 | 1,3-Dintrobenzene |
| 3 | Nitrobenzene |
| 4 | 2,4-Dinitrotoluene |
| 5 | 2-Amino-4,6-Dinitrotoluene |
| 6 | 2-Nitrotoluene |
| 7 | 2,6-Dinitrotoluene |
| 8 | 4-Amino-2,6-Dinitrotoluene |
| 9 | 3-Nitrotoluene |
| 10 | Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) |
| 11 | 2,4-Diamino-6-nitrotoluene |
| 12 | 4-Nitrotoluene |
| 13 | Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) |
| 14 | 2,6-Diamino-4-nitrotoluene |
| 15 | Methylnitrite |

| # No | Type of explosive constituents |
|---|---|
| 16 | Perchlorate |
| 17 | 1,2,3-Propanetriol trinitrate (Nitroglycerine) |
| 18 | Pentaerythritoltetranitrate (PETN) |
| 19 | 1,3,5-Trinitrobenzene |
| 20 | N,2,4,6-Tetranitro-N-methylaniline (Tetryl) (White Phosphorus |

*Source: Appendix 1 Table 2 of (GAO, 2003)*

### 3.3.2 Impact of explosives on air quality

In South Africa, thermal destruction of all explosives waste is required to render the waste stream safe for handling in terms of the Explosives Act (26 of 1956). Open burning and open detonation (OB/OD) is one of the methods used for explosive waste destruction, internationally, and is currently used for the treatment of explosive wastes in South Africa.

Whilst unavoidable from a safety perspective, OB/OD treatment results in uncontrolled air emissions that may include an array of inorganic, organic and metallic compounds of concern. The quantification of potential air quality, health risks from OB/OD operations is a prerequisite for responsible management, but poses a significant challenge given the highly variable composition of the waste streams, complex source emissions and differing thermodynamic conditions under which releases occur (Martin *et al*., 2012).

### 3.3.3 Explosives contaminated soil

The destruction of explosives during OB/OD may contaminate the soil and groundwater, due to the leaching of chemicals from the destructed components. Soils in close proximity to explosives manufacturing plants, explosives burning grounds and explosives testing ranges may be polluted by various residues of explosives. Soil concentrations as high as 38,600mg/g were reported for 2,4,6-trinitrophenol (TNT, trinitro-toluene) in soils located within 1 km of explosives manufacturing sites (Jenkins and Walsh, 1992). Other explosives detected in such soils included: 2-amini-4,6-dinitrotoluene (2-am-DNT); 2,4-dinitrotoluene (2,4-DNT) and hexogene (RDX) (Jenkins and Walsh, 1992, Fuller *et al*., 2005) – all of which are known to be harmful to the environment.

### 3.3.4 Human health effects of munitions

Constituents of munitions have the potential to cause adverse human health effects.

Table 3-4 summarises the potential health effects of five munition constituents closely associated with military munition as listed by EPA.

**Table 3-4: Potential effects of munitions constituents closely associated with military munition**

| Constituent | Potential toxicity/effects |
|---|---|
| TNT | The liver, cataracts and skin irritation are infections emanating from exposure of TNT and the possibility of human carcinogen. |
| RDX | Due to laboratory exposure towards animals, there are indicative prospects of organ damage. There are human related risks like human carcinogen, nervous system challenges, prostate challenges, nausea and vomiting possibilities. |
| Perchlorate | Being exposed to perchlorate may result into tearing, itching, and pain; accidental ingestion, which may create gastroenteritis with abdominal pain. The infections can further result into nausea, vomiting, and; other systemic effects may follow which includes ears irritation, dizziness, elevated blood pressure, blurred vision, and tremors amongst other illnesses. Metabolic dysfunction of the thyroid is one of the possible chronic effects. |
| HMX | Based on animal studies there is a prospective liver damage and breakdown of the central nervous system. |
| White Phosphorus | Inhalation may cause liver, heart, or kidney damage; severe exposure can lead to death; mild exposure may cause burning of the skin, throat irritation and affecting the proper functioning of the lungs, causing vomiting, creating stomach cramps, with drowsiness and possible reproductive effects. |

*Source: Appendix 1 Table 3 of (GAO, 2003)*

The level of toxicity and effect of these constituents on human health depended on the dosage, exposure duration, and the route of exposure, as well as the exposed population's sensitivity (GAO, 2003).

## 3.4 The explosives waste life cycle from generation to destruction to final disposal of residues

The life cycle of explosives (manufacturing) and associated wastes is outlined in Figure 3-1. The processes related to the scope of this research are highlighted in red, and discussed further in this section of the dissertation.

**Handling and storage of explosives waste:** The handling and storage of explosives waste are one of the most important aspects of the explosives waste life cycle, since most reported accidents and incidents are directly linked to the mishandling and storage of the explosives waste. Rucevska *et al*. (2017) have also stated that handling and storage of the explosive waste in South Africa is one of

the most prominent reasons for incidents. The Explosives Act (26 of 1956) provides measures for the safe handling and storage of explosives wastes.

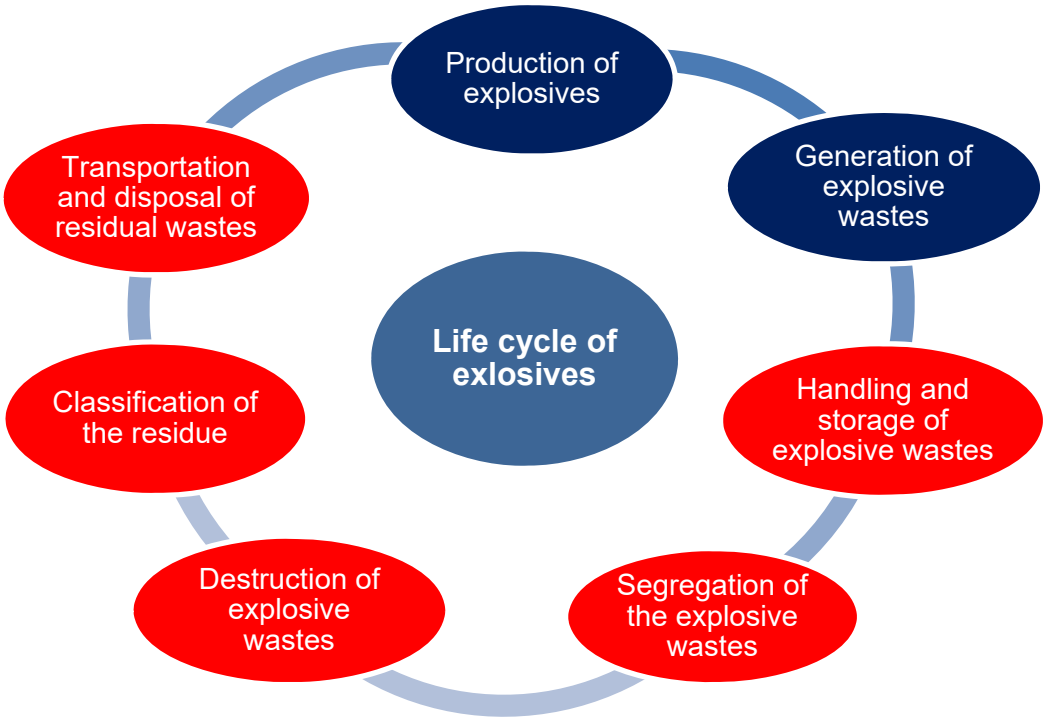


**Figure 3-1: The life cycle of explosive waste**

**Destruction of explosives wastes:** Hart and Stock (2019) stated that the destruction of explosives waste in South Africa is one of the main objectives of the DoD, and is incorporated under the *Installation Restoration Program*. Open burning of explosives waste is still considered the most preferred destruction method, however, the control of emissions from burning grounds are cause for concern (Wilkinson, 2006). Emissions from burning grounds are regulated in terms of GN R. 893 of 2013 (*List of activities which result in atmospheric emissions which have or may have a significant detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage*).

**Explosive waste residue classification, storage and handling:** The processes required for the handling, storage, and destruction of explosives are different and they are based on the nature and characteristics of the explosives that are being handled. The classification of explosive wastes, therefore, plays an important role in identifying the hazards related to the explosives residue. Explosive waste residues should also be classified in accordance with the *Waste Classification and Management Regulations* (GN R. 634 of 2013) to determine the level of physical-, health- and environmental hazards related to the waste, as well as assessed in accordance with the *Norms and Standards for the Assessment of Waste for Landfill Disposal (*GN R. 635 of 2013) to determine its waste type.

**Explosive waste residue transportation and disposal:** According to Ladyman *et al.* (2019), the classification of the wastes is necessary which is followed by the handling of the wastes. The classification dictates the process for the handling of the wastes and the residue that is created in the process is again assimilated. The results of the waste classification process, will inform waste transportation requirements. While the waste assessment (Type 0 to 4) will determine its landfilling requirements.

## 3.5 Laws applicable to the management of explosives wastes

The legal framework applicable to the management of explosives and related waste are quite extensive and focuses on the protection of human health and safety (in the workplace and of the public in general), the protection of the environment, and the protection of property.

### 3.5.1 International laws applicable to the management of explosives wastes

South Africa is a signatory to eight Multilateral Environmental Agreements (MEA's) for Wastes and Chemicals. The MEA's are international legal instruments entered into by three or more states relating to the environment governed by international laws. The main goal of the agreements is to ensure environmental protection. Considering that, the one particular agreement related to the management of explosives waste is the Basel Convention.

#### 3.5.1.1 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal

The Basel Convention was adopted in March 1989, and South Africa became a signatory to the convention in May, 1994. The Basel Convention's key objective is to control the export of hazardous waste. Transboundary transitioning of hazardous waste can transpire only if the country exporting is incapable of adequately managing their hazardous waste in an environmentally acceptable manner, or the importing country requires the exported wastes as raw material for their recycling and recovery industries (Kanamugire, 2017; White and Heckenberg, 2011).

### 3.5.2 South African laws applicable to the management of explosive waste – with a specific focus on the explosives manufacturer case study

In South Africa there are various pieces of legislation that exist for the management of explosives and explosive wastes. Starting with the Constitution of South Africa (108 of 1996), Section 24 stipulates that *everyone has a right to an environment which is not harmful to their health and wellbeing* and to have the environment protected through reasonable legislative and other measures. The Constitution is the umbrella law and other pieces of legislation needs to align with it (as indicated in Figure 3-2). In the context of explosives waste management, South Africa has several laws regulating different aspects of the explosives and explosives waste life cycles. The Explosives Act

(15 of 2003) (RSA, 2003) aims to provide for the control of explosives in general, while the National Environmental Management Act (107 of 1998) (NEMA) (RSA, 1998a), the National Environmental Management Air Quality Act (39 of 2004) (NEMAQA) (RSA, 2004), the National Water Act (36 of 1998) (NWA) (RSA, 1998b) and the National Environmental Management Waste Act (59 of 2008) (NEMWA) (RSA, 2008) aim to regulate activities with potential impacts on the environment. The disposal of explosives that is regulated by the Explosives Act (15 of 2003) (RSA, 2003b) is, however, excluded from the requirements of the NEMWA. The Occupational Health and Safety Act (85 of 1993) (RSA, 1993) and the Mine Health and Safety Act (29 of 1996) (MHSA) (RSA, 1996b) and its regulations aim to protect the worker in the workplace. The MHSA is not further elaborated on in this section, since it does not fall within the scope of this research.

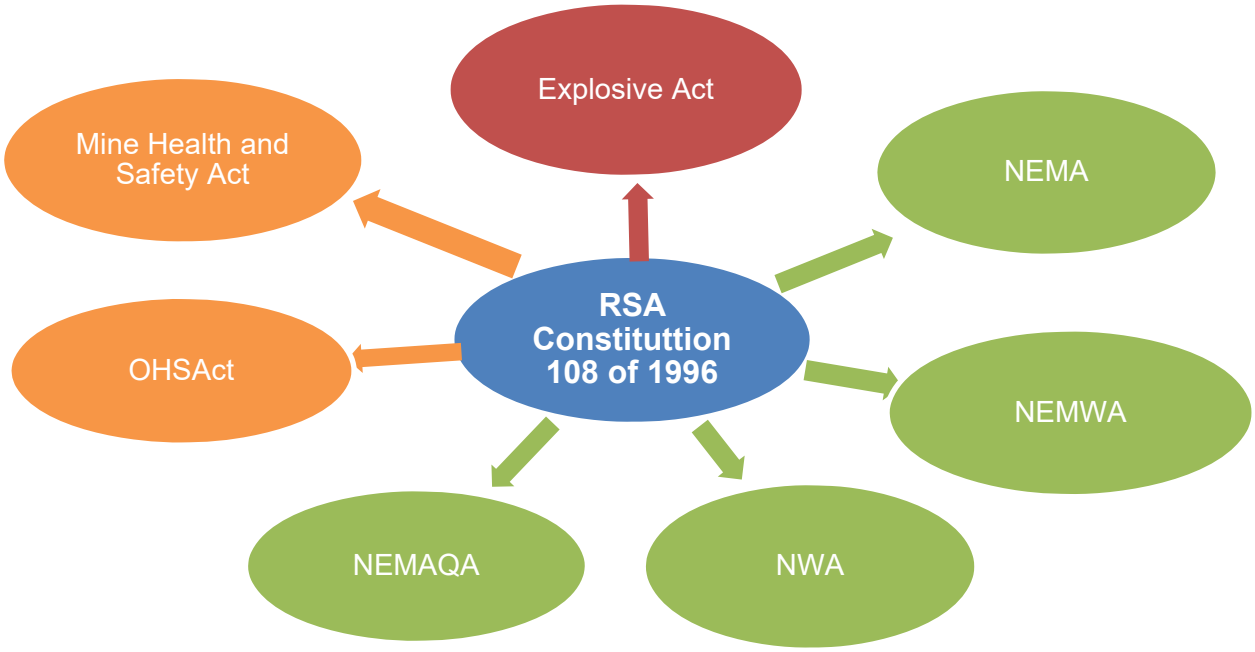


**Figure 3-2: Legislation governing explosive waste management is South Africa**

### 3.5.2.1 The Explosives Act (15 of 2003)

The Explosives Act (15 of 2003) has been amended many times to align South Africa's explosives regulations with global best practice in terms of classification, marking, transportation, packaging and disposal. According to Sivhabu (2018), the Act is focused upon the manufacture, storage, sales, transportation or any other activities related to the explosives in South Africa. The Act directs and provides a framework for the safe handling of the explosives and also contains the requirements for the explosive waste disposal (which is excluded from the NEMWA). The Act provides the requirements for authorisation of explosives manufacturers.

Of relevance to this research is Section 8 (1) of the Explosive Act (15 of 2003), which requires that the explosives be destroyed only in accordance with specific safety procedures and processes, which, in the South African context, is usually by means of open burning at burning grounds.

#### 3.5.2.2 Laws focusing on environmental protection

The management of the explosive wastes in South Africa is also intricately linked to the protection of the environment. The NEMA is the framework legislation for environmental protection in South Africa. Other laws, such as the NEMAQA, NWA and NEMWA are also applicable to the management of explosives waste from an environmental point of view. The sections below provide a brief overview of these Acts and how they relate to the management of explosives waste.

##### 3.5.2.2.1 National Environmental Management Act (107 of 1998) (NEMA)

As per Zhakata *et al*. (2016), the main focus of NEMA is that degradation and pollution be avoided entirely if possible, or that it is mitigated, remedied and/or rectified, if unavoidable. Section 2 of the NEMA provides integrated environmental management principles, which include but are not limited to the life-cycle approach to management of waste, the precautionary principle, producer responsibility and the polluter pays principle. A duty of care is placed on any individual or industries that may create significant level of pollution or act of degradation on the environment according to NEMA.

###### 3.5.2.2.1.1 Life-cycle approach

The life-cycle approach ensures that the waste generator has systems in place to analyse their waste management process in providing a comprehensive view of the processes and impacts related to the handling of the explosive waste. Arena *et al*. (2003) have iterated that the life cycle approach is considered one of the greatest tools for managing potential environmental impacts related to the management of chemicals and goods, considering all the phases and activities related to the entire value chain.

###### 3.5.2.2.1.2 Duty of care

The objective of the duty of care principle (also known as “extended producer responsibility (EPR)” in the NEMWA) is to ensure that manufactures (in this case explosives manufacturers) are responsible for their products until the post-usage stage of those products (Nahman, 2010). Implementing an effective EPR programme will assist the explosive industry to move away from landfill disposal and implement the waste management system in favour of recycling, minimisation and avoidance.

3.5.2.2.1.3 Precautionary principle

The precautionary principle requires that the explosives manufacture should take immediate control of processes and activities that may have detrimental consequences to the environment rather than to wait for incontrovertible scientific evidence.

According to Martuzzi and Tickner (2004) from the World Health Organisation, the precautionary principle is based on recognising that everyone has a responsibility to preserve the environment and to prevent any harm, now and into the foreseeable future. The principle recognises the needs of future generations and other species as being worthy of care and respect and the importance of upholding the integrity of ecosystems.

3.5.2.2.1.4 Polluter pays principle

The Polluter Pays Principle clearly states that, *"the costs of pollution should be borne by the entity which profits from the process that causes pollution".* During the process of explosives waste management, should pollution occur, the waste generator is expected to bear the costs of managing the pollution and prevent any recurring destruction to the environment.

3.5.2.2.1.5 Emergency incidents

Section 30 of the NEMA requires that the responsible person shall respond to emergency incidents and remedy or rectify the effects of any pollution on the environment. Emergency incidents shall be reported on and measures must be put in place to prevent such incidents from occurring in the future.

3.5.2.2.2 National Environmental Management: Air Quality Act 39 of 2004 (NEMAQA)

According to Zhakata *et al*. (2016), the National Environmental Management Air Quality Act (39 of 2004) (NEMAQA) is focused on regulating air quality of the country and maintaining an ambient quality of breathable air in South Africa. South Africa has set National Ambient Air Quality Standards (NAAQS) (GN. 1210 of 2009) for particulate matter, sulphur dioxide, nitrogen dioxide, carbon monoxide, ozone, benzene and lead, which may be emitted as part of thermal processes. The NEMAQA regulates the emissions from the destruction and burning of explosives at OB/OD facilities in the country through atmospheric emissions licencing (Table 3-5).

The *National Dust Control Regulations* (GN R. 827 of 2013) provide the requirements for the monitoring of dust (particulate matter) fallout, while the *National Atmospheric Emission Reporting Regulations* (GN R.238 of 2015) provide the requirements for reporting on emissions. There are, however, no specific protocols or guidelines in place for assessing air quality impact from these facilities or defining acceptable operating limits in respect of waste treatment capacity.

3.5.2.2.2.1 GN 1210 of 2009: National Ambient Air Quality Standard (NAAQS)

The *National Ambient Air Quality Standard* (NAAQS) (GN.1210 of 2009) requires the averaging period for air emissions (i.e. a period over which an average monitored value is determined) to be in compliance with the NAAQS. The monitoring methods are specified from SANAS 1929:2005 Ambient. Air Quality – Limits for common pollutants.

3.5.2.2.2.2 GN R827 of 2013: The National Dust Control Regulations

The purpose of the *Dust Control Regulations* is to prescribe general measures for the control of dust (also referred to as *"settleable particulate matter"*) in all areas of the country. The regulations provide acceptable dust fall rates for residential and non-residential areas, and outlines: the requirements for implementing a dustfall monitoring programme and –report, measures for the control of dust, ambient air quality monitoring requirements for $PM_{10}$ (Petavratzi *et al*., 2005).

3.5.2.2.2.3 GN R873 of 2013: Listed activities requiring an atmospheric emissions licence

GN R. 873 of 2013 provides a list of activities which may be detrimental to air quality and requires the application for an atmospheric emissions licence. Sub-category 8.3 provides for the destruction of explosives at burning grounds (Table 3-5). The regulations provide the required atmospheric emissions standards, as well as the type and frequency of monitoring required.

**Table 3-5: Listed activity and associated minimum emission standard for burning grounds**

| **Description** | Facilities where waste material from the manufacture of explosives and contaminated explosive packaging material are destroyed. | | |
|---|---|---|---|
| **Application** | All installations disposing of more than 100 kg of material per week | | |
| Substance or mixture of substances | | Plant status | mg/Nm$^3$ under normal conditions of 273 Kelvin and 101.3 kPa. |
| Common name | Chemical symbol | | |
| Dust fall | N/A | New | A |
| | | Existing | A |
| Sulphur dioxide | $SO_2$ | New | B |
| | | Existing | B |
| [a] three months running average not to exceed limit value for adjacent land use according to dust control regulations promulgated in terms of section 32 of the NEM: AQA, 2004 (Act 39 of 2004), in eight principal wind directions.<br>[b] Twelve months running average not to exceed limit value as per GN 1210 of 24 December 2009. Passive diffusive measurement approved by the licensing authority carried out monthly. | | | |

*Source NEM: AQA 39 of 2004 GN R 893 Subcategory 8.3: Burning Grounds*

Further requirements related to the specific burning grounds, and the specific location of the activity are outlined in the conditions of the atmospheric emissions licence (AEL).

3.5.2.2.2.4 GN R 238 of 2015: National Atmospheric Emission Reporting Regulations

The purpose of the *National Atmospheric Emission Reporting Regulations* (GN R. 238 of 2015) is to objectively evaluate and accurately report the data and information that has been identified from various non-point and mobile air emission sources. The National Atmospheric Emission Reporting Regulations requires that activities/processes listed in Regulation 4 and Annexure 1 (of the regulations), have to adequately monitor their emissions and report on their emissions (RSA, 2010). The data reported in terms of the regulations are used for the national atmospheric emission inventory.

3.5.2.2.3 National Water Act 36 of 1998 (NWA)

The National Water Act (36 of 1998) (NWA) was enacted with the intention to protect the water resources of South Africa with the aim to prevent pollution (Singh, 1999). Wash water from burning grounds is classified as “waste”, according to the NWA definition of waste, since it may have the potential to pollute a water resource. In terms of Section 19 of the NWA, the explosives manufacturer has the duty to prevent pollution from continuing, occurring or recurring. Eleven different water uses are listed in Section 21 of the NWA. Section 22 requires that water is used (i.e. the water uses listed in Section 21) in a “permissible manner”, which may require the application for a water use licence, a general authorisation, a schedule 1 water use, an existing lawful water use, or the Department may dispense of the need to apply for a licence. Section 20 of the NWA further provides for the control and response to emergency incidents, as it relates to possible pollution.

3.5.2.2.4 National Environmental Management: Waste Act 59 of 2008 (NEMWA)

Although explosives wastes are excluded under Section 4 of the National Environmental Management Waste Act (59 of 2008) (NEMWA), the effective management of waste remaining after the destruction process (at burning grounds) up to landfilling is provided for in terms of the NEMWA. The following sections of the NEMWA provides measures applicable to the classification, management, storage and disposal of waste:

- **Section 16 (1) General duty in respect of waste management**: The generator retains the ultimate responsibility for ensuring that the waste is handled, stored, transported and disposed of according to legislation and on an environmentally sound and responsible manner.
- **Section 18 (2): Extended Producer Responsibility:** Section 18 of the NEMWA provides for the promulgation of regulations applicable to extended producer responsibility. These regulations have been published in November 2020 (GN R. 1184).
- **Section 21, 24, 25 and 26**: **Storage, collection and transportation of waste:** This section requires that the generator of waste ensures that containers used for storage of waste are intact, not corroded and there will not be any accidental spillage or leaking of the

waste. The waste transporter must ensure that the waste cannot be blown away and nuisances such as odour, visual impacts and breeding of vectors do not arise; and pollution of the environment and harm to health are prevented. Section 26 of the NEMWA prohibits the unauthorised disposal of waste.

Several norms and standards, and regulations have also been developed, which regulates aspects, such as waste storage, waste classification, waste assessment for disposal purposes, disposal as well as waste information and reporting.

3.5.2.2.5 GN R 625 of 2012. National Waste Information Regulations

The *National Waste Information Regulations* (GN R. 625 of 2012) provide the requirements for waste information reporting, which include requirements for registering the activities and quarterly reporting. In the context of this research, these regulations require that generators of hazardous waste of more than 20 kg per day, which must be registered on the South African Waste Information System (SAWIS).

3.5.2.2.6 GN R 634 of 2013. Waste Classification and Management Regulations

The Waste Classification and Management Regulation were developed to replace the Minimum Requirements for the Handling and Disposal of Waste. All waste (remaining after the explosives destruction process) needs to be classified according to GHS-SANS 10234 (South African National Standard Globally Harmonised System of Classification and Labelling of Chemicals (GHS).

The main objective of waste classification is to:

- Ensure that there is a more efficient classification and management of hazardous waste;
- Provide for safe and appropriate handling, storage, reuse, recycling, recovery, treatment and disposal of waste;
- Enable accurate and relevant reporting on waste generation and management;
- Apply common principles applied in the classification of waste as appropriate, including:
  (i) pre-identification of waste,
  (ii) testing and analyses to determine the characteristics of the waste,
  (iii) classification of waste based on pre-defined physical, health and environmental hazard criteria, and
  (iv) further analyses as required to inform waste management options.
- Direct the consideration of higher order management options for waste, in line with the waste management hierarchy;
- Support the beneficial recovery of resources from waste that does not harm the environment or health;
- Promote the diversion of waste from landfill by implementing mechanisms for facilitating waste re-use, recycling and recovery; and

- Encourage separation of waste at source.

3.5.2.2.7 GN R 635 of 2013. Norms and Standards for Assessment of Waste for Landfill Disposal

The *Norms and Standards for Assessment of Waste for Landfill Disposal* (GN R. 635 of 2015) requires that waste is assessed prior to landfill disposal (Type 0 to Type 4). The leachable concentrations (LC) and total concentrations (TC) of the waste needs to be determined by comparing it to leachable- and total concentration threshold limits. This will inform the landfill class where the waste may be disposed of in terms of GN R. 636 of 2013, *The Norms and Standards for the Disposal of Waste to Landfill*.

3.5.2.2.8 GN R 636 of 2013. Norms and Standards for the Disposal of Waste to Landfill

The *Norms and Standards for the Disposal of Waste to Landfill* (GN R. 636 of 2013) provides the requirements for the disposal of waste to Class A to Class D landfills, according to the waste type.

3.5.2.2.9 GN R 926 of 2013. Norms and Standards for the Storage of Waste

The *Norms and Standards for the Storage of Waste* (GN R. 926 of 2013) deals with the registration of the waste storage facility, ensuring that there is no unauthorised access to the waste storage facility, and ensuring that the operation of the facility is safe and that impacts are mitigated.

3.5.2.2.10 GN 22 of 2019. Regulations regarding the control of the import or export of waste

The *Regulations Regarding the Control of the Import or Export of Waste* (GN. 22 of 2019) controls the import and export of general and hazardous waste to and from South Africa. In addition to the requirements of the Basel Convention, permission from the Department of Environment, Forestry and Fisheries are required to import or export waste.

### 3.5.2.3 Laws focusing on worker and workplace protection

As per Coulson (2018), the Occupational Health and Safety Act (85 of 1993) (OHS Act) is also focused on the protection and safety of the employees that are involved in the production, handling, storage or transportation of the explosives in the country.

3.5.2.3.1 The Occupational Health and Safety Act 85 of 1993 and its Regulations (OHS Act)

The OHS Act has requirements for the handling, storage, use and disposal of explosives and related processes. It provides a detailed structure of the handling procedures by the professionals as well as the safety precautions that must be in place for the safety of the employees handling explosives. The OHS Act also directs storage guides and instruction manuals for the handling of the explosives in the country. The *Explosive Regulations* (GNR.109 of 17 January 2003) provides guidance to the manufacturer on how to classify explosives, how to apply for explosives workplace license, how to

classify the danger area and danger building, how to safely handle the explosive, and which procedure to follow during emergencies and incidents.

3.5.2.3.1.1 GN R. 109 of 2003. Explosives Regulations

According to Chauke *et al*. (2017), the Explosives Regulations, which focuses on the access, manufacture and handling of explosives, provide some of the most explicit requirements on the day-to-day management of explosives in the workplace.

Regulation 13 of the Explosives Regulations gives guidance on how explosives waste should be handled. The explosives manager, a person appointed in terms of Regulation 12(1), should in writing prescribe a procedure for disposing all the explosives contaminated waste and any materials that have been in contact with explosives or an ingredient of an explosive. Explosives manufacturing sites should have a designated area for the storage of explosives contaminated waste, waste and floor sweeping should be stored at the designated area at the end of every working shift.

## 3.6 Chapter summary

Waste management is a significant aspect of containing the environmental damage arising out of waste generation in the explosive sector, significantly because of munitions waste.

The legal framework outlined in this section may present opportunities and challenges to the explosives sector in terms of achieving legal compliance. Chapter 4 discusses the current compliance of an explosives manufacturer (case study) to the legal framework outlined in Chapter 3.

# CHAPTER 4 RESULTS AND DISCUSSION

As indicated in Chapter 1, the research aim was to explore the legal framework applicable to the management of explosives waste, and the possible challenges or obstacles to compliance within the explosive manufacturing industry. In order to gain a better understanding of the legal frameworks and possible challenges to compliance with the legal requirements, data collection and analysis process that followed aimed at addressing the following three objectives the study:

- ***Research objective (RO) 1:*** Determine the legal framework applicable to the management of waste by the explosive sector;
- ***Research objective (RO) 2:*** Evaluate compliance of a specific explosives manufacturer to the legal requirements for the management of explosives waste, as a case study; and
- ***Research objective (RO) 3:*** Identify challenges and opportunities for achieving legal compliance.

In this chapter of the study, the legal framework for the management of explosives wastes are summarised. The evaluation of compliance to selected legal requirements is discussed in the context of a selected explosives manufacturer, by reviewing previous audit reports, as well as verifying certain aspects of compliance through document review, observations and interviews. Opportunities for improving compliance, and challenges for achieving compliance were also determined through conducting interviews, supported by a literature review. The scope was limited to explosive waste handling, storage, destruction, transportation and final disposal.

## 4.1 Results related to RO1: Determining the legislative framework applicable to the management of waste by the explosives sector

The legal framework applicable to the management of explosives waste related to the scope of this study is provided in in Section 3.5 in the *Literature Review chapter*. A summary of the legal framework is provided in Table 4-1. The legal framework outlined in Section 3.5 (and summarised in Table 4-1) provides the South African (minimum) requirements in respect of explosives waste management. The framework includes laws and regulations applicable to the management of environmental pollution, occupational health and safety aspects, as well as public protection (injury or damage to property, amongst others) due to waste generated from the explosives manufacturing sector.

**Table 4-1: Legal framework applicable to the management of explosives wastes**

| Legislation/regulation | Applicability |
|---|---|
| The Constitution of the Republic of South Africa, 1996 | Section 24 of the Constitution states that every person has the right to an environment that is not detrimental to their human health and well-being and to have the environment protected through reasonable legislative and other measures |
| Explosives Act (15 of 2003) | The Explosives Act emphasised on the authorisation or permission of the explosive manufacturing by maintaining the safety standards (i.e. explosives licence). This Act also ensures safe destruction and transportation of explosive materials by maintaining proper guidelines. |
| National Environmental Management Act (107 of 1998) | The NEMA provides for the protection of the environment. Section 2 outlines the Integrated Environmental Management Principles, while Section 28 provides for the duty of care and remediation of environmental damage. Section 30 is applicable to environmental emergencies and incidents. |
| National Environmental Management Air Quality Act (39 of 2004) | The NEMAQA provides for the protection of air quality through norms and standards, atmospheric emissions licencing, etc. Monitoring and reporting of atmospheric emissions are required. |
| *GN. 1210 of 2009: National Ambient Air Quality Standard* | The National Ambient Air Quality Standards (GN. 1210 of 2009) defines the standard which need to be maintained during the manufacturing and destruction of explosives to prevent air pollution. |
| *GN R. 873 of 2013: Listed activities (NEMAQA)* | Category 8: (Thermal Treatment of Hazardous and General Waste), Sub-category 8.3 (Burning Grounds) of GNR. 873 of 2013 describes facilities where explosive waste material from the manufacturing and packaging material contaminated with explosive are destroyed. An atmospheric emissions licence is required for all facilities disposing of more than 100 kg of material per week. The regulations prescribe the atmospheric emissions standards, as well as monitoring requirements. |
| *GN R. 827 of 2013: The National Dust Control Regulation* | The National Dust Control Regulations (GN R. 827 of 2013) provides the requirements for the monitoring and control of settleable dust (particulate matter). |
| *GN R. 238 of 2015: National Atmospheric Emission Reporting Regulation* | The National Atmospheric Emission Reporting Regulations (GNR. 238 of 2015) provides the requirements for the monitoring and reporting of emissions. |
| National Water Act (36 of 1998) | The NWA provides for the protection of water resources. The Act provides requirements for safe waste disposal practices, which are also applicable to the destruction and disposal of explosives waste. Section 22 outlines the requirements for permissible water uses, while the different water uses are outlined in Section 21. The explosives manufacturer holds a water use licence, which provides requirements for monitoring ground water quality for nitrates and other elements, which may be related to explosives manufacturing. |

| Legislation/regulation | Applicability |
|---|---|
| National Environmental Management: Waste Act (59 of 2008) | The NEMWA regulates the classification, handling, storage, collection, transportation and final disposal of waste.<br>As mentioned earlier, Section 4 of the NEMWA excludes explosives waste that are provided for in terms of the Explosives Act. The NEMWA does, however, regulate the components of explosives waste remaining after the destruction. |
| GN R 625 of 2012: *National Waste Information Regulations* | The National Waste Information Regulations (GN R. 625 of 2012) requires that certain waste management activities (listed in these regulations) are registered on the national waste information data base and requires quarterly reporting on waste quantities generated, disposed of, recycled, recovered, etc. |
| GN R 634 of 2013: Waste Classification and Management Regulations | The Waste Classification and Management Regulations (GN R. 634) requires that waste is classified in accordance with SANS 10234 to determine the physical-, health- and environmental hazards related to the waste. A safety data sheet needs to be developed, and the information needs to be outlined on the waste manifest documentation. |
| *GN R 635 of 2013: Norms and Standards for Assessment of Waste for Landfill Disposal* | The Norms and Standards for Assessment of Waste for Landfill Disposal (GN R. 635 of 2015) requires that waste is assessed prior to landfill disposal (Type 0 to Type 4). The remnants remaining after destruction at burning yards need to be assessed in accordance to the requirements of these regulations. |
| *GN R 636 of 2013: Norms and Standards for the Disposal of Waste to Landfill* | The Norms and Standards for the Disposal of Waste to Landfill (GN R. 636 of 2013) provides the requirements for the disposal of waste to Class A to Class D landfills, according to the waste type. With regards to the remnants of explosives waste from the burning grounds, these need to be adequately disposed of according to its waste type.<br>The landfill disposal of explosives waste are prohibited in terms of GN R. 636 of 2013 |
| *GN R 926 of 2013: Norms and Standards for the Storage of Waste* | The Norms and Standards for the Storage of Waste (GN R. 926 of 2013) deals with the registration of the waste storage facility, ensuring that there is no unauthorised access to the waste storage facility, and ensuring that the operation of the facility is safe and that impacts are mitigated. The storage of hazardous waste in an area exceeding 80 $m^3$ requires the registration of the facility and compliance to the requirements of the norms and standards. |
| *GN 22 of 2019: Regulations regarding the control of the import or export of waste* | These regulations (GN. 22 of 2019) control the import and export of general and hazardous waste to and from South Africa. In addition to the requirements of the Basel Convention, permission from the Department of Environment, Forestry and Fisheries are required to import or export waste. |
| Occupational Health and Safety Act (85 of 1993) and its regulations | Section 43 (1) b makes provision for the minister to make regulations on the interest of health and safety of people at work, and the conditions under which the manufacture of explosives and the activities incidental thereto may take place. |

| Legislation/regulation | Applicability |
|---|---|
| | Section 47 requires the licencing of explosive workplaces. |
| *GN R.109 of 2003: Explosives Regulations* | The Explosives Regulations make provision for the classification of explosives for manufacturing; licensing of explosives workplaces; danger area and danger buildings; safeguarding of explosives workplace; design, construction and manufacture; importation of explosives; supervision of explosives workplace; safe handling of explosives; emergencies; incidents; closure of explosives workplace authorities; standards of training; as well as offences and penalties. |

Different Acts are applicable, depending on the phase of the explosives waste life cycle. As mentioned earlier, the NEMWA excludes explosives wastes, however, the NEMWA is applicable to the waste generated after destruction, where the remnants of the destruction process need to be classified in accordance with the *Waste Classification and Management Regulations*, and assessed prior to any landfill disposal. The management of all remnants/waste generated after destruction from the burning grounds need to comply with the provisions of the NEMWA. The NEMA, NWA and NEMAQA are applicable to environmental protection.

Explosive destruction at OB/OD facilities in South Africa is regulated in terms of the Explosives Act (15 of 2003). Due to the inherent risks associated with the manufacture of energetic materials, levels of control in respect of health and safety procedures at OB/OD facilities are typically very high. More stringent requirements, particularly in respect of permitting procedures, are, being developed with the focus on risk characterisation and air quality management for OB/OD facilities.

## 4.2 Results related to RO 2: Evaluate compliance of a specific explosives manufacturer to the legal requirements for the management of explosives waste, as a case study

To address research objective 2, several methods were employed for data collection. These included an evaluation of previous audit reports, verifying current compliance to selected legal requirements, on-site observations, as well as interviews. The sub-sections below discuss the results of each of the method employed for data collection. A detailed evaluation of previous audits is also demonstrated in this section in order to comment on the status of compliance of the explosives manufacturing site.

### 4.2.1 Results related to evaluation of previous audit reports (2010 – 2019)

The findings of five audit reports from legal compliance audits conducted between 2010 and 2019 were reviewed to determine any trends in non-compliances.

Table 4-2 provides a summary of the trends related to legal non-compliance, focusing on permits and licenses, water-related findings, air pollution related findings, findings related to hazardous substance and waste management, reporting, as well as emergency incidents and response, as it relates to the scope of this research (as defined in 1.4.1of this dissertation).

**Table 4-2: Previous audit results (main findings per audit)**

| Audit year | Summary of findings | Status of compliance |
|---|---|---|
| 2009 | It was identified that permit documents and other legal requirements are all effectively documented in the proper place. In terms of a water related finding, it is identified that there are ***some of the parameters for example the nitrates, alkalinity and chlorides tested ten times more than the required specification of WUL*** (Water Use License). In the auditing process of ambient air quality, it has been highlighted that all the emissions meet the requirements of the air quality standards. During the audit it has been highlighted that a proper management system is in place that helps in reporting any emergencies or incidents related to environment spillage. As per all the determinations in 2009 it has been highlighted that the legal compliance is satisfactory and there are no complaints highlighted for environmental incidents. | Satisfactory, however there are areas of non-compliance with the management of effluent on site which can be easily rectified. |
| 2011 | It has been identified that a water use license was issued on 14 September 2011 for different uses that includes storing of water, disposing of waste and many more. In terms of analysing water related findings, it has been highlighted that in January 2011 ***there are results from groundwater monitoring that exceed the specification of the WUL, the borehole numbered N27 which is the proximity of the burning ground showed high levels of lead, Iron and manganese***. ***Pollution is detected and which can be highly possible due to neighbouring farmers' fertilisers***.<br>The audit concluded that the management system is generally effective in ensure compliance to the conditions of the atmospheric emissions licence. During the audit process there were no non-compliances noted in terms of effective control and handling of hazardous substances. A proper standard maintenance process is recommended in terms of providing effective precautions for environmental problems. Effective implementation of environmental precautions is required in terms of managing hazards. In the auditing process it has been highlighted that a fair number of findings and recommendations related to SHE management are identified which is required to be easily rectified. | Unsatisfactory, environmental related incidents needs to be properly investigated and reported to the authorities |

| Audit year | Summary of findings | Status of compliance |
|---|---|---|
| 2013 | The investigation and follow-up of previous water- and air quality related findings were found to be unsatisfactory. ***In terms of waste management processes, it has been identified that the company needs to be registered on the South African Waste Information Systems (SAWIS) to report the waste remnants generated from the process of waste burning.*** | Unsatisfactory |
| 2015 | It has been observed that the manufacturing site conducted its annual internal audit and the three yearly external audits for compliance to the water use license conditions. Effective determination of the examination process for auditing work is also made on air pollution. ***It has been identified that there is no evidence of classification of waste, which is a non-conformance under the GNR 634 and GNR 635 of the NEMWA.*** Based on the auditing process it has been highlighted that there was a proper balance in the findings and recommendation process. | Unsatisfactory |
| 2017 | In the year of 2017, it has been highlighted that a new application for an ***atmospheric emissions license*** was made that is valid up to 30 June 2021 which is applicable for the burning grounds. SAWIS registration has been addressed. No significant non-compliances were identified during the audit process. The audit report indicated that the legal compliance of the organisation was satisfactory. | Satisfactory. |
| 2019 | In the audit proceedings of 2019, it has been highlighted that the annual external, ***Water Use License*** compliance audit was conducted as per the recent report. The waste process is handled by a licensed and registered waste contractor who is licenced in terms of the NEMWA (GN. 921 of 2013), therefore, all documents perused indicated that the waste contractor is in compliance with the requirements of the NEMWA. The waste separation process is identified in waste management processes where a safety data sheet is made that helps in recording difference requirements. In the analysis process, the organisation's complaint status was acceptable and no major findings were observed. | Good |

### 4.2.2 Results related to evaluation of current compliance to selected legislation

To verify whether the scope of the audit reports adequately addressed the legal requirements applicable to the scope of this study, an evaluation of the current compliance of the explosives manufacturer to selected legal requirements was performed. The purpose of the evaluation was not to conduct a full legal compliance evaluation, but rather to verify the completeness of the audit reports (i.e. whether the audits adequately addressed legal requirements applicable to the storage of explosives wastes, the destruction of explosives, and the management of related wastes), with the aim of identifying any areas of non-compliance which were not identified in the audit reports.

Table 4-3 provides an overview of the current compliance status of the explosives manufacturer to the selected legal requirements. It is noted that each level of compliance for the manufacturing site was assigned a compliance status i.e. good, satisfactory or non-satisfactory. The explosive manufacturer's compliance to selected legal requirements were evaluated in 2020 by the researcher.

Recommendations were provided based on the level of compliance and actual legal requirements versus current practices.

In Section 4.2.2.1 the detail of the non-compliances to selected legal requirements are highlighted in the context of explosive sectors.

**Table 4-3: Summary of results of evaluation of legal compliance to selected legislation**

| Activity/process | Section/Regulation | Requirement | Current compliance state | Notes |
|---|---|---|---|---|
| **Explosives Act (15 of 2003)** | | | | |
| **Destruction of explosives** | Section 8 (1) | *Explosives may only be destroyed in accordance with such safe procedure as may be prescribed* | Compliant | The organisation has a list of standard procedures and FOI (facility operating instructions) that prescribed how explosives waste should be treated and handled. |
| **Destruction of explosives** | Section 8 (3) | *Any person who uses, keeps, transports or stores explosives in contravention of this Act is liable for any damage if the explosives are destroyed in terms of this section and if the damage is the result of the manner in which the person used, kept, transported or stored the explosives.* | Compliant | Storing and transportation of waste is done according to the manufactures explosives license in terms of the Explosive Act. |
| **National Environmental Management Air Quality Act (39 of 2004)** | | | | |
| **Activity/process** | **Section/Regulation** | **Requirement** | **Current compliance state** | **Notes** |
| **Operation of the burning ground and reporting of emissions** | Section 21 of NEM:AQA and listed activities in GN R. 893 of 2013 | *The organisation should obtain an AEL for operating a listed activity.*<br>*The holder of the AEL is required to do Bi-Annual Environmental Performance Reporting.* | Compliant | The organisation conducts a Listed Activity in terms of NEM:AQA (for the operation of the burning grounds) and has obtained an AEL for this activity.<br>Bi-annual submissions are made. |
| **Data provision** | GN R283 of 2015: National Atmospheric Emission Reporting Regulations | *Reg 4. A person classified as a data provider in regulation 4(1) must register on the NAEIS within 30 days from the date upon which these Regulations came into effect (before 2 May 2015)* | Compliant | The organisation has registered on the National Atmospheric Emissions Information System (NAEIS) and report on their emissions. |

<table>
<tr><td>Ambient air quality monitoring</td><td>GN. 1210 of 2009: National Ambient Air Quality Standards</td><td>Reg 1. Ambient air quality monitoring must be done on any point sources that may be affecting the ambient air pollutant concentrations.</td><td>Compliant</td><td>Argos Scientific (Perused Report No AS1198-SW for March 2018 - February 2019) conducts ambient air quality monitoring. This report indicated that the $SO_2$ and $NO_2$ results were well below the South African 24hr and annual National Ambient Air Quality Standards.</td></tr>
<tr><td>Dust fall monitored</td><td rowspan="2">GN R. 827 of 2013: The National Dust Control Regulations</td><td>Reg 3. The organisation should monitor any dust fall at site</td><td>Compliant</td><td>Dust fall is being caused by activities on site and it is monitored.</td></tr>
<tr><td>Dust fall monitored-limits</td><td>Table 1: Acceptable dust fall rates<br><table><tr><th>Restriction Areas</th><th>Dustfall rate (D) (mg/m²/day, 30-days average)</th><th>Permitted frequency of exceeding dust fall rate</th></tr><tr><td>Residential area</td><td>D < 600</td><td>Two within a year, not sequential months.</td></tr><tr><td>Non-residential area</td><td>600 < D < 1200</td><td>Two within a year, not sequential months.</td></tr></table></td><td>Compliant</td><td>Thlago Environmental Health & Safety Solutions monitors dust fallout on a monthly basis, the perused report indicates that all four samples had concentrations of $SO_2$ and $NO_2$ that were well below the applicable limits per gas analysed.</td></tr>
<tr><td colspan="5">National Environmental Management Waste Act (59 of 2008)</td></tr>
<tr><td>Activity/process</td><td>Section/Regulation</td><td>Requirement</td><td>Current compliance state</td><td>Notes</td></tr>
<tr><td>Storage of explosives wastes (remnants/waste from</td><td>Section 21 of the NEMWA and GN R. 926 of 2013: Norms and Standards for the Storage of Waste</td><td>Not applicable to the storage of the explosives themselves, but applicable to the storage of remnants/waste remaining after the destruction at burning grounds if exceeding 80 $m^3$ in volume.</td><td>Compliant</td><td>There is designated storage area for all waste streams. The area for the storage of hazardous waste does not exceed the 80 $m^3$ threshold. Some of the norms and standards outlined in GN R. 926 is,</td></tr>
</table>

| | | | | |
|---|---|---|---|---|
| **destruction process)** | | | | however, implemented as part of voluntary best practise. |
| **Waste classification** | Waste Classification and Management Regulations (GNR. 634 of August 2013) | *Classification of waste not excluded in Annexure 1 (i.e. Remnants/waste after the destruction at burning grounds)* | Compliant | An external company was sourced to classify all waste streams |
| **Waste assessment** | Norms and Standards for the assessment of Waste for Landfill Disposal (GNR. 635 of August 2013) | *Assessment of waste (type 0 – 4) not excluded in Annexure 1 of GNR. 634 for landfill disposal* | Compliant | An external company was sourced to classify all waste streams |
| **Transportation of explosives wastes** | Section 25 of the NEMWA: Transportation of waste | *The Minister, an MEC or a municipality may, by notice in the Gazette, require any person to-*<br>*(a) register with the relevant waste management officer in the Department, province or municipality, as the case may be; and*<br>*(b) furnish such information as is specified in that notice or as the waste management officer*<br>*may reasonably require.*<br>*(2) Any person engaged in the transportation of waste must take all reasonable steps to prevent any spillage of waste or littering from a vehicle used to transport waste.*<br>*(3) Where waste is transported for the purposes of disposal, a person transporting the waste must, before offloading the waste from the vehicle, ensure that the facility or place to which the waste is transported, is authorised to accept such waste.*<br>*(4) Where hazardous waste is transported for purposes other than disposal, a person transporting the waste must, before* | Partial Compliance | Appointed explosives drivers only do internal transportation of waste contaminated with explosives. ***It was observed that during transportation the waste is not covered***. Removal of remnants from the burning ground is only by an external registered and approved service provider; the service provider has the permit and is registered as a hazardous waste transporter. |

| | | | | |
|---|---|---|---|---|
| | | *offloading the waste from the vehicle, ensure that the facility or place to which the waste is transported, is authorised to accept such waste and must obtain written continuation that the waste has been accepted.* | | |
| **Exportation of waste** | GN. 22 of 2019: Regulations Regarding the Control of the Import or Export of Waste | *Applicable to the import and export of waste* | Not applicable | No waste is exported |
| **Disposal and export of explosives waste** | GN R. 636 of 2013. Norms and Standards for disposal of waste to landfill | *Disposal of explosives wastes is not allowed in accordance with GNR. 636 of August 2013.*<br>*Disposal of remnants/waste after the destruction process is only allowed at authorised landfill sites, in accordance with the assessment.* | Compliant | No explosives are being disposed of without being destructed first. |
| **Reporting** | GN R. 625 of 2012: Waste Information Regulations | (*a) Generators of hazardous waste in excess of 20kg per day must register and report on SAWIS.* | Compliant | The site is registered on SAWIS. The Waste Information regulations exempt generators of hazardous waste of more than 20kg per day of reporting. |
| **National Water Act (59 of 2008)** | | | | |
| **Activity/process** | **Section/Regulation** | **Requirement** | **Current compliance state** | **Notes** |
| **Pollution of water resource** | Section 19 – Prevention and remedying effects of pollution | *The manufacture must establish whether any of its activities caused causes or may cause pollution to a water resource. In order to do this, monitoring of water must be done on a regular basis. If any such pollution or possible pollution has been identified, reasonable measures must be taken to prevent the continuation or recurrence thereof.* | Non-compliant | In one of the reports it was noted that there are areas of ground water pollution near the burning ground |

#### 4.2.2.1 Changes in quality of water due to explosive waste management

The explosive waste created in the explosive manufacturing plants contaminates the water in the surrounding areas (Ronen, 2020). As per the views of Istvan and Ronen (2020) groundwater is easily contaminated in the areas where explosives are tested. The burning ground and testing ground of the explosive manufacturing plant are the main areas where the groundwater is polluted (as observed during the 2007 and 2011 legal compliance audits). In November 2011 during a legal compliance audit of the manufacturing site it was highlighted that there are results from groundwater monitoring that exceed the specification of the WUL, the borehole numbered N27, which is in the proximity of the burning ground, showed high levels of lead, iron and manganese.
Trends in water quality monitoring results from 2013 up to 2020, however, indicated a gradual improvement of ground water quality, and no non-compliances related to ground water quality have been raised since 2013.

#### 4.2.2.2 Changes in quality of air due to explosive waste management

Air pollution is the main issue that is created from the waste generated in the explosive manufacturing industry. Air pollution is caused by the process of thermal destruction through open detonation of explosives and open burning of explosive waste. On the other hand, Joy *et al.* (2016) denotes that the rules and regulations imposed by the air quality officers have reduced the air pollution from explosive manufacturing plants.

The results of the evaluation of audit reports, as well as the legal compliance evaluation conducted by the researcher, indicated that the explosives manufacturer were in compliance with the conditions of their AEL and the other requirements of the NEMAQA. Changes in air quality due to explosives waste management is, thus, not currently cause for concern.

#### 4.2.2.3 Risk of soil contamination due to explosive waste management

In 2016, WSP Environment & Energy (WSP) was appointed by the manufacturing site to undertake a review of all available information and to assess the facility contamination level and draft a Site Assessment Report. The observation made from assessment showed minor impacts by salts, energetics and various metals near some of the site processing buildings. None of the audit reports highlighted any non-compliances or issues related to soil pollution and explosives management. Soil pollution from explosives handling, storage and use are, therefore, not currently cause for concern.

### 4.2.3 Conclusions related to the results of evaluation of audit reports and evaluation of compliance to selected legal requirements

The level of compliance of the explosives manufacturer has improved from 2009 to 2019. During the last audit (in 2019), it was fully demonstrated that the manufacturing site has implemented systems

that are effective to ensure continuous legal compliance. The results of the evaluation of previous audit reports have demonstrated that the manufacturing site management has processes in place to improve environmental legal compliance.

A summary of noted non-compliances, related to this research scope included:

- From 2009 to 2011 there were areas of non-compliance raised by the external auditors in relation to the water use license (WUL). It was noted that some effluent parameters were above the specifications of the WUL.
- In 2015 it was noted that the manufacturing site did not classify their explosive waste remnants from the burning ground, which was a non-compliance to GNR 634 and GNR 635 of the NEMWA.

The evaluation of the last audit report (2019) indicated that no legal non-compliances were raised, in relation to the management of explosives wastes, which was the scope of this study.

In relation to the current status of legal compliance, the explosives waste manufacturer complies with the requirements of the legislation under investigation.

### 4.2.4 Perceived legal compliance by respondents

Interviews were conducted, which focused on explosive waste management and disposal process to help understand how the explosive manufacturer manages its waste and to determine the perceived level of legal compliance. The interview process also helped to identify the challenges and opportunities for achieving legal compliance, which is one of the most primary objectives of this study (Section 4.3). The interviews focused on compliance and challenges with compliance related to the explosives waste management life cycle – from the collection, during transportation and including final disposal. Thirty manufacturing site employees were interviewed based on their level and area of expertise, as indicated in Section 2.3.4 of this study.

#### 4.2.4.1 Collection of explosive waste in a proper way

Collection and managing waste in a properly guided procedure is mandatory for the explosive industries as it can cause significant harm to the environment and human health. The explosive industry is associated with extremely harmful chemicals in their wastes stream, hence it becomes necessary to properly collect and eliminate those wastes to avoid any physical harm to the environment and human health.


**Figure 4-1: Status of compliance during collection of explosives waste as perceived by interviewees**

From the interview process it has been identified that almost 82% of the respondents perceive the collection of explosive wastes to be performed in a proper way, while 11% or respondents indicated that they were uncertain. Approximately 7% of respondents perceived that the explosive waste collection process is not being performed in a proper way (and mentioned that there may be potential for incidents). (Figure 4-1).

#### 4.2.4.2 Transportation and disposal of explosive waste

Proper disposal and transportation of the explosive wastes are mandatory because in most of the cases the generated wastes in the manufacturing plant are burnt and transformed into ash so that they can be safely transported. Explosive trucks are used to transport the explosive waste in most of the sites. Explosive trucks are specially manufactured to carry the waste generated from the manufacturing of explosives.

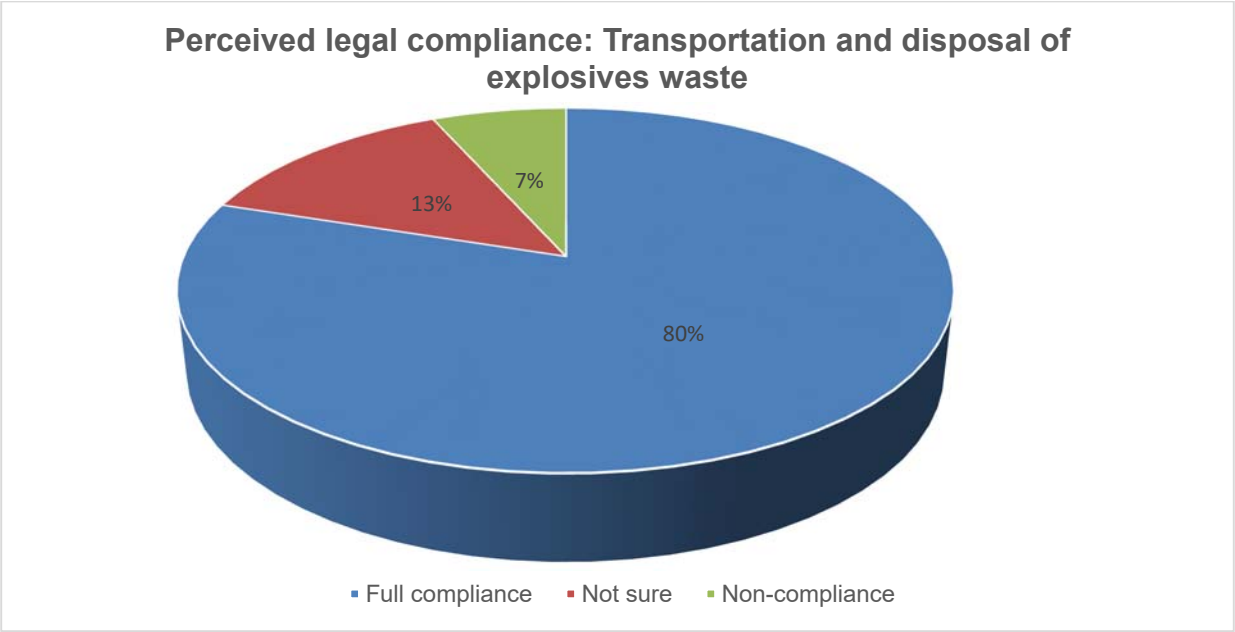


**Figure 4-2: Status of compliance during the transportation and disposal of waste as perceived by interviewees**

The majority of respondents (80%) perceived the transportation and final disposal of explosives wastes to be in line with legal requirements. Only 7% (two respondents) indicated that they perceived transportation and disposal to be potentially non-compliant with legislation, while 13% indicated that they were uncertain about the level of legal compliance (Figure 4-2). The concerns mentioned included a lack of proper disposal at licensed landfill sites, and potential loss of containment during transportation.

Challenges related to legal compliance and opportunities for improvement identified during interviews are outlined in 4.3 of this dissertation.

### 4.2.5 Results from observations

The aim of the process observation was to develop an understanding of the day to day activities in relation to the legal compliance status of the manufacturing site, focusing on national, provincial and local environmental legislative requirements. As part of the observation, actions were identified to help address challenges and issues that require attention in order for the manufacturing site to ensure its operations are in compliance with relevant legislation and to effectively manage identified environmental and associated business risks.

#### 4.2.5.1 Areas of non-conformance when handling waste

In reference to the process flow observation flowchart, Figure 4-3, and the planned task observation conducted in this study, there are several areas of non-conformance found in the production process of the manufacturing site. In accordance with the “process flow observation flowchart”, the following non-compliances were noted:

- Explosives waste transported to the burning grounds is not covered totally, which in turn creates several issues, such as blowing off the waste material through the air, which can contaminate the entire surrounding area (Op 7, Figure 4-3).
- In addition, observations revealed that explosives wastes are not adequately stored, with storage skips or bins overflowing with waste (Op 6, Figure 4-3). This observation leads to the conclusion that the manufacturing site might not have sufficient storage capacity for explosive contaminated wastes.
- A third observation made was related to the storage of waste at the laboratory, where waste streams were mixed instead of being kept separate (glass waste were contaminated with explosives wastes), there were other production areas where contaminated oil rags was mixed with general waste.

In accordance with the viewpoint of Ghosh *et al*. (2016), inaccurate placing of contaminated waste material, in turn, leads to hazardous as well as dangerous consequences and can further mix with soil and cause soil pollution as well. However, the primary exclusives that are stored in plastic containers by this manufacturing site must have high polyethylene content, so that chances of contamination are reduced to some extent.

According to Zhao and Ke (2017) China enforced regulations in order to reduce the risks emanating from the unwanted facility location and inventory management of the explosives waste after the popular “8.12" Tianjin explosion hazard. Nanchuan at the Southwest China, explosive waste poses rising threats to people and the environment, these threats are observed mainly during the transportation, collection and storage process (Zhao and Ke, 2017).
Canada, United States, Germany and the United Kingdom, have jointly agreed to reduce the health risks posed by the explosives waste on human and the environment, however there are challenges still posed by the explosive remnants of war. Not only are these explosive remnants potentially hazardous to human and environmental health, they are also often difficult to trace, costly to remove and arduous to manage (Linkov *et al*. (2014).

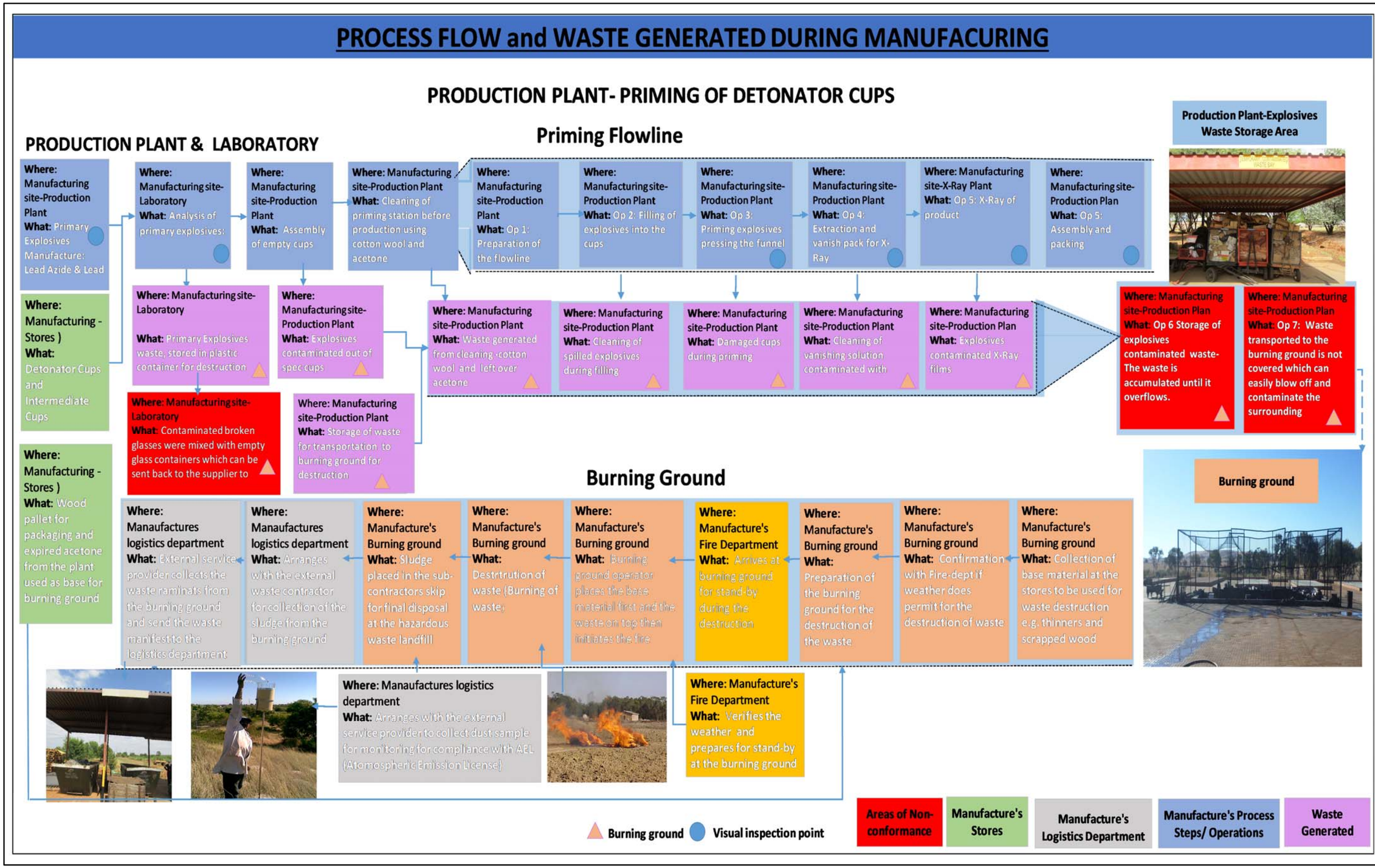


**Figure 4-3: Areas of non-compliance (red) noted during observations**

### 4.3 Results related to RQ3: Challenges and opportunities for achieving legal compliance

The third research question aimed to determine the challenges and opportunities for achieving legal compliance by the explosives sector. The results related to this research question are divided into two sub-sections: (i) results from interviews given in section 4.3.1 and (ii) results from the literature given in section **Error! Reference source not found.**.

#### 4.3.1 Challenges and opportunities mentioned during interviews

It has been observed from interview responses as shown in Figure 4-4 that 74% of the respondents perceive that there are no challenges related to explosives waste management and legal compliance. Approximately 22% of respondents indicated that there were challenges with compliance related to explosives waste management, while 4% indicated that they were unsure. Although the majority of respondents indicated that there were limited challenges, most of the respondents (78%) agreed that opportunities for improvement exist. Approximately 7% of respondents indicated that there are no opportunities for improvement, while 15% were uncertain (Figure 4-4).

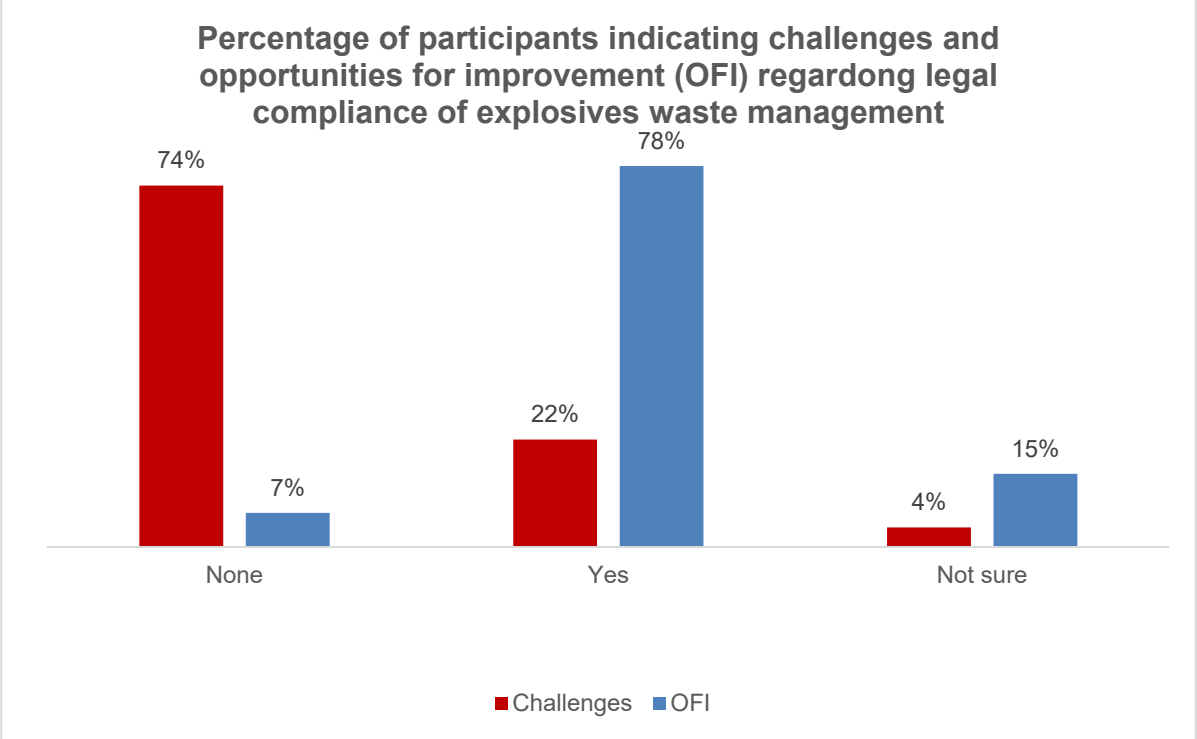


**Figure 4-4: Challenges and opportunities for improvements as perceived by interviewees**

The specific challenges for legal compliance mentioned by participants included:

- Implementation of policies and procedures (as outlined in legislation) not being effective;
- Contamination of non-hazardous waste streams with explosives waste;
- A lack of awareness and knowledge of requirements for explosives waste management by employees of the explosives manufacturer;

Opportunities for improvement mentioned by respondents included:

- Improved waste management through implementation of legislation;
- Improved awareness and communication from management to workers regarding requirements for explosives management;
- Improved interventions to improve the understanding of the laws and requirements regarding generation, transportation, reduction and disposal of explosive waste.

The specific responses related to the aspects mentioned above are discussed in more detail below.

#### 4.3.1.1 Improvement of waste management through implementation of legislation

Requirements for the management of explosives waste are outlined in legislation (as summarised in Section 4.1of this dissertation). The prescribed regulations play a crucial role in the dynamics surrounding the explosives industry at every level keeping in mind the costs to the economy, society and the environment. As stated in the manufacturing site's environmental policy, the overarching objective that is sought to be achieved is to ensure reduction and effective management of the resultant residue from explosives manufacturing activities.

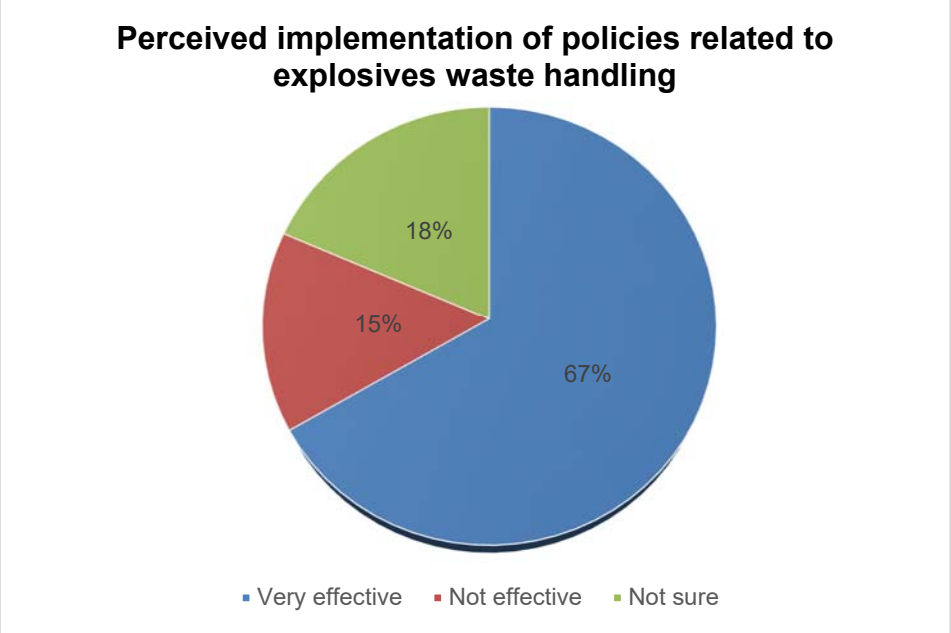


**Figure 4-5: Perceived status of policy implementation by the explosives manufacturer**

Government policies on the generation and disposal of explosive waste are very strict in South Africa. It includes requirements related to worker and workplace protection, environmental protection and protection of the public. The distance of the burning ground from the habitable population plays a key factor in public protection. Various mitigation and management measures during the

manufacturing, destruction and disposal phases will impact on the health and safety of employees, as well as the environment (as illustrated in Section 4.1).

Interviewees were requested to respond to the current implementation of legislation and policies by the explosives manufacturer – as it relates to the management of explosives wastes (Figure 4-5). Approximately 67% of the participants perceived the implementation of policies and legislation to be very effective, while 15% perceived it as being ineffective, and 18% being uncertain. This means that about 18% of the participants were either not aware of the existence of any policy or regulation regarding waste management in explosives manufacturing site or not certain about the level of implementation of policy (Figure 4-5).

Respondents were requested to indicate whether they perceive opportunities for improvement to exist when it comes to policy implementation. Approximately 78% of the respondents indicated that they feel that there is scope of improvement through the implementation of policy and legislation as presented in Figure 4-6. However, approximately 7% of respondents indicated that they do not perceive any opportunities for improvement through implementation of policy, while 15% indicated that they were uncertain.

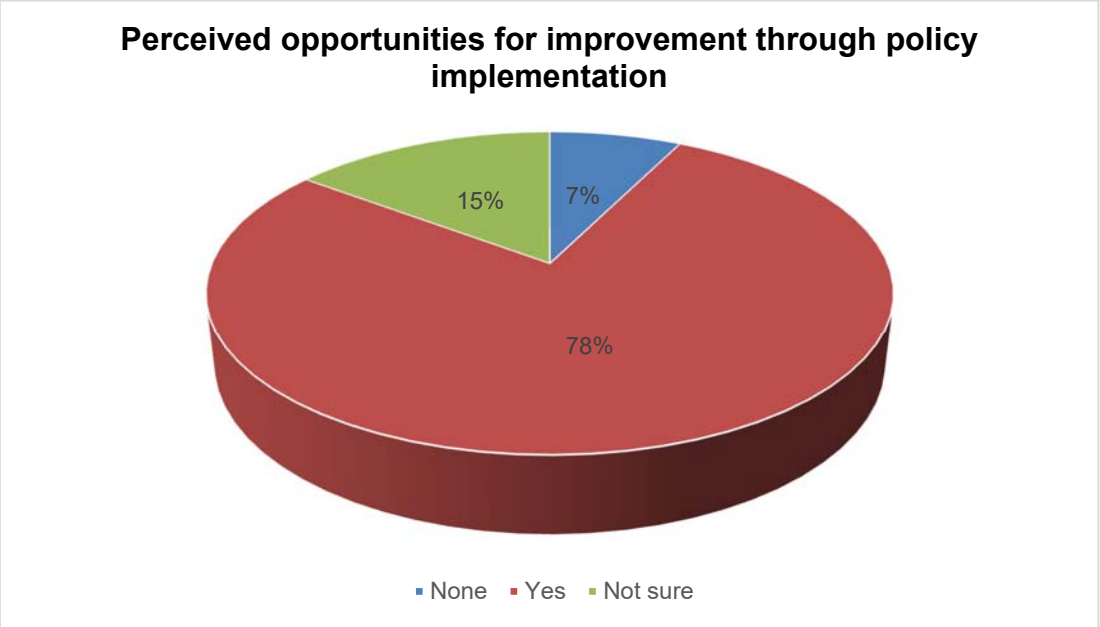


**Figure 4-6: Opportunities for improvement through policy implementation as perceived by interviewees**

#### 4.3.1.2 Training of employees

Training of employees is very essential to successfully deal with the explosive materials in the explosive industry since the employees lack of skills in managing the wastes or materials can cause severe accidents. In general, employees responsible for explosives manufacturing and waste management should receive training from site management for the generation and safe disposal of

explosive waste and ideally from explosives management experts in the local government. From the results of interviews, it has been found that the training received from the site handling team is perceived to be very effective (by 100% of respondents). Interviews indicated that:

- The employees working at the explosive manufacturing sites strictly follow the rules that were taught to them during induction and training.
- The awareness about the generation of explosive waste and how to reduce it is good among the employees.
- The employees are also well aware of the site-specific transportation and disposal policies.

Thus the training received from the site handling team was considered to be effective and embedded in the work flow followed in the explosive manufacturing plants in South Africa.

On the other hand, the results of the interviews indicated that respondents expected government officials to provide training for explosives waste management, and that training from government officials were perceived to be lacking (by 89% of participants). Although it is not a legal requirement for government officials to conduct explosive management training, interviewees had the expectations that it would be ideal for training to be provided by officials, as they are the enforcers of the regulations and would be able to provide clarity on exactly what is expected by the regulations enforced by them.

### 4.4 Chapter summary

This chapter has presented the findings of the study that answers the research objectives, which are determining the legal framework applicable to the management of waste by the explosive sector, evaluating legal compliance of the explosives manufacturing sector and identifying the challenges and opportunities for achieving legal compliance.

The findings of the study concerning the first objective (RO1) identified that there are set legal frameworks both nationally and internationally. In South Africa, there are legal requirements dealing with worker and workplace protection, public protection and environmental protection. The Explosives Act is the main piece of legislation dealing with the explosives life cycle. Section 4 of the NEMWA excludes explosives wastes from the ambit of the Act, while the Act is applicable to the management of waste after the destruction process, which includes storage, classification and assessment. The NEMAQA regulates the destruction of explosives at burning grounds, while the National Water Act focuses on protection of water resources. The Occupational Health and Safety Act, as well as the Mine Health and Safety Act, and its regulations are applicable to worker and workplace protection.

In response to the second objective (RO 2), on evaluation of legal compliance of the explosives manufacturing plant to legislation applicable to explosives waste management, the results of evaluation of legal compliance audit reports indicated that non-compliances were mostly related to water quality issues (mainly from nitrates from the explosives destruction process), as well as waste classification and waste assessment. The additional verification of legal requirements by the study indicates an improvement of the legal compliance status of the explosives manufacturer, and all legal requirements evaluated complied with legislation. Observations indicated explosives waste storage being the main concern. Results of interviews also indicated that the explosives waste handling, collection, transportation and disposal processes are perceived as being compliant.

In response to the third objective (RO3) of identifying challenges and opportunities for achieving legal compliance, challenges related to training and a lack of implementation of policies and legislation was identified. Opportunities for improvement related to the implementation of policies and legislation and improved training.

The following chapter will draw a conclusion to the research objectives with respect to the data analysis findings.

# CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

The researcher has set three main objectives to evaluate the challenges of legal compliance for the management of waste by the explosives sector in South Africa. The objectives of the study were to:

- Research objective 1: Determine the legal framework applicable to the management of waste by the explosive sector;
- Research objective 2: Evaluate compliance of a specific explosives manufacturer with the legal requirements for the management of explosives waste, as a case study; and
- Research objective 3: Identify challenges and opportunities for achieving legal compliance.

## 5.1 Conclusions

The sub-sections below provide the conclusions related to the three research objectives.

### 5.1.1 Conclusion related to RO1: Applicable legislative framework

Chapter 3 of this dissertation provides an overview of the legislative framework applicable to explosives waste management. The scope of the study focused on the handling, storage, transportation and final disposal of explosives wastes.

The legislative framework includes the regulation of explosives as it relates to environmental protection, human health, as well as occupational health and safety.

The Explosives Act (15 of 2003) (RSA, 2003) aims to provide for the control of explosives in the country, while the Occupational Health and Safety Act (85 of 1993), and the Explosives Regulations promulgated in terms of these regulations, provide the workplace requirements on the day-to-day management of explosives. As far as environmental protection is concerned, the principles and requirements provided for in the National Environmental Management Act (107 of 1998) (NEMA) (RSA, 1998a), the National Environmental Management Air Quality Act (39 of 2004) (NEMAQA) (RSA, 2004), the National Water Act (36 of 1998) (NWA) (RSA, 1998b) and the National Environmental Management Waste Act (59 of 2008) (NEMWA) (RSA, 2008) aim to regulate activities with potential impacts on the environment. The disposal of explosives that is regulated by the Explosives Act, 2003 (15 of 2003) (RSA, 2003b) is, however, excluded from the requirements of the NEMWA.

The South African legal framework adequately provides requirements for the different phases of the explosives waste management life cycle. Each of the laws regulate different aspects of explosives waste management, depending on the objects of the Act, i.e. protection of air- or water quality, regulation of waste from an environmental context, as well as occupational health and safety management.

### 5.1.2 Conclusion related to RO2: Compliance to the legislative requirements for the management of explosives waste

The second objective aimed to evaluate the compliance of explosives waste management practices of a specific explosives manufacturer to the legal requirements for the management of explosives waste. The level of compliance was determined by reviewing audit reports from 2010 to 2019, supported by the researcher's own verification of legal compliance to selected requirements, observations, as well as interviews to determine the perceived level of compliance and possible problem areas.

The level of compliance of the explosives manufacturer has improved from 2010 to 2019. During the last audit (in 2019), it was fully demonstrated that the manufacturing site has implemented systems that are effective to ensure continuous legal compliance.

A summary of noted non-compliances, related to this research scope included:

- From 2009 to 2011 there were areas of non-compliance raised by the external auditors in relation to the water use license (WUL). It was noted that some effluent parameters were above the specifications of the WUL.
- In 2015 it was noted that the manufacturing site did not classify their explosive waste remnants from the burning ground, which was a non-compliance to GNR 634 and GNR 635 of the NEMWA.

The evaluation of the last audit report (2019) indicated that no legal non-compliances were raised, in relation to the management of explosives wastes, which was the scope of this study. In relation to the current status of legal compliance, the explosives waste manufacturer complies with the requirements of the legislation under investigation.

Observations indicated explosives waste storage being the main concern. Results of interviews also indicated that the explosives waste handling, collection, transportation and disposal processes are perceived as being compliant.

From the results related to research objective 2, it can be concluded that the storage of explosives wastes needs to be improved upon.

### 5.1.3 Conclusion related to RO3: Challenges and opportunities for achieving legal compliance

The third objective aimed to identify challenges and opportunities for achieving legal compliance (as it relates to explosives waste management). Challenges related to training and a lack of implementation of legislation were identified. Opportunities for improvement related to the implementation of legislation were identified. Globally, there are laws in place to ensure efficient

explosive waste management. However, the inability of implementing and enforcing compliance result in increased pollution caused by explosives waste.

## 5.2 Recommendations

Recommendations are further provided in order to ensure that explosives waste management is suitable and adequate. As influenced by the viewpoint of Sotamenou *et al.* (2019), the recommendations are mentioned in the following sub-sections:

### 5.2.1 Practical recommendations for achieving legal compliance

Although the results of the research indicated that the explosives manufacturer (selected as a case study) was largely compliant with legislation, the storage of explosives waste and the training of employees as it relates to explosives waste management, were highlighted as two areas requiring improvement. To this extent, the following practical recommendations were made:

- Improving burning grounds to adequately handle waste;
- Improving waste separation;
- Undertaking internal and external audits in the waste storage area; and
- Training of employees on explosives waste management.

The sub-sections below provide more detail on each of these recommendations.

#### 5.2.1.1 Protection and preparation of burning grounds to adequately handle waste

Burning grounds need to be maintained in order to ensure the successful destruction of contaminated waste materials and to prevent pollution to the water resource. Explosive manufacturers should work closely with local authorities and fire departments to verify any additional requirements, which may apply to a specific area.

#### 5.2.1.2 Improvement of ground water quality

Continuous monitoring on ground water quality should be performed to monitor the possible effects of explosives manufacturing on ground water quality. The research indicated that ground water quality was largely compliant to the conditions of the water use licence since 2011. Continuous ground water quality monitoring will ensure that the explosives manufacturer are in a position to identify any potential sources of water pollution.

#### 5.2.1.3 Improvement of the waste separation site

During process observation, it was noted that several oil rags were being disposed of with various other general and explosive wastes, which may have dangerous consequences at the waste

separation site. For instance, oil rags in front of the boiler house can initiate some new hazards and dangerous situations might further happen due to this aspect.

General and hazardous waste should be separated and managed in accordance with the norms and standards for the storage of waste, as well as international best practice.

#### 5.2.1.4 Necessity of undertaking internal and external audits regarding the waste storage area

Along with all the other recommendations, this particular recommendation at the same time is considered to be highly necessary for accurate handling of waste management. In reference to the 2019 audit report, it can be highlighted that, no internal as well as external audits are undertaken in the waste storage area.

In accordance with the viewpoint of Godfrey and Oelofse (2017), audits at the same time help to create an accurate data analysis. By conducting both internal and external audits of the waste storage area, problematic areas can be predetermined. It is recommended that explosive manufacturers perform audits on the storage of explosive wastes. Based on the thinking of Gobbi *et al.* (2017), internal auditors can determine several issues of an organisation and can analyse various critical situations or upcoming risks.

#### 5.2.1.5 Training of employees on handling of explosive wastes

According to the viewpoint of Sotamenou *et al.* (2019), training of employees is considered to be vital to prevent and/or react to a potentially harmful situation. To adequately handle contaminated explosives waste with accurate techniques, the explosive manufacturers need to incorporate various training sessions within their working sectors.

Although the evaluation of audit reports reveals that the explosive manufacturer's waste management practices seem to be in good order, training sessions may be beneficial in maintaining the compliance status, since legislative requirements applicable to the management of waste are changing rapidly.

### 5.2.2 Recommendation for further studies

The following is recommended in terms of doing further research:

- The scope of this research was limited to the handling, storage, transportation and final disposal of explosives waste. Further research beyond the scope of the study could be considered, to also include processes up- and down-stream of the explosives manufacturing process, focusing on establishing environmental legal compliance.

- The environmental legal compliance of a larger range of explosives industries (from different phases of the supply chain) as it relates to explosives waste management, could be included in future research.

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