An Overview of the Occurrence, Evaluation and Remediation of Petroleum Hydrocarbon Contamination in South Africa: Case Studies of Contamination from Filling Stations in Gauteng

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A research report submitted to the Faculty of Science, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Science.

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Declaration

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

Ntandoyenkosi Brian Muthwa

June 2020, Johannesburg South Africa

Dedication

To my grandfather Zacks Kufakwezwe Muthwa, who endured daily whipping at the hands of an unnecessarily cruel man to learn how to read and write. Your endurance has made the lives of all your descendants easier and more enjoyable. Siyabonga Phungaze elimhlophe. S'cubu kasosiwa.

Acknowledgements

I would like to start off by thanking Mr Gift Matsabatsa, my very first manager. Gift took a chance on me and introduced me to contaminated land management. When I started off on the job, I had no clue that there were even people doing what I've over the years come to enjoy and love so much. On that same breath I would like to acknowledge and thank Mr Pieter Badenhorst of Geo Pollution Technologies. Pieter took me in when I still very fresh and taught me almost all I now know and do in contaminated land management.

I would also like to thank the many colleagues (both in industry and consultation) I have worked with through the years. You have contributed in many ways to this work and most of you won't even be aware of how you've helped. From water cooler conversations to in depth consultations, your contributions are highly appreciated.

Then to my supervisor Dr Humphries. I was most likely your weirdest student to supervise. Thank you so much for your contributions and patience through the production of this work. Your approach helped me with the management of the many demands that pulled for my attention.

Lastly, I would like to thank my sweet daughter, Uminathi and my dear wife Kanyisa. Thank you for being patient with me as I worked on this. I needed a lot of it.

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GLOSSARY

ASTM	American Society for Testing and Materials
BETX	Benzene, toluene, ethylbenzene and xylenes
EPA	(American) Environmental Protection Agency
GC-MS	Gas Chromatography-Mass Spectrometry
HDPE	High Density Polyethylene
MEC	Member of the Executive Council
LEL	Lower Explosive Limit
LNAPL	Light Non-Aqueous Phase Liquid
MTBE	Methyl Tertiary Butyl Ether
MW	(groundwater) Monitoring Well
NEMA	(South African) National Environmental Management Act
PID	Photo Ionisation Detector
SVS	Soil Vapour Survey
TAME	Tert-Amyl Methyl Ether
TMW	Tank Monitoring Well
TPH	Total Petroleum Hydrocarbons
VER	Vacuum Enhanced Recovery
VOC	Volatile Organic Compound
WHO	World Health Organisation

1. INTRODUCTION

1.1 GENERAL INTRODUCTION

Petroleum hydrocarbon compounds are processed into many products including diesel, petrol, paraffin and lubricants. These products are used by ordinary South Africans on a daily basis as they go about their lives. However, some petroleum hydrocarbon compounds, like benzene, used as ingredients in the manufacturing of petrol, are known carcinogens and may increase the risk of cancers, such as lung, skin and bladder cancers (Konečný *et al.*, 2003, World Health Organisation, 2010, Kpone e*t al.*, 2015 and Iffis *et al.*, 2017), or are otherwise hazardous and may compromise human and ecological health (Chilcott, 2007).

Urbanisation and economic growth have significantly accelerated motorisation in South Africa. Van der Post (2017) reports that at the end of February 2017 the South African electronic National Administration Traffic Information System (eNatis) had a total of 12 027 860 registered vehicles. Of these, approximately 4.6 million were registered in Gauteng, 1.9 million in the Western Cape and 1.6 million in KwaZulu-Natal. Each of these 12 million vehicles uses either diesel or petrol as fuel. Because of the carcinogenic petroleum hydrocarbon compounds contained in and used in the manufacture of diesel and petrol, the National Environmental Management Act 107 of 1998 classifies diesel and petrol as dangerous goods, for which authorisation must be granted by a competent authority for their handling and storage (Government of the Republic of South Africa, 1998). Despite the legislation in place, accidental releases of diesel and petrol may occur during storage, handling and transportation. The accidental releases may be due to leaking storage tanks, spillages during vehicle refuelling, tank overfills, pipeline leakages and bulk fuel tanker road accidents. Accidental releases may result in petroleum hydrocarbon contamination of environmental receptors like soil, surface water, groundwater and air. Human exposure to contaminated receptors may lead to cancer or an otherwise comprised health including narcosis, rapid unconsciousness, chemical pneumonitis, eye and respiratory system irritation, aplastic anaemia, reduced resistance to infections, a variety of dermatitic conditions and neurological disorders (Chilcott, 2007; Sellappa *et al.*, 2010 & World Health Organisation, 2010).

1.2 AIMS AND OBJECTIVES

The aim of this study is to critically assess the occurrence, evaluation and remediation of petroleum hydrocarbon contamination in South Africa, using purposive or judgemental selected case studies of fuel handling facilities located in Gauteng that have been confirmed to be contaminated by petroleum hydrocarbon compounds. In the interest of keeping the anonymity of the oil company and consultants involved, the sites will be identified by general location without giving detailed information. The main objectives are to:

1.2.1 Identify cases where petroleum hydrocarbon contamination occurred in Gauteng.

1.2.2 Analyse the methods used to detect and evaluate petroleum hydrocarbon contamination in the cases identified.

1.2.3 Analyse the methods used to remediate petroleum hydrocarbon contamination in the cases identified.

1.2.4 Critically evaluate South African legislation that governs the evaluation and remediation of petroleum hydrocarbon contamination and contrast it with international practice.

1.3 RESEARCH QUESTIONS

The following questions will be answered by the results of the study:

1.3.1 What is the nature, occurrence and cause of petroleum hydrocarbon contamination in South Africa?

1.3.2 What are the potential impacts of petroleum hydrocarbon contamination to the environment?

1.3.3 How is petroleum hydrocarbon contamination detected, evaluated and remediated in South Africa?

1.3.4 Which legislation governs the occurrence, evaluation and remediation of petroleum hydrocarbon contamination in South Africa and how does it compare to international standards?

1.4 CHAPTER SEQUENCE

This report is separated into five chapters to facilitate readability. A summary of the contents and purpose of each chapter is presented in this section.

Chapter 1 provides a brief background of the study. It briefly introduces the aims and objectives of the study and presents the questions that the results of the study are expected to answer.

Chapter 2 presents a review of published literature on the occurrence of hydrocarbon contamination locally and internationally. It details the findings of some studies previously conducted on the human and ecological impacts that results from exposure to contamination. The legislation governing contamination and some successes in remediation is also discussed.

Chapter 3 provides a description of the study area from which the case studies were selected. It also presents the research design and methodology used to execute the study.

Chapter 4 presents a summary of the data that were collected as part of the research process. A discussion of each of the case studies used to meet the aims and objectives of the study are presented in this chapter.

Chapter 5 presents a summary, discussion and analysis of the data presented in the preceding chapter; while Chapter 6 provides conclusions drawn from the data obtained in the study.

2. LITERATURE REVIEW

2.1 OCCURRENCE OF HYDROCARBON CONTAMINATION

Das and Chandran (2011) noted that leaks and accidental spills occur regularly during exploration, production, refining, transport and storage of petroleum hydrocarbon products. As a result, petroleum compounds are said to be one of the most recurrent soil contaminants (Banks *et al*., 2003, Guo *et al.*, 2012 and Adeniji *et al.,* 2017a), and are ubiquitous in water, air and biota (Zhang *et al.*, 2014). Petroleum hydrocarbon compounds occur in the environment in four forms, viz. dissolved in surface and ground water, sorbed on solid particles, as a component of soil gases, and because of its limited solubility, forming a non-aqueous phase liquid (NAPL) which may be lighter or denser than water (Konečný *et al.*, 2003).

Increasing global production and probability of accidents has contributed significantly to the widespread occurrence of hydrocarbon contamination (Guo *et al.*, 2012). Zacharyasz *et al*. (2012) noted that despite significant improvements in the technical conditions of facilities that produce, store and transport petroleum products, the threats that petroleum products pose to the environment are real. This was indeed the case when a pipeline failure resulted in a spillage of 70 tons of petrol in Międzychód, Poland in 1996. A study conducted in the spillage area (Zacharyasz *et al.*, 2012) revealed that the spillage had contaminated more than 3,000 m^3 of land beyond allowable standards. It is estimated that in Ogoniland, Nigeria, more than 6,000 oil spill incidents occurred between 1976 and 2011 and resulted in release of approximately 477 million litres of oil (Kpone e*t al.*, 2015).

Fuel spillages from road accidents are also common in South Africa, especially during the busy holiday seasons. In July 2017, a tanker transporting diesel from Mossel Bay to Beaufort West overturned on the Meiringspoort Pass near De Rust, Little Karoo. This resulted in a spill of about 42,000 litres of fuel (Isaacs, 2017). In December 2017, multi-vehicle crashes at Van Reenen’s Pass, Harrismith involving a diesel tanker led to a spill that impacted about 4 km of the road (African News Agency, 2017). It should be noted that the details of roadside tanker spillages are generally reported from a road safety perspective, without much mention of the health and environmental impacts. In the Meiringspoort Pass incident, it was only reported that the spill may affect aquatic life in the nearby river, and cattle and wildlife that drink from the river. No further details on the potential, or actual environmental impacts were reported. That means a layman will most likely never really understand the environmental impacts of fuel spills due to limits of the information presented to them. Details of leaks and spills that occur at privately owned facilities, such as filling stations and depots, are hardly ever publicly reported. In the recent past though, non-governmental environmental advocacy groups have started bringing such issues to the public's attention.

A study conducted by Konečný *et al*. (2003), revealed that the extent and spatial distribution of contamination and its resulting effects are a function of the geohydrological and geological conditions of the contaminated area. Precipitation has been noted to promote the migration of petroleum hydrocarbons (Zhang *et al.*, 2012). In cold areas, fuel spills are said to be among the most extensive and environmentally damaging pollution problems constituting potential threats to human health and the ecosystem. In these areas the rate of natural attenuation is very slow, and the rate of off-site migration is often relatively fast (Rayner *et al.*, 2007).

2.2 POTENTIAL IMPACTS OF HYDROCARBON CONTAMINATION

Humans are exposed to hydrocarbons through inhalation of ambient air into which hydrocarbons have volatilised, and consumption or dermal contact with impacted water and soil (Zhang *et al*., 2014).

Acute exposure to hydrocarbon compounds is known to cause toxicity to the central nervous system in humans, and results in symptoms such as nausea, vomiting, fatigue, headaches, dizziness, and respiratory difficulties such as pneumonia and skin and eye irritation (Konečný *et al.*, 2003; Zhang *et al.*, 2014 and Kpone e*t al.*, 2015). Chronic exposure can weaken the immune system through decreases in the number of white blood cells and oxidative stress. It is also known to be associated with disorders in the blood production system giving rise to conditions like aplastic anaemia (Kpone e*t al.*, 2015). Some hydrocarbon compounds, like benzene, are known carcinogens and increase the risk of cancers like lung, skin and bladder cancers (Konečný *et al.*, 2003; Kpone e*t al.*, 2015 and Iffis *et al.*, 2017). Perceived health risks and financial concerns in communities subjected to exposure are also known to cause increases in depression and stress (Kpone e*t al.*, 2015). Exposure during pregnancy has been associated with reduced birth weight and impaired development of off-spring (Kpone e*t al.*, 2015).

Guo *et al*. (2012) studied the potential impacts of petroleum hydrocarbons on the soil microbiology. They found that the total cultivable bacteria and fungi, and urease activity were inversely proportional to the concentration of petroleum hydrocarbons in the soil. That is because petroleum hydrocarbons contain multiple toxic compounds in high concentrations and are therefore biologically, chemically and physically harmful to soil micro-organisms. This is significant considering that microbial biomass is pertinent to the decomposition of organic matter in terrestrial ecosystems, and therefore crucial to nutrient release and soil fertility. The accumulation of hydrocarbon compounds due to biological and geochemical mechanisms in animal and plant tissue is also known to cause death, or mutation; and can be toxic to sediment dwelling organisms and fish (Das and Chandran, 2011). It may also result in decreased survival, reduced growth or impaired reproduction and lowered species diversity (Adeniji *et al.*, 2017a and Adeniji *et al.*, 2017b).

A study conducted in a rural community located close to the oil rich Niger Delta revealed soil and groundwater petroleum contamination above allowable standards (Kponee *et al.*, 2015). The contamination was a result of historic oil spillages that occurred between 1976 and 2011, and are estimated to have resulted in a loss of approximately 477 million litres of oil. In 2001, a layer of approximately 8 cm of refined oil was found floating on the groundwater that supplies the community's drinking water. Benzene concentrations approximately 1 800 times higher than the United States Environmental Protection Agency's drinking water standard and over 900 times higher than the World Health Organization's drinking water guideline were detected (Kponee *et al.*, 2015). Residents of the community that consumed the contaminated water on a daily basis reported health symptoms related to neurological effects, haematological effects and irritation. It was also noted a significantly higher proportion of residents reported a diagnosis of anaemia. This is expected from those who have been exposed to elevated benzene concentrations.

In Johannesburg, South Africa the occupational exposure of diesel station workers to BTEX compounds at a bus depot was studied by Moolla *et al.* (2015a). The study found that because of poor ventilation and high exposure during long shifts, the average benzene concentration during the sampling period exceeded the EPAs chronic inhalation exposure limit. The lifetime cancer risk estimation showed that on average there is a 3.78 x 10^{-4} cancer risk, corresponding to an average chronic daily intake of 1.38 x 10^{-3} mg/kg/day of benzene exposure. There were also incidences where individuals were at potential hazard risk of benzene and toluene that may pose non-carcinogenic effects. This study was seen to demonstrate that health risk assessments in conjunction with medical studies are highly necessary in South Africa to serve as a foundation to amend national exposure limits which will protect employees in high risk jobs.

On similar study conducted in Johannesburg (Moolla *et al.*, 2015b), the results indicated that o-xylene and benzene were the most abundant of the BTEX compounds at a refuelling bay in a bus depot. Benzene was within South African occupational limits, but above international limits. Toluene, ethylbenzene and xylenes were within both national and international occupational limits. The occupational air quality at the refuelling bay was a health concern, especially with regards to benzene exposure. Future reduction strategies were considered crucial. The discrepancies between national and international limit values were concluded to merit further investigation to determine whether South African guidelines are sufficiently precautionary.

2.3 LEGISLATION GOVERNING HYDROCARBON CONTAMINATION

The United States Environmental Protection Agency (EPA) and the World Health Organisation (WHO) have set the internationally accepted standards for hydrocarbon contamination in different media such as soil, air and ground and surface water (Kponee *et al.*, 2015). The screening levels are risk-based and are used for the different exposure pathways, such as ingestion of water and dermal contact with contaminated sediments.

Section 24 of The Constitution of the Republic of South Africa (Government of the Republic of South Africa, 1996) indicates that everyone has a “right to an environment that is not harmful to their health or wellbeing” and “to have the environment protected.”

The Constitution paved the way for the National Environmental Management Act (NEMA) 107 of 1998 (Government of the Republic of South Africa, 1998). NEMA states that “every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring, or, in so far as such harm to the environment is authorised by law or cannot reasonably be avoided or stopped, to minimise and rectify such pollution or degradation of the environment.” Furthermore, “the costs of remedying pollution, environmental degradation and consequent adverse health effects and of preventing, controlling or minimising further pollution, environmental damage or adverse health effects must be paid for by those responsible for harming the environment.” This is colloquially known as the “Polluter Pays Principle.” Enforcement of legislation related to the management of contaminated land is still in its infancy in South Africa and is widely left to the interpretation of the user. Instructive, but non-binding guidelines were released by the Department of Environmental Affairs to provide clarity on the management of contaminated land. These include the “Framework for the Management of Contaminated Land” (Environmental Affairs, 2010) and “Norms and Standards for the Remediation of Contaminated Land and Soil Quality in the Republic of South Africa” (Department of Environmental Affairs, 2013). These are the currently used guidelines that govern the management of contaminated land in South Africa.

2.4 REMEDIATION OF HYDROCARBON CONTAMINATION

Part 8 of the National Environmental Management: Waste Act 59 of 2008 (Government of the Republic of South Africa, 2008) indicates that “an owner of land that is significantly contaminated, or a person who undertakes an activity that caused the land to be significantly contaminated, must notify the Minister and the Member of the Executive Council (MEC) of that contamination as soon as that person becomes aware of that contamination.” The minister may then instruct the polluter to further assess the site and characterise the suspected contamination. If the site is found to indeed be contaminated, a remediation order will be issued to remedy the identified contamination to site specific target levels. Remediation of contaminated land is considered an important aspect of promoting the right of every South African to an environment that is not harmful to human and ecological health as indicated in the Constitution.

Bioremediation, or the use of naturally occurring or introduced microorganisms to clean up contaminated media such as soil and groundwater is one of the most commonly used remediation strategies (Speight, 2018). Zacharyasz *et al.* (2012) found that the physical and chemical properties (temperature, pH, moisture content, oxygen availability, contaminant concentration etc.) of the natural environment influence the rate of biodegradation of petroleum hydrocarbons. Optimal conditions include temperatures between 25 and 30 °C and pH between 6.5 and 7.5 as these conditions are favourable for the growth of bacteria which is crucial for biodegradation. It was with this in mind that the soil contaminated during the Polish spill discussed in Section 2.1 was treated by airing the contaminated zones, adding nutritious substances, watering the soil and enriching the microflora by introducing microorganisms and ready made bacteria prepared for the environment.

The introduction of air or oxygen to the soil (bioventing) was also found useful and successful in the removal of hydrocarbons from the water fraction and significantly promoting biodegradation (Rayner *et al.*, 2007). In a study conducted with soil contaminated by hydrocarbons in excess of 5 000 mg/kg, it was estimated that with the operation of a bioventing system, the contamination could be reduced to less than 200 mg/kg in a year or two.

3. STUDY AREA AND METHODOLOGY

3.1 STUDY AREA

Gauteng, one of South Africa's nine provinces is located on the north eastern part of the country (Figure 1). Gauteng, loosely translating to "place of gold" from seSotho has a history linked to the discovery of gold in Johannesburg (South African History, 2011). It is the smallest of South Africa's nine provinces as it only covers approximately 18,000 km^2 or 1.4% of the country's total surface area (Municipalities of South Africa, 2018). Despite its size, it is the most populous of the provinces with more than 17.7 million people (Statistics South Africa, 2018a) residing in it. It is also the most densely populated with approximately 758 people occupying a square metre of land (South African Gateway, 2018). Gauteng is considered to be the economic engine room of South Africa and is responsible for about 35% of the country's gross domestic production (Statistics South Africa, 2018b).

Figure 1: A map showing the location of Gauteng, South Africa (Encyclopaedia Britannica, 2018).

According to the South African Petroleum Industry Association (2018) there are approximately 4 600 filling stations in the country. Gauteng is at the heart of the country's economic development and industrialisation (Municipalities of South Africa, 2018), and almost 38% of eNatis registered vehicles are registered in Gauteng (Van der Post, 2017). It is therefore expected that most of the country's filling stations are located in Gauteng. Contamination resulting from the storage and handling of petroleum hydrocarbon products used to fuel vehicles is therefore expected to be higher in Gauteng than anywhere else in the country. For this reason, the occurrence, evaluation and remediation of petroleum hydrocarbon contamination in South Africa will be studied using case studies of filling stations in Gauteng.

3.2 METHODOLOGY

Judgmental or purposive sampling was used in the study. Judgemental sampling is a non-probability sampling technique that is based entirely on the judgement or knowledge of the researcher to select a sample that is composed of elements that contain the most characteristic, representative or typical attributes of the population (Babbie and Mouton, 2001; Strydom, 2002). The sample is chosen because it has specific characteristics that will enable a detailed exploration, and will be most likely to lead to a better understanding of the central themes and puzzles which the researcher wishes to study (Ritchie *et al*., 2003). Judgmental sampling requires researchers to use their expertise and professional judgment to select samples that will enable them to fulfil the aims and objectives of their research. Judgmental sampling is best suited for studies on which the researcher may select a case or sample that is particularly informative, specifically select members or sample in a specialised and not easily accessible population, or where specific individuals or sample are selected for in depth analyses (Neuman, 2000).

For this study, the researcher has applied skills gained in his eight years' experience in working with petroleum hydrocarbon contaminated sites, and used professional judgment to select sites that will be used as case studies. These will be fuel handling and storage sites in Gauteng where petroleum hydrocarbon contamination has occurred, has been evaluated, and is currently being monitored or has been remediated. These are cases where the reported suspicion of contamination was identified and reported according to proper protocol. The contamination will be a result of accidental losses of primary containment of petroleum hydrocarbon products from leaking tanks and pipelines, or spillages from vehicle refuelling, tank overfills or bulk road tanker accidents. Sites that are particularly informative, were well handled and will allow an in-depth investigation that will fulfil the aims and objectives of the study, and answer the research questions were selected. Information on how the contamination occurred at each site, how it was detected and evaluated, the impacts it had on the receiving environment and the remediation strategies employed to mitigate the impacts was collected for this study.

The researcher is currently an environmental consultant for the petroleum industry and is involved in the assessment, monitoring and remediation of hydrocarbon contaminated soil, air and groundwater in commercial and retail sites, road side tanker spills and private installations. He has conducted and reported on Phase I, Phase II, Tier I, Tier II, due diligence, environmental audits, risk assessments, groundwater quality monitoring and remediation sites in South Africa, Lesotho and Swaziland over the last eight years.

4. RESULTS

4.1 LEGISLATION GOVERNING HYDROCARBON CONTAMINATION IN SOUTH AFRICA

4.1.1 The Constitution of the Republic of South Africa

The Constitution of the Republic of South Africa Act 106 of 1996 is the supreme law of the Republic and any law or conduct inconsistent with it is invalid, and all the obligations imposed by it must be fulfilled (The Constitution of the Republic of South Africa, 1996). Section 24 of the Constitution indicates that "Everyone has the right to an environment that is not harmful to their health or wellbeing; and to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that prevent pollution and ecological degradation."

4.1.2 The National Environmental Management Act

The need for environmental protection through legislation gave rise to the National Environmental Management Act 107 of 1998 (Government of the Republic of South Africa, 1998). The National Environmental Management Act (NEMA) is intended to serve as the general framework and guideline within which environmental management and implementation plans must be formulated. It also promotes co-operative environmental governance as it establishes principles to be used in decision making, on all matters that have the potential to impact on the environment. Among the principles it sets forth is the need for sustainable development. That is to mean that any development which is not socially, environmentally and economically sustainable must be avoided. However, if it cannot be altogether avoided, it must be minimised and remedied.

Sections 24(2) and 24(D) of NEMA indicate that certain activities deemed to have a high risk of environmental degradation or pollution may not commence without prior authorisation from the MEC or Minister. These activities are referred to as "Listed Activities" and are detailed in Government Gazette No. 38282 published on 04 December 2014. It is required that the potential impacts of these activities be better understood through a Basic Assessment or a detailed Environmental Impact Assessment. The assessment is to be conducted by an independent Environmental

Assessment Practitioner who has no stake in the outcome of the assessment, and studied in detail by a Competent Authority who then authorises, or declines the commencement of the activity based on anticipated impacts and the adequacy of proposed remedies. Should a listed activity commence without the prerequisite authorisation it is deemed as an “illegal commencement of a listed activity” and the proponent may be fined up to R5 million, the activity discontinued, and/or issued a directive to assess the impacts of the activity and remediate any impacted areas.

In terms of activities involving petroleum hydrocarbon products, the applicable listed activities are the development and/or expansion of facilities of infrastructure for the storage, handling and/or bulk transportation of petroleum products (deemed dangerous goods) in volumes of 80 m^3 and above. A Basic Assessment is needed to inform the decision of the Competent Authority if the volume is above 80 m^3 but less than 500 m^3, otherwise a full Environmental Impact Assessment is needed.

The costs of remedying pollution, environmental degradation and any adverse health effects that arise from development or trying to prevent it, control it or minimise its further occurrence are to be paid for by those who have caused it. This may be the landowner, a person in control of or using the land on which the environmental degradation took place; or a combination thereof. The cost includes the cost of investigating, assessing and evaluating the impacts of specific activities and reporting on them. This principle is generally known as the Duty of Care principle.

In the case of fuel handling and storage facilities, the Duty of Care principle is generally translated to mean that the landowner and oil company supplying the fuel are to take all reasonable means to ensure that fuel is always contained and avoid the occurrence of accidental releases. Measures such as the use of secondary containment (e.g. bunds, high density polyethylene (HDPE) lining), fuel volume record reconciliation through frequent manual dips or use of an automated tank gauge system, training staff in proper fuel handling etc. are used to prevent accidental releases and resultant environmental degradation. However, when an accidental release does occur the landowner and oil company are responsible to minimise and remedy the impact of that release. That is done by providing means of spill containment such as spill kits and training staff on their use. If the spill cannot be contained by a spill kit, a spill containment and clean up contractor may be appointed. An independent environmental consultant is also appointed to investigate, assess and evaluate the extent to which environmental degradation has taken place as a result of the release; and offer recommendation on remediation strategies that can be used to minimise impacts. The cost of all this is the responsibility of the person or organisation that is responsible for the degradation i.e. landowner and oil company depending on the level of liability of each.

NEMA also calls for a transparency in the occurrence of incidents where hazardous substances are accidentally released to the environment. In such instances the person responsible for the incident, owns or was responsible for the accidentally released hazardous substance has a duty to within 14 days of the incident, notify the Director-General, the police services, fire prevention services, provincial head of department, municipality and all persons who may be affected by the incident. The notice should specify the nature of the incident, substances involved, their acute effects on humans and the environment, measures taken and to be undertaken to minimise the effects and the causes of the incident as indicated by the Department of Environmental Affairs provided template in Figure 2. The template is also provided in Appendix A.

4. INCIDENT DETAILS

In terms of NEMA section 30(5)(a) and (d), the responsible person must report on the nature of the incident as well as the causes of the incident, whether direct or indirect, including equipment, technology, system, or management failure

4.1 Location of the incident	[Provide physical address of the location where the incident happened including the GPS co-ordinates]		
4.2 Incident start date and time:		4.3 Incident duration:	
4.4 Duration of exposure:			
4.5. Incident description:			

Background of the incident:

Operation:

Incident type:

Root Cause of the incident:

Contributory Factors to the incident:

Conclusion:

4.6. Wind speed and direction		4.7. Ambient air temperature	
4.8. Weather conditions		4.9. Other relevant meteorological conditions	

5. POLLUTANTS RELEASED DURING INCIDENT

In terms of NEMA section 30(5)(b), the responsible person must report on the substances involved and an estimation of the quantity.

List all the pollutants directly released during the incident (i.e. exclude those pollutants that resulted from mitigation measures, e.g. flaring, treatment, dilution etc.)

5.1. Substance or mixture of substances	5.2. Reference Number	5.3. Phase eg solid, liquid or gas	5.4. Total Quantity emitted/released	5.5. Units eg Kg, L etc	5.6. Nature of emission/release
[The name recognised by any national or internationally recognised chemical referencing system]	[Reference to any national or internationally recognised chemical referencing system]	[solid, semi-solid, liquid or gas]	[the total measured or estimated quantity released into the environment]	[the unit of measure in respect to the quantity]	[Emitted from truck, underground pipe, stack, etc.]

NB! Please ensure that all the information provided in brackets are removed before submitting this report to the all the Authorities.

environmental affairs Department: Environmental Affairs REPUBLIC OF SOUTH AFRICA / ENVIRONMENTAL MANAGEMENT INSPECTORATE	Document Type:	Emergency Incident Report	
	Title for the incident:		
	Date of the incident :		
Reference:		Initial Submission Date:	
Revision No.:		Compiled by:	

This form provides a template for the emergency incident report required in terms of section 30(5) of the National Environmental Management Act (Act No. 107 of 1998) (hereinafter "NEMA") in which the responsible person or, where the incident occurred in the course of that person´s employment, his or her employer, must, within 14 days of the incident, report to the Director General, provincial head of department and municipality such information as is available to enable an initial evaluation of the incident, including: (a) the nature of the incident; (b) the substances involved and an estimation of the quantity released and their possible acute effect on persons and the environment and data needed to assess these effects; (c) initial measures taken to minimise impacts; (d) causes of the incident, whether direct or indirect, including equipment, technology, system, or management failure; and (e) measures taken and to be taken to avoid a recurrence of such incident.

In terms of section 30(1)(a) of NEMA, an "incident" means an unexpected sudden occurrence, including a major emission, fire or explosion leading to serious danger to the public or potentially serious pollution of or detriment to the environment, whether immediate or delayed.

In line with section 24 of the Constitution of the Republic of South Africa (Act No. 108 of 1996), "serious" is taken to be a measure of the impact of an incident where such an incident has had, could have had, is having, or will have a negative impact on human health or well-being.

1. RESPONSIBLE PERSON

In terms of section 30(1)(b) of NEMA, the "responsible person" includes any person who: (i) is responsible for the incident; (ii) owns any hazardous substance involved in the incident; or (iii) was in control of any hazardous substance involved in the incident at the time of the incident

1.1 Name:		1.2 Designation:	
1.3 Postal Address		1.4 Physical Address:	
1.5 Telephone (B/H):		1.6 Telephone (A/H):	
1.7 Fax:			
1.8 E-mail:			
1.9 Nature of Business:			

2. EMERGENCY INCIDENT SUMMARY INFORMATION

Mark the appropriate boxes

2.1 Fire:		2.2 Spill:		2.3 Explosion:		2.4 Gaseous Emission:	
2.5 Injuries		2.6 Reportable injuries:		2.7 Hospitalisation:		2.8 Fatalities:	
2.9 Open water impacts:		2.10 Ground water impacts:		2.11 Atmospheric impacts:		2.12 Soil impacts:	
2.13 Own emergency response involved		2.14 Fire prevention services involved		2.15 Government hazardous materials emergency response involved		2.16 More than 1 governmental emergency response service involved	
2.17 Emission of non-toxic substances at low concentrations		2.18 Emission of non-toxic substances at high concentrations		2.19 Emission of toxic substances at low concentrations		2.20 Emission of toxic substances at high concentrations	
2.21 No evacuation required		2.22 Immediate area evacuated		2.23 Immediate surrounds evacuated		2.24 Evacuation of the general public	
2.25 Others							

3. INITIAL EMERGENCY INCIDENT REPORT

In terms of section 30(3) of NEMA, the responsible person or, where the incident occurred in the course of that person´s employment, his or her employer must forthwith after knowledge of the incident, report through the most effective means reasonably available: (a) the nature of the incident; (b) any risks posed by the incident to public health, safety and property; (c) the toxicity of substances or by-products released by the incident; and (d) any steps that should be taken in order to avoid or minimise the effects of the incident on public health and the environment to: (i) the Director General; (ii) the South African Police Services and the relevant fire prevention service; (iii) the relevant provincial head of department or municipality; and (iv) all persons whose health may be affected by the incident.

3.1 Description	3.2 Date:	3.3 Time:	3.4 Medium:	3.5. Name and contact details:
Relevant fire prevention service: (in case of fire)	[submission date]	[submission time]	[Fax, phone, SMS, letter, etc.)	[Who was the report made to?]
LOCAL :				
PROVINCIAL: (Those deal with Environmental issues)				
DIRECTOR GENERAL: (Department of Environmental Affairs)				
Any other Director General of National Department, E.g. Department of Water Affairs				

6. SECONDARY POLLUTANTS RESULTING FROM INCIDENT

In terms of NEMA section 30(5)(b), the responsible person must report on the substances involved and an estimation of the quantity released.

List all the pollutants that resulted from mitigation measures, e.g. flaring, treatment, dilution etc.

6.1. Substance or mixture of substances	6.2. Reference Number	6.3. Phase	6.4. Total Quantity emitted/released	6.5. Unit	6.6. Nature of emission
[The name recognised by any national or internationally recognised chemical referencing system]	Reference to any national or internationally recognised chemical referencing system]	[solid, semi-solid, liquid or gas]	[the total measured or estimated quantity released into the environment]	[the unit of measure in respect to the quantity]	[Emitted from truck, underground pipe, stack, etc.]

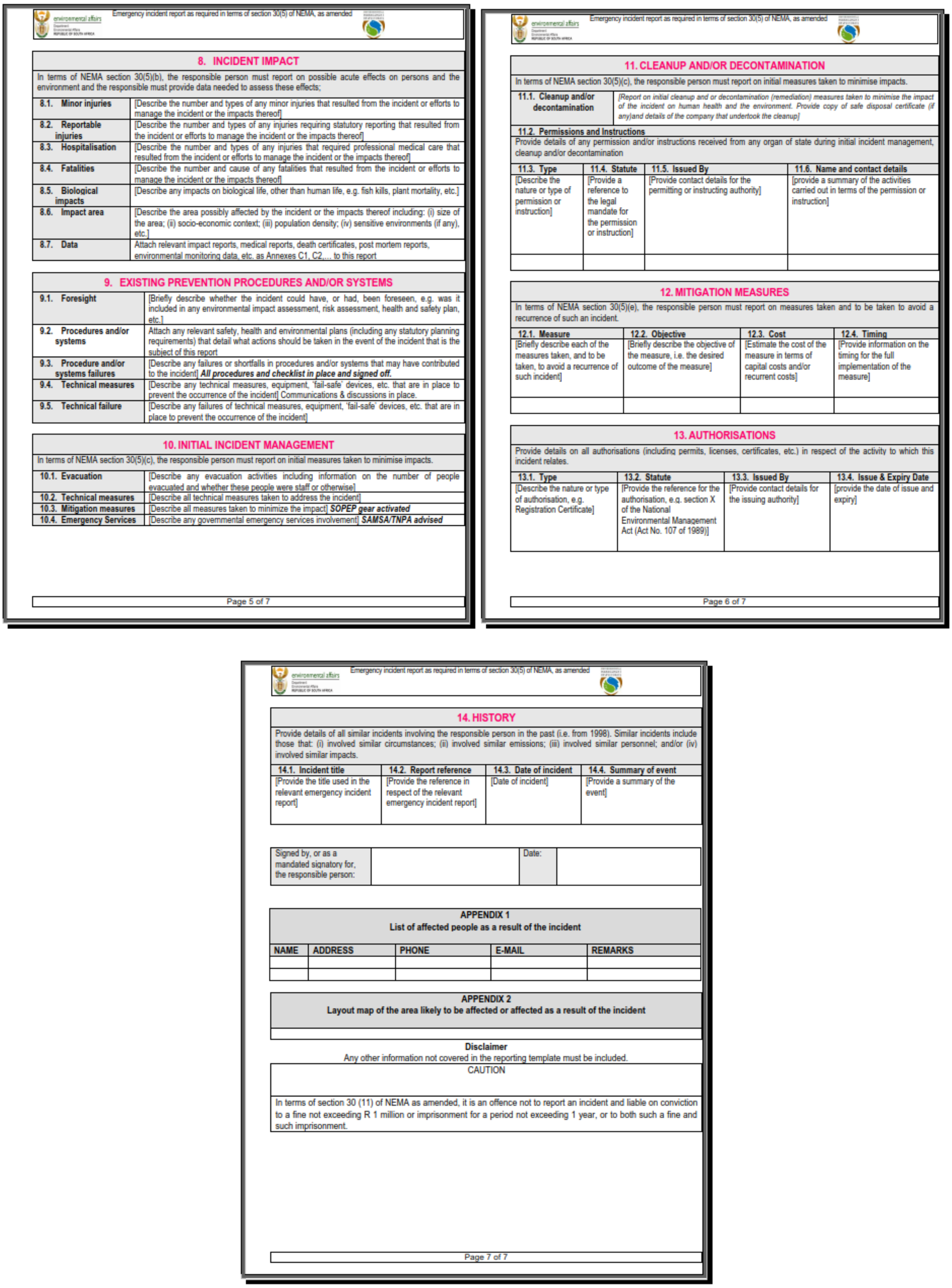
7. POLLUTANT CONCENTRATIONS

In terms of NEMA section 30(5)(b), the responsible person must report on the substances involved and an estimation of the quantity released.

List all the pollutants detailed in previous section:

7.1. Substance or mixture of substances	7.2. Reference Number	7.3. Estimated pollutant concentration on different radius			
		7.3.1. 10m	7.3.2. 100m	7.3.3. 500m	7.3.4. >2000m
[The name recognised by any national or internationally recognised chemical referencing system]	[Reference to any national or internationally recognised chemical referencing system]	[estimate the concentration of the pollutant in water, soil and/or air within a 10m radius of the epicentre of the incident] [provide the units used in a case of estimating concentration (e.g. ppm]	[estimate the concentration of the pollutant in water, soil and/or air within a 100m radius of the epicentre of the incident] [provide the units used in a case of estimating concentration (e.g. ppm)]	[estimate the concentration of the pollutant in water, soil and/or air within a 500m radius of the epicentre of the incident] [provide the units used in a case of estimating concentration (e.g. ppm)]	[estimate the concentration of the pollutant in water, soil and/or air within a > 2000 m radius of the epicentre of the incident] [provide the units used in a case of estimating concentration (e.g. ppm)]

[1] Concentration at the plume
[2] Concentration that was falling on the ground



Emergency incident report as required in terms of section 30(5) of NEMA, as amended

8. INCIDENT IMPACT	
In terms of NEMA section 30(5)(b), the responsible person must report on possible acute effects on persons and the environment and the responsible must provide data needed to assess these effects;	
8.1. Minor injuries	[Describe the number and types of any minor injuries that resulted from the incident or efforts to manage the incident or the impacts thereof]
8.2. Reportable injuries	[Describe the number and types of any injuries requiring statutory reporting that resulted from the incident or efforts to manage the incident or the impacts thereof]
8.3. Hospitalisation	[Describe the number and types of any injuries that required professional medical care that resulted from the incident or efforts to manage the incident or the impacts thereof]
8.4. Fatalities	[Describe the number and cause of any fatalities that resulted from the incident or efforts to manage the incident or the impacts thereof]
8.5. Biological impacts	[Describe any impacts on biological life, other than human life, e.g. fish kills, plant mortality, etc.]
8.6. Impact area	[Describe the area possibly affected by the incident or the impacts thereof including: (i) size of the area; (ii) socio-economic context; (iii) population density; (iv) sensitive environments (if any), etc.]
8.7. Data	Attach relevant impact reports, medical reports, death certificates, post mortem reports, environmental monitoring data, etc. as Annexes C1, C2,… to this report

9. EXISTING PREVENTION PROCEDURES AND/OR SYSTEMS	
9.1. Foresight	[Briefly describe whether the incident could have, or had, been foreseen, e.g. was it included in any environmental impact assessment, risk assessment, health and safety plan, etc.]
9.2. Procedures and/or systems	Attach any relevant safety, health and environmental plans (including any statutory planning requirements) that detail what actions should be taken in the event of the incident that is the subject of this report
9.3. Procedure and/or systems failures	[Describe any failures or shortfalls in procedures and/or systems that may have contributed to the incident] ***All procedures and checklist in place and signed off.***
9.4. Technical measures	[Describe any technical measures, equipment, 'fail-safe' devices, etc. that are in place to prevent the occurrence of the incident] Communications & discussions in place.
9.5. Technical failure	[Describe any failures of technical measures, equipment, 'fail-safe' devices, etc. that are in place to prevent the occurrence of the incident]

10. INITIAL INCIDENT MANAGEMENT	
In terms of NEMA section 30(5)(c), the responsible person must report on initial measures taken to minimise impacts.	
10.1. Evacuation	[Describe any evacuation activities including information on the number of people evacuated and whether these people were staff or otherwise]
10.2. Technical measures	[Describe all technical measures taken to address the incident]
10.3. Mitigation measures	[Describe all measures taken to minimize the impact] ***SOPEP gear activated***
10.4. Emergency Services	[Describe any governmental emergency services involvement] ***SAMSA/TNPA advised***

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Emergency incident report as required in terms of section 30(5) of NEMA, as amended

11. CLEANUP AND/OR DECONTAMINATION

In terms of NEMA section 30(5)(c), the responsible person must report on initial measures taken to minimise impacts.

11.1. Cleanup and/or decontamination	*[Report on initial cleanup and or decontamination (remediation) measures taken to minimise the impact of the incident on human health and the environment. Provide copy of safe disposal certificate (if any)and details of the company that undertook the cleanup]*

11.2. Permissions and Instructions

Provide details of any permission and/or instructions received from any organ of state during initial incident management, cleanup and/or decontamination

11.3. Type	11.4. Statute	11.5. Issued By	11.6. Name and contact details
[Describe the nature or type of permission or instruction]	[Provide a reference to the legal mandate for the permission or instruction]	[Provide contact details for the permitting or instructing authority]	[provide a summary of the activities carried out in terms of the permission or instruction]

12. MITIGATION MEASURES

In terms of NEMA section 30(5)(e), the responsible person must report on measures taken and to be taken to avoid a recurrence of such an incident.

12.1. Measure	12.2. Objective	12.3. Cost	12.4. Timing
[Briefly describe each of the measures taken, and to be taken, to avoid a recurrence of such incident]	[Briefly describe the objective of the measure, i.e. the desired outcome of the measure]	[Estimate the cost of the measure in terms of capital costs and/or recurrent costs]	[Provide information on the timing for the full implementation of the measure]

13. AUTHORISATIONS

Provide details on all authorisations (including permits, licenses, certificates, etc.) in respect of the activity to which this incident relates.

13.1. Type	13.2. Statute	13.3. Issued By	13.4. Issue & Expiry Date
[Describe the nature or type of authorisation, e.g. Registration Certificate]	[Provide the reference for the authorisation, e.g. section X of the National Environmental Management Act (Act No. 107 of 1989)]	[Provide contact details for the issuing authority]	[provide the date of issue and expiry]

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Emergency incident report as required in terms of section 30(5) of NEMA, as amended

14. HISTORY

Provide details of all similar incidents involving the responsible person in the past (i.e. from 1998). Similar incidents include those that: (i) involved similar circumstances; (ii) involved similar emissions; (iii) involved similar personnel; and/or (iv) involved similar impacts.

14.1. Incident title	14.2. Report reference	14.3. Date of incident	14.4. Summary of event
[Provide the title used in the relevant emergency incident report]	[Provide the reference in respect of the relevant emergency incident report]	[Date of incident]	[Provide a summary of the event]

Signed by, or as a mandated signatory for, the responsible person:		Date:	

APPENDIX 1
List of affected people as a result of the incident

NAME	ADDRESS	PHONE	E-MAIL	REMARKS

APPENDIX 2
Layout map of the area likely to be affected or affected as a result of the incident

Disclaimer
Any other information not covered in the reporting template must be included.

CAUTION

In terms of section 30 (11) of NEMA as amended, it is an offence not to report an incident and liable on conviction to a fine not exceeding R 1 million or imprisonment for a period not exceeding 1 year, or to both such a fine and such imprisonment.

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Figure 2: Incident Report in Terms of Section 30 of NEMA (www.sawic.environment.gov.za).

4.1.3 The National Environmental Management: Waste Act

The National Environmental Management: Waste Act Act 59 of 2008 is intended to be the law that regulates waste management while protecting human health and the environment by providing reasonable measures to prevent pollution and ecological degradation; and thus, securing ecologically sustainable development. It is also intended to provide the national norms and standards for regulating the management of waste and the remediation of contaminated land (Government of the Republic of South Africa, 2008). This is particularly important for the development of facilities that handle and store hazardous goods, like refineries, depots and filling stations. The Waste Act allows for these developments, which are key to everyday life, and also sets the standard of what must be done in the event of accidental release and required remediation.

Section 7 of the Waste Act indicates that the Minister must set the National Norms and Standards for the classifications of waste (as either general or hazardous), its storage, treatment and disposal. It is with this in mind that the National Norms and Standards for the Remediation of Contaminated Land and Soil Quality (Norms and Standards) were released in 2014. A more detailed discussion of the Norms and Standards is presented in Section 4.1.4.

Section 36 of the Waste Act deals with the identification and notification of investigation areas. It states that the Minister of Environmental Affairs may identify as an investigation area any land on which high risk activity has or is taking place and may result in land contamination or under reasonable grounds believes to be contaminated. The owner of land that is suspected to be contaminated is also responsible for notifying the Minister of the site being an investigation area. The notification is done by providing site specific information that indicates the location of the site, activities at the site, suspected contaminants and responsible person. The information is then populated into a form provided by minister as presented in Figure 3. The template is also presented in Appendix B.

environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

Notification of contaminated land

The following information should be supplied to the Minister or MEC by the owner of the contaminated land, or person who undertakes the activity that caused contamination of land:

- Information required should be typed in the space provided
- Name and Signature of delegated person
- The following should be attached:
  - (i) Current site plan - with scale bar showing north direction, local water drainage and other locally significant features on-site and immediate off-site. The plan should also show the historical location of structures that may have affected the distribution of contamination (e.g. building, underground storage tanks, treatment baths, etc);
  - (ii) Locality map

1. Details of the Land owner			
Name:			
Identity number:			
Town/Suburb:			
Postal code:			
Tel:		Fax:	
2. Details of the Land user			
Name of contact person:			
Company name:			
Registration number:			
Physical address:			
Postal code:			
Tel:		Cell:	
Fax:		Email:	
3. Details of the site			
Farm name:			
Farm/erf number:			
Province:			
District Municipality			
Local Municipality			

1

Four (4) or more corner coordinates of the portion of land that is contaminated			
Size of the area contaminated			
4. Details of the Site Assessment Practitioner			
Name and Surname			
Company name			
Physical Address			
		Code	
Postal Address			
		Code	
Telephone/Cell		Fax	
Email Address			
5. Department of Water and Sanitation: Water Management Area/ Quaternary Drainage			
Responsible Officer (DWS)			
Physical Address			
		Code	
Postal Address			
		Code	
Telephone			
Email Address			
6. Description of the Nature of contamination			

I declare that the information contained in this form is true

Name of responsible person

Signature of responsible person

Designation

Date

Submission of this form should be directed to:
The Director: Land Remediation-Dr Mpho Tshitangoni
Environment House, 473 Steve Biko Road, Arcadia, Pretoria, 0083
Private Bag X447, Pretoria, 0001

2

Figure 3: Notification of Investigation Area in Terms of Section 37 of the Waste Act (www.sawic.environment.gov.za).

The Minister would then direct the landowner or person responsible for the contamination to conduct a site assessment to ascertain whether the site is truly contaminated. The assessment is to be done by an independent party that has no stake in the outcome of the assessment. The assessment report is to be submitted to the Minister within a specified period. The Minister reviews the report and may reach one of four conclusions i.e. the investigation area is contaminated and presents a health and/or environmental risk and must be remediated urgently; the investigation area is contaminated and presents a health and/or environmental risk and must be remediated within a specified period; the investigation area is contaminated but does present an immediate risk, but the risk should still be monitored and managed; or the investigation area is not contaminated.

If the outcome of the Minister's review is that the land is contaminated and measures are required to neutralise the risk, it is communicated through a remediation order. The site is then declared a Remediation Site. The conditions stipulated in the remediation order are legally binding, with non-compliance being an offence that carries a fine and/or imprisonment of up to R 10 million and 10 years respectively. The Act also requires that Remediation Sites be listed as such in the Deeds Registry, with their ownership non transferrable unless the new owner is aware of the contamination status and is willing to accept liability linked to it. The process flow of the identification and notification of investigation areas and the resultant consequences are summarised in Figure 4.

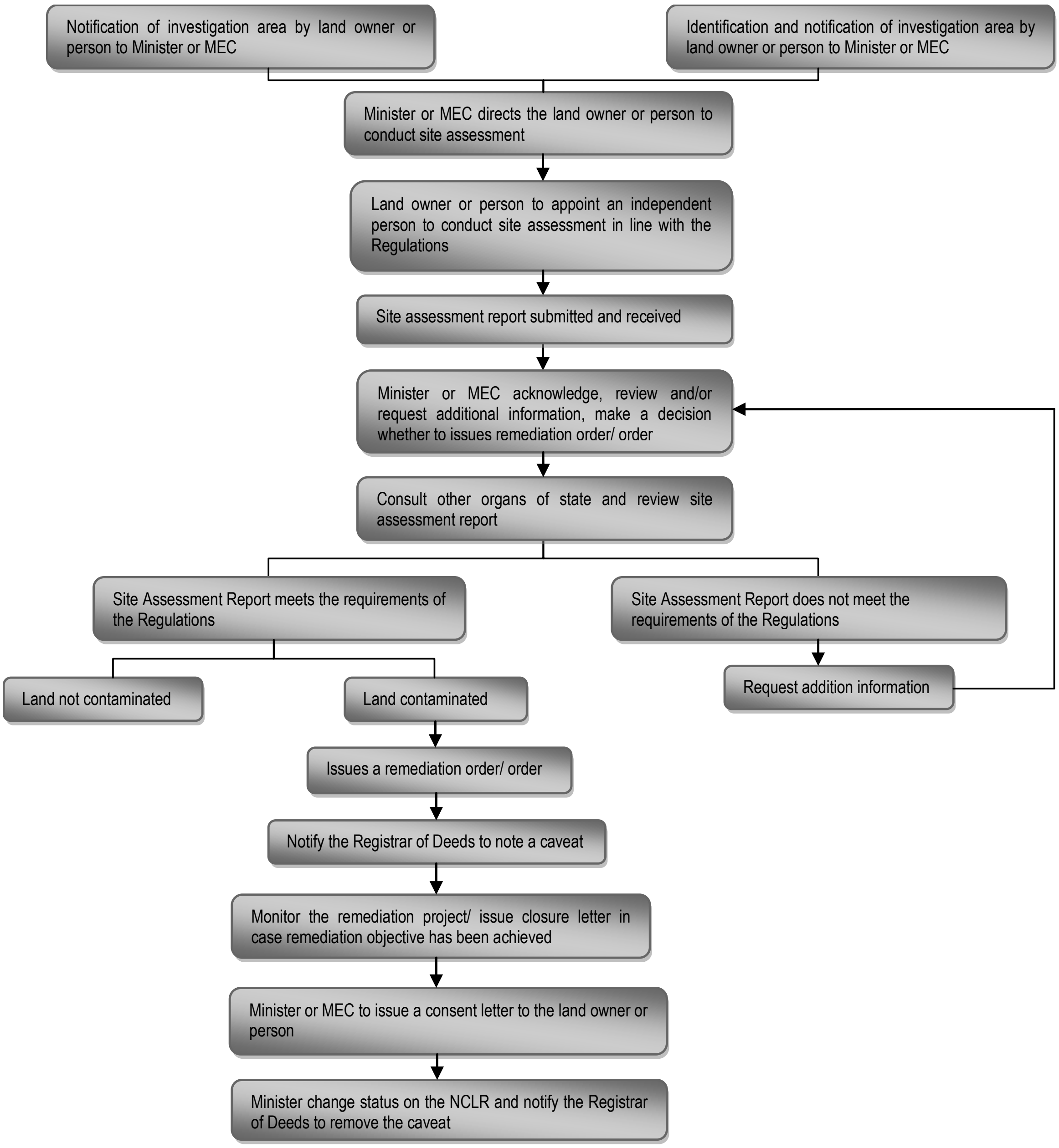

Figure 4: Process flow of the identification and notification of investigation areas and the resultant consequences (Department of Environmental Affairs, 2014).

4.1.4 The Framework for the Management of Contaminated Land

The remediation of contaminated land is considered an integral part of the comprehensive environmental strategy for sustainable management of environmental resources and reflects the constitutional rights of all South Africans to an environment that is not harmful to human health. It was, however, noted that there isn't a single consistent set of guidelines or legally applied regulations to assess the status and risk posed by contaminated land or to provide the basis for the acceptance of remediation plans. The Framework for the Management of Contaminated Land (Framework) was therefore developed to provide the ‘norms and standards’ for enabling the identification and registration of contaminated sites, to provide a risk-based decision support protocol for assessing sites, and to offer a set of guidelines for the submission of site assessment reports (Environmental Affairs, 2010).

The Framework has a tiered system of Soil Screening Values for priority soil contaminants. Soil contaminants that may be linked to petroleum hydrocarbon contamination are presented in Table 1, with the determined Tier 1 screening values as set out in the norms and standards. The tiered and risk-based approach adopted by the Framework is founded on international best practice in developed countries and is similar to the American Society for Testing and Materials (ASTM) E1739.

The Framework only provides screening values for soil and not for water. In the absence of South African specific water screening values, international standards such as the Tier 1 Risk Based Screening Levels (RBSLs) provided in look up tables by the ASTM (2015) are generally used for water. Tier 1 RBSLs are generic values for particular exposure pathways such as ingestion of groundwater, inhalation of vapours on which contaminants have volatilised etc., within a specific land use scenario i.e. residential, commercial or industrial. Where these are exceeded, further site characterisation will lead to the development of site-specific target levels (or Tier 2 standards) that can used to screen the contamination status of the site.

Table 1: Soil Screening Values for Contaminants that May be Linked to Petroleum Hydrocarbon Contamination (Department of Environmental Affairs, 2010)

Parameter (mg/kg)	SSV1	SSV2		
	All Land uses Protective of Water Resources	Informal Residential	Standard Residential	Commercial/ Industrial
Petroleum Organics				
Alkanes				
C7-C9	2,300	2,300	2,400	23,000
C10-C14	440	440	500	4,400
C15-C36	45,000	45,000	91,000	740,000
Monocyclic Aromatic Hydrocarbons				
Benzene	0.03	1.3	1.4	10
Toluene	25	120	120	1,100
Ethylbenzene	26	57	60	540
Xylenes	45	91	95	890
Aromatics				
Naphthalene	28	28	33	290
Pyrene	5.3	920	1,900	15,000
Benzo(a)pyrene	0.34	0.34	0.71	1.7
Petroleum Additives				
Methyl Tertiary Butyl Ether (MTBE)	0.0036	360	370	5,800

The list is not exhaustive and the Framework itself is considered to be a living document onto which further chemical compounds of concern may be added in the future. The tiered system described in the Framework requires the construction of a simple conceptual model that defines the linkage or pathway between a contamination source and potential environmental receptors. This is commonly referred to as the source-pathway-receptor model. In this model a risk only exists when there is a complete link between the contamination source and environmental receptors.

The Framework provides a protocol of site assessment to provide a conceptual risk-based decision support tool that is based on the recognition of source-pathway-receptor linkages as shown in Figure 5, and explained below.

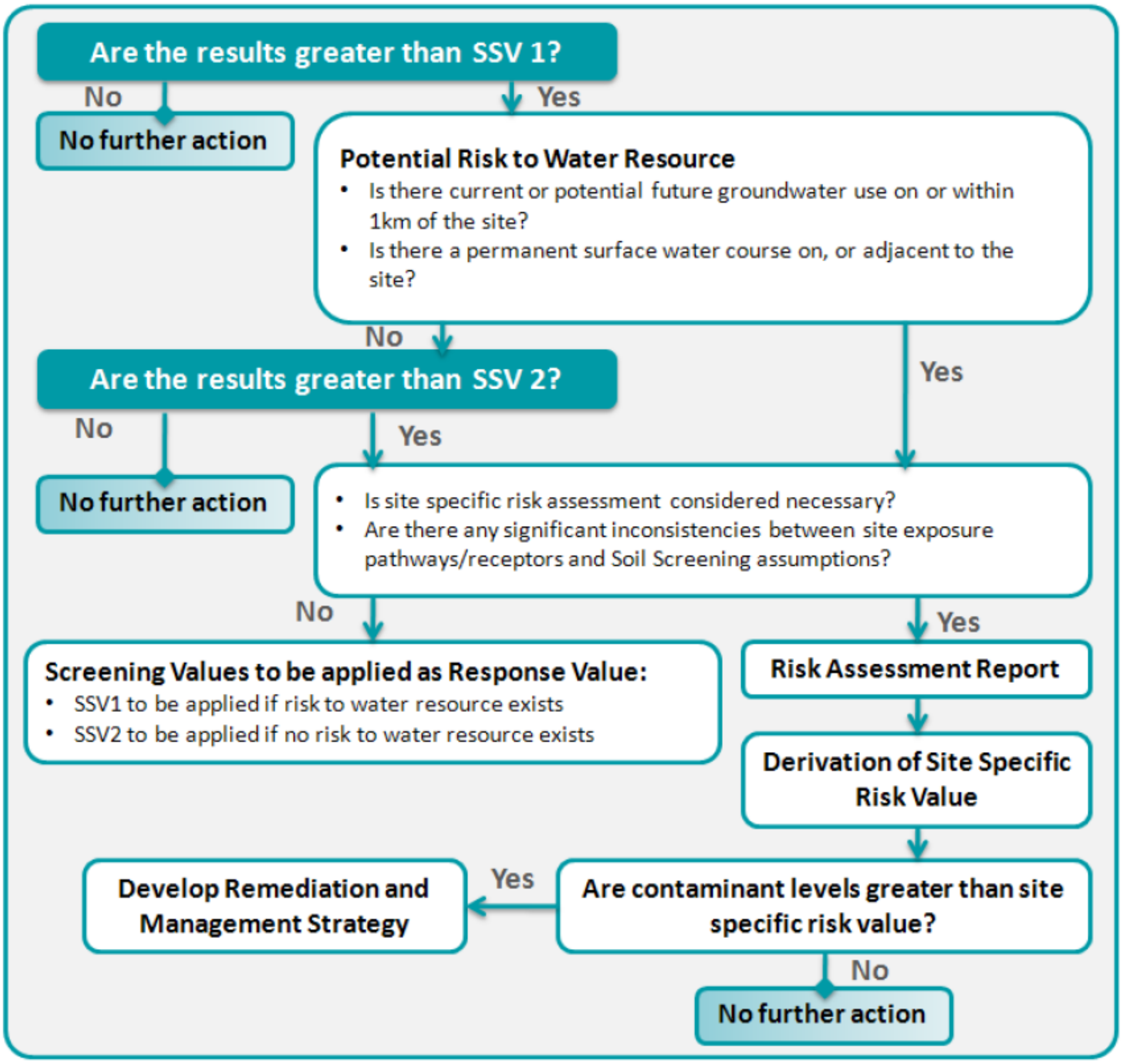

Figure 5: Process Flow of Decision Making for Assessment of Contaminated Land (Department of Environmental Affairs, 2010).

The conceptual model involves the derivation of a tiered system of Soil Screening Values (SSVs) which are used for comparison with contaminant concentrations measured in the soil on the investigated site. The SSVs are split into two tiers i.e. SSV1 and SSV2. SSV1 is the first tier for site screening. It represents a conservative concentration that is the lowest of three potential source-pathway-receptor model calculations i.e. direct pathways for protection of a child receptor, taken as the most sensitive receptor in the context of potentially high exposures anticipated for informal residential settlements in South Africa; indirect pathway for the protection of water resources in terms of human health based on the ingestion of drinking water; and indirect pathway for the protection of aquatic ecosystems. The lowest concentration provided by the three pathway-receptor models is selected as the Soil Screening. SSV1 is mainly protective of water resources.

In cases where no risk to the water resource is identified, the soil contaminant levels are compared to SSV2. SSV2 has three categories which are based on risk to receptors that are defined by activity patterns and associated exposure related to land use. There are two values derived for residential land use and development. The most sensitive is the child receptor, taken as the sensitive receptor for informal settlements, since the exposure levels for the child on a standard residential development define a slightly higher level of contaminant concentration. Commercial and industrial land use is defined by exposure criteria for an adult maintenance worker based on outdoor exposure criteria. If the values are less than the most appropriate of the three categories of SSV2, then the site is not a risk to human health and is not defined as being contaminated.

If soil contaminant concentrations are higher than the SSV2 criteria then a decision can be made to either proceed to a site-specific risk assessment to define acceptable risk levels, or to adopt the SSV2 concentrations as remediation values for development of a remediation plan.

4.2 OCCURRENCE, NATURE AND CAUSES OF HYDROCARBON CONTAMINATION IN SOUTH AFRICA

Various case studies were reviewed to understand the occurrence, nature and causes of hydrocarbon contamination. However, in the interest of keeping the oil company and consultants involved unidentifiable, the sites will only be identified by general location without giving detailed identifying information. The results are summarised in this section.

4.2.1 Case 1: Gauteng North

Following long-term discrepancies in fuel reconciliation records, a vacusonic test was conducted on all underground fuel storage tanks in July 2016 at a filling station in the north of Gauteng. The test revealed compromised integrity of the tanks on-site. The site management reported that a total volume of approximately 1,000 ℓ of petrol and diesel had been lost. Soil and groundwater samples recovered at the site had adsorbed and dissolved phase gasoline and diesel range organic compounds.

4.2.2 Case 2: Gauteng South

In November 2003, a fuel overfill occurred at a depot in Gauteng South. The site management reported that the overfill incident resulted in a spill of an estimated 100,000 ℓ of unleaded petrol. Environmental assessments subsequently conducted at the site revealed adsorbed phase petroleum hydrocarbon concentrations in the soil samples, and dissolved phase hydrocarbons in groundwater samples recovered from the shallow aquifer. Petrol occurring as a light non aqueous phase liquid (LNAPL) was also noted in the subsequently installed groundwater monitoring wells.

4.2.3 Case 3: Gauteng South

In December 2016 a bulk fuel road tanker travelling on a major road in the south of Gauteng overturned and shed its load. An estimated 1,700 ℓ of diesel spilled onto the highway median before emergency containment procedures could be activated. A clean-up operation involving the recovery of spilled fuel and impacted soil was undertaken. An environmental assessment was conducted concurrently with the clean-up operation.

4.2.4 Case 4: Gauteng West

Between February and May 2013, a diesel pipeline leak occurred at a filling station in Gauteng West. The leak was confirmed by a pressure test conducted at the site. Site management reported a total loss of approximately 3,000 ℓ of fuel as a result of the leak. Adsorbed phase gasoline, diesel and poly aromatic compounds were detected in the soil and groundwater samples collected on-site. Free phase petrol with thicknesses between 0.8 and 2.50 m was measured in the on-site groundwater monitoring boreholes.

4.2.5 Case 5: Gauteng East

In March 2015, a complaint was made to the local municipality by a concerned neighbour that hydrocarbon vapours were emanating from a large excavation made as part of a new commercial development down-gradient of a filling station in Gauteng East. Assessments subsequently conducted indicated the filling station to be the most probable source of contamination.

4.2.6 Discussion

As can be seen from the five case studies summarised above, the reason for the occurrence of petroleum hydrocarbon compounds in the natural environment around the case study sites were accidental releases during transportation, handling and storage. Releases were mainly due to spillages during road tanker accidents, pipeline leaks, tank leaks or spillages during refuelling. Releases occurred as free phase product visible to the naked eye (especially during spillages), adsorbed in the pore spaces between soil particles, as a light non aqueous liquid (LNAPL) floating on the groundwater or in a gaseous phase as vapours in the soil that may migrate to the surface.

It may also be noted that with the practice of some proactive measures, all the incidents presented above that resulted in the occurrence of contamination could have been prevented. In Case 1, a vacusonic test had to be conducted in the tanks to prove the leak after manual dip records indicated discrepancies. Had an automatic tank gauging system been installed in the tanks, the discrepancies would have been identified sooner and prevented the leak remaining unattended for an extended time. In Case 2, had the fuel infrastructure been fitted with automatic shut off valves that detected that the tank's capacity has been reached and prevent more fuel coming in, the overfill and resultant contamination could have been prevented. In Case 4, pipelines with constant pressure measurement and an alert system to indicate pressure losses and thus leaks, would have prevented the incident. Driver training on safe driving measures such as defensive driving, driver rests to prevent fatigue, spill management etc. could have prevented the incident in Case 3.

The lack of proactive preventative measures seems to be a contributing factor to the occurrence of hydrocarbon contamination in the cases presented. A relook at the design of filling stations and an adoption of preventative measures can go a long way at the reduction of contamination of the receiving environment.

4.3 METHODS COMMONLY USED TO DETECT AND EVALUATE HYDROCARBON CONTAMINATION IN SOUTH AFRICA

The Framework (Environmental Affairs, 2010) discussed in more detail in Section 4.1.4, indicates that it is common international practice to detect and evaluate contamination in a phased approach. Phase 1 involves a desktop review and site walkover assessment with limited investigation and testing. Phase 2 involves a more detailed intrusive investigation and testing for site characterisation. Phase 3 involves an evaluation of remediation objectives and plans and is supported by control and monitoring measures. However, some urgent or priority work may require that the phased approach move forward in a concurrent single report. This is generally the case with sites suspected of petroleum hydrocarbon contamination. The Phase 1 and 2 may be combined into a single Phase 2 report, mainly with the interest of time and cost saving. The details of the three phases of assessment are summarised in Figure 6.

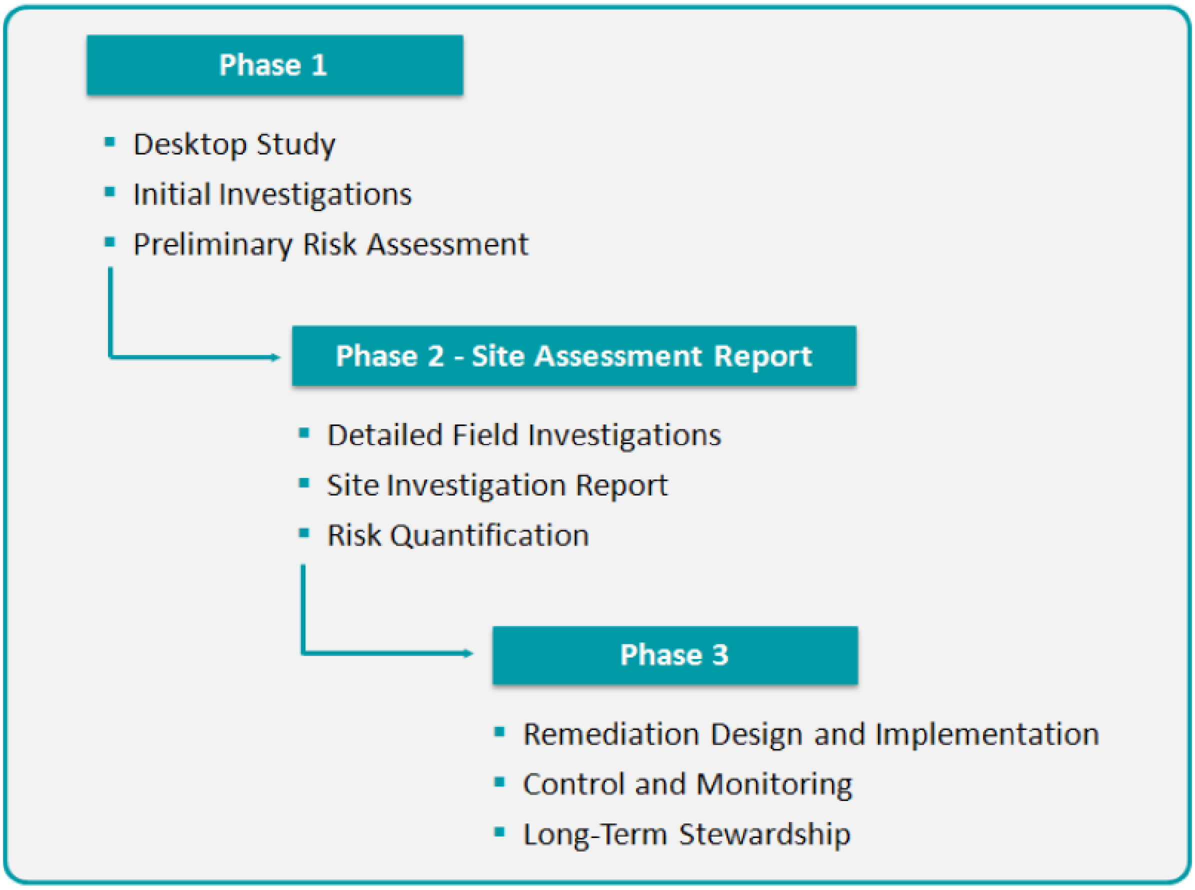

Figure 6: The three phases of contamination assessment (Department of Environmental Affairs, 2010).

This section will review the contents of the Phase I and Phase 2 (generally combined) reports of some case studies considered. Section 4.5 will give a review of some Phase 3 reports.

4.3.1 Phase I and II at Case 1: Gauteng North

As briefly introduced in Section 4.2.1, a total volume of approximately 1,000 ℓ of petrol and diesel had been lost as a result of a leak in Gauteng North.

A combined Phase I and II Assessment was conducted between November 2016 and January 2017. The assessments included a Soil Vapour Survey (SVS) comprising of 20 probing positions strategically spaced across the site to focus on areas surrounding the fuel infrastructure. The SVS was conducted using a MiniRae Photo Ionisation Detector (PID). The soil screening technique is based on the principle that the volatile organic compounds present in a medium such as soil, will attempt to reach equilibrium in the unsaturated zone. By extracting a sample of this air with a shallow probe, it is possible to determine the concentration of vapour phase VOCs in the soil. It is done by placing a soil sample in a receptable such as a sealable plastic bag while leaving a headspace. The soil sample is then placed on the side for a brief period to allow movement of soil gas into the headspace. The headspace is then tested with the probe of the PID. It may also be done by drilling a small hole into in-situ soil and testing the gas in the hole. The SVS recorded vapour phase volatile organic compound (VOC) concentrations ranging between 6 and 624 ppm, thus revealing the presence of a vapour plume around the fuel infrastructure. It should be noted that values recorded during the SVS that are greater than 50 ppm indicate that potentially significant contamination may be present in the subsurface soil at that location.

Four mechanical hand auger holes were drilled to the maximum depth at which the auger yields soil sample returns (refusal depth) at locations where the highest VOC concentrations were recorded during the SVS, and at other strategic locations to determine the vertical extent of contamination and to facilitate soil sampling. VOC concentrations between 73 and 2,914 ppm were recorded during the screening of soil samples collected as the auger holes were drilled. Seven soil samples were recovered from the four auger holes and were submitted to a laboratory for analyses of targeted petroleum hydrocarbon compounds by GC-MS screening. Adsorbed phase gasoline (benzene, toluene, ethylbenzene, xylenes, naphthalene, (1,2,4 and 1,3,5) trimethylbenzene, methyl tertiary butyl ether and TPH C6-10) and diesel (TPH C10-28, C28-40 and C10-40) range organic compounds were detected in the analysed soil samples. Benzene concentrations detected in some of the soil samples exceeded SSV1.

To facilitate groundwater sampling, three groundwater monitoring wells were installed by the air percussion drilling method to depths of 10 metres below ground level (mbgl) each. The static groundwater level was measured between 1.3 and 1.9 mbgl, without any LNAPL. Dissolved phase gasoline and diesel range organic compounds were detected in groundwater samples recovered from two of the monitoring wells. None of the targeted petroleum hydrocarbons were detected in the other groundwater sample. Some of the detected compounds exceeded the Tier 1 Risk Based Screening Levels (RBSLs) for exposure through groundwater ingestion in residential and commercial land use areas and inhalation of indoor air vapour in residential areas. The assessment of the conceptual site model indicated that no complete source-pathway-receptor linkages exist between the secondary contamination sources on site (contaminated soil and groundwater) and human receptors in the vicinity of the site through groundwater ingestion and inhalation of indoor air vapours.

4.3.2 Phases I and II at Case 2: Gauteng North

Case 2 summarised in Section 4.2.2, concerns a fuel overfill that occurred in November 2003, at a depot in Gauteng North. The overfill incident is reported to have resulted in a spill of an estimated 100,000 ℓ of unleaded petrol. A site walk over survey was conducted at the site shortly after the incident. Surface staining indicative of hydrocarbon contamination was observed at the rail siding below the offloading pipe couplings and at other product handling areas including the bulk truck offloading area, gantry and at the pump bays. Four hydraulic augured monitoring wells were installed at the site to facilitate soil and groundwater sampling. The static groundwater level ranged between 0.9 and 2.5 mbgl in the newly installed monitoring wells. Dissolved phase gasoline and diesel range organic compounds were detected in the groundwater samples recovered from three of the four monitoring wells. Some of the benzene concentrations detected exceeded the Tier 1 RBSLs for ingestion of groundwater in a commercial/ industrial environment. However, in the absence of groundwater users at, or within the immediate vicinity of the site, this source-pathway-receptor linkage was considered incomplete.

By July 2006 an additional four groundwater monitoring wells were installed around the incident area in an attempt to delineate the horizontal extent of the contamination plume. LNAPL with a thickness of 3 mm was measured in the monitoring well located in the immediate vicinity of the incident area. Benzene concentrations detected in some of the groundwater samples recovered from the site exceeded the Tier 1 RBSLs for groundwater ingestion in a commercial/industrial environment. Considering the site's conceptual model (incompleteness of the source-pathway-receptor linkage due to the absence of groundwater users and industrial land use around the site) active groundwater remediation was not considered necessary and groundwater quality monitoring was continued to observe trends over time.

During the latest groundwater quality monitoring event conducted in June 2018, a total of 13 groundwater monitoring wells were identified at the site. The additional wells were installed over time due to other spillage incidents that occurred at the site and to better understand the site's contamination status. The static groundwater level was measured between 1.1 and 3.6 mbgl in the accessible monitoring wells. LNAPL with a thickness of 950 mm was noted in the monitoring well drilled at the immediate location of the 2003 incident area (loading area). The LNAPL trend analysis indicated an increase in free phase product thicknesses measured during the latest monitoring event when compared to the previous events. However, due to its stability and confinement to a single area, no active remediation was considered necessary. Dissolved phase gasoline and diesel range organic compounds were detected in the sampled recovered from the monitoring wells. A historic trend analysis of gasoline range organic compounds detected showed a generally decreasing trend. The Tier I RBSLs for ingestion of groundwater in a commercial area, and inhalation of indoor air vapours in residential and commercial areas were additionally exceeded by certain compounds detected at the site. The source-pathway-receptor linkage through groundwater ingestion was considered incomplete as no groundwater users have been identified at, or within the immediate vicinity of the site. The source-pathway-receptor linkage through inhalation of indoor air vapours was considered potentially complete. However, considering that the impacted boreholes are not in close proximity to buildings, this linkage was not considered to be significant.

4.3.3 Phases I and II at Case 4: Gauteng West

Between February and May 2013, a diesel pipeline leak occurred at a filling station in Gauteng West as summarised in Section 4.2.4. The leak was confirmed by a pressure test conducted at the site. Site management reported a total loss of approximately 3,000 ℓ of diesel as a result of the leak. Environmental assessments including a site walkover, SVS, soil and groundwater sampling were conducted in 2013. The static groundwater level was measured between 2.7 and 2.8 mbgl in the tank monitoring wells. LNAPL with thicknesses of 15 and 100 mm was noted in two on-site tank monitoring wells. A total of 14 SVS points were drilled and surveyed using a MiniRae PID. Vapour phase VOC concentrations between 0.1 and 51 ppm were measured within the substrate. Soil samples were recovered from hand auger holes, pipeline trench sidewalls and composite samples of the excavated material from the trench. Both gasoline and diesel range organic compounds were detected in the soil samples recovered from the site. Benzene concentrations detected in some of the samples recovered from the site exceeded SSV1 and SSV2. The site was therefore registered as an investigation area in terms of Part 8 of the Waste Act as discussed in Section 4.1.3.

Six groundwater monitoring wells were subsequently installed at the site to facilitate groundwater sampling and to delineate the extent of the dissolved phase impact. Laboratory analysis results indicated gasoline range organic compounds in all analysed groundwater samples. Benzene concentrations detected in four of the six monitoring wells exceeded the Tier 1 RBSLs for ingestion of groundwater and inhalation of indoor air vapours applicable to both residential and commercial areas; and inhalation of outdoor air in a residential land use scenario. Sensitive receptors identified were on-site tenants, off-site residents (residential land use situated approximately 200 m west of the site) and surface water bodies at a golf course located approximately 250 m down gradient of the site. In terms of the source-pathway-receptor assessment methodology, it was determined that no complete exposure pathways between the secondary contamination sources on-site (adsorbed, dissolved and free phase) and human receptors existed (both on and off-site).

4.3.4 Phases I and II at Case 5: Gauteng East

A combined Phase I and II assessment was conducted at a development site following complaints made by the developer of strong hydrocarbon vapours emanating from a large excavation on the property as summarised in Section 4.2.5. A large excavation and three large soil stockpiles comprising approximately 5,000 m^3 of excavated material were observed. A hydrocarbon odour was noted on the south eastern corner of the large excavation, and hydrocarbon staining was observed at a depth between 3 to 4 mbgl against the eastern wall of the said excavation. The lower explosive limit (LEL) measurements taken during continuous vapour monitoring at the site were below 10% confirming no immediate fire risk at the time. On and off-site personnel did confirm that the vapours appeared to be abating.

An SVS conducted in the three large soil stockpiles revealed no detectable vapour phase VOC concentrations i.e. all measured points read 0.0 ppm. A composite soil sample was collected from each stockpile and was submitted for laboratory analysis. Groundwater seepage was observed at a depth of approximately 4.0 mbgl in the eastern wall of the excavation and was collected to confirm the presence and significance of hydrocarbon constituents.

An SVS comprising 13 probing positions was conducted at the nearest filling station assumed to be the source of hydrocarbon impact at the development site. The SVS revealed vapour phase VOC concentration of 0.0 to 35 ppm with the highest value recorded on the north western end and downslope of the site. Four tank monitoring wells were identified at the site. LNAPL with a thickness of 50 mm was measured in one of the wells. The static groundwater level at the site was measured between 2.05 and 2.18 mbgl.

Gasoline and diesel range organic compounds were detected in some of the soil and groundwater samples analysed. Benzene concentrations detected in some of the soil and groundwater samples exceeded the Tier 1 RBSLs for groundwater ingestion in both residential and commercial areas. As no groundwater users were identified at or within the immediate vicinity of the site this contamination exposure pathway was considered incomplete. The RBSLs for inhalation of indoor and outdoor air vapours in commercial and residential areas were exceeded by benzene concentrations detected in some of the samples.

Three groundwater monitoring boreholes were drilled in October 2015 to delineate the contamination plume. LNAPL with thicknesses of 30 and 240 mm was recorded in two of the on-site tank monitoring wells. Dissolved phase gasoline range organic compounds were detected in all groundwater samples recovered from the newly installed wells. None of the plausible source-pathway-receptor linkages were considered complete, given the absence of groundwater users within the vicinity of the site. The site was however registered as an investigation area in terms of Part 8 of the Waste Act.

4.3.5 Discussion

As it can be seen from the review of the cases above, various methods were used to detect and evaluate hydrocarbon contamination during the Phase 1 and 2 levels of assessment. Each chosen method involved knowledge of the nature or form in which the contamination may occur as summarised in Section 4.2. The hydrocarbon compounds occurring in the soil gas were measured using the Photo Ionisation detector during the soil vapour survey. Adsorbed and dissolved phase concentrations were detected and evaluated by collecting samples of the soil and water suspected to be contaminated and submitting them to a laboratory for analyses. Free phase product occurring as a light nonaqueous phase liquid (LNAPL) floating on the groundwater was measured using a dual phase meter that differentiates between LNAPL and water.

The methods used in the above case studies are deemed sufficient as they are able to give an indication of the contamination status of the site, and the next steps required to address it, if any are needed. The phased approach ensures that investigations can be discontinued when the need for further assessment is not justified.

4.4 IMPACTS OF HYDROCARBON CONTAMINATION

Within the scope of this study, it was not possible to assess whether or not long-term impacts could occur. This may be mainly attributed to the fact that the data collected during the investigation of the cases presented in this document was mainly in the interest of short-term control of the incidents. No long-term follow-ups were conducted to determine the impacts that could have resulted in the long-term. In the cases studied, the only impact reported was a short-term discomfort from vapours detected mostly around filling station buildings which were mitigated by opening windows and doors and thus allowing natural ventilation.

This speaks to the conclusion made by Moolla *et al* (2015a) that an understanding of potential long-term impacts of hydrocarbon contamination and health risk assessments are highly necessary in South Africa to serve as a foundation to amend national exposure limits to help protect employees in high risk jobs.

4.5 REMEDIATION STRATEGIES COMMONLY USED IN SOUTH AFRICA

The Framework defines remediation as the management of a contaminated site to prevent, minimise, or mitigate damage to human health or the environment, and acknowledges that it may include both direct physical actions (e.g. removal, destruction, and containment of contaminants) and institutional controls. This section will discuss some case studies of methods commonly used to remediate petroleum hydrocarbon contamination.

4.5.1 Phase III at Case 6: Gauteng North

For the purposes of this point a new case, Case 6 in Gauteng North will be introduced. Case 6 is a filling station on which routine pressure tests were being conducted on the fuel infrastructure. While the test was in progress, petrol was seen flowing to the surface from one of the pump manholes. Upon a closer inspection, it was discovered that the petrol was being released from a pipe connection loosened earlier by the pressure testing contractor. An estimated 100 ℓ of petrol was spilled on the surface as a result of the incident, while some 50 ℓ was contained in the pump manhole. The spilled product was immediately contained using spill containment kits that contain absorbent materials such as peat fibre and pads, and other implements to aid in the clean-up. Spill kits are generally provided at the filling stations and are stored in wheely bins similar to those presented in
Figure **7**, and are kept in the forecourt areas.

Figure 7: Examples of spill kits generally found in filling stations (SpillTech, 2019).

Absorbents in the spill kit were used to contain the spilled petrol. The petrol contained in the dispenser manhole was recovered by a spill containment contractor. The used absorbents and recovered petrol were disposed off-site as hazardous waste.

4.5.2 Phase III at Case 3: Gauteng South

As summarised in Section 4.2.3, in December 2016 a bulk fuel road tanker travelling on a major road in the south of Gauteng overturned due to driver fatigue and shed its load. An estimated 1,700 ℓ of diesel spilled onto the road median. Since the contamination was located in a busy road immediate clean up or remediation actions needed to be undertaken to minimise the health, safety and environmental impact of the spillage incident. This involved the use of spill containment kits that contain absorbent material similar to those discussed in Section 4.5.2, but at a larger scale to contain the spilled fuel. The soil around the spill area was excavated in layers and screened with a PID until all the visibly contaminated and vapour VOC containing soil was excavated. The excavated soil was then disposed as contaminated material at a hazardous landfill site. The excavation was backfilled with clean imported soil and was compacted to an engineer's specification.

In some instances, contaminated soil may be laid in an impervious sheet and mixed with chemicals that promote bacterial activity that will enhance the degradation of the contamination i.e. bioremediation. This is a time-consuming process and requires a lot of space where the soil may be spread in thin layers and frequently turned to promote aeration. In most cases where spills occur, as in this case, there are space, time and budget limitations. Therefore an "excavate and dispose" approach is generally adopted. This is generally the same approach also used in instances where a pipeline or tank failure has resulted in soil contamination around the leak area. The impacted subsurface soil is exposed, screened for vapour phase VOCs and analysed at a laboratory. If the excavated soil is deemed contaminated and not suitable for reuse, it is excavated and disposed as hazardous waste, or bioremediated on site. Otherwise it is blended with clean imported material and is re-used to backfill the excavation.

4.5.3 Phase III at Cases 4 and 5

As indicated in Sections 4.2.4 and 4.2.5, LNAPL was detected either on the on-site tank or groundwater monitoring wells by dual phase interphase meters in Cases 4 and 5. LNAPL in the shallow aquifer is generally treated by vacuum enhanced recovery (VER). VER involves the application of a vacuum in a well with the pump at the bottom of the LNAPL layer as shown in Figure 8. The LNAPL is then vacuumed out of the well into containment at the surface. Mobile VER are generally used as they are cost effective. The recovered product is disposed as hazardous waste at registered land fill site.

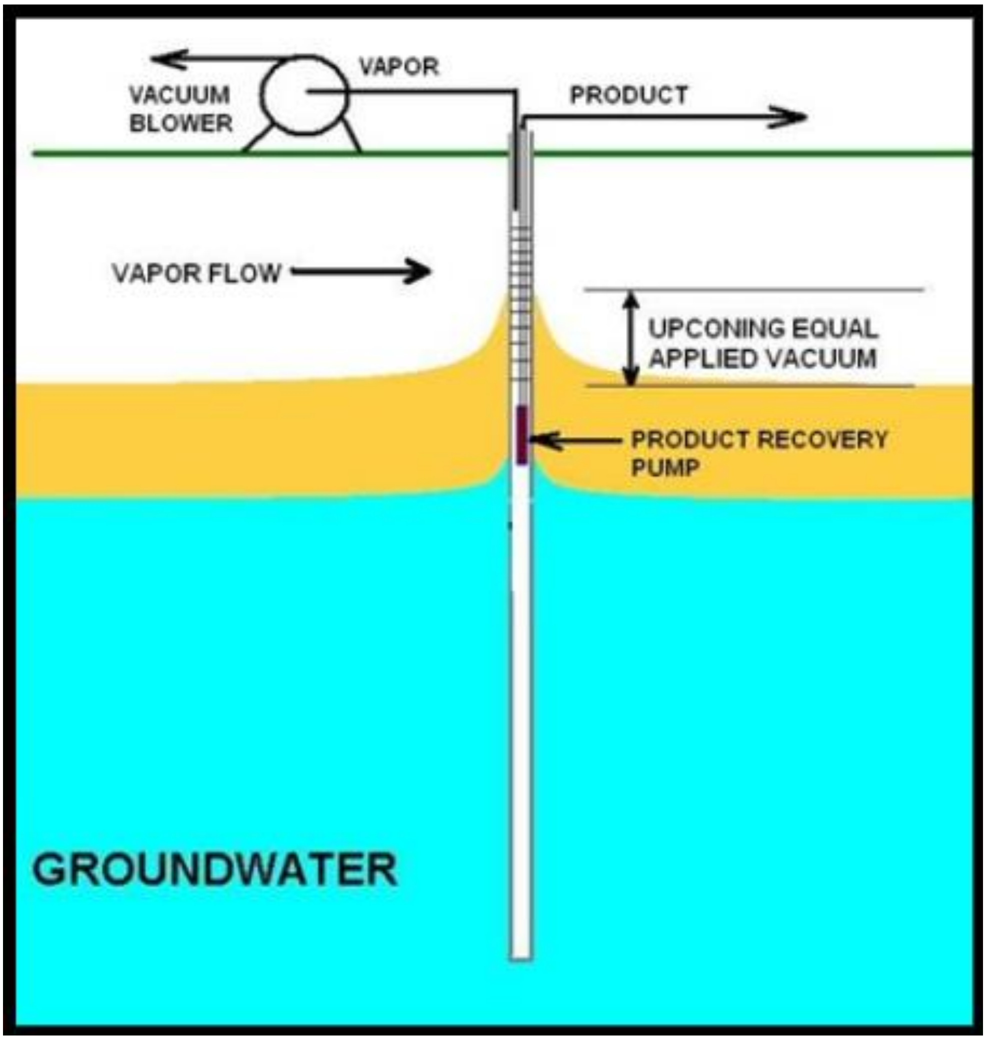

Figure 8: A simplified sketch of how vacuum enhanced recovery of LNAPL works (Berestka, 2019).

In Case 4, following spikes in LNAPL measured at the site in the August 2015 monitoring event, VER was conducted to address it. Although rebounds followed by additional VER events were noted in the May and November 2016 monitoring events, the thickness of LNAPL significantly reduced after each VER event until none was found present as shown in Figure 9.

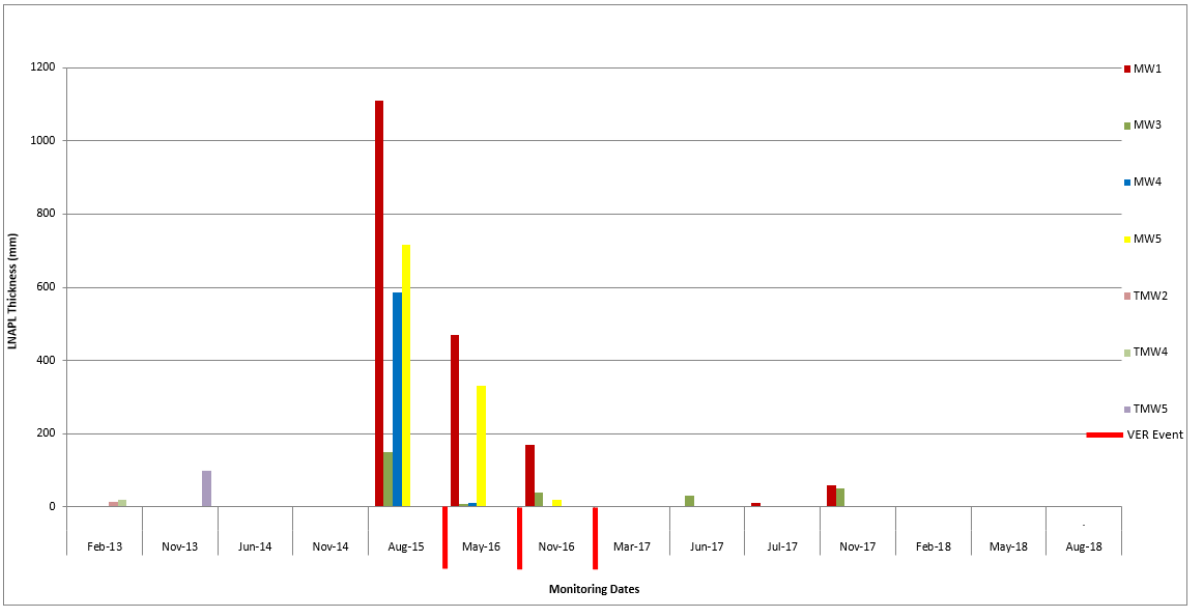

Figure 9: Trends in the thickness of LNAPL measured in the impacted groundwater monitoring wells (MW) and tank monitoring wells (TMW) in Case 4.

Similarly, VER was conducted in Case 5 to address LNAPL after the spike in the August 2015 monitoring event. Additional VER events were conducted after the February, May, and November 2016 monitoring events when rebounds occurred. The thickness of LNAPL significantly reduced after each VER event until none was found present as shown in

Figure **10**.

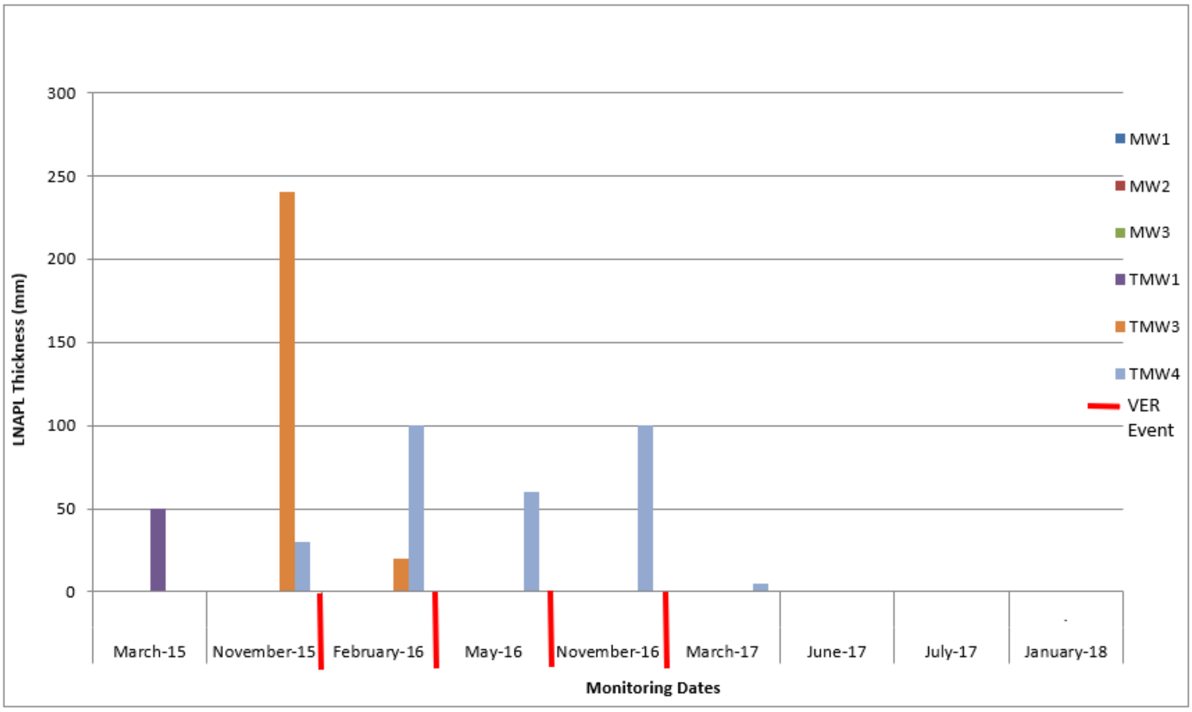

Figure 10: Trends in the thickness of LNAPL measured in the impacted groundwater monitoring wells (MW) and tank monitoring wells (TMW) in Case 5.

4.5.4 Phase III at Cases 7: Gauteng North

To further illustrate remediation strategies used, a new case is introduced. Case 7 is a former private fuel installation located in Gauteng North. Although the site's contamination history is mainly unknown, hydrocarbon impact was detected during the installation of a deep diving swimming pool. Due to shallow groundwater levels a dewatering sump was constructed during pool installation. Groundwater collecting in the dewatering sump was noted to have a hydrocarbon odour and sheen. In an attempt to deal with the impacted groundwater, a temporary pump-and-treat system was installed. Pump-and-treat systems involve treating impacted water by pumping it into the system and recovering/removing volatile organic compounds as water is passed through an aeration unit as shown in Figure 11.

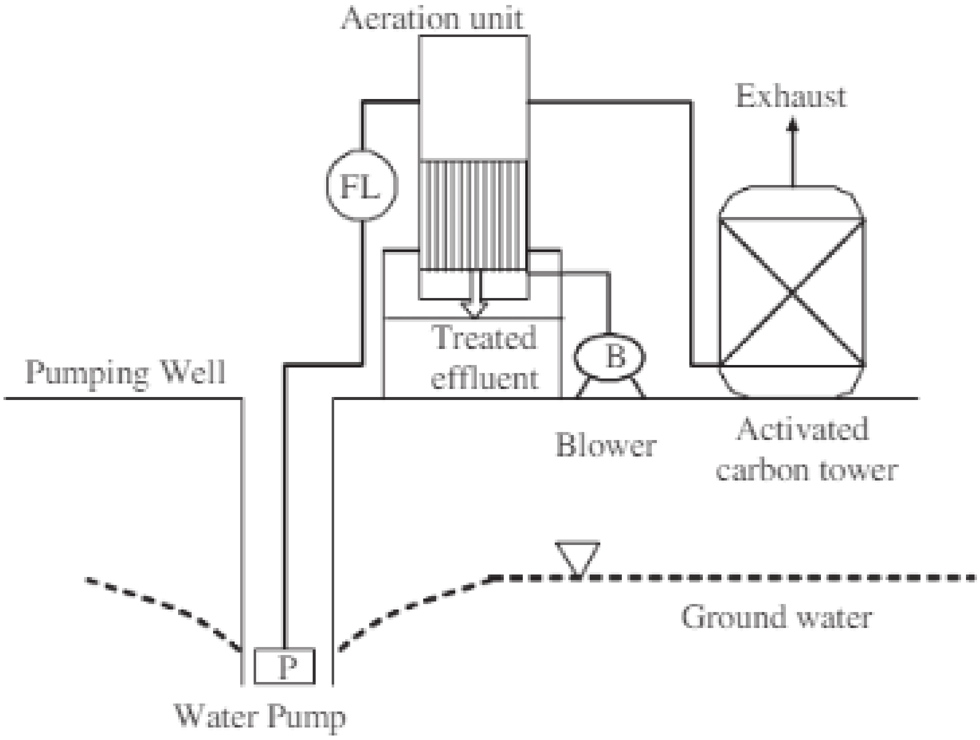

Figure 11: Schematic showing the pump-and-treat method (Hata *et al.*, 2010).

Water samples were recovered pre and post treatment in April 2017 and February 2019 at Case 7, and were analysed for targeted hydrocarbon compounds. Trace concentrations of benzene (0.0015 mg/ℓ), naphthalene (0.001 mg/ℓ) and TAME (0.01 mg/ℓ) were detected pre-treatment .On the post treatment samples except for benzene which was detected at 0.0004 mg/ℓ, all targeted compounds were below the detection limits. Even though trace concentrations were detected in the untreated samples, a reduction in detected concentrations was apparent in the treated samples when comparing with the untreated samples in both sampling events.

As can be seen from the summary of the cases above, various methods are generally used to prevent, minimise, or mitigate damage to human health or the environment that can be caused by petroleum hydrocarbon contamination. The method used or deemed appropriate is dependent on the nature of the contamination in question. Free phase product from surface spills is usually addressed by using site provided spill containment kits. Impacted soil is usually excavated and removed from the site for disposal as hazardous waste. Alternatively, where time, space and budget allow, it may be laid in thin layers and aerated to promote bioremediation. LNAPL is usually addressed by means of vacuum enhanced recovery, while dissolved phase is usually addressed by the pump-and-treat method.

4.5.5 Discussion

As can be seen from the various cases presented above, there are options for remediation of hydrocarbon contamination. Each of them deals with attempting to break the source-pathway-receptor linkage as discussed in the earlier sections of this report. These included the immediate containment of a spill through spill containment kits. As the impacts were assessed and their severity better understood, the soil around where the spill occurred and was contaminated was removed and replaced with clean imported soil. Where long term impact was noted in the form of a light nonaqueous phase liquid floating on the groundwater, it was removed through vacuum enhanced recovery. Dissolved phase contamination was addressed through pumping the contaminated water and treating it before releasing it back to the environment.

5. SUMMARY AND DISCUSSION

Seven cases were studied to determine and provide a critical assessment of the occurrence, evaluation and remediation of petroleum hydrocarbon contamination in South Africa. The cases studied included filling stations, a fuel spill site and a former private fuel installation.

The main reason for the occurrence of petroleum hydrocarbon compounds in the natural environment of the cases studies was accidental releases during transportation, handling and storage of fuel. This highlights the need for investing in spill and leak prevention measures such as automatic tank gauge systems, continuous pipeline pressure monitoring etc. These systems can go a long way at preventing releases and the resultant contamination of the environment.

The contamination occurred as either free phase product, adsorbed in the pore spaces between soil particles, as a light non aqueous phase liquid floating on the groundwater, dissolved in water or in a gaseous (vapour) phase. The method of evaluation used in each case required a knowledge of the nature or form in which the contamination may occur. Hydrocarbon contamination in gaseous phase was measured by screening the soil using a PID. Contamination adsorbed in the pore spaces between soil particles and dissolved in groundwater was measured by the collection of representative samples and submitting them for analyses at a laboratory. Soil samples were retrieved by mechanical hand augering into in-situ soil. LNAPL was detected and its thickness measured using a dual phase interphase meter that detects and distinguishes between water in a well and LNAPL.

A phase approach was used to evaluate each case. This is international best practice intended to assess the site in stages with the intention of cost and risk management. All the cases reviewed were adequately assessed and managed, though as indicated above, are deemed to have been preventable. However, responsible environmental management required that measured be put in place to manage or minimise the impact and risk posed to the receiving environment. The specific methods used or deemed appropriate is considered dependent on the nature of the contamination in question, and the remedial objectives. Free phase product from surface spills was addressed by using site provided spill containment kits that contain absorbent materials and cleaned up by spill containment contractors. Impacted soil was excavated and removed from the site for disposal as hazardous waste. LNAPL was addressed by the vacuum enhanced recovery method, while dissolved phase was addressed by the pump-and-treat method.

It is understood that remediation is a costly exercise. It is therefore better and more cost effective to prevent the occurrence of contamination than to remediate it after it has occurred.

Within the scope of this study, it was not possible to assess whether or not long-term impacts could occur in the cases studied. This was mainly due to a lack of long-term data in the cases. Each of the cases was treated in the short term and no long-term follow-ups were conducted. Only short-term discomfort from vapours detected around the filling station buildings was reported.

South African has well developed and robust legislation governing the management of contaminated land. Everyone in South Africa has a constitutional right to an environment that is not harmful to their health and well-being, and to have the environment protected. The country’s environmental law (National Environmental Management Act, National Environmental Management Waste Act, Framework for the Management of Contaminated Land etc.) is based on international best practice.

6. CONCLUSIONS

Hydrocarbon contamination occurs in the natural environment as a result of accidental releases in the supply chain of fuel. It occurs as free phase product following spillages, adsorbed to soil particles, dissolved in water, as a vapour between soil particles or LNAPL floating on groundwater. It is evaluated and detected through instruments such as the PID, interphase meter etc. and laboratory analysis of representative soil water and air samples. South Africa has a robust and matured international standard legislation governing the management of contaminated land. Cases related to land contamination are generally well managed with measured timeously put in place to manage and minimise the impact and risk posed by contamination.

Even though there is a growing body of literature related to long term impacts and risk assessments of long-term exposure to hydrocarbon contamination, there is still a need for further studies to inform it.

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8. APPENDIX A

Incident Report in Terms of Section 30 of NEMA

NB! Please ensure that all the information provided in brackets are removed before submitting this report to the all the Authorities.

environmental affairs Department: Environmental Affairs REPUBLIC OF SOUTH AFRICA ENVIRONMENTAL MANAGEMENT INSPECTORATE	**Document Type:**	**Emergency Incident Report**
	Title for the incident:	
	Date of the incident :	

Reference:		**Initial Submission Date:**	
Revision No.:		**Compiled by:**	

This form provides a template for the emergency incident report required in terms of section 30(5) of the National Environmental Management Act (Act No. 107 of 1998) (hereinafter "NEMA") in which the responsible person or, where the incident occurred in the course of that person´s employment, his or her employer, must, within 14 days of the incident, report to the Director General, provincial head of department and municipality such information as is available to enable an initial evaluation of the incident, including: (a) the nature of the incident; (b) the substances involved and an estimation of the quantity released and their possible acute effect on persons and the environment and data needed to assess these effects; (c) initial measures taken to minimise impacts; (d) causes of the incident, whether direct or indirect, including equipment, technology, system, or management failure; and (e) measures taken and to be taken to avoid a recurrence of such incident.

In terms of section 30(1)(a) of NEMA, an "incident" means an unexpected sudden occurrence, including a major emission, fire or explosion leading to serious danger to the public or potentially serious pollution of or detriment to the environment, whether immediate or delayed.

In line with section 24 of the Constitution of the Republic of South Africa (Act No. 108 of 1996), "serious" is taken to be a measure of the impact of an incident where such an incident has had, could have had, is having, or will have a negative impact on human health or well-being.

1. RESPONSIBLE PERSON

In terms of section 30(1)(b) of NEMA, the "responsible person" includes any person who: (i) is responsible for the incident; (ii) owns any hazardous substance involved in the incident; or (iii) was in control of any hazardous substance involved in the incident at the time of the incident

1.1 Name:		**1.2 Designation:**	
1.3 Postal Address		**1.4 Physical Address:**	
1.5 Telephone (B/H):		**1.6 Telephone (A/H):**	
1.7 Fax:			
1.8 E-mail:			
1.9 Nature of Business:			

2. EMERGENCY INCIDENT SUMMARY INFORMATION

Mark the appropriate boxes

2.1 Fire:		**2.2 Spill:**		**2.3 Explosion:**		**2.4 Gaseous Emission:**	
2.5 Injuries		**2.6 Reportable injuries:**		**2.7 Hospitalisation:**		**2.8 Fatalities:**	
2.9 Open water impacts:		**2.10 Ground water impacts:**		**2.11 Atmospheric impacts:**		**2.12 Soil impacts:**	
2.13 Own emergency response involved		**2.14 Fire prevention services involved**		**2.15 Government hazardous materials emergency response involved**		**2.16 More than 1 governmental emergency response service involved**	
2.17 Emission of non-toxic substances at low concentrations		**2.18 Emission of non-toxic substances at high concentrations**		**2.19 Emission of toxic substances at low concentrations**		**2.20 Emission of toxic substances at high concentrations**	
2.21 No evacuation required		**2.22 Immediate area evacuated**		**2.23 Immediate surrounds evacuated**		**2.24 Evacuation of the general public**	
2.25 Others							

3. INITIAL EMERGENCY INCIDENT REPORT

In terms of section 30(3) of NEMA, the responsible person or, where the incident occurred in the course of that person´s employment, his or her employer must forthwith after knowledge of the incident, report through the most effective means reasonably available: (a) the nature of the incident; (b) any risks posed by the incident to public health, safety and property; (c) the toxicity of substances or by-products released by the incident; and (d) any steps that should be taken in order to avoid or minimise the effects of the incident on public health and the environment to: (i) the Director General; (ii) the South African Police Services and the relevant fire prevention service; (iii) the relevant provincial head of department or municipality; and (iv) all persons whose health may be affected by the incident.

3.1 Description	**3.2 Date:**	**3.3 Time:**	**3.4 Medium:**	**3.5. Name and contact details:**
Relevant fire prevention service: (in case of fire)	[submission date]	[submission time]	[Fax, phone, SMS, letter, etc.)	[Who was the report made to?]
LOCAL :				
PROVINCIAL: **(Those deal with Environmental issues)**				
DIRECTOR GENERAL: (Department of Environmental Affairs)				
Any other Director General of National Department, E.g. Department of Water Affairs				

4. INCIDENT DETAILS

In terms of NEMA section 30(5)(a) and (d), the responsible person must report on the nature of the incident as well as the causes of the incident, whether direct or indirect, including equipment, technology, system, or management failure

4.1 Location of the incident	[Provide physical address of the location where the incident happened including the GPS co-ordinates]		
4.2 Incident start date and time:		**4.3 Incident duration:**	
4.4 Duration of exposure:			
4.5. Incident description:			

Background of the incident:

Operation:

Incident type:

Root Cause of the incident:

Contributory Factors to the incident:

Conclusion:

4.6. Wind speed and direction		**4.7. Ambient air temperature**	
4.8. Weather conditions		**4.9. Other relevant meteorological conditions**	

5. POLLUTANTS RELEASED DURING INCIDENT

In terms of NEMA section 30(5)(b), the responsible person must report on the substances involved and an estimation of the quantity.

List all the pollutants directly released during the incident (i.e. exclude those pollutants that resulted from mitigation measures, e.g. flaring, treatment, dilution etc.)

5.1. Substance or mixture of substances	5.2. Reference Number	5.3. Phase eg solid, liquid or gas	5.4. Total Quantity emitted/released	5.5. Units eg Kg, L etc	5.6. Nature of emission/release
[The name recognised by any national or internationally recognised chemical referencing system]	[Reference to any national or internationally recognised chemical referencing system]	[solid, semi-solid, liquid or gas]	[the total measured or estimated quantity released into the environment]	[the unit of measure in respect to the quantity]	[Emitted from truck, underground pipe, stack, etc.]

6. SECONDARY POLLUTANTS RESULTING FROM INCIDENT

In terms of NEMA section 30(5)(b), the responsible person must report on the substances involved and an estimation of the quantity released.

List all the pollutants that resulted from mitigation measures, e.g. flaring, treatment, dilution etc.

6.1. Substance or mixture of substances	6.2. Reference Number	6.3. Phase	6.4. Total Quantity emitted/released	6.5. Unit	6.6. Nature of emission
[The name recognised by any national or internationally recognised chemical referencing system]	Reference to any national or internationally recognised chemical referencing system]	[solid, semi-solid, liquid or gas]	[the total measured or estimated quantity released into the environment]	[the unit of measure in respect to the quantity]	[Emitted from truck, underground pipe, stack, etc.]

7. POLLUTANT CONCENTRATIONS

In terms of NEMA section 30(5)(b), the responsible person must report on the substances involved and an estimation of the quantity released.

List all the pollutants detailed in previous section:

7.1. Substance or mixture of substances	7.2. Reference Number	7.3. Estimated pollutant concentration on different radius			
		7.3.1. 10m	7.3.2. 100m	7.3.3. 500m	7.3.4. >2000m
[The name recognised by any national or internationally recognised chemical referencing system]	[Reference to any national or internationally recognised chemical referencing system]	[estimate the concentration of the pollutant in water, soil and/or air within a 10m radius of the epicentre of the incident] [provide the units used in a case of estimating concentration (e.g. ppm]	[estimate the concentration of the pollutant in water, soil and/or air within a 100m radius of the epicentre of the incident] [provide the units used in a case of estimating concentration (e.g. ppm)]	[estimate the concentration of the pollutant in water, soil and/or air within a 500m radius of the epicentre of the incident] [provide the units used in a case of estimating concentration (e.g. ppm)]	[estimate the concentration of the pollutant in water, soil and/or air within a > 2000 m radius of the epicentre of the incident] [provide the units used in a case of estimating concentration (e.g. ppm)]

[1] Concentration at the plume

[2] Concentration that was falling on the ground

8. INCIDENT IMPACT

In terms of NEMA section 30(5)(b), the responsible person must report on possible acute effects on persons and the environment and the responsible must provide data needed to assess these effects;

8.1. Minor injuries	[Describe the number and types of any minor injuries that resulted from the incident or efforts to manage the incident or the impacts thereof]
8.2. Reportable injuries	[Describe the number and types of any injuries requiring statutory reporting that resulted from the incident or efforts to manage the incident or the impacts thereof]
8.3. Hospitalisation	[Describe the number and types of any injuries that required professional medical care that resulted from the incident or efforts to manage the incident or the impacts thereof]
8.4. Fatalities	[Describe the number and cause of any fatalities that resulted from the incident or efforts to manage the incident or the impacts thereof]
8.5. Biological impacts	[Describe any impacts on biological life, other than human life, e.g. fish kills, plant mortality, etc.]
8.6. Impact area	[Describe the area possibly affected by the incident or the impacts thereof including: (i) size of the area; (ii) socio-economic context; (iii) population density; (iv) sensitive environments (if any), etc.]
8.7. Data	Attach relevant impact reports, medical reports, death certificates, post mortem reports, environmental monitoring data, etc. as Annexes C1, C2,… to this report

9. EXISTING PREVENTION PROCEDURES AND/OR SYSTEMS

9.1. Foresight	[Briefly describe whether the incident could have, or had, been foreseen, e.g. was it included in any environmental impact assessment, risk assessment, health and safety plan, etc.]
9.2. Procedures and/or systems	Attach any relevant safety, health and environmental plans (including any statutory planning requirements) that detail what actions should be taken in the event of the incident that is the subject of this report
9.3. Procedure and/or systems failures	[Describe any failures or shortfalls in procedures and/or systems that may have contributed to the incident] ***All procedures and checklist in place and signed off.***
9.4. Technical measures	[Describe any technical measures, equipment, 'fail-safe' devices, etc. that are in place to prevent the occurrence of the incident] Communications & discussions in place.
9.5. Technical failure	[Describe any failures of technical measures, equipment, 'fail-safe' devices, etc. that are in place to prevent the occurrence of the incident]

10. INITIAL INCIDENT MANAGEMENT

In terms of NEMA section 30(5)(c), the responsible person must report on initial measures taken to minimise impacts.

10.1. Evacuation	[Describe any evacuation activities including information on the number of people evacuated and whether these people were staff or otherwise]
10.2. Technical measures	[Describe all technical measures taken to address the incident]
10.3. Mitigation measures	[Describe all measures taken to minimize the impact] ***SOPEP gear activated***
10.4. Emergency Services	[Describe any governmental emergency services involvement] ***SAMSA/TNPA advised***

11. CLEANUP AND/OR DECONTAMINATION

In terms of NEMA section 30(5)(c), the responsible person must report on initial measures taken to minimise impacts.

11.1. Cleanup and/or decontamination	*[Report on initial cleanup and or decontamination (remediation) measures taken to minimise the impact of the incident on human health and the environment. Provide copy of safe disposal certificate (if any)and details of the company that undertook the cleanup]*

11.2. Permissions and Instructions

Provide details of any permission and/or instructions received from any organ of state during initial incident management, cleanup and/or decontamination

11.3. Type	11.4. Statute	11.5. Issued By	11.6. Name and contact details
[Describe the nature or type of permission or instruction]	[Provide a reference to the legal mandate for the permission or instruction]	[Provide contact details for the permitting or instructing authority]	[provide a summary of the activities carried out in terms of the permission or instruction]

12. MITIGATION MEASURES

In terms of NEMA section 30(5)(e), the responsible person must report on measures taken and to be taken to avoid a recurrence of such an incident.

12.1. Measure	12.2. Objective	12.3. Cost	12.4. Timing
[Briefly describe each of the measures taken, and to be taken, to avoid a recurrence of such incident]	[Briefly describe the objective of the measure, i.e. the desired outcome of the measure]	[Estimate the cost of the measure in terms of capital costs and/or recurrent costs]	[Provide information on the timing for the full implementation of the measure]

13. AUTHORISATIONS

Provide details on all authorisations (including permits, licenses, certificates, etc.) in respect of the activity to which this incident relates.

13.1. Type	13.2. Statute	13.3. Issued By	13.4. Issue & Expiry Date
[Describe the nature or type of authorisation, e.g. Registration Certificate]	[Provide the reference for the authorisation, e.g. section X of the National Environmental Management Act (Act No. 107 of 1989)]	[Provide contact details for the issuing authority]	[provide the date of issue and expiry]

14. HISTORY

Provide details of all similar incidents involving the responsible person in the past (i.e. from 1998). Similar incidents include those that: (i) involved similar circumstances; (ii) involved similar emissions; (iii) involved similar personnel; and/or (iv) involved similar impacts.

14.1. Incident title	14.2. Report reference	14.3. Date of incident	14.4. Summary of event
[Provide the title used in the relevant emergency incident report]	[Provide the reference in respect of the relevant emergency incident report]	[Date of incident]	[Provide a summary of the event]

Signed by, or as a mandated signatory for, the responsible person:		Date:	

APPENDIX 1
List of affected people as a result of the incident

NAME	ADDRESS	PHONE	E-MAIL	REMARKS

APPENDIX 2
Layout map of the area likely to be affected or affected as a result of the incident

Disclaimer

Any other information not covered in the reporting template must be included.

CAUTION

In terms of section 30 (11) of NEMA as amended, it is an offence not to report an incident and liable on conviction to a fine not exceeding R 1 million or imprisonment for a period not exceeding 1 year, or to both such a fine and such imprisonment.

9. APPENDIX B

Notification of Investigation Area in Terms of Section 37 of the Waste Act

environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

Notification of contaminated land

The following information should be supplied to the Minister or MEC by the owner of the contaminated land, or person who undertakes the activity that caused contamination of land:

- Information required should be typed in the space provided
- Name and Signature of delegated person
- The following should be attached:
  - (i) Current site plan - with scale bar showing north direction, local water drainage and other locally significant features on-site and immediate off-site. The plan should also show the historical location of structures that may have affected the distribution of contamination (e.g. building, underground storage tanks, treatment baths, etc);
  - (ii) Locality map

1. Details of the Land owner			
Name:			
Identity number:			
Town/Suburb:			
Postal code:			
Tel:		Fax:	
2. Details of the Land user			
Name of contact person:			
Company name:			
Registration number:			
Physical address:			
Postal code:			
Tel:		Cell:	
Fax:		Email:	
3. Details of the site			
Farm name:			
Farm/erf number:			
Province:			
District Municipality			

Local Municipality			
Four (4) or more corner coordinates of the portion of land that is contaminated			
Size of the area contaminated			
4. Details of the Site Assessment Practitioner			
Name and Surname			
Company name			
Physical Address			
Postal Address			
		Code	
Telephone/Cell		Fax	
Email Address			
5. Department of Water and Sanitation: Water Management Area/ Quaternary Drainage			
Responsible Officer (DWS)			
Physical Address			
Postal Address			
		Code	**0010**
Telephone			
Email Address			
6. Description of the Nature of contamination			

I declare that the information contained in this form is true

Name of responsible person

Signature of responsible person

Designation

Date

Submission of this form should be directed to:
The Director: Land Remediation-Dr Mpho Tshitangoni
Environment House, 473 Steve Biko Road, Arcadia, Pretoria, 0083
Private Bag X447, Pretoria, 0001