Best Fracking Waste Management Practices for South Africa

from The United States

Master’s Thesis

Presented to

The Faculty of the Graduate School of Arts and Sciences
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ABSTRACT

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A thesis presented to the Graduate Program in Global Studies

Graduate School of Arts and Sciences
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The purpose of this paper is to present a comparative evaluation of best practices in fracking waste management in the United States for future recommendations to South Africa. As South Africa lifts its moratorium on fracking, it must create a specific legal framework with clear outlines about how natural gas will be extracted, stored and disposed of in a way that does not compromise the health and safety of residents or the environment. This paper first explores legal frameworks for fracking waste management in the United States, focusing specifically on a fracking accident in Pennsylvania that forced the state to outline ways to mitigate risks posed by fracking activities. Pennsylvania’s example offers best practices and proposes possible legislative considerations and amendments within South Africa’s current oil and gas legislation. Considered to be one of most advanced fracking countries worldwide, the United States offers important lessons to South Africa as it begins extracting its natural gas resources. Existing waste management legislation in South Africa provides a glimpse of how this nation manages its oil and gas waste, and the degree of protection is assigns surface and underground water that may be affected by fracking operations. This paper will conclude with recommendations for legislative
development in South Africa to mitigate potential risks resulting from fracking accidents, as was seen in the Pennsylvania case study.
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Introduction

This research paper delves into the controversial topic of hydraulic fracking to extract natural gas, a non-renewable source of energy. Various laws and statutes related to fracking are evaluated and a comparative analysis of waste management laws as they relate to this practice has been outlined between the United States and South Africa.

An analysis of existing environmental laws in South Africa revealed that South Africa has a well-developed oil and gas industry. However, because fracking has not yet been fully explored in South Africa, standalone hydraulic fracking laws and regulations have not yet been developed. Now that South Africa recently lifted a moratorium on fracking and began exploring the possibilities of using fracking to extract important natural gas reserves, it is important to draw on lessons learned from other similar cases. This research shall inform what is deemed to be best practices in fracking waste management to advise South Africa to take a precautionary approach and thus mitigate against fracking accidents, which result in the leakage of waste water into underground water sources, leading to water contamination.

“What are the best practices regarding fracking waste management in the United States of America and South Africa?”

This research paper outlines the statutes, regulations and policies on fracking, and evaluates what might be “best practices” in fracking waste water management. It compares the Marcellus Basin in Pennsylvania with South Africa’s newly approved fracking region, the Karoo Basin in the Northern Cape. A comparative analysis of various waste management strategies
employed within the two basins is undertaken. Gaps in regulations that govern waste water emanating from fracking activity have been highlighted as lessons learned.
Finally, best practice will be gleaned and offered as possible recommendations for the South African government as it explores and launches its nascent fracking efforts.

To highlight the global aspect of fracking, this paper draws a comparison between a developing nation, South Africa, to ascertain how it fairs when compared to a more developed country, the United States, which offers well-established infrastructure, systems, and laws pertaining to natural resource extraction. Although South Africa is a developing country, it is a leader among African nations with respect to its sound environmental policies and systems. In this regard, best practices within the U.S. might be successfully adapted to the South African context and used to outline policy recommendations for the nation’s fracking waste management program.

**Problem statement**

Fracking is regarded as a clean source of energy. Fracking contributes to energy security, it offers significant socio-economic benefits for society, and available environmental/waste laws can sufficiently mitigate against its environmental impacts. According to the scientific journal, *Science* (2013, p.1235009-1):

Natural gas has recently emerged as a relatively clean energy source that offers the opportunity for several regions around the world to reduce their reliance on energy imports. It can also serve as a transition fuel that will allow for the shift from coal to renewable energy resources while helping to reduce the emissions of CO2, criteria pollutants, and mercury by the power sector.

While the socio-economic benefits of fracking cannot be denied, fracking activity can contribute substantially to environmental damage, particularly because existing laws are not geared to deal with possible accidents, as the Pennsylvania case study illustrates. The following chapters will address legislation governing fracking, a case study explaining the fracking
accident in Pennsylvania in 2011, along with a comparison between regulations in South Africa and the United States. Finally, this study shows interesting parallels between two primary national laws governing the disposal of waste: The U.S. Resource Conservation and Recovery Act, and South Africa’s Environment Conservation Act, both of which provide overarching policies determining how waste should be categorized and managed.

Findings from this study reveal that U.S. federal laws, such as the Safe Drinking Water Act, the Clean Water Act, the Toxic Release Inventory Act, and the Clean Water Act, exempted fracking waste from being categorized as “toxic waste.” These ruling impacts how companies disclose chemicals in their fracking liquid makeup, how fracking accidents are defined, and how the public health system addresses injured parties who come into contact with fracking waste. Moreover, this study provides insight into the need to continually modify and update fracking policies to ensure that they accommodate new environments considered for natural gas exploration.

In 2015, the Department of Mineral Resources (DMR) in South Africa published a guideline for the exploration of petroleum exploration and production, incorporating regulations that would allow hydraulic fracturing under the Mineral and Petroleum Resources Development Act, 2002 (Jones, 2016)

An analysis of other existing environmental laws in South Africa revealed that, although South Africa has a well-developed oil and gas industry, it does not yet have standalone hydraulic fracking laws and regulations, because fracking has not yet been explored in this country. This research project will outline “lessons learned” and “best practices” gleaned from the U.S. case study to as a way of advising South Africa to take a precautionary approach toward its fracking
activities to avoid accidents, such as the leakage of waste water into underground water courses and other sources of water contamination.

Research Question

The primary question addressed in this research study is:

“What best practices exist in the United States of America and South Africa for fracking waste management?”

After evaluating different statutes, regulations and policies on fracking, it became clear that the Marcellus Basin in Pennsylvania and South Africa’s the Karoo Basin in the Northern Cape had enough similarities to provide a useful comparative analysis of waste management strategies employed within the two similar geological formations. Gaps in regulations governing fracking waste offer important lessons that point to the importance of implementing best practices. These will then be offered as potential recommendations for the South African government as it begins to develop its fracking program.

Another important reason for the U.S.-South Africa comparison is to highlight differences between the strategies of a developing country on the brink of natural gas extraction, in comparison to a more developed country with well-established infrastructure and fracking experience. As a leader among African states regarding environmental policies and systems, South Africa could readily adapt U.S. fracking policies to fit the South African context, thus avoiding potential environmental disasters as it launches its fracking program.
**Research Objectives**

The primary research objective of this study is to gain an understanding of waste regulations and their policy frameworks at a time when the world is moving towards cleaner sources of energy and environmental conservation. It is imperative to understand laws governing the statutes specific to fracking as well as the challenges regarding disposal and storage of fracking waste to provide thoughtful analysis and recommendations for nations such as South Africa that are launching fracking activities.

**Research Methodology - Case Study Method**

Secondary research methods have been utilized for this thesis. Stewart & Kamin (1993) defined secondary research as information and data collected by other researchers and archived at some stage. The reason for choosing this method of research is to sift through the vast amount of information available on fracking in order to derive tailored policy recommendations for South Africa.

This form of research is advantageous because of the readily available information to unpack and the cost-effective way data can be gathered through online sources (Stewart and Kamin, 1993). Time and budgetary constraints make it difficult to gather data from the Karoo region of South Africa’s Northern Cape or from the Marcellus Basin in Pennsylvania.

Furthermore, a case study on the challenges of fracking waste management in Pennsylvania offer important lessons that inform recommendations on behalf of South Africa. Vast information and historical content can be found on official government websites, such as the Environmental Protection Agency, that provided helpful background material on the history
and practices of fracking. Data from historical archives, censuses and government sites will be included in this analysis.

Additionally, it should be noted that within the U.S. Federal system, oil and gas regulations are determined by each state, while South African regulations are outlined at a national level, before they are implemented by provinces or municipalities within a province.

**Why is this topic important?**

An ExxonMobil Energy Outlook report estimates that by 2040, the global demand for energy will increase by 100% to feed the needs of the growing middle class (ExxonMobil, 2017). Electrification and power demands, along with an increased demand for transportation and fuel for that transportation, are some of the forces behind this trend (ExxonMobil, 2017). As a result, a growing demand for diverse types of energy, such as natural gas and nuclear power, has increased. Meanwhile, renewable energies, such as wind, solar and hydropower, are expected to become more relevant with time.

Energy companies in the United States have made great progress with technologies that allow for the accessing of oil and gas from tight rock formations through the process of hydro fracturing. These natural resources have reduced U.S. reliance on energy imports and enhanced energy security. Fracking was justified by the U.S. Government to reduce reliance on coal, and reduce greenhouse gas emissions from the burning of fossil (Merrill & Schizer, 2013).

Waste management and its regulations is of great importance because of its intersection with issues of global warming, environmental conservation, and protection and environmental justice and health. South Africa is showing signs of a more receptive attitude toward fracking, after years of investigation and conflict between the government, environmental activists and community members who farm in the Karoo region.
Although South Africa has a full-fledged oil and gas sector with well-founded and sturdy environmental policies and regulations, it does not yet have fracking-specific regulations in place or infrastructure to store or transport fracking waste to receptacles for recycling or disposal.

According to the EPA (2013), fracking gas wells should be located within or near water sources. Yet, fracking wells are often built according to different standards and can be problematic when waste escapes. “Between 2000 and 2013, approximately 3,900 public water systems were estimated to have had at least one hydraulically fractured well within 1 mile of their water source” (EPA, 2013). Therefore, if fracking waste is not stored or disposed of in a correct way, this could result in fracking accidents and contamination of water sources.

When fracking-related accidents occur, speculation surrounding the contamination of water sources and its impact on the health of residents has proliferated. While health outcomes following fracking accidents are difficult to pin down, much anecdotal evidence suggests that fracking waste is harmful to human and animal life. The poor management of fracking waste in Pennsylvania and the leakage of storage wells suggests that fracking-related accidents may be more bountiful than originally estimated. Thus, the way fracking waste will be stored in the Karoo Basin is imperative to the nation’s long-term environmental health. Early preventative measures against accidents could mitigate such disasters in the future. Therefore, Pennsylvania’s example serves as an important warning for the Karoo region of South Africa as it begins to outline fracking-related legislation.

**Justification for this research**

This topic was chosen after a series of online studies were conducted to analyze the correlation between fracking and the high prevalence of cancer in Wyoming. News of fracking-related accidents occurring in Pennsylvania, including earth tremors, reports of alleged
poisoning, and flammable water, piqued an interest and encouraged further exploration of the topic. Furthermore, unpacking the policies that govern fracking waste management systems in the Pennsylvania will go a long way in providing cautionary examples along with recommendations for best practices for South Africa’s future natural gas industry.

**Summary on fracking regulations in the United States**

Fracking regulations are not universal in the United States, but are instead managed on a state-by-state basis. Although the state regulates how land is used in the United States, energy companies are granted what is referred to as “eminent domain” in areas where they have pipeline projects. Eminent domain is defined as, “The power to take private property for public use by a state, municipality, or private person or corporation authorized to exercise functions of public character, following the payment of just compensation to the owner of that property” (Legal Information Institute, n.d.).

The implications of eminent domain are positive for oil and gas companies who desire a legal way to redistribute land to promote personal gain, and perhaps gains for the state. Their rights to the property also have implications for the types of activities that may take place and the location where waste is recycled, stored and disposed of (Eminent Domain, 2013).

**Parameters of study**

Pennsylvania was chosen for this research project because it is one of the states with the largest fracking activity in the U.S. South Africa was chosen to serve as a global comparison primarily because it has an equally well-developed oil and gas industry with huge potential for natural gas exploration as an alternative clean energy source. Both countries have similarities and differences in their policies and their choices of natural shale gas an alternative energy source. A
comparison of these two nations’ statutes and regulations governing fracking waste management will be provided using case studies focusing on basins where fracking activities are taking place.
Chapter 2

Literature Review on Fracking

What is fracking?

Daniel J. Soeder (2010) explains that “hydraulic fracturing (also called fracing, hydrofracking, and heretofore, fracking) is a drilling technique that improves access to unconventional natural gas within the miniscule pores of shale deposits.” Hydraulic fracturing or fracking is the process used when shale gas is extracted from shale rock formations.

This is essentially the process where the natural gas and oil are liberated from the rock and travel up a well (The process of hydraulic fracturing). This extraction takes place when a steel surface casing is inserted down the length of a drilled hole, followed by cement, to create a barrier between the groundwater source and the well. The well is then drilled further into the underground shale formation. Once the fracturing has taken place, fluids used for the process are recovered from the well and recycled for future use.
Figure 1: Schematic of fracking

Source: BBC.com

When wastewater from fracking is injected into underground wells, earth tremors have occurred, which may lead to possible underground water contamination. For instance, seismic activities in Ohio were thought to be caused by hydraulic activities from fracking. Research interest piqued after a study conducted by Yale Environment 360 discussed fracking wastewater recycling, storage and disposal in the United States. This study specifically outlined challenges faced in documenting the positive and negative outcomes of fracking due to a deficiency of good data and a wide range of disposal methods used by the oil and gas industry (Yale Environment 360, 2014).
Waste from fracking falls into three main categories, according to the Riverkeeper.org, New York’s clean water advocacy organization. These include:

- Flowback fluid, or waste water that returns to the surface once extraction has taken place. This water usually includes chemicals and liquids used for injection purposes (Riverkeeper.org).

- Produced water which flows up to the surface because of production Wastewater that flows to the surface during oil and gas well product (Riverkeeper.org).

- Solid waste, which is the soil, mud and rocks sued during the extraction and production process of fracking after a well has been drilled (Riverkeeper.org).

This wastewater is said to be deposited into rivers and streams, which then contaminates water sources and produces illnesses in affected communities that make use these water sources (Yale Environment 360, 2014). These articles raised questions that required further investigation in the hope of better understanding key issues, such as how waste management is effectively regulated in the US, and where the intersection lies between environmental and healthcare regulations in the United States.

According to Anna Pegels (2010) the global demand for energy and increasing urbanization create strong justifications for fracking, which is viewed as a “clean” energy source. As the world searches for alternative energy sources, the push for green energy increases as the reliance on coal as the main energy source declines.

**Policy and infrastructure**

Aging infrastructure of main primary energy sources and depleting levels of other energy sources has resulted in a search for alternative sources but also increased imports of energy (Wingas, n.d.). Natural gas produces about half as much CO2 as coal per kilowatt-hour of
electricity generated, but its emissions can be some 10 to 20 times more per kilowatt hour than those from nuclear or renewables (Wingas, n.d.). According to the Pennsylvania’s State Review of Oil and Natural Gas Environmental Regulations (STRONGER) hydro fracking should be evaluated in a way that considers depth of the reservoir to be fractured, proximity of the reservoir to fresh water resources, well completion practices, well design, and volume and nature of fluids. Pennsylvania’s Department for Environmental Protection (DEP, 2010) says states should have provisions in place to prevent the contamination of groundwater and surface water from hydraulic fracturing. It is required that programs be in place for hydraulic fracturing to ensure that there is a maintenance of wells, protection of groundwater sources and mineral resources and that there are measures in place to prevent the corroding of well casing and cement integrity (DEP, 2010).

Environmental impact

Hydro fracking allows for horizontal drilling, which entails that water with chemicals is injected underground to create fractures that then release the natural gas. This process is subject to controversy because of the chemicals that are used to dissolve the minerals and to open the fractures (Brantley & Meyendorff, 2013). This mix of chemicals is said to include some liquids that may not be regulated by federal laws and that could possibly contaminate ground and surface water. Further, the methane gas that escapes from the fractures is flammable and could cause explosions while the brine injected into the fractures could contribute to earth tremors (Brantley & Meyendorff, 2013).

Similar research to support why hydro fracking should be considered a dangerous activity was conducted by Rinaldi (2015) who argued that seismic activity is a consequence of fracking and additionally that when fracking creates fissures it allows for harmful gases to escape.
Further, he argued through his research that the toxicity levels from the wastewater produced from fracking was not recovered and harmful to the residents of Pennsylvania. With a large amount of wastewater generated with each fracking procedure this would entail that a large amount of wastewater is stored for an indefinite period underground, which is considered a point of concern because of its unknown chemical makeup (Rinaldi, 2015) It is commonplace for waste water to be stored in open pits that contributes to the increased levels of toxicity as the water evaporates from exposure to air. With the passage of time and lack of disposal of the wastewater, the wastewater would become more concentrated (Rinaldi, 2015)

**US Government Environmental Agency views surrounding fracking and its waste management**

Research done by the Environmental Protection Agency in 2015 on drinking water found that the proximity of the fracking wells to water sources is cause for concerns because of the possible risk of contamination. The EPA (2015) estimated that hydraulic fracturing took place in at least 25 states in the United States between 1990 and 2013 with an estimated 400 contained all the wells constructed and disclosed. These wells are near places of residence and as such near drinking water resources.

The EPA (2015, p. 8) argued that:

“approximately 6,800 sources of drinking water for public water systems located within one mile from a hydraulically fractured well during the same period.”

The drinking source is said to cater to more than 8.6 million people. Findings from the EPA research were inconclusive in that they did not specify the direct relation between proximity of hydrofracking waste sites to drinking water sources and possible contamination of these sources.
The scope of the EPA’s study assessed a few areas from the acquisition of water to its injection and finally the wastewater treatment and its disposal, which is my area of interest and key focus area for this research paper. When looking at the management of this wastewater the assessment looked at how the water was reused, treated or disposed of (EPA, 2015).

**Location of activity**

An alternative school of thought regarding waste water disposal is one arguing that hydraulic fracking disposal wells were strategically located in Southern regions of the United States where low socio-economic groups live, such as southern parts of Texas. In *the American Journal for Public Health* (2016), Johnston, Werder and Sebastian argued that “environmental injustices” were taking place when disposal wells were built in areas with high poverty rates (Johnston, Werder and Sebastian, 2016). This study noted that people of color lived less than 5 kilometers from disposal wells.

**The Health concerns**

The Deputy Commissioner of Remediation & Materials Management in New York found that hydraulic fracking in the Marcellus Shale Basin often requires large amounts of water to extract the natural gas. This, in turn, results in the production of large amounts of waste water with chemicals that are potentially harmful to those who are exposed to them, particularly if they happen to contaminate water sources (New York State Department of Environmental Conservation, 2015). Hydro fracking produces by-products that return to the wells after extraction occurs and their content and makeup vary depending on the characteristics of the formations where hydrofracking takes place (Zhang, Sun and Duncan, 2015). As such this waste water will include toxic chemicals and radioactive materials that are naturally occurring but hazardous if not disposed of properly. Two types of water result from hydraulic fracking. The
first returns to the surface after fracking has taken place, and the second is stored in wells. The water that returns to the surface is referred to as “flowback water.” It is usually produced in high quantities and contains naturally occurring toxic waste as well as radioactive material (Zhang et al., 2015). Proper storage is a pertinent concern because this surface water is likely to mix with potable water that communities use for drinking purposes.

**The South African perspective on fracking**

From a South African perspective, fracking is looked at in both a positive and negative light. The positive outcomes of fracking are job creation and diversification of energy resources in a country with an ensuing power crisis (Fracking stirs controversy in South Africa, 2011). There is also the economic benefit that is a major motivational factor for pursuing natural gas extraction as an alternative energy source in South Africa.

**Energy diversity justifications and the economic boost for South Africa**

According to the South African Oil and Gas Alliance (SAOGA), “South Africa has significant potential for unconventional gas discovery in the form of Coal Bed Methane and Shale Gas, for which it is ranked 8th and 12th in the world” (Upstream Oil & Gas in South Africa, n.d., p. 1). South Africa is estimated to have 390 trillion cubic feet of technically recoverable shale gas and a potential reserve of 30 trillion cubic feet. As such there have been 20 licenses issued for offshore exploration on South Africa’s coast.

Natural gas would contribute to the economy through creating an energy system that is more reliable and efficient. Natural gas is usable in almost all industries, has a growing international market, and is a more efficient as an energy source than coal in the South African context (Shale Gas Development in the Central Karoo, 2016). Domestic production of natural gas would decrease a need for imports of gas from neighboring Mozambique for example. Those
residing in the communities where fracking activities will take place would stand to benefit from the new local gas industry through a reduction in energy costs and an environmentally friendly power structure (Shale Gas Development in the Central Karoo, 2016).

The main source of energy revenue is mainly from the production of petroleum and coal, but because of the reduced reserves of coal as a non-renewable energy source, South Africa has attempted to diversify its energy sources. Gas has been underutilized as an energy source due to the abundance of other energy resources, such as coal and petroleum (Upstream Oil & Gas in South Africa, n.d.). Dependency on coal usage could be reduced with increased production and use of shale gas at a competitive price; high volumes of shale gas will likely be priced more competitively than other energy sources. Natural gas power generation would be more effective than the construction of new coal power plants (Shale Gas Development in the Central Karoo, 2016).

**Environmental concerns**

The challenges that have been highlighted as the main subject of concern by local communities where fracking is proposed is the amount of water required to extract natural gas through the processing of hydraulic fracking (Fracking stirs controversy in South Africa, 2011). Ensuing droughts in the region cause this method of gas extraction to be problematic. Another concern regarding hydraulic fracturing activities in the Karoo area is the scarcity of water resources and the challenges that hydraulic fracking will present to those already scarce resources. (Shale Gas Development in the Central Karoo, 2016). Landowners in the Karoo rely mostly on groundwater as their main water source, due to the scarcity of surface water. Secondly there is concern regarding surface spills during transportation of the natural gas product. (Shale Gas Development in the Central Karoo, 2016).
The impact of water quality and quantity are cumulative. With limited human resources to monitor and manage water quality from fracking, these resources must be regulated by energy authorities in South Africa. On the same note, this challenge is also an opportunity for South Africa to learn about and generate data regarding the hydrogeological structures and the geology of the Karoo (Shale Gas Development in the Central Karoo, 2016).

The infrastructural challenge

Another cause for concern is how to store and dispose of new types of waste that will be generated from hydraulic fracking. South Africa already has a waste management hierarchy that favors reducing waste, and where possible, reusing or recycling it (Shale Gas Development in the Central Karoo, 2016). Although there are existing waste management policies in place from South Africa’s existing Petroleum Exploration and Development Regulations, no specific provision has been made for “hazardous waste,” which is precisely how hydraulic fracking is categorized. Without a provision for hazardous waste sites, waste could end up stored or disposed of in ways that could lead to contamination and health-related problems for those living near the sites (Shale Gas Development in the Central Karoo, 2016).

However, it is especially important to note that there are management strategies and treatment already in place to deal with toxic and non-radioactive chemicals that from mining and extraction activities in the Karoo. (Shale Gas Development in the Central Karoo, 2016).

Summary

It can be concluded that, there are sound motivations for pursuing natural gas as an alternative energy sources to have alternative and efficient energy sources. Although concerns exist about waste generated from fracking activity and its impact on surface water, which is a
scarce resource in parts of the United States and South Africa, alternatives methods of gas extraction that use less surface water should be considered in South Africa’s case.
Chapter 3

United States and South African laws and regulations governing fracking and its waste management

This chapter provides a summary of the statutes and regulations in South Africa and the United States, including information on how fracking waste is managed. South Africa has yet to amend its existing environmental policies or to create standalone fracking legislation that addresses both hydraulic fracking and its waste. However, policies address waste and water management across a broad spectrum of cases that could encompass fracking waste, depending on its classification. Since the activity of hydraulic fracking intersects many issues related to environmental conservation and water safety, this chapter will summarize various acts, statutes, and strategies relevant to hydraulic fracking.

Fracking regulations are not universal in the United States and are managed on a state-by-state basis. Although each state regulates how land is used, energy companies are granted what is referred to as “eminent domain” in areas where they have pipeline projects. Eminent domain is defined as, “The power to take private property for public use by a state, municipality, or private person or corporation authorized to exercise functions of public character, following the payment of just compensation to the owner of that property.” (Legal Information Institute, n.d. p.1).

The implications of eminent domain on oil and gas companies are positive for these organizations in that it becomes a way to legally redistribute land in a way that promotes their personal goals as well as those of the state. Their rights to the property also has implications on
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regarding what activities may or may not take place and where for example, waste is recycled, stored and disposed of (Eminent Domain, 2013).

Part 1-The United States

An overview of the United States Energy Regulations

Energy in the United States is regulated widely through the United States Department of Energy, along with secretaries of Interior or corporation commissions. The oil and gas industry in the U.S. is regulated under the National Environmental Policy Act and the Toxic Release Inventory under the Emergency Planning and Community Right to Know Act. Meanwhile, fracking activities and waste are defined and explained under the Safe Drinking Water Act, the Clean Water Act, the National Environmental Protection Act, Resource Conservation and Recovery Act and the Energy Policy Act.

The Energy Policy Act of 2005

The Energy Policy is the overarching legislation enacted by the Senate, “to ensure jobs for our future with secure, affordable, and reliable energy” (Energy Policy Act of 2005). The Act was designed to additionally promote energy efficiency for various energy sources such as renewable energies, natural gas, hydroelectric energy, geothermal, coal and nuclear energy. Subtitle B of the Act addresses Natural Gas and its storage facilities, the natural gas market transparency rules while Subtitle C, section 322 defines hydraulic fracturing under the Safe Water Drinking Act as a form of underground injection through the subsurface emplacement of fluids by well injection (Energy Policy Act of 2005). There are no specifications regarding the definition of the fluids that are mentioned.
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Resource Conservation and Recovery Act (RCRA) of 1976

The Resource Conservation and Recovery Act (RCRA) is an amended version of the 1975 Solid Waste Disposal Act of 1965, a law put in place to address waste issues through the safe disposal and storage of municipal and industrial waste (RCRA, 2016).

The RCRA’s objectives are meant to provide sound waste disposal options that protect the environment and human populations. The Act formulated a framework that defined what was considered “hazardous” and activity. It is also responsible for suggesting ways to reduce waste by recycling hazardous waste. Furthermore, it outlines the management of solid wastes. According to the EPA, “solid wastes” are considered to be, “any garbage or refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, resulting from industrial, commercial, mining, and agricultural operations, and from community activities.” With additional regulation, solid waste can also be classified as hazardous waste. (RCRA, 2016).

Below is a diagram illustrating how waste is classified as hazardous or nonhazardous according to the Environmental Protection Agency (EPA).
Figure 3 illustrating how waste is defined in the United States

Source: Environmental Protection Agency

The RCRA Acts’ subtitle C is relevant to fracking waste as it was established to control hazardous waste within a specific time frame from its generation to its eventual disposal (RCRA, 2016). The Act also has a program outlining the use of underground storage tanks designed to specifically regulate hazardous wastes stored underground in tanks with substances containing petroleum (RCRA, 2016).

**National Environmental Protection Act of 1969**

The National Environmental Protection Act of 1969 (NEPA) was established as a national framework that was created to protect the U.S. environment regardless of industry. NEPA’s policies hold government branches accountable for their environment any activity takes place that could potentially affect the environment (NEPA, 2017).
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For federal related activities that are proposed the NEPA ensures that environmental assessments as well as environmental impact assessments take place to ensure that all potential impacts are assessed and taken into consideration before any activities are committed to (NEPA, 2017).

**Safe Drinking Water Act of 1976-2004**

The Safe Drinking Water Act (SDWA) was a regulation sanctioned by the Environmental Protection Agency (EPA) to set national safety water standards to protect potable water from natural and manmade contaminants and pollutants (Summary of the Safe Drinking Water Act). The infrastructure in place is designed to treat water and that if the water failed to reach the required standards of the state, it is the duty of the supplier of the water to notify customers (EPA, 2013). Under the Safe Drinking Water Act, wastewater disposal from fracking is regulated through the underground injection of waste disposal fluids containing naturally occurring radioactive materials. The EPA has Underground Injection Control (UIC) regulation designed to, manage disposal and extraction of fracking gas and its byproducts.

Where hydraulic fracking takes place with diesel as a fluid to aid the process, the EPA is given authority to regulate the process (The Process of Hydraulic Fracturing, n.d.). In circumstances where thick liquids such as these are injected underground at a high pressure to create a fracture with the release of pressure after fracturing, the fluid enters the well which are named Class II wells because of their contents and the process used to extract the liquids (The Process of Hydraulic Fracturing, n.d.).

**Clean Drinking Water Act of 1948**

The Clean Water Act (CWA) was created to regulate the discharge of pollutants into U.S. water sources (EPA, 2017). This act is also responsible for ensuring that quality standards are
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maintained for the protection of surface water. The Clean Water Act (CWA) was originally founded in 1948 and was known as the Federal Water Pollution Act before it was renamed in 1972 (EPA). The CWA is of importance when discussing issues of fracking waste and its management because the EPA is considered responsible for implementing pollution control programs and maintaining wastewater standards.

The CWA is also in place to ensure that the quality of water is not compromised with pollutants and toxic materials (EPA). It was deemed unlawful by the CWA to discharge any pollutant from a point source into navigable waters, unless a permit was obtained. The EPA has a National Pollutant Discharge Elimination System (NPDES) program is a program that is meant to control discharges while the EPA’s Office of Wastewater Management is responsible for the implementation of the programs.

Fracturing Responsibility and Awareness of Chemicals Act of 2013 (FRAC ACT)

The FRAC Act was signed off by Congress to recognize hydraulic fracking under the Safe Drinking Act as a federal regulation. The FRAC Act was amended as a counter to the Halliburton loophole and designed to mandate the full disclosure of chemicals used in fracking fluids.

The EPA’s Drilling Waste Management System

This system was designed by the EPA to address waste management in a way that lowers the volumes of the waste generated primarily through the separation of waste that is solid and that which is liquid (Drilling Waste Management Information System). Depending on the makeup of the waste different strategies are employed to either solidify or stabilize the waste using technology. This will allow the waste to be sorted in way where the waste can then be
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restored, recycled, reused or disposed of (Drilling Waste Management Information Systems), n.d.).

**Part 2 - South Africa**

**An overview of South African Energy Regulations**

The structure of the South African government is one whereby it is bound by the constitution of the Republic and that the government is made up of national, provincial and local spheres that are deemed to be interdependent and correlated.

(Government Gazette No 39971, 2016) Environmental functions are managed and shared within government through the national government drafting policy, creating frameworks with adherence standards (Government Gazette No 39971, 2016). National government is also responsible for implementing the objectives from policy and the environmental regulatory frameworks. The South African energy industry is well developed in comparison to the rest of Southern Africa (Government Gazette No 39971, 2016).

Below is a breakdown of the legislative structure specific to energy and waste management in South Africa.
South Africa’s waste strategy is based on the integration of both pollution and waste management together with the National Waste Management Strategy (NWMS) of 1999.

The definition of waste according to the South African Waste Information Center (SAWIC) is, “an undesirable or superfluous by-product, emission, or residue of any process or activity which has been discarded, accumulated or been stored to discarding or processing.” The broad definition includes industrial wastewater, radioactive liquids mining by products and waste from power generation (SAWIC).
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**South Africa’s National Environmental Management Act (NEMA) of 1998**

The Act was formed to promote the constitution’s mandate to protect the environment and life of South Africans through the protection of its natural resources, a promotion of sustainable development and the creation of the nation’s environmental management frameworks. (Best Practice Guideline for the Establishment and Operation of a Waste Derived Fuels Preparation Facility, 2015). The Act was created to ensure united and coordinated decision making on matters of the environment through the promotion of good governance and organized environmental functions executed by entities of the state (Government Gazette No 39998, 2016). The NEMA is also responsible for the formulation of initiatives such as the life cycle structure towards waste management in South Africa as well as what is considered duty of care. The duty of care holds polluters and degraders of the environment accountable for their actions and adds that it is their responsibility to either, prevent, mitigate or rectify pollution related issues where they would have already taken place. (Best Practice Guideline for the Establishment and Operation of a Waste Derived Fuels Preparation Facility, 2015).

**South Africa National Environmental Management: Waste Act of 2008**

The Environmental Management Waste Act of 2008 is a piece of legislation that created under the National Environmental Management Act (Act no. 107 of 1998) and is considered to be the holistic waste management regulation of South Africa. The strategy was put in place to promote the minimization of waste through its reduction, reuse and recycling of waste products. The State of South Africa is mandated under the Constitution to preserve and protect the environment from pollution and ecological damage. (Best Practice Guideline for the Establishment and Operation of a Waste Derived Fuels Preparation Facility, 2015).
**National Water Act of 1998**

This Act was developed to preserve the quality of water, a scarce resource through employing nationwide strategies that prevented pollution of water, addressed water related emergencies in a prompt manner and determining and managing the quantity of water provided as water is considered a scarce resource (National Water Act No 36, 1998). It is required that the nation have a national water resource strategy that is broken down per catchment and that the protection of the resource that is water through the classification system for water resources to determine its quality. National Water Act No 36, 1998).

**National Waste Management Strategy**

This strategy was put in place with objectives to minimize waste and to foster, reuse, recycling and recover the waste where possible. Further the strategy to ensure that waste services were delivered efficiently where most required and ultimately that the waste is promoted and contributed to South Africa’s green economy. (Best Practice Guideline for the Establishment and Operation of a Waste Derived Fuels Preparation Facility, 2015).

The Strategy was aimed to rehabilitate land that has been contaminated and ensure that those who made use of the land for storage or waste disposal complied to the regulations the Waste Act of South Africa. Waste is required to be categorized in terms of level of harm and toxicity levels due to its potential adverse impact on health. The waste would then need to appropriate waste management measures.

Below is a summary of goals the South Africa National Waste Management Strategy
The energy systems in the United States and South Africa have many similarities we can draw parallels from. The United States Resource Recovery Act and South Africa’s South Africa National Environmental Management Waste Act share similarities in that both are aimed at the safe disposal of waste. Additionally, both countries employ different strategies to implement an action to reduce the volumes of waste through correct classification and storage plan.

Source: (Zenande Leadership and Linkd Environmental Services, 2013)
The United States employs the Drilling Waste Management Information System while South Africa has a National Waste Management Strategy aimed at reducing waste through either, restoring, recovering, recycling or disposing of depending on its toxicity levels. The Safe Drinking Act and Clean Drinking Act of the United States discuss setting national safety water standards to prevent water contamination and pollution with specifics on waste water storage and disposal from fracking. Similarly, South Africa’s National Water Quality Act is also aimed at conserving the quality of the scarce resource of water through the prevention of pollution.

One of the ways water is safeguarded is through regulations that provide specifics in terms of its quantity and the correct classification of waste water. Since hydraulic fracturing is a relatively new extraction process in South Africa, no provision for the storage, classification and disposal of its waste have been outlined under the nation’s water act. This is an opportunity to advocate for new regulations added to the Act, since hydraulic fracking makes use of large quantities of water. These would need to be correctly classified and then managed in a way that prevents contamination and pollution.

Finally, a national water management strategy through set objective with guidance from the ministry is meant to be implemented for conserving, protecting, managing and controlling of the nation’s water.
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Chapter 4

Fracking and waste management: An analysis of policies and practices in Pennsylvania; applying lessons learned to (The Karoo) South Africa to prevent future accidents.

Why compare Pennsylvania and South Africa?

While significant differences exist between the two case studies, particularly with respect to unique geographical conditions and governmental policies in each location, a comparative study is useful primarily for the lessons the Pennsylvania case study offers South Africa potentially. Pennsylvania’s story presents a “worst case scenario” that exposes the state’s under-preparedness for fracking-related activity, environmental policy failures, and subsequent efforts to define and implement “best practices.” The South African case study in contrast provides context of an equally well-established oil and gas sector with great potential in gas but also with realities different from Pennsylvania, such as water scarcity and poor waste infrastructure suited for this new practice.

The concluding chapter provides an overview of Pennsylvania’s laws on fracking, and, the statutes that govern hydro fracking and its waste products. Next, it offers an example of an accident that occurred in 2011 at Pennsylvania's Marcellus Basin will be outlined and explains how it was addressed by the state of Pennsylvania. Finally, this chapter offers important policy recommendations to offer South Africa as it begins to develop its natural gas resources.
A Case study of the Bradford County Chesapeake accident- April 2011

Chesapeake Energy Corporation, a fracking company in Pennsylvania was given drilling and extraction rights in Pennsylvania with the state having rules in place to control the extraction of natural gas. A fracking accident occurred in rural Pennsylvania Bradford County in the township of Leroy in 2011 when the company’s defective well leaked chemicals into a nearby stream that is connected to the Susquehanna River, a source of drinking water for many in Pennsylvania (St Fleur, 2015). Pennsylvania's Department of Environment Protection (DEP) discovered that the well casing cracked, resulted in the fluids spilling into a nearby creek. According to State Impact Pennsylvania (2012) an estimated 10,000 gallons of fracking also spilled fluid into a Leroy Township.

The accident was considered a violation of Pennsylvania's Oil & Gas Act and its Clean Stream Law for its contamination of a water source although Chesapeake refused to be held accountable for the accident. Chesapeake was fined $190,000 for its faulty well casing that resulted in the leaking of methane into drinking water (St Fleur, 2015). When methane migrates the consequence is flammable gas bubbles on the surface of water (Methane Migration Means Flammable Puddles And 30-Foot Geysers, 2012). Methane gas exposure is associated with suffocation upon its inhalation (Radon).

Furthermore, recent studies have shown a correlation between fracking and low birth weight in children born close to fracking sites in Pennsylvania’s Marcellus Shale Basin have low birth weight (Horn,2017). For this reason, fracking companies in Pennsylvania are now required by state law to disclose the chemicals used in their fracking processes (Chemicals and Public Disclosure, n.d.)
According to FracFocus, the national hydraulic fracturing chemical registry, state legislation was passed in 2012 making it mandatory for companies partaking in any extraction activities to disclose information regarding their activity 60 days after the completion of any activity on state land. Furthermore, a detailed form outlining any gas extraction activities must be submitted to Pennsylvania's Department of Environmental Protection (DEP) before a license is issued to that company (Hydraulic Fracking: How it works, n.d.). This form includes information regarding the types of wells where fracking waste will be stored in, their depth, the owner of the property, and the type of cementing and tubing used for the wells.

The products of the wells are also a requirement in this document for example if the product is gas, whether it is combustible, if it is oil, the API as well as the Oil Gas Ratio. To note however, that these documents does not state the chemicals that were used for the fracking activities. Companies in the sector can keep the makeup of their fracking liquids between themselves while medical personnel in Pennsylvania are required to sign a non-disclosure agreement regarding any chemicals their patients may have been in contact or exposed to.

A study conducted by Janet Currie and her colleagues from Princeton University in 2014 was to find evidence to support the argument that babies born within a radius from fracking sites had lower birth weights. The sample compared babies from areas where fracking did not only take place as well as across the racial and social strata to determine if there was evidence to support this argument (Gibbons, 2017). The study found that babies born within, “a kilometer (just over half a mile) of fracking sites are 25 percent more at risk of low birth weights.” (Gibbons, 2017).

Although previous studies have found a direct relationship between those living near oil and gas developments and health problems such as asthma, neurological and cardiovascular
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diseases it is not always possible to find which part of the fracking process is directly responsible for these illnesses. In the study conducted by Currie and her team, although their findings supported this evidence, unfortunately they could not find which part of the fracking process was responsible for the low birth weights.

The study narrowed it down to air pollution rather than water pollution because fracking sites were not near municipal water sites where water for the residents originates. Lower birth weights are a concern to the state as they are associated with a future of health problems for the babies concerned from asthma ADHD. Critics of this study have argued that low birth weights should not be ruled out entirely because of fracking activities, but could also be a consequence of habits maintained by the parents of infants, such as smoking and drug use (Gibbons, 2017).

What is important to take from this final chapter is, first, that it provides an example of policy, practice and remediation efforts when fracking waste management goes wrong. Additionally, this chapter addresses dangerous environmental and health impacts of fracking accidents, although the health aspect has been contested by geological scientists and environmental scholars. Finally, this chapter offers a context for future fracking policy recommendations for the Karoo region, a semi-arid area within the Northern Cape Province of South Africa where fracking activities have been given the green light. The purpose of these policy recommendations is to advocate for best practices as South Africa’s nascent fracking program begins. Early prevention will help to mitigate potential accidents in this environmentally pristine region, and to develop contingency plans in the event an accident does occur.
Pennsylvania’s spotty fracking history and the resulting policy changes following a major wastewater accident in 2011 is a cautionary tale of what can go wrong if fracking wastewater is not managed properly. This wastewater spillage in the Marcellus Basin was one of the worst to take place in the short history of fracking accidents in Pennsylvania. The problem was especially concerning the contamination of drinking water with the compound 2-Butoxyethanol, which is associated with hydraulic fracturing drilling (St Fleur, 2015).
Contamination of water with fracking by-products such as nitrogen oxides and formaldehyde and exposure to the pollutants has been associated with birth defects, organ failure cancer and death (Hoffman, n.d). Exposure to Butoxyethanol is associated with vomiting, irritation of the nose, eyes and skin (Toxic Substances Portal-Butoxyethanol, 1999) as well as environmental impacts such as water and air pollution. The Marcellus Basin shale formation is an important example of a geographical formation that extends across several U.S. states, including New York, Pennsylvania, Tennessee, Virginia and Kentucky (Marcellus Shale Play, 2017). Considered the largest shale formation in the United States and second largest in the world stretching approximately 95,000 square miles wide (Marcellus Shale Play, 2017). According to the Energy Information Agency (EIA) of the United States, this rock formation is estimated to contain approximately 410 trillion cubic feet of shale gas. The Marcellus Shale Basin is also said to contain trace amounts of naturally forming radioactive materials within its rocks micro pores, which are toxic if exposed to human beings (Rinaldi, 2015).

These radioactive materials are rich in uranium, thorium and radium, which together form Radon. This toxin is leaked into the air because of fracking drilling activities and is associated with lung cancer related deaths (What we need to know about Radon, n.d.).

The Role of Pennsylvania’s Department of Environmental Policy

The Pennsylvania Department of Environmental Protection (DEP) is responsible for ensuring that Pennsylvania's, air, land and water are protected from pollution that, therefore, provides the state with a clean environment that is healthy and safe for its community. (Pennsylvania Department of Environmental Protection). The DEP is also responsible for regulating oil and gas drilling for the State of Pennsylvania and because of the Bradford county wastewater spill of 2011, the state tightened its fracking regulations, thereby outlining several
steps needed to store or process fracking waste. Fracking waste can be stored through deep well injection, open air pits or through treatment and reuse of the waste water.

Well operators in Pennsylvania can store fracking liquids and waste on condition that pits are lined and designed in a way that correctly contains and houses the products and prevents pollution and contamination (DEP). Section 145 of the Act states that it is required that a list of chemicals used in each well is disclosed. Regarding chemicals used in mining or drilling activities the Pennsylvania, Act 13 of 2012 states that chemical elements or compounds have specific abstract service numbers and that they are registered under the Chemical Disclosure Registry. Hydraulic fracturing chemicals methanol, hydrochloric acid and sodium hydroxide are chemicals added specifically for hydraulic fracturing (EPA, 2015).

Pennsylvania’s Oil and Gas Act states that companies involved in exploration and production must hold themselves accountable for pollution of water sources if the pollution takes place in the first 6 months after drilling has occurred and specifically if the drilling took place 1000 feet from the well (State Review of Oil & Natural Gas Environmental Regulation, 2010).

To better control fracking activities, Pennsylvania implemented the Prevention and Preparedness Contingency Plan aimed at identifying potential risks and should an accident be occurring at a well. Secondly, where accidents do occur, this would require an immediate action and mitigation (State Review of Oil & Natural Gas Environmental Regulation, 2010).

According to Pennsylvania's Department of Environmental Protection (DEP), operators are required to list the chemicals or additives used as well as the types of waste generated because of hydraulic fracturing. This includes the chemical waste makeup, proposed cleanup activities in the event of an accident, the method of storage used and quantities of waste among other requirements (State Review of Oil & Natural Gas Environmental Regulation, 2010).
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With regards to waste generation and management DEP Bureau of Waste Management has reports available to document the characteristics of hydraulic fracturing fluids and waste by those who generate it through use of its Form 26R, Chemical Analysis of Residual Waste as well as an Annual Report by the Generator (State Review of Oil & Natural Gas Environmental Regulation, 2010).

Policy changes in the years preceding the accidents

Because of environmental accidents at the shale reserve, the state of Pennsylvania uses a variety of methods to manage wastewater from hydraulic fracking. These prevention methods offer important practices that can inform other nations when developing natural gas reserves. The state of Pennsylvania specifically disposes of fracking wastewater, through:

- Re-use of wastewater by other fracking-related wells
- Treating and returning wastewater to surface water
- Injecting wastewater into underground disposal wells
- Transporting wastewater to out of state treatment facilities (State Review of Oil & Natural Gas Environmental Regulation, 2010)

Wastewater Recycling:

Waste water is initially treated by reusing flowback produced from fracking wells. According to Water World, “Up to 60% of the water injected into a wellhead during the fracking process will discharge back out of the well shortly thereafter, as flowback wastewater.” (Easton,
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n.d.). Recycling of this waste water takes place through a process of centralization where the waste water is treated and reused as flowback wastewater.

Marcellus Basin wastewater from fracking is stored on the surface in tanks and pits where it is used for road spreading for example while naturally occurring radioactive materials are either treated on site or buried deep in underground injection wells (Underground Injection Controls). The EPA highly encourages this practice because it reduces the use of surface water and the underground injection of waste water, which in turn conserves water.

Wastewater Treatment:

Options for treating wastewater in the Marcellus Basin includes the use of industrial treatment facilities and/or municipal sewage treatment plants, also known as publicly owned treatment works or POTWs, both of which are regulated in the United States under the National Pollutant Discharge Elimination System (NPDES) permit program under the Clean Water Act. The Clean Water Act is meant to safeguard water sources from pollutants (Clean Water Act of 1972). As part of the EPA, the Clean Water Act is meant to ensure good water quality standards for surface water and those who pollute water sources accountable unless they have a permit under the National Pollutant Discharge Elimination System (NPDES) (Clean Water Act of 1972).

The second treatment option for wastewater in Pennsylvania is through on-site treatment facilities that use physical/chemical processes to treat the water. (Water reuse, 2012). This includes desalination to the removal of solids, as well as radioactive and carcinogenic materials (Ways of Disposing of Flowback Water, n.d.). Treated fluids can then be reused by gas developers or other industrial users, or can be discharged to a subsequent treatment facility where it is treated in preparation for future fracking activities.
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Waste fluids can additionally be disposed of with or without treatment via Class II injection disposal wells, which are regulated by the Underground Injection Control program under the Safe Drinking Water Act (USEPA, 2012b). The Clean Water Act and the Safe Drinking Act are the main statutes followed by the state when dealing with its fracking waste and its management.

**Underground Storage Wells:**

Another option to manage fracking wastewater is the use of underground storage wells. Chapter 139 of the USEPA requires that wells have permanent casing to prevent pollution and contamination of water sources. Pennsylvania's Department for Environmental Protection DEP regulations require well operators to prepare a disposal plan for its industrial wastes and fracking liquids. It requires a plan be put in place to identify and dispose of fracking waste in line with the Pennsylvania Clean Streams Law and the Solid Waste Management Act. It is important to note the influence that the price of natural gas has on how waste is managed and disposed. For example, gas prices influence how many wells are drilled, which has direct impact on the volume of wastewater that is stored in wells versus other types of waste management options (Rahm et al, 2013).

**The South African context**

Under the National Environmental Management (NEMWA) Waste Act of 2008, provincial departments in South Africa and municipalities are responsible for the development of individual Integrated waste management plans, which are aligned with the national waste management strategy of South Africa.

The South Africa’s National Environmental Management Waste Act of 2008 is a guide for what is required for local governments legally to create their own plans and as such, waste
management plans in districts where fracking will take place will be required to be in line with the national policy and standards of South Africa (Zenande Leadership and Linkd Environmental Services, 2013).

South Africa’s current waste management hierarchy is illustrated in the below diagram

![Waste Management Hierarchy Diagram](image)

Source: (Zenande Leadership and Linkd Environmental Services, 2013)

**The Karoo Basin-Northern Cape, South Africa**

**Overview**

Johnson, Van Vuuren, Hegenberger Key & Show (1996) provide a description of the Karoo is an extension of the Main Karoo and Kalahari basins in South Africa, together with secondary basins within the rest of Southern Africa. The characteristics of the Main Karoo Basin is that it contains, “thick, organic rich shales” (South Africa Karoo Basin Overview, n.d., p. 1).

A Moratorium was placed on the Basin in 2011 pending investigations by the South African Department of Mineral Resource regarding the environmental impacts of hydraulic extraction and stimulation while a system was created to assist in the regulation of exploration activities onshore (South Africa Karoo Basin Overview). However, the ban was lifted by the South African government in 2012 and a decision for exploration of shale gas to commence in the basin through exploration permit applications issued by local government.
A great challenge associated with fracking in the Karoo would be the threat to the already limited water sources and surface water (De Wit, 2011). In towns where exploration concession is already in place, residents are solely reliant on aquifers as their water source. If the underground wells were to leak and contaminate the water sources, this would undoubtedly impact the health of those who consume the water.

Shell Oil, one of the companies involved in natural gas exploration, assured residents that it would ensure that shale gas wells would only be drilled at least 5 kilometers from any town to prevent potential contamination from occurring (du Toit, n.d.).
Finally, horizontal drilling associated with fracking coupled with the low permeability of the shale rocks in the Karoo would require repeat procedures of fracturing that could allow for gas to escape and fluids to leak into aquifers and groundwater systems that could therefore affect water quality (De Wit, 2011).

**Presentation of findings**

Based on the analysis of the United States and South African policies together with those from Pennsylvania, South Africa is likely to experience similar challenges to those faced in regarding fracking waste management in Pennsylvania; including possible accidents if there is a lack of sound infrastructure to house the fracking waste materials. Fracking waste is known to contain chemicals such as ethylene glycol and sulfuric acids, which affect human health negatively as they are toxic (Riverkeeper.org). To add to the list of contaminants harmful to human health are metals such as benzene, which is a carcinogen, as well as xylene and barium, which is associated with paralysis (Riverkeeper.org).

Some waste is also known to corrode infrastructure, which can allow leakage and lead to the contamination of surface and ground water, killing animals and vegetation in the process. If the organizations that will frack in the Karoo Basin choose not to disclose the makeup of their waste to the community and health practitioners, this, could impact how waste is handled, stored and disposed of. Without adequate infrastructure, such as non-corrosive well casings, leakages may occur and those who handle the waste might be unknowingly exposed to toxins that could compromise their health. In an arid area such as the Karoo with limited water resources, contaminating its water sources with waste would have dire consequences on farming, livelihoods and industries as there would be less water available for all stakeholders.
Recommendations

The analysis of the case study of Pennsylvania reveals that the incident that occurred in 2011 was attributed to failure in implementing sound waste management systems even though environmental laws were in place. Human error was found to be the main reason this incident occurred. It is therefore recommended that South Africa amends its existing laws so that they become robust enough to manage any potential infrastructure failure and inevitable human error. Drawing on Pennsylvania’s best practice measures, we can recommend to the Karoo Basin the following strategies that appear to be consistent with South Africa’s National Waste Management Strategy:

A waste management plan in line with South Africa’s National Waste Management Act of 2008 and Waste Strategy of 2011. A plan that promotes treatment and correct disposal of waste derived from fracking. Further, the provision of high quality materials such as cementing for the wells will help to avoid leakages into water sources.

Additionally, the incorporation of a detailed contingency plan into the Karoo’s waste management strategy. This would need to be broken down into clear specifics of how to address for example water related accidents resulting from leakages, flooding, faulty storage materials or tremors.

Goal 7 of South Africa’s NWMS looks to address land pollution but does there is no provision for remediation of water contamination. This would need to be recommended as part of the strategy while also making use of a contingency plan. An open disclosure of chemicals by fracking companies should be compulsory and to medical personnel to allow them to treat and advise on treatment options for those exposed to hazardous and toxic waste.
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South Africa would need to clarify who is responsible for accidents, illness derived from exposure to fracking waste, whether it is the state’s responsibility, that of the municipality or of the fracking organizations. Finally, a Waste Classification and Management System that clearly states what the classification of waste is and the standards for how and where to dispose of fracking waste. Where landfill is the most used option for waste disposal adequate structures would need to be put in place to ensure there is provision of non-solid waste and liquid waste to be disposed of.

Conclusion

In summary, the study has demonstrated the need for the United States to constantly update its laws to incorporate changes in the energy sector in order to mitigate against possible environmental impact. More importantly, it has been demonstrated that the environmental impacts of fracking far outweigh the gains associated with this activity. Therefore, as Pegels recommends (2010), South Africa is advised to explore other available sources of clean energy, such as solar and wind farms, in order to provide sufficient energy for its growing economy.
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### Table 2 - Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>DEP</td>
<td>Pennsylvania Department of Environmental Protection</td>
</tr>
<tr>
<td>NPDES</td>
<td>National Pollutant Discharge Elimination System</td>
</tr>
<tr>
<td>CDC</td>
<td>Center for Disease Control and Prevention</td>
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<tr>
<td>NEPA</td>
<td>National Environmental Protection Act</td>
</tr>
<tr>
<td>NWMS</td>
<td>National Waste Management Strategy</td>
</tr>
<tr>
<td>NEMA</td>
<td>National Environmental Management Act</td>
</tr>
<tr>
<td>UIC</td>
<td>Underground Injection Control</td>
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<tr>
<td>POTW</td>
<td>Publicly Owned Treatment Works</td>
</tr>
<tr>
<td>SDWA</td>
<td>Safe Drinking Water Act</td>
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<tr>
<td>SAOGA</td>
<td>South African Oil and Gas Alliance</td>
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<tr>
<td>DoE</td>
<td>South Africa Department of Energy</td>
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<tr>
<td>DWAF</td>
<td>South Africa Department of Water Affairs and Forestry</td>
</tr>
<tr>
<td>STRONGER</td>
<td>Pennsylvania State Review of Oil and Natural Gas Environmental Regulations</td>
</tr>
<tr>
<td>CSIR</td>
<td>The Council for Scientific and Industrial Research</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>CWA</td>
<td>Clean water Act</td>
</tr>
<tr>
<td>NWMS</td>
<td>South Africa National Waste Management Strategy</td>
</tr>
<tr>
<td>NWA</td>
<td>South Africa National Water Quality Act</td>
</tr>
<tr>
<td>SAWIC</td>
<td>South African Waste Information Center</td>
</tr>
<tr>
<td>NEMWA</td>
<td>South Africa National Environmental Waste Management Act</td>
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</table>
Table 3 - SWOT Analysis for fracking in the Karoo Basin

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
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</thead>
<tbody>
<tr>
<td>1. Sound environmental regulations and statutes regarding oil and gas</td>
<td>1. Potential water shortages in an area where water is already a scarce</td>
</tr>
<tr>
<td>explorations in South Africa</td>
<td>resource</td>
</tr>
<tr>
<td>2. An already existing waste management strategy</td>
<td>2. Contamination of ground and surface water sources due to poor</td>
</tr>
<tr>
<td>3. Potential for an alternative cleaner energy source with less reliance</td>
<td>infrastructure</td>
</tr>
<tr>
<td>on coal usage</td>
<td>3. Lack of waste infrastructure to house new types of waste</td>
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<tr>
<td>4. Decreased dependence on importing gas from neighboring countries</td>
<td>4. Legislation that has not made provision for fracking, its regulations,</td>
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<tr>
<td></td>
<td>its waste classification and waste management options</td>
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<td></td>
<td>5. Potentially poor air quality from the leakage of gases during the</td>
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<td></td>
<td>process of extraction. This could harm the ozone layer further and</td>
</tr>
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<td></td>
<td>compromise health</td>
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<table>
<thead>
<tr>
<th>Opportunities</th>
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<table>
<thead>
<tr>
<th>Threats</th>
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</thead>
</table>
# BEST FRACKING WASTE MANAGEMENT PRACTICES

| 1. This is a booming industry with big financial benefits for those who invest in it and those who have control over its pricing. There is no need to import. | 1. Further protests which could which could delay or stall extraction processes |
| 2. Employment creation in the Karoo in various areas from waste management, water treatment, construction to engineering etc. | 2. Media bias from anti fracking groups and those community members who believe their livelihoods will be at stake and their livestock threatened. |