THE IMPLEMENTATION OF GREEN SUPPLY CHAIN MANAGEMENT: MINIMISING ENVIRONMENTAL RISK IN THE SOUTH AFRICAN MANGANESE AND PHOSPATE MINING INDUSTRY

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ABSTRACT

This study explored the implementation of green supply chain with regard to minimizing environmental risk in the South African manganese and phosphate mining industries. A qualitative research paradigm methodology was used. Theoretical assumptions were utilized. References by other researchers in the green supply chain and mining supply chain were also used to broaden the knowledge horizons for the study. A total number of twelve supply chain and environmental professionals from the key role players in the South African manganese and phosphate mining industries were interviewed and provided valuable input to the study.

The study determined lack of information sharing between the role players in the supply chain that lead to the discovery of themes and sub–themes. The study identified seven main themes and eleven sub-themes as challenges in the implementation of green supply chain. Recommendations to address the challenges areoutlined and include the introduction of cleaner production practices by using cleaner technologies, inclusion of environmental aspects in the sourcing strategy, among others. The achievement of all these will ensure sustainable development.

Originating from the study are research recommendations for the South African manganese and phosphate mining industries. The recommendations include further research to establish a green supply chain model as well as perception and expectations of policy makers in the industries.

DECLARATION

I, Khomotso Bvuma, declare that the contents of this dissertation represent my own unaided work, and that the dissertation has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own work and not those of the Vaal University of Technology.

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K.BVUMA

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CHAPTER 1

INTRODUCTION AND BACKGROUND TO THE STUDY

1.1 INTRODUCTION

The aim of this study was to explore the challenges that exist in the implementation of a green supply chain for the South African manganese and phosphate mining industries. The study examined the challenges facing the manganese and phosphate mining industry, from the mineral resource assessment (exploration) to the mine construction (development) through to the production (operations) until the removal of equipment when resources are depleted (closure).

The long-held view has been that economic growth would inevitably lead to environmental degradation through the consumption of non-renewable resources, the overuse of renewable resources, and the production of waste and pollution (Dryzek 1997:20). Beamon (1999:332) posits that the current state and trend of environmental degradation calls for a need to change manufacturing philosophy. This thinking is in line with the principles underpinning the notion of sustainable development. Sustainable development is defined as the development that meets the needs of the present without compromising the ability of the future generations to meet their own needs (World Commission on Environment and Development [WCED] 1987:43).

For many years the concept of supply chain management focused on enhancing operational efficiency and minimising waste – not so much for environmental reasons, but for economic reasons (Svensson 2001:866). Essentially, the goal of supply chain management is cost reduction, transportation and storage efficiencies while service enhancement comes from better delivery performance and fewer stock-outs for the retailer (Finch 2008:393). According to Ganeshan and Harrison (1995: 1), supply chain is a network of facilities and distribution options that performs the function of procurement of materials, transportation of these materials into intermediate and finished products to customers, and also involves extraction and exploitation of natural resources (Srivastava 2007:53).

Today, the environment has become critical in the management of supply chains, hence the notion of green supply chain management has become increasingly recognised and accepted. Hui, Chan and Pun (2001:269) indicate that government policies and pressure from organized groups fighting for the protection of the environment are some of the factors that induce companies to adopt a green manufacturing or environmental system policy.

Srivastava (2007:53) defines green supply chain management (GrSCM) as the integration of environmental thinking and supply chain management, including product design, material sourcing and selection, manufacturing process, delivery of the final product to the consumer, and the end-of-life management of the product after its useful life. According to Gilbert (2001: 1), GrSCM is the process of incorporating environmental criteria or concerns into organisational purchasing decisions and long-term relationships with suppliers.

The mining of manganese and phosphate has serious environmental consequences for the environment. Engel (2008:1) states that South Africa has made significant progress with environmental management in the last decade by implementing laws and strategies that focus on sustainable development and green issues.

1.2 THE SCOPE OF THE STUDY

In order to explore the challenges in the implementation of green supply chain in the South African manganese and phosphate mining industries, this study discusses the mining industries, the relationship between the manganese and phosphate mining, the impacts on the environment and also the legislation, policy and regulations governing the industries. The study has featured selected participants from leading manganese and phosphate mining groups in the country, consulting houses, institutions involved in the metal and minerals industries, which include manganese mines, phosphate mines, mine rehabilitation consultants, mine, health and safety advisors and government entities.

1.3 PROBLEM STATEMENT

Mining is the largest producer of hazardous and general waste (DEAT 2006: xix). Historically, there has been a perception that the mining industry has always been driven almost solely by the profit motive as it generates foreign exchange, tax revenues and employment and that in the process it has conducted its business at the peril of the environment (McMahon & Van der Veen 2010:38). The World Summit on Sustainable Development held in Johannesburg in 2002 highlighted that the issue of waste globally has become a prominent issue (Middleton 2003:40). However, waste disposal remains a major challenge for mines in South Africa. Toxic waste, dust, acid mine drainage and metal pollution continue to pose major environmental risks within the manganese and phosphate mining industries (DEAT 2006: xx).

Despite a largely adequate and progressive framework for environmental governance having been developed since 1994, the overall condition of the environment continues to deteriorate. Unless effectively implemented and properly enforced, the solid framework for governance remains a mere intention (DEAT 2006: xix). The United Nations Environmental Programme (UNEP 2010:15) has raised concern on the increased levels of environmental degradation and the negative impact on the basic ecosystem services and biodiversity triggered by the expansion of mining operations into environmentally sensitive and fragile areas, as well as the important use of chemicals, energy and water. Few mines have paid attention to the possible effects of pollution by implementing regular monitoring of ground water, air quality and noise to maintain acceptable standards (Middleton 2003:330).

1.4 OBJECTIVE OF THE STUDY

1.4.1 Primary objective

The primary objective of this study was to explore challenges associated with the implementation of green supply chain in the South African manganese and phosphate mining industries with a view to recommending solutions.

1.4.2 Theoretical objectives

In order to achieve the primary objective of the study, the following theoretical objectives were set:

- to conduct a literature review on manganese and phosphate mining industries and related industries or role players in South Africa
- to explore the industry's supply chain.
- to establish the industry's adherence to sustainability issues of "green" and initiatives involving green supply chain.

1.4.3 Empirical objectives

In order to establish the primary objective of the study, the following empirical objectives were set:

- to establish the environmental constraints experienced by the South African manganese and phosphate mining landscape
- to identify the specific actions required by manganese and phosphate mining industry to adopt the green supply chain
- to establish ways of controlling environmental waste in the manganese and phosphate mining industries in South Africa

1.5 RESEARCH QUESTION

The research question needed to address the primary objectives of the study in order to identify the challenges in the implementation of green supply chain in the South African manganese and phosphate mining industries:

What are the challenges associated with the implementation of green supply chain in the South African manganese and phosphate mining industries?

1.6 RESEARCH METHODOLOGY

The research type used in the study is a qualitative research paradigm. The research design and strategy is also explained. Areas covered include a literature review, the method of data collection, the selection of participants, sample size and data analysis. The validity of and reliability (measure of trustworthiness) in form of credibility and dependability and triangulation is stated. The process of theory building and ethical considerations for the study are included.

1.6.1 Literature review

The literature review provides a theoretical framework for the study by referencing other researchers' studies and experience in similar or related fields. The literature includes text books, journals, newspaper articles, the internet, companies, annual reports, government reports and legislation publications.

1.6.2 Empirical study

The design of a research study begins with the selection of a topic and a paradigm. A paradigm is a whole framework of beliefs, values and methods within which research takes place. A qualitative research paradigm was used in this study. According to Creswell (1994:1), a qualitative study is a process of inquiry into understanding a social or human problem based on building a complex, holistic picture formed with words, reporting detailed views of informants, and conducted in a natural setting.

1.6.2.1 Selection of participants

Non-probability sampling and, more specifically, purposive sampling was used in this study. This approach is most appropriate for the objectives of the study because selection of respondents was based on their expertise in the area of supply chain management (Neuman 1997:205). Only experts in the supply chain at manganese and phosphate mining industries participated in the interviews. Participants in this study were drawn from selected organisations/institutions as follows: Foskor Ltd, Assmang Ltd, Samancor Manganese (Pty) Ltd, Tshipi’ e ntle, Kalagadi Manganese (Pty) Ltd, United Manganese Mines (UMK), South Africa Chamber of Mines, Mining consulting houses and Department of Environmental Affairs and Tourism.

If a suitable sampling strategy is used, the appropriate sample size selected and necessary precautions taken to reduce the sampling and measurement errors, then a sample should yield valid and reliable information (Salant & Dillman 1994:143). To compile the samples for this study, people in senior/middle management in the above-mentioned organisations/institutions were contacted and some of them agreed to participate in the interview while others nominated experts in the supply chain field

1.6.2.2 Method of Data collection

Primary data in this study were collected from books, journals, the internet and documents collected from participant’s organisations/institutions. Other data were collected from experts interviewed. The interviews were scheduled to last between 30-45 minutes. No issues were experienced during the interviews as all the respondents had received the questions in advance. The questions were semi-structured. A semi-structured interview is flexible, allowing new questions to be brought up during the interview as a result of what the interviewee says. The interview generally has a framework of themes to be explored (Lindlof & Taylor 2002:195).

Other participants that are based at the mining operations opted for telephonic interviews while other participants provided supporting documents to provide more details on their answers from the research questions.

1.6.2.3 Data analysis

Since the data collected were qualitative in nature, content analysis was used. Data analysis in qualitative research involves breaking down the data and searching for codes and categories which are then reassembled to form themes. According to Leedy & Ormrod (2010:144), content analysis is a detailed and systematic examination of the contents of a particular body of material with a view to identifying patterns, themes or biases. Codes serve to summarise, synthesise, and sort many observations made of the data and become the fundamental means of developing the analysis (Charmaz 1983:109). Data was logged for analysis. Data logging is the detailed recording and registering of data in interview transcript and field notes as well as collection of documents and visual data (Holloway 1997:45).

Participants in this study were notified of the need for having the interviews recorded and agreed to the suggestion. An audio-digital data recorder was used to record all the interviews. The recorded interviews were then transcribed, categorised and synthesised for the final analysis. The emerging themes were coded and interpreted.

1.6.2.4 Reliability and validity (measures of trustworthiness)

The triangulation method was used to ensure reliability of the study. Triangulation is a method of cross-checking data from multiple sources to search for irregularities in the research data (O'Donoghue & Punch, 2003: 78). According to Bogdan and Biklen (2006:34), triangulation is a powerful technique that facilitates validation of data through cross-verification from more than two sources. The accuracy of data was tested from various sources which will include primary data from the field notes, printed information from company and government reports.

In this study a member-checking method was used to ensure trustworthiness. There was an interaction between the interviewer and the interviewee during the planning stage and after the interviews.

1.7 DEFINITION OF KEY TERMS

Supply chain

Supply chain is defined as collective elements such as production, stakeholders, stores, logistics, purchasing and technology that are linked by the movement of a commodity's life cycle.

Supply chain management (SCM)

SCM is a process of managing supply chain activities from when a need arises until when the need is replaced or exhausted.

Green supply chain management

Green supply chain management is defined as supply chain management that takes into consideration the environmental sustainability.

Sustainable development

Sustainable development is defined as “development that allows humans to borrow from natural cycles to design systems to satisfy their current needs, where materials are borrowed from and returned to nature without negatively affecting the environment”.

Mining

Mining is defined as a process of extracting commodities from the earth either manually or by the use of technology.

Manganese

Manganese is a silvery-gray mineral commonly obtained through manganese ores; it is hard and very brittle, very difficult to fuse, but easy to oxidize (Hollenman, Wiberg & Wiberg 1985: 1110).

Phosphate

Phosphate is commonly used interchangeably with phosphorus. Phosphate consists of inorganic compounds containing phosphorous and it is mined as phosphate rock.

Resource

Resource is defined as the concentration of solid, liquid or gaseous material in or on the earth’s crust in such form that economic extraction of a commodity (such as manganese or phosphate) is regarded as feasible, either currently or at some time in future (Van Straaten 2002: 9).

1.8 CHAPTER CLASSIFICATION

A summary of the content of all chapters in this study is provided as a navigation guide.

CHAPTER 1: Introduction and background to the study

This chapter discusses the framework, background and the scope of the study. The problem statement and primary objective will be stated while the theoretical and empirical objectives are also addressed.

CHAPTER 2: South African manganese and phosphate mining industry landscape

This chapter discusses the overview of the manganese and phosphate mining industries in South Africa. It also reflects on the relationship between the manganese and phosphate mining. In addition the chapter examines the role players in the industries. The current issues and technologies available are also discussed. Risk and challenges faced by the manganese and phosphate mining industries are also included in this chapter.

CHAPTER 3: Green supply chain and sustainable development

The chapter provides in-depth description of green supply chain and sustainable development and its role in the manganese and phosphate mining industries. The chapter also highlights the mining process and the waste generated. Benefits and challenges on the implementation of green supply chain in the manganese and phosphate mining industries are also discussed.

CHAPTER 4: Research Methodology

This chapter describes the research methodology used for this study. The research design and strategy used are explained. Detailed coverage of the literature review from the stated sources, research paradigm, sampling techniques, selection of population and sample are provided. The methods of data collection and data analysis are stated. The validity and reliability (measure of trustworthiness) in the form of credibility, dependability and triangulation are stated. The chapter also includes the ethical considerations for the study.

CHAPTER 5: Data presentation, interpretation, and analysis

Findings from the empirical study are presented and analysed in this chapter. The chapter also highlights themes emanating from the primary data collected from the interviews.

CHAPTER 6: Conclusions and recommendations

This chapter provides a summary of the entire study and makes recommendations based on the literature review, the primary data as well as secondary data gathered throughout the study. This chapter provides the reflection of the study and declares if the objectives for the research have been achieved.

CHAPTER 2

THE SOUTH AFRICAN MANGANESE AND PHOSPHATE MINING INDUSTRY

2.1 INTRODUCTION

This chapter describes the landscape of the manganese and phosphate mining industries in South Africa and its socio-economic impact on the economy. An outlook on the global and South African manganese and phosphate mining industries is provided, highlighting the reserves, production, consumption and trade of manganese and phosphate. The chapter also provides detailed key role-players and the future of manganese and phosphate mining in South Africa.

2.2 MANGANESE AND PHOSPHATE AND THEIR PROPERTIES

Manganese and phosphate are classified as non-renewable resources. ‘Resource’ is the less specific term, and is defined as the concentrations of naturally occurring solid, liquid or gaseous materials in or on the earth’s crust in such form that economic extraction of a commodity is regarded as feasible, either currently or at some future time (Van Straaten 2002:9).

Manganese is the twelfth most abundant element in the earth's crust with the symbol Mn. It is widely distributed in soils, sediments, rocks and water. It is thought to be present in all organisms. At least 100 minerals contain manganese and it is an essential trace element for all life for plants and animal, including humans (National Environmental Research Centre (NERC) 1975: 21). The name ‘manganese’ comes from the use of its compounds in glass-making. These compounds were called ‘magnes’ in Latin, meaning ‘magnet’ (McCray 1998:14).

Manganese was identified as an element by researchers such as Scheele and Bergman. In 1774, Gahn isolated manganese by reducing it to manganese dioxide using carbon (Weeks 1932:22).

According to Gajigo, Mutambatsere and Adjei (2011:5), manganese is commonly obtained through manganese ore in the form of manganese oxide (also known as pyrolusite), or through iron ores. Manganese production is thus often subsumed under iron mining. Manganese never occurs naturally as a metal. Rather, it is contained as a natural constituent in over 100 minerals. These include sulfides, anhydrous carbonates, anhydrous silicates, and anhydrous phosphates. The most common ores of manganese are pyrolusite, manganite, psilomelane and odochrosite. Manganese is also found mixed with iron ores (NERC 1975:3).

Manganese is a silvery-gray metal resembling iron, but its common ions are aramagnetic. It is hard and very brittle, difficult to fuse, but easy to oxidize (Holleman, Wiberg & Wiberg 1985: 1110).

According to Supriya (1968:761), manganese can be classified into five categories:

- Hydrothermal deposits
- Sedimentary deposits
- Deposits composed mainly of low-temperature silicates and hausmannite associated with submarine flows
- Metamorphic deposits
- Residual accumulation and laterites

Phosphorus is the 15th element in the periodic table with the symbol P. It is also in the group 15 along with nitrogen and has a molecular weight of 31 g mol (Wieser 2006:2055)**.** The element was discovered by Hennig Brand in 1669; by preparing it from urine (urine naturally contains considerable quantities of dissolved phosphates). Hennig Brand was the first person in history to discover an element (Weeks 1933:302; Krafft 1969: 660).

Phosphorus is the eleventh most abundant element in living organisms and it is vital for life (Job, 2010: 2). The name comes from the Greek "*phosphoros"*, light-bearing; the ancient name for the planet Venus when appearing before sunrise (Trujillo, 2011). According to Smit, Bindraban, Schroeder, Conijin and Van der Meer (2009:1), phosphorus is one of the major nutrients needed to sustain life. Phosphorus-containing compounds are vital in energy metabolism including membrane, structural supports (teeth, bones), genetic components (DNA, RNA) and for plants' photosynthesis. There are two types of phosphorus, white phosphorus and red phosphorus (Bridgman 1914: 1344). White phosphorus ignites spontaneously in air and is a highly reactive, waxy, white-yellow, transparent solid with acrid fumes (Erkins 1944:1). Red phosphorus needs friction to ignite (Knapp 1985:1).

The phosphorus cycle is a biogeochemical cycle, which describes how different forms of phosphorus circulate within the earth. It is mainly restricted to the lithosphere, because phosphorus doesn't have a gaseous phase. Phosphorus is largely found as phosphates, stored in soil, fossils, animal and plant bodies and in water systems. All life forms require phosphorus in the form of phosphates, which has an essential role in RNA and DNA and in cellular metabolism (Gilbert 2009:716). Phosphorus is commonly used interchangeably with phosphate; the two are different in that phosphate consists of the element (P) combined with four oxygen atoms (Florida Industrial and Phosphate Research Institute, [FIPR] 2012). Phosphate is the common inorganic form of phosphorus, which is present in the natural environment. Phosphate nodules occur in a variety of shapes and sizes, ranging from less than a single gram to hundreds of kilograms.

According to Chazal (1904:10) the smell of the phosphate mineral is unique and omits a "peculiar odor, bearing a slight resemblance to burning horn' when rocks are rubbed together. Phosphate is an irreplaceable, and to a considerable extent, non-renewable substance (Innovation Network, Courange and Kiemkracht, [INC&K] 2011:1). Phosphates are nutrients and are essential to plant, animal and human life and, unlike oil, where alternatives can be found, there are currently no substitutes for phosphates (Domagalski & Johnson 2012:1; Gilbert 2009:718).

According to Van Straaten (2002:9), they are five major types of phosphate resources in the world:

- (Sedimentary) marine phosphate deposits
- Igneous phosphate deposits
- Metamorphic deposits
- Biogenic deposits

- Phosphate deposits as a result of weathering

The most commonly found phosphates rock is sedimentary phosphate and igneous phosphate. According to INC&K (2011:12), sedimentary and magmatic deposits are widely distributed throughout the world; guano-type deposits occur mainly in the Pacific region. Igneous phosphates find their origin in magmatic activity and they occur as apatite-enriched masses, sheets or veins in so-called alkaline intrusive complexes. Major phosphate-containing alkaline complexes are to be found in Russia, South Africa and Brazil.

2.3 MANGANESE AND PHOSPHATE MINING INDUSTRIES

2.3.1 Manganese and its uses

For over 2000 years manganese dioxide has been used to make colourless glass. Glass is made from sand (silica) and most sand contains iron (II) oxide, which naturally gives glass a green colour (McCray 1998:14). The great majority of manganese ore ends up in steel production; manganese in steel making is a reagent to reduce oxygen and sulfur as an ingredient in special alloy steels (NERC 1975:3). Jose (2012) describes manganese as one of the most versatile chemical elements that serves as an important material for innumerable applications, particularly in steel production.

Another common use of manganese that affects our day-to-day life is the production of tins and cans. According to Kaufman (2000:93), manganese alloys are used for most beverage cans and it also helps in corrosion resistance. Electrolytic manganese, a highly refined form of the metal is also used, though in smaller quantities for manufacturing battery parts. The metal is also utilised in chemical applications such as formulation of inorganic salts and carboxylates, medicines, and catalysts, and rust-proofing in metals (Jose 2012).

The other key application areas of manganese include plant fertilizers and animal feed (Schulte & Kelling 1999:2). Manganese is an essential micronutrient throughout all stages of plant development. It is important for vital plant functions. Manganese acts as the co-factor of various enzymes such as Manganese superoxide dismutase, manganese catalyses, pyruvate carboxylase, and phosphoenolpyruvate carboxykinase. Therefore the incorporation of manganese by cells is essential, particularly in photosynthesis, where manganese plays a critical role as an accumulator of positive charge equivalents in a reaction catalyzed in photosystem II (Ducic & Polle 2005: 105). Manganese can also be used in the coatings that expedite drying of paints and enamels, brick colourant, pigments in ceramics, matches and fuel oil addictive (Jose 2012).

2.3.2 Phosphate and its use

In the past, phosphorus was used for its candescent qualities in flares and munitions (Global Security (GL) 2004). Today the most common use for phosphates is as fertilizer in agriculture. Phosphorus is a vital plant nutrient and its main use - via phosphate compounds - is in the production of fertilizers (Ericsson & Gylesjo 2012:1). Smit *et al.* (2009:1) states that phosphorus is an essential macro-element for plants, therefore fertilizers contain phosphates in large amounts. According to Smit *et al.* (2009:8), phosphate occurs in the form of the mineral rancolite (carbonate apatite), which is soluble in citric acid and thus suitable as a direct-application fertilizer. Ferilizers are also manufactured by processing phosphate rock using sulphuric acid (INC&K 2011:13).

Heffer, Prud’homme, Muirheid and Isherwood (2006: 32) broke down the use of mined phosphate rock as follows: (1) agricultural fertilisers: 80 per cent; (2) animal feed additions, 12 per cent goes to industrial phosphates (e.g. detergents and metal treatment and other industrial application is 3 per cent. Phosphate coatings are used on steel parts for corrosion resistance, lubricity, or as a foundation for subsequent coatings or painting. It serves as a conversion coating in which a dilute solution of phosphoric acid and phosphate salts is applied via spraying or immersion and chemically reacts with the surface of the part being coated to form a layer of insoluble, crystalline phosphates (Dofour 2006:11). The main types of phosphate coatings are manganese, iron and zinc. Manganese phosphates are used for improving corrosion resistance in the general metal industry such as sliding properties of engine, gear and power transmission systems, and has hardness and superior corrosion and wear resistance (Phosphate net 2012).

Phosphorus is also used in steel manufacturing and in the production of phosphor bronze. Phosphorus is one of the most potent solid-solution strengtheners of ferrite. The addition of only

0.17 percent phosphorus increases both the yield and tensile strength of low-carbon sheet steel by about 62 MPa while also improving the bake hardening response and deep drawability (Trujillo 2011). Phosphorus is also used as an additive in steels to improve machining characteristics and atmospheric corrosion resistance (Roberts, Krauss & Kennedy 2000: 4).

Table 2-1 Summary of the effects of phosphorus on the properties of various steel grades

Properties	**Effects**
Strength	Strong increase
Bake hardenability	Increase
Ductility	Strong decrease
Texture (R –value)	Depends on composition and processing
Coating behaviour:	
Fe-Zn Galvanneal	Demands control of phosphorus. Can improve powdering.
Phosphatability	May improve
Enameling steels	Improves fishscaling. Accelerates pickling.
Spot weldability	Not harmful up to ~0.1%
Core loss of motor lamination steel	Strong decrease (improvement)
Embrittlement	Aggravates

Source: Key to metals, 2012

The above table shows the effects of phosphorus on the properties of various steel grades. Phosphorus gives increase in the strength of steel and depending on the composition and processing; it gives texture (R-value).

Phosphates are non-substitutable (Ericsson & Gylesjo 2012: 4). According to INC&K (2011:1), phosphate is essential for agricultural production and therefore plays a key role in the global production of food and biofuels. Roux, Jager, Plooy, Nicotra, Van der Linde and De Waal (1989: 138) identify the other use of industrial phosphates to include animal feed additives, pesticides, and red phosphorus which is used for the production of flame retardants, fireworks, semiconductors and matches. Examples of industrial uses in the food industry and in household applications are (INC&K 2011:21):

- phosphoric acid for pH control in soft drinks
- sodium phosphate in the meat and fish industry
- sodium pyrophosphate in baking mixes and potato processing
- phosphate compounds in detergents and cleaning agents
- phosphate compounds in toothpaste

Line pipe steels are among the most demanding as regards low phosphorus content. For the transmission of corrosive gases maximum content of phosphorus **P**=max 0.02 per cent will be necessary and **P**=max 0.01 per cent is desirable, while the remaining applications include animal feed, detergents, food and beverages and in water treatment as a flocculant directly before water treatment (Ericsson & Gylesjo 2012:1).

2.4 THE RELATIONSHIP BETWEEN MANGANESE AND PHOSPHATE MINING INDUSTRIES

There is a significant relationship between manganese and phosphate. This relationship involves non-renewable resources, elements used in the same products which have isolated reserves, and the politics involved. Manganese is the 12th most abundant element in the earth's crust, while phosphate is rated 15th. Some studies show that manganese is as closely abundant as phosphate (Emsley, 2001: 249). A combination of phosphate, magnesium and ammonium struvite contains many of the essential nutrients that plants need (Gilbert 2009:716).

Manganese and phosphate play an important role in food security globally. According to INC&K (2011:7), modern agriculture relies heavily on phosphate additions to animal feed and the application of phosphate fertilisers for crop production, which makes phosphorus an essential constituent of the global food market. Corathers (2009:100) adds that the manganese compound manganous chloride ($MnCl_2$) is an additive in animal food for cows, horses, goats, and other domestic animals. Fertilizers also contain manganous chloride so that plants get all the manganese they need.

BHP Billiton (Samancor Manganese) is South Africa's number one producer of manganese. It operates on briquetted phosphate rock at their smelter plant in Meyerton. Foskor is also the number one producer of phosphate rock in South Africa (Roux *et al.,* 1989:132). Samancor Manganese produces elemental phosphorus and ferrophos in an arc furnace at their plant in Meyerton. According to Van der Linde and Pitse (2006:2***)*** Chemfos (a subsidiary of Samancor Manganese), mined phosphate rock at Langebaan in the Northern Cape, and is a fertiliser blender. The manganese and phosphate industry support the same industry. For example, phosphorus is also used as an additive in steel to improve machining characteristics and atmospheric corrosion resistance (Roberts, Krauss & Kennedy 2000:4) and according to many studies done including that of Jose (2012), the addition of manganese to steel makes the final product hard, as well as resistant to corrosion (rusting) and mechanical shock. Both manganese and phosphate are used in building materials, where manganese is used in brick colourant and steel structures, the match-making industry, transportation and the beverage industry to list a few. In the beverage industry for example, manganese stiffens aluminum, so less of it is needed to make soft drink cans (Kaufman 2000) and phosphoric acid is added in soft drinks for pH control (Tucker, Morita , Qiao, Hannan, Cupples & Kiel 2006:936).

Another interesting study done by McCray (1998:14) states that for over 2000 years, manganese dioxide has been used to make colourless glass, and a recent study by Trujillo (2012) confirms that phosphates are used in the production of special glasses, such as those used for sodium lamps (street lights). Both studies state that the two minerals are toxic. There is an increasing demand for manganese and phosphate. Roux *et al.* (1989:138) said the growth in demand for phosphate has been phenomenal during the previous century, and the industry has contributed substantially towards improvements in living standards worldwide. Jose (2012) adds that more than 90 per cent of manganese consumption is used in the steel industry, and due to this strong link, manganese consumption serves as an index of industrial growth and in turn an indicator of economic growth.

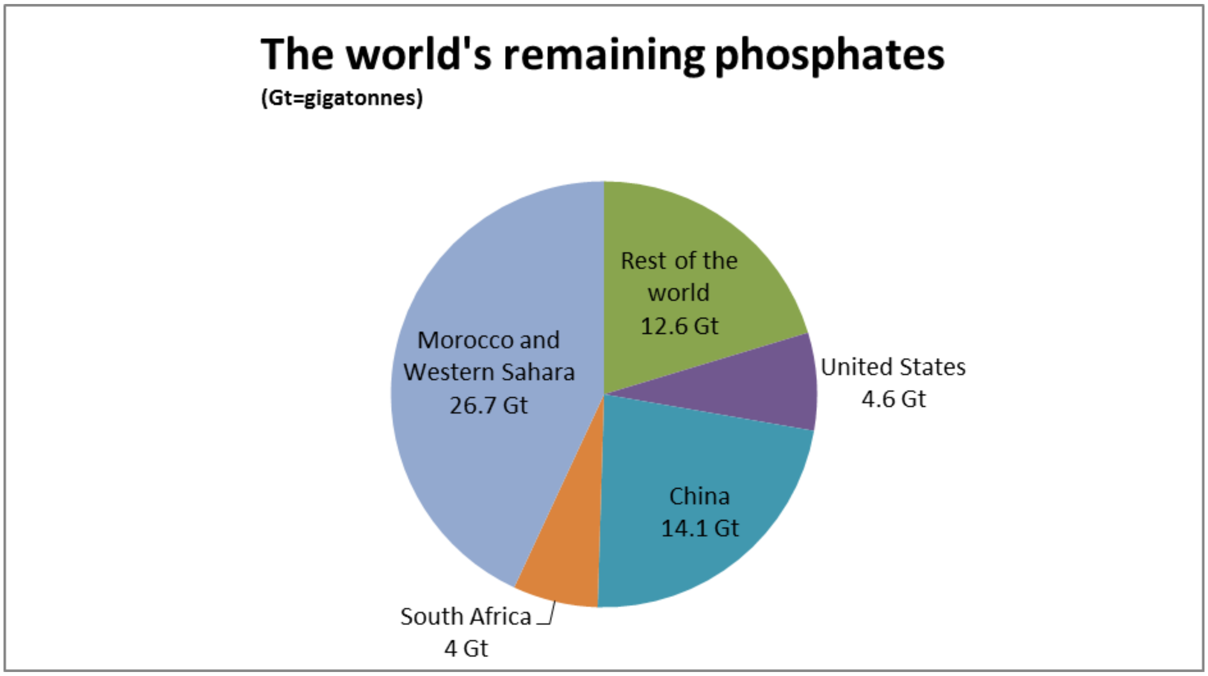
The most common alloy of manganese is ferromanganese. This alloy contains about 48 per cent manganese combined with iron and carbon. Ferromanganese is the starting material for making a very large variety of steel products, including tools, heavy-duty machinery, railroad tracks, bank vaults, construction components, and automotive parts (Verhoeven 2007:56). When phosphate is associated with magnetite, igneous phosphate may become a by-product of iron mining (INC&K 2011:12). While phosphate is used in battery cells, manganese oxide is also used in the original type of dry cell battery as an electron acceptor from zinc, and is the blackish material found when opening carbon–zinc type flashlight cells. The manganese dioxide is reduced to the manganese oxide-hydroxide MnO (OH) during discharging, preventing the formation of hydrogen at the anode of the battery (Dell 2000:139).

2.5 WORLD RECOVERABLE MANGANESE AND PHOSPHATE RESERVES, PRODUCTION, CONSUMPTION AND TRADE

2.5.1 World recoverable manganese and phosphate reserves

Reserves are those portions of the resource base that can be economically and legally extracted at the time of determination, i.e. currently extractable. The less strict term 'resource' is used since economic feasibilities were not conducted at all the sites, and the reliability and interpretation of geological and economic data vary (Van Straaten 2002: 9).

Roughly 80 per cent of the phosphate rock reserves are accounted for by sedimentary phosphates, the remainder consists of igneous phosphates (INC&K 2011:15). World reserves of phosphate rock, i.e. measured reserves were estimated at 15000 Mt in 2008 with a reserve base of 47000 Mt of phosphate rock (U.S Geology Survey (USGS) 2009).



Graph 2-1: The world's remaining phosphate reserves

Source: US Geological Survey (2009)

Graph 2-1 details the world's remaining phosphates reserves in gigatonnes. The most remaining reserves are in Africa with Morocco and Western Sahara leading. South Africa accounts to 4 gt remaining untapped known reserves.

Many studies have given different results in terms of the remaining phosphate reserves, but the most recent study by Ericsson and Gylesjo (2012:1) indicates that Morocco and West Sahara dominates the reserves with roughly 75 per cent of total reserves. The second largest reserves are found in China at 5.5 per cent of total, followed by Algeria, Syria, Jordan and South Africa with 2.2 to 3.3 per cent. Phosphate reserves are hence very much concentrated in one country and the unresolved conflict between Morocco and Western Sahara is already an open conflict which may affect future supply of phosphate rock.

According to the International Manganese Institute (IMnI), among some 300 minerals containing manganese, only a dozen are of mining significance. Current estimates of world manganese reserves, including low grade ore, reach several billion tons, but if only high grade ores (defined as having more than 44 per cent manganese content) are considered then reserves are in the range of 680 million tons of ore, essentially situated in the southern hemisphere, with Australia, Brazil, Gabon and South Africa, supplying over 90 per cent of the international market. Ghana and India, both large suppliers in the past, are now exporting only limited quantities of low or medium grade ore.

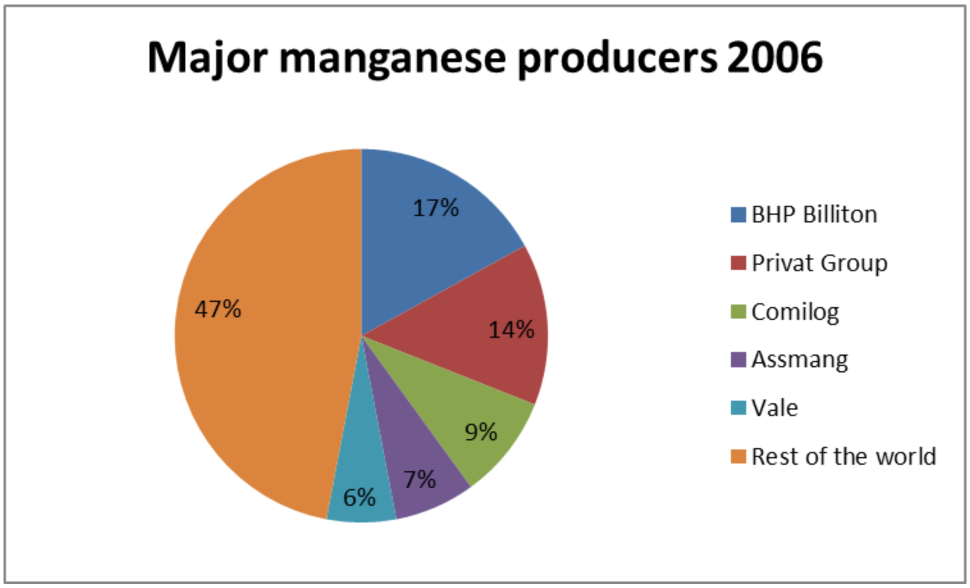
2.5.2 World manganese and phosphate production

The manganese value chain consists of three segments: ore producers, alloy producers and steel producers. The manganese ore industry, segmented by ore characteristics, comprises high grade ore producers who account for two thirds of production, and low grade ore producers contributing a third of production. Alloy production is performed either by independent alloy smelters (70 per cent of production) or by integrated alloy smelters (30 per cent of production). The latter are vertically integrated firms involved in both mining and smelter (Gajigo, Mutambatsere & Adjei 2011:8).

According to Gajigo *et al*. (2011: 9), manganese ore mining is dominated by a few firms. One of the world's largest manganese ore producing companies is BHP Billiton, a global mining company with operations in Australia and South Africa. It is followed by the Private Group (a Ukrainian company) with operations in Australia, Ghana and Ukraine. The remaining three companies among the top five manganese producers are Eramet Comilog (a French company producing over 3 million tons of manganese from mines in Gabon), Assmang Ltd., (producing over 2 million tons of manganese from mines in South Africa) and Vale (producing over 2 million tons from mines in Brazil).

The total world production of phosphate rock in 2010 was 176 Mt. Production in 1989 was only marginally lower at 165 Mt, but in the past 20 years large changes in location of phosphate rock production has taken place. China is by far the leading phosphate rock producer in the world. 75 per cent of the world's phosphate rock is produced from open pit mining. Underground mining is only feasible from high or special grade reserves (INC&K 2011:17). According to Ericsson and Gylesjo (2012:3), the phosphate mining industry is state controlled with an estimated market economy of just below 30 per cent, and if all the Chiness production is considered the figure leaps to 66 per cent making it the highest level of mineral controlled by states.

The Department of Mineral and Energy (DME), (2005:14) indicates that there are 350 individual mines producing manganese ore in China, as opposed to some 250 in the rest of the world. Although it is a dominant beneficiator of manganese, China possesses negligible ore resources, less than 5 per cent of the world resources. China has low grade carbonate ore, carrying less than per cent manganese, and is also lax in enforcing environmental regulations.



Graph 2-2 Major manganese producers, 2006

Source: Eurasian National Resources Corporation (2008:22)

The above graph shows the major manganese producers. BHP Billiton accounts to almost 50% of the manganese production and is also the leader in South Africa.

2.5.3 World manganese and phosphate consumption

The continuing rise in the worldwide demand for steel, and consequently, manganese, means that increasingly higher quantities of manganese demand are expected (Gajigo *et al.,* 2011:8). The total manganese demand is consumed by global serving industries including construction (23 per cent), machinery (14 per cent), and transportation (11 per cent) (Hagelstein 2009:3737). Demand is concentrated in two countries, namely China and India. For example, India’s national steel policy projects a production of 110 million Mt of steel by 2020 from a current production level of approximately 60 million Mt. The rebuilding that followed the Kobe earthquake in Japan in 1995 led to a rise in demand for steel in Japan and a corresponding rise in price (Gajigo *et al.*, 2011:13).

The increase in demand for fertiliser in 2008 may have been a taste of things to come, especially if demand for food rises as fast as some estimates suggest (Gilbert 2009:718). The consumption of phosphate rock has, on average, increased by some 3.4 per cent in the last 100 years, yet phosphate prices have remained somewhat stable (constant 1998 prices fluctuating between 26 and 43 US$/t) (INC&K 2011:2).

Virtually all phosphate consumed today is derived from geological formations with a high phosphorus concentration. To qualify as a phosphate ore, these formations must contain a minimum concentration of phosphorus that makes its mining economically feasible. Historically, this concentration ranges from 25 to 35 wt per cent of P_2O_5, but the actual exploitation of the ore depends on factors such as ease of mining, extractability of the phosphate component and location of the ore deposit (INC&K 2011:11). The four largest net consumers of phosphate who use it for the production of fertilizers include China, the US, India and Brazil, which are big countries with a substantial agricultural sector (INC&K 2011:2).

2.5.4 World manganese and phosphate trade

Manganese ore and alloy prices are determined on the spot market. This is because neither commodities are listed on commodity exchange or stock markets. However, links to iron ore and steel have implications for pricing and price trends (Gajigo *et al.*, 2011:10). Phosphate rock has historically been a relatively low-value bulk commodity (Evans 2012:10). According to USGS (2009) phosphate prices increased from 2007 onwards, peaked in 2008 followed by a decline to the price level and, from June 2010, again increasing. The reason for this sharp price increase is not immediately clear, but growing demand for fertilizer for production of crop and animal-derived food, biofuels, as well as a sudden rise in oil prices in the summer of 2008 may have resulted in a panic-driven phosphate market (INC&K 2011:7). Commodities like uranium also affect the phosphate price. According to Stockholm Environmental Institute (SEI) (2011), as the price of uranium increases so it encourages countries to extract more phosphate.

The steady slump in steel production from mid-2011 precipitated the shortfall in Chinese manganese imports, in addition to triggering the fall of international manganese prices, thereby making manganese the worst performing metal commodity of the year. Prices were strained further by the rising Chinese inventory, as well as the oversupply from Indonesia and South Africa (Jose 2012). Recession or financial crisis also affected the steel prices, the Asian financial crisis in the late 1990's, and the recent financial crisis (2008/09) has led to a fall in the steel prices because of natural cutbacks on the industrial production during the economic downturn. The impact of the recent financial crisis has been pronounced, steel production fell by about 18 per cent worldwide with large variations across regions (Gajigo *et al.*, 2011:13).

2.6 SOUTH AFRICAN MANGANESE AND PHOSPHATE RESERVES, PRODUCTION, CONSUMPTION AND TRADE

2.6.1 South African recoverable manganese and phosphate reserves

South Africa's largest and economically most important deposits of manganese are located in the Northern Cape Province. These deposits occur in a zone extending northwards over a distance of 150 km, from just south of Postmasburg to as far as the Wessels and Black Rock Mines north of Hotazel. The northern or Kalahari field is the most extensive and contains South Africa's major deposits of metallurgical grade ore. In the North-West province, deposits formed through the weathering of dolomite are found scattered across an area extending from west of Krugersdorp to the Botswana border (DME 2005:14).

The phosphate reserves at Phalaborwa are vast. Theoretically, the complex contains 2159 Mt of ore which could yield 298 Mt of merchant-grade phosphate rock per 100m of depth that is every 100m could sustain the current production, which is approximately three times the current domestic demand, for a century. Economic and practical mining considerations would reduce the theoretical reserves considerably. (Roux *et al.*, 1989:133).

2.6.2 South African manganese and phosphate production

The commercially important phosphate deposits in South Africa are confined to igneous and marine sedimentary geological environments. The former environment is by far the most important in South Africa in that roughly 95 per cent of the country's production comes from the Phalaborwa Complex in the northeastern Transvaal (Roux *et al.*, 2011:129). Van Straaten (2002: 259) states that there are several types of phosphate rocks in South Africa, the main source being of igneous origin (currently mined at Phalaborwa), as well as sedimentary and biogenic resources. The latter two types are however not mined at present. Large resources of phosphate-rich sediments are located offshore. Phalaborwa in the lowveld of Limpopo Province of South Africa, is adjacent to the Kruger National Park. The Phalaborwa Complex, about 2,050 million years old, is an igneous intrusion composed of three vertical pipes that continue, according to gravity data, to depths of more than 5 km (Van Straaten 2002:258). The Phalaborwa Complex was discovered in 1904 by E.T. Mellor, and was subsequently studied by such distinguished geologists as Cohen, Wilson-Moore, Du Toit, and Merensky (Roux *et al.*, 1989: 129).

According to Van Straaten (2002: 258), Palabora Mining Company (PMC) Ltd., a subsidiary of Rio Tinto, shares the mining area of the Phalaborwa Complex with Foskor Ltd., a wholly owned subsidiary of the state owned Industrial Development Corporation (IDC). While PMC focuses on the production of copper from the central carbonatite of the Phalaborwa Complex, Foskor is primarily a phosphate mining company. In 1979 Foskor and PMC concluded an agreement by which PMC would extend their open cast mine and Foskor would participate in the cost and receive certain categories of ore which are inexpensive phosphate rock concentrates (Foskor Limited 2012).

Besides Phalaborwa, there are a number of other carbonatitic complexes in South Africa and its neighbouring territories that have been mined for phosphate, or are potential phosphate sources. Glenover Complex mine is one of the other locations in South Africa for phosphate mining. The Glenover Complex in the northwestern Transvaal is situated about 90 km north of Thabazimbi and 70 km west-southwest of Ellisras, and was mined on a small scale until 1984, when the high-grade reserves were exhausted (Roux *et al*., 1989:129). Phosphate mineralisation at the Glenover Carbonatite Complex is associated with a breccia zone along the carbonatite-pyroxenite contact.

The whole ovoid-shaped complex is 4.7 km long and 3.5 km wide. The iron- and apatite-rich breccia body occurs near the centre of the Glenover Complex. Gold Fields of South Africa mined the high-grade breccia from 1958 until 1984, when the reserves were exhausted. The annual output was 70 to 90 kt of lumpy ore grading about 30 per cent PPs and 7 to 10 per cent iron. The ore was used by Samancor Manganese to produce elemental phosphorus and ferrophos in an arc furnace at the Metalloys plant in Meyerton. The Samancor Manganese–Metalloys plant operates on briquetted phosphate rock from Foskor at Phalaborwa (Roux *et al.*, 1989:129).

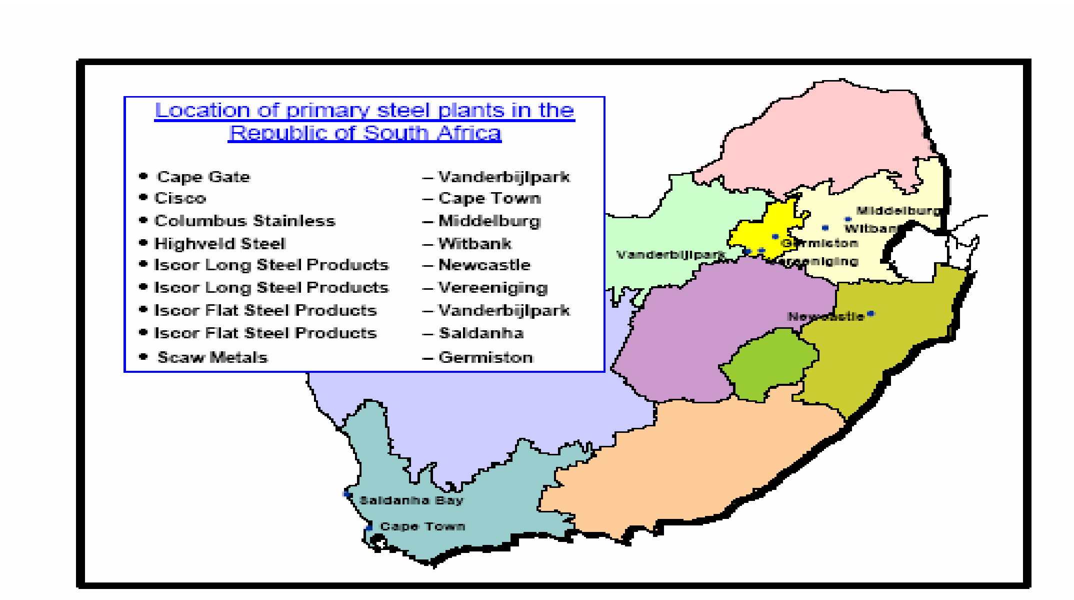
Other players within the phosphate mining industry are Schiel and Langberg. The Schiel Complex, also located in the Limpopo Province is a large syenitic complex with subordinate carbonatite, foskorite, and syeno-gabbro. With an age of 2,095 + 36 million years, it is almost the same age as Phalaborwa (Van Straaten 2002:269). African Metals Corporation (Amcor) started mining on the farm Langberg near Langebaan in 1943 to counter the shortage of imported phosphate, which was needed for the production of phosphoric pig iron at Newcastle and for the production of fertilizer.

According to Gajigo *et al.* (2011:23), there are five manganese mining companies that operate in South Africa: BHP Billiton (Samancor Manganese), Assmang Limited, Kalagadi Manganese, Tshipi Manganese and United Manganese of Kalahari (UMK). BHP Billiton (Samancor Manganese) is the world's largest manganese producer while Assmang Limited is fourth. Assmang and BHP Billiton (Samancor Manganese) account for 80 per cent of manganese production are the major players and dominate in South Africa (Gajigo *et al.*, 2011:23). Smaller producers are Metmin and National Manganese Mines (DME 2005:14).

2.6.3 South African manganese and phosphate consumption

Manganese is consumed by the steel-making industry in South Africa. The largest consumer of steel in South Africa is the building and construction industry, accounting for 23 per cent of total consumption. Manufacturers of cables, wire products and gates consume 17 per cent. Tube and pipe manufacture consumes 11 per cent while plate and sheet metal works account for 10 per cent. Packaging takes 7 per cent, the automotive sector 6 per cent and hardware, furniture and railway sectors consume 4 per cent, mining takes 3 per cent and agriculture, electrical appliances, fasteners and roofing and cold forming account for 1 per cent each. The remaining 15 per cent is not allocated (DME 2005:19).

The South African steel industry accounts for 75 per cent of crude steel production in Africa and 1 per cent of world production. South Africa, with an output of 9.5 Mt in 2003, is ranked as the 19th largest steel producer in the world, and seventh in terms of steel exports. There are six primary steel producers in South Africa: Cape Gate, Cisco, Columbus Stainless, Highveld Steel and Vanadium, Scaw Metals and Ispat-Iscor (Now Acellor Mittal). Acellor Mittal is by far the largest, producing 7.2 million tons a year with a 79 per cent market share. The remaining 21 per cent is shared among the five smaller players (DME 2005:18).



Map 2-1 Map showing location of primary steel plant in South Africa

Source: Department of Minerals and Energy (2005)

Map 2-1 highlights the major consumers of manganese through steel. The map shows the companies and their location in South Africa. As shown in the map, there are six major players with Iscor leading in terms of the number of plants and diversity.

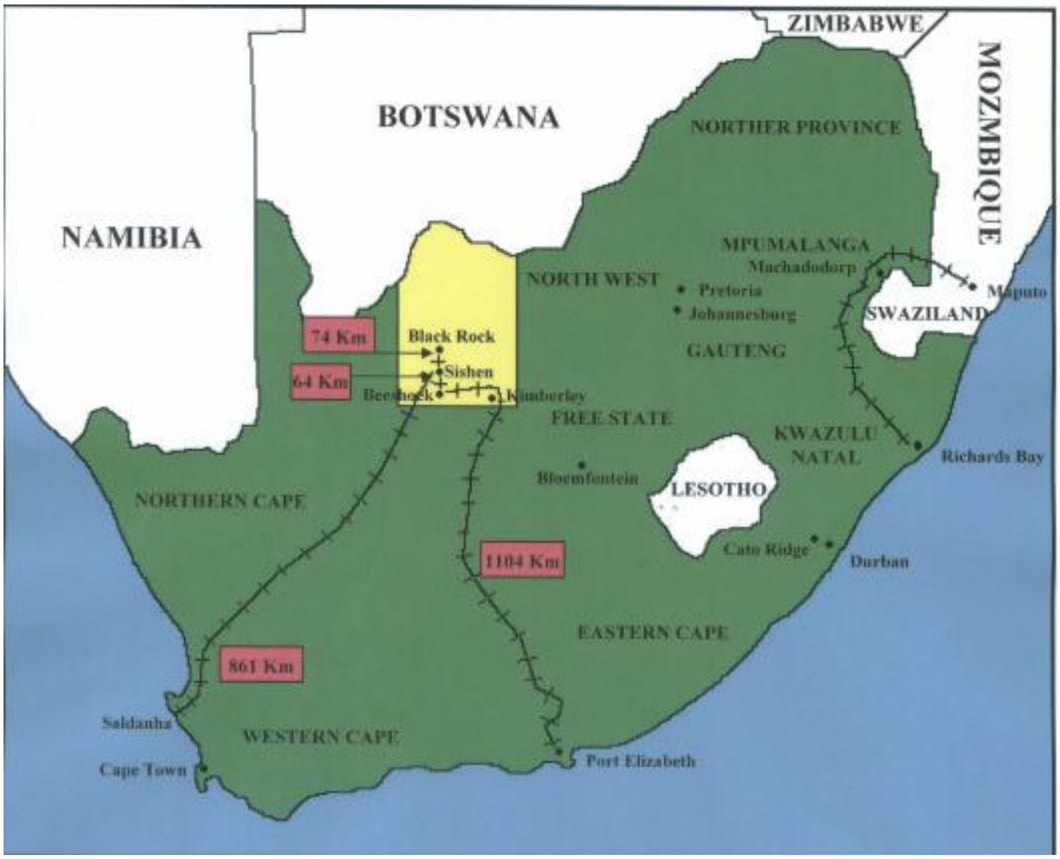
Currently there are no suitable substitutes for manganese in steel production. So growth in the production of steel should have a positive effect on the manganese demand (Gajigo *et al.*, 2011: 23). The fertiliser industry, initially based on sulphuric acid, which was a by-product and which imported rock phosphates, triggered the need for phosphate mining in South Africa. In 1919 and 1921 Kynoch, an explosives producer, and Cape Explosives (originally De Beers Explosives), respectively, started fertiliser production. The industry flourished in a protected trade environment and government support for agriculture in general. This led to the development of Sasol, Iscor (now Acellor Mittal) and Foskor in the early 1950s (Van der Linde & Pitse 2006: 2).

Sasol Limited, which previously had been a supplier to other fertiliser manufacturers only, established its own fertiliser company (Sasol Fertilisers) and started marketing directly to farmers in 1984 (Van der Linde & Pitse 2006:2).

2.6.4 South African manganese and phosphate trade

In 2002, mineral exports made up about 37 per cent of trade from South Africa. Most of these resources are developed by large national and trans-national companies. Only in recent years has the government encouraged small-scale mining. South Africa has a highly-developed domestic and export-oriented phosphate industry (Van Straaten 2002:258). Phalaborwa is more than 800 km from Richards Bay (Foskor Limited, 2012). Foskor's competitors in trade in Europe, namely the USA, the USSR, North and West Africa, and the Middle East, which all have high grades in excess of 18 per cent PzOs, are within 100 km of harbours, and enjoy relatively short shipping distances to their customers, but Foskor delivers phosphate rock domestically at a price far below the cost of the imported material. Price control by the State ceased in 1985, and the home market is not protected by import restrictions or duties. Because nitrogen is much cheaper in countries with resources of low-cost oil or natural gas than in South Africa, the possibility of importing finished fertilizers is a greater potential threat to the domestic producers of phosphate rock than the importation of phosphate rock. Foskor's position in the domestic market is protected not only by its low production cost and the transportation cost barrier faced by an external producer, but also by the high quality of the rock (Roux *et al.*, 1989:138).

Total revenue of R15.31 billion was generated from local and export sales of manganese. Of this 31.8 per cent was contributed by local sales while export sales accounted for 68.2 per cent. Export sales dominated earnings from the beginning of this period to the end (DME 2005:17). Approximately 95 per cent of the manganese produced is consumed in steel manufacturing, mostly in the form of manganese alloys. South Africa accounted for 19 per cent of global production and 23 per cent of its world exports during 2003. Four companies control 45 per cent of the sea trade, namely: BHP Billiton (Samancor Manganese), Assmang, CVRD and Eramet (DME 2005:14).



Map 2-2: Map showing South African export facilities

Source: Department of Mineral and Energy (2005)

Map 2-2 above show the South Africa export facilities for manganese. The map show that there are only two lines from the manganese mining area to the two ports namely Saldanha and Port Elizabeth. Saldanha port is the nearest is compared to Port Elizabeth port.

Prices of manganese ore are a function of the balance between supply and demand prevalent in the markets. Since South Africa owns more than 80 per cent of the world's known manganese resource the local industry can do a lot to influence price movements. This can be done by reducing the production of ore for exports to such an extent that the industry becomes price setters. This is not something that can be achieved overnight but the industry can set itself this goal for the long term (DME 2005:27)

2.7 THE KEY ROLE PLAYERS IN THE SOUTH AFRICAN MANGANESE AND PHOSPHATE MINING INDUSTRY

2.7.1 South African manganese and phosphate mines

According to Van Straaten (2002:258), the wealth of South Africa is largely based on its natural resources sector, specifically mining and farming, and its developed industrial sector. South Africa is a relatively developed country in terms of modern mining. There are three mining processes of mining identified in the world – open pit mining, hydro mining and underground. The South African manganese and phosphate mining industry have only adapted two – open pit mining and underground mining.

It is very expensive to operate in the South African manganese and phosphate mining industry. According to the study done by Gajigo *et al.* (2011:24), part of reason for the higher operation costs in the manganese mining industry is that the ore and sinter need to be transported from the manganese producing region in Northern Cape to the coast where the smelters are located. This means further costs not only in making arrangements for reliable rail transportation but also in power, water and warehousing, among others. The possibility of a phosphate mine was investigated as a matter of strategic importance after the Second World War. Eventually, in 1951, the State acquired the necessary claims from Dr Merensky, and the Industrial Development Corporation (IDC) established the Unie Fosfaat Ontginningsmaatskappy (Eiendoms) Beperk to develop the deposit. A few years later, the name was changed to the Phosphate Development Corporation Limited and in 1987 to Foskor Limited. Production started in 1954 under difficult conditions. The nearest railhead was 60 km away, and all transportation was by truck over dirt roads (Roux *et al.,* 1989:132).

Steel continues to be the largest and most influential end-use market for manganese and market prospects are heavily tied to the industry. More than 90 per cent of manganese consumption is used in steel industry, and due to this strong link, manganese consumption serves as an index of industrial growth and in turn an indicator of economic growth (Jose 2012). Five manganese producers operate in the South African market: BHP Billiton (Samancor Manganese), Assmang Limited, Kalagadi Manganese, Tshipi Manganese and United Manganese of Kalahari (UMK). Samancor Manganese and Assmang Limited are the major players. BHP Billiton (Samancor Manganese) is the world's largest manganese producer while Assmang Limited is fourth. Until recently, these two companies accounted for 100 per cent of South Africa manganese production. Samancor Manganese's production mostly feeds its parents company's alloy production in Australia while the largest markets for Assmang Limited are steel and alloy producers in the US, Europe and Asia (Mbendi 2012).

According to Gajigo *et al.* (2011:23), the other companies are on the edge to enter the market. The leading three companies are Kalagadi Manganese, Tshipi Manganese and UMK. The companies are majority-owned by historically disadvantaged South Africans, and qualify as broad-based black economic empowerment (BBBEE) firms. The owners are Kalahari Resources, Ntsimbintle Mining Limited and Chancellor House respectively. As of early 2011, both Kalagadi Manganese and Tshipi Manganese were at advanced stages of mine development, but yet to start manganese production. Manganese ore mined in the Hotazel area of the Northern Cape is transported by rail to a bulk minerals handling terminal at Port Elizabeth, a distance of more than 700 kilometres. The mechanical plant has been in operation for over 40 years and is now considered to be antiquated (DME 2005:18), while the phosphate mined at Phalaborwa is far worse.

2.7.2 The Department of Mineral Recourses (DMR)

South Africa is considered a pace-maker with respect to mining sector regulation, and promotion of local entrepreneurs' participation in the industry, through its BBBEE strategy. Integrating local beneficiation into mining operations is being promoted, but yet to materialise for most operations (Gajigo *et al.*, 2011:23).

The Department of Mineral Resources aims to formulate and implement policy to ensure optimum use of the country's mineral resources such as manganese and phosphate. The vision of the DMR is to enable a globally competitive, sustainable and meaningfully transformed minerals and mining sector to ensure that all South Africans derive sustainable benefit from the country's mineral wealth. Mining and minerals policy is based on the principles of the Freedom Charter, according to which the mineral wealth beneath the soil will be transferred to the ownership of the people as a whole (DMR 2012).

Unlike for energy, water or nitrogen, there is no single international organisation responsible for phosphate resources (Gilber 2009:717). According to the DME (2005:27), the increasing of local consumption of manganese ore is definitely advised, in pursuit of the dream to beneficiate almost all or all manganese produced locally. This would help ease the burden of transporting the bulky ores from both the rail and port infrastructure.

2.7.3 Other players within the mining industry

The mining industry of South Africa, one of the best developed in the world, forms a crucial part of South Africa's economy. Sales of minerals and mineral products contribute about 16 per cent of the GDP. The mining sector directly employs approximately 550,000 people. It is estimated that approximately 10 million people, a third of South Africa's population, rely on the mining sector (Van Straaten 2002:258). South Africa's wealth, at the end of 2010, was recorded at $4.71 trillion (Baartjies & Gounden 2011:7). South Africa has an abundant supply of minerals which are mined as primary products, so-products or by-products: coal, diamond, base metals, chrome, iron ore, manganese, platinum group metals (PGM), rare earths, gold, uranium, phosphate and others. According to Baartjies & Gounden (2011:2), gold, PGM, coal and iron ore are regarded as strategic minerals with one company controlling 45 per cent of iron ore reserves, one company controlling 55 per cent of PGM reserves and three companies controlling gold reserves.

2.8 THE FUTURE OF MANGANESE AND PHOSPHATE MINING IN SOUTH AFRICA

According to studies done recently, the importance of manganese and phosphate resources is rising. According to INC&K (2011:7), phosphate should be regarded as a strategic, geo-political commodity due to the large reserves found in few countries, including South Africa. Gilber (2009:716) agrees that phosphate is becoming a strategic material for many countries and in the future it's going to become more and more valuable. China, with many small producers, poses a commercial threat to the global alloy market due to uneconomic overproduction of manganese alloys as well as the production of electrolytic manganese metal (EMM) and electrolytic manganese dioxide (EMD), but this represents an opportunity for long-term South African ore sales growth (DME 2005:14).

Experts disagree on how much phosphate is left and how quickly it will be exhausted, but many argue that a shortage is coming and that it will leave the world's future food supply hanging in the balance (Gilber 2009:716). According to Ericsson and Gylesjo (2012:1), there are projects with a total capacity of over 50 Mt in the pipeline around the world including South Africa and Namibia, therefore the concern for a situation in which the world would run short of phosphate resources is unfounded. INC&K (2011:29) disagrees; serious competition between phosphate consumption for biofuel and food production will however result in political measures to restrain the production of biofuels from both existing agricultural land as well as marginal lands.

SEI (2011), suggest that there should be an increased need for global governance of phosphate, global agreement should be in place, there should be monitoring and best practices in the usage of phosphate and there should be consensus among stakeholder. SEI (2011) highlights the South African role in the phosphate mining industry as increasing market control of supply of phosphorus, increasing domestic agro capacity towards food self-sufficiency, and thus forcing the issue of sustainable phosphorus onto the political agenda.

The presence of vertical integration in the manganese value chain means that the leading steel firms are directly involved in the manganese production. Consequently, world demand for manganese and ferroalloys products depends directly on the outlook of the steel industry. Manganese ore and alloy prices are determined on the spot market. This is because neither commodity is listed on commodity exchange or stock markets. However, links to iron ore and steel have implications for pricing and price trends (Gajigo *et al.*, 2011:12).

The manganese industry is very sensitive to production variations and therefore any change in production must be well thought out, as it could have both negative and positive consequences. If an increase in production can be absorbed by local beneficiation activities, this would be advisable. The downward trend of ore export and the upward trend of local consumption by beneficiation industry must be sustained (DME 2005:27). Recent innovations in the green energy sector are boosting demand for EMM and EMD, thus representing a potential for the manganese industry. EMM, a highly purified form of manganese, is being increasingly used for fabricating cathodes, while EMD, a more refined variety of EMM, is being used to produce anodes of the lithium-ion batteries that power electric vehicles (Jose 2012).

2.9 CONCLUSION

The overview of the manganese and phosphate mining industries in South Africa was discussed. The relationship between manganese and phosphate was described both commodities are non-renewable resources, are used in the same products and have isolated reserves in South Africa. The chapter has further highlighted the role of manganese and phosphate in food security globally. The consumption and production trends with the key role players such as Samancor Manganese and Foskor were identified. Logistical challenges which affect the exports sales within the industries was discussed.

The role played by Department of Mineral Resources (DMR) and its attributes to the industries was described, while the future is still arguable. Current minerals reserves in South Africa with mining companies involved were also elaborated on. The next chapter discusses green supply and sustainable development.

CHAPTER 3

GREEN SUPPLY CHAIN AND SUSTAINABLE DEVELOPMENT

3.1 INTRODUCTION

The chapter provides in-depth description of green supply chain and sustainable development and its role in the manganese and phosphate mining industries. Various impacts of the manganese and phosphate mining industries to the environment are also discussed. Benefits and challenges on the implementation of green supply chain in the manganese and phosphate mining industries are highlighted while the cost drivers and environmental legislations and policy are stated.

The wealth of South Africa is largely based on its natural resources sector, specifically mining and farming, and its developed industrial sector. Being one of the best developed in the world the mining industry in South Africa forms a crucial part of South Africa's economy (Mutemeri & Petersen 2002:286). Sales of minerals and mineral products contribute about 16 per cent of the Gross Domestic Product (GDP). Mineral exports made up about 37 per cent of all exports from South Africa. On the one hand, the industry represents an important source of job and wealth and on the other hand, it contributes to a negative environmental impact through pollution, depletion of non-renewable resources and a threat to the health and safety of workers and communities. These problems have pushed the industry to respond and to engage in strategies for sustainable development (Adisa 2004:639).

Environmental issues are becoming an important element in the task of management, and there are good reasons to believe that this new development is likely to be more than a passing trend. Relevant work is emerging from a number of sub-disciplines: once considered a subset of health and safety, the environment is now seen as pertinent to work in distribution logistics, product and process design, operations strategy and procurement and supply chain management (New, Green & Morton 2002:93). Although corporations in most industrialised countries have adopted environmental protection practices required by government agencies since the early 1970s, these regulations largely focus on control of water and air emissions and waste disposal (Morrow & Rondinelli 2002:161).

3.2 THE CONCEPT OF GREEN SUPPLY CHAIN

3.2.1 Green supply chain defined

A supply chain is made up of several elements that are linked by the movement of products along it. The supply chain starts and ends with customers. Suppliers are external to the organisation and can supply raw materials, partially finished and finished goods to be used in the internal manufacturing process of an organisation. The organisation will procure the materials required and pass these goods on to production where they will, in turn, create finished goods for distribution to an organisation's external customers (Saskatchewan Ministry of the Economy, 2012:49)

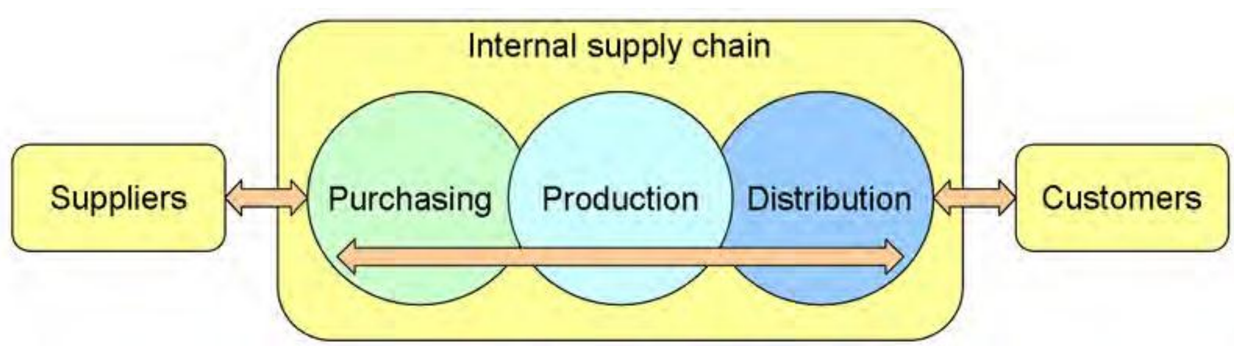


Figure 3-1: Basic components of supply chain

Source: Saskatchewan Ministry of the Economy (2012:49)

The above figure show the traditional supply chain also refered to as basic components of supply chain. The supply chain starts with the suppliers who supply raw materials and operating tools to enable production while it ends with customers who have needs to be satisfied.

The new environmental era represents a new challenge to manufacturing and production enterprises worldwide. The challenge is to develop ways in which industrial development and environmental protection can symbiotically coexist (Beamon 1999:336). With increasing awareness of environmental protection worldwide, the green trend of conserving the earth's resources and protecting the environment is overwhelming (Chien & Shih 2007:383). For many years the concept of supply chain management focused on enhancing operational efficiency and minimising waste – not so much for environmental reasons, but for economic reasons (Svensson 2001:866). Today, the environment has become critical in the management of supply chains. Hence the notion of green supply chain management has become increasingly recognised and accepted.

The traditional supply chain is defined as an integrated manufacturing process in which raw materials are manufactured into final products, then delivered to customers (via distribution, retail, or both) (Beamon, 1999: 336). Supply chain management includes product development, management of information systems, production control, quality control, customer service and recycling and waste management (Koskinen & Hilmola 2008:211). The Council of Supply Chain Management Professionals (CSCMP, 2000-2010: 1) describes supply chain management as follows:

> Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers and customers. In essence, supply chain management integrates supply and demand management within and across companies.

Another study by Jain and Benyoucef (2007:469) describes successful future supply chain features as:

- strategies, technologies, people and systems
- environmental protection as the global ecosystem will always be strained by growing population and the emergence of new high- technology economies,
- re-engineering (customisation, lean, agile, flexible, demand-chain management and integrated supply-chain scheduling issues for long supply chains)

The notion of green supply chain (GrSCM) has emerged in the last few years and covers all phases of product's life cycle from design, production and distribution phases to the use of products by the end users and their disposal at the end of the product's life cycle (Luthra, Kumar, Kumar & Haleem 2011:232). Green supply chains aim at confining the wastes within the industrial system in order to conserve energy and prevent the dissipation of dangerous materials into the environment (Luthra *et al.,* 2011:233). Srivastava (2007:53) defines green supply chain management as the integration of environmental thinking and supply chain management, including product design, material sourcing and selection, manufacturing process, delivery of the final product to the consumer, and the end-of-life management of the product after its useful life. According to Gilbert (2001:1), GrSCM is the process of incorporating environmental criteria or concerns into organisational purchasing decisions and long-term relationships with suppliers.

The ultimate objective of extending the traditional supply chain is to allow consideration of the total immediate and eventual environmental effects of all products and processes (Beamon, 1999: 336). Green supply chain management is integrating environmental thinking into supply chain management (SCM) (Luthra *et al*., 2011:232). Green supply chain management, also known as environmental supply chain management (ESCM) or sustainable supply chain management(SSCM) (Seuring, 2004:1059), combines green purchasing, green manufacturing/materials management, green distribution/marketing and reverse logistics (Sarkis 2005:330). Luthra *et al*. (2011:233) conclude that GrSCM is the summing up of green purchasing, green manufacturing, green packing, green distribution and marketing.

Green supply chain management and conventional SCM differ in various ways. The former takes into consideration to ecology as well as economy as an objective, while the conventional SCM is usually concentrated on economy as a single objective. GrSCM is green, integrated and ecologically optimised, while conventional SCM does not take into consideration human toxicological effects. Conventional SCM concentrates more on controlling the final product, no matter how harmful its effects are to the environment during production and distribution, while Green supply chain recognises the disproportionate environmental impact of supply chain processes within an organisation (Luthra *et al*., 2011:233).

The GrSCM practices include reducing energy consumption, recycling and re-use, using biodegradable and non-toxic material, minimising harmful emissions, and minimising or eliminating waste (Duber-Smith, 2005: 24). According to Stevels (2002:6), GrSCM leads to lower environmental load and reduced consumption of resources for society. Green supply chain management seeks to minimise the undesirable environmental impact of the supply chain process within the participating organisations (Zanjirani Farahani, Asgari & Davarzani 2010:197).

3.2.2 Green supply chain drivers

Muduli and Barve (2011:484) state that in order for mining companies to secure its continued ‘social licence’ to operate, the mining industry must respond to various sustainability challenges it faces by engaging its many different stakeholders and addressing their sustainability concerns. Whereas economic and social development is in the interests of the mining industry, the third pillar of sustainable development, namely environmental protection, appears to be of least importance. The pressure and drive accompanying globalisation has prompted enterprises to improve their environmental performance (Zhu & Sarkis 2006:12). More recently a steady increase can be seen in both public and private sector recognition of global warming as societal issues (Linton, Klassen & Jayaraman 2007:1077).

Environmental issues present several difficulties for managers. Environmental issues are highly contestable: there is generally ample scope for scientific disagreement about merits of alternative courses of action (New *et al.*, 2002:94). According to Beamon (1999:336), based on the recognition that the environmental effects of an organisation, these include the environmental impacts of goods and processes from the extraction of raw materials to the use of goods produced to the final disposal of those goods. Companies recognise that to obtain more sustainable solutions, the environmental properties of products and services must meet customer requirements (Zhu & Sarkis 2006:474).

The drives or pressures upon companies to implement GrSCM include regulations, marketing, suppliers, competitors and internal factors (Zhu & Sarkis, 2006:473). In this regard, Sarkis (1998:159) agrees that standards, regulation and competition have together prompted organisations to become more aware of any consequences for the environment. Government regulation usually requires companies to reduce or eliminate their toxic air and water pollution by using technologies that control or clean emissions at the 'end of the pipe' (Morrow & Rondinelli, 2002:161). In the past there have been many examples of environmental and public health concerns that were exaggerated and eventually either discounted or seen as a reduced threat by many after additional evidence and insights were obtained (Linton *et al.,* 2007:1077).

The pressure of environmental protection does not come solely from the demands of regulations; consumers and clients also exert pressure on companies (Hall, 2000:456). Customer demands have now become the most important type of external pressure (Doonan *et al.*, 2005).

3.3 THE IDEA OF SUSTAINABLE DEVELOPMENT

3.3.1 Sustainable development defined

The term 'mining' stems from the Latin word *mineralis* (i.e., related to mines) and it can be defined as the process of extracting economically valuable minerals and ores for the benefit of humankind. Mining is a primary industry, meaning that the minerals it produces are derived from the Earth's crust, including those extracted from oceans, lakes and rivers. In general, the goods produced by this industry are used as raw material in secondary industries (National Confederation of Industry 2012:19).

Years ago, the concept of environmental quality was almost non-existent. Then, the concept came to mean cleaner air and cleaner water. Now, environmental quality has come to mean 'safe drinking water, healthy ecosystems, safe food, toxic-free communities, safe waste management, and the restoration of contaminated sites' (Beamon 1999:332). Sustainable development has become a wide-ranging term which has its applications in almost every sector. This burning issue is setting guidelines for healthy living, doing business, generating products, extracting raw materials, recycling and reusing materials and reducing waste and energy, thus reducing the use of virgin materials and saving them for our future generations (Muduli & Barve 2011:484).

Recent reactions to growing environmental concerns of product and process-derived pollution have included rapid substantive changes. For example, legislation was adopted worldwide over a relatively short timeframe to phase out chemicals with Ozone Depleting Potential (Linton *et al.*, 2007:1077). The most adopted and most-often-quoted definition of sustainability is that of the Brundtland Commission (World Commission on Environment and Development 1987:8), namely: "development that meets the needs of the present without compromising the ability of future generations to meet their needs". This implies future generations have rights over resources and current generation has a duty to include future generations' needs in its decision-making. Given the vagueness that surround this definition, hundreds of different interpretations have evolved to operationalise sustainability. As a result, this all-encompassing definition of sustainability has raised more questions than answers. According to Linton *et al.* (2007:1076) these questions include:

- What resources will future generations require?
- At what levels can pollutants be released without having a negative effect on future generations?
- To what extent will new sources of depletable resources be identified in the future?
- At what level can renewable resources be exploited while ensuring that these resources remain renewable?
- To what extent can technology address sustainable use of resources with continued increases of material wealth?
- To what extent can market forces drive sustainability?
- Do lifestyles need to change and if so how?
- What sort of policies are required to achieve sustainability?

However organisational definitions of sustainability in the engineering literature have been more encompassing, and have explicitly incorporated the social, environmental, and economic dimensions of the macro-viewpoint by defining organisational sustainability as "a wise balance among economic development, environmental stewardship, and social equity," and sewage effluents, sedimentation of river and other stored water bodies, leachates from wash-off from dumps, solid waste disposal sites, broken rocks, cyanide and other toxic chemicals waste release, salinity from mine fires, acid mine drainage, etc. (Muduli & Barve 2011:485).

3.3.2 Sustainable development in the manganese and phosphate mining industries

It is widely recognised that firms play an important stewardship role in addressing sustainable development pressures, and such concerns have become part of many companies' operational and competitive strategies. A focus on supply chains is a step towards the broader adoption and development of sustainability, since the supply chain considers the product from initial processing of raw materials to delivery to the customer. However, sustainability also must integrate issues and flows that extend beyond the core of supply chain management: product design, manufacturing by-products, by-products produced during product use, product life extension, product end-of-life, and recovery processes at end-of-life. (Linton *et al.,* 2007:1078)

Environmental sustainable management choices include indentifying raw material chemistry utilising clean production processes, minimising waste generation, recycling material, controlling occupational exposure and collecting representative environmental data (Hagelstein 2009:3736). Consideration of the extended supply chain includes the reduction and elimination of by-products through cleaner process technologies and quality and lean production techniques (Linton *et al.,* 2007:1078).

3.4 MANGANESE AND PHOSPHATE MINING SUPPLY CHAIN

In terms of a classification of the mining supply chain, the industry comprises the steps of exploration, extraction and processing (metallurgy and non-metallic materials). The exploration step is intended to identify and study in detail those mineral deposits that are technically, economically and environmentally viable; it is followed by the steps of mine development and production. To this end, mining companies invest in research, both to diversify new sources and to enhance the knowledge of mineral reserves of active mines in order to further their activities. Mining is that step of extraction operations where mineral raw materials are produced (National Confederation of Industry 2012:19).

There are four (4) distinct phases of the mineral value chain, each with their unique procurement requirements. These include:

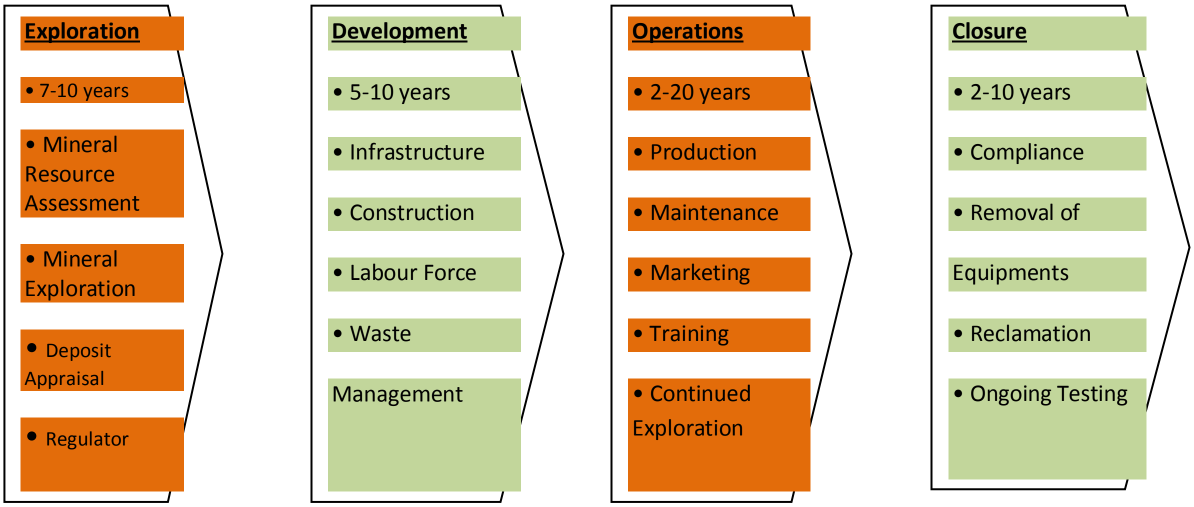


Figure 3-2: Distinctive phases of mining

Source: Saskatchewan Ministry of the Economy (2012)

The four (4) phases of mining as shown above is a value chain for manganese and phosphate mining processes in South Africa. The time frame may defer as is depended on availability of resources, but the process remains as above. In the past, the last phase wasn't incorporated into the value chain, but due to the increase of environmental awareness and government proposed legislation, it now a standard.

3.5 WASTE GENERATED IN THE MINING INDUSTRY

Mining activities do severely impact on the environment. The soil, water, human health, built-up environment, air and animal life are affected by the mining processes (Mabiletsa & du Plessis 2001:186).

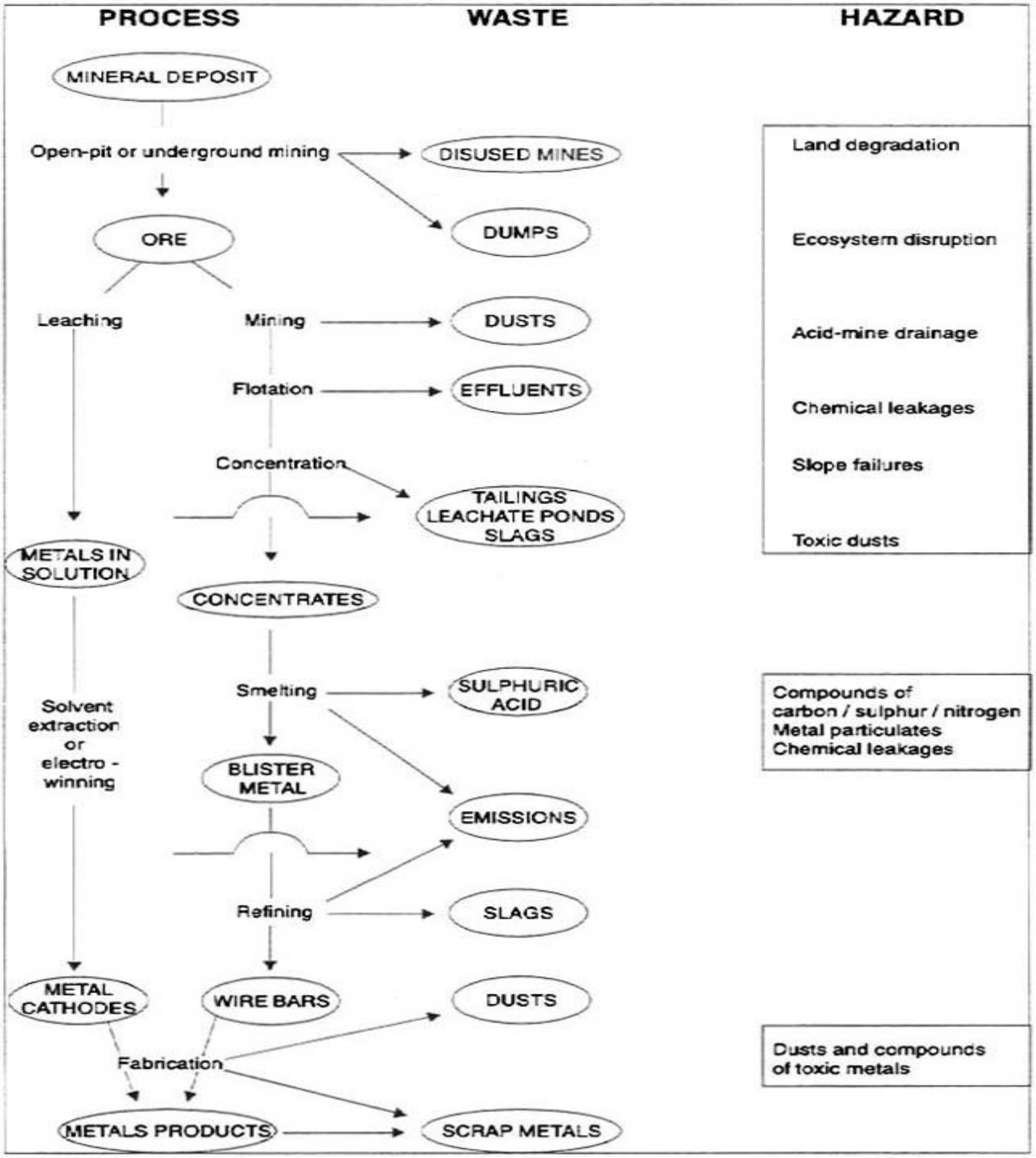


Figure 3-3: Manganese mining process showing environmental impact

Source: Warhurst (1991a).

Figure 3-3 show the environmental impact of manganese mining process. The figure show each step in the mining process and the waste created. The figure futher state the hazards posed by these process. Some of the hazards highlighted such as land degration, toxic dust and acid-mine drainage are discussed in details in 3.6 below.

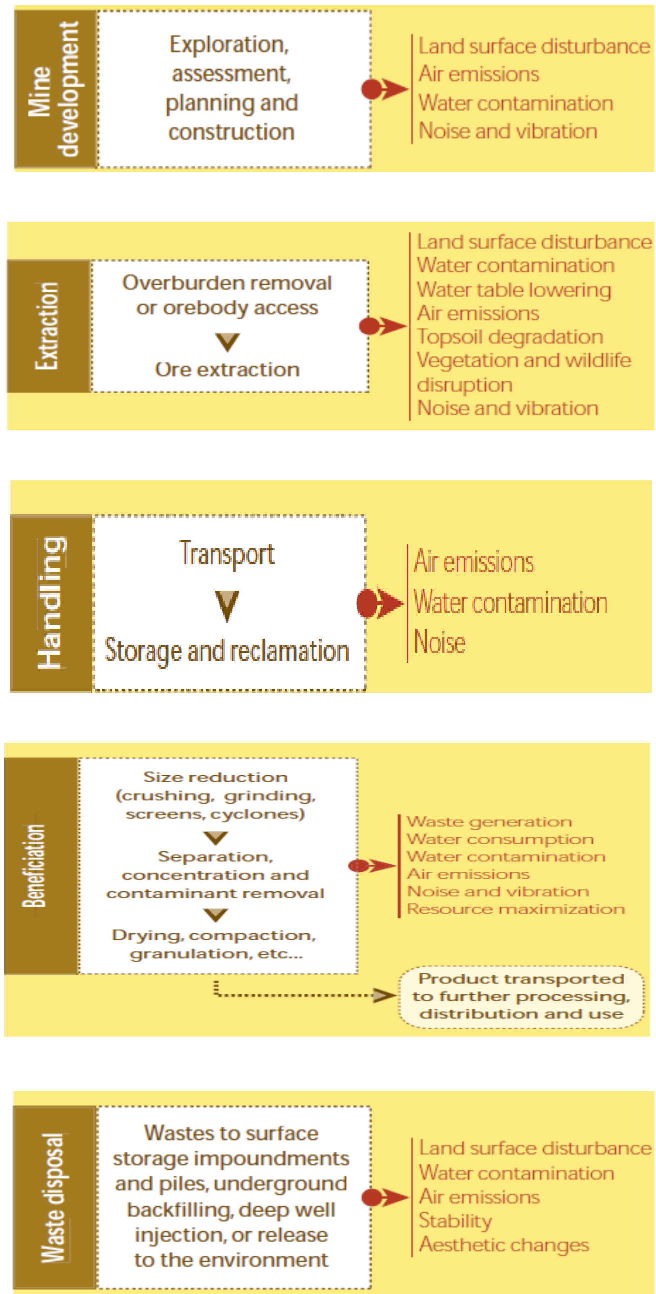


Figure 3-4: Phosphate mining process showing environmental impact
Source:UNEP (2001:36)

Figure 3-4 show the environmental impact of phosphate mining process. The figure details each step of the process and the waste generated. As part of sustainability, the process include the last step closure of which concentrate on ensuring that the mining area is safe and hazards free for future land use by the next generation.

Atmospheric emissions from mining activities are found throughout all stages of a mining project. Depending on its size, a mining project may process millions of tons of ore during its lifetime, and this ultimately generates a massive amount of materials suspended in the atmosphere, especially particulates. It should be stressed that these emissions have harmful effects on the environment and human health, so their control and management are paramount. (National Confederation of Industry 2012:19).

Whilst the mining industry has stimulated the economic growth of South Africa, its activities have also impacted on the social and environmental well-being of the communities and ecosystems in which it operates. Manufacturing and production processes are viewed as the culprits in harming the environment, in the forms of waste generation, ecosystem disruption, and depletion of natural resources (Beamon 1999:332). Environmental impacts resulting from industry are represented by emission inventories of chemical release to the air, water and soil (Hagelstein 2009:3738). According to Beamon (1999:332), waste generation and natural resource use, primarily attributed to manufacturing, contribute to environmental degradation by outstripping the earth's ability to compensate and recover, and thus are not sustainable by the earth's ecosystem.

3.6 IMPACTS FROM MANGANESE AND PHOSPHATE MINING TO THE ENVIRONMENT

3.6.1 Land

Mining activities cause movement, deformation, caving-in of the overburdened strata and this situation affects the surface buildings, agricultural fields, irrigation infrastructures, bridges, railway infrastructure and electrical lines. Mentis (2006:193) also points out that mining activities cause severe disturbances to the soil environment in terms of soil quality and productivity.

Large volumes and masses of materials are extracted and handled in mining operations, where two types of solid waste are generated in larger quantities – rock waste and tailings. Rock waste refers to excavated materials generated by the extraction or mining activities during mine stripping (Hudson, Fox & Plumlee 1999:62) Rock waste has no economic value and is usually piled in dumps. Tailings are the waste from mineral processing activities. These processes are intended to standardise the size of fragments, remove related minerals with no economic value and enhance the quality, purity or content of the final product. There are other wastes consisting of a wide range of materials, such as sewage treatment effluents and tyre and battery casings from the operation of mineral extraction and processing plants (National Confederation of Industry 2012: 41). According to UNEP (2001:15), the land surface and sub-surface is disturbed by activities such as:

- the extraction of ore
- the deposition of overburden;
- the disposal of beneficiation wastes
- the subsidence of the surface

These activities could result in a wide range of potential impacts on the land, geological structure, topsoil, aquifers and surface drainage systems. Additionally, the removal of vegetation may affect the hydrological cycle, wildlife habitat and biodiversity of the area. In some instances, sites of archaeological, cultural or other significance may be affected.

3.6.2 Water

Water quality can be affected by the release of slurry brines and contaminants into process water. Surface waters may be contaminated by:

- the erosion of fines from disturbed ground such as open-cut workings, overburden dumps and spoil piles and waste disposal facilities
- the release or leakage of brines
- the weathering of overburden contaminants, which may then be leached

Large volumes of water are typically required by mining and beneficiation activities. This water consumption may lead to a fall in the level of the water table, affecting the surrounding ecosystem and potentially resulting in competition with other users (UNEP 2001:15). The National Confederation of Industry (2012:31) states that Mining interferes with the drainage, storing and flow of water and this is more prevalent with underground mining. The water/mining relationship must be considered in every possible aspect, not only in the stages of mine exploration, operation, closure, and post-closure, but also taking into account all ore processing activities, as can be seen in the following figure:

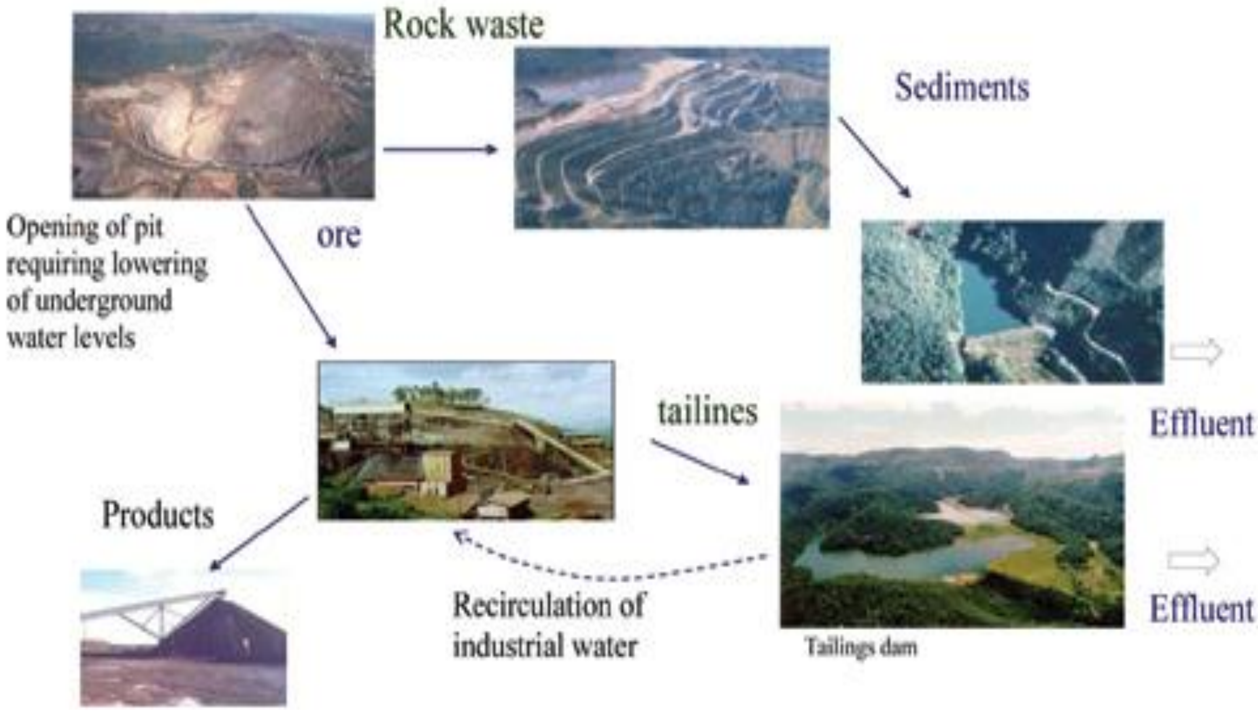


Figure 3-5: Main steps of mining activity and their interference with water resources
Source: National Confederation of Industry (2012:31)

The above figure 3-5 details the main steps of mining activities and their interference with water resources. The figure show the disturbances caused by the mining activities and the end results thereof.

3.6.3 Air

Air quality can be affected by emissions of:

- dust
- Exhaust particulates and exhaust gases such as carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NOx), and sulfur oxides (SOx)
- volatile organic compounds (VOC's) from fueling and workshop activities
- methane released from some geological strata

Greenhouse gases such as CO_2 and methane are believed to contribute to global warming.
Dust is a common problem throughout all mining activities. Dust generated by vehicle traffic can be reduced through a variety of means. Where water resources are not limited, regular watering

with mobile water trucks or fixed sprinkler systems is effective. Otherwise the application of surface binding agents, the selection of suitable construction materials and the sealing of heavily used access ways may be more suitable. Dust emitted during beneficiation can be controlled by means such as water sprays, baghouses and wet scrubbers. Captured dust can generally be returned to the beneficiation process (UNEP 2001:14).

Atmospheric emissions from mining activities are found throughout all stages of a mining project. Depending on its size, a mining project may process millions of tons of ore during its lifetime, and this generates a massive amount of materials suspended in the atmosphere, especially particulates. It should be stressed that these emissions have harmful effects on the environment and human health, so their control and management are paramount (National Confederation of Industry 2012:42)

- The global climate change results in global warming and flooding with catastrophic effects including the resurgence of diseases such as malaria and typhoid, or starvation. The issue of climate degradation has become a concern due to changes in the atmosphere, which absorbs increasing volumes of carbon dioxide from the combustion of fossil fuels (Kruger, 2006: 87). The impacts of climate change are outlined by Van Schalkwyk (2008: 18) as:
- change in the global rain patterns
- increase in various infectious diseases in Mexico, U.S., East Africa and Middle East
- dwindling of water resources in many countries
- frequent occurrence of violent storms in the tropical belt
- global food security being threatened by drought and bio-fuel production in search of cleaner, renewable energy sources, pushing up food costs, leading to riots in some countries.

3.6.4 Acid mine drainage

The quality of mine water depends largely on the chemical properties and the geological materials that come into contact with it. Hence, the mining process disrupts the hydrological pathways and contaminates oozing water from aquifers (water-absorbing rocks), depressing the water table. Such water is saline and has heavy concentrations of salts like calcium sulphate, sodium sulphate, magnesium sulphate or sodium bicarbonate, depending on the area. This polluted water is also called acid mine drainage (AMD) (Hudson, Fox and Plumlee 1999:60).

Acid mine drainage involves highly acidic water, usually containing a high concentration of metal sulphide and salt as a consequence of mining activity. According to Manders, Godfrey and Hobbs (2009:1), the major sources of AMD include drainage from underground mineshafts, runoffs and discharge from open pits and mine waste-dumps, tailings and ore stockpiles, which make up nearly 88 per cent of all waste produced in South Africa. Drainage from abandoned underground mine shafts into surface water systems either as decants or spillage may occur as the mine shaft fills with water.

According to the United States Environmental Protection Agency, AMD is currently one of the world's biggest environmental threats, second only to climate change. The toxic effects of exposure to the water (from manganese, phosphate and other metals) include cancers, birth defects, kidney failure and mental disorders. Acid mine drainage is a side effect of mining operations all over the world. This drainage can occur through natural run-off after rain, from old mine shafts filling with water or from mine companies disposing of water used during mining operations (Mbendi 2012). Although another study done by Annandele, Beletse, Stirzaker, Bristow and Aken (2009:337) indicates that neutralised AMD may be used for irrigation for some crops, because of the acidic and toxic nature of the water, it cannot be used either for animal or human consumption or for agricultural purposes.

3.7 LEGISLATIVE ENVIRONMENT

Mining legislation in particular determines the way mining companies will behave and it also, in the long run, influences the level of investment in the sector. In South Africa, the constitution has included clauses aimed at protecting the environment for the benefit of future generations. The general administration of the industry falls under the department of Minerals and Energy. The most important are the Minerals Act (Act 50 of 1991) and the National Environmental Management Act of 1998. Most regulations affecting the industry are made under this law.

Under the Minerals Act, mines are required to have an Environmental Management Plan (EMP). The EMP must be approved by the Department of Minerals and Energy. The aim of the EMPs is to regulate the industry from the start to the end. This is referred to as the cradle to the grave approach. The EMPs are also supposed to assist companies in complying with the law. An EMP describes the pre-mining environment, the aim and description of the project, the environmental impact assessment and an indication of how the impacts will be managed. Once approved by the Department of Minerals and Energy, the EMP becomes a legally binding document. If and when the EMP is violated, it is cause for suspension or withdrawal of the mining licence or even prosecution of the licence holder (South African Resource Watch, 2012)**.** The other important piece of legislation is the water permit which regulates water use and discharge. This must be obtained from the Department of Water affairs and Forestry. The water permit is important because one of the major operations in mining is dewatering, tailings management and the management of dust and other emissions.

Today, the constitution refers to concepts of responsible mining by empowering people with the right to an environment that is not harmful to their health, and an environment that is protected for present and future generations. It also ensures that government introduces legislation to protect the environment, prevent pollution and ecological degration, promoting conservation and secure ecological sustainable development (Glazewski 2005 143). As a result of the commitment to reform the mining industry of South Africa, the Mineral and Petroleum Resources Development Act 28 of 2002, administered by the Department of Minerals and Energy, enforces environmental protection and the management of the impacts of prospecting and mining. There have been major structural and content changes to environmental legislation in South Africa in the past years. Although the mining industry is not up to world standards at the moment, the trends are in the right direction (Grimbeek 2010 4). Environmental regulations are considered to include domestic environmental regulations, government environmental policies and international environmental agreements (Zhu & Sarkis, 2006).

Environmental regulations prompt companies to adopt relevant strategies and practices to enhance their environmental performance (Chien & Shih 2007:386). Although corporations in most industrialised countries have adopted environmental protection practices required by government agencies since the early 1970s, these regulations largely focus on control of water and air emissions and waste disposal (Morrow & Rondinelli 2002:161). Linton *et al.* (2007: 1079) argue that policies that have been developed with the intent of producing more environmentally favourable modes of product end-of-life disposal have to date resulted in more storage of product and less redeployment of parts and materials into new products than intended.

In response to more stringent environmental regulations and changes in environmental management philosophy, there has been a corresponding need to develop operational guidelines and standards to assist organisations in moving towards ecologically sustainable business practices. The ISO 14000 series standard is designed to address these needs (Beamon 1999:334) by:

- encouraging an internationally common approach to environmental management;
- strengthening companies' abilities to improve and measure environmental performance, through continual system audits, and
- improving international trade and removing trade barriers.

According to Grimbeek (2010:4), the major environmental legislation applicable to manganese and phosphate mining industries are:

Mineral Act 50 of 1991

- Regulation 992 requires the annual submission of an Environmental Management Programme (EMPR) performance assessment report to track the compliance levels of mining operations to their commitments made in the EMPR.
- Minerals Development Bill: mining will no longer be allowed under a temporary mining authorisation, an approved EMPR will be a pre-requisite for new ventures.

National Water Act 36 of 1998

- Licensing/authorisation of water imposes more control over water use.
- Section 19 refers to strict liability without negligence or intent. This implies that a company can be held responsible for pollution emanating from its property even if it

can't be proven without a doubt that the company is directly responsible for the pollution.

- Section 153 & 154 provide for unlimited fines, clean-up costs and damages in the case of a successful prosecution under the Act.
- The introduction of the Waste Discharge Charge System by the Department of Water Affairs also includes a pricing strategy. The latter will mean that a significant levy will be imposed on polluted water leaving the property of a company.
- Regulation 704 (July, 1999) refers to stringent measures in terms of pollution prevention in the mining sector such as restriction on location of waste sites, freeboard on dams, erosion protection.
- The White Paper on Integrated Pollution Control and Waste Management will eventually mean a separate document for mine waste management and hence more stringent and costly prescriptive measures.

Atmospheric Pollution Prevention Act 45 of 1965

- More emphasis will be on ambient pollution levels, i.e. moving away from merely stack monitoring.
- Acceptable pollution levels will be determined per zone, i.e. expansions /development in certain areas will be subject to the assimilative capacity of the specific area.

Environmental Conservation Act 73 of 1989

- Listed activities as well as scheduled processes are defined in the act which requires environmental impact assessments prior to operation/construction by independent approved consultants.
- Speculation of including issue of closure financial provision for sites other than mining operations (covered under the Minerals Act).

Promotion of Access to Information Act 2 of 2000

- Compulsory disclosure of environmental records under certain conditions mentioned in section 70 of this Act, i.e. when the disclosure will reveal a violation of the law and/or revealing a significant threat to the environment or health of citizens.

National Road Traffic Act 93 of 1996

- Regulations on transport of hazardous substances.
- Receiving of listed goods if quantity exceeds specified volume requires special treatment.

National Environmental Management Act 107 of 1998

- Enables the public to institute private prosecutions for environmental violations.
- Provides for the personal liability of directors of a company who serve on the board of directors at a time when environmental violations occur.
- Provision is made for extensive penalties, including the cost of remediation and the legal costs incurred by the applicant in a criminal or civil court case.

Many multinational corporations have designed, certified, and implemented environmental management systems under ISO 14001 because it provides a harmonised standard for managing a corporation's environmental impacts (Morrow & Rondinelli 2002:161). The adoption of environmental management systems (EMS) as frameworks for integrating corporate environmental protection policies, programmes, and practices is growing among both domestic and multinational companies around the world. Many companies that adopt an EMS follow industrial standards, such as 'Responsible Care' in the chemicals sector (Morrow & Rondinelli 2002:159).

3.8 BENEFITS OF IMPLEMENTING GREEN SUPPLY CHAIN IN THE MANGANESE AND PHOSPHATE MINING INDUSTRIES

Environmental degradation continues to impose a significant burden on companies, the public and government. Although companies are becoming increasingly aware of the incidence and the implications of their actions, many companies have as yet to implement reasonable measures to prevent or remedy the effects of such degradation (Hollard, 2006). According to Muduli & Barve (2011:486), many possibilities to reduce the environmental burden of mining activities exist, for example, optimisation of the environmental performance through good housekeeping and total quality management, appropriate end-of-pipe techniques, recycling of waste and non-renewable products, substitution of, or a ban on the use of environmentally unfriendly products, or by incremental and more radical technological innovations. However implementation of these technologies faces a lot of challenges.

Environmental sustainability is a value embraced by the most competitive and successful companies. A firm needs to find the right processes to internalise environmental issues in a way consistent with its long-term interests. The appropriate processes are different for every firm, and there are no ready answers as to which processes are appropriate under what circumstances. Therefore a good framework can help managers find the appropriate processes by providing a way of structuring their thoughts (Corbett & van Wassenhove 1993:118). The potential for great opportunities and profit have been recognised by many who have called for extended producer involvement and responsibility. This involvement has appeared in calls for the provision of a product as a service or for manufacturers to provide a series of services to support and supplement the sale of the original product (Wise & Baumgartner 1999:133).

Organisations operate in a context of extreme uncertainty. Most expect the future to hold increased environmental regulation and taxation schemes, but it is rarely possible to predict what these will look like over the medium term (New *et al.*, 2002: 94). In the earliest evolutionary stages of environmental management, organisations separate environmental performance from operations. However, as organisations evolve, they begin to integrate environmental objectives within the framework of their existing operational objectives (Beamon 1999:336). While other companies are adopting major components of industry/international standards for environmental management without formally certifying them (Morrow & Rondinelli 2002:161), the role of customer pressure in the spread of environmental management systems such as ISO14000 and the European Eco-Management and Audit Scheme (EMAS), with which parallels may be drawn with the diffusion of quality management systems such as ISO9000 (New *et al.,* 2002:94), is making an impact.

Pursuing the green manufacturing of products is very beneficial in the alleviation of environmental burdens (Chien & Shih 2007:385). South African chemical and mining companies that compete in the global market have recognised that high standards of health and safety are vital for staying in business. These companies use the local legislation as minimum standards with which they comply and they strive towards best international practices as far as is practical. For example local legislation requires all manganese operations to keep all exposure longer than an 8 hour per day below 1 mg/m3 – responsible companies are working towards level of 0.2 mg/m3 (Grimbeek 2010:1). According to Chien and Shih (2007:387), environmental protection activities can have a positive effect on a corporation's financial performance. Tsoulfas and Pappis (2006:1593) agree that a sustainable approach can lead to internal cost saving, open new markets and find beneficial uses for waste. Zhu and Sarkis (2004:270) also recognise that GrSCM can cut the cost of materials purchasing and energy consumption, reduce the cost of waste treatment and discharge, and avoid a fine in the case of environmental accidents.

Another factor that contributes to company compliance is to strengthen relationships with suppliers resulting in lower inventory levels, costs and higher accuracy. Involvement of the suppliers in the design process and technology affects overall performance of a whole chain (Sarkar & Mohapatra 2006:148).

A used product may be either disposed or recycled (generally recovered) (Tsoulfas & Pappis 2006:1598). The disposition of the product at the end of its life relies to a great extent on actions taken at earlier stages. The initial product design has great influence on the degree to which a product can be reused, remanufactured, recycled, incinerated or disposed of. For example, the high lead content in cathode ray tube and electronics products results in complications for disposal due to the toxicity of lead (Linton *et al*., 2007:1079).

As in the phase of collection and transportation, recycling and disposal may significantly contribute to the total environmental gain and the attainment of the environmental goals of a company. Ideally, companies should borrow from natural cycles to design their systems as part of a larger natural cycle, where materials are borrowed from and returned to nature, without negatively affecting its overall balance (Tsoulfas & Pappis 2006:1598). Recycling is the process of collecting used products, components, and/or materials from the field, disassembling them (when necessary), separating them into categories of like materials (e.g. specific plastic types, glass, etc.), and processing into recycled products, components, and/or materials (Beamon 1999: 337). Re-use is the process of collecting used materials, products, or components from the field, and distributing or selling them as used. Thus, although the ultimate value of the product is also reduced from its original value, no additional processing is required (Beamon 1999:337).

According to Tsoulfas and Pappis (2006:1598), it is necessary to ensure that the generation of hazardous wastes is reduced and also that adequate disposal facilities are available for the environmentally sound management of hazardous wastes, hence the procurement or purchasing decisions will have an impact on the green supply chain through the purchase of materials that are either recyclable or reusable, or have already been recycled.

Tsoulfas and Pappis (2006:1597) further elaborate; stating that the use standardised parts ensures that these parts could be reused not only by the original producer, but also by a larger group of producers. For example, automotive companies use standardised screws, speedometers, etc. In most cases this policy is also money-saving. In the case of containers that are standardised, for example, and which can be used by different companies, they can indicate the return, reuse and recovery possibilities, and make available the necessary information of their products concerning recycling and provide adequate safety instructions. The end-users should be aware of what they could do after the product has completed its life cycle (Tsoulfas & Pappis 2006:1599).

3.9 CHALLENGES TO IMPLEMEMTING A GREEN SUPPLY CHAIN IN THE MANGANESE AND PHOSPHATE MINING INDUSTRIES

Minerals have an increasing impact on the lives of people and development of a country. As populations grow, higher amounts of minerals are required on a daily basis to meet growing needs, and as people migrate to urban areas the demand for minerals goes up. The comfort and technology provided by modern housing certainly relies on a number of minerals as the primary raw material in people’s daily lives (National Confederation of Industry 2012:19). According to King and Lessidrenska (2009:180) companies should maintain sustainable development even during the time of financial crisis in preparation for the future when the population increases. This is a way of building goodwill in order for the company to thrive through crisis.

Another study found that an increased emphasis on sustainability in the supply chain is related to lower costs and a neutral or positive effect on value (Rao & Holt 2005:899). However, others have identified trade-offs between what is economically rational for supply chain members and what is of greatest value to the entire system or population (Walley & Whitehead 1994:3). Extending the supply chain to include issues such as remanufacturing, recycling and refurbishing adds an additional level of complexity to existing supply chain design in addition to a new set of potential strategic and operational issues, which in turn can increase costs, at least in the short term. Two basic problems give rise to these issues: (a) the uncertainty associated with the recovery process with regards to quality, quantity and timing of returned products, containers, pallets and packaging, and (b) the collection and transportation of these products, containers, pallets and packaging (Linton *et al.*, 2007:1079).

During the 1970s and 1980s many corporations, attempting to get ahead of complex, costly and rapidly changing environmental regulations, began to adopt voluntary pollution prevention practices that sought to reduce or eliminate the sources of pollutants from manufacturing processes, rather than controlling them after emission (Morrow & Rondinelli 2002:161). Today's most successful manufacturers have tight coordination with their supply chain partners, enabling real-time information to travel immediately up and down the supply chain and well-coordinated movement of inventories (Sanders 2007:1334). Environmentally responsible manufacturing processes, GrSCM practices, and their many related principles have become important strategies for companies to achieve profit and increase market share objectives by lowering their environmental impact and enhancing efficiency (Zhu & Sakis, 2006).

Suppliers contribute to the overall performance of a supply chain, and poor supplier performance affects the performance of the whole chain (Sarkar & Mohapatra 2006:148). Supplier/manufacturer relationships are considered important in developing a sustainable competitive advantage for the manufacturer (Sheth & Sharma 1997 91). Clark (1999:14) adds that screening of suppliers for environmental performance has now become a key deciding factor in many organisations.

Historically, cost has been used as the prime performance measure. Usually, high cost is a big pressure on GrSCM as compared to conventional SCM. The initial investment requirement by green methodologies such as green design, green manufacturing, green labeling of packing, etc., are too high. Engaging in environmental management involves two types of costs, direct cost and transaction cost (Luthra *et al.*, 2011:239). According to Beamon (1999:337), effective environmental management results in the avoidance of the following:

- cost avoidance of purchasing hazardous materials as inputs, which reflect the internalised costs associated with environmental harm
- cost avoidance of storing, managing, and disposing process waste, particularly as waste disposal becomes increasingly expensive
- cost avoidance of stigmatisation or market resistance to environmentally harmful products
- cost avoidance of public and regulatory hostility towards environmentally harmful organisations

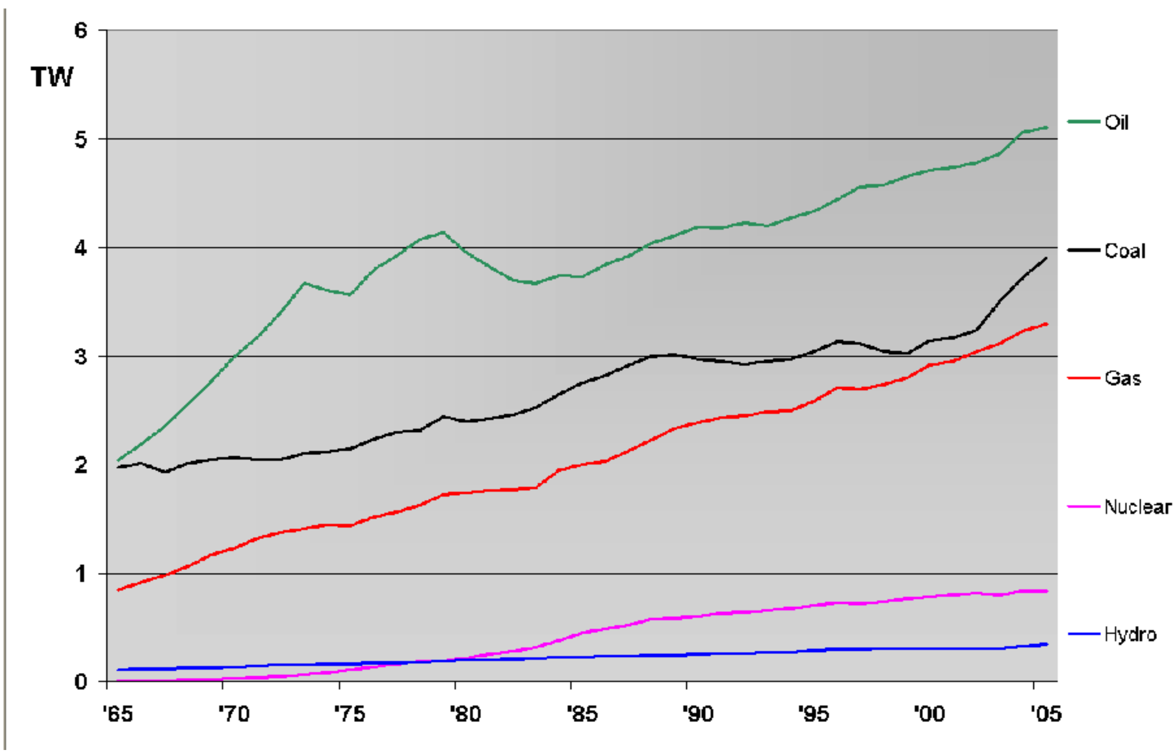
Innovative green practices are associated with the explicitness of green practices, accumulation of green-related knowledge, organisational encouragement and quality of human resources (Yu Lin & Hui Ho 2008:19).Training and education are the prime requirements for achieving successful implementation of GrSCM in any organisation, while informal linkages and improved communication help the organisations to adopt greenpractices (Ravi & Shankar 2005:1016).

Using less energy is obviously good for the environment. It is also self-evidently good for business because it cuts companies' costs, and eventually avoids potential environmental liabilities. It is therefore a prerequisite to the long-term sustainability of business. To replace non-renewable and polluting technologies, it is crucial to support the use of renewable energy resources, as well as to reduce energy consumption (Tsoulfas & Pappis 2006:1597).

3.10 RESOURCES AND TECHNOLOGIES AVAILABLE

Until recently, the main environmental emphasis has been on the manufacturing phase and to some degree on the disposal phase. This emphasis has given very good results, but at the same time the number of products per household, energy consumption and waste have increased more and have caused a larger environmental impact (Tsoulfas & Pappis 2006:1594). Every product generated, transported, used and discarded within the supply chain causes a certain impact on the environment. This impact is a function of the material and energy consumed and of the wastes released in the product's whole life cycle, which in turn depend upon the type of the product and the technology used (Daniel, Diakoulaki & Pappis 1997:250).

According to Kruger (2006: 130), there are three types of primary energy: primordial, fossil and renewable. The global leading sources of energy are fossil fuels (oil, coal and gas) which provided between 80 and 90 per cent of the total world energy in 2005.



Graph 3-1: World energy consumption, 2005

Source: Resource (2010: 16)

Innovation and technology incorporate the innovation into corporate culture, encouraging new ideas and processes and solutions by all the employees of the firm (Digalwar & Metri, 2004: 93). An increasing number of companies are implementing modern information technologies in order to facilitate communication between the supply chain partners and at the same time these companies would like to integrate customers into their processes. Sharing information with the customers and suppliers enables companies to know exactly what is happening in the supply chain. Having the right information, in the right place, at the right time makes the logistical decision making more streamlined and ultimately creates competitive advantage (Koskinen & Hilmola 2008: 211).

According to Gant (1996:1), technology is a kind of knowledge. An organisation with rich experiences in the application and adoption of related technologies will have higher ability in technological innovation. Product design and process technology typically determine the types of pollutants emitted, solid and hazardous wastes generated, resources harvested and energy consumed (Tsoulfas & Pappis, 2006: 1594). Today almost all organisations are in the process of adopting some type of e-business technology to streamline SCM activities. For example, e-procurement has automated and streamlined many corporate purchasing processes (Sanders, 2007: 1333). The growth of information technology (IT) has rapidly changed the face of business over the past decade. IT has made possible the sharing of large amounts of information along the supply chain, including operations, logistics, and strategic planning data. This has enabled real-time collaboration and integration between supply chain partners, providing organisations with forward visibility, improving production planning, inventory management, and distribution (Sanders 2007:1332).

The study by Tsoulfas and Pappis (2006:1597) suggests installed water-saving techniques and the use of closed re-circulating systems as technologies that can be used to reduce water usage in the manganese and phosphate industries. In this regard, Luthra *et al.* (2011:237) warn that resistance of organisations to technology advancement adoption is resistance to change. Hagelstein (2009:3736) adds that environmental assessments including biological monitoring are necessary to validate mandated particulate metal emission reductions and control technologies during metal processing.

3.11 CONCLUSION

The concept of green supply chain was defined and its drives explained. The differences in conventional supply chain and green supply chain management were articulated. A figure showing the basic components of supply chain is given where the chain does not recognise the environmental aspects. The concept of sustainable development was defined. The significant role played by sustainable development in the manganese and phosphate mining industries was also discussed, while wastes generated were also listed and elaborated upon. The four distinct phases of mining supply chain process were stated. Due to the ever-changing technologies in the mining industries, the resources and technologies in the industries were mentioned and discussed.

Benefits and challenges of implementing green supply chain in the manganese and phosphate mining industries were explained. The chapter further discussed the environmental legislation in the industries. Cost drives were also explored in order to address the challenges and benefits of the implementation. The next chapter discusses the research methodology used in this study.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 INTRODUCTION

This chapter discusses the research methodology to be used in the study. Areas covered will include the literature review, method of data collection, selection of participants, sample size and data analysis. The validity of and reliability (measure of trustworthiness) in form of credibility and dependability and triangulation will be discussed. The process of theory building and ethical considerations for the study will also be included.

4.2 QUALITATIVE RESEARCH PARADIGM

This study adopted a qualitative research paradigm. A paradigm is a whole framework of beliefs, values and methods within which research takes place. Jonker and Pennink (2010: 69), add that a paradigm is a set of fundamental assumption and beliefs as to how the world is perceived which then serves as a thinking framework that guides the behaviour of the researcher. According to (Joubish, Khurram, Ahmed, Fatima & Haider 2011:2082), qualitative approach to research are based on a “world view” which is holistic and has the following beliefs:

- There is not single reality
- Reality based upon perception that are different for each person and change over time
- What we know has meaning only within a given situation or context

Today there are four types of paradigm. Lather (2006:35) maps the four paradigm: positivism, interpretivism, critical orientation and poststructurialism. Lee and Lings (2008:372) also describe a paradigm as set of practices or methods used, like questions asked, phenomena examined and interpretation of rules of a particular discipline or research.

According to Leedy and Ormrod (2010:2), qualitative research methods provide researchers with the flexibility and freedom needed to explore phenomena where the literature is lacking and thus, help to highlight important variables for future research; it involves examining issues, qualities, or problems that are not easily reduced to numerical values. The human interaction in qualitative inquiry affects interviewee and informats, and the knowledge produced through qualitiative research affects our understanding of the human condition (Kvale & Brinkmann, 2005:157). Qualitative research collects descriptive, non-numeric data that is likely to describe something, such as what a person sees in a picture or type of behaviour that a person might react to (Christensen, Johnson & Turner 2010: 434)

The main methods employed in qualitative research are observation, interviews and documentary analysis. According to Saunders, Lewis and Thornhill (2009:119), the most frequently used paradigm in qualitative research is interpretivism because it focuses upon the details of situation, the reality behind these details, subjective meaning and motivating actions.

In this study, exploratory and descriptive design strategies are used in order to meet the aims and objectives of the study. Another important characteristic of qualitative research is that the process is inductive rather than deductive in that researchers gather data to build concepts, hypotheses or theories rather than deductively testing theories or hypotheses (Merriam, 2002: 5).

4.2.1 Exploratory

There are few studies done on the implementation of green supply chain in the mining industry. An exploratory design is adopted in order to familiarise with basic details, settings and concerns. In qualitative research, the researcher tries to establish a deeper understanding of the management dilemma and conceptualises ways of solving them. This is achieved by looking at the background information that could answer the research questions (Cooper & Schindler 2008: 704).

In a qualitative research project, respondents are made to relate to key stories and incidents which relate to the research topic. Saunders, Lewis and Thornhill (2007:134) warn that when conducting exploratory research, the researcher out to be willing to change his direction as a result of revelation of new data and new insights. This study sought to explore the implementation of green supply chain in the manganese and phosphate mining industries with a view to providing solution which would enable the industries to minimise environmental waste.

4.2.2 Descriptive

Descriptive research design is used to obtain information concerning the current status of the phenomena and to describe "what exist" with respect to variables or conditions in a situation. Descriptive studies can yield rich data that lead to important recommendation. Lee and Lings (2008: 247) adds that descriptive studies entail explaining the deep understanding of a situation. According to Shields and Rangarajan (2013:109), descriptive research, is used to describe characteristics of a phenomenon being studied. It addresses the "what" question (what are the characteristics of the situation being studied?).

Since this research is a qualitative paradigm, it strives to provide an in-depth understanding of the implementation of green supply chain management in the South African manganese and phosphate mining industries. Environmental risks are established and a possible solution to alleviate them is provided in chapter 5, providing more clarity on the research findings.

4.2.3 Inductive

Research approach can be divided into two categories: deductive approach and inductive approach, the difference relates to the existence and placement of hypotheses and theories (Saunders *et al*, 2009:117). This study has adopted inductive approach. An inductive process means that the researcher approaches the field without a hypothesis or explicit framework. Bernard (2011:7) affirms inductive approach involves the search for pattern from observation and the development of explanations- theories- for those patterns through series of hypotheses.

The focus of this study hopes to bring solution in the implementation of green supply chain in the manganese and phosphate mining industry to minimise environmental risks.

4.3 THE INTERPRETIVE QUALITATIVE RESEARCH TYPE

Interpretivism research believe that reality is constructed by social actors and people's perceptions of it; they recognise that individuals with their own variety backgrounds, assumptions and experiences contribute to the on-going construction of reality existing in their broader social context through social interaction (Wahyuni 2012:71). Because human perspectives and experiences are subjective, social reality may change and can have multiple perspectives (Hennink, Hutter & Bailey 2011:3).

According to Collins (2010: 38), interpretivism is associated with the philosophical position if idealism and is used to group together diverse approaches, including social constructionism, phenomenology and hermeneutics. Interpretivism studies on usually focus on meaning and may employ multiple methods in order to reflect different aspects of the issue

Interpretivism favour to interact and to have dialogue with the studied participants. In using qualitative methodology to collect research data; the researcher seeks to discover the meanings that participants attach to their behaviour, how they interpret situations, and what their perspectives are on particular issues (Wood 2006:32).

4.4 RESEARCH DESIGN

The research design refers to the overall strategy that a researcher choose to integrate the different components of the study in a coherent and logical way, thereby, ensuring that it will effectively address the research problem; it constitutes the blue print for the collection, measurement and analysis of data (Trochim, 2006). Ericksson and Kovalaine (2008:2), further adds that the research process progresses mostly through a circular process which involves revising and revisiting the original ideas and thoughts, revising plans, the reading list and rewriting the chapter.

In this study the research design includes the selection of participants and inducting them to the research processes, introducing the participants to the interviews, undertaking the interview and feedback on the interviews for validity and facilitating data collection in a recorded form using an audio-digital data recorder. Research design involves planning, preparation and execution of a research project. The design process covers all the issues from theoretical reading, methodology, empirical data gathering, analysis and the writing process.

4.4.1 Selection and profile of participants

As noted by Bryman (2012:1), qualitative research has practically applied more than one method of sampling, for instance by selecting a sample purposively which is followed by using the snowball technique to obtain studied subjects. The study used judgemental and purposive sampling. Judgements sampling occurs when elements selected for the sample are chosen by the judgement of the researcher (Black 2010:225). Purposive sampling comprises participants selected by the researcher based on their experience and knowledge of the research requirement (Devers & Frankel 2000:264).

The participants in this research are high profile supply professionals in the manganese and phosphate mining industry. The professionals are managers from the organisations/institution they represent. According to Neuman (1997:205), purposive sampling is based on the researcher's knowledge of a research area and the important opinion makers within the research area, while judgmental is based on the researcher's ability to make a sound judgement on who to approach. The researcher's knowledge of the South African manganese and phosphate mining industries and other role players in the industries enables her to approach the high profile individuals to participate in the study.

4.4.1.1 Access to institutions

According to Flick (2003:56), it is important for the researcher to develop trust in order to create a working relationship with the organisations/institutions. The researcher must seek permission from the participants at the targeted organisations/institutions to undertake the research and obtain informed consent (Ehigie & Ehigie 2005:622).

In this study, the researcher was very careful in the choice of participants where middle managers and senior managers of the organisations/institutions were used. The choice of communicating with these managers was important in order to have both the involvement of decision makers and implementers. The managers were identified through the business telephone book and the medium of communication was telephone and email.

Clarity of the research objective was established at the initial stage as the researcher approached organisations/institutions personnel involved by stipulating the proposition of the study. Informed consent was also addressed.

4.4.1.2 Access to individuals

As it is most basic that research should not cause distress or harm to those who have chosen to participate. According to Cooper and Schindler (2008:37), permission to conduct research forms part of the strategy which requires written consent were appropriate, but oral consent is usually allowed for most business research.

In this study, the researcher approached the selected participants by telephone and briefed them on the value proposition for the projects; an e-mail was sent as follow up confirmation. At another organisation/institution where the introduction of the research project was not accepted, the consent was reached after the researcher clarified the purpose and aspects of the study.

4.4.2 Data collection methods

Data is collected in form of primary and secondary data. The primary data is collected using semi-structured interviews, while the secondary data constitute internal publications provided by participants to the research and publicly available data which are relevant to the topic being observed (Wahyuni 2012:73).

4.4.2.1 Interviews

A great deal of qualitative material comes from talking with people. According to (Boeiji, 2010: 5), the main feature of an interview is to facilitate the interviewee to share their perspectives, stories and experience regarding a particular issue. Woods (2006:49), highlights that if the interviews are going to tap into the depth of reality of the situation and discover subjects' meanings and understandings, it is essential for the researcher:

- to develop emphathy with interviwee and win their confidence;
- to be unobstrusive, in order not to impose one's own influence on the interviwee.

The interview generally has a framework of themes to be explored (Lindlof & Taylor 2002:195). However, specific topics to be explored will be provided in advance to the interviewees. A semi-structured interview was used in this study. A semi-structured interview, also known as non-standardised or qualitative interview is a hybrid type of interview which lies in between a structured interview and an in-depth interview (Saunders *et al,* 2009:118). Therefore it offers the merit of using a list of predetermined themes and questions as in a structured interview, while keeping enough flexibility to enable the interviewee to talk freely about any topic.

A semi-structured interview does not limit respondents to a set of pre-determined answers. In collecting data by means of interviews, the researcher should not direct the respondent's answer through his tone of voice or rephrase the research the question (Goddard & Melville 2005:49). A semi-structured interview is flexible, allowing new questions to be brought up during the interview as a result of what the interviewee says. .

Primary data was collected by interviewing consultants, policy makers and respondents from various mining companies, Semi-structured interviews were used to elicit responses from the respondents. Open-ended questions were used during the interview in order to elicit in-depth information on the constraints /successes of implementing green supply chain in the South African manganese and phosphate mining industries.

The tools used for data collection in this study included: pen and pencil, note book, digital voice recorder and questionnaire. Most of the interviews were re-scheduled, but the re-schedules went well. Each interview was scheduled to last for between 30-45 minutes, but some lasted over an hour.

4.4.2.2 Recording the data

In qualitative research, recording of data can be done in various ways including taking notes, and using electronic devices such as tape recorder, video recorder or digital voice recorder. According to Boeiji (2010:3), when data is collected from multiple sources, a neat archive is essential to store the data to enable easy retrieval. The use of digital recorder is ideal for data storage which allows for easy retrieval.

In a study by Wahyuni (2012:74), there are three ways of taking notes during the interview: observational, methodological and theoretical. Observational notes, also known as field notes, are used to describe the situation during the interview. Methodological notes are the records of any issues and concerns regarding the methods used, while theoretical notes focus on what themes and finding emerged from the interview process. According to Ehigle and Ehigle (2005: 622), the recorded materials are transcribed in non-numerical terms, certifying them as qualitative transcripts.

In this study, a digital voice recorder and note taking were used to record proceedings of the interviews. Some of the participants used reports and presentations to elaborate further on some of the points during the interview. The observations on body language were recorded in the field notes immediately after the interviews.

4.4.2.3 Transcriptions

Transcription is a transformational process, taking live conversation and changing it into text format. However, transcripts are silent in that recording of the body language (gestures, facial expressions and positioning) are absent (Barbour 2008:193).Transcription is an interpretive process from oral speech to written texts. Speech and written texts provide different language and culture (translation from one another form to another) (Kvale & Brinkmann 2009:178). Field notes were used in conjunction with transcripts to ensure that body language - gestures, facial expressions and positioning - are also analysed for the study.

4.4.3 Data analysis

In qualitative research, analysis frequently takes place at the same time as data collection (Woods 2006:63). Research requires the interpretation of data and the description of understanding of what this data can represent (Leedy & Ormrod 2010:2), therefore it is important that data is examined as it accumulates to see if any major themes or patterns are emerging.

In practice, qualitative content uses a coding method. Coding simply means labelling. Codes serve to summarise, synthesise and sort many observations made of the data and become the fundamental means of developing the analysis (Charmaz 1983:109). According to (Barbour 2008:293) coding entails condensing data under broad headings and sub-categories which allows subsequent retrieval for the purpose of comparison.

In this study, the researcher analysed the research data transcript until saturation point when themes continued emerging repeatedly from the transcripts. Seven themes emerged from the study with sub-themes. The research findings are articulated in chapter 5.

4.4.4 Validity and reliability (trustworthiness)

Qualitative research seeks to produce credible knowledge of interpretations on organisation and understanding, with emphasis on uniqueness and contexts (Parker 2012:54), thus the traditional validity and reliability does not fit well with qualitative research.

Trustfulness entails validity and credibility of information provided to an enquirer (Maxwell, 2005:106). A study done Guba and Lincoln (1994) state that trustworthiness consists of four elements: credibility, transferability, dependability and confirmability. Bryman (2012:3) agree and further details that credibility parallels internal validity, transferability resembles external validity, dependability parallels reliability and conformability resembles objectivity.

Transferability can be enhanced by a thoroughly job of describing the research context and the assumptions that were central to the research (Trochim 2006), while conformability refers to whether you can show people that you cited appropriately in your research in terms of not being influenced by biases either from your own personal values or theoretical background (Lee & Lings 2008:210).

The participants responded to the open-ended questions based on their knowledge and experience without the aid from the researcher. In some instances, the participants referred their colleagues to participate in the research which confirms the trustfulness and honest approach for this study.

4.4.4.1 Credibility

The credibility criteria involves establishing that the results of qualitative research are credible or believable from the perspective of the participant in the research. According to (Thorpe & Holt 2008:30), it is also possible that by having one's views and experiences validated, research will be experienced as empowering, and thus increases the research subject's willingness to share Credibility deals with the accuracy of data to reflect the observed social phenomena, this means it focuses on whether the study measures or tests what is intended. Credibility is concerned with the fieldwork or data collection phase when the completeness and accuracy of the interview responses, participant observations rely on both the scope of the qualitative research (representative of the sample and sample size) as well as trustworthiness of the measurement (Roller 2012:2).

The value proposition for this research was communicated at the introduction stage where participants were made to understand that the purpose of the study was to "establish the challenges associated with the implementation of the green supply chain in the South African manganese and phosphate mining industries" and also that their role in the study was important and appreciated in order for them to feel trusted with their contributions. The fact that the process implementers and decision makers in their respective organisations/institutions in the manganese and phosphate mining industry agreed to participate gives credibility to the study.

After each and every interview, a follow up communication was send out by email regarding the contributions and for clarification, showing a portrayal understanding and credibility of the research process.

4.4.4.2 Dependability

Dependability corresponds with the notion of reliability which promotes replicability or repeatability. Dependability is concerns taking into account all the changes that occur in a setting and how these affects the way research is being conducted (Wahyuni 2012: 77).

The idea of dependability emphasise the need for the researcher to account for the ever changing context within which research occur. (Hammersley 1987:67) adds that, dependability relies on the participants' collaboration in contributing credible, applicable and valid data which is sorted out through triangulation.

The environmental audits reports and figures provided by the participants from the manganese and mining industries in South Africa and their role players such as external consultants confirms the dependability of the data collected.

4.4.4.3 Triangulation

Triangulation is a method of cross checking data from multiple sources to search for irregularities in the research data (O'Donoghue & Punch 2003:78). According to (Wood 2006: 50), the most common forms of triangulation in qualitative work are:

- Of method. The use of several methods to explore an issue increases the chances of depth and accuracy.
- Of time. This allows for the processual nature of events.
- Of persons. This involves consulting a range of people, perhaps in different roles and position about a particular issue.

The idea is that one can be more confident with a result if different methods lead to the same result. When a researcher combines interviews with observation, the findings will be tempting to believe. Observations in qualitative research test and fill out accounts given in the interview, and vice versa (Wood 2006:51). Triangulation is a technique of examining a specific research topic by comparing data obtained from: two or more methods, two or more segments of the sample population, and/or two or more investigators. In this way, a researcher is looking for patterns of convergence and divergence in the data (Roller 2012: 8).

According to Willis (2007:219), triangulation limits biases and limitations and allows you to have broader perspectives of the issues you are investigating; therefore more than two methods are used as to avoid clashing answers. The accuracy of data will be tested from various sources which will include primary data from the field notes, printed information and the transcribed texts.

4.5 ETHICAL CONSIDERATIONS

The main ethical debate in qualitative research revolves around the tension between covert and overt research, and between the public's right to know and the subjects' right to privacy. Normative guidelines and codes of ethics and rules are needed in order to govern the integrity of science endeavour and create ways to handle mistakes of an academic institution and organisation (Ericksson & Kovalainen 2008: 68). Ethical considerations are required in research in order to remove misconduct in science. Such misconduct runs against the principle of informed consent (people agreeing to take part in research on the basis of knowledge of what it is about); invades privacy; involves deception, all of which is inimical to generating qualities of trust and rapport, essential ingredients for qualitative research (Woods 2006:78).

There are number of ethical issues that may arise during research. Leedy and Ormrod (2010:3) note that most fall into one of the following categories:

- Protection from harm, which generally refers to the researcher's responsibility to not expose participants to unnecessary physical or psychological harm.

- Informed consent, which refers to an individual's right to be informed of the nature of the study given the choice to participate or not.

- Honesty with professional colleagues, this refers to the researcher's responsibility to report their findings in a complete and honest, with no misrepresentation.

According to Cooper and Schindler (2008:34), research must be designed in such a way that participants do not suffer physical harm, discomfort, pain, embarrassment or loss of privacy. Therefore, it is the responsibility of the researcher to explain the value of the research to the participants, their rights and protection, and also to obtain informed consent.

The leading role players in the manganese and phosphate mining industry come from the private sector with government being the shareholder in others. The leading manganese and phosphate mines are among the top five leading global resources companies of which calls for a high level of ethical considerations.

4.6 CONCLUSION

The qualitative research paradigm methodology used in the study was discussed in this chapter. The research fields of exploratory, descriptive, induction and purposive sampling were elaborated upon. The research also covered the ethical considerations for the study, research design, selection and profile of the participants, access to institutions and individuals. Interviews, field notes, institution newsletters, the recording process and transcription of the data used for data collection were described.

Data analysis and interpretation using the content analysis method was stated, while validity and reliability (measure of trustworthiness) are expressed through credibility, dependability and triangulation.

CHAPTER 5

DATA PRESENTATION, ANALYSIS AND INTERPRETATION

5.1 INTRODUCTION

This chapter consists of data presentation, analysis, and interpretation of the interviews for the study. The profile of the participants is provided. The data were transcribed and content analysis used for the interpretation. The interpreted data were then analysed for themes emanating from the study.

5.2 PRESENTATION AND ANALYSIS OF DATA

The respondents' comments have not been edited in order to preserve their authenticity.

5.2.1 When asked to describe the supply chain in the manganese and phosphate mining the following respondents replied in part:

<u>Respondent 1</u>

> "The supply chain in our organisation starts when a product/service is required for the mine, the user compiles a scope of work with specifications, this is usually done with the assistance of external consultants. The scope gets approved by the stakeholders. Stakeholders are usually the Engineer, the Maintenance, GM and Safety. The scope is made of drawings, product/service descriptions, and specifications. The scope will be send to Supply department for sourcing. A selection criterion is then decided by the stakeholders including Supply."

<u>Respondent 4</u>

> "The supply chain in my organisation kicks starts when a need must be realised. I will use an example of a need to build a new storage facility in the plant. The requester will create full specification with drawings, requirements and BOQ*. The specification will

be send to the supply department depending on the value it will either go to contracts or purchasing. The supply department will check the scope for completeness and source at least three quotes". *Bill of Quantity.

Respondent 6

"The process starts with the need. The need is then discussed by relevant stakeholders; I'll use the need to source fleet of vehicles to be used in the plant for transporting plants, tools and equipment's. The stakeholder will form a team that will look into the need. In the need discussion, the different departments within the organisation are involved in the drafting of the final scope. The supply's role is to help the team with market analysis and strategy. From the draft scope, the supply specialist will present a strategy to the team and the team would approve. The strategy will cover the risks, the market trend, possible suppliers, total cost of ownership ... among other things. In some instances, a request for information will be issued to get the market feeling. Where a decision has been taken that a tender be issued, the supply specialist will draft a tender document with the scope and issue the tender to the approved vendors. Upon receipt of the proposals from invited vendors, the team sits again to evaluate the tender. The tender is evaluated commercially and technically. Recommendations are made and the suitable vendor is then appointed to supply the vehicles."

Respondent 7

"The process starts with when there's a need. The end user will send out scope to the sourcing department for the need to be fulfilled. The sourcing person will analyse the need and satisfy himself that it is complete before preparing a tender documents to send out to potential bidders. The bidders will receive the tender and prepare quotations and send back to the sourcing person on or before the closing date which has been specified in the tender document. The quotations from the bidders will then be evaluated as per set criteria. The successful bidder gets appointed and they start with the job or deliver the goods. Once the job has been delivered, they get paid… sometimes we do part payment especially for services."

Respondent 8

> "First of all we would have to get a need from the end users on site and that need has to include that description of the plant or the equipment that is required, the quantities of the equipment that will be required, the location at which the equipment will be utilised or used and as well the duration with which the equipment would be utilised. Once the need is defined, the need in a scope of work document would then be sent through to supply chain representatives who would then do quite a number of steps which would be your market analysis in terms of looking for the suppliers in the market who are able to provide the equipment that's required based on their specifications."

Respondent 11

> "If we were to replace a valve that is in a pressurised environment, you'll start with the need of that. The need will comply with the specification of that valve that attaches and the composition of the valve. Whether is it a flange valve, is it a closed valve or whatever the case may be. From there, it will be issue…the end user will start with the process and give purchasers the requirement and the detail specifications of that valve. Then from there, there's the purchasing team, or the buying team, starts with three-code system to source the correct the valve at the correct price, right delivery etcetera and from there once the best supplier is sourced, the valve gets to be procured."

In responding about the supply chain in the manganese and phosphate mining industries it was notable from the respondents that the supply chain process starts with a need from the end user, who compiles the specification and sends it to the supply department to start with sourcing. Thus the **need and specification** emerged as a theme on this question.

The need and specification are the responsibility of the end-user. The specifications are drafted by the end user or in some instances third party consultants. The supply department will request quotation on behalf of the end user and a contractor will be appointed to fulfill the need.

5.2.2 When asked to describe the environmental challenges in the manganese and phosphate mining the following respondents replied in part:

<u>Respondent 1</u>

"Waste generated from the operations includes contamination to soil, water, air."
"If environmental aspect is a concern, the product specification would have addressed it as part of the scope by the end user. The Procurement inserts the scope into the tender document and issue as is, no alterations or changes are made. The tender is then sent out to at least 5 suppliers for response. Once the tender is back an evaluation gets done by the stakeholders, recommendation done and awarded to the suitable supplier who scored the best in terms of the selection criteria. The successful supplier will be notified and a contract drafted. The product/service will then be delivered."

<u>Respondent 2</u>

"Oh Yes, the nature of mining process affects the environment and there's nothing we can do about it except to manage the impact. During our processes, we produce lot of dust and fumes which are harmful to both humans and the environment. Another factor which is now being managed through legislation is the use of electricity and water."
"Actually we don't, if the environment is something to consider when buying a specific product then it would be included in the scope from the end user, and like I said it's rare that you will find such requirement."

<u>Respondent 5</u>

"I am not an expert in that, but just to name a few… smoke, dust, tailing dams, sludge and general waste from the operations." "Not at the moment, we buy according to the specification; if the environmental aspect is of importance then it will form part of the request by the end user."

<u>Respondent 6</u>

"Yes, the risks here would be the general waste from the production and the fumes and dust…and the spillages during production."

Respondent 7

> "The moving of material from one point to another, use of extensive energy, scrap generated from production and waste from the raw material."

Respondent 8

> "The market analysis is done based on the need that you have, so if in terms of the need from the client and the environmental issues are of a concern, that would be part of the work that you'd have to figure out as part of your analysis, whether you need to take that into consideration or not but if the environmental issues are not of a high importance from the scope document that you might have received, you would look at it but in terms of your risk matrix that you'd have for your market, the rating would be quite low."

Respondent 11

> "The current environment risk is the most frequent one, it's dust, it's water and fire emissions and gases. Fire emissions stroke gases." "Not now, but it not something that's currently… I know it's a mandatory requirement for South Africa to ensure that we meet the green environmental efficiencies but it's not something that comes first in mind in the procurement spectrum because of we will…in procurement we are support service for technical guys so if they did not source a green valve, and I don't know where is there any other RND within the valve spectrum where it's green, it's just mainly a performance and a safety issue from the valve's perspective."

The above comments from the respondents indicate that they are aware of the environmental concerns associated with their mining operations. However, the main challenge for respondents seems to be the **operationalisation of environmental issues in areas such as procurement**. Respondents are aware of the toxins that are released from the air, water and soil during their mining operations, but have nothing much to do with it.

Respondents expressed themselves further in the following way:

Respondent 1

> "Knowledge sharing among across the supply chain, There are new processes and plants introduced every day in the market which one might not necessarily know about."

"First I would say, staff and decision makers need to be educated on the subject and more collaboration between the different stakeholders within the supply chain would help."

Respondent 3

"More research into latest technologies. Collaboration between suppliers and users. Improvement in the current laws in terms of environment protection. Government can also run campaigns that educate and make aware of the dangers…although this will be expensive, but its worth the cause."

Respondent 4

"We have to work together, the suppliers, end users and supply. If we can work together, advise each other. Guide each other…currently we are working solely in our comfort departments."

Respondent 9

"I think it's not easy because you find that in any operation people do have their favourites. They have people that they want to work with maybe because they've worked with the supplier for a long time, they have a relationship with that particular supplier so I think you need a supply person to have your facts in order, so you cannot just go and tell somebody no the product is not good enough for the environment if you don't have the facts as in to what impact does that have because when you do engage the people at that level you need to be able to tell your story properly. If you don't, you're going to get a lot of pushback because people already maybe have, one, they may have preferences, they may have people that…or certain service providers that they are used to and don't want to change so it's always a very difficult thing because especially if there's an incumbent service provider or any provider doing that service. In that instance, you are going to meet a lot of challenges because not everybody is ready and willing to actually change so you've got to be…take cognisance of that as a supply person."

From the above comments, respondent's thinks that **lack of collaboration in sharing knowledge** among the stakeholders is another challenge in the implementation of green supply chain in the industries. The respondents are convinced that should they collaborate among themselves so that they can share information from their respective competencies about new processes, plants introduced in the market and the ever-changing technologies.

5.2.3 On the question of how does organisation control environmental risks/challenges

the respondents had the following to say:

Respondent 1

> "In the mining environment, you have to use energy, water, heavy industry equipment, lubricate the machines, build infrastructure… all this things are necessary in order to ensure the mine exist… or we might as well close shop. Having said that, the mine puts in together mechanism such as dust suppression in the roads, dust bags, sewerage systems to minimise the impact and besides the law requires us to do so or else we cannot operate."

Respondent 2

> "We definitely make sure that whatever we purchase falls within the policies and regulation set out by government, for instance the carbon footprint, dust emissions and others… and in terms of the environment… the government has a long way to go in terms of policies and regulation, and this should have been the time where legislation is forced as there's still lot of emerging mines, which they can do the right thing from the initial by procuring low energy plants, and investing in process that minimise the fumes released into the air."

Respondent 3

> "Of course, of course, we have to comply. Environmental laws like the safety laws are considered… for instance we cannot go ahead and procure a plant that is not safe or will potentially harm the environment..that's were the ISO certification comes."

Respondent 5

> "Ja. There are systems put in place to monitor the levels so that the mine comply with the set environmental laws by government… and where possible they are reduced or eliminated."

Respondent 6

"There are systems in place which include monitoring the impact so that it does go over the limit, but the problem is this is not the best solution, I would say if we source products that are green, and then the monitoring will be minimised or got rid of. We are not there yet, although a something is being done… such as recycling, dust suppression, dust bags… As an organisation, we are not in point where green practices are a priority, where green practices forms part of our processes."

Respondent 7

"There's a lot of policies, like the one I gave you that address the issue of the environment… the thing is this policies only address the policies and regulations put together by government… like the energy use, protecting the rivers… recycling water used."

Respondent 8

"I think the environmental challenges that we have in the organisation are based on the product that we operate, manganese is quite a dangerous material so exposure, we try to limit exposure to employees by making sure that the correct PPE is worn at all the designated areas and in terms of our processing plants, we make sure that we have back filters that can catch some of the fumes and some of the fires that are produced during the process so we try to limit the amount of harmful chemicals that we release to the environment because of the processes that we work on."

Respondent 9

"So I don't think we can be hundred per cent green, but I think at the moment it's about trying our utmost best to ensure that our impact within in the environment that we work with, not only the ground, but in terms of the processing of our materials, there's also the carbon footprint that we are talking about these days, backwards and forwards. Is the type of energy that they're using green enough? Are we making sure that we recycle, we reuse and then all those other things that we need to ensure that we are doing? What are the impacts that we're having on water in terms of polluting the water or reusing the water? So all those impacts we need to ensure that we can minimise the impact on the environment."

Respondent 11

> "Obviously for risk mitigation control processes from an environmental perspective it needs to be fully analysed and how we do that is all the extraction fans has to be in place for emission control and your stack analysis to ensure that whatever air that comes out there it's not a…it does not contaminate the environment, so that information gets to be monitored on a regularly basis by our end users."

From the above comments, there is a current theme which happens to be a challenge namely, the **proper use of monitoring and control systems.** The respondents acknowledge that there are currently monitoring systems that monitor levels of pollution and contamination to the environment. They also note that these systems are not 100per cent effective and they are implemented only to comply with the set government regulations in the industries. The systems and procedures in place correct the damage after the fact, such as stack analysis mentioned by respondent 11. The respondent added that sourcing green plants will ensure that there's a minimum or nothing to monitor.

Respondents added the following comments when asked about how to control environmental risks

Respondent 3

> "Today the government is faced with rectifying environmental mistakes done by previous mine owners because laws were not set properly or managed, but now its an opportunity to minimise the same mistakes from happening. You know when a mine is not safe to operate, the government will come and close it immediately, but when a mine is not meeting its requirement in terms of environmental laws, the government will come and request to see the plan in place to address the issue, by so saying..it is quite clear that the environment is not as important as safety."

Respondent 4

> "The only thing would be the government intervention; the government must just come in and assist these mines to comply…either by pushing them in a way of strengthening the current laws if or giving incentives for compliance."

Respondent 6

"Yes. I don't think the government is doing enough in that regard."

Respondent 7

"Talking about making it a priority, I believe this can only be achieved if the regulation by the government makes it a priority, if the government is not serious about it, then the pressure to management is low or non-existence." "Yes. I think the policies for environment are not as strict maybe like the safety policies."

Respondent 11

"Look, it's gonna be quite something new within in the procurement fraternity to talk green. It's not something that it's in the clear. We still having a lot of legislation issues which we haven't even complied to so and coming to monitor green and in South Africa as well it's a little bit vague 'cause there is no legislation currently that directly and explicit to say every item that has to be…so what I'm saying is for us procuring green items it has to start from a …the drive gets to be started from a government to ensure compliancy." "There's nothing tangible, to my knowledge, there's nothing tangible that we can say if we were to procure above item it has to be green and these are the efficiencies and it's legislated and documented."

Lack of clear policy and legislative direction emerges as an important theme that respondents also raised as a challenge. The data above indicates that from government there is no clear policy direction when it comes to environmental issues. The policies and regulation set by government are not explicit and do not address prevention to environmental risks, but the cure which is to monitor and then correct. The data further mentioned that the government does not see environmental risk as a priority, like safety for instance. The government needs to make it a priority so that management can adapt and make it a policy within the industries.

5.2.4 When asked to describe challenges in the implementation of green practices in their organisations.

Respondent 1

"Unfortunately cost is one of the major factors, although there are benefit that comes with it, operating a green mine…the cost is a challenge because it means that the mine should provide capital to change and re-build most of the plants and processes used, not to mention that whenever a new process or technology is introduced, one brave mining operation should test it, which again cost money..it is a normal practice that whenever a mine wants to invest in a new process they visits other mining operations that have done it before."

Respondent 2

…. "Cost, cost and cost, I believe if there was enough money, the company would buy the latest technology available in the market."

Respondent 3

"No, Yes…in a way. The mine must be built, that's the main objective and in the process we will try our best to minimise the risks associated. You know, if we concentrate much on the environmental risk we will end us not having a mine, besides the cost associated with procuring products that are not harmful to the environment. The mine, it is the nature of the mine to create substances especially during production that will one way or another harm the environment. What I'm saying is if we have to protect the environment 100 per cent, we might as well not mine."

Respondent 4

"I think the major obstacle is the cost associated with such implementation. Because the implementation will mean new skills, replacements of existing plants and processes and this plant has been built many years ago and changing it will require major capital injection of which I do not think the company can afford." "Cost. I'm confident that if money was available, the mine would by better improved products and monitor services performed that they do not release harmful substances to the air, and probably build systems that would channel and automatically recycle waste."

Respondent 6

"Yes, cost is the main one because should money be available the implementation would be easy."

Respondent 7

"I think the main challenge is cash, it is very costly to consider all the aspect of protecting the environment…what I'm saying is we need world class systems, better monitoring systems to detect gas leaks before they get to the ground among other things…also to mention that employees must be made aware and trained on how to protect the environment. I don't think documenting it and making it part of the vision is enough."

Respondent 9

"I think it's cost. I think your costs would rise. I think your costs would rise more with the more greener you are being. We need to find ways to ensure that we can be able to cost effectively manage the environment or the impact on the environment because I think for me bottom line is a business is there to make money so they will try and avoid as much costs as they can because that's impact on my bottom line so at the end of the day you need to ensure that whatever it is that you do, you minimise those costs but don't minimise those costs by impacting or cutting corners within the environment because the cost to future generations is going to be insurmountable."

Respondent 10

"Lack of funds. I think the lack of funds is the biggest issue". "The money's the biggest issue".

The above comments from the respondents indicate that **cost** is a major challenge in the implementation of green supply chain in the industries. Costs emerged as a critical theme. The respondents are convinced that the implementation of green supply chain is costly as it requires new world class technologies that will detect and control the waste generated. The greener you become the more costly it is.

Mines are a business and are established to make money. Cutting costs is one of the leading strategies. If capital was available, the industries would adapt green supply chain.

5.2.5 On the question of the future of manganese and phosphate mining industry and South Africa

Respondent 1

> **"**And the end users must be with the times, be educated and willing to test the new products in the market…because the other challenge is that end users are used to working with certain products and are reluctant to change to new products…so change management will also help."

Respondent 4

> "Change management is required … and if the company can make it a policy that all goods and services will take into consideration the environmental aspects like for instance the BBBEE. Then everybody in company will comply… but this is not done."

Respondent 5

> "The need to want to change, you know the challenges in implementing green practices within this company should be pushed by the top management and the guys at the bottom will comply. Everything that we do as a department links back to the company strategy, such as BBBEE. If top management makes policy that requires that all product purchased must be purchased from suppliers who manufacture them in a green process, package them, deliver as such…then the procurement department will adapt and make this a priority in the adjudication stage."

Respondent 6

> "The mining companies should just take responsibility like any other industries in the country and adhere to policies put in place. The only time you hear of case where a mine took responsibility is when the damage is severe, but the day-to-day operation such as oil leaks are not accounted to, so as much as the government will monitor, the most responsibility lies with the company itself to do the right thing, but generally speaking if all people involved play their part, the green principles in the mining industry can be achieved..

Respondent 7

“South Africa as a developing country is doing well in terms of adopting world laws such as carbon emission, I just don’t think the same emphasis exist in the mining industry…is it perhaps due to the contribution to the GDP, or job creation… I can’t answer that, but again strict policies must be introduced and monitored and also awareness. A culture of minding about the environmental must be planted in each of us.”

Respondent 8

“I think there’s still a number of gaps because as much as we always talk about the environment, in terms of our day-to-day work and in terms of our day-to-day activities, we rarely take that into consideration. It has to be something that needs to be instilled more, then we live those values, not just do it because we have to have a tick box that says that we looking after the environment. I think we are long way from getting there but I think slowly but surely we will get to a point where, in any discussion or in any actions that we take, the first thing that we would consider besides how the equipment is gonna run and what type of equipment are we looking at is gonna be the environmental impact of any decision that we make.”

Respondent 10

“I can only think of it. I don’t know physically about challenges but I can only think that the challenges. If you look at change and change management, this is what it’s all about and people are reluctant to change even if it’s to their benefit. It has been done so for thirty years, why do you bother with it? Just let it be. That’s the attitude that people have and it comes with managing change and managing people’s attitude towards your environmental risk that’s out there, that’s bottom line, and, ja, change people’s minds…difficult.”

Respondent 12

“We’ve always used that so we’ll carry on doing that. No new innovation or new thinking about alternative methods of production”.

“I reckon they should…I don’t think we…I’m not sure if we…I don’t think we have an environmental…we have environmental guys but I don’t think we actually have an environmental head or somebody that’s high up in the organisation so maybe what they

> should do is maybe the guy that's in charge of HSEC must be HSEC and environmental or something like that. Somebody with a bit of weight behind them and have certain GLDs in place like they do for HSEC."

Leadership and managing change continues to hinder progress in the industries. The industries are used to the way of doing things in a particular manner which has been done for several years. People are reluctant to change and try new ways of doing things. Management need to commit to environmental issues by enforcing a culture that promotes flexibility and encourages change among stuff.

The respondents recognise that there are still gaps, but they can be corrected although it will not be done instantly. The respondents add that the environmental concern should be a policy that is included in the sourcing of new products and services in to the organisation.

5.3 THEMES AND SUB-THEMES ORIGINATING FROM THE PRIMARY DATA

The themes and sub-themes emanating from the primary data can be summarised in Table 5.1:

Table 5-1 Themes and sub-themes emanating from the interviews

THEMES	SUB-THEMES
Need and specification	• **The supply chain process start with a need from the end user.**
Operationalisation of environmental issues, especially in procurement	• **Environmental issues are not a priority.** • **Do not always form part of the specification**
Lack of collaboration and knowledge sharing	• **Lack or limited collaboration between stakeholders.**

Proper application of monitoring and control systems	• **Systems to minimise the environmental risk exposure available.** • **Monitoring procedures in place to minimise environmental risk.**
Lack of clear policy and legislative direction	• **Government's emphasis on environmental issues.**
Cost of implementing the green supply chain practices	• **Cost is a major factor in the implementation of green supply chain.**
Lack of strong leadership and managing change	• **Management commitment towards environmental issues lacking.** • **Stakeholders' ability to change.**

5.4 CONCLUSION

The chapter provided data presentation, analysis and interpretation for this study. The profile of the participants and the organisations they represent were described. Detailed accounts from the respondents, from which the themes and sub-themes of this study emerged, were provided. The themes were highlighted and elaborated on. A summary of the interviews with the 12 respondents was provided.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

This chapter provides the summary, recommendations and conclusions following the research into the implementation of green supply chain in the South African manganese and phosphate mining industries. The urge to minimise environmental risk in the South African manganese and phosphate mining industries triggered interest for pursuance of this study.

The aim of the study was to explore challenges associated with the implementation of green supply chain in the South African manganese and phosphate mining industries with a view to recommending solutions. In pursuit of this outcome, a study was undertaken on green supply chain as a primary source to minimise environmental risks, stakeholder awareness, challenges associated with the implementation and its future in the industries. These considerations formed the basis of the conceptual framework that culminated in the project design that guided the study.

6.2 AIMS AND PRIMARY OBJECTIVE FOR THE STUDY ACHIEVED

The aims and the primary objectives for the study as stipulated in chapter one, to explore the challenges associated with the implementation of green supply chain in the South African manganese and phosphate mining industries with a view to recommending solutions were successfully accomplished.

6.2.1 Theoretical/ Secondary objectives achieved

This study set out to achieve three theoretical/secondary objectives and they were all successfully accomplished as indicated hereunder:

Theoretical objective 1: To conduct literature review on manganese and phosphate mining industries in South Africa

A critical review of the manganese and phosphate mining industry and its landscape was conducted in chapter two of the study. This was accomplished through invaluable knowledge on the industry obtained from the industry itself and from some of its major role players.

Theoretical objective 2: To conduct a literature review on supply chain management and how it relates to the mining industries

The literature review on supply chain management and how it relates to the mining industries chain was presented in chapter 3. The chapter discussed the origins and different types of supply chains as well as sustainable development, among other things.

Theoretical objective 3: To conduct a literature review on green supply chain management, sustainable development, and the environmental issues associated with the manganese and phosphate mining industry.

In chapter 3 the study investigated the green supply chain management as a primary source for sustainable development. Environmental issues associated with manganese and phosphate mining industries were also reviewed. This included waste generated in the industries together with the impacts: air pollution, water pollution, land degradation and acid mine drainage.

6.2.2 Empirical objective achieved

The four empirical objectives set out for the study were accomplished.

Empirical Objective 1: To establish the environmental constraints experienced by the South African manganese and phosphate mining landscape

The empirical study helped identify these constraints. Cost came out as the leading constraint. Extending the supply chain to include issues such as remanufacturing, recycling and refurbishing adds an additional level of complexity to existing supply chain design in addition to a new set of potential strategic and operational issues, which in turn increase costs. Other constraints include: lack of knowledge sharing, change management, lack of skills.

Empirical Objective 2: To describe the South African manganese and phosphate supply chain

This study has described the supply chain process in the industries from exploration to mine closure (Figure 3.2).

Empirical Objective 3: To identify the specific actions required by manganese and phosphate mining industry to adopt the green supply chain

The mining industries mistakenly begin implementing actions following an initial environmental diagnosis without critically reviewing objectives and policies. While upgraded equipment is entirely responsible for reducing and minimising environmental waste from mining activities, improved management practices serve as valuable guidance and help an operation identify additional opportunities for waste minimisation.

Empirical Objective 4: To establish ways of controlling environmental waste in the manganese and phosphate mining industries in South Africa.

This study has established that mines have systems in place to measure and monitor environmental waste, but this is done after the effect rather than done preventatively. This challenge can be addressed by introducing cleaner technologies that will tackle waste at the source rather than after it is discharged.

6.3 MINIMISING ENVIRONMENTAL RISK IN THE SOUTH AFRICAN MANGANESE AND PHOSPHATE MINING INDUSTRIES

After analysing the research data, seven major themes emerged along with other sub-themes, some of which characterised the implementation of green supply chain in the manganese and phosphate mining industries. The following section highlights the major challenges in the implementation of green supply chain and discusses ways of managing them.

6.3.1 Operationalisation of environmental issues

Mining practices will remain for as long as there are minerals available for extraction. The long-held view has been that economic growth would inevitably lead to environmental degradation through the consumption of non-renewable resources, the overuse of renewable resources, and the production of waste and pollution (Dryzek, 1997: 20). The present system of functioning in the industries is deteriorating the environment and soon a day will come when the damages done to our earth will become irrevocable. Mining is the largest producer of hazardous and general waste (DEAT, 2006: xix). GrSCM is essential if the earth is to be kept green. According to the literature, economic and social development is in the interests of the mining industry, but the third pillar of sustainable development, namely environmental protection, appears to be of least importance (Muduli & Barve, 2011: 484). This theory is supported by the respondents where they say it's not as important, with some even comparing it to safety.

Respondents mentioned dust as another source of pollution in the mining activities; the literature also recognises dust as a common problem throughout all mining activities. (UNEP, 2001: 14; Adisa, 2004: 639) and acknowledges that pollution negatively affects the environment. This is confirmed by a study done (DEAT, 2006: xx) where toxic waste, dust, acid mine drainage and metal pollution continue to pose major environmental risks within the manganese and phosphate mining industries.

Respondent 5 mentioned that the implementation of GrSCM must be pushed by top management and the bottom employees will comply. Green supply commitment through the corporate environmental approach and management commitment to environmental issues improve the possibility of GrSCM implementation.

6.3.2 Lack of collaboration and knowledge sharing

Supply chain management includes product development, management of information systems, production control, quality control, customer service and recycling and waste management (Koskinen & Hilmola, 2008: 211). Due to the ongoing development of green technologies, regulations and climate stabilisation agreements, sharing green experiences and current knowledge between stakeholders within the supply chain has become a necessity, that is, the interaction with government, suppliers, customers and competitors.

The industries require the commitment of all stakeholders to enhance environmental management capabilities by providing training programmes and sharing their green system. Knowledge sharing in green supply chain leads stakeholders to develop new capabilities for effective actions. Training and education are the prime requirements for achieving successful implementation of GrSCM in any organisation, while informal linkages and improved communication help the organisations to adopt green practices (Ravi & Shankar 2005: 1016). The respondents agree with this literature and they believe that training is required in the implementation of GrSCM, but it required funding.

IT has made possible the sharing of large amounts of information along the supply chain, including operations, logistics, and strategic planning data. This has enabled real-time collaboration and integration between supply chain partners, providing organisations with forward visibility, improving production planning, inventory management, and distribution (Sanders, 2007: 1332). All operating manganese and phosphate mining industries have adopted ERP systems which integrates all information in the company, as stated in the study and those that are in the project phase are working towards adopting. The ERP systems used in this industries are SAP, JDE, PASTEL and Syspro.

6.3.3 Proper application of monitoring and control systems

Respondents see pollution as part of doing business in the mining industry. Another respondent went as far as saying in order to stop pollution the mine might as well close. Waste and pollution in a production process can be a sign that the process is not as efficient as it could be; it is not fully understood or properly controlled.

Few mines have paid attention to the possible effects of pollution by implementing regular monitoring of ground water, air quality and noise to maintain acceptable standards (Middleton, 2003: 330). The respondents confirmed that the industries have systems in place that monitor, measure and maintain waste generated, Examples mentioned include dust suppression, dust bags and that this is done in order to comply with set regulations. This is supported by Morrow & Rondinelli (2002: 161) who say that, although corporations in most industrialised countries have adopted environmental protection practices required by government agencies since the early 1970s, these regulations largely focus on control of water and air emissions and waste disposal. According to Duber-Smith (2005: 24), GrSCM practices include reducing energy consumption, recycle and re-use, using biodegradable and non-toxic material, minimising harmful emissions, and minimising or eliminating waste.

Waste costs money to generate and again to dispose of. The introduction of green manufacturing will eliminate monitoring systems that are currently used to measure the waste generated. Green manufacturing is defined as production processes which use inputs with relatively low environmental impacts, which are highly efficient, and which generate little or no waste or pollution.

6.3.4 Lack of clear policy and legislative direction

The industries consider environmental management as compliance with regulations while evaluating trade-offs between environmental and economic performance. There is policy and legislation that governs the industries (as stated in chapter 3: Legislative environment).

South Africa has made significant progress with environmental management in the last decade by implementing laws and strategies that focus on sustainable development and green issues (Engel, 2008: 1). Government regulation usually requires companies to reduce or eliminate their toxic air and water pollution by using technologies that control or clean emissions at the 'end of the pipe' (Morrow & Rondinelli, 2002: 161). The respondents recommend the revision of current policies and legislations, to be stricter and penalties must be severe where there's no compliance, that is, the penalty fee for non-compliance must be higher than the cost of initiating GrSCM.

The respondents compare the green issue with safety and feel that the environmental protection is not emphasised enough. The respondents and the literature agree that, unless GrSCM is effectively implemented and properly enforced, the solid framework for governance remains a mere intention (DEAT, 2006: xix). It is not clear whether the manganese and phosphate mining industries have adopted the minimum green strategies because it is the right thing to do or simply to comply with the environmental regulations as stated by Muduli & Barve (2011: 484), that in order for mining companies to secure their continued 'social licence' to operate, the mining industry must respond to various sustainability challenges it faces by engaging its many different stakeholders and addressing their sustainability concerns. Hui, Chan & Pun (2001: 269) indicate that government policies and pressure from organised groups fighting for the protection of the environment are some of the factors that induce companies to adopt a green manufacturing or environmental system policy.

6.3.5 Cost of implementing green supply chain practices

Cost would remain a challenge in the industries because profit is the main objective of mining. Extending the supply chain to include issues such as remanufacturing, recycling and refurbishing adds an additional level of complexity to existing supply chain design in addition to a new set of potential strategic and operational issues, which in turn can increase costs, at least in the short term (Linton *et al.*, 2007: 1079). Luthra *et al.* (2011: 239) further says that, usually, high cost is a big pressure in GrSCM as compared to conventional SCM. The initial investment requirement by green methodologies such as green design, green manufacturing, green labelling of packing etc., are too high. The respondents have strongly supported this study and highlight costs as a major constraint in the implementation of GrSCM. The respondents are convinced that should money be allocated, the implementation of GrSCM would be possible. However, the DME (2005: 27) also recognise that GrSCM can cut the cost of materials purchasing and energy consumption, reduce the cost of waste treatment and discharge, and avoid a fine in the case of environmental accidents.

Leaders of the supply chain department should balance low cost and innovation process while maintaining good environmental performance. The implementation of GrSCM requires capital initially, but it is an investment in a long term. The introduction of green procurement might be costly, but it means savings in the monitoring and control measures which the industries are spending money on. Green procurement involves an environmental purchasing consisting of involvement in activities that include the reduction, reuse and recycling of materials in the process of purchasing. Besides green procurement is a solution for environmentally concerned and economically conservative business, and a concept of acquiring a selection of products and services that minimises environmental impact.

During the 1970s and 1980s many corporations, attempting to get ahead of complex, costly, and rapidly changing environmental regulations, began to adopt voluntary pollution prevention practices that sought to reduce or eliminate from manufacturing processes the sources of pollutants, rather than controlling them after emission (Morrow & Rondinelli, 2002: 161). The manganese and phosphate mining industries can follow the same and be ahead of other mining industries by following this trend.

6.3.6 Leadership and managing change

Beamon (1999: 332) posits that the current state and trend of environmental degradation calls for a need to change manufacturing philosophy. Respondents are also convinced that the implementation of GrSCM requires change management. They further elaborated by saying management should bring about this change.

According to Tsoulfas and Pappis (2006: 1594), the main environmental emphasis has been on the manufacturing phase and to some degree on the disposal phase. This revelation is confirmed by the respondents as they noted that the environmental protection is a function of the plant people in the operation. Environmental issues are becoming an important element of the task of management, and there are good reasons to believe that this new development is likely to be more than a passing trend. (New *et al.,* 2002: 93).

According to Muduli and Barve (2011: 486), many possibilities to reduce the environmental burden of mining activities exist, which will also require the involvement of all stakeholders in the supply chain, including supply chain practitioners. For example, optimisation of the environmental performance through good housekeeping and total quality management, appropriate end-of-pipe techniques, recycling of waste and non-renewable products, substitution of, or a ban on the use of environmentally unfriendly products, or by incremental and more radical technological innovations.

6.4 LIMITATION OF THE STUDY

This study, being qualitative, had a limitation on the number of participants. A total of 12 participants from the manganese and phosphate mining industries were interviewed.

These were all professionals in the industry and included three senior management. The response by respondents from the industry was positive (12 approvals). Accessing the industry had other limitations due to its nature, as the mining industry is a sensitive subject, taking into consideration the current politics of nationalisation and its contribution to job creation in society. The institutions in the industry are not easily accessible without good reasons and introducing a research topic is not one of the most desired reasons to gain access. However, through perseverance it was possible to gain access and to successfully complete this project.

6.5 RECOMMENDATIONS

Hilson (2000: 706) observed that challenges in the implementation of green supply chain manifest themselves in the following ways:

- A lack of clear, continuous policies to support waste minimisation and cleaner production
- Incomplete regulatory frameworks and uneven enforcement
- Ignorance of the characteristics of industrialised production processes
- No clear understanding of the difference between compliance investments and cleaner technologies
- Inefficient coordination among different government agencies at different levels

To an extent this study has corroborated the observation made above in that:

- Stakeholders are aware of the environmental risk associated with the manganese and phosphate mining industries, but do not take it seriously, like the safety issue for instance. Stakeholders across the supply chain must make environmental issues a priority in order to minimise environmental waste.

- There are systems and monitoring procedures in place to adhere to the environmental policies set by government. Government should emphasise and set strict environmental regulations so that management can develop comprehensive environmental management plans.
- Lack of knowledge sharing and reluctance to change has also emerged as a major challenge. Internal and external (suppliers) stakeholders must share information regarding new technologies and better processes to minimise waste. Stakeholders must also be willing to change and try out new suppliers, systems and technologies available in the market.
- Cost has also emerged as a serious challenge in the implementation of green supply chain.

Thus the following recommendations are made:

Policy recommendations

At a policy level the study recommends that the introduction of cleaner production practices must be standard for all manganese and phosphate mining industries in South Africa. That is, management and organisational measures must be in a position that a mine can handle, minimise and anticipate problems with waste. In other words the critical elements of the strategy should cover:

- Use of cleaner technologies
- Training for stakeholders
- Inclusion of environmental aspects in the sourcing strategy
- Redesigning of plants to better accommodate wastes
- Make funds available for environmental awareness and change management
- Collaboration between stakeholders (internal and external) to encourage knowledge sharing

Management recommendations

Top management in the industries need to take the initiative of change management by pushing awareness among the supply chain stakeholders. The awareness can be achieved by holding environmental awareness seminars for suppliers and vendors, undertaking programmes to educate about the benefits and relevance of green supply chain initiatives, providing platforms for information and offering rewards to stakeholders for pursuing the initiative. Due to the fact that supply chain practitioners are custodians of the supply chain process, policies must be introduced where sourcing strategies are only approved if the green issue is recognised.

Further research recommendations

It is apparent that the mines have limited knowledge of cleaner technologies and cleaner production practices. First, further research will need to be undertaken to establish a green supply chain model. Secondly, a study needs to be conducted on the perceptions and expectations of South African policy makers in this industry. Thirdly, a feasibility study needs to be done on the link between the implementation of green supply chain, cost saving and competitive advantage.

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ANNEXURE 1

INTERVIEW QUESTIONS

1. Describe supply chain process in your organisation.

2. Tell me about the environmental risk/challenges in your organization.

3. How do you control environmental risks/challenges in your organisation?

4. Describe the challenges your organization faces in the implementation of green practices.

5. What do you think is the future of Manganese/Phosphate mining industry in South Africa?

ANNEXURE 2

PROOF OF LANGUAGE EDITING

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