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EXPLORING THE ENVIRONMENTAL IMPACTS OF FLY ASH ON ESKOM'S BUSINESS SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT, A STUDY ON KRIEL POWER STATION IN MPUMALANGA PROVINCE OF SOUTH AFRICA.

A Dissertation submitted in fulfilment of the requirements for the degree of
Master of Environmental Science

With

Witwatersrand University, Johannesburg, South Africa,
(School of Geography, Archaeological and Environmental Science within the Faculty of Science)

BY

KHULISO JAMES RASIMPHI (Student number: 1699084)

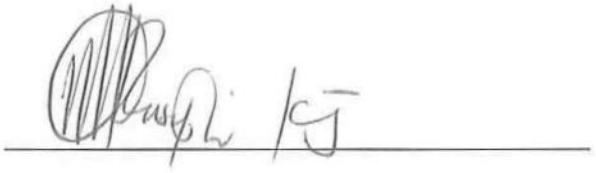
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31 August 2018, Johannesburg

DECLARATION

I, Khuliso James Rasimphi, hereby declare that this dissertation is my own, unaided and original work. It is being submitted for the Degree of Master of Science (by research) at the University of the Witwatersrand, Johannesburg. All the sources that I have used and quoted in this study have been indicated and acknowledged in the form of reference. This study has not been and will not be presented for a degree purpose at another institution.



(Signature of candidate)

31 day of August 2018 in JOHANNESBURG

ABSTRACT

Fly ash generated at coal fired power stations is associated with various environmental impacts. The aim of this study was to particularly investigate alternative ways in which fly ash generated at Kriel Power Station can be managed effectively to minimize environmental impacts in order to ensure alignment with the notion of sustainable development. The study was primarily focused on exploring the impacts of Kriel Power Station's fly ash as well as current fly management practices within the context of contemporary principles of environmental management and sustainable development.

Quantitative and qualitative research methods were used for data collection. Purposive sampling was used as primary sampling procedure to select fitting sample from the study population. Data from structured questionnaire surveys, semi- structured interviews as well as existing records was used for data collection. This study has found that fly ash utilization is an ideal management practice which is aligned with sustainable development notion as compared to disposal to ash dams. Kriel Power Station's fly ash was found to consist of various valuable elements which can be used for various industrial production purposes. The findings further suggest that the very same valuable chemical elements found in Kriel Power Station's fly ash can cause adverse environmental impacts such as water, land and air pollution depending on the management approach. One of the key findings of this research is that fly ash utilization program is currently not well marketed in South Africa; and there is a need for all relevant stakeholders to work together to educate the public on the opportunities presented by fly ash.

As part of concluding remarks, this study also suggested some enabling policies which can be established in order to optimize fly ash utilization from the regulator level (national level) to the generator and end user level (institutions). Recommendations on relevant future studies which can potentially be undertaken to explore adverse impacts as well as benefits of fly ash were also made.

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First and far most, I would like to thank God who has always been the provider of my strength. When completing this research, I always believed that I can do it through God my inspirer.

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LIST OF ACRONYMS

ACAA	American Coal Ash Association
ADB	Asian Development Bank
ASLP	Australian Standard Leach Procedure - ASLP MHSA
CAR	Central African Republic
CoE	Centre of Excellence
CV	Calorific Value
DEA	Department of Environmental Affairs
DPME	Department of Planning, Monitoring and Evaluation
DST	Department of Science and Technology
DWS	Department of Water and Sanitation
Dx	Eskom Distribution Division
EAEWMR	Eskom's Annual Environmental Waste Management Report
EIA	Environmental Impact Assessment
GDARD	Gauteng Department of Agriculture and Rural Development
GHT	Geo-Hydro Technologies
GSCM	Green Supply Chain Management
Gx	Eskom Generation Division
ICMM	International Council on Mining and Metals
IFC	International Financial Corporation
KPS	Kriel Power Station
LC	Leachable Concentration
NEMA	National Environmental Management Act
NEMWA	National Environmental Management Waste Act
NFSD	National Framework for Sustainable Development
NSSD	National Strategy for Sustainable Development
NWA	National Water Act
PRC	People's Republic of China
PSU	Penn State University
SA	South Africa
SABS	South African Bureau of Standards
SACAA	South African Coal Ash Association

SACNASP	South African Council for Natural Scientific Professions
SANS	South African National Standards
TCT	Total Concentration Threshold
Tx	Eskom Transmission Division
USA	United Nations of America
WUL	Water Use Licence
XRF	X-ray fluorescence

CHAPTER ONE

FRAMES OF REFERENCE

1.1 INTRODUCTION

Fly ash is the fine particles which subsequently occur during the activity of burning underground and open cast mine coal which gets extracted from the boiler through the flue gases system. Over the years, fly ash has been treated as waste and has mostly been managed through ash disposal facilities known as ash dumps. With the growing environmental consciousness and need in merging the ecological wellness into the sustainability concept, change in environmental management practice is required with regard to fly ash management.

Environmental sustainability which is a subset of sustainable development can be referred to as a way of satisfying the needs of present and forthcoming generations while taking good care of the ecological systems, which in actual fact, is the main source through which such needs can be satisfied (Morelli, 2011). According to United Nations Economic Commission for Africa (UNECA, 2017), sustainable management of Africa's sources of natural resources has not been consistently improving. The number of endangered species in Africa remains high; and 25% of Africa's land resource is categorized as wasteland, with a huge amount of persons still living on poor quality land (UNECA, 2017). There is a need for African countries to start managing their socio-economic activities in a manner which will reduce the environmental footprint and ensure sustainable development. The percentage of wasteland in Africa is shocking and it is about time that a sustainable management practices must be channelled towards "green" waste management.

African countries which are mostly categorized as being at their developing stages have a mandate to develop their economies to meet their people's needs, at the same time safeguarding that the output and practicality factors of the primary ecological systems are strongly upheld (Chevalier, 2014). Some of the main reasons resulting into Africa's ecological degradation include population and economic growth; increasing energy demand and great increase in investments towards infrastructure projects (Chevalier, 2014). In his study, Chevallier (2014) recommends that African countries need to implement an all-inclusive and generic ecosystems management approach which will be aligned with the development and organizational priorities;

he further highlighted that scientific data should be used to determine ecosystems' wealth and their services for incorporation into sustainable conservation funding.

South Africa has also recently adopted the National Framework for Sustainable Development (NFSD) with a determination to stimulate the national concept for sustainable development (DEA, 2008). The aforesaid NFSD does recognize the rising pressure on ecological systems and resources resulting from economic development strategies. NFSD's objective is to enhance systems for incorporated planning and operation, maintaining ecological systems and resources proficiently in order to achieve a green economy (DEA, 2008). It is clear that South Africa is in a process of steering its focus towards green economy which by all means seeks first to avoid environmental impacts before resorting to managing those impacts.

According to Prevost (2003), approximately 77% of South Africa's primary energy need is satisfied thorough coal fired power stations; this figure is also displayed as the current figure in the South Africa's Department of Energy website. Over 90% of electricity in this country is coal-derived (Prevost, 2003). According to energy strategic plan for 2015 – 2020, the status core is likely to remain the same due to shortage of sufficient substitutes for energy production besides coal generated energy in South Africa (SADE, 2017). According to Eskom (2017), one of Eskom's 8 business sustainability heights is to ensure Environmental and Climate Change Sustainability through addressing the connections between ecological management and operational sustainability. Eskom as an organization has already initiated measures to channel its business activities towards ecological wellness and sustainability.

1.2 THEMATIC FOCUS

Eskom's operational mandate is to efficiently and sustainably provide electricity to South Africa. This process includes electricity generation, transmission, distribution and sales to South Africa as well as some of the Southern African Development Community (SADC) countries (Eskom, 2017). Relative to the economic and population growth, Eskom has experienced an increase in energy demand from its customers. The aforesaid demand has ultimately resulted into the energy capacity expansion programme aimed at increasing the generation capacity by 17 384MW, which commenced in 2005 and is expected to be completed by 2020/21. As a result of an increased demand and energy production, the ratio of coal-in and ash-out has also increased (Eskom, 2017).

The current primary fly ash management practice in all Eskom's coal fired power stations including Kriel is through ash dam disposal. Kriel Power Station is currently disposing 90% of its produced ash at the ash disposal facility while only 10% gets recycled through to the cement industry. The other challenge with Kriel is that its existing ash disposal facility has reached its life span and plans are in place to construct a new ash disposal facility which will service the station until its closure in 2039 (Eskom, 2017).

Ash dams constructions and operations are associated with various environmental implications which include expansion of environmental footprint, air pollution, water pollution and general environmental degradation. Firstly, ash dams usually take over huge extent of land which results into destruction of flora and dislocation of fauna; at some instances, wetland systems and their inhabitants also get threatened resulting into ecological footprint. Secondly, fly ash disposed at the ash storage facilities potentially becomes a primary source of air quality pollutant due to its very fine texture which allows it to easily get blown by wind into the air and therefore polluting ambient air quality. Due to its light weight, fly ash has the potential to easily be carried and transported to a farthest away distance from its source making it to pose local and regional impact. Carbon content contained in fly ash has the potential to contribute to carbon footprint and therefore increasing the greenhouse effect risk. Through air as the exposure media, fly ash can also impact on human health as people can inhale it. Thirdly, fly ash from ash dams can, through air as the exposure media, fall on the ground to impact on surface and groundwater resource. If the ash dams do not have a proper seepage resistant system, ash contaminated water has the potential to seep through into the ground water and therefore causing pollution. Lastly, all the above discussed implications of constructing and operating an ash dam facility causes all sorts of environmental degradation which includes ecosystem degradation, ambient air quality degradation, ground and surface water quality degradation. Over and above, constructing and operating ash dams becomes counterproductive, economic inviable and is also associated with a huge exposure to environmental legislative liability (Eskom, 2017).

In view of the above, the focus for this study was to investigate Kriel Power Station's current environmental management practices with regard to boiler generated coal-ash, aligned with Eskom's business sustainability measurement which focuses on environmental and climate change sustainability. In addition, the study further pursued to identify the actual and potential environmental impacts which could or are actually resulting from the current ash management

practices and identify possible environmental management approaches and solutions which can be employed to optimize ash utilization through other avenues other than ash disposal.

1.3 RESEARCH QUESTIONS

In context of the thematic focus of this study, the following questions have guided the research process:

I. What is the chemical composition of fly ash?
II. In what ways is the current management or storage of fly ash aligned with contemporary principles of environmental management in Kriel Power Station.
III. What are economic and environmental opportunities do fly ashes present within the context of contemporary environmental and sustainable discourse?
IV. What are the potential impacts of fly ash on environmental, social, economic aspect?
V. What are the technological aspects which can be implemented in order to reduce the generation of fly ash and also to optimize its utilization?
VI. What is the importance of integrated environmental management principles in optimizing fly ash utilization?

1.4 RESEARCH AIM AND OBJECTIVES

The aim of this study was to investigate alternative ways in which fly ash can be managed effectively to minimize environmental impacts in order to ensure alignment with the notion of sustainable development.

In view of the questions and aim of this study, the following objectives have guided the process for this study:

I. To examine and understand the chemical composition of fly ash.
II. To identify the potential impacts of fly ash on environmental, social and economic aspects.
III. To evaluate the extent at which the current management or storage of fly ash is aligned with contemporary principles of environmental management.
IV. To establish the socio-economic and environmental opportunities that fly ash present within the context of contemporary environmental and sustainable discourse.

V. To investigate the availability of technological options which can be used to reduce generation of fly ash and also optimize utilization of generated fly ash from coal fired power stations.

VI. To evaluate the importance of implementing integrated environmental management principles in order to optimize fly ash utilization.

1.5 THEORETICAL CONSIDERATIONS

As defined by Morelli (2011) and Goodland (1995), environmental sustainability has everything to do the current generation making use of available natural resources in a conservative and balancing way in order to preserve such natural resources for later generations. In the context of Morelli (2011) and Goodland (1995) arguments, Eskom as an organization has to use available resources such as water, coal, virgin land, etc. in a manner justifiable to future generations as they also have to use the very same resources to sustain themselves. In terms of organizational sustainability, Danciu (2013) and Chen (2015) argues that for organizations such as Eskom to stay long in the business, they must run their operations in a manner which balances economic growth with social and environmental aspects. If an organization only focuses on generating profit without taking care of the environmental and social issues around it, it will soon run out of resources and personnel to sustain it.

In order to achieve environmental sustainability, various systematic tools exist which can assist organizations to successfully implement their set environmental sustainability objectives. Some of the systematic tools which can be used include ISO14001 standard which enables organizations to strengthen its environmental management application which in turn can also prove to be crucial in ensuring that the organization addresses its environmental sustainability objectives (Ahmad et al, 2009). The reviewed literatures are suggestive that environmental sustainability implementation program requires a boost of from systematic approach which is well monitored for its effectiveness for the program to be successful hence they identify ISO14001 standard a great tool to offer such assistance (Miguel and Da Fonseca, 2015).

In countries such as the USA which is considered the world economic powerhouse, industries are continuously placed under a significant amount pressure to run their operations sustainability subsequent to the current environmental impacts in the country which resulted from historical industrial activities (Theis and Tomkin, 2012). Countries such as Canada, Romania and the USA

have resorted in adopting sustainable development goals and strategies in order to ensure that viability between social, economic and environmental aspects is continually ensured (Theis and Tomkin, 2012; Environment Canada, 2017; and Burja, 2012).

Many developing countries such as South Africa often request major projects funds from certain mandated financial institutions such as World Bank or regional banks. The aforementioned financial institutions are of lately, including strict conditions to force the borrowers to ensure that sustainability concept is embedded in the development which their being funded on just like the World Bank did in Central African Republic (World Bank, 2010). Regional institutions and banks are also starting to show some support to countries who have significant historical pollution to clean up their mess and operate sustainably going forward (ADB, 2012).

Countries located within the Sub-Saharan Africa are also faced with various environmental challenges which require them to act now than later to ensure sustainable usage of natural resources (Klein et al, 2013). Another sustainability challenge to Sub-Saharan African countries is that most of these countries are very rich in natural resources such as minerals (coal, gold, platinum, etc.); the extraction process of the aforementioned minerals is often associated with massive environmental pollution and degradation which are often cause by unsustainable management practices(IFC, 2014).

South Africa, just like many other countries around the world has also adopted the concept of sustainable development to an extent that a National Framework of Sustainable Development (NFSD) has been established (DEA, 2008). A nested model of sustainability, goals and implementation plans for South Africa is also developed to provide an outline in terms of the objectives of NFSD. South Africa is among the fast growing and economically advanced countries in Africa and with its current pace of industrialization, it also has environmental challenges which some resulted from one dimensional economic growth which overlooked other pillars of sustainability (DPME, 2017). Among other challenges which faces South Africa today include high volumes of recyclable waste such as ash, etc. which gets disposed and cause other environmental impacts instead of being recycled (DEA, 2012). Other literatures points to the issue of inconsiderate legislation as contributing to slow progress by South Africa to maximize on waste recycling programs (Dernbach and Mintz, 2011).

Chapter 2 will provide an in-depth review of, but not limited to, the above outlined pieces of literatures and theories in order to gain a comprehensive view of the concept of sustainability as the core of this study.

1.6 METHODOLOGICAL CONSIDERATIONS

In terms of the approach, this research has used two approaches which include positivism and critical realism; these two approaches were carefully selected taking into account the research problem, questions and objectives. Aligned with selected research approaches, this research also used qualitative and quantitative research methods to investigate the research problem and respond to research questions.

The study area for this research was at Eskom Kriel Power Station, a coal-fired power station which is located at approximately 12 kilometres south west of Kriel town, within Mpumalanga province of South Africa. Kriel Power Station is also located about 4 km north of Matla Power Station. The study area is located within a 15 kilometres radius from different types of residential areas which include Thubelihle Township, Kriel Town, Rietfontein Township, farm homesteads and mine compounds. Some of the local farmers adjacent to the Kriel Power Station depend on groundwater resource for domestic use. Kriel Power Station, through boiler combustion, generates about 90% of fly ash and 10% of coarse ash (Eskom, 2017). A significant portion of generated ash is disposed of within the unlined ash dam facility. Kriel Power Station is located deep within Highveld Priority Area in terms of air quality as the area is considered to have high air quality pollution.

The study population for this research included relevant employees from Kriel Power Station, other Eskom business units as well as other sectors outside Eskom. The researcher selected used purposive and snowball sampling procedure to select the sample from the study population. In terms of data collection, structured questionnaire was used to collect primary research data while semi-structured interviews were used to collect data to triangulate primary research data. Reviewing and adoption of existing data was used as a secondary data collection tool. Data collected through structured questionnaire survey and interviews was mainly saved in the computer system and codified into Microsoft Excel for analysis. The researcher also interpreted the secondary data before extracting relevant evidence for inclusion as part of research evidence.

1.7 SCOPE OF STUDY

This study mainly focused on investigating Kriel Power Station's current environmental management practices with regard to boiler generated coal-ash as well as the associated risks and opportunities. Existing laboratory tested data of Kriel Power Station's fly ash was used to understand the chemical composition and characteristics of fly ash. Although this study has used laboratory tested data to understand chemical composition of fly, it did not go deeper in understanding every single chemical element found in fly ash in terms of associated risks and opportunities. Fly ash composition is unique from one geographical landscape to another; and the findings of this study are not an overall Eskom coal fired power stations representative.

1.8 ETHICAL CONSIDERATIONS

The following ethics were upheld throughout the study (Creswell, 2014):

(i) Obtaining necessary permissions – before commencing with the study, the researcher obtained a clearance letter from the University of Witwatersrand and also a consent letter from Kriel Power Station management permitting the study to take place in their premises.

(ii) Deceiving participants – The researcher was honest to the participants and disclosed all the information regarding the study beforehand.

(iii) Privacy - participants' privacy were always respected and their privacy terms did dictate the research planning.

(iv) The right to confidentiality and anonymity – participants' details and information were not disclosed without their consent.

CHAPTER 2

THEORETICAL CONSIDERATIONS AND LITERATURE REVIEW

2.1 INTRODUCTION

Chapter 2 focuses on exploring relevant selected pieces of theories and literatures on environmental management and sustainability taking into account the global context, Sub-Saharan Africa context and South African context as well as gaps in knowledge.

The concept of sustainable development cannot be separated with that of business sustainability. Ecological, social and economic sustainability approach of the business directly translates to sustainable development of such business. In order for Kriel Power Station and Eskom at large to self-sustain for a very long time as a business, it needs to maintain a balanced approach with regard to implementation of its social, economic and environmental principles within its operations. If Eskom Kriel Power Station does not manage its operations in a manner which ensures balance in terms of implementation of sustainable development pillars (i.e. environment, social, or economic aspect), the end results are bound to be disastrous especially towards a sustainability pillar which is neglected. The balanced approach need to be embedded throughout the life cycle of the business operation; thus, a sustainable development thinking need to be applied for social, economic and environmental aspects of the business from the designing stage, to material input stage, up until the output stage. If some elements within the operation (e.g. by-products which include ash) are not managed in accordance to the balanced approach, chances are that they may end up being a liability either to social, economic or environmental aspect of the business. In every identifiable problem to social, economic and environmental spectrum, there is always an opportunity through which such problem can be managed sustainably; and this also applies to Kriel Power Station's generated fly ash.

The position of this study is centred within the historical and contemporary discourse of sustainable development which emphasizes the need for social, economic and ecological aspects to be embedded into each other. Pelenc et al. (2015) identifies that there are two types of sustainability frameworks which comprise of weak sustainability framework as well as strong sustainability framework. Huang (2018) refers to weak sustainability framework as an indicator which allows for mutual substitutability between natural wealth and human-made capital. Weak

sustainable framework claims that the system is sustainable if the overall capital stocks remain high irrespective of whether the ecological system is being degraded on not (Huang, 2018). Strong sustainability framework on the other hand maintains a belief that the man-made and natural capitals balances each other; and that environmental sustainability should be assured as it forms the basis for man-made capital to thrive (Huang, 2018). Unlike weak sustainability framework, strong sustainability framework maintains a belief that economic enhancement cannot be sustainable at the expense of environmental pollution and degradation. Strong sustainability framework maintains that natural capital cannot be viewed as a substitute as it serves as a primary source of provision to man-made capitals hence it should be treated as critical capital which should be conserved (Pelenc et al., 2015).

In light of the above, this study has adopted a strong sustainability framework as the main assumption of the theory due to its main beliefs which are grounded at protecting the environment. Taking into account the continuous environmental pollution and degradation caused by Eskom coal fired power stations, through unsustainable operational activities such as disposal of ash at the ash dams, it is critical to ensure that environmental assurance is achieved hence the selection of strong sustainability framework which prioritizes natural capital as primary and critical.

This chapter takes off by exploring the global context with regard to environmental management and sustainability through reviewing various definition of sustainability concept followed by uncovering the viewpoints of various literatures across the globe with regard to environmental management and sustainability. Secondly, the chapter will then move on to explore relevant literatures and theories on environmental sustainability within the Sub-Saharan Africa in order to understand measures being implemented within the African continent in an effort to ensure environmental sustainability as well as the challenges thereof. Thirdly, the chapter will conclude by exploring relevant literatures and theories looking at the South African context; and this is where South African's commitment to environmental sustainability will be explored as well as South Africa's progress on implementation of sustainable waste management programs. In addition, the chapter will also look at management practices of fly ash with Eskom as an organization which this study is focused on as well as the contribution of legislation on sustainable management of waste and fly ash in particular. Lastly, before conclusion, the chapter will look at gaps in knowledge with regard to the reviewed literature and theories putting emphasis on the significance of undertaking this study.

2.2 ENVIRONMENTAL MANAGEMENT AND SUSTAINABILITY: GLOBAL CONTEXT

Morelli (2011) refers to ecological sustainability as a balancing act which allows current human generation to fulfil its needs without exploiting natural resources to ensure the regeneration of the said resources. In addition, Goodland (1995) also states that environmental sustainability seeks to sustain those systems maintaining human life. In his study on concept of environmental sustainability, Goodland (1995) identifies that the source capacities of the global ecosystems provide raw material inputs while sink capacities assimilate outputs or waste; he further added that both capacities source and sink capacities are critical and should be effectively maintained. In reference to the proposed study, management of coal resource which is the input material is as important as the management of produced ash which is an output or by-product because if management of any of these capacities are neglected can result into negative environmental footprint hence this study will also look at available sustainable contemporary ash utilization opportunities.

Danciu (2013) argues that, business sustainability is relative to organizational approach in managing socio-economic and environmental aspects. Similar to Danciu (2013), the study undertaken by Chen (2015) also suggest that implemented environmental management practices are relative to company's innovative performance, which can further improve financial performance. In the context of the proposed study, it therefore becomes crucial to ensure that environmental management approach for managing fly ash benefits the company financially at the very same time achieving ecological sustainability.

According to Ahmad et al (2009), environmental management tools such as ISO14001 standard plays a critical part in managing environmental issues within organizations. Ahmad et al (2009) does however highlight that ISO14001 standard is not a sustainable management tool; however it has a significant and positive influence in implementing modern principles of environmental management which are aligned with sustainable development concept. Although life cycle assessment of environmental aspects is identified as the possible sustainability integrating tool into ISO14001 systems, it remains a challenge for environmental managers who mostly have limited specialist knowledge on certain subject matters to connect the dots on how to determine this life cycle perspective. Miguel and Da Fonseca (2015) claims that ISO 14001 can have a considerable pertinent influence for Ecological Sustainability as specified in the "introductory"

and "scope" sections of ISO/DIS 14001:2015. Both Ahmad et al (2009) and Miguel and Da Fonseca (2015) studies assumes that all the ISO14001 standard users will interpret and grab the sustainability concept outlined in the standard alike which may not be as such from one person to another.

According to Basiago (1999), there is an emerging global uneasiness which is resulting from environmental resources such as fossil fuel which cannot be renewed and therefore restraining production; consequently, limited production put economic growth under severe stress in a long run due to unstable natural environment and pollution effects. Danciu (2013) recommends that, among others, sustainable environmental innovation can be implemented by companies as a way to preserve environment by executing things such as process improvement, management and waste reduction.

According to Theis and Tomkin (2012), in order to ensure that sustainability model becomes a reality, economic feasibility is crucial in a sense that the buy in from industries should be sought in order to ensure the optimum performance of sustainability model. Theis and Tomkin (2012) further claims that In United States of America (USA), the current portrayal of industries is that of hostility towards the environment as compared to the early stages when the American Conservation Movement was initially established due to current consciousness on environmental issues and its impact. This hypothesis is however not verified through the scientific research. In addition, there is also a claim that the then industries could have not managed their operational activities better due to a very limited inducement, insufficient regulations and science to aid in managing environmental issues and natural resources astutely and more consciously as compared to today (Theis and Tomkin, 2012). Theis and Tomkin (2012) warns that, nowadays, the USA is faced with multiple types of environmental impacts as a result of most of current decisions creating multiple impacts at one go; what is further indicated as critical is the dire need to understand the outcome of decisions before implementing them in order to alleviate unintended consequences to ensure sustainability of developments.

Theis and Tomkin (2012) further argues that sustainability concept faces some challenges and some of these challenges include environmental pollution, limited electricity resources, irregular topographical dissemination of electricity and carbon dioxide emissions and climate change. Out of the four challenges facing sustainability concepts, the notable ones include environment pollution, carbon dioxide emissions and climate change. In terms of environmental pollution as

challenge to sustainability, it is argued that the environmental impacts were being witnessed for a very long time but they were unheeded (Theis and Tomkin, 2012). This argument by Theis and Tomkin (2012), seem to differ with their very own initial argument which indicated that, the reason for environmental issues not being overemphasized at USA during early years of industrialization (American Conservation Movement days) was purely due to unavailability of incentives, regulations and science to ensure effective environmental management by industries. The other critical challenge for sustainability is said to be carbon dioxide emissions as it presents worrying prediction trends in terms of climate change which is attributed by social behaviour, economical activities, and available technologies and energy source which requires better management in order to minimise climate change impacts (Theis and Tomkin, 2012).

Theis and Tomkin (2012) also added that, to meet sustainability goals which seeks to improve environmental management, creative thinking which involves life cycle assessment of industrial activities, products and services need to be undertaken effectively; this basically mean that, the assessment of input material and output material need to be undertaken in order to understand measures and technologies required to sustainably manage by-products such as waste.

In their discussion paper titled, "Sustainable Operations Management", Drake and Spinler (2013) argues that, if there is an imbalance between the ratio in which generated waste reaches the ecological system and the ratio in which it can be serviced by the system, then waste will accrue substantially and that ecological system will be unbalanced. Drake and Spinler (2013) does not provide enough direction on what operations can do to manage their by-products as they just noted that more academic investigations are required to provide answers in terms of sustainability options looking at resource reuse and recovery. Drake and Spinler (2013) do acknowledge that they are the scholars in operations management which in way may have influenced some biasness on their conclusions especially considering the fact that there has not been a detailed research undertaken to validate their hypothesis.

As part of the US Competitiveness Project, Esty and Charnovitz (2013) raised a few environmental sustainability measures which the authors argue that they are critical to enhance USA's competitiveness; and these include the following: firstly, focusing on sustainability which basically talks to ensuring viability between socio-economic and environmental components does assist companies in minimising risks, which if not effectively managed, might later cost the company fortunes; their second argument is that sustainability gives a vital all-

encompassing end for environmental policy and eventual laws and regulations which can improve the scale of the company and its national competitiveness. Thirdly, they argue that a better US competitiveness strategy also will enhance economic growth and wide wealth that make commitments to environmental protection easier to sustain.

According to Environmental Canada (2017), Canadian government has established a national act which is known as the "Federal Sustainable Development Act" aimed at outlining amongst other things, the key principles to guide the process for implementation of sustainable development in the country. The underpinning principle of sustainable development as far as Canadian government is concern is that the country must measure its progress on sustainable development based on the effective use of its natural, social and economic resources. Canadian government acknowledges that to realise its sustainable development goals there should be a commitment to mitigate environmental impacts caused by its policies and associated operations; and also through efficient use of environmental resources and other goods and services.

As part of its environmental sustainability priorities, Canadian government has established four high priorities which include addressing climate change and air quality; maintaining availability of quality water; preserving the environment; and reducing ecological impacts (Environment Canada, 2017). The Canadian government does outline the fact that for these priorities to be realised, government, public and private sectors will have to work together. The route that Canadian government has taken does in a way fortify the perception that developed countries are leading the pack with regard to implementation of sustainability concept realization despite the fact that a lot still need to be done in terms of consultations and research works as part of implementation of the identified 4 high priorities (Environment Canada, 2017). This piece of literature does not provide enough insight in terms of measures that will be taken to manage Canadian coal fired power stations' ash by-products as it only stipulated that business shall be encouraged to enhance capital cost allowance for clean generation equipment in order to mitigate against high emissions.

Goosen (2012) claims that sustainable development has now been adopted by many organizations and their stakeholders as the ideal model to implement with a lot of organizations now maintaining their actions and communications centred viability on socio-economic and environmental aspects; he further added that in order to come up with the much needed

solutions to environmental problems, a harmonized approach will be crucial for the organizations.

Goosen (2012) and Esty and Charnovitz (2013), both agree on the argument that there is close relations between organization's ecological performance and its financial performance. According to Goosen (2012), organizational top management's consciousness towards addressing environmental concerns within their organization will increase with time; he further added that the aforementioned awareness shall be attributed by the viewpoint that an increasing number of the businesses around the world are integrating their environmental activities and performance in their financial statement and reports. Although organizations are including environmental performance in their reporting, Goosen (2012) further argues that this should not be all that gets done by top management as they still have the responsibility to continue ensuring that environmental problematic areas which still require focus are prioritized.

In line with sustainability concept, Goosen (2012) argues that environmental and economic solutions are very crucial in an economy that is facing limitations in terms of natural and economic resources. It is also crucial to ensure that waste reduction and management systems are established in order to manage the side effects of depleting natural resources; he further claims that the concept of utilizing reclaimed materials for construction is only relevant for developing countries. Goosen (2012) does not provide the scientific backing or evidence of various claims in his literature which leaves a gap to be explored by engaging and getting viewpoints of relevant stakeholders in relation to sustainability and environmental management.

Providing the Romanian perspective on environmental management and sustainability, Burja (2012) argues that various economic activities result into all sorts of environmental impacts ranging from resources depletion, air, water and land pollution, as well as climate change; in return, all the aforementioned impacts translate to degradation of human life quality and the burden also get passed over to the next generation. In his explanation, Burja (2012), raises the issue of economic activities as the bases through which issues such as environmental and social issues are rooted. In an effort to address the aforementioned economic activities, the European Union established a model which sets the economic activities as targets to achieve sustainability by means of establishing socio-economic and environmental objectives (Burja, 2012). Burja (2012) also highlighted that Romania adopted the European vision of sustainable development and integrate it into its National Sustainable Development Strategy of Romania. Although Burja

(2012)'s literature does harmonize with other reviewed pieces of literatures so far, on the importance of sustainable development, it is not a tell all in terms of what approach can a developing country use to effectively get started with the sustainability concept; however, the study does indicate to us that the European Union and Romania as a country realises the gap caused by economic activities which calls for balanced approach between social, economic and environmental aspects when persuading economic activities.

With regard to the People's Republic of China (PRC), the Asian Development Bank (ADB) has come very strongly in support of PRC's environmental sustainability objectives; additionally, ADB has also committed its support to PRC in terms of its 12^{th} five-year plan to advance environmental sustainability and climate change focus (ADB, 2012). What is also noteworthy from ADB (2012) is that the bank is playing a critical role in assuring its support to PRC with regard to promoting sustainable economic activities which are cleaner through, among other things, preserving degraded rural ecological systems, and promoting growth of liveable urban cities. Effective environment and natural resource management is identified as key to ensure sustainable management of land and water resources by ADB (ADB, 2012).

Asian Development Bank's support to People's Republic of China to ensure environmental sustainability can also be viewed in light of the recent challenges experienced by PRC were estimations undertaken in 2009 indicated that a total of 2.04 billion tons of industrial solid waste was produced in China; large quantities of these wastes include mine tailings, slag, and coal ash (ADB, 2012). What can be viewed as a positive is that, about two-thirds (1.38 billion tons) of the aforementioned industrial solid waste produced at PRC was utilized with one-fourth (0.475 billion tons) being treated and 0.185 billion tons being kept and disposed (ADB, 2012). In ADB (2012), it was mentioned that European Union had an indicative budget of €330 million, with 30% of the said budget reserved for programs to promote environmental awareness; environmental aspects which are targeted by this program include, amongst others, the following: waste management, water and air pollution, environmental indicators, sustainable consumption and production, and environmental impact assessment. What still remains the gap is that this piece of literature does not provide much detail in terms of what ADB will undertake to ensure that its vision and objectives regarding environmental sustainability are realized.

In India, a practice known as the Green Supply Chain Management (GSCM) has been established to specifically add environmental issues as part of supply chain while attending to

matters of effect and relations of procurement to the environment. This process filters environmental impacts throughout the whole procurement process including raw materials extraction phase up until the product end of line stages. The objective of GSCM is also to ensure integration of the process in order to reduce waste and environmental impact while maximising production (Meera and Chitramani, 2014). This effort by China is primarily established to ensure environmental sustainability through GSCM which also resound with what other countries are trying to achieve through initiatives which are meant to minimise environment impacts.

In a study undertaken by Aigner and Lloret (2013) regarding sustainability and competitiveness in Mexico, some interesting findings were found in relation to sustainability. The study revealed that 72 of the 100 self-selected firms indicated that the implementation of environmental sustainability practices advances their companies' bottom line (Aigner and Lloret, 2013). What is further noted in this study is that most of Mexican companies recognize that the implementation of sustainability concept has improved their attractiveness and their capacity to react effectively to contemporary market conditions (Aigner and Lloret, 2013). Some level of biasness is projected with the 100 firms which were self-selected and therefore putting the validity of the response from the research questionnaire to a certain level of uncertainty. What is clear in this passage of review is that a number of countries around the world are allocating more resources to strengthen environmental management and also ensure sustainability.

2.3 ENVIRONMENTAL MANAGEMENT AND SUSTAINABILITY: SUB-SAHARAN AFRICA

Klein et al (2013) argues that, in order for countries in the Sub-Saharan Africa to attain lasting sustainable development, there is dire need for these countries to ensure that their economies and growth models take into account the Green Economy concepts. Klein et al (2013) consolidated various pieces of literature focusing on green economy and sustainability on lessons learnt from 5 Sub-Saharan African countries which include Benin, Ethiopia, Ghana, Namibia and Nigeria. It is very crucial for Sub-Saharan Africa to play it safe by ensuring that green economy is implemented taking into account the already visible impacts of climate change in the region which are causing changes in rain patterns and therefore influencing the availability of fresh water resource.

In table 2.1 below, Klein et al (2013) further strengthen his argument on the resource constrains which Sub-Saharan African countries are faced with which requires urgent intervention through implementation of green economy concept in order to achieve suitable economic growth and natural resource utilization. In terms of climate change as a segment of concern, Klein et al (2013) revealed that Benin, Ethiopia, Namibia and Nigeria are faced with droughts challenges; in terms of water scarcity, Benin is said to be having serious challenge as the northern part of the continent has always struggled with water scarcity, while Ethiopia, Namibia and Nigeria are also faced with unreliable supply of water resource; when it comes to desertification and land degradation, table 2.1 below reveals that a significant part of the sampled countries are sitting with degraded land and some are semi-arid desert. This information does give a perception in a sense that the specific 5 Sub-Saharan African countries have very limited resources such as water which need to be carefully managed. With the issue of drought which seems to be of great concern, it is important to ensure that natural resource such as ground water is conserved.

Table 2.1 also signifies the impact of human activities towards land degradation and therefore serving as an eye opener with regard dangers of implementing human activities which later comes back to haunt human survival as resources becomes scarce and living conditions becomes unsusceptible.

Table 2.1: Major challenges related to development and Green Economy in Sub-Saharan Africa

	Benin	**Ethiopia**	**Ghana**	**Namibia**	**Nigeria**
Climate change	Droughts, floods	Droughts due to global warming	Increasing pressure on disaster and relief agencies	Increasing frequency of droughts	Extreme events such as droughts
Water scarcity	Water scarcity is highest in the north. Vulnerability studies conducted in 2001 predict a reduction in rainfall in the range of 20 % to 30 % nationally by 2025 with resultant water reduction from 40 % to 60 %	Uneven distributio n is the major problem.		Most important challenge: increased water scarcity, exacerbated by unstable rainfall patterns	Less than 50 % of the country's water demand is met by the available supply

Desertification & land degradation		Population living on degraded land: 72 %.	Population living on degraded land: 69 %.	92 % of the land area is defined as hyper-arid, arid or semi-arid. Population living on degraded land: 28 %.	40 % of the land area is defined as hyper-arid, arid or semi-arid.

Source: Klein et al, 2013

Klein et al (2013) warns countries which are still going through an industrial development process not to follow on the footsteps of those with already developed industries to curb against already existing environmental challenges and environmental deterioration. In addition, Klein et al (2013) indicated that the industrialization process of today does so at a luxury of a variety of new and cleaner technologies and options which can be used in order to ensure sustainable growth; added that Africa should not be tempted to adopt an approach of only focusing on growing the economy first and then later undertaking a clean-up as this approach is very expensive. Decisions that support development configurations which are unsustainable, in terms of technologies and infrastructure, have a potential to have higher cost implications as those technologies and infrastructure may need to be changed at a good cost in order to reduce their impact on the environment in the near future; the unfortunate part will be the irreversible damage which will have been caused by such technology and infrastructure in polluting and destroying the natural resources (Klein, 2013).

In a case of Central African Republic (CAR), the analysis undertaken by World Bank (2010) revealed that CAR's costs of ecological dilapidation is associated with the reduction of natural wealth as well as the cost of human capital reduction resulting from environmental health risks. The study signifies the importance of managing sustainability pillars (Social, Economic and Environment) as integrated. The ecological effects which were looked at by World Bank (2010) as impacting human health include, amongst others, unsafe water supply, severe breathing illnesses and long-lasting disruptive lung sicknesses caused by air pollution. World Bank (2010) also claims that the scale of Central African Republic's ecological footprint is very small; however, the status quo may change due to population growth which is resulting into shrinkage of biological capacity per capita. The study claims that CAR is using its natural wealth adequately; however, the study does not fully indicate CAR's economic growth and

industrialization process rate which could be the reason for limited exploitation of natural resources.

In a guide developed to ensure sustainable and responsible mining in Africa, International Financial Corporation (IFC) (2014) states that the nature of mining sector is such that it results into massive environmental footprint which has triggered the need for mining companies to develop operational policies and procedures to ensure effective management of these impacts. IFC (2014) indicates that Africa's mining visions accepted by state leaders in 2009 support transparent, equitable and optimal exploitation of resources, sustainable ground and socio-economic growth; it further hint that the interviewed companies as part of the exercise highlighted that a balance is required between social, economic, environment and government issues. Applicable to Africa's mining sector are the 10 principles for mining and sustainable development as promulgated by International Council on Mining and Metals (ICMM) which include amongst others the following: "integration of sustainable development considerations within the corporate decision making process; implement risk and management strategies based on valid data and science; seek continual improvement of environmental performance; contribute to conservation of biodiversity and integrated approach to land use planning; and facilitate and encourage responsible product design, use, re-use , recycling and disposal of products" (IFC, 2014).

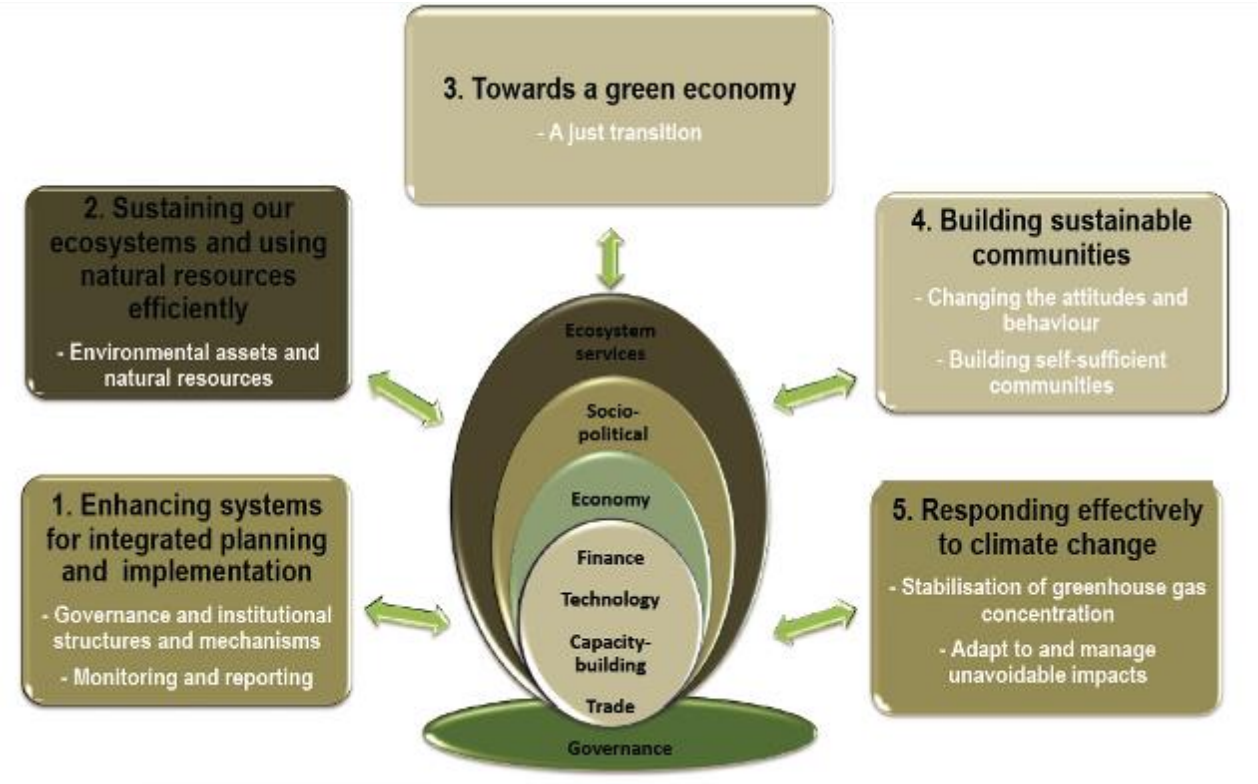
IFC (2014) seems to be in agreement with Klein et al (2013) with regard to sustainable development being an ideal method of ensuring viable economic growth; IFC (2014) further echoes that organizations which are able to operate in a way which provides opportunities, generates proper jobs, take into account human rights and at the meantime being able to protect the environment has a very good chance of managing its risks better, snatches opportunities and assist in building strong communities around it.

What appears to be common remarks with these pieces of literatures is that environmental management as a sole tool to achieve sustainability will fail; and also pursuing economic activities or pushing social corporate investments as sole components to achieve sustainability it is also a recipe for failure; however, in order to achieve a long lasting social, economic and environmental capital, these three aspects must always be embedded within each other.

2.4 ENVIRONMENTAL MANAGEMENT AND SUSTAINABILITY: SOUTH AFRICA

According to DEA (2008), South Africa is one of the countries which have embraced sustainable development concept in response to a global consciousness towards sustainability agenda; in order to ensure a guided journey towards implementing a sustainable development concept, South Africa also established a National Framework for Sustainable Development (NFSD). DEA (2008) further highlight that, NFSD was established to demonstrate South Africa's vision and interventions to navigate the country towards sustainable path; NFSD were established bearing in mind the increasing pressure on ecosystems as a result of economic growth. What is also noteworthy from the NFSD is that it sets the values and development of sustainability in the country and the methods to achieve them. Demonstrated through a nested model of sustainability (refer to figure 2.1 below), South Africa's approach towards achieving sustainability involves embedment of social, economic and environmental systems with governance systems holding the centre by means of ensuring integration through regulatory framework.

Figure 2.1: Nested model of sustainability, priorities and means of implementation



Source: DEA 2017

Advanced from National Framework for Sustainable Development, South Africa has also established a National Strategy for Sustainable Development (NSSD) which outlines key five strategic interventions, as depicted in figure 2.1 above, required to put in motion the implementation of NFSD. The key understanding is that population and consumption patterns increase is causing an increase on the impact on natural resources (DEA, 2017). DEA (2017) further claims that with the current global consciousness towards environmental topic, development activities are now being looked at as a great opportunity through which innovative ideas can be used to improve environmental performance. South Africa is one of the countries which are continuously thriving in implementing their strategies for sustainable development; however, there is still significant work which still needs to be done to undo negative environmental impacts which have resulted from past economic activities. As much as NSSD provides us with some strategies going forward, it does not provide an indication for pre-existing industries in terms of what they can implement to reverse the pre-existing environmental impacts; only a recommendation for academic research to explore measures which can be implemented to improve the status quo is indicated by DEA (2017).

In terms of water resource and sustainability, South Africa is a country with water shortage and it has limited fresh water resource; in addition, South Africa is said to be rated 30th driest country on earth with rainfalls ranging from 100mm/year on the western side of the country to 1500mm/year on the eastern side of the country (DPME, 2017). DPME (2017) further echoes that South Africa has to put more focus on conserving water resource bearing in mind the increased groundwater usage as well. High water pollution trends have been observed in some regions across South Africa; what is found to be the root cause of the country's water pollution, amongst others, is inadequate enforcement to prevent industrial pollution (DEA, 2012). In order to well manage water resource and minimize pollution thereof, DPME (2017) urges that enforcement need to be strengthened to ensure compliance; the lowlight associated with using enforcement as a means to ensure environmental protection is that it is reactive and it takes power to minimize and reduce pollution away from the polluter or industry. DPME (2017)'s approach seems to overlook the green economy transition which is one of the strategies to ensure effective implementation of sustainable development in South Africa as it only focuses on enforcing the industry and the mines to comply without promoting the adoption of green economy initiatives which can be used to ensure a buy in and sustainable operation of the industry and the mines.

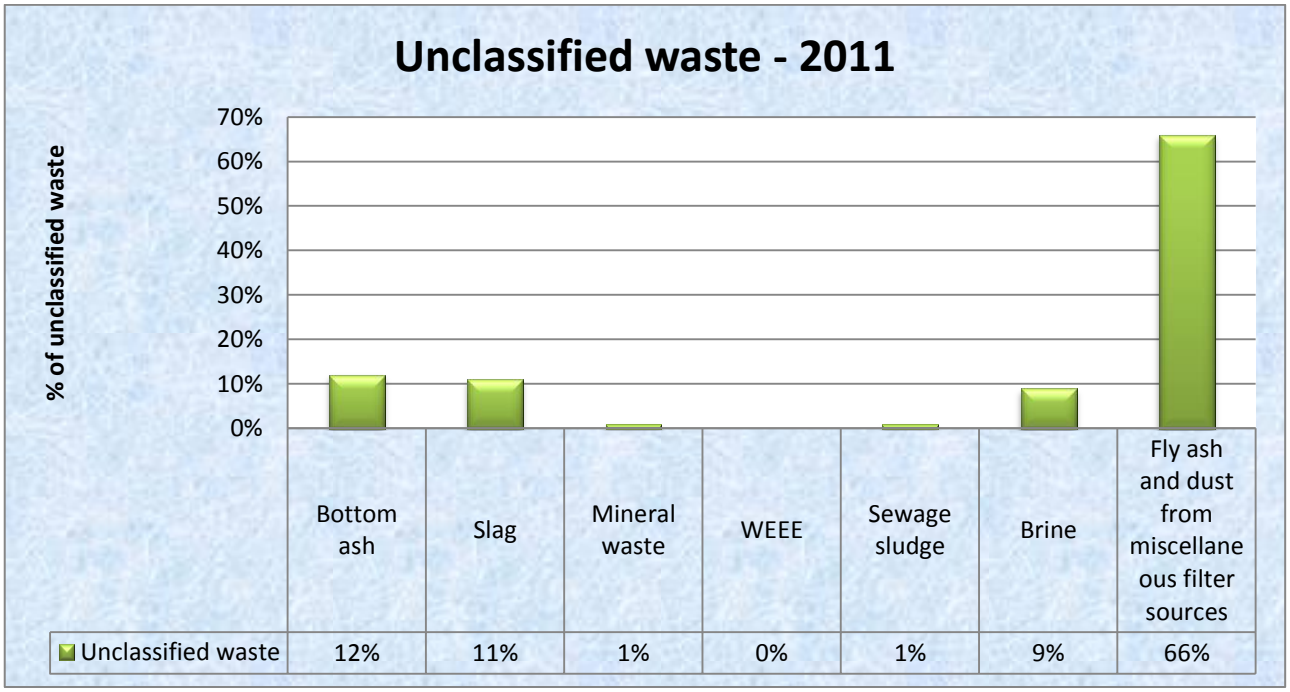
With regard to the state of air quality and sustainability in South Africa, DPME (2017) indicates that the mining and industrial activities coupled with domestic emissions have caused significant air pollution in certain areas; regions such as Highveld and Vaal Triangle are declared high priority areas due to excessive atmospheric emissions caused by ash produced and liquid fuel burnt during coal firing. DPME (2017) warns that the worsening state of air quality poses a great risk on the viability of sustainability aspects as it affects economic growth and poverty eradication. As highlighted by DEA (2008), DPME (2017) also echoes on the importance of the National Framework for Sustainable Development (NFSD) in ensuring sustainable development. DPME (2017) also highlighted the importance of moving towards waste free society for South Africa through investments such as environmental friendly product design and recycling infrastructure projects. Innovative waste management should be every sector's responsibility in order preventing environmental pollution (DPME (2017).

According to Du Plessis et al (2013), South Africa still depends immensely on coal fired power stations for its energy production; in 2010, projections indicated the country's consumption of 122.7 Mt of coal. South Africa generates over 28 million tonnages per year of fly ash; and large amount of the generated fly ash is managed through disposal to the ash dam facilities (Mupambwa et al, 2015). Du Plessis et al (2013) claims that South Africa's energy generating parastatal company (ESKOM), has produced 36 Mt of fly ash and only recycled 1. 84 Mt in 2010; the remainder was then disposed of into the ash disposal facilities. DEA (2012)'s National Waste Information Baseline Report indicated that 31 420 488 tonnages of fly ash and dust was generated in South Africa in 2011; and only 6% (1 885 229 tonnages) of the generated dust and ash was recycled while the other 29 535 259 tonnages was disposed of into the landfills. South African government through the Department of Environmental Affairs did acknowledge that fly ash has the noteworthy utilization prospective, most particularly in the cement and construction industry wherein it can be used as the aggregates and cement additives (DEA, 2012). According to Landman (2003), South African Coal is very rich in ash content making it very significant for South Africa to use more of its produced ash to minimize footprint caused by ash disposal sites.

Ginster and Matjie (2005) study literature indicates noteworthy expenses associated with ash disposal as a way of managing ash hence SASOL has been tirelessly searching for viable options for ash utilization. Ginster and Matjie (2005) claims that more often than not, the ash sales market is smaller compared to what gets generated. In 2005, Ginster and Matjie (2005)

highlighted that half of ash volumes generated from SASOL's Free State plant (Sasolburg) was utilized while ash volumes produced from SASOL Secunda was mostly disposed of into the landfill site due to the location which is far from the market (e.g. Johannesburg); the study further acknowledges the emerging ash utilization opportunities which also have their limitations since they involve low ash volume application. Opportunities to use more ash are starting be available while few of the identified large scale ash utilization opportunities were not yet confirmed as effective since they had to be further investigated (Ginster and Matjie 2005). SASOL recycling programme was largely focused on coarse ash from gasification activity as 70% of coal consumption in SASOL is used in the gasification process which produces coarse ash while 30% of coal is consumed in the power plant (Ginster and Matjie 2005).

Figure 2.2: Percentage (by mass) composition of unclassified waste



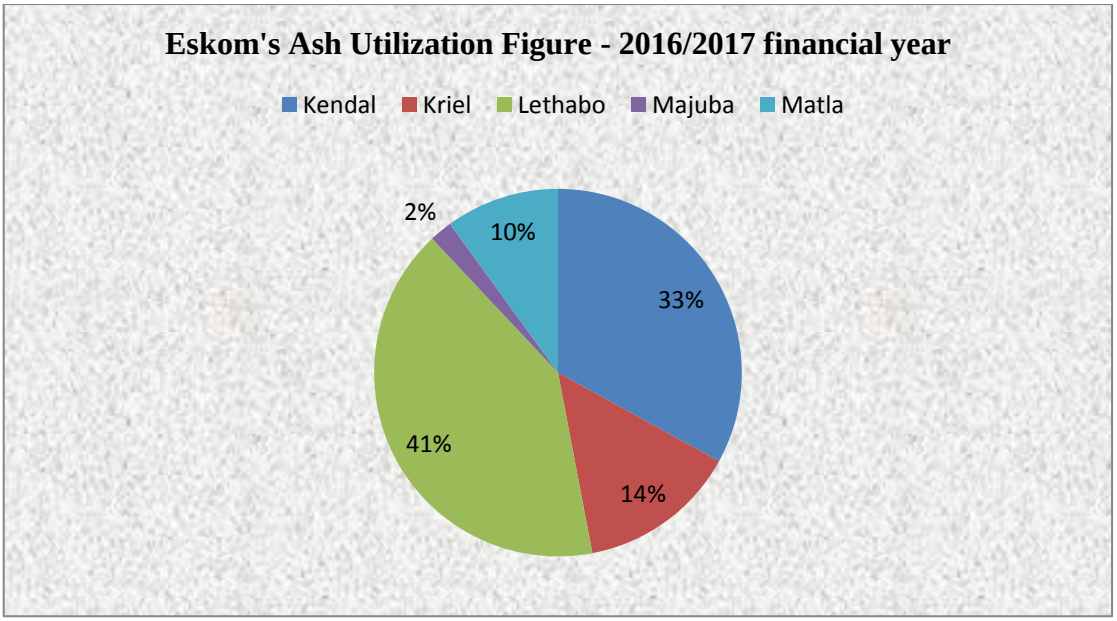
Source: DEA, 2012

As depicted in figure 2.2 above, fly ash and dust from miscellaneous filter sources accounted for 66% of generated unclassified waste cluster based on the information released by DEA (2012) for year 2011 in South Africa; with bottom ash coming second with 12%. In the afore referenced DEA (2012) national waste information baseline report , fly ash and dust from miscellaneous filter sources accounted for the highest number of generated hazardous waste as well as the highest number of hazardous waste disposed into the landfill site. Low figures of recycled fly ash versus what is generated may be a missed opportunity by South Africa to use

waste to strengthen the economy as Godfrey (2015) argues that programs to recycle waste such as fly ash can assist in fighting high unemployment rate in South Africa through creation of low skill jobs while growing the economy and upskilling the involved personnel.

Eskom Coal fired Power Stations are the primary coal consumers in South Africa and therefore making them main coal ash generators. Eskom's Annual Environmental Waste Management Report (EAEWMR) (2017), indicates that 32.60 mega tons of ash was generated across all Eskom's coal fired power stations and only 2.8 mega tons which equates to 8.5% of produced ash was utilized during 2016/2017; 7% of the abovementioned 32.60 mega tons of ash came from Kriel Power Station. As depicted in figure 2.3 below, out of 12 Eskom power stations (excluding new builds - Medupi and Kusile power stations), only 5 power stations which include Kendal, Kriel, Lethabo, Majuba and Matla are utilizing some few tonnages of their generated ash; and Kriel Power Station which is the focus of this study only recycled 14% of its produced ash and therefore disposing an alarming 86% of ash into the disposal facility (EAEWMR, 2017).

Figure 2.3: Eskom coal fired powered station's ash utilization figures for 2016/2017 financial year



Source: ESKOM, 2017

According to Department of Science and Technology (DST) (2014), goals for prioritized waste streams were formed through the engagement of relevant stakeholders; one of the prioritized

waste streams was ash and the goal is to ensure 50% utilisation of ash, through increased recovery by 2024. The key enabling institutions which must play a critical role in ensuring that 50% of ash is utilized by 2024 in South Africa includes government (Department Environmental Affairs, Department of Water and Sanitation, Department of Mineral Resource, Department of Energy); local authorities; industry and industry forums; universities; science councils and colleges (DST, 2014). DST (2014), indicated that the focus area South Africa to achieve 50% ash utilization by 2024 include areas of power generation which are listed as Mpumalanga (Witbank, Secunda, Ermelo, Kendal); Limpopo (Lephalale); Gauteng (Vaal area). As per Van Der Merwe (2014)'s acknowledgement, there is limited research undertaken regarding fly ash utilization in South Africa. Very few researches have been undertaken to understand fly ash characteristics, composition and utilization in Africa and South Africa. The reviewed theories and literatures on South African perspective indicate that ESKOM, which is the main fly ash generator, recycles less than 9% of its produced ash.

Legal framework also plays a very critical role in ensuring that industries are sustainably managed in a manner which promotes viability in implementation of social, economic and environmental aspects. Dernbach and Mintz (2011), claims that the concept of sustainability lacks implementation support simply due to unavailability of adequate legal framework through which it should survive, notwithstanding the existence of so many environmental laws. Dernbach and Mintz (2011) further argues that for a concept of sustainability to be truly realised, new laws need to be implemented or the existing ones must be amended in order address the current risks and opportunities.

In terms of South African context, the definition of waste as stipulated and quoted from section 1 of the National Environmental Management: Waste Act (NEM:WA) (59 of 2008) is (DEA, 2017):

"(*a) any substance, material or object, that is unwanted, rejected, abandoned, discarded or disposed of, or that is intended or required to be discarded or disposed of, by the holder of that substance, material or object, whether or not such substance, material or object can be re-used, recycled or recovered and includes all wastes as defined in Schedule 3 to this Act; or*
(b) any other substance, material or object that is not included in Schedule 3 that may be defined as a waste by the Minister by notice in the Gazette,

(i) once an application for its re-use, recycling or recovery has been approved or, after such approval, once it is, or has been re-used, recycled or recovered;
(ii) where approval is not required, once a waste is, or has been re-used, recycled or recovered;
(iii) where the Minister has, in terms of section 74, exempted any waste or a portion of waste generated by a particular process from the definition of waste; or
(iv) where the Minister has, in the prescribed manner, excluded any waste stream or a portion of a waste stream from the definition of waste."

According to DEA (2012)'s National Waste Information Baseline Report, fly ash together with dust from miscellaneous filter sources is considered as hazardous waste. This classification of Fly ash as hazardous waste limits fly ash utilization as the law requires the potential users to first apply for waste management licence in terms of schedule 1, category A of the NEM: WA 59 of 2008 (DEA, 2017). Alternatively, potential fly ash users are expected to apply for exemption from undergoing through waste management licence application process as per section 74 of NEM: WA or regulation 9 under Waste Classification and Management Regulations published under Government Notice R634 (DEA, 2017). All these processes are time intensive and the response is not guaranteed; however these regulatory loopholes do allow for an opportunity for waste utilization. In terms of potential legislative obstacles which may impact on execution of a South African goal to recover 50% of ash by 2024, DST (2014) identified existing policy classification, delayed licence issuance and lack of guidance as the potential foreseeable hindrances.

According to a report compiled by Zitholele Consulting (2016) and submitted to the Department of Environmental Affairs (DEA) regarding motivation for application for exemption of waste management activity licences for specific uses of pulverised coal fired boiler ash, Eskom claimed to have taken on the role of facilitator to the exemption process in order to unlock industry enablers such as the legislative constraints to allow for more ash utilization in South Africa.

On the 2nd of June 2017, South African government released a notice for *proposed regulations to exclude waste streams from definition of waste* which exclude a few activities which are undertaken from ash combustion plants as waste (DEA, 2017). The proposed exclusions of activities that can be performed through utilization of ash from combustion plants include brickmaking, block making, production of cement, landfill covering, backfill in closed mine

collieries, inorganic fertilizers, soil ameliorant, asphalt and road construction, foundations as well as bulking agent for composting (DEA, 2017). In agreement with Moon (2013)'s argument, the aforementioned proposed DEA (2017) regulations which are aimed at excluding certain waste from definition of waste will promote socio-economic benefits from ash sales without overlooking environmental aspects as the regulations also identifies potential negative and positive environmental impacts and management measures to ensure that sustainability viability is achieved. If these regulations are indeed passed, a lot of potential fly ash users will be encouraged to utilize it. What came out very strongly from the literature review of various environmental legislation frameworks is that legislation is a key driver towards ensuring sustainability and it should be used to ensure viability during the implementation of socio-economic and environmental components.

2.5 GAPS IN KNOWLEDGE

The concept of sustainability and environmental management is very broad and requires a drive from top-bottom which may include national, sectorial and organizational level to implement it. Similarly, an environmental impact of fly ash on organizational sustainability and sustainable development is also a broad topic which needs to be explored per case study in order to obtain a deep understanding per case study. Danciu (2013) argues that the concept of sustainability is not an easy one to achieve as organizations are needed to overpass a couple of sustainability stages while developing capabilities to overpower challenges which come with the said stages. What literatures or theories are silent about is the "how part". The literatures only and mainly insinuate that the responsible usage of the resources is such that the environmental protection is ensured while organizations are making profit. These are high level concepts which are farfetched and can have different approach of implementation from one organization to another; hence this study is important to explore Kriel Power Station as a case study in order to better understand its organizational context and adequate approach to ensure development of sustainable operations.

Adding to above, Drake and Spinler (2013) argue that there is a need for operational managers to generate research that empowers production methods to function more adeptly taking into account environmental and social impact of the business. This signifies the magnitude of a gap in knowledge to understand the production effects of companies on the social and environmental aspects of sustainability. Drake and Spinler (2013) further added that the aforementioned

prospective researches should engage practitioners and/or policy makers and also embrace the multidisciplinary nature of the sustainability challenge. Looking at the mere fact that most of the ash generated in South Africa is disposed of at landfill or ash dam facilities, there a pivotal role which need to be played by scientific researches in exploring the nature of various coal ash generated in various locations in the country in order to inform sustainable decision making on their management approach.

In a study undertaken by Ayanda et al (2012) on Characterization of Fly Ash Generated from Eskom Matla Power Station in Mpumalanga, it was found that fly ash consist of alkaline and heavy metals that are detrimental to human health and the environment. Disposal of fly ash within the disposal facilities can result to heavy metals leachate into soil environmental as well as water bodies (surface and groundwater) (Ayanda et al, 2012). According to Ayanda et al (2012), many countries utilize ash produced instead of disposing it. Even though this study identifies environmental impacts of ash disposal at the ash dams, it does not give direction on what needs to be done in order to better manage fly ash to minimize its environmental impacts.

Sahoo et al (2016); Van Der Merwe et al 2014; Mupambwa et al (2015); and Nawaz (2013) agree that chemical properties of fly ash varies from one source to another due to many aspects such as coal characteristics, ignition temperature levels, burning procedure, applied ratios of air and fuel, age of the ash, coal characteristics, variances in source, etc. According to Ramezanianpour (2014), the results of a study on bituminous, sub-bituminous, and lignite ashes attained from different coal-fired power stations in North America revealed a huge fly ash chemical composition variance and therefore assenting to the fact that fly ash chemical composition will differ from one generator to another due to many characteristics modifiers.

There is a notable gap in knowledge and there is more work still needed to be done in order to explore the uniqueness of fly ash characteristics which is said to be caused by various factors such as the operational regime of each specific ash generator hence the need to investigate Kriel fly ash's unique characteristics (Kruger and Krueger, 2005). Landman (2003) also conducted a literature review on fly ash which focused on aspects of solid-state chemistry and ultramarine pigments in which similarities were noted with Kruger and Krueger (2005) study in that, fly ash is a unique matter with varying physiognomies based on the coal origin as well as the boiler burning practice. Accurate determination of the chemical composition of fly ash is a key in the qualitative and quantitative analysis of the features of noxiousness and value in fly ash (Eze et

al, 2013). Ginster and Matjie (2005) identified knowledge gaps on ash utilization opportunities and location of the ash generators particularly for SASOL as the contributor for slow ash utilization.

Based on above findings, there is arguably a very strong reason to specifically investigate and understand fly ash generated from Kriel Power Station in order to employ a fitting management practice with viable sustainability aspects. The reviewed literature identifies concerns and gaps associated with ash utilization in South Africa which need to be addressed through gaining understanding of specific characters of ash from generation source.

2.6 CONCLUSION

Various pieces of theories and literatures reviewed in this chapter have definitely provided a clear overview on perceptions regarding environmental management and sustainability in global, Sub-Saharan Africa and South African context. What kept on coming up very strongly is that the sustainability concept is embraced all over the world. Countries all over the world are becoming more and more conscious towards sustainability as they realise that it is more expensive to clean up pollution than to implement sustainable economic growth which takes into account environmental and social impact as equal aspects now. Another notable drive observed with the reviewed literatures is that major funders around the world now want to see their clients implementing developments which are sustainable by ensuring viability on social, economic and environmental aspects; this has been demonstrated by Asian Development Bank on People's Republic of China, International Finance Corporation on their African funded clients and World Bank on their Central African Republic project.

It is also important to note that the implementation of sustainability concept has not been an easy undertaking as it comes with a lot of challenges such as establishment of the relevant technologies; finances, science supported measures, etc. In terms of South African context, the National Department of Environmental Affairs has already paved a way by developing National Strategies for Sustainable Development (NSSD) which is influencing the policies towards sustainability. DEA (2012) indicates that South Africa is losing a lot of revenue on a recyclable waste which gets dumped at landfill sites instead of being recovered. Theories and literatures reviewed revealed some extremely low ash utilization figures especially by South Africa's main fly ash generator which is Eskom. South Africa as a country has a 10 year plan to turn the corner

with regard to fly ash utilization; however, the figures show that the current practice is not aligned with sustainability concept.

The chapter concluded by highlighting the importance of legislation on ensuring environmental sustainability. The reviewed literatures indicated that, at times, legislation also do limit industries to optimize waste utilization due to strict requirements such as undertaking of environmental impact assessment process and obtain waste management licence before recycling certain waste. The chapter also identified gaps which need to be explored regarding environmental sustainability and fly ash management; and this study seeks to address some of the knowledge gap identified.

CHAPTER THREE

METHODOLOGICAL CONSIDERATIONS

3.1 INTRODUCTION

Chapter 3 focuses on describing the methodological approach of the study. Research methodology is a process of solving a research problem systematically; methodology includes steps that are commonly implemented by an investigator in exploring the research problem (Kothari, 1990). This chapter will include description of research positionality, recapping of research aim and objectives, research design, data analysis as well as methodological reflection.

In terms of research positionality, this chapter briefly describes two (2) research approaches which have been used throughout this research and their effect on achieving the intended outcome of this research. Subsequent to describing the research positionality, research aim and objectives are also recapped to ensure their alignment with the methodology being utilized. What is also described in this chapter is the research design together with its associated components such as description of the study area, study population, sampling procedure and data collection tools. This chapter also describes the data analysis method applied in the research as it is also critical in ensuring that the research data validity remains reputable. Every methodology applied in the research has its own strength and weaknesses; it is therefore critical for the researcher to look back and reflect on the effects of the research methodology including its advantages and disadvantages hence this chapter will also include a section to briefly discuss methodological reflections.

3.2 RESEARCH POSITIONALITY

As a person, I have always believed that things do not just happen. This belief might have been attributed by my father who, from an early age, always taught me to take a moment to briefly investigative the root cause of behaviours or formations before making conclusion about them as there is always underlying facts. My father would always tell me that my reactions to things should not be sorely motivated by an outward appearance of things; he taught me to always give myself an opportunity to apply my thoughts and common science in understanding reactions and formations before passing judgement. I am a person who always believe that in life, there is a

perceived truth and real truth; and that I should always seek to uncover the real truth through application of investigative reasoning and logic.

I guess this character of mine went even bigger when I was studying for my bachelor's degree in Environmental Science as I grew stronger in believing that truth related to objects, behaviours, formations, etc. can be obtained through putting together facts and then apply reasoning and logic on those facts to get to the real truth. I always see myself as a realistic person who always tries to keep a genuine perception of things without adding unrealistic connotations on them. When it comes to workplace behaviour, I have always believed that before I communicate any work related information (e.g. water qualities, air quality, waste figures, etc.), I must always apply reasoning and logic on those figures and the credibility of the method through which they were obtained. As a registered natural scientist who always abides with the code of conduct stipulated by South African Council for Natural Scientific Professions, I have to always uphold the profession's code of conduct through executing my activities in truth.

Based on the discussion above, I have decided to base this research's positionality on positivism as well as critical realism approaches. According to Buddharaksa (2010), positivism is defined as a scientific technique of natural science to study human doings using impartial investigation and therefore assuming the harmony of the sciences. When it comes to realism, what the rationalities indicate as genuine is accepted as the truth; and objects are accepted as having an existence sovereign to the human mind (Penn State University (PSU), 2018). Realism can be broken down into two elements which are critical and direct realism. Critical realism approach, which is adopted in this study, argues that what humans experience are feelings, not the things directly (Penn State University, 2018).

Main elements of positivism approach include the following (Sousa, 2010): firstly in terms of ontology (nature of being), positivism approach follows a continuous combinations of happenings as it involves mind-independent or objective views while making use of data collected over time (observables) and maintaining constancies. Secondly in terms of epistemology (nature of knowledge and how it is generated), positivism approach involves forecasts and objectivism in a sense that data collection is undertaken by means of observations or experimentations as well as supposition of laws. Thirdly, the methodology used by positivism approach is basically the quantitative research method which involves reasoning and induction of the collected data. Fourthly, the etiology (means of causation of circumstance) of positivism

approach is that of cause–effect kindred which is more deterministic as it involves the closed systems which leave little to no room of doubt in terms of collected data.

This research has also used a deterministic attitude of positivism approach to determine various environmental management practices for Kriel Power Station's fly ash and the eventual environmental impacts or effects resulting from such practices. Reductionism approach was also used to ensure that sets of research ideas and data aimed at responding to research questions are reduced to workable and measurable subsets for thorough scrutiny. Quantitative questionnaire survey was also used as a data collection method in order to get participants' views on various themes related to research problem and questions. Experiential observations and measurements records were also used to objectively understand the reality of the research ideas and data sets such as the characteristics of Kriel fly ash. Finally, the existing experimental test results on the subject matter were also reviewed and accepted as part of evidence to ensure that objectivity is achieved.

On the other hand, the main elements of critical realism approach include the following (Sousa, 2010): firstly, similar with positivism, the ontology for critical realism is fundamentally mind-independent which involves usage of observables and un-observables for data collection. Further in understanding the nature of being (ontology), critical realism also make use of entities, happenings; relations as well as genuine, definite, and experiential data as source of research evidence. Secondly, in terms of nature of knowledge and how it is generated (epistemology), critical realism follows numerous but imperfect and partial socially created data while putting more importance on description and explanation of the collected data as well as predicting the tendencies thereof. Thirdly, in terms of methodology, critical realism involves the use of qualitative research methods; abstraction, retroduction which is more of an abductive reasoning and retrodiction which is the act of predicting the past. Fourthly, the etiology of critical realism is based on the understanding the numerous causations carried around by the workout of intertwining influences and arrangements under changeable eventualities; propensities and counter propensities; unlike positivism approach, critical realism looks at the open systems while assessing the evidence.

Critical realism was chosen as one of the approach in this study in order to ensure objectivity by using genuine data. This approach was also used to compare trends depicted from analysing data gathered through questionnaires as well as other monitoring reports which include ground water

monitoring reports around Kriel Power Station. Qualitative method which is part of critical realism was used as another data collection method to collect data for triangulating findings gathered from a primary data collection method which is the quantitative questionnaire survey. Abductive reasoning was also used subsequent to observing participants views within questionnaire surveys and interview responses as well as existing empirical records in order to understand and deduce a simplest explanation of the evidence while retrodiction was also used to understand the state of the environmental prior to current footprint such as the ash dam footprint. Critical realism has also been useful in understanding the interconnectedness of environmental issues resulting from Kriel Power Station's fly ash and its disposal at the ash dams.

In conclusion, the positionality of the researcher was mainly around the two (2) approaches which are critical realism and positivism which were used to test different hypothesis throughout the study. The aforementioned approaches were implemented and found to be adequate and effective in addressing the research questions, aim and objectives.

3.3 RECAPPING RESEARCH AIM AND OBJECTIVES

The primary aim of this study is to investigate alternative ways in which fly ash can be managed effectively to minimize environmental impacts in order to ensure alignment with the notion of sustainable development. The objective of this research include understanding chemical composition of fly ash through examination; followed by identifying potential impacts of fly ash on environmental, social and economic aspects as well as assessing the extent at which current fly ash management practice is aligned with contemporary principles of environmental management. In addition to above, other objectives of this study also include the following: to establish the socio-economic and environmental opportunities that fly ash present within the context of contemporary environmental and sustainable discourse; to investigate the availability and the role of technology in reducing generation as well as to evaluate if whether integrated environmental management principles is critical in order to optimize fly ash utilization.

3.4 RESEARCH DESIGN

According to Creswell (2014), research design is defined as the types of probe within qualitative, quantitative, and mixed methods approaches that offers a particular direction for

techniques in the plan of the study. This section presents research methods which were applied, description of the research site, study population and sampling procedure which was used in conducting this research as well as data collection tools used.

Zainal (2007) referred to case studies as a method which enables a researcher to carefully study the data within a specific context in detail with a focus towards a selected small physical area or a very narrow number of persons as the themes of study. Yin (2003) argues that the case study's exclusive strength is its capability to deal with a diversity of evidence, documents, artefacts, interviews, and observations which are further than what might be available in the conservative historic study. Yin (2003) further identifies that only three case studies types are suitable for research purpose; namely: explanatory, descriptive, and exploratory case studies. For this research, an exploratory case study was used merely because the research topic has not been explored by many researchers before in South Africa. Exploratory case study is defined by Zainal (2007) as, "a tool to explore any phenomenon in the data which serves as a point of interest to the researcher". In addition, exploratory case study was also selected in line with the research positionality as well as research methods.

3.4.1 Research Methods

(i) Qualitative research method

One of the research methods used in this research is the qualitative research method. According to Creswell (2014), qualitative research is a method of investigating the sense of individuals or groups' attribute to a social problem. Open ended interview questions which were oriented around participant's setting and aligned with the research questions were developed. The researcher used email bound interviews. Existing documents and records were also reviewed as part of qualitative research method.

(ii) Quantitative research method

Quantitative research method was also used in order to understand the measurable data gathered. Quantitative research is critical in testing objective theories by examining the relationship among variables (Creswell, 2014). Existing quantitative data on Kriel fly ash characteristics was used. Questionnaire surveys were also conducted in order to gather information from

participants. Performance, attitude and observational data were used to perform data analysis and interpretation (Creswell, 2014).

3.4.2 Description of Research Site

Eskom‘s operational mandate as a parastatal organization is to efficiently and sustainably provide electricity to South Africa. This process includes electricity generation, transmission, and distribution and sales to South Africa. Eskom has various divisions such as Generation (Gx), Transmission (Tx) and Distribution (Dx) which, through execution of their divisional mandate, can result into adverse environmental impacts. Tx and Dx divisions are primarily responsible for installing the transmission lines (e.g. 475 kV lines) and distribution lines (e.g. 11 kV lines) respectively. During the establishment and implementation of transmission and distribution lines, Eskom can cause environmental impacts such as water pollution through crossing, impeding and altering the wetlands and river systems and banks, ecological dislocation and degradation through clearance of servitudes for the power lines, avifauna dislocation and electrocution by erected power lines (Eskom, 2017).

Eskom’s Generation division (Gx) is the basis of Eskom’s existence as everything is initiated there. Gx division consist of fleet of power stations using different technologies such as coal fired power stations, hydro power plants, nuclear power plants. Environmental impacts associated with Eskom’s coal fired power stations include air pollution caused by coal combustion which results into emission of fly ash through smoke stacks and ash disposal sites; Eskom coal fired power stations are also associated with significant ecological footprint as they require huge land for their establishment e.g. land required to set up ash disposal areas known as ash dams. Coal fired power stations also consumes a lot of water which makes them strategic water users in South Africa. Compared to hydro and nuclear power plants, coal fired power stations takes over a huge amount of land in which the facilities such as ash dam disposal facilities and the associated ash water retention dams can be established.

Eskom has a total number of 15 coal fired power stations across South Africa. Eskom Kriel Power Station is one of the 15 aforementioned coal-fired power stations. Kriel Power Station is located along Bethal/Ogies road at Mpumalanga province of South Africa. It is located about 4 km from Matla Power Station just outside the town of Kriel (refer to figure 3.1).

Figure 3.1: Kriel Power Station site boundary (marked with red)



Source: Kriel Power Station (2017)

Kriel Power Station receives both underground and opencast coal from the mines for combustion in the boilers as part of the energy generation process. As a by-product of coal combustion in the boilers, a significant amount of fly and coarse ash is produced. The aforesaid ash is largely disposed of at the existing wet ash dam facility as waste while a very small portion of it is recycled through to the cement manufacturers.

According to an investigation carried out by Jones and Wagener (2014), the existing ash dams' facility at Kriel Power Station is currently having an approximated 6.5 years of life remaining, up to July 2023. The study concluded that the most feasible option to provide additional deposition capacity is to construct a new ash dam. The diminishing life span of the existing ash dam facility is understandably due to the extension of the station's life span with another 30 years from year 2010 to year 2039; it is also for this reason that this study is critically needed at Kriel Power Station to inform and assist in the decision making. As a precautionary measure, the station has also reached an agreement with the neighbouring sister power station of Matla, that Kriel will transfer some of its ash to Matla ash dam facility, in a case where Kriel completely runs out of ashing space, while still busy executing a plan to construct a new ash dam. The aforementioned precautionary plan, if executed, will definitely expand Kriel's environmental footprint due to the fact that new ash transfer lines will have to be established

linking the two stations and these lines will be running within the vegetated and wetland area; it also increases air quality impacts in the receiving Matla ash dam facility.

In addition to above, Kriel Power Station is located adjacent to the agricultural land with farmers who still relies on borehole water as their primary source of water and that of their livestock; this basically mean that polluted groundwater due to ash disposal activities will continue to have a socio-economic impact on these farmers. Kriel Power Station is also surrounded by communities such as farming communities, Rietfontein Township, Kriel town and Thubelihle Township within 15 kilometres radius that can potentially be impacted by air pollution from ash dam operation resulting into human health impacts.

In order to ensure environmental sustainability, it was important to undertake this study to investigate the feasible environmental management alternatives which can be applied to ensure that sustainable fly ash management is achieved. Communities surrounding Kriel Power Station are composed of mostly low and middle class personnel; an increase in ash utilization can create job opportunities through activities such as establishment of brick manufacturing firms, concrete production, etc. This study will also be shared across the whole of Eskom organization for benchmarking and also for informing the decision making process.

3.4.3 Study Population and Sampling Procedure

3.4.3.1 Study Population

Best and Kahn (1999) described the study population as any collection of persons that shares one or more physiognomies which interest the researcher. A total of 156 individuals were identified as comprising the overall number of population for this study.

Kriel Power Station has a total number of around 736 employees who are widely spread across departments such as operating, maintenance, human resource, Engineering, Production, Projects Integration, Risk and Assurance and Outage; however, only few employees out of the 692 employees were identified as falling within the study population as per the definition above. The department which have relevant individuals who formed part of the study population include Ash and Coal as well as Operating departments; Auxiliary (Civil & Materials Handling)

Engineering and Risk and Assurance department. The total number of individuals falling under the study population from Kriel Power Station amounted to 56 personnel.

Further to above indicated study population sources and number, the researcher also identified an additional 100 personnel from various Eskom business units and other sectors who also form part of the study population as per the definition above; these include environmental practitioners from all other 14 coal fired power stations, relevant Engineers from Eskom's Engineering department (Project Development Department), environmental practitioners from Eskom's sustainability division (Air Quality CoE, Water CoE, Waste CoE, EIA CoE), Relevant officials from Department of Environmental Affairs (DEA), Department of Water and Sanitation (DWS) and Nkangala District Municipality and Kriel Power Station's Ash Optimization team members (include ash recycler). The researcher is a registered member of South African Coal Ash Association (SACAA) and has therefore also included few members from SACAA as part of the study population.

3.4.3.2 Sampling Procedure

(i) Sampling procedure for human participants

Purposive sampling was used as a primary sampling procedure to select fitting sample from the study population. According to Teddlie and Yu (2007), purposive sampling is intended to select a diminutive quantity of events that will produce the greatest data regarding a specific occurrence. In order to obtain an acceptable representativeness from the sample, critical case sampling which is a subset of purposive sampling was also used to select the sample. Based on the fact that the study population comprised of 156 individuals whom the researcher viewed as small number, all 156 individuals within the study population were selected as part of the sample through the use of critical case sampling technique (refer to table 3.1). The inclusion of all 156 participants in the sample was undertaken to obtain a strong overall representativeness of the sample. Snowball sampling was also used as a secondary sampling procedure. Snowball sampling is referred to as a chain sampling simply because one participant or respondent can refer the researcher to another participant who in turn further refers the researcher again to another participant and so on (Teddlie and Yu, 2007). A total of 5 participants were included in the participants' database through snowball sampling referrals (more detail on table 3.1 below).

During the sampling process, only one criterion was used to determine sampled participants' suitability to participate in the study; and the condition was that participants must at least have a minimum experience of 3 years with regard to coal or fly ash characters, impacts and management. This suitability requirement was set in order to ensure that acceptable views from participants who have basic knowledge of fly ash, its impacts as well as its opportunities were sourced.

Table 3.1: Sample size, selection justification and number of responses received per industry

Participants' Industry	Sample Size	Justification	Responses received
Environmental Practitioners – Eskom	*50*	These included environmental practitioners across all Eskom coal fired power stations. Environmental practitioners in Eskom coal power station plays critical role in the process of planning, designing and operation of waste disposal facilities which include ash dumps or dams. Environmental Practitioners are the key persons in all power stations enforcing adequate management of ash. There is about 50 environmental practitioners in all 15 coal fired power stations at Eskom and were all purposefully sampled as key participants to share their deep knowledge on the research topic.	*39*
Sustainability Centre of Excellence (CoE)	*17*	These included water CoE, Environmental Impact Assessment (EIA) CoE, Waste and Biodiversity CoE, Air Quality CoE, Reporting, Assurance and Systems CoE. The sampled participants' purposefully sampled for their expertise on air, water, land and waste. They have vast experience related to various power stations which they oversee and support with expert advices. Their importance in this study is to assist with their expert knowledge related to the impacts of fly ash on water, land and air as well as gathering their view points in terms of contemporary and sustainable ash management practices.	*13*
Environmental Consultancy	*15*	These included consultancy which currently assist Kriel Power Station with fugitive dust and ground water monitoring at the ash dam complex. Environmental consultants are regarded as specialists on their fields hence they were included in this project to share their expert knowledge on impact of ash on land, water and air conditions as well as to provide their views on the contemporary principles of fly management which ensures sustainability.	*11*
Engineering - Eskom	*13*	These included civil engineers, chief advisors and other engineers involved in ash dam design and operations. In terms of designing ash dams, chief advisors who are only 3 across Eskom takes a lead role; however on-site civil and dust handling plant engineers are involved in writing operational scopes to ensure that dry dust handling system and ash dams are well maintained; and their knowledge is therefore important in understanding the issues related to ash dam designs and if they think opportunities do exist to manage fly ash differently beside the current way of disposing into the ash dams.	*13*

Kriel Power Station's Ash Dam Operators	*6*	Ash dam operators (managers and supervisors) at Kriel Power Station are important persons who understand the relationship of ash management practices and environmental impacts; they also have an understanding of other measures that may be pulled in to ensure sustainable fly ash management. They also have a general idea with regard to the effectiveness of current ways of fly ash storage.	*6*
Authorities /Government	*15*	These included the Department of Environmental Affairs (DEA), Department of Water and Sanitation (DWS), GDARD, Nkangala District Municipality, Ekurhuleni. They regulate the manner in which the industry must manage its waste with a primary objective to protect water, air, and land. The identified government officials were identified based on their vast knowledge in dealing with fly ash related cases which include authorizations and incidents. They provide an insight from authority perspective with regard to impacts associated with fly ash and sustainable opportunities available to better manage fly ash if there is any.	*10*
Kriel Power Station's Ash Optimization Committee	*8*	This is a group of individuals which include personnel from Ulula Ash Resources (ash recycler), Material Handling Maintenance, Operating, Production, Environment, Commercial, Civil Engineering, and Coal Management. These individuals have full understanding of the social, economic and environmental impacts associated with ash dam operation as they have a better understanding of fly ash's chemical composition. They are the champions on an investigation committee which was established to seek opportunities through ash can be utilized and to implement any existing solutions. Their comprehensive view is critical for this study.	*8*
Mining & SASOL	*7*	Few participants from mining industry as well as Sasol were sampled to provide their views on fly ash management. Participants from the mine were selected on the basis that fly ash is the by-product of their product which is coal and they therefore have an understanding of how a by-product of their product should be managed through the safety data sheets. 3 Sasol representatives who have an extensive understanding of fly ash from coal fired power station (also known as steaming plant in Sasol) were selected to share their on the link between fly ash impacts and management approach as well as their views if sustainable fly ash management practices do exist.	*10 (3received through snowball)*
Research & Testing and Kriel's Chemical Service Departments	*10*	Relevant individuals from Eskom's centralized Research and Testing department as well as Kriel Power Station's Chemical Services Department were purposefully included within the sampled participants as they analyse coal and ash chemical on a daily basis in order to understand the composition thereof. Due to their expertise in chemistry, they also understand various chemical reactions within fly ash and its impact on land, air and water. They were sampled to share their rich understanding of fly ash and also to share their views on how it can be managed better.	*8*
Other – Eskom	*15*	These included includes risk & assurance, Group Capital and Operating representatives as well as other relevant environmental activists. These are participants who do not fall under any segments or sectors above, however they are deemed knowledgeable with regard to fly ash topic. These individual were also included to share their knowledge of fly ash and its impacts as well as its sustainable management.	*17 (2 received through snowball)*
TOTAL	***156***		***135***
TOTAL%	***100%***		***86.5%***

Source: field based material

(ii) Sampling procedure for existing records/data

The other important aspect of this study was to probe the chemical composition of fly ash as well as the environmental impact of fly ash disposal.

Chemical composition of fly ash- coal ash assessment report (Golder Associates, 2016)

In order to understand fly ash chemical composition, a most recent Kriel Power Station's coal ash assessment report developed by Golder Associate was selected for inclusion as part of sample frame. A sampling procedure followed to probe the chemical composition of fly ash included collection of four representative sample batches for water conditioned fresh fly ash from conveyor belt, fresh fly ash from the plant, old fly ash under conveyor belt as well as weathered fly ash from ash dam.

A representative fresh sample of fly ash (ID: 473959) conditioned with 30% water was collected directly from the conveyor belt which is few metres away from the ash dams while another set of representative older sample of fly ash (ID: 473977) was collected from heaps of ash below the conveyor belt still few metres away from the ash dams. Another set of dry and fresh fly ash (ID: 476160) sample was directly collected from the plant (unit 1 dry dust plant). The samples collected in from the plant were collected into a plastic bag using a small hand spade by Eskom employees and then submitted to Golder Associates. Another representative sample of weathered fly ash for more than one year was taken from ash dam 1; with approximately 7 kg sample collected from ash dam 1 to provide a representative sample of oxidised ash material on the dam All samples collected outside the plant were collected by Golder Associates personnel. Weathered samples collected from the dump were collected by augering to a depth of approximately 40 cm before collecting a number of discrete samples at different locations on the dump. (Golder Associates, 2016).

Environmental impact of fly ash disposal – groundwater monitoring report (GHT, 2017):

Data from the latest routine groundwater monitoring report developed by Geo-Hydro Technologies (GHT) was also used to understand the impact of fly ash on groundwater. A total of five boreholes located around the ash dams were selected to form part of the sample frame; these include Kriel borehole 06D located on the Southern side of the ash dam, borehole 08D

located on the Eastern side, borehole 35 located on the western side, borehole 28 located on the Southern side and borehole 62 which is located on the eastern side. Organic and inorganic parameters were included as part of the sampling procedure.

The sampling procedure included the following protocols (GHT, 2017):

- Noting of location, time of day and date of the site assessment;
- Lowering the water level measuring device or equipment into the borehole until water surface is encountered;
- Rinse the sampler on surface and make sure that everything works well;
- Measuring the distance from water surface to reference measuring point on borehole casing and record on the site assessment and response form;
- Collecting the water sample;
- Filling sample bottle to the brim; and
- Preserving sample accordingly and submit for analyses to an accredited laboratory.

3.4.4 Data Collection Tools

(i) Questionnaire Survey

Structured questionnaires survey was used as a primary data collection method. According to Saunders *et al* (2009), questionnaires can be used as a data collection instrument for three types of data variables which include opinions, behaviour and attributes. In this study, the questionnaire was used to understand participants' perception with regard to the research problem or research themes; these viewpoints portrayed participants' opinions and attributes.

Structured questionnaires were administered to participants in electronic format. The questionnaire was constructed with 2 sections which are Section A and Section B. Section A contained general information related to demography. Section B contained 25 Likert-style rating scale questions with a scale of 1 – 5. The scale was structured as follows: 1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; and 5 = Strongly Agree.

A total of 144 questionnaires were communicated to sampled participants through electronic means and later tracked for any feedback. Email reminders, to follow-up with non-responsive participants, were sent through every two weeks during the period of four weeks in which the

questionnaire survey was being administered. The 2 weekly follow ups did upsurge the response level significantly. Out of a total of 144 participants who were purposively sampled, 118 (82%) participants responded to the questionnaire while 26 (18%) participants could not respond. The electronic transmittal proved to be effective as it did yield a response rate which is above the 80% mark. A total of 5 participants were included in the sample through chain sampling as the researcher was referred to these participants by another participant. All 5 participants who were sampled through snowball sampling did respond to the questionnaire and therefore putting the overall number of participants who responded to the questionnaire at 123.

(i) Interviews (Qualitative method)

Semi-structured interviews were used as another data collection method with an objective of triangulating the responses gathered from the questionnaire survey which is the primary data collection method. According to Cohen and Crabtree (2006), semi-structured interviews afford participants the liberty to share their observations using personal self-expressions unlike structured interviews. The structure of interview guides or questions included 2 sections which are Section A and Section B. Section A contained general information related to demography while Section B contained interview questions. The interview guide consisted of 15 questions of which 13 of them were open ended while the remaining 3 of those were dichotomous questions with an option for participants to provide additional comments.

A total of 12 participants were invited to participate in the research interviews via email. Quite interestingly, all 12 participants requested that emails must be used as a communication medium between the researcher and them to undertake interviews. Analogous semi-structured interview guides together with project information sheets and consent letters were then administered to all 12 participants in electronic format. Email reminders, to follow-up with non-responsive participants, were sent through every two weeks during the period of four weeks when the interviews were being administered. Out of a total of 12 participants who were purposively sampled, 12 (100%) participants responded to the interview questions. The electronic transmittal proved to be effective as it did yield a response rate which is above the 100% mark.

(ii) Existing records

Collection of data from existing records was also used as a secondary data collection method. According to Hox and Boeije (2005), secondary data refers to readily available information which was originally assembled for a dissimilar purpose to its current use. Two existing data sources were used; and these include groundwater monitoring report which was compiled by Geo-Hydro Technologies Consulting in August 2017 and coal ash assessment report which was developed by Golder Associates in September 2016 for Eskom Kriel Power Station.

With regard to collection of groundwater performance results, the researcher reviewed the routine monitoring report with the special focus on the results of five boreholes (boreholes identities are KB06D, KB08D, KB35, KB28, KB62) located around Kriel Power Station's ash dam complex. The researcher then extracted results for both organic and inorganic parameters from the report which directly indicate the impact of ash disposal into the ground for inclusion as evidence for this study. The data extracted from existing ground water report included performance results for parameters such as, but not limited to the following: PH, Chemical Oxygen Demand (COD), Sulphates, etc.

In terms of data collection to determine chemical composition of fly ash, the researcher reviewed the existing coal ash assessment report with the special focus on the results of four representative sample batches for water-conditioned fresh fly ash from conveyor belt, fresh fly ash from the plant, old fly ash under conveyor belt as well as weathered fly ash from ash dam. The researcher then extracted the results for both organic and inorganic parameters from the report which then provide a representative evidence of chemical composition of fly ash.

3.5 DATA ANALYSIS

Data analysis process can be referred to as a systematic approach meant to organize field data to enhance its connotation; data analysis activity is an untidy and unstraightforward process which also requires more time to execute (Marshall and Rossman, 1990).

(i) Data analysis for questionnaire survey responses (primary data)

Questionnaire surveys responses which were all received through electronic means were saved in one electronic folder named field work responses for questionnaire survey. All the collected questionnaire surveys responses were then reviewed for any gaps and those with any identified gaps were then disqualified and proof of disqualification retained. In order to ensure easiness during primary data analysis process, participants were asked to rate their responses to the questions in a Likert scale format with a rating scale starting from 1 to 5. Qualifying questionnaires were then codified, before unique identifiers of various data pieces were allocated to all responses ranging from 1 till questionnaire 123. All the collected data was then converted into a series of numbers, as per Likert scale, for data capturing through Microsoft Excel spreadsheet for further statistical analyses. Prior to statistical examination, the data was assessed and cleaned through analysing organized data for precision. Any inaccuracies which were picked up in the data were addressed promptly through comparing the suspicious data with original data on the questionnaires (Bryman and Bell, 2007).

Subsequent to capturing of all participants' responses in Microsoft Excel spreadsheet, responses based on the 25 questions which were included in the survey were then filtered using sort and filter feature to obtain an overall participants responses; then a Microsoft Excel spreadsheet summation of participants' responses to the questions was established as per the arrangement of Likert scale. This summation then gave a simple but detailed analysis of participants' views per question, which then enabled the researcher to generate overall fieldwork evidence in a form of tables, graphs, charts and texts. The aforementioned spreadsheet also included participant's industry, role and expertise.

The researcher chose to use Microsoft Excel for codifying data because he is competent in operating the software package which offers great statistical functions. The importance of coding the collected data with Microsoft Excel was to ensure that the data can easily be retrievable in future. Microsoft Excel includes a whole lot of features which include complex statistical distribution and probability tests. In a nutshell, Microsoft Excel allows a researcher to easily capture and save information, use its recovery abilities, engage in diverse numerical analyses, produce graphs and numerical reports, and write project reports, as it is the case with this research.

(ii) *Data analysis for semi-structured interviews responses (triangulating data)*

Responses to interview questions which were all received through electronic means were saved in one electronic folder named field work responses for interview questions. All the collected responses were then reviewed for any gaps and those with any identified gaps were then disqualified and proof of disqualification retained. The entire qualifying interview responses were then codified; and unique identifiers were then allocated to each response. Responses were received from 12 participants. All the responses from 12 participants were then captured into Microsoft Excel spreadsheet as texts. Subsequent to capturing of all participants' responses in Microsoft Excel spreadsheet, participants responses based on the 15 interview questions were then interpreted and summarised in order to generate overall fieldwork evidence in a form of tables, graphs, charts and texts.

(iii) *Data analysis for existing records (secondary data)*

Data analysis to determine chemical elements for fly ash:

The researcher used existing data to establish the chemical composition of fly ash. The ash samples were sent to UIS Analytical Service which is a SANAS-accredited laboratory. Analysis undertaken as part of determining chemical composition of fly ash included the following (Golder Associates, 2016):

- Total elemental composition by XRF (majors) and acid digestion (trace elements);
- Di-ionised water leach (Australian Standard Leach Procedure - ASLP) for mono disposed, non-putrescible material.
- Mineralogical analysis by X-ray Diffraction;
- Whole Effluent Toxicity Test (WETT);
- Organic screening (zero head space); and
- A governmental Notice Regulation (GNR) 635 criterion for determining Total Material Type concentration threshold limits on fly ash was used.
-

The researcher then extracted data which was already analysed by Golder Associates (2016) for inclusion in the research as part of findings as well as for derivation of further analysis and discussions in this study.

Data analysis to determine groundwater chemical elements:

The researcher used an existing data to determine groundwater impact of fly ash disposal. Due to the fact that Kriel Power Station has no WUL yet, all water samples from each monitoring site (2014 to 2016) was classified according to the SABS South African National Standard: Drinking water SANS 241-2:2015 Edition 1 and according to the SANS 241:2006 Edition 6.1 (GHT, 2017). Statistical analyses were undertaken on the groundwater quality data. The following inorganic and organic parameters were tested on the 5 sampled boreholes as indicated under 3.4.4 above. The water samples are analysed by an accredited laboratory (GHT, 2017). The researcher then extracted data which was already analysed by GHT (2016) for inclusion in the research as part of findings as well as for derivation of further analysis and discussions in this study.

3.6 METHODOLOGICAL REFLECTION

Research methodology is a critical component in the research stages which directly links with the success and/or failure of the research. In other words, if the research methodology is watertight, the research outcome is also likely to be positive while opposite can be the case. It is important to take note that challenges are and will always avail themselves during execution of research methodology; however, what remains critical is to ensure that such challenges do not render the collected data unreliable and invalid. This section therefore reviews and reflects the outcome of methodologies implemented throughout this study in relation with the integrity of data collected.

As a starting point, it is important to reflect on the positionality which this research had undertaken as outlined in section 3.2 above. The researcher went for positivism as well as critical realism as research approaches. The aforementioned two approaches suited the research and researcher very well especially during the process of establishing research methods as well as the sample frame. The aforementioned selected approaches together with the fact that the researcher is an Eskom employee, affected the study positively in terms of assisting the researcher to appreciate the objectivity, reliability and validity of the study. As an Eskom employee, the researcher understand that Eskom as an organization is striving to achieve sustainable business operations which is also aimed at reducing environmental footprint; hence

it was easier for the researcher to objectively apply positivism and critical realism approaches to the benefit of the study and Eskom.

Usage of quantitative research method in terms of administering questionnaire surveys assisted the research to gather very detailed responses from participants which also provided an overall representative sample. The creation of the questionnaire survey and interview guides began with the generation of statements from the literature review as well as ideas from the researcher's supervisor for this project. The formulation of statements included in the research instruments was undertaken under full supervision and consultation with Professor D. Simatele, who supervised this dissertation and is also an expert in the field of study. The questionnaire survey and interview guide instruments were designed with an objective to yield maximum understanding of the statements by the participants, and were also simplified by the inclusion of straightforward instructions under section A which explained the process to complete the questionnaire and interview guide. As part of the methodology, participants' were guaranteed of the anonymity and privacy of their data. This upfront assurance motivated participants to complete the questionnaires and interview guides openly.

Quantitative research method was also critical in coding, interpreting and analysing the data collected through the questionnaire survey as well as the interview questions. Running of semi-structured interviews was undertaken to gather participants' views in order to triangulate responses collected through questionnaire survey. As part of positivism approach, scientifically tested evidence was obtained from existing data which was then assessed through critical realism approach. These two approaches (positivism and critical realism) were very critical in further validating and strengthening the research findings.

In terms of sampling process, purposive sampling which is aligned with positivism philosophy yielded expected results as all participants who were purposefully sampled did respond with a great detail. Around 85% of participants who responded to both interview questions and questionnaire have more than 5 years' experience dealing with fly ash as well as coal; mixture of these participants included senior managers, middle managers, senior advisors, line managers, supervisors, senior consultants, etc. which then provide an informed and detailed participants responses. The approach used of developing two data collection tools from human participants in terms of survey and semi-structured interviews also yielded positive results as the response rate was 82% for those who chose to participate in the survey and 100% for those who

opted for interview. Communication with participants through electronic means (emails) also worked effectively as most participants emailed their responses on the first electronic request sent to them while only few had to be reminded after two weeks. The secondary data sources in terms of groundwater report as well as coal ash assessment report also provided in-depth information which was good enough to provide a comprehensive understanding of chemical composition of fly ash as well as fly ash impact on ground water.

In terms of analysis of data, usage of Microsoft Excel to analyse data gathered from human participants was also effective without any challenges. Similarly, sampling and data analysis methods used to collected data in the existing records related to fly ash chemical composition as well as impact of fly ash on groundwater were also watertight. As indicated in section 3.5 above, the existing data was analysed in the reputable laboratories which are SANAS accredited. In a nutshell, the procedure followed to collect data for this study was very smooth in terms of its execution and very limited challenges were encountered.

3.7 CONCLUSION

Chapter 3 has indeed put in clarity the methodology adopted by this study. What was noted as key from the beginning of the chapter was positivism and critical realism approach which the researcher chose to align the methodology of this study with. What was also evident throughout this chapter was that, the researcher's positionality is significant in designing the research. As a result, qualitative and quantitative research methods were used in this study. Questionnaire survey and interview guides were used as the instruments for collecting data while existing records were also used to collect secondary data. The purposive sampling procedure used to select research sample also proved to be effective as it yielded information rich responses from participants.

CHAPTER FOUR

PRESENTATION OF RESEARCH FINDINGS

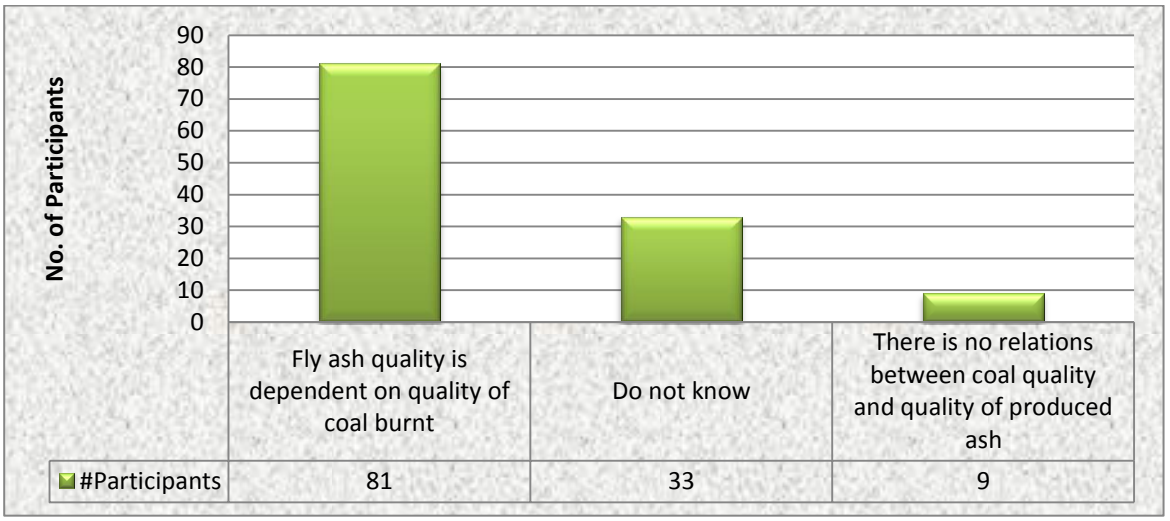
4.1 INTRODUCTION

This chapter is dedicated to presenting the empirical evidence or research findings from the research process. The chapter is structured around the key thematic content identified in research questions. At the outset, chapter 4 presents empirical evidence regarding the chemical composition of Kriel Power Station's fly ash followed by presentation of the assessment outcome with regard to the alignment of the current fly ash management practice with contemporary principles of environmental management in Kriel Power Station. Investigation results with regard to social, economic and environmental opportunities presented by fly ash within the context of contemporary environmental and sustainable discourse forms part of the evidence presented in this chapter. Chapter 4 also presents the critical empirical evidence associated with the exploration outcome of the potential impacts of fly ash on environmental, social, economic aspect. Evidence related to the investigation of technological aspects which can be deployed in order to reduce the generation of fly ash and also to optimize fly ash utilization are also presented in this chapter. Last but not least, chapter 4 concludes with a presentation of evidence related to a review outcome of the importance of integrated environmental management principles in optimizing fly ash utilization.

4.2 AN ASSESSMENT OF THE CHEMICAL COMPOSITION OF FLY ASH AT KRIEL POWER STATION

This section presents data collected from the field which include participants' viewpoints obtained through questionnaires and interviews as well as existing evidence gathered through scientific observations or experiments which are relevant in understanding the determinants and actual chemical composition of Kriel Power Station's fly ash. As part of an inclusive approach and as a starting point in understanding the chemical composition of fly ash, it was important that the primary determinants of fly ash character get appreciated. As a result, participants were asked to share their views on the link between coal quality (input material) and generated fly ash (by-product); and the fieldwork results summarising participants' perceptions in this regard are indicated on figure 4.1 below.

Figure 4.1: Participants' perceptions on the effect of coal on fly ash qualities



Source: field based material – refer to Annexure A1

Based on figure 4.1 above, it is evident that most participants' views the quality of coal burnt as influential on the chemical composition of the fly ash produced as 66% of participants indicated that there is a link between fly ash quality and coal burnt while 7% do not perceive that the quality of coal burnt has any determination on fly ash quality. A significant number of participants (27%) do not know. Putting forward his additional views related to the statement above, one practitioner from coal fired power station also indicated that, "*coal quality more often refers to the calorific value and %ash, not necessarily the makeup of the fly ash*"-*(*Pers.com 2017a*)*.The empirical evidence presented in figure 4.1 suggest that fly ash characteristics will differ or match based on the quality of coal burnt hence it is important to understand the chemical composition of Kriel Power Station's fly ash.

Subsequent to understanding that there is a relationship between coal quality and fly ash generated, it is also important to identify the chemical composition of Kriel Power Station's fly ash. Knowledge of the chemical composition of the fly ash is important in further exploring potential environmental impacts and utilization opportunities which could respectively result from, and be pursued from Kriel Power Station's fly ash; in addition, understanding the fly ash character will also assist in determining the sustainable management practice which can be implemented. Table 4.1 below indicate the main oxides within Kriel Power Station's fly ash; while table 4.2 depicts the total trace elements found in Kriel Power Station's fly ash.

Table 4.1: Chemical composition of Kriel Power Station's fly ash in percentage units

Main Elements (Main Oxides)	Sample Sets and Sample Areas			
	Fresh Fly Ash on conveyor (473959)	Old Fly Ash – below conveyor (473977)	Weathered fly ash (473953)	Fresh fly ash (476160)
SiO2, Silicon Dioxide	50.8	47.9	48.5	51.1
Al2O3, Aluminum Oxide	26.2	25.9	21.2	30.9
Fe (total), Iron	2.17	2.21	3.61	2.33
Fe2O3, ferric oxide	3.10	1.54	5.17	1.63
TiO2, titanium dioxide	1.45	1.38	1.37	1.76
CaO, Calcium oxide	6.73	5.89	9.15	9.06
MgO, magnesium oxide	1.20	1.05	1.96	2.09
Na2O, sodium oxide	0.210	0.190	0.260	0.340
K2O, potassium oxide	0.755	0.777	0.843	1.012
MnO, Manganese oxide	0.031	0.034	0.044	0.044
P, Phosphorus	0.193	0.216	0.227	0.285
Ba, Barium	0.115	0.113	0.139	0.177
Cr, Chromium	0.013	0.019	0.013	0.017
Cu, Copper	0.006	0.004	0.005	0.006
Ni, Nickel	0.006	0.005	0.006	0.006
Pb, Lead	0.001	0.003	0.001	0.001
Sr, Strontium	0.170	0.158	0.212	0.268
V, Vanadium	0.11	0.011	0.010	0.014
Zn, Zinc	0.002	0.002	0.004	0.002
Zr, Zirconium	0.027	0.023	0.026	0.030
C, Carbon	0.830	0.830	1.220	0.520
S, Sulfur	0.210	0.230	0.150	0.310
LOI, Loss on ignition	8.8	14.3	11.6	0.7

Source: Golder Associates (2016)

Table 4.1 above indicate that, silicon dioxides are, by far, the main attributes of fly ash followed by aluminium oxides. Sulphur content within fly ash is amongst the elements which are the smallest in the composite. What is also noteworthy is that fresh fly ash contains more silicon

dioxides and aluminium oxides than other sample batches. Elements such as Nickel, Copper, and Lead have least concentrations within Kriel Power Station's fly ash.

Table 4.2: Total Trace Elements found in Kriel Power Station's fly ash

Elements/Chemical Substance in fly ash	Unit	Fresh Fly Ash on Conveyor	Old Fly ash below conveyor	Weathered Fly Ash (473953)	Fresh Fly Ash
Al	%	13.87	13.71	11.19	16.35
AS, Arsenic	Mg/kg	7.7	8.3	8.7	8.9
B, Boron	Mg/kg	127.2	98.5	140.1	168.1
Ba, Barium	Mg/kg	1121	1107	1340	1733
Ca, Calcium	%	0.71	0.71	0.71	0.71
Cd, Cadmium	Mg/kg	0.1	0.1	0.1	0.1
Co, Cobalt	Mg/kg	11.7	10.3	12	14.8
Cr(T), Chromium Total	Mg/kg	127	179	125	166
Cu, Copper	Mg/kg	58.1	39.6	48.7	59.7
Fe, Iron	%	2.17	2.21	3.61	2.33
Hg, Mercury	Mg/kg	0.08	0.05	0.08	0.04
K, Potassium	%	0.63	0.65	0.70	0.84
Mg, Magnesium	%	0.72	0.63	1.18	1.26
Mn, Manganese	Mg/kg	233	258	323	335
Mo, Molybdenum	Mg/kg	5.66	4.9	4.84	5.49
Na,	%	0.16	0.14	0.19	0.25
Ni, Nickel	Mg/kg	28.6	26	28.3	33.5
Pb, Lead	Mg/kg	35.5	32.3	34.2	38.1
Sb, Antimony	Mg/kg	1.16	1.17	1.01	1.6
Se, Selenium	Mg/kg	0.72	0.87	0.9	1.01
Si,	%	23.75	22.39	22.65	23.89
Ti	%	0.87	0.83	0.82	1.06
V, Vanadium	Mg/kg	98	98	103	115
Zn, Zinc	Mg/kg	27	22	55	29

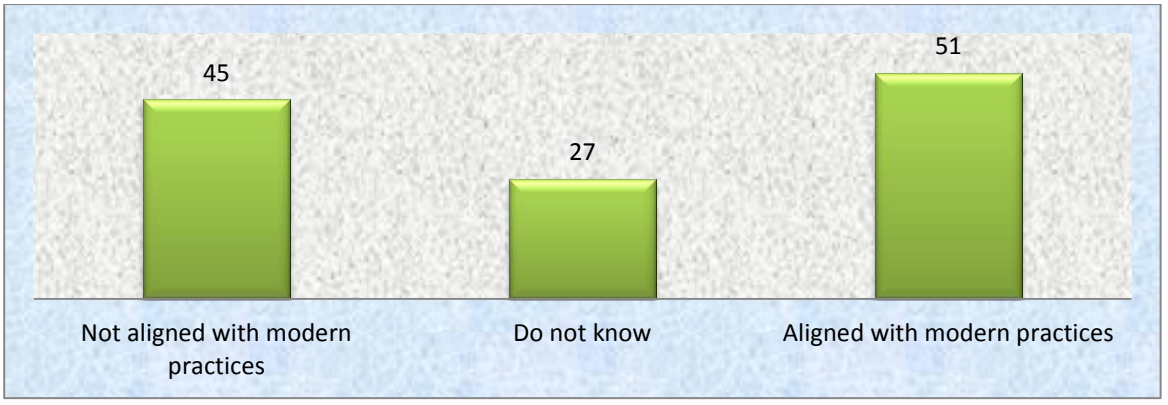
Source: Golder Associates (2016)

Based on the results as indicated in table 4.2 above, percentages for silicon are the highest in Kriel Power Station's fly ash chemical composition and therefore aligning with the results indicated in table 4.1 above. Another notable element is manganese which is mostly high on fresh fly ash sample batch as well as barium which is above 1000mg/kg in all samples taken. Arsenic is among the chemical elements within Kriel Power Station's fly ash which are above 7.5 mg/kg while chemicals such as mercury and cadmium are found to be less than 1mg/kg. The diversity of chemical elements within Kriel Power Station's fly ash as indicated in table 4.1 and 4.2 above present an exploration opportunity for potential further use; however, Kriel Power Station's fly ash also contains chemicals such as arsenic which can potentially be harmful to human health.

4.3 AN EVALUATION OF CURRENT FLY ASH MANAGEMENT PRACTICE AT KRIEL POWER STATION

This section presents data collected from the field which include participants' viewpoints obtained through questionnaire survey and interviews which is relevant in understanding if ever the current management practice which involves storage of fly ash in the ash dams is aligned with the modern principles of environmental management. Another objective of this research is to find out if ever the current fly ash management practices at Kriel Power are harmonizing with the modern ways of managing environment. It is important to establish the aforementioned harmonization in order to be able to determine measures which may be required to sustainably manage the said practice. Figure 4.2 below depicts participants' perception with regard to fly ash disposal at ash dams.

Figure 4.2: **Participants' perception on fly ash disposal at ash dams**



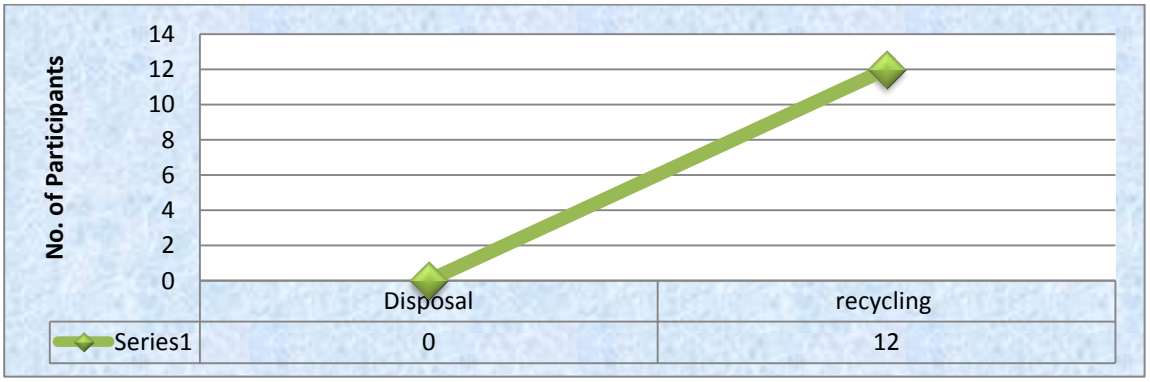
Source: field based material – refer to Annexure A2

Figure 4.2 above indicate that 36.5% of participants views fly ash disposal at ash dams as misaligned with contemporary principle of environmental management while 41.5% perceive it as being aligned; and 22% do not know if ever the current practice is aligned or misaligned with the contemporary principles. Empirical evidence in figure 4.2 depicts balanced participants' perceptions between those who views ash disposal as aligned with modern practices and those who have an opposing view. The indecisive perceptions in this regard present an opportunity to further explore the modern practice of fly ash management which is aligned with sustainability concept.

Further to above, participants also provided their views with regard to the link between fly ash management practices and the eventual environmental impacts. One participant from environmental consultancy indicated that, *"Better fly ash management practices (recycling: cement, concrete, concrete products etc.) will result in improved ecological conditions while bad management practices (release of fly ash in the environment; air pollution, water pollution etc.) will result in adverse ecological effect"- (*Pers.com 2017b*).* In addition, other participants indicated that ineffective fly ash management practices such as inadequate dust control, under designed and unlined ash dams, ineffective operational controls resulting into spillages, result to all sorts of air, water and land pollution.

Kriel Power Station currently disposes most of its generated fly ash at the ash dams. In order to determine if whether the current fly ash management practice at Kriel Power Station is aligned with the contemporary principle of environmental management, participants were asked to indicate the option which they view as sustainable between disposal and recycling (figure 4.3).

Figure 4.3: Participants' perception on the sustainable fly ash management option

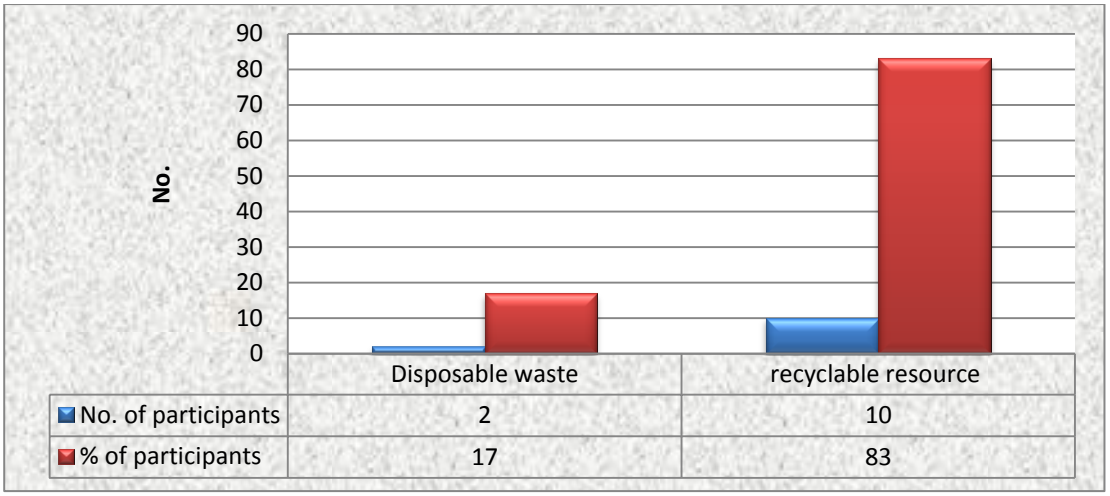


Source: field based material – refer to Annexure A3

Figure 4.3 indicate that 100% of interview participants perceive recycling as a sustainable option aligned with modern principle of environmental management. To substantiate their perceptions indicated in figure 4.3 above, participants further indicated that recycling is sustainable because it has more economic opportunities and it also reduce ecological footprint caused by ash dams operations. With regard to ash disposal, participants are generally concerned with the land footprint associated with ash dams' establishment as well as environmental impacts which comes as secondary impacts related to ash dams operations.

Another critical aspect which has a significant influence on how fly ash is managed is how people view and classify fly ash within the context of modern principles of environmental management. Figure 4.4 below summarises participants' perception on how fly ash classified.

Figure 4.4: Participants' perception with regard to fly ash classification (N.12)



Source: field based material

As indicated in figure 4.4 above, 83% of participants perceive fly ash as a recyclable resource while only 17% views it as waste which should be disposed of accordingly. Adding some justification to their perceptions (figure 4.4), the two participants who views fly ash as disposable waste indicated that, *"fly ash can be recycled in future by building industry when mixed with sand. Research is needed*"- *(*Pers.com 2017c*);* while the other participant indicated that, "*If only half of ash is recyclable and the other half is disposed of, then the classification can be both*"- *(*Pers.com 2017d*)*. Based on figure 4.4 above, fly ash is largely viewed as a resource hence it is critical to investigate its further potential uses; participants' views further

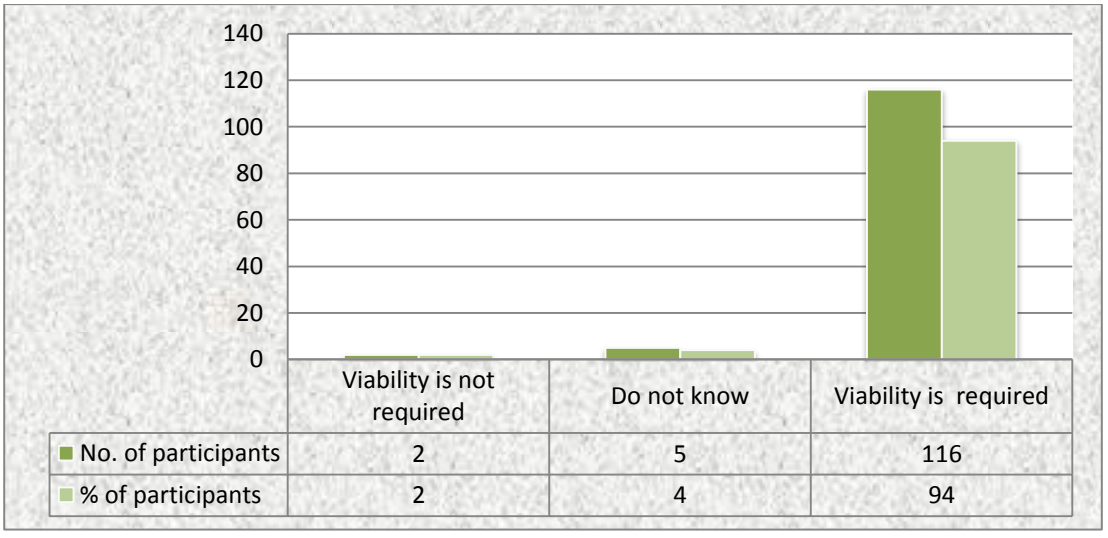
suggest that the current management practice of largely disposing fly ash at Kriel Power Station is not ideal as most generated fly ash can be recycled.

4.4 AN INVESTIGATION ON THE SOCIAL, ECONOMIC AND ENVIRONMENTAL OPPORTUNITIES PRESENTED BY FLY ASH

This section presents data collected from the field which include participants' viewpoints obtained through questionnaire survey and interviews which is relevant in understanding, within the context of contemporary environmental and sustainable discourse, the social, economic and environmental opportunities which are presented by fly ash.

Before exploring what could be the opportunities presented by fly ash, it is necessary to dissect and understand what is meant by the phrase 'modern sustainable conversation'. As a result, participants were asked to provide their views, which are depicted in figure 4.5, on whether sustainability concept requires any balancing act to be applied between social, economic and environmental aspects.

Figure 4.5: Participants' views on sustainability concept (N.123)



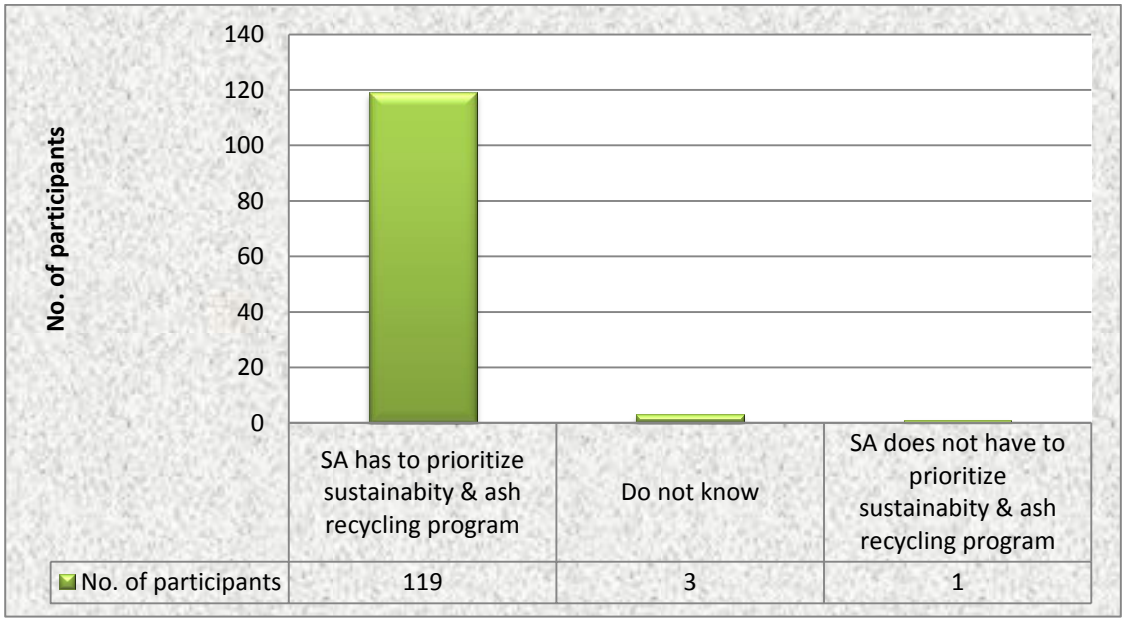
Source: field based material

Figure 4.5 strongly depicts that participants view the concept of sustainability as critical with 94% of participants indicating that sustainability can only be achieve when there is viability

amongst social, economic and environmental aspects while a mere 2% perceive viability as unnecessary. 4% had nothing to say as they did not know.

In addition to the participants' perceptions on sustainable concept as indicated in figure 4.5 above, participants were further asked to provide their views on whether South Africa (SA) as a developing country should prioritize the sustainable development agenda and even concern itself with the implementation of fly ash utilization programs. Figure 4.6 below synopsizes participants' views regarding the importance of implementation of ash recycling programs and overall sustainability concept.

Figure 4.6: Participants perception on the need for South Africa to implement sustainability and ash recycling programs



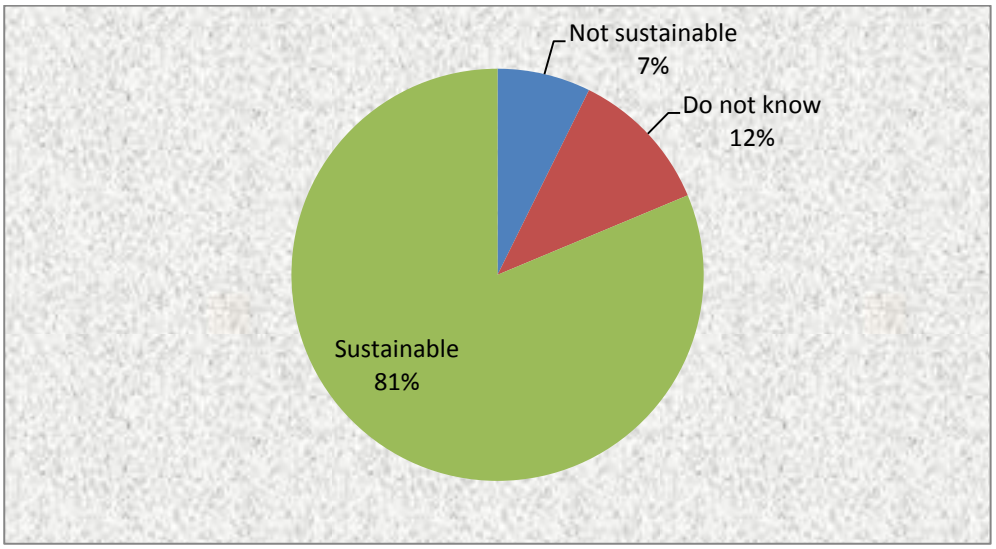
Source: field based material – refer to Annexure A4

Participants' views under figure 4.6 below strongly harmonize with participants' views on their position with regard to sustainability concept as demonstrated on figure 4.5. A total of 119 participants (97%) view it as necessary for South Africa to do more to ensure that the concept of sustainability and ash recycling programs are implemented while only one participant (1%) strongly views it as unnecessary. Three participants (2%) did not know what to answer. Figure 4.5 and 4.6 demonstrate that participant across all sectors view sustainability concept as the way to go. What is also evident in both aforementioned figures is that only few participants did not know what to answer and therefore demonstrating the eagerness of participants to engage on the

sustainability concept discourse. Empirical evidence presented in figure 4.5 and 4.6 above triggers the need for undertaking an investigation to establish a sustainable management practices for Kriel Power Station's fly ash which allows viability of sustainability components.

One of the questions to be answered by this research is whether fly ash presents any opportunities within the context of contemporary environmental management and sustainable discourse. In order for the aforementioned opportunities associated with fly ash recycling be realised, the ash utilization program has to be sustainable. Figure 4.7 below synopsizes participants' perceptions on whether fly ash utilization program is sustainable.

Figure 4.7: Participants views on fly ash utilization program

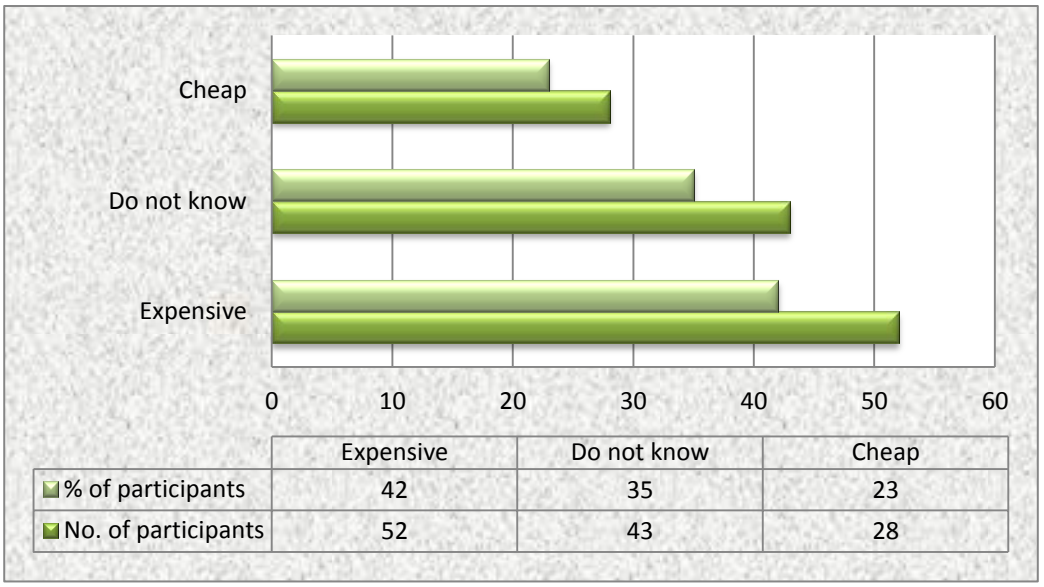


Source: field based material - refer to Annexure A5

Based on figure 4.7 above, 100 participants views fly ash utilization program as being sustainable option while only 9 views it as an unsustainable. One of the environmental practitioners from coal fired power station also indicated "*that ash utilization has the potential to assist in solving the problem of unemployment and sustainable development in South Africa"*- *(*Pers.com 2017e*)*; while another practitioner also from a different coal fired power station indicated that *"reusing of fly ash will generate income and sustainable economic enhancement for South Africa"*- *(*Pers.com 2017f*).* Based on the presented evidence in figure 4.7, industries which are not utilizing their generated fly ash are missing out on an opportunity to venture in a sustainable fly ash management practice.

Participants' views as depicted from figure 4.5 to 4.7 above strongly indicate that sustainability is the way to go and that fly ash recycling is a maintainable option. In order to go deeper in exploring if indeed fly ash utilization is a sustainable option and if indeed it does present opportunities within a modern context of environmental management and sustainability, participants were asked to provide their views, which are summarised in figure 4.8 below, related to financial benefits of ash utilization as compared to ash disposal.

Figure 4.8: Participants' perceptions on the cost of ash disposal (N.123)



	Expensive	Do not know	Cheap
% of participants	42	35	23
No. of participants	52	43	28

Source: field based material

Participants' responses on figure 4.8 indicate that 42% of participants views ash disposal at ash dams as expensive while 23% perceive it as cheap. A significant amount (35%) of participants did know the answer. The results depicted in figure 4.7 and figure 4.8 coincides in a sense that they strongly indicate fly ash utilization as a cheaper and sustainable environmental management option to use. Based on figure 4.8 results, the current management practice, at Kriel Power Station, of disposing a large portion of fly ash at the ash dams is an expensive practice.

Participants' views have so far indicated that utilization is the ideal management practice for fly ash; and that it is cheap and it can be sustained. In order to establish as to how well spread and/or rooted are the opportunities presented by fly ash, participants were also asked to provide their views on the extent in which they perceive the diversity of fly ash market in South Africa

with regard to the market being able to absorb more fly ash from the industries. Participants perceptions on the market diversity is necessary as it is an indication of potential existing opportunities related to fly ash utilization; and it also provide an indication on the extent in which the program could be sustained. Table 4.3 depicts participants perceptions related to market base availability.

Table 4.3: Participants' perceptions on whether South African (SA) Market can still absorb more fly ash

Participants Perceptions	Participants Number	%
The market is wide open with more opportunities	103	84%
Do not know	16	13%
The market is restricted with less opportunities	4	3%
TOTAL	**123**	**100%**

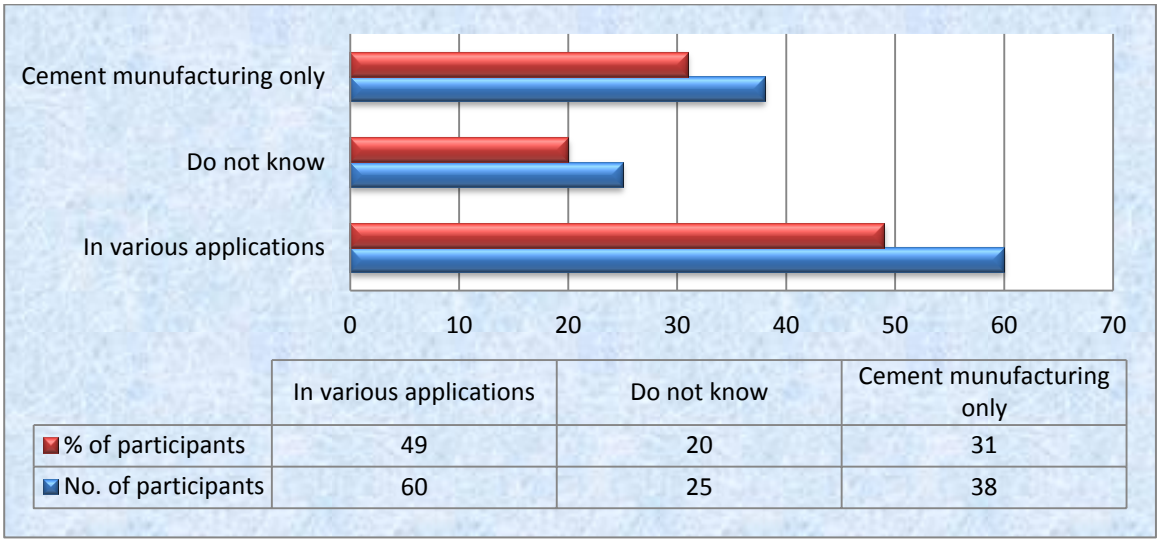
Source: field based material

Table 4.3 above indicate that a significant amount of participants perceive that fly ash has a great opportunity to be utilized in various markets while a trivial amount of participants views the market base as limited. In addition to the subject of availability of fly ash market base in South Africa, one of the environmental practitioners from coal fired power station indicated that *"there is a market for fly ash which can be explored and disposal should be the last option. This will assist the economy and also help in reducing the Environmental footprint"- (*Pers.com 2017g*).;* while another practitioner from Eskom's Water Management CoE indicated that *"Increase in fly ash sales is dependent not only on the regulation that promotes alternative uses but also on the existence of the market and maturity of the technology to ensure health and safety standards are complied with"- (*Pers.com 2017h*).* The empirical evidence as indicated in table 4.3 as well as participants' comments above largely suggests that the fly ash generators have limited reasons for not utilizing their generated ash as the marked is wide open to consumed fly ash.

Participants' views as indicated in table 4.3 above indicate that enough market exist for fly ash recycling. In order to further understand the diversity of fly ash utilization opportunities, participants were asked for their views on whether cement industry is the monopolised market in

South Africa which to absorb the fly ash; and participant's' perceptions are synopsized in figure 4.9 below.

Figure 4.9: Participants' perceptions regarding streams through which fly ash can be utilized (N.123)



	In various applications	Do not know	Cement munufacturing only
% of participants	49	20	31
No. of participants	60	25	38

Source: field based material

Results as depicted in Figure 4.9 above indicate that 49% of participants do not view cement industry as the only industry through which fly ash can be recycled while 31% views cement industry as the only industry through which fly ash can be recycled. 20% of participants did not know what to answer. A participant who is also part of Kriel's Ash Optimization Committee commented that, *"South Africa need to do more research and product development on fly ash utilization outside the cement market"- (*Pers.com 2017i*).* A participant from environmental consultancy also provided a very profound comment indicating that:

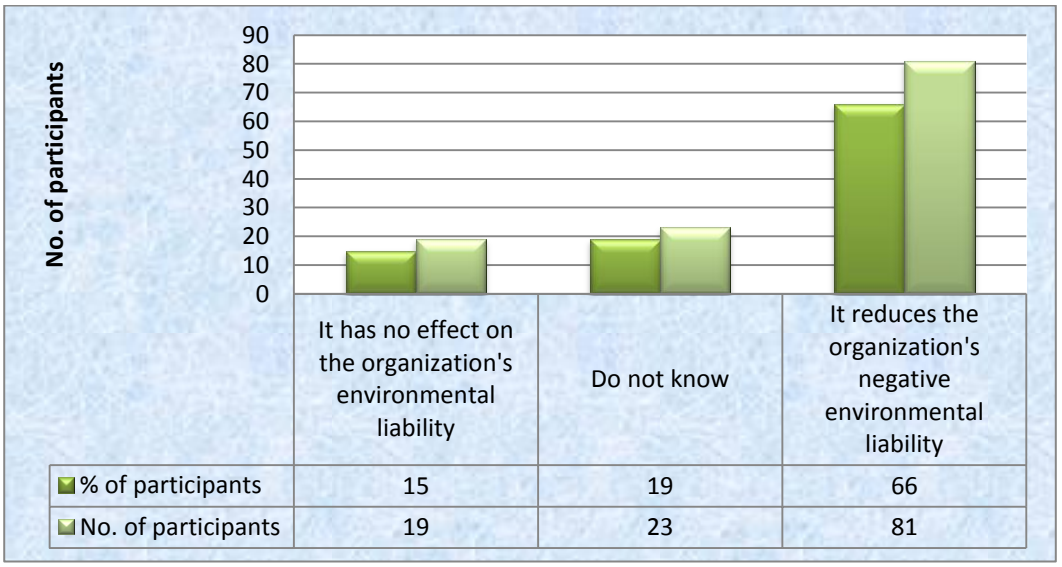
> *"a wide range of potential uses for fly ash have already been identified, including treatment of acid mine drainage and stabilisation of sludge from a variety of industrial processes. The fly ash management opportunities include the manufacture of cement, concrete, concrete products, cellular concrete products, bricks/blocks/ tiles etc. Fly ash has similar physical and chemical properties to those of soil. It can be used directly as a soil amendment, or in land reclamation, with organic matter, lime or gypsum, in composts, or made into granulated materials or potassium silicate fertilisers. Other applications include cosmetics, toothpaste, kitchen counter tops, floor and ceiling tiles, bowling balls, flotation devices, stucco, utensils, tool handles, picture frames, auto*

*bodies and boat hulls, cellular concrete, geo-polymers, roofing tiles, roofing granules, decking, fireplace mantles, cinder block, PVC pipe, Structural Insulated Panels, house siding and trim, running tracks, blasting grit, recycled plastic lumber, utility poles and cross arms, railway sleepers, highway sound barriers, marine pilings, doors, window frames, scaffolding, sign posts, crypts, columns, railroad ties, vinyl flooring, paving stones, shower stalls, garage doors, park benches, landscape timbers, planters, pallet blocks, molding, mail boxes, artificial reef, binding agent, paints and under coatings, metal castings, and filler in wood and plastic products" (*Pers.com 2017b*).*

Other participants also indicated that fly ash can replace Portland cement in concrete production to build bridges, roads, brick-making etc.; fly ash can also be used for mining rehabilitation. Based on figure 4.9 and participants' views above, it is evident that fly ash presents numerous utilization opportunities in such a way that fly ash disposal cannot be justified on the basis of lack of other avenues through which fly ash can be utilized.

Adding to the opportunities presented by fly ash presented above, participants also perceive fly ash utilization as an opportunity for organizations to minimize the environmental liabilities associated with disposal at the ash dams; refer to figure 4.10 below for participants' views.

4.10: Perception of participants on fly ash utilization and environmental liabilities (N.123)



Source: field based material

Based on fieldwork results as depicted on figure 4.10 above, a total of 66% participants strongly agreed that fly ash utilization does minimize organization liabilities. Only 15% participants disagreed with the statement while 19% did not know what to answer. In order for organizations to minimize some of their long term environmental liabilities, they need to start optimizing on fly ash utilization (figure 4.10).

Opportunities presented by fly ash within the context of modern environmental management and sustainability discourse do not occur automatically; an action has to be taken to unlock those opportunities. Participants were therefore asked to provide their views on whether adequate measures are being implemented by main fly ash generators to sensitize communities with fly ash recycling opportunities. Participants' views as depicted in table 4.4 are important as they serve as an indication of other areas which can be explored to increase fly ash utilization.

Table 4.4: Participants' views on the need for more community awareness on fly ash utilization

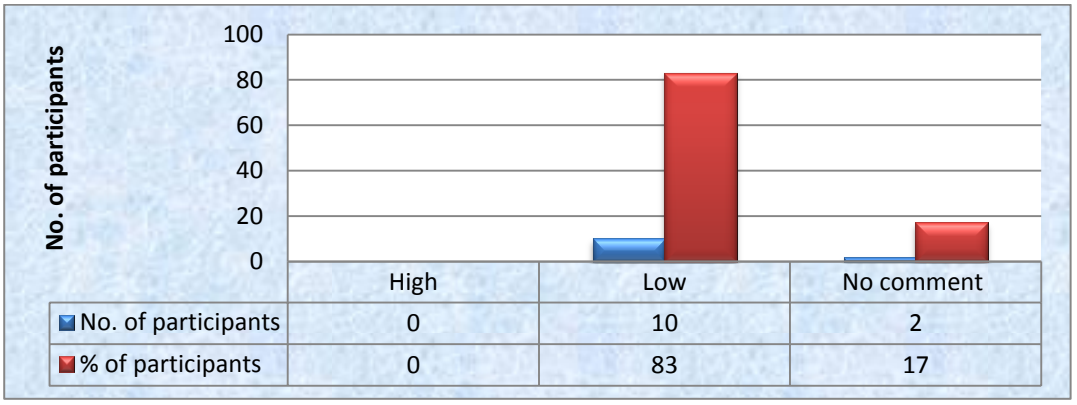
Participants' perceptions	Participants Number	%
Community awareness is so far sufficient	4	3%
Do not know	15	12%
More community awareness is required	104	85%
TOTAL	**123**	**100%**

Source: Field based material

Based on table 4.4, at least 85% of participants perceive community awareness as critically needed to unlock ash utilization interest from communities while a very tiny minority of 3% perceive the opposite. Participants from various sectors had numerous additional comments about the issue of community awareness as being critical in unlocking fly ash usage; and their comments include the following: one of the environmental practitioners from coal fired power stations stated that, "fly *ash utilization can be enhanced by designing power plants to cater for ash recycling, so that it is advertised and made aware to people. Advertising recycling programmes after 20 years of operation compromise the opportunity of locals to know about it (*Pers.com 2017f*).*The environmental practitioner further added that *"fly utilization can reduce pollution while creating economic opportunities, and it is possible to balance with regulators, NGOs, etc. (*Pers.com 2017f*).*

Other participant who works at the laboratory to perform daily tests to determine Kriel's fly ash qualities commented that, *"fly ash topic need to be stretched to communities in terms of education. Entrepreneurship can grow but only if it can be communicated to the community. Community should be made to see that waste can generate them money. Ways in which communities can use fly ash safely should be developed"-(*Pers.com 2017J*).* Adding on the benefits of community awareness in increasing fly ash recycling, other participant from Kriel projects development department also stated the following: - *"more community projects can benefit from fly ash utilisation in the manufacturing of bricks"- (*Pers.com 2017k*);* while another participant from coal fired power station indicated that, "*the process of acquiring ash from ash generators is somehow unknown to the general public and entrepreneurs; there is a need for an awareness drive on how the general public can utilise ash as a resource"-(*Pers.com 2017l*).* Lastly, one of the engineers who solely manage complex projects such as ash dams' construction projects indicated that, "fly *ash utilisation will struggle to take off in a big way unless the big generators run awareness campaigns to promote the utilisation and encourage innovation in the space*" *(*Pers.com 2017m*).* Further to above, perceptions of participants which are captured in figure 4.11 below also harmonizes with participants' views indicated in table 4.4 above in that more community awareness is critically needed to unlock fly ash utilization.

Figure 4.11: Perceptions of interview participants on the awareness level of local communities (N.12)

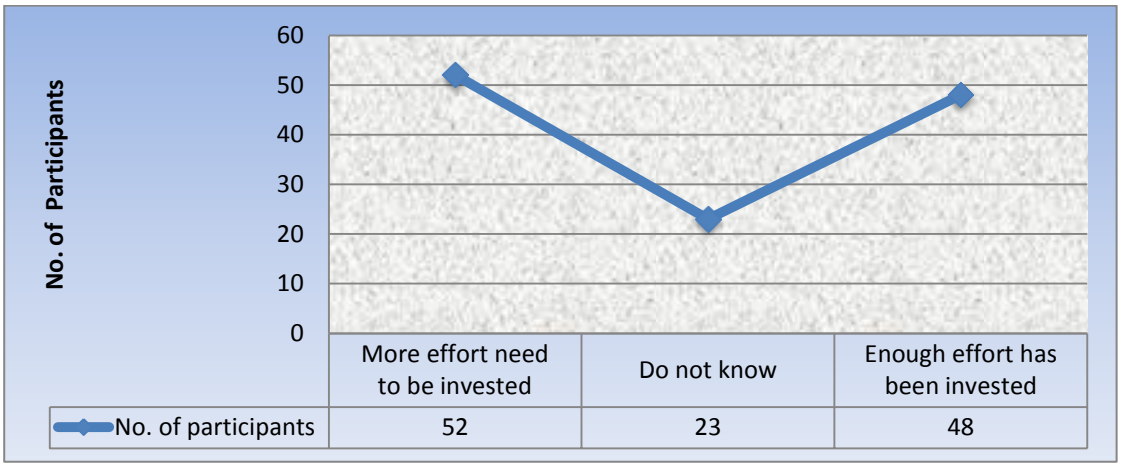


Source: field based material

Based on figure 4.11, participants' views indicate that local communities are not aware of the opportunities presented by fly ash. One participant from Eskom's Air Quality CoE argued that,

"*although local communities are not aware, entrepreneurs are aware of the ash utilization opportunities"-(*Pers.com 2017n*)*. Over and above conducting community awareness to spread the benefits of fly ash to potential users, participants were asked for their views on whether fly ash generators are indeed playing adequate role to ensure that fly ash is indeed accessible and utilized. Participants were asked this question precisely to determine if ever further opportunities could be explored through maximising the current fly ash utilization program. Figure 4.12 below synopsizes participants' views on whether the generators are putting enough effort maximise fly ash utilization.

Figure 4.12: Participants' perceptions on the commitment of fly ash generators in maximizing fly ash utilization program



Source: field based material – refer to Annexure A6

Figure 4.12 above indicate that 42% of participants views South Africa still having some work do in order to create more opportunities to ensure fly ash recycling while 39% are agreeing that the current measures being implemented by the ash generators are enough. Only 19% did not know what to answer. Based on the evidence presented in table 4.4, figure 4.11, figure 4.12 and participants' additional comments above, Eskom Kriel Power Station together with other fly ash generators in South Africa have more work to do in order to sensitize communities and also establish measures to optimize fly ash utilization.

In addition to the social, economic and environmental benefits associated with fly ash, already presented above, one participant from environmental constancy also indicated the following:

Social benefits: *Job creation by doing more research on the benefits of Fly ash in all industries and employing people to produce all kinds of products.* ***Economic benefits:*** *Successfully managing fly ash has become an increasingly important piece of overall success for power plants. In this business environment, power plants must carefully control expenses, capital commitments and risks and smart management of coal combustion products provides a significant opportunity in several important ways such as the following: cost Reduction and Cost Management for Landfill. Managing fly ash results in landfill cost avoidance by reducing current ash disposal expenses and by delaying or avoiding the significant costs of future landfill or pond development; an Environmentally-Friendly Solution. Beneficiation and utilization of fly ash is a "green" solution that turns expenses into revenue and demonstrates a utility's commitment to the environment and the communities in which they do business.* ***Environmental benefits:*** *Some of the most prevalent examples of the environmental benefits gained from the use of Fly ash include: waste stream reduction and associated reductions in requirements for landfill; the conservation of resources such as gypsum, limestone and natural gas when Fly ash is used as a replacement in cement production; and the reduction of greenhouse gas emissions when used as a cement replacement (saving up to one tonne of carbon dioxide per tonne of cement)"-(*Pers.com 2017b*).*

Other participants also added comments which harmonize with the views indicated by pers.com (2017b) above. Based on empirical evidence above, fly ash benefits are not only biased to economic, social or environmental aspect of the sustainability concept as evidence suggests that the benefits are well balanced across all three pillars of sustainability concept.

In order to obtain a comprehensive understating of various issues which hinders exploration of fly ash opportunities, interview participants were also asked to provide their views on what they perceive as the critical issues which serves as bottlenecks in fly ash recycling program. The objective of asking for participants' views in this regard was to establish issues which will undermine the efforts to explore fly ash opportunities. Participants articulated their various perceptions on current challenges to fly ash recycling program which include the following: fly ash is expensive to recycle; entrepreneurs and the general public are uninformed and unaware about the benefits of fly ash in general; the uncertainty on the quality of the fly ash as well as storage options by third parties; South African Legislation and regulation is very strict in terms of getting approval to sell and to buy ash; classification of ash as hazardous waste; and the long distance between ash generators and users.

4.5 EXPLORATION OF POTENTIAL IMPACTS OF FLY ASH ON ENVIRONMENTAL, SOCIAL AND ECONOMIC ASPECT

This section presents data collected from the field which include participants' viewpoints obtained through questionnaires and/or interviews as well as existing evidence gathered through scientific observations or experiments which are relevant in understanding potential impacts of fly ash on environmental, economic and social aspects. One of the objectives of this research is to explore the potential impacts of fly ash on social, economic and environmental aspects. As a result, participants were asked to share their perceptions on the impacts of fly ash disposal facilities or ash dams. Synopsized participants views are depicted in table 4.5 and figure 4.13 below.

Table 4.5: Participants' perceptions on the adverse impacts of fly ash disposal

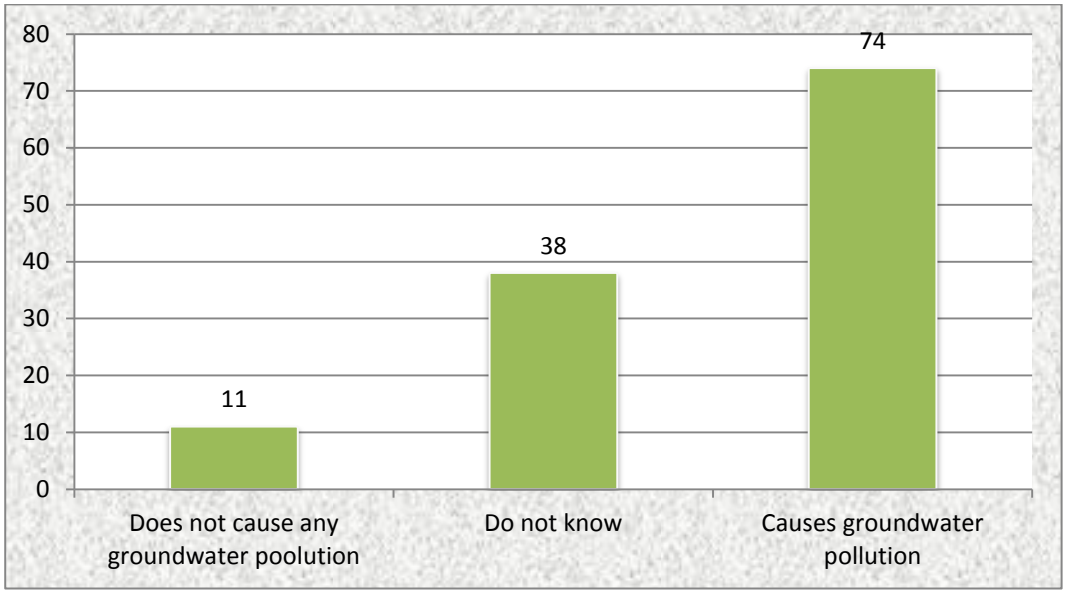
Participants' perceptions	Participants Number	%
It significantly contributes to pollution (air & water) and ecological degradation	86	70
Do not know	22	18
It does not contributes to pollution (air & water) and ecological degradation	15	12
TOTAL	**123**	**100%**

Source: Field based evidence

The results depicted in table 4.5 above indicate that 70% of participants views ash disposal activity as a causative factor for water and air pollution as well as ecological degradation. The results in table 4.5 also indicate a small percentage (12%) of participants who perceive fly ash disposal facilities as not a causative factor for pollution and degradation. An environmental practitioner working under Eskom's Group Capital Division indicated that, *"poor management of fly ash result in safety, health and environmental challenges. The measures that are in place to manage fly ash are not effective. Some of the challenges currently regarding fly ash include lack of commitment from management on managing fly ash management"- (*Pers.com 2017p*).* Another environmental practitioner from Environmental Impact Assessment CoE argued that, *"fly ash should be recycled to reduced cost, air pollution, water pollution and environmental degradation. Ash disposal facilities footprint will be minimised if more ash is recycled"-*

*(*Pers.com 2017q*)*. Based on empirical evidence presented in table 4.5 as well as participants' additional comments above, disposal of fly ash at Kriel Power Station' ash dam is associated with potential water pollution, air pollution and ecological degradation.

Figure 4.13: Participants' perceptions towards unlined fly ash disposal facilities



Source: field based material – refer to Annexure A7

Evidence gauged from figure 4.13 above indicate that 60% of participants perceive unlined ash disposal facilities as significant contributors to ground water pollution while 9% have an opposite perception. 31% of participants did not know what to answer. What is common in both table 4.5 and figure 4.13 is that participants strongly indicate that fly ash disposal facilities are responsible for pollution; another common aspect is that they both have a significant number of participants who did not know what to answer. An environmental specialist from environmental consultancy also added that "*fly ash can pollute ground water in a case of wet tailings facilities, but not true for dry systems as it is highly dependent upon geology. This can be seen from extremely limited groundwater impacts at Tutuka and Majuba coal fired power stations; only ash that contains high Hexavalent Chrome that can be leached even if bound with cement may be an issue*"- (Pers.com 2017o). An environmental practitioner from coal fired power station also commented that "*Fly ash leads to groundwater pollution through seepage*" (Pers.com 2017s). Based on the participants' perceptions captured in figure 4.13 and additional comments above, it can be concluded that fly ash disposal at unlined facilities is largely associated with

groundwater pollution even though geology does determine the rate of such groundwater pollution.

In order to provide a further perspective with regard to the impact of fly ash into the groundwater, tables 4.6 and 4.7 below respectively provides information related to leachate characteristic of Kriel Power Station's fly ash as well as the groundwater qualities from selected boreholes around Kriel ash dam complex. Figure 4.14 below depicts the results of a numerical model which was conducted within Kriel Power Station's ash dam complex. Table 4.6 and 4.7 as well as figure 4.14 are included to provide the actual perspective regarding the impact of fly ash on the environment (groundwater) based on scientific experiments conducted.

Table 4.6: Leachate characteristics of fly ash composition elements

Elements/Chemical Substance in fly ash	Unit	Fresh Fly Ash on Conveyor	Old Fly ash below conveyor	Weathered Fly Ash (474010)	Fresh Fly Ash
pH	mg/l	11.56	11.17	10.57	10.63
AS, Arsenic	mg/l	<0.001	0.002	0.001	0
B, Boron	mg/l	0.05	0.07	0.24	0.08
Ba, Barium	mg/l	0.17	0.12	0.09	1.91
Cd, Cadmium	mg/l	0.0004	0.0003	0.0004	0.0004
Co, Cobalt	mg/l	<0.001	<0.001	<0.004	0.0014
Cr(T), Chromium Total	mg/l	0.24	0.25	0.12	0.43
Cr (VI)	mg/l	0.21	0.23	0.1	0.25
Cu, Copper	mg/l	<0.001	0.0006	0.0037	0.0024
Hg, Mercury	mg/l	0.003	0.0001	0.0004	0.0005
Mn, Manganese	mg/l	0.008	0.0008	0.0174	0.0016
Mo, Molybdenum	mg/l	0.0485	0.0421	0.0195	0.0643
Ni, Nickel	mg/l	0.0008	<0.001	0.003	0.0123
Pb, Lead	mg/l	<0.001	<0.001	0.0009	0.0011
Sb. Antimony	mg/l	0.0011	0.0012	0.0015	0.0027
Se, Selenium	mg/l	0.015	**0.021**	0.018	0.013
V, Vanadium	mg/l	0.017	0.03	0.032	0.001

Zn, Zinc	mg/l	<0.001	0.005	0.029	0.007
Tds, Total Dissolved Solids	mg/l	315	264	202	2664
CI, Chloride	mg/l	2.65	3.17	3.06	<0.25
SO4, Sulphates	mg/l	30	41	117	114
NO3-N, Nitrate	mg/l	<0.1	<0.1	0.1415	1.1507
F, Fluoride	mg/l	0.33	0.33	0.55	1.22
CN(T), Total Cyanide	mg/l	<0.01	Nd	Nd	Nd

Source: GHT, 2017

As indicated in table 4.6 above, all 4 batches of fly ash samples indicated that pH's leachate characteristics is highly sided on alkaline nature with pH figures ranging from 10.57 mg/l to 11.56 mg/l. Another high figure indicated on table 4.6 above is that of selenium and chromium. Fly ash's leachate characteristics for sulphates were noted to fall within the drinking water standard as they are well below 500 mg/l. Two environmental practitioners from coal fired power stations also argued that trace elements contained in fly ash such as arsenic, chromium, thallium, selenium and mercury hydrogen sulphides, etc., have potential to seep through unlined ash dams to cause groundwater pollution (Pers.com 2017r and Pers.com 2017t).

Table 4.7: Groundwater qualities for selected boreholes around the ash dam complex

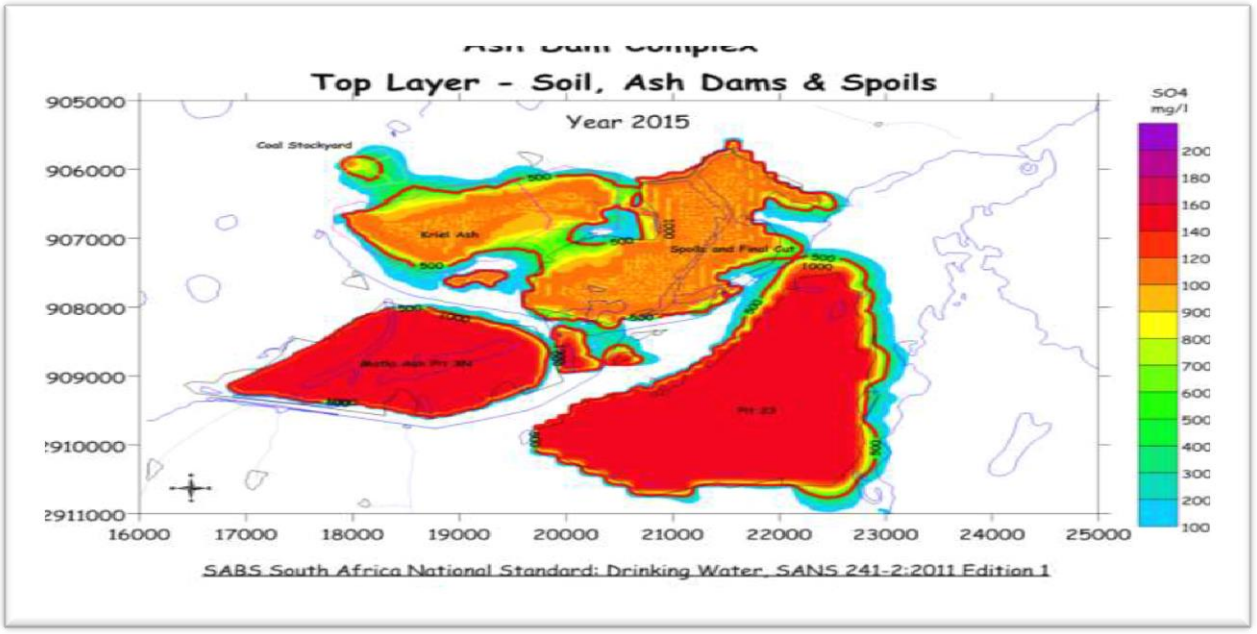
Element Analyzed	Unit	Groundwater Boreholes around Ash Dam Complex				
		KB06D (S)	**KB08D(E)**	**KB35(W)**	**KB28(S)**	**KB62(E)**
pH	%	8	7.7	8.5	6.5	8.1
EC	**mS/m**	64	154	47	35	40
Na	**mg/L**	141	27.7	55.1	26.1	62.8
Ca	**mg/L**	10.5	195	22	21.1	18.5
Mg	**mg/L**	4.9	91.8	15.4	11.8	7.8
K	**mg/L**	3.1	10.7	4.4	5.6	2.8
CI	**mg/L**	11	65	12	5	13
SO4	**mg/L**	6.3	725	81	124	2
F	**mg/L**	3.22	0.26	0.26	0.26	0.41
NO2-N	**mg/L**	0.132	0.116	0.128	0.117	0.150
NO3-N	**mg/L**	0.292	0.786	0.272	0.594	0.278

Fe	**mg/L**	0.004	0.004	0.004	0.004	0.004
Mn	**mg/L**	0.001	0.001	0.076	0.001	0.039
Cu	**mg/L**	0.002	0.002	0.002	0.002	0.002
Al	**mg/L**	0.002	0.002	0.002	0.002	0.002
Cr	**mg/L**	0.003	0.003	0.003	0.003	0.003
Pb	**mg/L**	0.004	0.004	0.004	0.004	0.004
Zn	**mg/L**	0.002	0.002	0.002	0.003	0.002
B	**mg/L**	0.262	0.349	0.214	0.013	0.262
COD	**mg/L**	23.9	8.7	58.9	25.8	23.9
MALK	**mg/L**	344	60	146	14	344
PALK	**mg/L**	0	23	0	26.5	0
Si		10.20	30.20	4.56	27.20	10.20

Source: GHT, 2017

Based on the information obtained from the ground water monitoring results above (table 4.7) , pH on all 5 boreholes around the ash dams appears to be ranging between 6.5 and 8.5 while sulphates were noted to be ranging from 2 mg/l to 725 mg/l. Chemical Oxygen Demand was found to be ranging in between 8.7 to 58.9.

Figure 4.14: Kriel Power Station's Ash Dam Complex _Groundwater numerical model for 2015

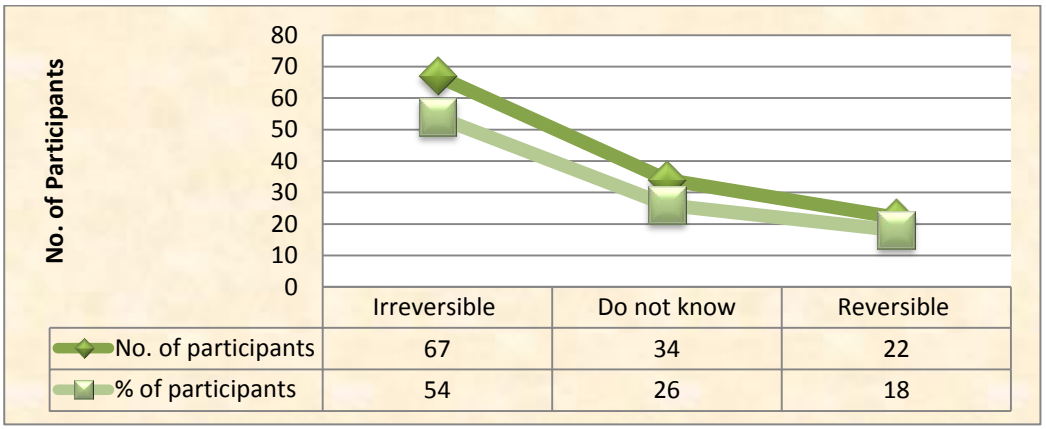


Source: GHT, 2016

Based on the numerical model indicated in figure 4.14 above, sulphates levels within Kriel Power Station' ash dam complex were already above the recommended standard limit of 500mg/l in 2015. An environmental practitioner from coal fired power station argued that "*groundwater gets polluted particularly if the ash dams are not lined. However, this type of ash disposal has severe impact on air quality, effect on local soil, vegetation and toxicological effects on human. The disposal often requires large land to be used; dump sites may also encroach agricultural land*" (Pers.com 2017u). Based on the evidence presented in table 4.6, table 4.7 and figure 4.14, fly ash consists of chemical elements which can potentially result into adverse environmental impacts depending on the ash dam management approach and geological background.

Environmental impacts are not always rated the same in terms of severity. In order to establish and understand if ash dam facilities footprints do cause any adverse ecological impact with significant severity, participants were asked to share their perceptions the severity ash dams establishments on fauna and flora. Figure 4.15 below synopsizes participants' views.

Figure 4.15: Participants' perceptions on the severity of ash dam establishments on fauna and flora (N.123)

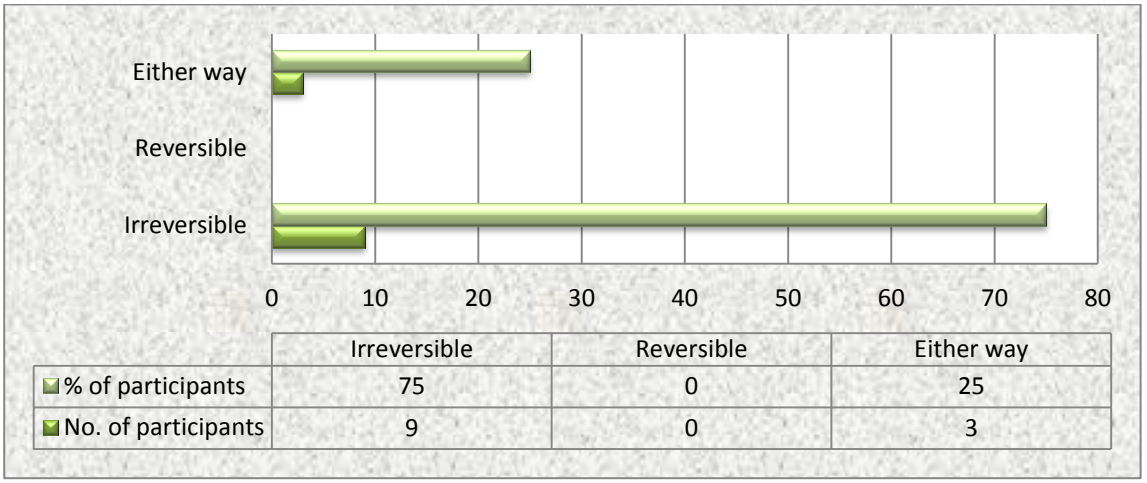


Source: Field based material

Figure 4.15 indicate that only 18% of participants' views the ash dam establishments as having reversible impacts on fauna and flora while 54% perceive it as irreversible. A significant amount of participants did not know what to answer. In addition to participants' views indicated in

figure 4.15, interview participants also agree that environmental impacts caused by ash dam facilities such as groundwater pollution are irreversible (refer to figure 4.16 below).

Figure 4.16: Perceptions of participants with regard to environmental impacts caused by ash disposal facilities (N.12)



	Irreversible	Reversible	Either way
% of participants	75	0	25
No. of participants	9	0	3

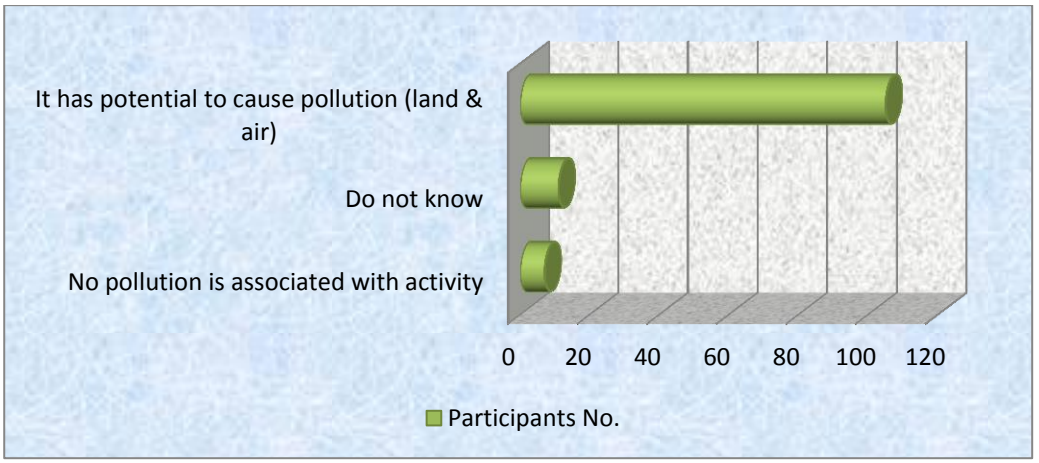
Source: field based material

Based on figure 4.16 above, participants also largely perceive the impacts of fly ash disposal as irreversible (75%) with only few participants (25%) indicating that potential impacts from ash disposal can either be reversible or irreversible depending on the circumstances. A specialist from Eskom's air quality CoE indicated that, *"Air impacts are reversible while groundwater impacts may not be reversible"- (*Pers.com 2017n*).* An environmental specialist from environmental consultancy commented that, "*Certain impacts associated with ash disposal facilities can be reversible; however, this can happen only by incurring high cost and time. For example, contaminated water would require extensive treatment to get it back to the state it was in before contamination. However, certain impacts such has the death of fauna (i.e. fish and invertebrates) is irreversible" (*Pers.com 2017v*).* Empirical evidence presented in figure 4.15, figure 4.16 and in the additional participants' comments above largely draws a conclusion that ash dams establishments and operations thereof result into irreversible ecological impacts.

Ash dam facilities are often located a few kilometres away from the coal combustion boilers; as a result, various transportation mechanisms are applied to transport fly ash from the boilers to the ash dams. In order to have a comprehensive understanding of the impacts associated with fly ash disposal and associated activities, participants were asked to share their views on the fly ash

transportation activity and its impact on the environment; and the said participants' views are summarized in figure 4.17 below.

Figure 4.17: Participants' views related to fly ash transportation activity to ash dams



Source: field based material – refer to Annexure A8

The outcome of participants' views as depicted on figure 4.17 above indicate the following: 6% of participants perceive fly ash transportation as having no potential to cause pollution while 85% perceive the opposite. 9% of participants did not know what to answer. Based on figure 4.17 above, it can be concluded that fly ash transportation to disposal facility is equally as risky, in terms of causing pollution, as the disposal activity itself. Part of the objective for this study is to explore the social impacts of fly ash. Table 4.8 and figure 4.18 below summarizes participants' perceptions on the impact of fly ash on the human health. The objective of requesting participants' views in this regard was to determine if the current fly ash management practice is environmentally unsound and if there are social impacts associated with the practice.

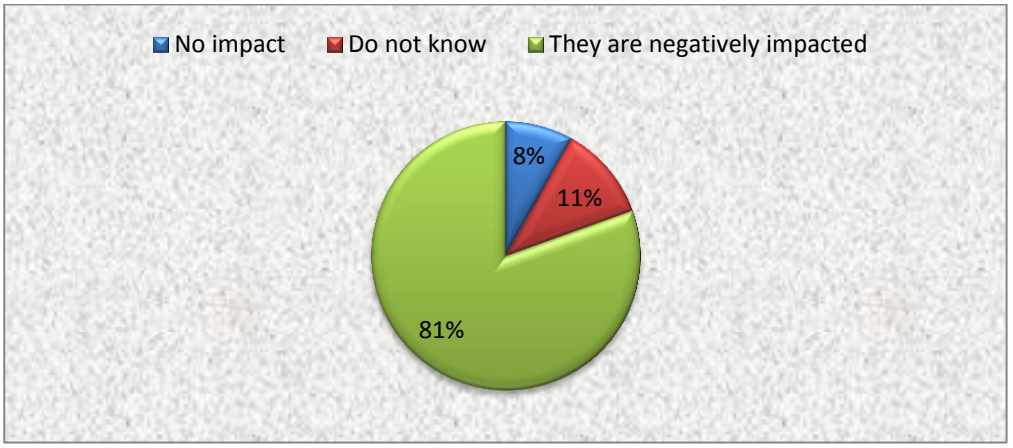
Table 4.8: Participants' perceptions on whether dust fallout from ash dams can adversely impact human health through air quality pollution

Participants' perceptions	Participants Number	%
Yes, it does impact on human health	112	91%
Do not know	7	6%
No, it does not impact on human health	4	3%
TOTAL	**123**	**100%**

Source: field based material

Based on table 4.8 above, almost all participants perceive that dust fallout from ash dam facilities has potential to cause adverse impacts on human health impacts while only 3% of participants perceive the opposite. One of the environmental practitioners from Eskom's Group Capital divisions also indicated that, "*measures that are implemented to control fugitive dust from ash dam facilities such as water sprinklers are ineffective due to poor control".* Figure 4.18 below provide additional participants' perspective with regard to the effect of ash disposal site to human health with particular reference to adjacent communities.

Figure 4.18: Participants' perceptions regarding the impact of ash disposal facilities to the health of neighbouring communities



Source: field based material – refer to Annexure A9

Based on figure 4.18 above, only 10 participants perceive ash disposal as having no impact to local communities while a total of 99 participants perceive that it does have an impact. Only 14 participants did not know what to answer. Further to the views indicated in figure 4.18 above, participants also added their perceptions on fly ash disposal and impact on local communities (refer to table 4.9 below).

Table 4.9: Perceptions of interview participants on whether ash dam's disposal activity does adversely impact on local communities (N.12)

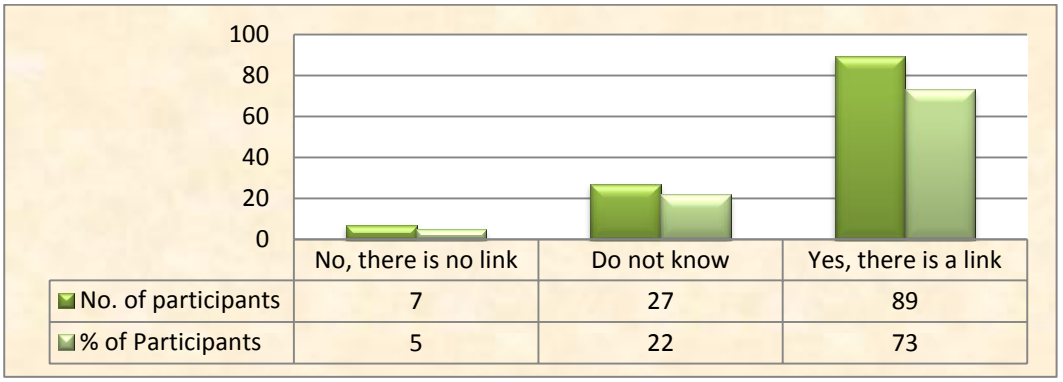
It does impact local communities adversely	It does not impact local communities adversely
12 (100%)	0 (0%)

Source: field based material

In addition to the views in table 4.9, another environmental practitioner commented that, *"communities close to the ash dams possibly inhale impacted ambient air, especially during dry season. They may also draw polluted water from the resources impacted by the ash dams. Air and water related diseases are very possible, and considering need for medications associated with these diseases, it may lead to accelerated mortality in these communities"- (*Pers.com 2017w*).* Another participant from environmental consultancy indicated that, *"a number of ash dams in South Africa are in close proximity to rural communities who depend on natural resources such as water from rivers and boreholes for their day-to-day needs. Contamination of these resources may negatively impact their living"- (*Pers.com 2017v*).* An environmental practitioner participant from also indicated that, "*dust coming from the ash disposal facility will have impact of the health of the communities staying closer to the ash dam. Health problems related to the above include respiratory problem, lung diseases*" - *(*Pers.com 2017d*);* while another participant from Eskom's Air Quality CoE argued that "*people should not live adjacent to ashing facilities*" - *(*Pers.com 2017n*).* Based on the evidence presented in figure 4.17, figure 4.18, table 4.9 and additional participants' comments above, it can be concluded that Kriel Power Station's ash disposal facility poses great risk on human health, especially to communities living adjacent to the disposal site.

Participants were also asked to provide their opinions on whether the likelihood and severity of environmental impact from fly ash has any direct link with the selected environmental management practice. Participants' perceptions in this regard were asked with an objective of gathering views which would assist in understanding if ever environmental management approach is important or not in minimizing impacts associated with fly ash. Figure 4.19 below synopsizes participants' views.

Figure 4.19: Participants' perceptions on the link between environmental impacts and selected management practice (N.123)



Source: field based material

An in-depth look on the fieldwork results as shown in figure 4.19 above reveals that, almost all participants from environmental practitioners sector have indicated that the link exist between the management approach and eventual impacts; only one environmental practitioner opted to disagree. Quite interestingly, two participants from government/authority sector indicated that there is no link between the management approach and eventual impacts. The evidence in figure 4.19 above largely suggest that the selected fly ash management approach in Kriel Power Station will determine the occurrence likelihood and severity of impacts from fly ash as the two are directly linked.

4.6 AN INVESTIGATION ON THE TECHNOLOGICAL MEASURES TO EFFECTIVELY MANAGE FLY ASH LIFE CYCLE

This section presents data collected from the field which include participants' viewpoints obtained through questionnaires and interviews which are relevant in investigating technological aspects which can be deployed in order to reduce the generation of fly ash. In order to establish the extent at which South Africa has advanced in securing the access to technologies which are necessary to ensure that more fly ash is processed and utilized in various sectors, participants were asked to provide their perceptions, which are depicted in table 4.10 below, on technological advancement.

Table 4.10: Participants' perceptions on the availability of advanced ash processing technologies in South Africa to assist in programs to increase ash utilization

Participants' perceptions	Participants Number	%
Technology available	61	50
Do not know	47	38
Technology not available	15	12
TOTAL	**123**	**100%**

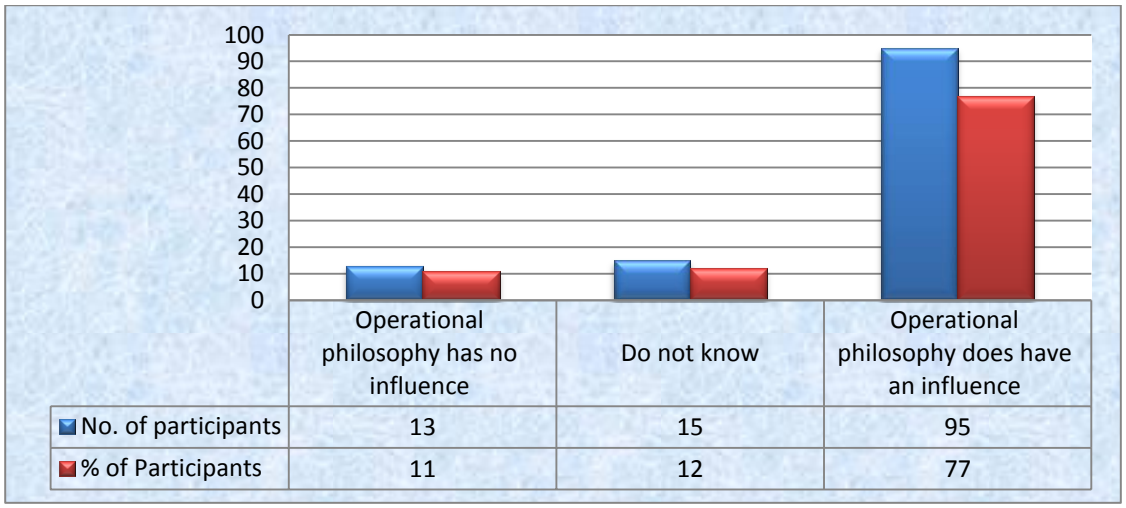
Source: Field based material

Based on the fieldwork results indicated in table 4.10 above, it is evident that a huge number of participant are not sure if South Africa has available technology to assist in fly ash utilization as

38% of participants did not know. Despite a huge number of participants who did not know, the results show that 50% of participants perceive that technology is available to assist in fly ash processing and utilization while only a mere 12% disagreed. Based on the results outlined in table 4.10 above, it can be concluded that technological options to assist in fly ash recycling do exist and they are accessible to South Africa.

One of the objectives for this study is to identify if any technologically related measures exist, which can be implemented in order to reduce fly ash generation from combustion activity. Participants were then asked to provide their views on whether there is any relation between the manner in which power plants execute their combustion activities and fly ash generation rated. Figure 4.20 below summarizes participants' perceptions.

Figure 4.20: Participants' perceptions on the influence of coal power plants' operational philosophy on the amount of fly ash generated (N.123)



Source: field based material

Based on figure 4.20 above, a strong number of participants (95) perceive that operational regime does influence the amount of fly ash produced while only 13 participants disagreed. Another participant from environmental consultancy commented that, "*should there be opportunities to further investigate technologies to better treat and recycle the ash rather than disposal at ash dumps that would be a step in the right direction"-(*Pers.com 2017x*).* Further to above, a participant from environmental consultancy sector added that:

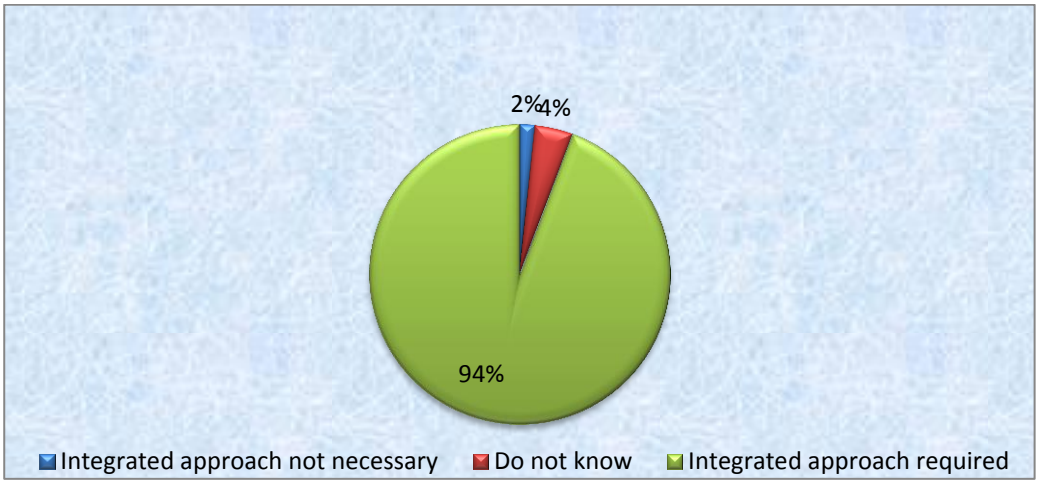
*"The chemical content of the coal burned (harder, older anthracite and bituminous or younger lignite or sub-bituminous coal) will largely influence the chemical properties of the fly ash. Class F fly ash is produced when burning harder, older anthracite and bituminous. Class C fly ash is produced when burning younger lignite or sub-bituminous coal). Class F fly ash is pozzolanic in nature, and contains less than 7% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime—mixed with water to react and produce cementitious compounds. Alternatively, adding a chemical activator such as sodium silicate (water glass) to a Class F ash can form a geopolymer. Class C fly ash has pozzolanic properties and some self-cementing properties. In the presence of water, Class C fly ash hardens and gets stronger over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate (SO4) contents are generally higher in Class C fly ashes" "-(*Pers.com 2017b*).*

Other participants also added that coal characters such as the ash content, calorific value and source of coal (underground and opencast mine) has an effect on the quantity of coal ash which ultimately gets generated. Assumptions which can be drawn from figure 4.20 and participants' additional comments above are that, the manner in which Kriel Power Station operate its boilers and the quality of coal (in terms of CV, ash content, sulphur content) directly determines the amount of generated fly ash.

4.7 REVIEW OF THE IMPORTANCE OF IMPLEMENTING AN INTEGRATED APPROACH TO OPTIMIZE FLY ASH UTILIZATION

This section will present data collected from the field which include participants' viewpoints obtained through questionnaires and interviews which are relevant in determining the importance of implementing integrated environmental management principles to optimize fly ash utilization. Fly ash, in South Africa, is mainly generated by coal fired power stations which are primarily owned by Eskom and SASOL. In order fly ash optimization program should be sorely left with the aforementioned primary generators, participants were asked to provide their views on whether the integrated environmental management approach by various stakeholders (e.g. ash generators and users, regulators, NGOs, etc.) is importance to ensure that fly ash utilization is optimized. Participants' views are depicted in figure 4.21 below.

Figure 4.21: Participants' perceptions on the integrated environmental management approach



Source: field based material – refer to Annexure A10

Based on the results shown in 4.21 above, participants have demonstrated a prodigious perception in that stakeholders need to work as a team to optimize fly ash utilization. A total of 116 participants' views an integrated approached as critical in optimizing the ash utilization program while a mere 2 participants perceive the integration as unnecessary. A participant from Eskom's Environmental Assessment centre of excellence also added that:

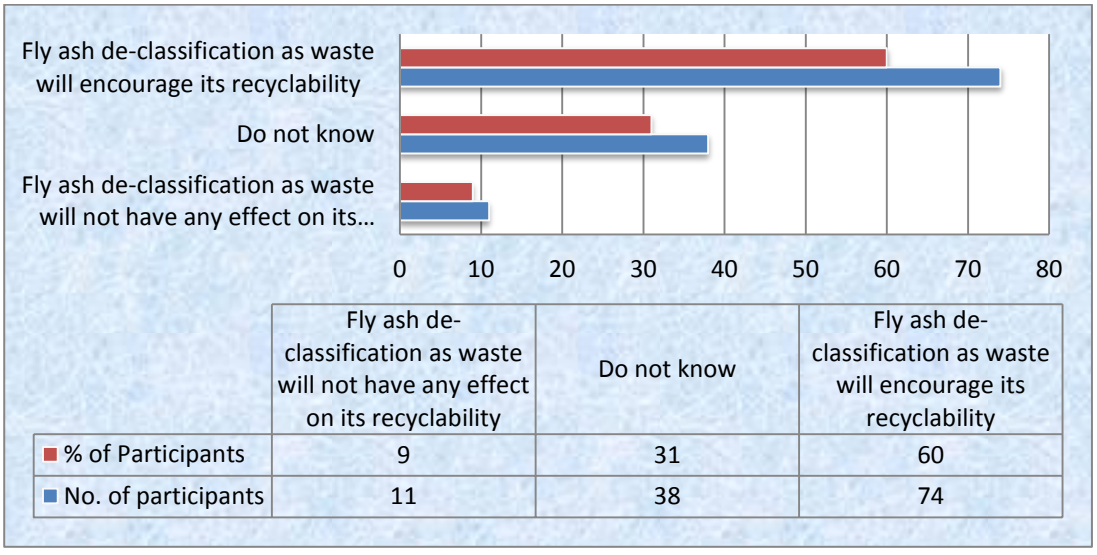
> "*The country should focus on integrated utilisation of ash (and waste, in general). This will enhance livelihoods though small business enhancement. Utilisation of ash cannot be left to the generating industry, but calls upon government to create an enabling environmental for partnerships for ash utilisation. Thus, a challenge should be posed on all government departments, e.g. Agriculture, Human Settlements, Small Businesses, together with environmental departments (DWA and DEA) to be part of the ash utilisation strategy to drive the sustainability goals"-(Pers.com 2017y).*

One environmental practitioner from Eskom's CoE commented that, "*regardless of legislative requirements, buy in and drive for the recycling of fly ash in various avenues is needed. Government intervention in the form of trade-offs is necessary for organisations such as Eskom. A clause that forces them to recycle fly ash in their Record of Decision/EMP is necessary" -(Pers.com 2017aa).* Other additional comment coming from a member of Kriel's Ash Optimization Committee stated that, *"government institutions need to enforce policies and strategies that encourage utilization of fly ash e.g. every road build must contain 30% ash in it.*

Funds need to be made available for infrastructure to recycle fly ash especially from disadvantaged communities"-(Pers.com 2017i). Participants also listed some stakeholders whom they perceive as critical role players and those include ash generators, government and its entities, communities, off-takers of ash, academic researchers, industries, regulators, environmental practitioners, local communities, business communities and Funders such as Industrial Development Cooperation. Based on evidence presented in figure 4.21 above, it can be concluded that an integrated approach is critical to ensure that fly ash utilization program is optimized.

Participants were also asked to provide their views on how they perceive South African legislation as an enabler to ensure that integrated optimization of fly ash utilization concept is achieved. Table 4.11 and figure 4.22 respectively indicate participants' views on whether the regulator and legislations are playing an enabling role within the web of integrated environmental management approach to ensure fly ash optimization.

Figure 4.22: Participants' perceptions on the proposed waste legislation changes (N.123)



	Fly ash de-classification as waste will not have any effect on its recyclability	Do not know	Fly ash de-classification as waste will encourage its recyclability
% of Participants	9	31	60
No. of participants	11	38	74

Source: field based material

Table 4.11: Participants' views on the current role of legislations in enabling fly ash recycling

Participants Perceptions	Participants Number	%
Legislation is not conducive to promote fly ash recycling	64	52
Do not know	34	28
Legislation is conducive to promote fly ash recycling	25	20
TOTAL	123	100%

Source: field based material

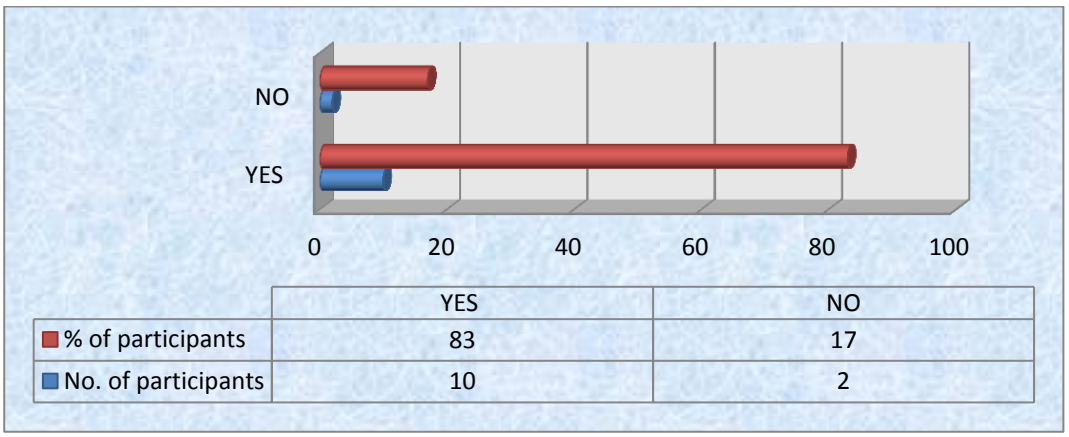
Correlating participants' views as depicted in table 4.11 and figure 4.22 above, participants perceptions harmonizes in that legislation is significant in unlocking ash utilization opportunities. In both table 4.11 and figure 4.22, more than 50% of participants perceive that legislation changes is necessary to ensure optimization of fly ash utilization. Noteworthy in figure 4.22 and table 4.11 is that, a very close and significant number of participants did not know what to answer. Other participant from government commented that, "*excluding coal ash from waste will improve the utilisation but the risk is that power stations will then become unperturbed and no longer act hurriedly in addressing dust spillages"-(Pers.com 2017ab);* while another participant from chemical engineering background at a coal fired power station indicated that*, "regulation to exclude ash from waste will open more opportunities of research on more usage as well"*-(Pers.com 2017ac).

An environmental practitioner from environmental consulting firm recommended that, *"any potential new fly ash processing technologies and/or uses must be legislated or at least be in accordance with formal legislation so as to ensure that everyone is using the same standards or rules*"-*(*Pers.com 2017x); while another environmental practitioner from coal fired power station argued that, *"Authorities' strict regulations and less research limit the use of fly ash for other processes. Government should allocate more resources to protect the environment"-(Pers.com 2017ad).* Not all participants are agreeing with utilization of fly ash though as another participant from environmental consultancy argued that, *"even if fly ash is delisted as "waste" it still contains hazardous substances which would pose issues with any recycling/reusing option"*- (Pers.com 2017ae). Another environmental specialist from environmental consultancy

expressed views that, "*technology, legislation and markets must work together to ensure value for ash*"; the participant further added that, "*there is an old ash dump in Vereeniging (Emfuleni) that has successfully been worked away over the last two decades*" (Pers.com 2017af). Based on empirical evidence presented in table 4.11, figure 4.22 and participants' comments above, it can be concluded that legislation in South Africa need to be more conducive to ensure the optimization of fly ash utilization.

Although participants have already indicated perceptions (refer to figure 4.22 and table 4.11 above) that legislation is currently serving as a bottleneck with regard to fly ash utilization, it was also necessary to explore if legislation in South Africa does not at all enable fly ash recycling. Figure 4.23 depicts interview participants' perceptions on whether South Africa (SA) has any legislation which encourage ash recycling.

Figure 4.23: Participants' perceptions on whether SA has any environmental legislation which seeks to promote ash recycling (N.12)



	YES	NO
% of participants	83	17
No. of participants	10	2

Source: field based material

Figure 4.23 above indicate that, despite perception that the South African legislation is unconducive, 83% of participants' views that the current legislation does promote recycling while only 17% disagreed. Adding to their views as indicated in figure 4.23 above, other participants indicated that the current national waste management strategy seeks to achieve waste reduction through waste management hierarchy; and that the proposed regulations to exclude waste streams such as coal ash from the definition of waste are other efforts by government to optimize waste recycling. Based on evidence presented in table 4.11 and figure

4.23, it can be concluded that the current legislation does have loopholes which promote fly ash recycling however, those loopholes are not ideal for potential ash recyclers.

4.8 CONCLUSION

Chapter four has successfully presented the empirical evidence which included participants' perceptions as well as experimental data in response to six research questions. The empirical evidence has indicated that, based on its chemical properties and management approach, Kriel Power Station' fly ash can be a cause of pollution to the environment; however, its properties also presents great recycling opportunities which can benefit social, economic and environmental spheres. Evidence also indicated that fly ash disposal at ash dams is not a sustainable option as it results into all sorts of pollution while on the other hand; fly ash recycling is viewed as a sustainable option with a lot of benefits which include social, economic and environmental. Empirical evidence also indicated that fly ash recycling program is faced with a number of challenges which need to be addressed. Perceptions on the power stations' operational philosophy and existence of technology to respectively reduce fly ash generation and also optimize fly ash utilization were also gathered; and most participants indicated that opportunities to improve current fly ash management approach are there and they should be utilized. The results also indicated that the optimization of fly ash utilization cannot be a one man's show; and that all relevant stakeholders including generators and regulators must work together to make the program a success. Generally, participants' views indicate that fly ash utilization is the way to and more work still need to be done, including conducting awareness, for the program to be successful.

CHAPTER FIVE

ANALYSIS AND DISCUSSION

5.1 INTRODUCTION

Chapter 5 presents analysis and discussion of empirical evidence. The primary purpose of this chapter is to add meaning to the fieldwork results as presented in chapter 4. Part of analysis and discussion include comparing the findings of this study with findings from other previous literatures. Limitations of this study's findings will form part of the discussion. Chapter five is critical in responding to the aim of this study which is to investigate alternative ways in which fly ash can be managed effectively to minimize environmental impacts in order to ensure alignment with the notion of sustainable development. Hereunder follows a systematic presentation of interpretations and discussions of collected empirical evidence to address research objectives.

5.2 CHEMICAL COMPOSITION OF FLY ASH

As a starting point in understanding the chemical composition of fly ash, fieldwork results as depicted in figure 4.1 above strongly suggest that, combustion of poor coal quality ultimately result into a low grade fly ash. This observation has also been presented by a number of scholars, such as Sahoo et al (2016); Van Der Merwe et al 2014; Mupambwa et al (2015); and Nawaz (2013), who also indicated that the chemical properties of fly ash will vary from one source to another due to many aspects such as coal type and coal characteristics. The observed results strongly suggest that, the one size fits all approach cannot be used to assume the chemical composition of Kriel Power Station's fly ash or fly ash from any other source as a variety of influential factors do play a vital role in circumscribing the final physiognomies of fly ash.

The laboratory test results, as presented in table 4.1 above, indicate that typical elements comprised in Kriel Power Station's fly ash are SiO2, Silicon Dioxide Al2O3, Aluminum Oxide; Fe (total), Iron; Fe2O3, ferric oxide ;TiO2, titanium dioxide ;CaO, Calcium oxide; MgO, magnesium oxide; Na2O, sodium oxide; K2O, potassium oxide ; and MnO, Manganese oxide (Golder Associated, 2016). Empirical evidence also revealed that Kriel Power Station's fly ash

mainly contains 47.9% to 51.1% of Silicone Dioxide. The second highest percentage of chemical element in Kriel's fly ash is Aluminium Oxides ranging between 21.2% and 30.9%. The percentage range for Silicone Dioxide found at Kriel Power Station's fly ash slightly varies with the percentage range proclaimed by Mupambwa et al (2015) as a typical range for South African fly ash. Mupambwa et al (2015) pronounced that the typical fly ash percentages in South Africa range from 50.1% to 67%. Based on the observed variance on SiO2 percentage range between Kriel Power Station's fly ash and Mupambwa et al (2015)'s pronounced typical percentages for South African fly ash, it can be deduced that fly ash character varies from one geographical location to another; and therefore, few fly ash samples which may have been taken in various geographic locations may not necessarily provide an accurate representation of fly ash' chemical composition for the ash generated in Kriel Power Station and/or the whole of South Africa.

According to the results depicted in table 4.2, Kriel Power Station's fresh fly ash from the plant contains high concentrations of Silicone Dioxide and Aluminium Oxides compared to the fly ash in other areas outside the plant. The test results indicate that the chemical elements such as As, Ba, B, Cu and Pb contained in Kriel Power Station's fly ash exceed the total concentration threshold of 0 (TCT0) limits but are below the total concentration threshold of 1 (TCT1) as specified in South Africa's government notice regulation 634 regarding waste classification. Based on TCT threshold limits, Kriel ash materials classifies as Type 3 waste (Golder Associates, 2016). Based on the results of the study undertaken at Virginia's Yorktown power station by Gottlieb et al in 2010, there is some likeness which can be drawn from the fly ash at Virginia's Yorktown power station as well as Kriel Power Station's fly ash in terms of trace elements which include nickel, vanadium, arsenic, chromium, copper, molybdenum, and selenium. Despite these similarities detected in trace elements, the concentrations at Kriel Power Station's fly ash are low compared to those of Yorktown Power Station's fly ash (Golder Associates, 2016 and Gottlieb et al, 2010). Based on these observations, a conclusion can be made that, as much as two different batches of fly ash from different geographical locations may have identical chemical compositions, the concentrations thereof may be critical in determining the further use of particular fly ash as well as the associated environmental risks.

In terms of physical hazards, empirical evidence reveals that Kriel Power Station's fly ash is not flammable, explosive or oxidising and does not release toxic gases when in contact with water or acid. In terms of health hazards, empirical evidence also reveals that the percentage

concentrations of chemical elements obtained from the XRF and acid digestion were comparable to the cut-off concentration limits for hazard classes (Golder Associates, 2016). Findings further revealed that Total concentrations of major elements which exceeded 1% included SiO2, Al2O3, Fe (total), Fe2O3, TiO2, CaO and MgO and C. The TiO2 can be considered as a Group 2B carcinogen (possibly carcinogenic to humans) based on the IARC Monographs. However, these chemical elements, including TiO2 in its current form at Kriel Power Station (solids, low leachability), do not constitute a health risk (Golder Associates, 2016).

Based on the test results for chemical composition, Kriel Power Station's fly ash can be used adequately through recycling programs as it presents manageable risks to human health particularly when it is being handled with care. High concentration of Silicone Dioxide in Kriel Power Station fly ash presents various recycling opportunities such as glass making, sand casting, cement production, optical fibres, tiles, etc. A high concentration of Aluminium Oxides found within fly ash also presents opportunity to recycle ash for production of aluminium which can be used in various industrial applications.

5.3 ALIGNMENT OF FLY ASH DISPOSAL ACTIVITY WITH MODERN PRINCIPLES OF ENVIRONMENTAL MANAGEMENT AND SUSTAINABILTY

Findings, as presented in figure 4.2, expresses that a slight majority of participants perceive fly ash disposal at ash dams as aligned with modern principles of environmental management while a minority number of participants view it otherwise. The observation made by majority participants in this regard differs with the observation made by Ayanda et al (2012) which discarded the view that storage of fly ash at ash dams is aligned with contemporary principles of environmental management and therefore stating that storage and disposal of coal fly ash can lead to the release of leached metals into soils, surface and groundwater. Based on the aforementioned empirical evidence, there is a visible and significant contrast in participants' views which could also be a signal for knowledge gap among other participants who are not directly involved in fly ash handling and storage activities. The subject of gaps in knowledge was also highlighted by Ginster and Matjie (2005) as one of the issue which negatively impact the optimization of ash utilization opportunities at SASOL. The fact that over half of Eskom coal fired power stations largely manage fly ash through disposal to ash dams may be one of the contributory factor on why other personnel view disposal as a aligned with contemporary

principle of environmental management. Based on the observations, one can deduce that more awareness training on fly ash impacts and its ideal management practices based on the national strategies and goals need to be undertaken from national level to institutional level.

Further to above, the current ecological sustainability challenges associated with fly ash disposal activity such as air pollution, water pollution, land pollution as well as huge ecological footprint justify the relegation of an activity as unideal approach which is definitely misaligned with contemporary principles of environmental management. The observation by majority participants which idealized disposal of fly ash is also misaligned with one of South Africa's national waste minimization goals which is to ensure 50% utilisation of ash, through increased recovery by 2024 (Department of Science and Technology (DST), 2014).

A huge number of interview and questionnaire survey participants has largely indicated that recycling of fly ash, instead of disposing it, is a sustainable option due to the fact that fly ash is actually a recyclable resource (see figure 4.2. and figure 4.4 above). This view strongly contradicts with the view which considers fly ash disposal as aligned with contemporary principles of environmental management; however this view is aligned with the goal set for South Africa to utilize more ash as indicated in the DST (2014) report. This observation also harmonizes with Tiwari et al (2016)'s observation which indicated that the Government of India have implemented a huge effort in managing their produced fly ash effectively through a designated unit called Fly Ash Unit/Mission aimed at maximising fly ash utilization. Based on this piece of information, Kriel Power Station can also take advantage of its generated fly ash by utilizing it to generate revenues and also reduces liabilities associated with ash dam footprint; this can also reduce the cost associated with establishing, constructing, operating and decommissioning of ash dams.

Based on the evidence discussed in this section, it is clear that the slight majority views the current fly ash management practice at Kriel Power Station as ideal in terms of contemporary principles of environmental management; however, it can be argued that this view is largely influenced by people's stereotypes to traditional way of fly ash management with less information on the risks associated with the management approach. One can further infer that, despite participants' knowledge in ash dams operations, there is a clear gap in knowledge in relation to actual impacts associated with ash dams hence awareness drives may be necessary. Strong observations suggesting that fly ash is a resource reduces the ash disposal activity to an

unidealistic environmental management practice for managing fly ash which is not aligned with sustainability concept. Based on the observations above, it can be further argued that the current fly ash management approach at Kriel Power Station is mainly focused on pursuing production ambitions (economic) while overlooking the wellbeing of environmental and social aspects which are also being impacted by fly ash disposal activity. The current approach lacks viability in terms of balancing economic, social and environmental aspects of sustainable development.

5.4 POTENTIAL IMPACTS OF FLY ASH ON ENVIRONMENTAL, SOCIAL AND ECONOMIC ASPECTS

As illustrated in table 4.5, this study has found that fly ash disposal at the ash dam facilities is largely viewed as contributing significantly to air pollution, water pollution and ecological degradation. This observation has also been presented by scholars such as Tiwari et al (2016) and Shamshad et al (2012) who both argued that thermal power stations result into environmental footprint as they require huge land for fly ash disposal and they are also major sources of air, water and soil pollution. Based on the fieldwork observations, it can further be argued that fly ash establishments are often associated with clearance of huge areas of undisturbed land which in most cases would be supporting the indigenous fauna and flora in the particular area. Despite implementation of controls to suppress dust from ash dam facilities, some of the dust from fly ash disposal, does escape the ash dams as fugitive dust to pollute surrounding areas; and eventually causing land and surface water pollution as it settles to the ground.

The fieldwork observations presented in figure 4.13 also reveals that fly ash disposal at unlined facilities such as Kriel Power Station can result into ground water pollution. This observation was also presented in Gottlieb et al (2010) study which indicated that fly ash which used to be stored in the sand and gravel pits from Yorktown power station in Virginia resulted in contamination of boreholes with chemicals such as nickel, vanadium, arsenic, beryllium, chromium, copper, molybdenum, and selenium. Based on these observations, it can be argued that that aspects such as fly ash's chemical composition, fly ash's leachate characteristics, strength and weaknesses of applied control measures in the disposal facility (e.g. ash dam liner, etc.) and aquifer/geology of the area are critical in determining fly ash's potential likelihood and severity of in causing groundwater pollution. It is therefore important to investigate and

understand the status of the aquifer or geology and potential reaction of groundwater thereof when mixed with a particular type of fly ash.

The impact caused by ash dam establishments is viewed as largely irreversible – this is according to the views of both interview and survey participants (see figure 4.15 and 4.16). In addition to this observation, a strong case can indeed be presented in that most of the impacts associated with ash dam disposal are irreversible; however, there are certain cases wherein decontamination measures can be applied to reverse the impacts. Ash dams' establishments are arguably associated with irreversible impacts in terms of fauna and flora or ecosystem destruction although the contemporary environmental management principle encourages undertaking of ecological offsets projects in cases where ecosystems have been irreparably damaged.

Fly ash from ash dams does not only pose environmental risks; however, it also poses health risk to human beings – this is according to the findings. The participants' views, as depicted in table 4.8, table 4.9 and figure 4.19, suggest that fugitive dust fallout from fly ash disposal facilities can result in human health; and that communities staying closer to ash dam facilities are impacted negatively by air and water pollution emanating from ash dams. This observations was also presented in Ayanda et al (2012) study which argued that fly ash consist of alkaline and heavy metals that are detrimental to human health and the environment. Based on the observations, it can be argued that, due to its very fine texture, fly ash can easily be blown by wind and therefore putting human beings at risk of inhaling fly ash particles and ultimately suffering from respiratory health related issues. Through reaction with water, fly ash on unlined ash dams has a potential to seep into the aquifer and eventually reach nearby water boreholes to cause pollution. In this case, human beings may then be affected when they pump the water from the polluted borehole for domestic use or livestock feeding.

According the findings, the impacts of fly ash disposal are not only visible at the ash dams; however, the transportation mechanisms to convey fly ash to the ash dams also contribute to pollution (figure 4.17). Findings strongly suggest that transportation activity of fly ash to the ash dam facilities has a potential to cause air and land pollution. In addition to this observation, one can argue that fly ash often gets transported to the ash dams through conveyor belts; and at times, fugitive dust fallout and ash spillages do occur during transportation and end up causing pollution on the immediate soil and atmosphere. The main reasons of spillages from conveyor

belts are often maintenance issues such as belt misalignment; fugitive dust fallout may result mainly due to inadequate water conditioning of fly ash before transportation to ash dams.

The sensory experience also suggests strongly that the likelihood and severity of fly ash's environmental impacts is directly connected with the selected management approach. This observation was also presented by scholars such as Chen (2015) and Openshaw (1992) who argued that the environmental management practices are relative to company's innovation performance; and that, where there is a weakness in the management practices, fly ash can be very dangerous instead of being useful. Based on these observations, one can argue that failure for Kriel Power Station to implement an effective fly ash management approach which is embedded on sustainability concept will cause a severe crack on management practice and these cracks will show up through impacts on either social, economic and environmental aspects.

One of the findings of this study was that the leachate characteristics of Kriel Power Station's fly ash in terms of pH, is ranging between a figure of 10.57 and 11.56 (see table 4.6). The results further indicate that the leachable concentration (LC) of chemical elements such as As, Ba, B, Cr (total), Cr (VI), Mo and Se exceeds the LCT0 limits (Golder Associates, 2016). Based on the fieldwork evidence, it can be argued that Kriel Power Station's elevated fly ash's pH in terms of leachate character should be treated with a concern as the results could be evocative of that fly ash disposal especially within unlined facility presents high likelihood of contamination to groundwater as it introduces changes on groundwater pH from neutral to extreme alkaline. Further to above, the chemical elements which are above LCT0 should trigger an immediate concern, because if not effectively managed, they may accumulate and eventually result into significant groundwater pollution.

Contrary to the evidence discussed above indicating elevated fly ash pH in terms of leachate character, the evidence from actual groundwater tests results, as presented in table 4.7, indicate that pH around the ash dam complex ranges between 6.5 and 8.5. The pH results of 5 borehole around the ash dam complex are within the neutral zone and acceptable. Based on the observations, it can be argued that the reason for the pH results which are within the neutral zone is due to the fact that Kriel Power Station's ash dam complex is located immediately adjacent to historical opencast mine which left a legacy of significant amounts of unattended coal spoils around the ash dam complex; and therefore the seepage of mainly acidic water from

aforementioned coal spoils obviously assist in balancing down the high pH water from ash dam complex to neutral.

In addition to above, the results of a numerical modelling conducted around the ash dam complex using sulphates as a water quality indicator revealed that in year 2015 already, there was a significant pollution on groundwater around complex (see figure 4.14). The evidence also showed that ash dam compartments 1 and 2, which were the initial compartments to be constructed, had pollution over 1200mg/l while the newer ash dam compartment 3 was showing pollution around 900mg/l. Sulphates limits were measured against the drinking water standard limit of 500mg/l since Kriel Power Station has not yet received its water use licence under the National Water Act, 36 of 1998. Based on the empirical evidence, it can be argued that comparing sulphates performance on Kriel Power Station's groundwater performance at the ash dam complex with drinking water standard is also a limitation in a sense that the ash dam complex is not lined and it is bound to pollute; however, the numerical model does put into perspectives the risks of groundwater pollution due to disposing of fly ash at Kriel Power Station's unlined ash dam. Based on the evidence, it is clear that the fly ash disposal activity at Kriel Power Station's ash dam is significantly contributing to groundwater pollutions as sulphates concentrations have been constantly on the rise.

This passage of evidence discussion has indeed indicated that fly ash disposal activity is associated with numerous pollution trails which include land, water, air as well as significant environmental footprint which also negatively affect the functionality of ecosystems. It has also came up in this passage of discussion that it is not only the environment which sits on the receiving end when it comes to impacts of fly ash disposal; however, local communities also suffer health effects due to air quality and groundwater pollution. The management approach was highlighted as critical in ensuring that fly ash does not pose environmental impacts or at least they are minimized.

5.5 SOCIAL, ECONOMIC AND ENVIRONMENTAL OPPORTUNITIES PRESENTED BY FLY ASH

The concept of sustainable development can only be achieved if viability between social, economic and environmental aspects is pursued – this was a strong view demonstrated by participants (see figure 4.5). Similar observation was also presented by Danciu (2013) indicating

that sustainability is about managing corporate firms in such a way as to ensure that they stay around for future generations with social and environmental programs firmly intact; and that business sustainability is relative to organization's approach in managing social, economic and environmental aspects. In addition, fieldwork results presented in figure 4.6 above largely indicate that South Africa needs to prioritize the sustainable development agenda. Based on the above observations, it can be concluded that Kriel Power Station's activity to dispose fly ash at the ash dams completely misses a great opportunity to align with sustainability concept.

In addition to the observations presented above, one can strongly argue that the concept of sustainability has evolved and countries together with their industries have come to realise that developments which are only focused on economic growth faces immense liabilities which tend to haunt them on the later stage; such liabilities are associated with depletion of natural resources as well as social imbalances. Industries, such as Kriel Power Station, are also realising that corporate investment mandates which are fulfilled sustainably ensures a long term stability of an organization; for example, instead of disposing fly ash at ash dams, fly ash can be given to local communities for concrete and brick-making; and therefore uplifting local communities' livelihood and social profiles while also saving on disposal costs and minimizing environmental impacts associated with ash disposal.

In terms of economic benefits, results depicted in figure 4.7 and figure 4.8, largely indicate that disposing of fly ash at the ash dams is expensive compared to recycling; and that fly ash utilization is a sustainable management option as it ensures that environmental footprint and disposal costs are minimized while creating employment opportunities to the ash recyclers. This observation was also presented by American Coal Ash Association (ACAA) (2017) which pointed out that valuable environmental and economic benefits can be achieved through utilizing recycled industrial material such as fly ash in construction. Based on the presented observations, one can strongly argue that the activity to dispose fly ash at ash dams is a significant setback for fly ash generators such as Kriel Power Station as they miss out on opportunities to utilize ash while actually generating revenue; ash disposal is associated with high construction and operational costs. After decommissioning, the ash disposal activity is further associated with costly environmental liabilities which the organization need to closely manage for years.

According to the findings presented in figure 4.7, fly ash utilization program is largely viewed as economically sustainable provided there is adequate optimization drive. Participants' views further suggest that South African market can still absorb more fly ash (see table 4.3). This observation has also been presented by Nawaz (2013) who argued that developed countries should utilize more than 80% of their produce fly ash. Based on this information, one can also supplement that, South Africa is a developing country with an economy which is steadily growing; this basically mean that activities such as construction of infrastructure and superstructures are in full swing in the country and it is these activities which are supposed to be used as the market base to consume tons and tons of fly ash being generated around the country. South Africa also sit with a number of used mine workings which are not yet rehabilitated and therefore potentially presenting environmental challenges such as acid mine drainage; neutralizing capability of fly ash can be used to rehabilitate opencast and underground mines' shafts and therefore minimizing the South African challenge of acid mine drainage. In addition to fieldwork findings, it has been observed that the main issue which arguably result into a seed of doubt being planted on the thoughts of most fly ash potential users in South Africa is that, fly ash utilization is a new market and many still need to understand its diverse benefits and dynamics.

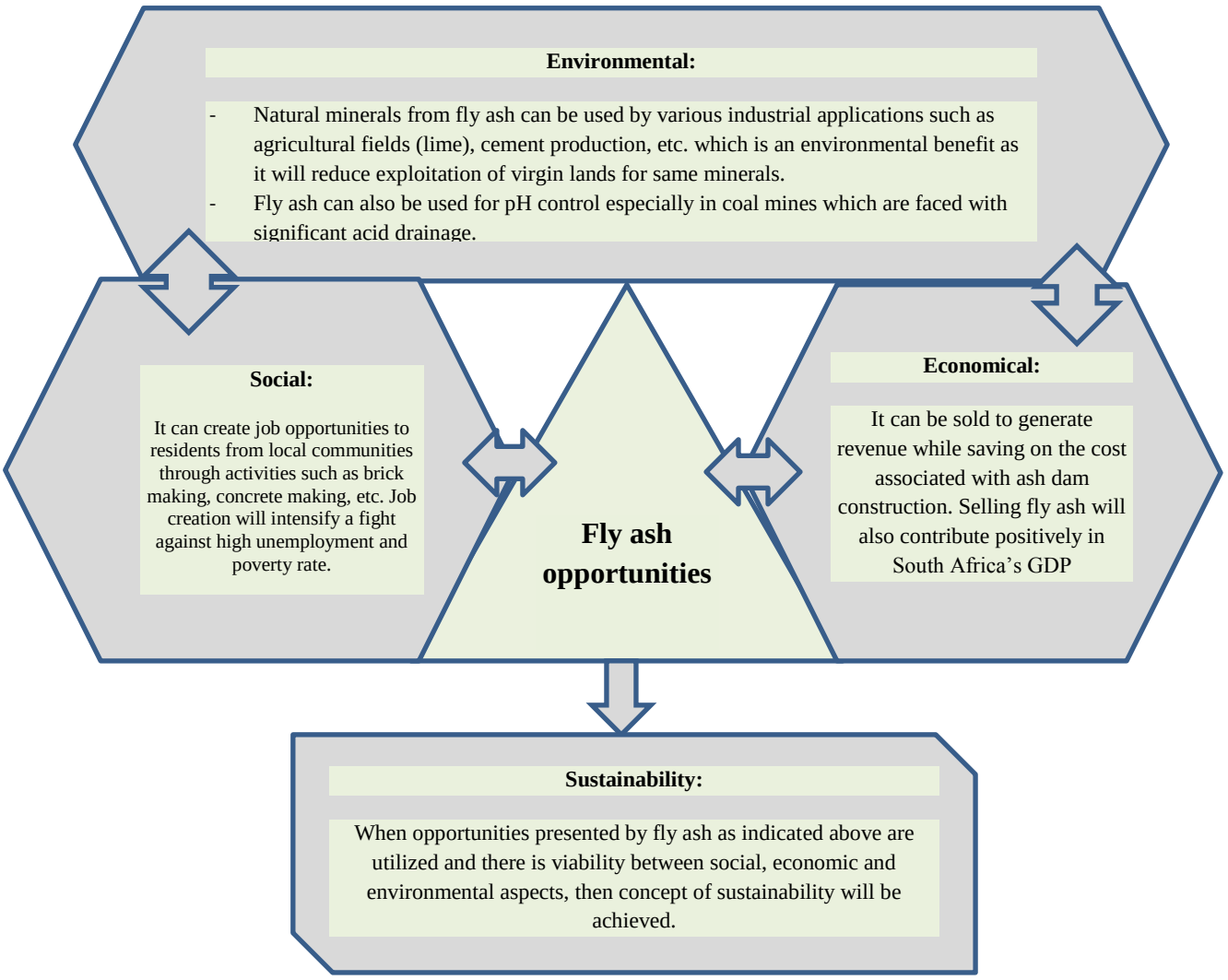
As presented in figure 4.12, the results suggest that the biggest fly ash generators in South Africa such as Eskom are indeed putting enough effort to increase fly ash utilization. However, further evidence indicate that as much as ash generators may be putting enough effort to increase fly ash utilization, they still need to undertake more awareness on fly ash utilization to unlock interest from communities (table 4.4 and figure 4.11). Based on the findings, it can be argued that ash generators are indeed doing something to increase fly utilization; however, the shortfall on this effort is that, it is mainly focused within the organizations themselves and it therefore lacks innovation to attract potential entrepreneurs through means such as creative marketing and awareness campaigns. On the issue of innovation, what is evident with particularly Eskom Kriel Power Station is that the main focus is channelled and limited on recycling fly ash through cement industry which is already saturated; very little effort has been invested on exploring more opportunities to recycle fly ash in areas such as agriculture, mines, concrete, jewellery making, etc.

The fieldwork results, as depicted in figure 4.9, strongly suggests that more avenues exist through which fly ash can be recycled besides the cement industry. This observation was also

presented by Nawaz (2013) who highlighted that fly ash can be recycled through avenues such as brick-making, cellular concrete blocks, road construction, landfill application, ceramics, agriculture, insulating bricks, recovery of metals, dam constructions, etc. based on the presented evidence, it can be argued that the well-known fly ash recycling approach in South African as well as in Kriel Power Station is through cement industry hence it is important to undertake more research to examine fly ash characteristics and further determine other streams through which fly ash can be recycled over and above cement industry. Kriel Power Station has internally invested on expanding the fly ash utilization program and most employees appears to view fly ash utilization as an ideal management option which requires immediate implementation; however, the challenge is that most communities staying within 15 kilometres radius from power station have little to no idea about any other use of ash except the fact that it is a waste from energy generation which makes their life a living hell through air and groundwater pollution. It can therefore be further argued that, no matter how hard fly ash generators such as Kriel Power Station can try to promote ash utilization, if they do not run awareness campaigns to attract potential utilizers, the program to optimize fly ash utilization will struggle to take off the ground in a big way.

Views of research participants strongly suggest that optimizing fly ash utilization program does assist the organization to alleviate its environmental liabilities (see figure 4.10). Although the presented evidence is not clear on how ash utilization can assist in curbing the environmental liability, it can be argued that ash disposal at Kriel Power Station's ash dam poses a liability risk; groundwater pollution associated with Kriel Power Station's unlined ash disposal facility is associated with operational and post-operational liabilities which have a potential to result into civil cases where liability related issues are not well managed. Strict rehabilitation conditions associated with ash dams after decommissioning are also part of liabilities which an organization may avoid by just intensifying fly ash utilization program and phase out ash disposal activity. Figure 5.1 below provides an exemplary illustration on the benefits of fly ash within the context of modern principles of environmental management and sustainability discourse.

Figure 5.1: Fly ash opportunities within the context of sustainability and contemporary environmental management.



Source: field based material

As depicted in figure 5.1 above, Kriel Power Station can benefit largely if it uses fly ash instead of disposing. If the station commits to recycle almost all of its generated fly ash, it will greatly ensure a balance between social, economic and environmental aspects in terms of its operational sustainability. Kriel Power Station can also use fly ash utilization program to empower local communities by giving them employment through activities such as brick-making. Fly ash can also be provided to various industries that requires fly ash or its minerals for different production purposes; this in return will economically benefit Kriel Power Station as the disposal cost will be alleviated while generating revenue from recycling. It terms of environmental

aspect, fly ash recycling will ensure that adverse environmental impacts associated with fly ash disposal are minimized or eliminated in case all the generated fly ash gets recycled.

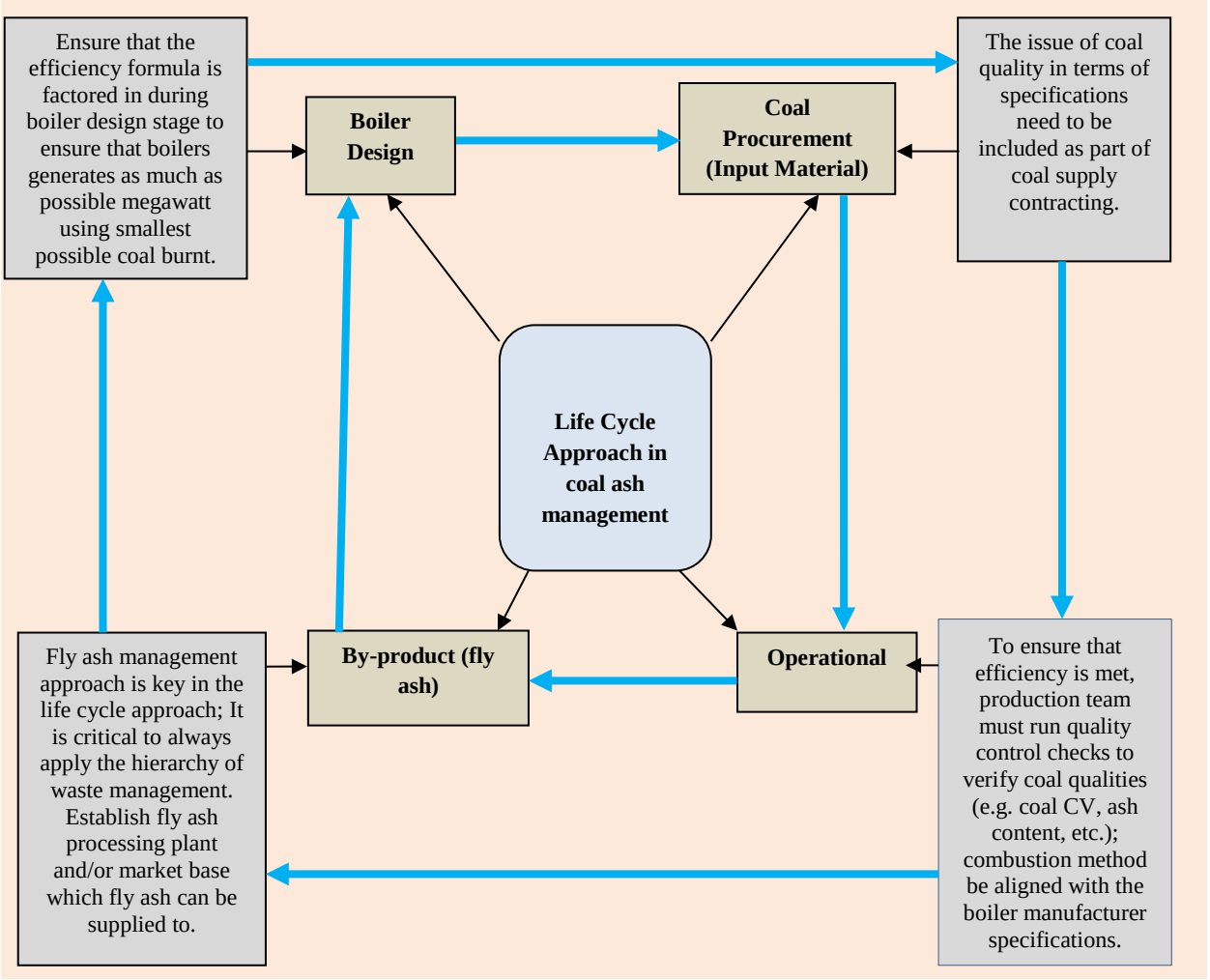
Based on the observations discussed above, it can be argued that sustainability thinking and approach is the way to go; and that a sustainable way of fly ash management is through recycling. There are a number of benefits directly linked with fly ash utilization which can be categorized under social, economic and environmental ranges. Awareness to communities on opportunities which exist in terms of fly ash recycling is required to optimize the program.

5.6 TECHNOLOGICAL MEASURES TO EFFECTIVELY MANAGE FLY ASH LIFE CYCLE

The manner in which power stations are operated can influence the amount of fly ash generated – this is according to the fieldwork results as presented in figure 4.20. This observation was also presented in a study undertaken by Kruger and Krueger (2005) which indicted that fly ash is a diverse substance with differing characteristics depending on the source of the coal used in the power plant and the method of combustion. Based on empirical evidence, one can further argue that operational regime as well as coal quality does contribute significantly to fly ash generation. If the coal is poor in terms of its energy content (Calorific Value), it will therefore require more coal to be burnt in order to produce required heat to run the boiler; and as result, generating large quantities of ash in the process. It is therefore very important that as part of operational regime, Kriel Power Station ensures that coal with acceptable quality gets burnt in order to reduce the amount of ash which is produced and potentially disposed of at ash dams.

According to the fieldwork outcome, advanced ash processing technologies are now accessible for industries such as Kriel Power Station (table 4.10). Based on this observation, one can further add that advanced ash processing technologies are available in South Africa as it is evident with the ash that is already being enhanced for use in cement manufacturing, road construction, brick making and concrete making. For organizations which want to establish new fly ash processing plants, there are arguably a number of companies which can assist with designing the processing technologies and they are well spread across the world including in South Africa. Figure 5.2 below is a life cycle process which is a great example of how Kriel Power Station can use technology and operational philosophy to reduce fly ash generation as well as optimize utilization of already generated fly ash.

Figure 5.2: An example of life cycle perspective in managing Kriel Power Station's fly ash.



Source: field based material

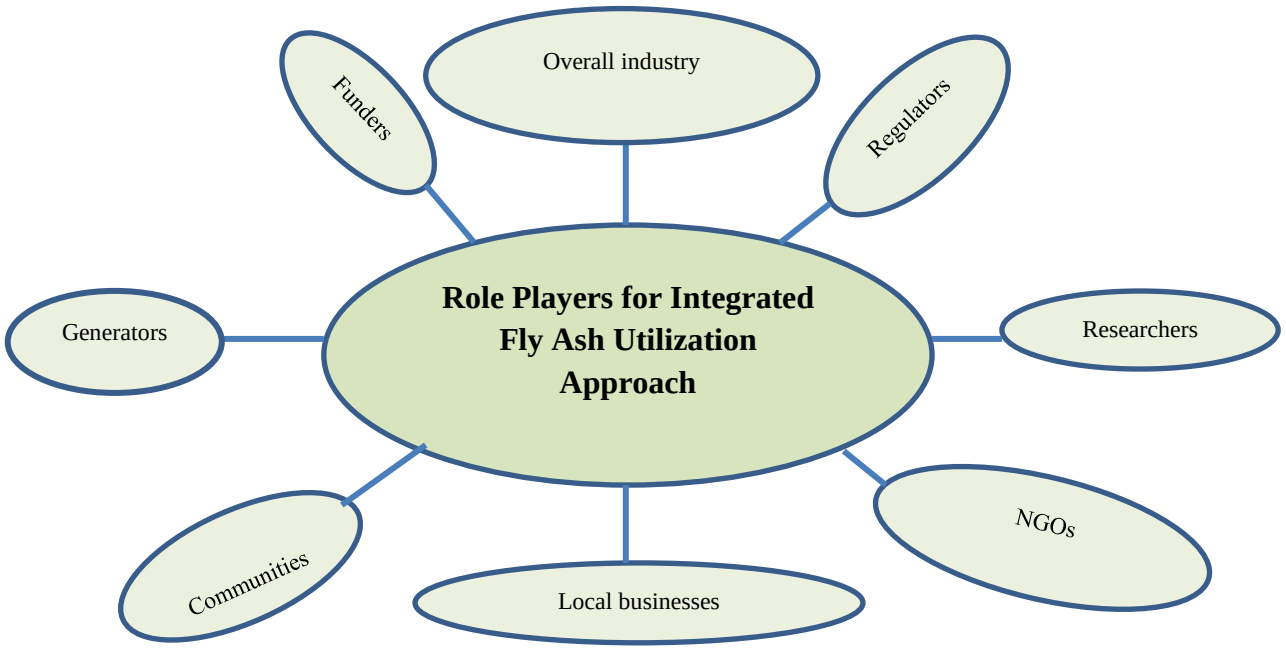
Figure 5.2 above is an example of a process flow which can be useful for Kriel Power Station in ensuring that coal ash generation activity is sustainably managed from as early as the plant design stage up to by-product management stage. In order to completely do away with fly ash disposal and its impacts, Kriel Power Station needs to be operated with great efficiency level. When one talks about efficiency, this should be based on the whole life cycle, starting from raw material (coal) input all the way to the output material including by-products such as waste.

In addition to above, it is also important that organizations such as Kriel Power Station must invest in researches to explore potential technologies to optimize fly ash utilization; the research is necessary because ash utilization market is still emerging and is at its infancy stage in South Africa hence it is critical to gather necessary facts about the market to ensure sustainability of the program.

5.7 THE IMPORTANCE OF IMPLEMENTING INTEGRATED ENVIRONMENTAL MANAGEMENT PRINCIPLES

As presented in figure 4.21, results shows that regulators, fly ash generators, ash utilizers and NGOs need to work together to ensure that more ash is utilized. In addition to this observation, it can be further argued that industries which need access to fly ash from generators such as Kriel Power Station are widely spread across South Africa; and it is important that the identified role players do work together to successfully implement the ash utilization program. Figure 5.3 below is a typical example of various role players who need to be unified and work together to ensure that the utilization of fly ash is optimized.

Figure 5.3: Critical role players to ensure integrated approach in optimization of fly ash utilization.



Source: field based material

What is basically illustrated in figure 5.3 above is that, fly ash utilization program cannot be a one organization's show. Stakeholder need to work together. For example, if the regulator promulgates laws which disables fly ash recycling, the ash utilization program will not take off; the same applies to fly ash generators, if the generators such as Kriel Power Station do not create enabling environment to ensure fly ash off-take within operational configurations, the potential off-takers will not be able to access the ash; and lastly, if the potential fly ash users still

chose to only rely on virgin minerals from the mines or quarries as input material to their production processes instead of using minerals already extracted and accessible in fly ash, that will also affect the utilization program in a big way. In addition to above argument, it is also important to note that as much as fly ash presents a lot of opportunities, these opportunities may not be realized unless all stakeholders do their part to create enabling environment for fly ash optimization.

Integrated usage of waste need to be ensured and government has to play a critical role in creating enabling environmental for the industry to be able to utilize more ash. Talking about government creating the enabling environment, the fieldwork results indicate that the main obstacle hindering fly ash utilization through modern means in South Africa is the legislation which still defines fly ash as hazardous waste (see table 4.11); and the results further suggest that once the current draft regulation which is aimed at excluding coal ash as waste is finalized, ash utilization will increase (see figure 4.22). This observation has also been presented by Dernbach and Mintz (2011) who also argues that the concept of sustainability lacks implementation support simply due to unavailability of adequate legal framework through which it should survive, notwithstanding the existence of so many environmental laws.

Based on the observations, it can be further argued that the current legislative landscape in South Africa as compared to other countries around the world serves as the barrier when it comes to fly ash utilization. The fact that fly ash in South Africa is still classified as waste by the National Environmental Management: Waste Act, 59 of 2008 makes it difficult for potential ash users to enter into ash recycling activities as they are required to have waste management licence or alternatively go through very long processes to obtain exemption from undergoing the waste management licence application route. However, as supported by fieldwork results, fly ash generators such as Kriel Power Station cannot use the legislative barrier as a justification of not optimizing fly ash utilization because other avenues exist within the legislation which encourages fly ash utilization even though they are perceived to be long routed (see figure 4.23).

5.8 CONCLUSION

This chapter has indeed successfully put together various pieces of fieldwork findings and discussion thereof, in an exertion to address the aim and objectives of this study. Empirical evidence discussed in this chapter has clearly indicated that Kriel Power Station's fly ash consist of various chemical elements which, if managed sustainably can, benefit other industries as it can further be used for various production applications.

This chapter has also clearly indicated that fly ash can have either beneficial or adverse impacts depending on the adopted management approach. Management approach which views fly ash as waste may very well result into a lot of issues such as air, water and land pollution while the management approach which views ash as resource will potentially result into less environmental issues and viability within sustainable aspects. Sustainability concept is no longer a nice to have, but a concept that enables companies to protect the environment using less resource and therefore maximizing on financial performance. When viability amongst sustainability aspects such as social, environmental and economic is ensured everyone is then happy. The discussion presented in this chapter also revealed that more opportunities, which are aligned with contemporary principles of environmental management, do exist with regard to fly ash recycling but some of those opportunities require more research to be well understood. Evidence also revealed that the qualities of input material such as coal, affect the quantities and qualities generated fly ash. Although there are visible great opportunities which exist with regard to fly ash recycling, findings indicate that these opportunities may not be realized if various stakeholder do not work together to create enabling environment for fly ash utilization.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

This chapter presents the principal conclusions and key learning points which were learnt during the exploration of environmental impacts of fly ash on Eskom Kriel Power Station's business sustainability and sustainable development. Firstly, this chapter highlights the key findings explored from the research; understanding the key findings is important as it provides intimation on the overall outcome of the research. Secondly, this section also provides some policy recommendations which can potentially be useful in ensuring that there is a continual improvement in fly ash management. Lastly, the chapter conclude by also identifying and recommending some research gaps which were not covered by this research but requires attention by future researchers.

6.2 SUMMARY OF KEY FINDINGS

The primary focus for this research was on exploring Kriel Power Station's current fly ash environmental management practices in line with contemporary principles of environmental management and sustainability. In addition, this study also identified the actual and potential environmental impacts resulting from the current ash management practices; and also identified possible environmental management approaches and solutions which can be employed to optimize ash utilization through other avenues other than ash disposal.

An assessment of Kriel Power Station's fly ash chemical composition was one of the critical objectives for this study. The study found that Silicon Dioxides (SiO_2) followed by Aluminium Oxides (Al_2O_3) are the primary oxides within Kriel Power Station's fly ash; with SiO_2 concentrations ranging between 47% and 52% while Al_2O_3 concentrations ranging between 21% and 31% under various fly ash conditions (i.e. fresh fly ash, old fly ash and weathered fly ash). The study also found that Barium (Ba) is the main substance found in high concentration in Kriel Power Station's fly ash; however, other substances which can be useful in alloys industries such as Nickel (Ni), Manganese (mn), Copper (Cu) Chromium (Cr (T)), etc. are also

found in Kriel Power Station's Fly Ash. This research also found that most participants view fly ash characteristic as directly related to the quality of coal burnt.

One of the key findings of this research, which was identified through the review of various literatures as identified in chapter 2 is that, sustainable development approach which seeks to strike a balance between social, economic and environmental aspects is no longer 'a nice to have' approach but it is indeed 'a need to have' approach. According to the findings, the development which only focuses on pushing the interest of one aspect of sustainability, it is likely to pay the price of neglecting the other aspects few years down the line. This study also found that the current practice of disposing fly ash at Kriel Power Station's ash dam is largely viewed as misaligned with the sustainable development notion as well as the contemporary principles of environmental management as it does not take advantage of an opportunity to utilize fly ash resource in various sectors of the economy. In addition, the outcome of this research also suggest that failure to recognize fly ash as a resource will result into fly ash being treated as waste which is fit for disposal hence continue causing all sorts of adverse social, economic and environmental impacts.

One of the objectives of this study was to investigate the social, economic and environmental opportunities presented by fly ash. The findings of this study largely indicate that fly ash recycling programs in South Africa need to be intensified in order to align with sustainable development concept. In addition, findings of this study also suggest that fly ash utilization programs are sustainable because fly ash recycling is a cheaper option compared to disposal; and South Africa has a good market base which is ready to absorb more fly ash for a many good years to come. The findings also largely suggest that the cement industry is not the only option through which fly ash can be recycled as there are more opportunities in various sectors in which fly ash can be used. What is also critical to note as revealed by the findings is that fly ash utilization relieves organizations such as Kriel Power Station from environmental liabilities associated with ash disposal pollution and legal implications thereof. Findings of this study also suggest that fly ash opportunities will only be fully realised when those responsible (e.g. ash generators, government, etc.) conduct effective and strategic awareness campaigns with local communities and entrepreneurs to sensitize them on the ways to access fly ash and benefits associated with fly ash utilization.

This study also explored the impacts of fly ash on environmental, social and economic aspects. The study largely found that fly ash disposal activity together with the associated fly ash transportation means is viewed as the contributor to pollution and ecological degradation. The findings indicated that pollution types such as surface and ground water pollution, land pollution and air pollution mainly result from ash disposal facilities. The study also found that a strong perception exist that fly ash disposal within unlined ash dam such as Kriel Power Station cause groundwater pollution; however, laboratory test results suggested that the leachate characteristics of most chemical elements within Kriel Power Station's fly ash is generally low (<10) except for elements such as Total Dissolved Elements (TDS) which ranges between 200 and 3000 mg/l; sulphates which ranges between 30 and 120 mg/l; and pH which ranges between 10.5 and 12 mg/l (i.e. fresh fly ash, old fly ash and weathered fly ash).

Interestingly, the findings from groundwater monitoring activity around Kriel Power Station's ash dam complex reveals that the actual groundwater pH around the ash dam complex is ranging between 6.5 and 8.5 which is within a satisfactory buffer according to South African drinking water standard. The study also found that in 2015 already, the sulphates concentration on groundwater underneath Kriel Power Station's ash dam complex was already above 500mg/l which is indeed a concern. The study also found that fly ash establishment are perceived to result into irreversible ecological impact, particularly in terms of destruction of flora and dislocation of fauna.

The technological measures which are necessary to effectively manage fly ash throughout the life cycle were also investigated. The findings indicate that South Africa is viewed to have access to modern technologies which are necessary to process fly ash for use in various sectoral applications. Another important finding related to technological measure, as echoed by participants, is the issue of operational regime; it was largely indicated that power stations' operational philosophy can increase fly ash generation or reduce it. For example, if a power station is burning low quality coal in terms of having less CV, this will possible result into combustion of more coal to generate required heat as opposed to when the coal contains high CV.

The outcome of this study also largely suggested that an integrated approach by various relevant stakeholders in order to optimize fly ash utilization is absolutely significant. Findings strongly suggest that stakeholder should stop working in isolation when it comes to exploration of ash's

opportunities. The other significant finding from this study is that most participants' view South African legislation as currently the main bottleneck when it comes to optimization of fly ash utilization program as it still classifies ash as waste instead of it being classified as a resource. In general, this study found that fly ash utilization is largely viewed as a sustainable practice of management which just require more dedication and integrated approach to make it a success. Fly ash utilization as a management approach was largely found to be associated with more opportunities in social, economic and environmental aspects of sustainability as compared to ash disposal.

6.3 POLICY RECOMMENDATIONS

As indicated in section 4.7 above, fly ash utilization in South African can only be optimized through implementation of an integrated fly ash utilization program. All stakeholders need to work together to optimize fly ash utilization; however, there are critical role players such as ash generators (Eskom) and regulators (DEA) who need to play an enabling role through policy making. Establishments of fly ash utilization enabling policies will ensure that a principled and systematic approach is adopted to promote fly ash recycling.

South Africa's National Environmental Management: Waste Act (59 of 2008) still classifies ash as waste which then result in many people viewing ash as a rejected coal by-product fit for disposal at the ash dams. Evidence presented in section 4.4 has greatly highlighted huge benefits associated with fly ash utilization. It is therefore crucial that South African government, in particular DEA, should look at identifying various activities wherein fly ash can be used and then establish relevant policies to encourage application of certain percentages of fly ash as part of production in those activities. For example, a policy can be established to encourage the blending of fly ash percentages in all brick-making and concrete making activities. In addition, a policy which encourages the application of fly ash in closed mine shaft for pH balancing will definitely minimize the extraction of limestone for mine workings rehabilitation while encouraging fly ash utilization. What is critical is that, when establishing the ash optimization policies, the central government need to ensure that the integrated management approach is implemented to ensure that all stakeholders are within the same level of understanding. The policy which only encourages the ash generator to utilize fly ash and not encouraging the potential fly ash user to use fly ash is bound to fail.

Main fly ash generators such as Eskom and Sasol should be looking at placing policies which encourages fly ash utilization and also promote community awareness on the benefits of fly ash. It is through the said policies wherein these organizations will be able to establish fly ash utilization strategies and objectives in order to channel their drives for fly ash utilization. Fly ash utilization program which is not driven through the organizational policy is barely sustainable and it lacks accountability. For this policies to be successful, institutions which uses fly ash such as construction sector, cement manufacturing sector, etc. need to also look at establishing policies which promotes principled usage of certain percentages of fly ash for various production applications.

6.4 FUTURE RESEARCH

Although this study did identify the chemical composition of Kriel Power Station's fly ash, it neither explored in detail, the actual benefits nor adverse impacts presented by each fly ash chemical element. There is a need for further studies to be undertaken in order to understand in detail what each and every fly ash chemical element can offer as a resource to broader potential markets; there also a need to investigate in detail on the extent of adverse fly ash impact on air quality, water quality, land as well as affected ecosystem. Even though this research has found that fly ash market is huge in South Africa, it is also crucial to investigate if Kriel Power Station's fly is what the market is looking for. Undertaking of a primarily environmental economics research in future will also be useful for Kriel Power Station to establish the immediate, medium and long term benefits of its fly ash utilization as compared to ash disposal.

Kriel Power Station also need to invest on examining in detail, the technological aspects which are resulting into excessive generation of fly ash within the operations as well as the extent at which human factor within the operation is affecting fly ash generation. Investigations on the type of processing technologies and their efficiency factors also need to be undertaken in order to determine the suitable technology that Kriel Power Station can adopt to process its produced fly ash. Conducting of research with relevant stakeholders such as brick-makers, concrete users, etc., need to be undertaken in an effort to investigate the practical strength and limitations of Kriel Power Station's fly ash on the market. Eskom as an organization also needs to invest in researches to investigate fly ash characteristics per power station as ash qualities differs from one geographical location to another. This will assist in determining the uses of fly ash per site and therefore generally promoting Eskom fly ash to relevant markets.

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LIST OF PERSONAL COMMUNICATIONS

Personal communication 2017A, comments received through email from an environmental officer based at a coal fired power station in Mpumalanga, on the 13th of November 2017.

Personal communication 2017B, remarks gathered during an interview (via email) conducted with a groundwater specialist from environmental consultancy on the 7th of November 2017.

Personal communication 2017C, observations gathered during an interview (via email) conducted with an environmental engineer from government on the 16th of November 2017.

Personal communication 2017D, remarks gathered during an interview (via email) conducted with an environmental senior advisor from coal fired power station on the 23rd of October 2017.

Personal communication 2017E, comments received through email from an environmental officer based at a coal fired power station in Mpumalanga, on the 30th of October 2017.

Personal communication 2017F, views received through email from an environmental officer based at a coal fired power station in Mpumalanga, on the 23rd of October 2017.

Personal communication 2017G, comments received through email from an environmental officer based at a coal fired power station in Mpumalanga, on the 10th of November 2017.

Personal communication 2017H, remarks received through email from a water specialist based at Eskom's Water Management CoE, on the 26th of October 2017.

Personal communication 2017I, perceptions received through email from commercialization manager, on the 30th of October 2017.

Personal communication 2017J, comments received through email from a chemical analyst based at a coal fired power station in Mpumalanga, on the 2nd of November 2017.

Personal communication 2017K, insights received through email from a project manager based at a coal fired power station in Mpumalanga, on the 31st of October 2017.

Personal communication 2017L, comments received through email from an environmental practitioner based at Eskom subsidiary company, on the 22nd of November 2017.

Personal communication 2017M, input received through email from a senior ash dams project manager, on the 13th of November 2017.

Personal communication 2017N, observations gathered during an interview (via email) conducted with a senior air quality specialist based at Eskom's air quality CoE on the 23rd of October 2017.

Personal communication 2017O, notes received through email from a groundwater specialist based at an environmental consultancy, on the 4th of December 2017.

Personal communication 2017P, notes collected through email from an environmental practitioner based at a coal fired power station in Mpumalanga, on the 6th of November 2017.

Personal communication 2017Q, observations gathered during an interview (via email) conducted with an environmental officer based at a coal fired power station in Mpumalanga on the 17th of November 2017.

Personal communication 2017R, comments gathered during an interview (via email) conducted with an environmental specialist based at an environmental consultancy on the 20th of November 2017.

Personal communication 2017S, views gathered during an interview (via email) conducted with an environmental officer based at a coal fired power station in Mpumalanga on the 23rd of October 2017.

Personal communication 2017T, observations collected during an interview (via email) conducted with a senior environmental advisor based at Eskom CoE, on the 13th of November 2017.

Personal communication 2017U, insights collected during an interview (via email) conducted with an environmental officer based at a coal fired power station in Mpumalanga on the 22nd of November 2017.

Personal communication 2017V, comments gathered during an interview (via email) conducted with an environmental specialist based at an environmental consultancy on the 20th of November 2017.

Personal communication 2017W, perceptions gathered during an interview (via email) conducted with an Eskom's senior environmental specialist on the 31st of October 2017.

Personal communication 2017X, views gathered on the 20th of November 2017 via email, as additional comments to questionnaire survey responses, from an environmental specialist based at an environmental consultancy.

Personal communication 2017Y, views gathered on the 14th of November 2017 via email, as additional comments to questionnaire survey responses, from Eskom's environmental senior manager based at Sustainability.

Personal communication 2017Z, views gathered on the 7th of November 2017 via email, as additional comments to questionnaire survey views, from Eskom's environmental senior advisor based at Sustainability.

Personal communication 2017Aa, comments gathered on the 13th of November 2017 via email, as additional comments to questionnaire survey views, from Eskom's environmental senior advisor based at Sustainability.

Personal communication 2017Ab, input received through email from a senior compliance manager, on the 23rd of October 2017.

Personal communication 2017Ac, observations received through email from a senior engineering advisor, on the 12th of November 2017.

Personal communication 2017Ad, comments gathered on the 23rd of October 2017 via email, as additional comments to questionnaire survey views, from Eskom's environmental manager based at coal fired power station.

Personal communication 2017Ae, observations received through email from a senior environmental specialist based at environmental consultancy, on the 23rd of October 2017.

Personal communication 2017Af, comments received through email from a senior environmental specialist based at environmental consultancy, on the 13th of November 2017.

ANNEXURE A: FIELD BASED MATERIAL (A1 to A10)

Annexure A1 - Participants' perceptions on the effect of coal on fly ash qualities		
Participants Perceptions	**Participants Number**	**%**
Fly ash quality is dependent on quality of coal burnt	81	66%
Do not know	33	27%
There is no relations between coal quality and quality of produced ash	9	7%
TOTAL	**123**	**100%**

Annexure A2 - Participants' perception on fly ash disposal at ash dams		
Participants Perceptions	**Participants Number**	**%**
Not aligned with modern practices	45	37%
Do not know	27	22%
Aligned with modern practices	51	41%
TOTAL	**123**	**100%**

Annexure A3 - Participants' perception on the sustainable fly ash management option		
Participants Perceptions	**Participants Number**	**%**
Disposal	0	0%
Recycling	12	100%
TOTAL	**12**	**100%**

Annexure A4 - Participants perception on the need for South Africa to implement sustainability and ash recycling programs

Participants Perceptions	Participants Number	%
SA has to prioritize sustainability & ash recycling program	119	97%
Do not know	3	2%
SA does not have to prioritize sustainability & ash recycling program	1	1%
TOTAL	**123**	**100%**

Annexure A5 - Participants views on fly ash utilization program

Participants Perceptions	Participants Number	%
Sustainable	100	81%
Do not know	14	12%
Not sustainable	9	7%
TOTAL	**123**	**100%**

Annexure A6 - Participants' perceptions on the commitment of fly ash generators in maximizing fly ash utilization program

Participants Perceptions	Participants Number	%
More effort is still required	52	42%
Do not know	23	19%
Enough effort has been invested	48	39%
TOTAL	**123**	**100%**

Annexure A7 - Participants' perceptions towards unlined fly ash disposal facilities

Participants Perceptions	Participants Number	%
Does not cause any groundwater pollution	11	9%
Do not know	38	31%
Causes groundwater pollution	74	60%
TOTAL	123	100%

Annexure A8 - Participants' views related to fly ash transportation activity to ash dams

Participants Perceptions	Participants Number	%
It has potential to cause pollution (land & air)	105	85%
Do not know	11	9%
No pollution is associated with an activity	7	6%
TOTAL	123	100%

Annexure A9 - Participants' perceptions regarding the impact of ash disposal facilities to the health of neighbouring communities

Participants Perceptions	Participants Number	%
No impact	10	8%
Do not know	14	11%
They are negatively impacted	99	81%
TOTAL	123	100%

Annexure A10 - Participants' perceptions on the integrated environmental management approach

Participants Perceptions	Participants Number	%
Integrated approach not necessary	2	2%
Do not know	5	4%
Integrated approach required	116	94%
TOTAL	123	100%

ANNEXURE B: PARTICIPANT INFORMATION SHEET (INTERVIEWS)

School of Geography, Archaeology and Environmental Studies
Department of Geography and Environmental Studies
University of Witwatersrand/ Private Bag 3, WITS, 2050
Enquiries: Tel: (011) 717-6516

RE: Participant Information Sheet (Interview)

Good day, 14 June 2017

I am a Master of Science (MSc) student under the school of Geography, Archaeology and environmental Studies at the University of the Witwatersrand (Wits) who is currently conducting a research titled as follows: **Exploring the Environmental Impacts of Fly Ash on Eskom's Business Sustainability and Sustainable development, a Study of Kriel Power Station in Mpumalanga, South Africa.** The primary aim of this study is to investigate alternative ways in which fly ash can be managed effectively to minimize environmental impacts in order to ensure alignment with the notion of sustainable development. This research will be critical in investigating sustainable fly ash management opportunities in order to minimize adverse environmental impacts and subsequent ecological footprint.

I am hereby inviting you to be part of the study; kindly take note that your basic knowledge on coal fly ash management practices and associated impacts was the reason for your selection in this study. Your participation in this study will involve answering semi-structured qualitative interview questions through face to face or telephonic sessions with me. Alternatively, semi-structured interview questions will be made available to you though electronic means such as email and internet; you can then complete the interview questions and thereafter scan and a completed questions back to me using your preferred electronic means. Kindly take note that the time, place and option of interview will be dictated by you. The interview questions are estimated to take about 30 minutes of your time. With your consent, telephonic and face to face interviews will be audiotaped in order to ensure data accuracy. Your participation in this research is completely voluntary, and you may refuse to participate without being at risk to any penalty or loss. No participation rewards will be offered. All of your responses will be kept confidential, and no information that could identify you will be included in the research report. The interview material will only be viewed by the researcher and the principal supervisor. It is within your right to refuse answering any question which you are not comfortable answering; and you may in any point withdraw your participation from this study without being penalised or losing any benefit.

Your views will be integrated into the final MSc research report which will be available from me or Wits University. In case you have any question or you require a summary of this research, please do not hesitate to contact me. Your interest to participate in this research is highly acknowledged and appreciated.

Yours faithfully,

Khuliso Rasimphi: (Student No: 1699084)
Cell: 076 250 2002 / Tel: 017 615 2634
Email: RasimpKJ@eskom.co.za

Professor Danny Simatele: Supervisor
Cell: 083 383 6884 / Tel: 011 717 6516
Email: Danny.Simatele@wits.ac.za

ANNEXURE C: CONSENT FORMS (INTERVIEWS)

School of Geography, Archaeology and Environmental Studies
Department of Geography and Environmental Studies
University of Witwatersrand/ Private Bag 3, WITS, 2050
Enquiries: Tel: (011) 717-6516

RE: Consent Form

I, the undersigned, understand that:

Khuliso James Rasimphi has requested an interview with me for his research project titled: **Exploring the Environmental Impacts of Fly Ash on Eskom's Business Sustainability and Sustainable development, a Study of Kriel Power Station in Mpumalanga, South Africa.**

Before commencing with the interview, the researcher informed me of the following:

- He is a student currently conducting a research under the University of Witwatersrand for Master of Science (MSc) degree.
- He explained to me the title of his research as well as the research aim.
- He explained to me that the outcome of the interview will be integrated in the final MSc research report.
- My inclusion in the research participants' database was informed by the view that I hold information which is valuable to the success of the research.
- The interview questions are estimated to take about 30 minutes of my time.
- My participation in the research is completely voluntary and no participation rewards will be offered.
- All of my responses will be kept confidential, and no information or quotes that could identify me will be included in the research report.
- The interview material (transcripts) will only be viewed by the researcher and the principal supervisor.
- It is within my right to refuse answering any question which I am not comfortable answering; and I may at any point withdraw my participation from the interview session.
- In case I have any requests, questions or concerns regarding the research, he has provided me with relevant contact details.

Legal Rights and Signatures:

Khuliso Rasimphi: Researcher
Cell: 076 250 2002 / Tel: 017 615 2634
Email: RasimpKJ@eskom.co.za
Student No: 1699084

Professor Danny Simatele: Supervisor
Cell: 083 383 6884 / Tel: 011 717 6516
Email: Danny.Simatele@wits.ac.za

I_____, consent to participate in Khuliso James Rasimphi's research. My signature below indicates my consent.

I agree to be audio-taped (tick if appropriate)		I do not agree to be audio-taped (tick if appropriate)	

_____ _____

Participant Signature Date

ANNEXURE D: INTERVIEW QUESTIONS INSTRUMENT

School of Geography, Archaeology and Environmental Studies
Department of Geography and Environmental Studies
University of Witwatersrand/ Private Bag 3, WITS, 2050
Enquiries: Tel: (011) 717-6516



RE: Questionnaire (Qualitative Interview)

Research Title: **Exploring the Environmental impacts of fly ash on Eskom's Business Sustainability and Sustainable development, a study of Kriel Power Station in Mpumalanga, South Africa.**

Dear Interview Participant

Thank you for taking time to complete this research interview questionnaire. There are 2 sections to be completed which are section 1 (demographic information) and section 2 (questionnaire). Kindly complete all the questions carefully. Completion of the entire questionnaire should take you about 20-30 minutes to answer.

SECTION 1: Demographic Information

Kindly complete demographic information in the table below:

Participant's Institutional Association (e.g. Government/Authority/Regulator, Power Generation, Ash Utilizers/Off-takers, Environmental Consultancy)	
Designation/Position	
Contact details (Optional)	
Gender (Optional)	

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Department of Geography and Environmental Studies
University of Witwatersrand/ Private Bag 3, WITS, 2050
Enquiries: Tel: (011) 717-6516

SECTION 2: Questionnaire

1. **Under which of the following 2 categories would you classify fly ash?** (tick in the correct box on the right)	Disposable Waste	☐	Recyclable Resource	☐
Additional Comments:				
2. **Which fly ash management opportunities do you think exist beside disposal at the ash dams?**				
Response:				
3. **In what way would you say the quality of coal has any influence on the quantity of fly ash produced?**				
Response:				
4. **What is your view about the potential environmental impacts such as air quality pollution, water pollution, ecological degradation, etc., which are associated with fly ash disposal?**				
Response:				
5. **Livelihood and health of neighbouring communities staying closer to ash dam facilities can potentially be impacted negatively by air and water pollution from the ash dams?** (tick in the correct box on the right)	Agree	☐	Disagree	☐
Additional Comments:				
6. **Based on your knowledge, in what way would you say fly ash management practices have an influence towards environmental impacts from ash disposal facilities?**				
Response:				
7. **In your view, can you elaborate on which one would you say is a sustainable ash management option between ash disposal and recycling?**				
Response:				
8. **How would you describe the awareness level of potential ash utilizers from local communities on ash utilization opportunities?**				

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Enquiries: Tel: (011) 717-6516

Response:				
9. Are you aware of any environmental legislation which seeks to promote ash recycling (tick in the correct box on the right)	Yes	☐	No	☐
Additional Comments:				
10. Which influence would you say fly ash characteristics can have on its recyclability?				
Response:				
11. What do you think are the social, economic and environmental benefits of ash utilization?				
Response:				
12. In your view, what are the current challenges associated with ash recycling?				
Response:				
13. With a motivation, would you say that environmental impacts caused by ash disposal facilities are reversible or irreversible?				
Response:				
14. What measures do you think need to be implemented in order to mitigate against environmental impacts from disposal ash?				
Response:				
15. Who do you think needs to play a role to ensure that ash utilization program is a success?				
Response:				
ADDITIONAL GENERAL COMMENTS:				

ANNEXURE E: QUESTIONNAIRE SURVEY INSTRUMENT

School of Geography, Archaeology and Environmental Studies
Department of Geography and Environmental Studies
University of Witwatersrand/ Private Bag 3, WITS, 2050
Enquiries: Tel: (011) 717-6516

RE: Questionnaire (Survey)

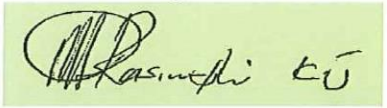
Dear participant 20 October 2017

I am a Master of Science (MSc) student under the school of Geography, Archaeology and environmental Studies at the University of the Witwatersrand (Wits) who is currently conducting a research titled as follows: **Exploring the Environmental Impacts of Fly Ash on Eskom's Business Sustainability and Sustainable development, a Study of Kriel Power Station in Mpumalanga, South Africa.** The primary aim of this study is to investigate alternative ways in which fly ash can be managed effectively to minimize environmental impacts in order to ensure alignment with the notion of sustainable development. This research will be critical in investigating sustainable fly ash management opportunities in order to minimize adverse environmental impacts and subsequent ecological footprint.

I am hereby inviting you to be part of the study; kindly take note that your basic knowledge on coal fly ash management practices and associated impacts was the reason for your selection in this study. Your participation in this study will involve answering a questionnaire; you may then complete the questionnaire and thereafter relay a completed questionnaire back to me using your preferred electronic means. The questionnaire is estimated to take about 15 minutes of your time. Your participation in this research is completely voluntary, and you may refuse to participate without being at risk to any penalty or loss. No participation rewards will be offered. All of your responses will be kept confidential, and no information that could identify you will be included in the research report. The research material including your completed questionnaire will only be viewed by the researcher and the principal supervisor. It is within your right to refuse answering any question which you are not comfortable answering; and you may in any point withdraw your participation from this study without being penalised or losing any benefit.

Your views will be integrated into the final MSc research report which will be available from me or Wits University. In case you have any question or you require a summary of this research, please do not hesitate to contact me. Kindly take note that by submitting the completed online questionnaire, your agreement to participate in the research is assumed. Your interest to participate in this research is highly acknowledged and appreciated.

Yours faithfully,



Khuliso Rasimphi: (Student No: 1699084)
Cell: 076 250 2002 / Tel: 017 615 2634
Email: RasimpKJ@eskom.co.za

Professor Danny Simatele: Supervisor
Cell: 083 383 6884 / Tel: 011 717 6516
Email: Danny.Simatele@wits.ac.za

School of Geography, Archaeology and Environmental Studies
Department of Geography and Environmental Studies
University of Witwatersrand/ Private Bag 3, WITS, 2050
Enquiries: Tel: (011) 717-6516

Dear Survey Participant

Thank you for taking time to complete this survey. Before you start, kindly take time to read the instructions below:

- There are 2 sections to be completed which are section 1 (demographic information) and section 2 (questionnaire).
- Kindly complete all the questions carefully
- Completion of all the questionnaire should take you about 10-15 minutes to answer
- After completing the survey, kindly submit it to the researcher (email: RasimpKJ@eskom.co.za)

SECTION 1: Demographic Information

Kindly complete demographic information in the table below:

Participant's Institutional Association (E.g. Government/Authority/Regulator, Power Generation, Ash Utilizers/Off-takers, Environmental Consultancy, etc.)	
Designation/Position	
Contact details (Optional)	
Gender (Optional)	

SECTION 2: Questionnaire

Your views are critical; there are no wrong or right answers. Tick in the ☒ box which strongly represent your views.

Participants Response Criteria:

1. Strongly Disagree	2. Disagree	3. Neither Agree nor Disagree (Neutral)	4. Agree	5. Strongly Agree

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N0	Link to Objective	Statement	S disagree ◄—► S agree				
1	RO4	In order to achieve sustainability, viable sense of balance amongst social, economic and environmental aspects need to be ensured.	1☐	2☐	3☐	4☐	5☐
2	RO1	Combustion of poor quality coal result into production of better quality fly ash.	1☐	2☐	3☐	4☐	5☐
3	RO2	Fly ash disposal at the ash dam facility contributes significantly to air pollution, water pollution and ecological degradation.	1☐	2☐	3☐	4☐	5☐
4	RO4	Fly ash can only be recycled through cement industry.	1☐	2☐	3☐	4☐	5☐
5	RO5	Advanced ash processing technologies are now available in South Africa to assist in programs to increase ash utilization.	1☐	2☐	3☐	4☐	5☐
6	RO4	South Africa is a developing country, it does not need to concern itself with sustainability and fly ash recycling concept.	1☐	2☐	3☐	4☐	5☐
7	RO1	Fly ash quality is dependent on quality of coal burnt.	1☐	2☐	3☐	4☐	5☐
8	RO2	Environmental impact caused by ash dam establishments on fauna and flora is reversible.	1☐	2☐	3☐	4☐	5☐
9	RO3	The biggest fly ash generators in South Africa such as Eskom coal fired power stations are putting enough effort to increase fly ash utilization.	1☐	2☐	3☐	4☐	5☐
10	RO3	Disposal of fly ash within ash dams is aligned to modern principles of environmental management.	1☐	2☐	3☐	4☐	5☐
11	RO4	Fly ash utilization is a sustainable management option as it ensures that environmental footprint and disposal costs are minimized while creating job opportunities to the recyclers.	1☐	2☐	3☐	4☐	5☐
12	RO2	Fugitive dust fallout from Fly ash disposal facilities cannot result in human health impacts.	1☐	2☐	3☐	4☐	5☐
13	RO3	The main obstacle hindering fly ash utilization through modern means in South Africa is the legislation which still defines fly ash as hazardous waste.	1☐	2☐	3☐	4☐	5☐
14	RO4	Fly ash utilization minimizes the environmental liability associated with ash dams operations.	1☐	2☐	3☐	4☐	5☐
15	RO2	Livelihood and health of neighbouring communities staying closer to ash dam facilities are impacted negatively by air and water pollution from the ash dam.	1☐	2☐	3☐	4☐	5☐

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16	RO5	The manner in which power plants operate their plants can influence the amount of fly ash generated	1☐	2☐	3☐	4☐	5☐
17	RO4	More community awareness on fly ash utilization can unlock communities' interest in fly ash usage	1☐	2☐	3☐	4☐	5☐
18	RO2	Fly ash transportation activity to the ash dam facility can result into air and land pollution.	1☐	2☐	3☐	4☐	5☐
19	RO4	Even if fly ash utilization program is given enough drive by generators, it will not be economically sustainable.	1☐	2☐	3☐	4☐	5☐
20	RO4	Once the current draft regulation which is aimed at excluding coal ash as waste is finalized, ash utilization will increase.	1☐	2☐	3☐	4☐	5☐
21	RO4	It is a cheaper to dispose ash at an ash disposal facility than to recycle ash it.	1☐	2☐	3☐	4☐	5☐
22	RO2	Fly ash disposal at unlined facilities can result in ground water pollution.	1☐	2☐	3☐	4☐	5☐
23	RO3	Regulators, fly ash generators, ash utilizers and NGO need to work together to ensure that more ash is utilized.	1☐	2☐	3☐	4☐	5☐
24	RO3	Probability and severity of environmental impact from fly ash is directly linked with the selected environmental management approach.	1☐	2☐	3☐	4☐	5☐
25	RO3	I strongly believe that South African market can still absorb more fly ash in different sectors	1☐	2☐	3☐	4☐	5☐

ANY ADDITIONAL COMMENTS:

ANNEXURE F: ETHICS CLEARANCE CERTIFICATE

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Rasimphi

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H17/07/25**
PROJECT TITLE	Exploring the environmental impacts of fly ask on Eskom's business sustainability and sustainable development, a study of Kriel Power Station in Mpumalanga, South Africa
INVESTIGATOR(S)	Mr K Rasimphi
SCHOOL/DEPARTMENT	Geography, Archaeology and Environmental Studies/
DATE CONSIDERED	21 July 2017
DECISION OF THE COMMITTEE	Approved
EXPIRY DATE	13 September 2020

DATE 14 September 2017 **CHAIRPERSON** _____
(Professor J Knight)

cc: Supervisor : Professor D Simatele

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

_____ 14/09/2017
Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES