The socio-economic and environmental consequences of abandoned coal mines in Jackaroo Park, eMalahleni Municipality, Mpumalanga Province in South Africa

By

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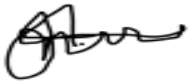
DECLARATION

I, the undersigned, hereby declare that the research report submitted for the degree of MSc: Environmental Sciences, University of the Witwatersrand, Johannesburg is my original work and expressed in my own words. Work done by other authors (such as quotations, citations, figures etc.) is acknowledged by means of comprehensive references. I further declare that there is no other institution of higher education in which this work has been previously submitted in fulfilment for any other degree.

Signed: 

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This research is dedicated to all those working towards mitigating the impacts of abandoned mines and striving for sustainable development in mining-affected regions.

ABSTRACT

The abandonment of coal mines in Jackaroo Park, eMalahleni Municipality, Mpumalanga Province, South Africa, has led to severe socio-economic and environmental challenges. However, there remains a paucity in scientific understanding of the extent of the impacts with a view to inform the development of effective remediation strategies and policy measures to alleviate the ongoing adverse effects of abandoned mines and promote sustainable development of surrounding communities. This study examines the socio-economic and environmental consequences of abandoned coal mines in Jackaroo Park.

The study employed a mixed-methods approach, incorporating qualitative data from document analysis and interviews with community members, local leaders, and policymakers, as well as quantitative data from assessment of water parameters and environmental observations. The results reveal severe social, economic and environmental impacts including soil and water contamination, loss of biodiversity, and air quality deterioration, decrease in employment and investment opportunities, increase in criminal activities, decrease in the value of the houses, and disrupting traditional ways of living and, loss of cultural heritage. Moreover, the research observed that the current government policies and rehabilitation efforts are not effectively addressing the social, economic and environmental challenges being experienced in Jackaroo Park. The major policy and action gaps include lack of rehabilitation and closure, lack of comprehensive data and monitoring and the proliferation of illegal mining activities, among others. The study emphasizes the importance of community involvement and stakeholder collaboration in mitigating the adverse impacts of abandoned coal mines and promoting sustainable development in mining regions. The study contributes to the broader discourse on the environmental and socio-economic sustainability of post-mining landscapes, offering valuable insights for policymakers, environmentalists, and community advocates seeking to address the legacy of coal mining in South Africa and beyond.

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LIST OF ABBREVIATIONS

AGSA:	Auditor General of South Africa.
AMD:	Acid Mine Drainage.
CAGR:	Compound Annual Growth Rate.
IEA:	International Energy Agency.
MPRDA:	Minerals and Petroleum Resources Development Act.
NEMA:	National Environmental Management Act.
NGOs:	Non-governmental Organisations.
PRISMA:	Preferred Reporting Items For Systematic Review and Meta-Analysis.
USA:	United States of America.
USEPA:	United States Environmental Protection Agency.

CHAPTER 1: INTRODUCTION

1.1 Background to the study

Coal mining has a long history, with early mines being found in the Roman Empire, ancient China, and other early historical economies. Coal was the key energy source during the Industrial Revolution of the 19th and 20th centuries, used to fuel steam engines, heat structures, and produce electricity (Syahrir et al., 2021). Although coal mining remains a significant economic activity today, it is predicted to decline in the future because of its contribution to climate change and other environmental problems (Johnson et al., 2015; Liang et al., 2023).

There is a global call for the reduction in the use of coal as a source of energy (Korsbakken et al., 2016). Thus, demand for coal is set to decline as governments pursue regulations to minimise coal-related greenhouse gas emissions to mitigate climate change (Worlanyo and Jiangfeng, 2021). In the United States of America (USA), for example, coal production is competing with greater energy efficient options such as wind, improved gas production and solar energy (Blondeel and Van de Graaf, 2018; Rauner et al., 2020). This will contribute to the increase in the number of coal mines that will be closed.

However, there are various other reasons for coal mine closure worldwide, such as rising production costs, and changes in government policy (Jordan et al., 2018). Some reasons of closure can be classified as mine abandonment. Mine abandonment occurs when extraction, beneficiation or processing of ores and minerals end without appropriate measures taken to prevent the associated environmental consequences and health impacts on humans and the environment, including wildlife (McCarthy, 2011; Ambani and Annegarn, 2015). In some cases, the mine owners make a conscious decision to vacate the mining area as it will no longer be productive and useful to them (Dutton, 2022). The South African regulations and policy, such as, Department of Mineral Resources and Energy, National Strategy for the Management of Ownerless and Derelict Mines (2009), and the National Strategy for the Management of Derelict and Ownerless Mines in South Africa, highlight that abandoned mines are also known as derelict mines and ownerless mines where a mine has ceased to operate, environmental management including rehabilitation and/or demolition have not been conducted to acceptable

standards and the holder has been liquidated, the mine has been abandoned or left without any responsible legal entity/person (Mhlongo and Akintola, 2021).

Akinlabi et al. (2019) emphasizes that coal mining has significant impact on the environment and there is substantial evidence of a strong link between environmental pollution from mining activities and the health and wellbeing of humans in the surrounding neighbourhoods when the mine is left abandoned. Coal mine abandonment has been associated with a plethora of incidences related to health, injury and death of community members in the adjacent areas (Jordan et al., 2018; Noy, 2020). Several environmental challenges are associated with abandoned coal mines and these include Acid Mine Drainage (AMD), ground subsidence, mine waste, fly ash and deforestation (Masood et al., 2020, Lahiri-Dutt, 2023). Groundwater from abandoned mines have seriously affected the health of the people through the discharge of non-point source pollution (Masood et al., 2020, Favas et al., 2018). Studies indicate that several coal mines have been abandoned in South Africa, estimation shows that there are more than 6000 abandoned mines in general, with at least 2,322 categorized as posing risk to the communities at large (AGSA, 2022).While the environmental and socio-economic consequences of abandoned mines are generally known, the impacts of specific abandoned coal mines in Jackaroo park in South Africa are not fully understood.

In South Africa most coal mining takes place in Mpumalanga province. In 2016, Mpumalanga had 239 active coal mines and 788 abandoned mines, including coal mines (Ledger, 2016). Most coal mining operations are best situated away from residential areas to avoid causing harm to the nearby communities and organisms that live around them (Alhamed and Wohnlich, 2014). However, in Mpumalanga province, some mines are situated close to residential areas, affecting the nearby communities (Molelekwa, 2023). Abandoned coal mines are an increasing concern in eMalahleni, with some located between 300 and 500 metres from residential areas.

Abandoned mines have been associated with significant environmental and socio-economic impacts (Noy, 2020; Lahiri-Dutt, 2023). Numerous reports have documented issues such as injuries, fatalities, water contamination, and related concerns (Favas et al., 2018; Mhlongo, 2023). However, there remains a need for a thorough scientific investigation to systematically identify and analyse these impacts, which could inform the development of effective measures to address the challenges posed by abandoned coal mines comprehensively. Jackaroo Park in eMalahleni, an area with several abandoned coal mines, has seen limited exploration of its

environmental and socio-economic ramifications. The lack of proactive intervention from relevant authorities and the absence of a cohesive strategy to address these challenges exacerbate the situation. This study seeks to assess the environmental and socio-economic effects of abandoned coal mines in Jackaroo Park, eMalahleni, and propose viable mitigation and adaptation strategies.

1.2 Research problem

The socio-economic and environmental consequences of abandoned coal mines in Jackaroo Park, eMalahleni Municipality, Mpumalanga Province in South Africa, present a critical issue that has yet to be thoroughly addressed. Globally, the consumption of nearly two billion tonnes of metal annually results in significant geological scars on the Earth's crust, raising important questions about the effects on societies (Nadudvari et al., 2021). Abandoned mines, such as those in Jackaroo Park, alter ecosystems, adversely affecting human habitats and health by polluting soil, air, and water.

South Africa, with thousands of reported abandoned coal mines, faces increasing challenges due to the global shift towards renewable energy and the resultant closure of coal mines (Wang, 2023). Despite the country’s robust environmental and social legislative framework, the open-cast coal mines were developed before the democratic era and most abandoned without following mine closure procedures (Cole et al., 2024). Consequently, there have been weak efforts to restore the land to a state that is safe for the community and the environment.

The social and environmental consequences of these abandoned mines remain largely unexamined, posing significant sustainability challenges. This lack of knowledge hinders sustainable development efforts and prevents policymakers from designing effective policies. Additionally, stakeholders such as environmental non-governmental organisations (NGOs), human rights movements, and social development organizations lack the foundation to create appropriate programs for the affected communities. Therefore, this study aims to fill this research gap by examining the socio-economic and environmental consequences of abandoned coal mines in Jackaroo Park. Understanding these impacts is crucial for developing sustainable solutions and policies to mitigate the adverse effects on local communities and the environment.

1.3 Aim and Objectives

The aim of the study is to assess the social and environmental consequences of abandoned coal mines in Jackaroo Park, eMalahleni Municipality, Mpumalanga Province in South Africa.

The objectives of the study are as follows:

- To examine the environmental impacts associated with abandoned coal mines in Jackaroo Park.
- To examine the socio-economic consequences of the abandoned coal mines on adjacent communities in Jackaroo Park.
- To make recommendations on appropriate action for addressing the local environmental and socio-economic impacts of abandoned coal mines in Jackaroo Park.

1.4 Significance of the study

In view of the current and impending consequences of abandoned coal mines on the society, a study that examines the environmental and socio-economic consequences of abandoned coal mines merits attention. The study brings to the attention of the academic community, responsible authorities and the communities, a comprehensive insight into environmental and socio-economic challenges associated with abandoned coal mines. Focusing on the challenges motivates stakeholders to take proactive steps toward addressing the issues.

This work also contributes to the existing global literature on abandoned mines and their impacts on environmental and socio-economic aspects of surrounding communities. Thus, the academic community will directly benefit through understanding the specific case for Jackaroo Park, giving them an opportunity to do a comparative analysis with other communities who may be under the threat of abandoned mines.

The study's findings will provide valuable policy recommendations to support the implementation of principles that foster effective environmental management and protect communities from the biophysical impacts of abandoned coal mines. Consequently, Environmental Non-Governmental Organizations, government departments, and community-based associations can utilize these findings and recommendations to develop and implement strategies that address the challenges faced by communities residing near abandoned coal mines.

1.5 Overview of the research methodology

This study focuses on abandoned mine sites in Jackaroo Park. Utilizing a mixed methods research design, the study incorporates both quantitative and qualitative procedures (Creswell and Creswell, 2023; König and Drebler, 2021). The qualitative approach is rooted in phenomenological philosophy, which seeks to uncover the essence of phenomena by emphasizing subjective experiences, perceptions, and meanings, rather than relying on external explanations or assumptions (Creswell and Creswell, 2023). The quantitative approach is based on the positivist paradigm, which is rooted in the belief that reality is objective, measurable, and governed by natural laws that can be discovered through empirical observation and logical analysis. Mixed methods design, which comes from the pragmatic school of thought, is employed by researchers from diverse fields (Åkerblad et al., 2021). Using a case study framework, the research includes document analysis, key informant interviews, and direct observations to collect data.

The data mining approach, incorporating components of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) methodology, was used to collect data. Documents related to abandoned coal mines in Jackaroo Park and eMalahleni were sourced from various sources and screened for relevance. Some were obtained from local organizations and institutions. These documents were analysed to identify community concerns and distinguish between local and regional impacts, focusing on Jackaroo Park. Key informant interviews with local residents, leaders, and municipality authorities provided additional data. Personal observations through site visits recorded visible evidence of social and economic impacts. Mobile water pH testing was conducted to determine pollution levels in abandoned coal mines.

The data analysis involved grouping themes emerging from the analysed documents. Themes from key informant interviews were categorized into environmental and social issues, with their consequences and related recommendations noted. Responsible persons or organizations for implementing the recommendations were identified. This analysis generated a categorized list of environmental and social issues along with their consequences, fulfilling the objective of providing recommendations to address the environmental and social impacts of abandoned coal mines.

1.6 Structure of the study

The study is divided into various sections as outlined below.

Chapter 1: Introduction

The first chapter introduces the topic of the research, which focuses on the social and environmental consequences of abandoned mines in eMalahleni, Mpumalanga province, South Africa. This chapter presents the research background, problem statement, study aim and objectives, research questions, and significance of the study. A brief explanation of the methodology is also presented.

Chapter 2: Literature review

Chapter 2 presents the relevant literature related to the research topic. It will cover theoretical and conceptual frameworks on social and environmental impacts of abandoned coal mines.

Chapter 3: Methodology

In chapter 3, the research design, data collection and analysis methods and their justification are discussed.

Chapter 4: Results and discussions

Chapter four presents the results and provides analysis of the research findings and discusses them in detail. The chapter focuses on identifying the trends and dynamics of social and environmental impacts associated with abandoned coal mines.

Chapter 5: Conclusions and recommendations

This chapter presents the conclusions of the study, emanating from the key findings. It also discusses the implications and makes recommendations in line with the findings.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The socio-economic and environmental consequences of abandoned coal mines have garnered increasing attention due to their far-reaching implications for communities and ecosystems. Globally, abandoned mines are associated with significant challenges, including land degradation, water contamination, loss of biodiversity, and socio-economic disruptions such as unemployment and health hazards. These impacts are particularly pronounced in coal mining regions, where historical mining activities have left a legacy of environmental degradation and socio-economic vulnerabilities. Jackaroo Park, located within the eMalahleni Municipality of Mpumalanga Province in South Africa, exemplifies these challenges, given its history as a coal mining hub. This chapter reviews existing literature to provide a comprehensive understanding of the environmental and socio-economic impacts of abandoned coal mines, with a focus on global, regional, and local perspectives. It also explores theoretical frameworks and empirical studies that inform the current knowledge base, highlighting gaps that this study seeks to address.

2.2 Coal mining: A global overview

Coal is one of the most popular energy sources today, with hard coal seeing a slight increase in use in recent years. Coal also boasts the largest reserves among non-renewable energy resources (Blondeel and Van de Graaf, 2018; Shearer et al., 2019). In 2023, global coal production was anticipated to reach 8,917.3 million tonnes (mt), a 1.9% increase compared to 2022, driven primarily by growth in China and India. The United States, Australia, China, India, and Indonesia are the top producers of coal worldwide, contributing 80% of the overall production (Yu et al., 2023).

Global coal mining is a significant industry with substantial economic and environmental implications (Akinlabi et al., 2019). It remains a vital energy source for heating, industrial activities, and electricity production worldwide, especially in Asia, where many nations extensively rely on coal to meet energy demands (Marais and de Lange, 2021) . However, coal mining is associated with numerous environmental concerns, including the release of greenhouse gases like carbon dioxide and methane, which significantly contribute to climate change (Akinlabi et al., 2019). Other key environmental issues include habitat destruction,

soil erosion, and water pollution, all of which impact local ecosystems and biodiversity (Finkelman et al., 2021).

Coal, being a non-renewable energy resource, often results in mine closures or rehabilitation after reserves are depleted; however, some mines are left abandoned. Coal mining dates back to the Neolithic era, playing a crucial role in the economies of significant civilizations. The societal and environmental effects of mining have been extensively discussed in the literature (Akinlabi et al., 2019; Blondeel and Van de Graaf, 2018; Lee et al., 2005; Munawer, 2018; Pooe and Mathu, 2011; Wang et al., 2019). However, the consequences of mine closures and abandonment require further research (Githiria and Onifade, 2020). Proper mine closure can control environmental and social consequences, but abandonment without appropriate measures leads to severe impacts. This was evident in the wave of coal mine abandonments across Europe at the close of the 20th century (Githiria and Onifade, 2020).

The need to investigate the social and environmental consequences of coal mine abandonment globally cannot be overstated. A country-specific approach can provide a detailed understanding of the trends and dynamics involved.

2.3 Coal mining in South Africa

Coal has been integral to South Africa's mining history since European settlers established the Cape Colony in 1652, discovering coal reserves to the east. Initially used for heating and powering steam engines in diamond and gold mining industries, larger deposits were later found in KwaZulu-Natal and Mpumalanga, which were also easy to mine (Maphosa, 2021; Ncube, 2022). The low cost of extraction and availability of coal made it a major economic driver (Schwarts et al., 2021). The coal sector is crucial to South Africa's energy industry, significantly shaping the country's socio-economic landscape (Shackel, 2023).

South Africa has 19 coal fields containing a total of 28 coal seams, mined in varying amounts (Makgetla and Patel, 2021). These coal seams are found primarily in the Karoo Basin in the western and central regions, with anthracite and bituminous coal located in the northern and central parts of KwaZulu Natal Province. The Witbank, Ermelo, and Highveld coalfields in Mpumalanga mainly contain bituminous coal (Schalkwyk and Thovhogi, 2021). Most mines in Mpumalanga are relatively shallow and utilize open-cast methods, making the operations

cost-manageable compared to the more expensive underground mining operations (Mashayamombe, 2020).

Over 50% of South Africa's coal production comes from underground mining, with the remainder from surface mining methods (Minerals Council South Africa, 2021). eMalahleni, South Africa's coal mining capital, houses more than 10 open-cast mines, 4 coal-fired power plants, steel mills, and vanadium operations (Minerals Council South Africa, 2021). Coal mining contributes significantly to Mpumalanga's economy, accounting for 19% of the province's gross value added (GVA) in 2015 (Thurlow, 2018), and about 5% of the formal workforce, with each worker typically supporting around three dependents (Stats SA,2022).

Despite these economic benefits, the environmental impacts of coal mining are severe. These include acid mine drainage, sinkholes, dust generation, spontaneous combustion, disruption of plant species, open pits, soil contamination, and erosion, all contributing to poor public safety and health, including respiratory problems (Pretty and Odeku, 2017). South African coal industry and research institutions are developing measures to mitigate environmental damage from mining, including minimal disturbance techniques, in situ treatment of coal, water, and soil, and biotechnological methods for environmental repair (Mbedzi et al., 2020). Legislative initiatives have been introduced to control the environmental impacts of coal mining (Mubanga and Kwarteng, 2020). However, critics argue that the government has not sufficiently regulated the industry or protected the environment, prioritizing economic growth over environmental sustainability (Sovacool, 2021). Concerns about the long-term sustainability of coal mining, potential impacts on climate change, air and water quality, and public health persist. Critics claim the government is too lenient in enforcing compliance, particularly in the historic Witbank Coalfield where significant environmental damage has already occurred (Deveci et al., 2022).

2.4 An overview of the mining cycle

Mining companies and local communities are often ill-equipped to effectively manage mine downscaling, closures, or abandonment, leading to challenges in establishing successful post-mining economies (Hendrychová et al., 2020). Resource depletion in the mining sector has contributed to numerous mine closures or abandonments, while heightened international competition and mining industry competitiveness have further exacerbated this trend (Strambo et al., 2019).

Ndeleki (2018) emphasises that mine downscaling and mine closure can lead to protests actions by mining communities. In the post-mining period, mining settlements that have historically been subsidised and serviced by mining operations face significant challenges in municipal administration and the preservation of infrastructure such as mine houses, recreational facilities, telecommunications, transportation, educational institutions and health facilities (Marais, 2018).

2.5 Abandoned coal mines: A global overview

The global concern about abandoned coal mines stems from its repercussions for the environment, society, and economy. An estimated 10,129 mines have been abandoned in Canada, 52,324 in Australia, 6,000 in South Africa, and 5,383 coal mines in China. (GlobalData, 2023). While these are the leading countries with regards to the number of abandoned coal mines, world over, abandoned coal mines exist in various countries, and they pose serious threats to the environment and the communities living close to them (Alhamed and Wohnlich, 2014).

Concerns about abandoned mines and their effects on the environment and public safety are a persistent issue in Canada (Mackasey, 2000; Worlanyo and Jiangfeng, 2021). These concerns are also widespread in Australia (Lottermoser and Ashley, 2006), South Africa (Mhlongo, 2023), Germany (Alhamed and Wohnlich, 2014) and other countries across the world. In Canada, Dolter and Victor (2016) observed that tailings overflow at abandoned mine sites and mine subsidence were once thought to be rare incidents by the public and media but studies have provided more evidence of the proliferation of tailing overflows at abandoned coal mine sites. Employees in the mining sector have realized that abandoned mines need to be evaluated since they represent risks to human health and safety as well as the environment (Mackasey, 2000). Various countries have attempted to identify, investigate, and address issues at mine sites that have been abandoned. The need to rehabilitate abandoned coal mines across the world cannot be overemphasized. In Canada, there are some current attempts to generate thermal energy from abandoned coal mines, the latest example being efforts at Wellington coal mine under Nanaimo, B.C.(McDonald, 2023). Finding, locating, and evaluating abandoned mines is the first stage in restoration(Mackasey, 2000).

Some abandoned mines cause issues with public health and safety, environmental safety, and aesthetics (Alhamed and Wohnlich, 2014). Paradoxically, a lot of public complaints focus on the latter. The "hidden hazards" presented by chemical and physical stability qualities have received little attention (Mackasey, 2000). In Canada and Australia, some studies have established that housing projects have been built on unstable subterranean workings or on regions that have tailings containing arsenic from abandoned coal mines (Araujo et al., 2022; Lottermoser and, Ashley 2006; Park et al. 2019). Homes for the elderly, schools, railroads, and even highways have all been located in dangerous regions (Neil, 1992; Vivoda, 2019). Airborne materials or harmful water leaks have poisoned soils and rivers (Mackasey, 2000). Weber (2024) reports that in the Alberta Rockies, Canada, an old coal mine is periodically discharging water so iron-heavy that it colours nearby waterways, and another is releasing a hazardous substance to fish at rates more than dozens of times greater than regulatory limits.

AMD represents the occurrence and mobilization of highly acidic water containing elevated concentrations of heavy metals, posing significant environmental challenges worldwide (Worlanyo and Jiangfeng, 2021). This phenomenon arises from the exposure of sulphide-rich wastes to the environment, resulting in the generation of effluents characterized by low pH levels and high levels of hazardous and toxic elements (Rauner et al., 2020; GlobalData, 2023). Particularly detrimental effects are observed upon cessation of mining activities, as the water table returns to its natural levels and interacts with residual acidic leachates deposited on rock surfaces during the presence of AMD (Lee et al., 2012).

In China, numerous abandoned coal mines are scattered across regions such as Shanxi, Guizhou, Chongqing, Hunan, and Jiangxi (Liang et al. 2023). These sites primarily contain anthracite coal with a high methane adsorption capacity, resulting in substantial residual methane within the mines. This residual methane emerges as a significant source of methane emissions, as it desorbs and escapes into the goaf, subsequently finding its way to the atmosphere through conduits such as wellheads and mining-induced fractures (Liang et al. 2023).

These issues are not exclusive to Canada, Australia, China; they occur all throughout the world. People and the environment are at risk from abandoned mine hazards. There is a need to further interrogate these issues at a local scale to come up with specific remedial strategies and recommendations to minimise the deleterious impacts of abandoned coal mines on people and the environment.

2.6 Abandoned coal mines in South Africa

South Africa harbours a considerable number of derelict coal mines, presenting a spectrum of environmental and socio-economic quandaries (Dutton, 2022; Mhlongo, 2023). Many of the mines have since been abandoned due to various reasons, including depletion of coal reserves, economic factors, and changes in mining regulations. Abandoned coal mines in South Africa often result in environmental degradation, including AMD, land subsidence, soil and water contamination, and deforestation (Mhlongo, 2023). AMD is a particularly serious issue, as it leads to the contamination of surface and groundwater with acidic water and heavy metals, posing risks to human health and ecosystems.

The presence of abandoned coal mines can also have significant socio-economic impacts on local communities. These mines often leave behind derelict infrastructure, such as mine shafts, buildings, and equipment, which can pose safety hazards and impede local development efforts. Furthermore, the loss of mining-related employment opportunities can exacerbate poverty and unemployment in affected areas (Aman et al., 2022). Addressing the environmental and socio-economic challenges associated with abandoned coal mines requires comprehensive rehabilitation and reclamation efforts. However, rehabilitation initiatives face various challenges, including limited funding, technical complexities, and legal and regulatory hurdles (Mhlongo & Akintola, 2021). Despite these challenges, there have been efforts by both government and non-governmental organizations to rehabilitate abandoned mine sites and mitigate their environmental and social impacts.

Within the South African context, there exists a close correlation between mine closure and abandonment, albeit discernibly distinct concepts. South Africa has a legal framework governing mine closure and rehabilitation, including the Minerals and Petroleum Resources Development Act (MPRDA) and the National Environmental Management Act (NEMA). These regulations require mining companies to submit closure plans and provide financial provisions for rehabilitation activities. However, enforcement and compliance with these regulations remain key challenges Mhlongo, 2023). Mine closure encompasses a diverse array of processes, encompassing the restoration of excavated land to its original state and the procurement of pertinent documentation such as closure certificates (Ackerman et al., 2018). Integral to the mining lifecycle, closure planning traverses various facets, intricately

intertwined with local communities (Jordan et al., 2018). When closure protocols are disregarded, and mining entities vanish without assuming accountability to regulatory bodies and neighbouring communities, the mine assumes an abandoned status (Molelekwa, 2023).

Mines may be abandoned for a number of reasons. Some of the reasons include depletion of ore minerals, unprofitable prospects in recovering residual minerals or when the mining entity fails to meet the legal requirements related to mine closure (Laurence 2006; Marais et al., 2022). Low market pricing of ore minerals can lead to mining operations to be temporarily stopped, with the hope that higher prices will make them commercially viable in the future. When this is not possible, the mine will end up closing or being abandoned.

2.7 Environmental impacts of abandoned mines in South Africa

Abandoned mines may be left unrestored, thus posing significant threats on the environment, society, and the economy. Efforts are currently underway to rehabilitate abandoned mines around South Africa (Cornelissen et al., 2019). Unrehabilitated abandoned mines hinder the achievement of Sustainable Development Goals (SDGs) due to their undeniable contribution to environmental degradation (Ambani and Annegarn 2015; McCarthy 2011; Ochieng et al., 2010; Mhlongo, 2019). These abandoned mines affect public safety, health, causing respiratory problems, distress on the natural environmental, and criminal activities (Pretty and Odeku, 2017).

2.7.1 Land subsidence and sinkholes

Mpumalanga Province is a major coal mining region in South Africa, characterized by extensive underground and opencast coal mining operations. Abandoned coal mines in this region have led to land subsidence and the formation of sinkholes, particularly in urban areas such as Witbank. For example, the Emalahleni (Witbank) area has experienced numerous sinkholes, endangering infrastructure, roads, and residential areas. Land subsidence and sinkholes not only disrupt local ecosystems but also pose significant risks to human safety and property (Bell et al., 2001).

2.7.2 Water contamination

Some parts of Mpumalanga and Gauteng provinces are severely impacted by water pollution from coal mining and industrial activities. Abandoned coal mines contribute to water contamination in this region, with pollutants leaching into surface and groundwater sources.

2.7.3 Acid mine drainage

According to Ambani and Annegarn (2015), AMD is one of the most harmful types of contamination to water quality. The technique by which AMD is produced is well known; water that arises in or is drained from coal and gold mines that are rich in sulphide material contains harmful heavy metals and sulfuric acid due to the exposure of pyrite and other minerals by mining processes (McCarthy, 2011). This water can extremely endanger human health and contaminate the ecosystem if it is not treated (Ochieng et al., 2010).

The effects of abandoned coal mines tend to vary depending on the mining methods used and geological conditions (Bell et al., 2001). For example, the abandoned Middle Colliery in the Witbank Coalfield, South Africa, research on the water quality from the mine showed that the waters were highly polluted and that the water in the Blesbokspruit catchment was characterized by low pH and high total dissolved solids (Bell et al., 2001).

The Witwatersrand Basin in South Africa is one of the most significant mining regions globally (Lourenco and Curtis, 2021). However, the legacy of mining activities in this basin has resulted in severe AMD issues. For example, the Grootvlei Mine, once a major gold mining operation, has left behind extensive mine dumps and polluted water bodies (Lourenco and Curtis, 2021). These acidic mine waters contain high concentrations of heavy metals such as iron, manganese, and arsenic, posing serious risks to aquatic ecosystems and public health. The impacts of AMD from abandoned coal mines extend beyond the mine site, affecting downstream communities and water resources. This have had devastating effects on aquatic ecosystems and has contributed to the contamination of drinking water sources for local communities. Most plants cannot tolerate low pH water because of high concentration of hydrogen ions which restricts respiration and root uptake of mineral salts and water (Lee et al. 2012).

2.7.4 Land pollution

Most abandoned mines are characterised by spoil heaps and waste dumps which are difficult to rehabilitate. These spoil heaps not only affect the aesthetics of the environment, but they also contain elements that cannot sustain plant life. Some acidic water flows from the spoil heaps and infiltrates the ground thus directly affecting the quality of groundwater sources. The acidity of the seepage water and the high concentration of total dissolved solids adversely affect local vegetation species in the case of the abandoned mine in the Witbank Coalfield, South Africa (Munnik et al., 2010). Spoil heaps expose soils to potential contamination with heavy metals and other pollutants and contaminated soils can affect plant growth, reduce agricultural productivity, and pose risks to human health through the food chain.

KwaZulu-Natal Province is home to numerous abandoned coal mines, particularly in the Newcastle and Dundee coalfields(Minetek, 2007). The legacy of coal mining in this region includes air pollution and dust emissions from mine dumps and open pits. For example, the Vryheid Colliery, an abandoned coal mine in northern KwaZulu-Natal, has left behind extensive mine dumps that contribute to airborne dust pollution, affecting air quality and public health in surrounding communities (Minetek, 2007). Dust and particulate matter from abandoned mine sites can contribute to poor air quality, affecting both human health and the environment, for example, Mpumalanga province has recorded challenges of particulate matter and dust on health and the environment. (Munnik et al., 2010). This was a result of coal mining activities and uncontrolled underground fires. Respiratory problems and other health issues were reported among the local residents, and the deposition of pollutants posed harm to nearby vegetation and wildlife (Munnik et al., 2010).

2.7.5 Ecosystem damage and land degradation

Abandoned mines disrupt the ecosystem (McCarthy, 2011). In Mpumalanga Lake District, the wetlands were severely affected by the opencast mining techniques (McCarthy et al., 2011). Such disruptions consequently affect the concept of sustainability which entails the use of available resources without compromising the needs of the future generation. Ecological disturbances can become barriers to animal movement and migration, further impacting biodiversity (McCarthy, 2011).

In South Africa, abandoned mines are increasingly linked to illegal mining activities (Pretty and Odeku, 2017). These activities are often characterized by poor mining practices that result in significant land degradation. For instance, mining sites frequently experience ground subsidence (Lee et al., 2005), the formation of open pits, soil erosion, and a loss of vegetation cover (Finkelman et al., 2021; Goswami, 2015). Consequently, such environmental damage adversely affects biodiversity, disrupts ecosystems, and diminishes the overall ecological health of the affected areas. In addition, illegal mining has been linked to a plethora of social problems, including prostitution, killings and theft.

2.8 Socio-economic impacts of abandoned mines in South Africa

The social impacts of abandoned coal mines in South Africa are profound and wide-ranging, affecting local communities in various ways. A plethora of literature on abandoned mines tend to focus more on the environmental impact and less is known on the social consequences (Githiria and Onifade, 2020). However, a study by Vivoda et al. (2019) identified 14 social aspects of mine abandonment and some of these included, economic, business, employment, security, education and training infrastructure, amenities, livelihoods, land, housing and health, environment, demography, participation, inclusion, and general social aspects. Other studies describe how mine abandonment affects nearby towns (Neil et al., 1992). The abandonment of mining areas has had severe social consequences (Schwartz et al., 2021; Shackel, 2023; Nnaji et al., 2023).

2.8.1 Health risks

Abandoned mines negatively impact public health. This is because exposure to toxic substances from abandoned mines can pose serious health risks to nearby communities (Olufemi et al., 2019; Marais and de Lange, 2021). Residents may suffer from waterborne and airborne health issues due to contaminated and polluted air, water, and soil. An example is the case of heavy metals from the abandoned gold tailings at Wonderfonteinspruit catchment (west and far west Rand) which posed health threats to most of the informal settlers around the area (Mhlongo et al., 2016; Nnaji et al., 2023). Also, land contaminated by abandoned mines often becomes unsuitable for agriculture, residential development, or other

forms of land use (Mhlongo et al., 2016). This limits the potential for sustainable development and diversification of local economies.

In the Witbank area of Mpumalanga Province, where coal mining has been a dominant sector, abandoned coal mines have left behind polluted water bodies and mine dumps. This pollution poses significant health risks to nearby communities, including respiratory problems, skin diseases, and other ailments associated with exposure to toxic substances. For example, residents living near abandoned mine dumps may inhale airborne pollutants, leading to respiratory issues such as asthma and bronchitis. Additionally, contaminated water sources can contribute to gastrointestinal diseases and other health problems (Mhlongo et al., 2016).

2.8.2 Housing and infrastructure challenges

The Emalahleni (Witbank) area has experienced land subsidence and the formation of sinkholes due to abandoned coal mines. These geological hazards pose risks to housing and infrastructure, displacing communities and undermining the stability of residential areas (Akinlabi et al., 2019). For instance, sinkholes have damaged roads, buildings, and other infrastructure, forcing residents to relocate and causing disruptions to daily life (Tunatazama, 2015). The loss of housing and infrastructure exacerbates social vulnerabilities and undermines community resilience.

2.8.3 Livelihood disruption

In the Newcastle coalfields of KwaZulu-Natal Province, abandoned coal mines have had significant economic impacts on local communities (Minetek, 2007). The decline of the coal mining industry has led to job losses and reduced economic opportunities, resulting in widespread poverty and unemployment (Bennett, 2016). For example, when mining operations cease and companies abandon mine sites, local residents who relied on the industry for employment may struggle to find alternative sources of income. This can lead to social dislocation, increased crime rates, and deteriorating living conditions (Shackel, 2023).

2.8.4 Social stigma and marginalisation

Social stigma and marginalisation associated with abandoned coal mines has been an underrated negative impact. However, research has shown that communities suffering from environmental impacts of coal mining also suffer stigmatisation (Bennett, 2016). The Highveld Priority Area in South Africa, which spans parts of Mpumalanga and Gauteng provinces, suffers heavily from air pollution caused by coal mining activities (AGSA, 2009). This pollution has led to significant social challenges for communities in the region, including stigma and marginalization linked to environmental degradation and health risks from abandoned coal mines (Centre for Environmental Rights, 2017). Residents often face discrimination and are excluded from decision-making processes, which worsens social inequalities and hampers efforts to address environmental injustices. Furthermore, the stigma of living in a polluted area adversely affects community well-being and weakens social cohesion (Centre for Environmental Rights, 2017).

2.8.5 Cultural loss

Some abandoned mines are currently being converted into cultural sites for tourism (Chef, 2024). This can be regarded as a positive development of turning a challenge into an opportunity. However, abandoned mines can initially be considered as disruptive to cultural land and societal values. In the Dundee coalfields of KwaZulu-Natal Province, abandoned coal mines have had cultural impacts on local communities. These mines often occupy land that holds cultural significance to indigenous communities, including burial sites and sacred areas. The destruction of these cultural heritage sites due to mining activities can lead to the loss of traditional knowledge, identity, and spiritual connections (Cui et al., 2020). For example, when mine sites are abandoned and left unreclaimed, indigenous communities may lose access to ancestral lands and cultural practices, further eroding their social fabric and sense of belonging (Cui et al., 2020).

2.8.6 Other socio-economic impacts

Abandoned mines directly affect the economy through a decrease in purchasing power and foreign investment (Wang et al., 2021; Minetek, 2007). Also, these mines were a source of income to the local hence their closure reduced their buying power thereby directly affecting

the economy. Abandoned mine sites may leave behind infrastructure that requires ongoing maintenance and management, such as mine shafts, waste dumps, and tailings ponds. These can further strain local resources (Shackel, 2023).

Marais et al. (2021) noted that, closed mines have contributed to social disruption. For example, the case of a local community in Pilgrim's Rest in Mpumalanga (Siyongwana and Shabalala, 2019), a study showed that several people were left unemployed. Once-thriving communities that were dependent on mining jobs faced unemployment. This lack of employment contributed to the widespread of poverty, deterioration of standards of living and outward migration as individual were looking for better opportunities. The closure of mines and the resulting economic challenges led to social disruption, including increased crime rates, substance abuse, and other social issues (Stretesky and Grimmer, 2020). The sense of community and cultural identity also eroded as people were forced to leave their homes (Marais et al., 2021; Marais and de Lange, 2021)

Overall, the situation of abandoned coal mines in South Africa underscores the importance of proactive and sustainable mine closure practices, as well as ongoing monitoring and management of legacy mine sites to minimize their environmental and socio-economic impacts.

2.9 Legislative frameworks for mine closure in South Africa

South Africa's mine closure framework is based on three main laws: the Minerals and Petroleum Resources Development Act (MPRDA), the National Environmental Management Act (NEMA) and the Mine Health and Safety Act (MHSA). These three laws provide a solid legal foundation for managing the environmental, social and safety aspects of mining, during and after closure. This section looks at the provisions and requirements in the context of mine closure and rehabilitation.

2.9.1 Minerals and Petroleum Resources Development Act

The MPRDA (Act No. 28 of 2002) is the main legislation governing mining in South Africa. It requires mining rights holders to be responsible for the environmental and socio-economic impacts of their operations. According to Section 43 of the Act, companies must submit a closure plan as part of their environmental management programme (EMP). The closure plan

must detail the steps to rehabilitate disturbed areas and restore land use to as near original state as possible (Republic of South Africa, 2002).

The MPRDA also introduces the concept of a rehabilitation provision, where mining companies must set aside funds for closure and post-closure activities. This ensures that there are sufficient resources for environmental restoration even if the company goes out of business (Republic of South Africa, 2002).

2.9.2. National Environmental Management Act

NEMA (Act No. 107 of 1998) is the main environmental law in South Africa and provides the principles for sustainable development and environmental management. With the 2014 amendments, NEMA incorporated environmental management provisions into the mining sector, in line with the MPRDA. Under NEMA, mining operations must comply with environmental impact assessments (EIA) and management plans that include mine closure (Republic of South Africa, 1998).

Sections 24 and 28 of NEMA enforces the "polluter pays" principle, where mining companies are liable for preventing, mitigating and remediating environmental harm. The Act also requires regular audits and reporting on compliance with closure and rehabilitation commitments. Non-compliance can result in penalties or legal action (Republic of South Africa, 1998).

2.9.3. Mine Health and Safety Act

The MHSA (Act No. 29 of 1996) is about the health and safety of mine workers and surrounding communities. While primarily focused on operational safety, the Act also deals with safety during mine closure. It requires operators to manage the risks associated with abandoned and closed mines such as ground instability and hazardous structures to prevent harm to people and property (Republic of South Africa, 1996). MHSA requires safety plans for mine closure and removal or securement of infrastructure. This will prevent accidents or illegal mining in abandoned sites.

Challenges and Gaps

Theoretically, it is indeed pleasing to have these laws in place but the reality is that they are not strictly followed. Compliance with financial provisioning and rehabilitation requirements

is said to be low in most instances especially in the case of older mines (Sovacool, 2021; Mhlongo & Akintola, 2021). What is more is that the jurisdictional conflict between the MPRDA, NEMA, and MHSA has resulted in some enforcement gaps and duplications thereby making it difficult to close mines (Cornelissen et al., 2019).

In conjunction with the relevant provisions of the MPRDA, NEMA and MHSA, South Africa has a legal framework for managing mine closure. That said, for South Africa to avoid the social, economic and environmental consequences that have been witnessed from abandoned mines, such as the one in Jackaroo Park, these provisions must be implemented. In order to promote environmentally and socially responsible mining practices, it is necessary to enhance compliance enforcement measures, strengthen inter-agency collaboration, and eliminate economic and technological obstacles.

2.10 Conclusions

The literature reviewed provides a comprehensive understanding of the global and local dynamics of coal mining, its environmental and socio-economic impacts, and the challenges of mine abandonment and closure. Globally, coal mining remains a critical energy source, but it poses significant environmental risks, including greenhouse gas emissions, habitat destruction, and water contamination. In South Africa, the coal industry has historically driven economic development but left a legacy of abandoned mines that exacerbate environmental degradation, including acid mine drainage, land subsidence, and water and soil contamination. The socio-economic implications of abandoned coal mines are equally profound, disrupting livelihoods, public health, and local infrastructure while perpetuating poverty and social inequalities. The failure to adequately address the challenges of mine closure and rehabilitation has intensified these impacts, highlighting gaps in governance, enforcement, and resource allocation.

Addressing these issues requires a multifaceted approach that includes enforcing stricter regulatory frameworks, fostering sustainable rehabilitation practices, and engaging local communities in decision-making processes. Future research should focus on tailored strategies to mitigate the localized impacts of abandoned mines and explore innovative approaches, such as repurposing mine sites for economic and environmental gains. Proactive and sustainable management of mine closure and abandonment is essential to ensuring a balance between economic development and environmental sustainability.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter presents the methodological approaches used for data collection, analysis, presentation, and interpretation in this study. While discussing the techniques, the aim, objectives, research questions, and conceptual framework that were introduced in previous chapters are all taken into account. Important subjects discussed in the chapter include the research approach, sampling strategies, methods and procedures for collecting field data, and the systematic literature review process. These are discussed in terms of the validity and reliability of the methods used.

3.2 Description of the case study site

The study was carried out in Jackaroo Park, near the Farm Kromdraai 292 JS, 6 kilometres north of eMalahleni (Figure 3.1).

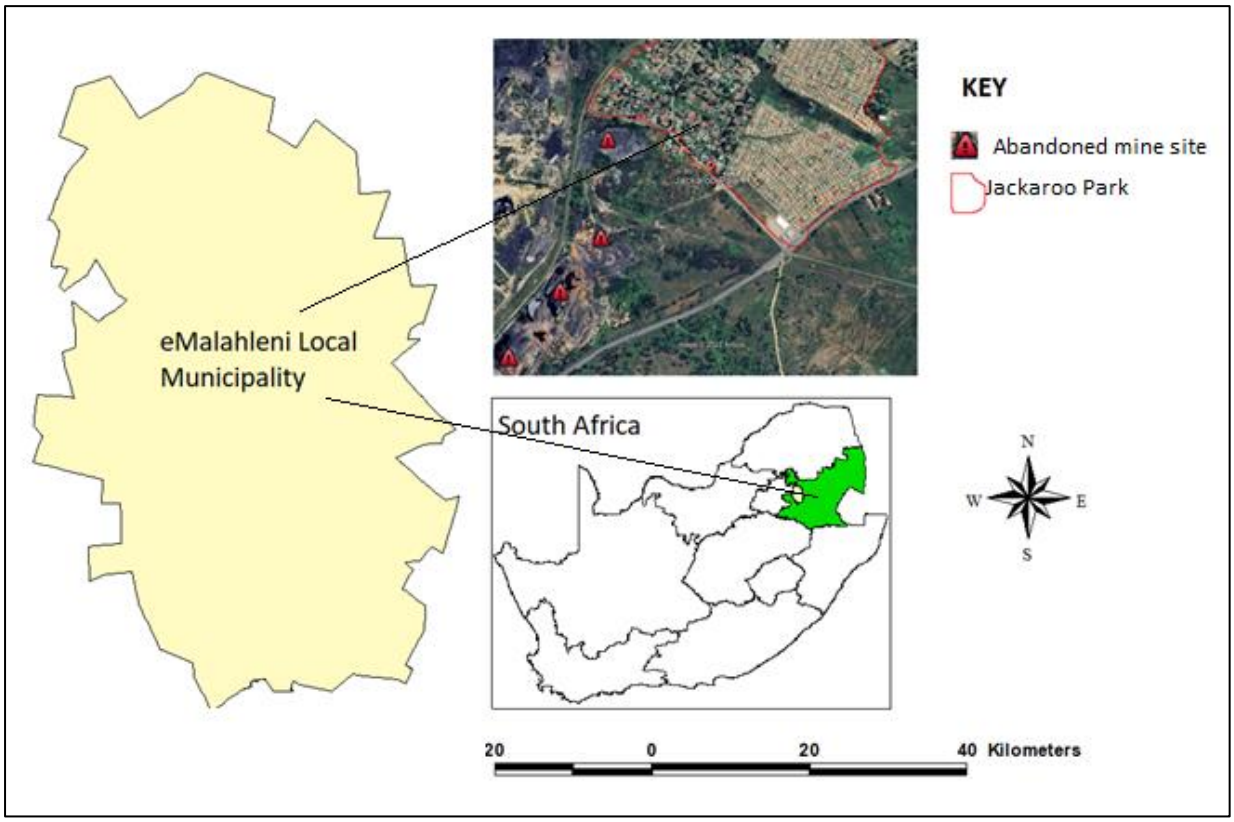

Figure 3.1: Map of abandoned mine site (Jackaroo) (Source: Produced by Author).

Jackaroo Park is a residential neighbourhood with a population size of 2 451 people and an area of 9.18 km^2 (Frith, 2022). The neighbourhood includes apartments, flats, standalone houses and other vacant farm portions that are all close to where people live. The neighbouring mines, including Eensaamheid, and Delmas, the local municipality, and power stations such as Duvha and EskomPark in eMalahleni are the principal employers of people living in this study area (Molelekwa, 2023).

Various companies mined coal in the region of Jackaroo Park prior to the promulgation of the Mineral and Petroleum Resources Development Act 28 of 2002 (MPRDA) and abandoned the sites without sufficient restoration (Mpumalanga Provincial Treasury, 2015). Other operations were licensed in terms of the MPRDA, such as Witbank Brickworks (Pty) Ltd, which was awarded mining rights under Section 23(1) of the Mineral and Petroleum Resources Development Act, 28 of 2002, on 9 May 2016 for a period of 15 years, and the mining right was registered on 17 November 2016. This site was the focus of the case study, in particular an abandoned site owned by Witbank Brickworks (Pty) Ltd, which was founded in 1961. In addition, the company owned the Uitspan mine in Jackaroo, which was located on the estate Kroomdraai. Later, the business leased agricultural parts to other companies for mining purposes, which resulted in the companies exhausting the coal reserves and abandoning the sites without completing the rehabilitation process. The site has abandoned mine that includes a number of large open pits filled up with coloured water, a railway line, abandoned mine dumps, power lines, and pampas grass. Illegal miners have taken up residence on the property, posing major security threats to the local people (High Court of South Africa Mpumalanga, 2017).

3.3 Research approach

This research is a case study focusing on abandoned mine sites in Jackaroo Park, eMalahleni in Mpumalanga province of South Africa. The study employed the concurrent mixed methods research design as the investigational approach, integrating both quantitative and qualitative methodologies. The quantitative approach is grounded in the positivist paradigm (Creswell and Creswell, 2023) , while the qualitative approach is based on phenomenological philosophy (König and Drebler, 2021; Creswell & Creswell, 2023). According to Akerblad et al., (2021), researchers across various disciplines adopt mixed methods design, which originates from the pragmatic school of thought. The design was deemed the most appropriate

as it combines the strengths of both qualitative and quantitative methods, providing a comprehensive understanding of the issue. Quantitative methods allow for the collection and analysis of numerical data, such as levels of pollution, health statistics, and socio-economic indicators, offering measurable evidence of impacts. Meanwhile, qualitative methods capture the lived experiences, perceptions, and insights of affected communities, providing context and depth to the numerical data. This integrated approach ensures a holistic analysis, enabling researchers to explore the environmental, health, and socio-economic dimensions of abandoned coal mines while addressing both statistical trends and human narratives. Figure 3.2 shows the concurrent mixed methods research design adopted for this study.

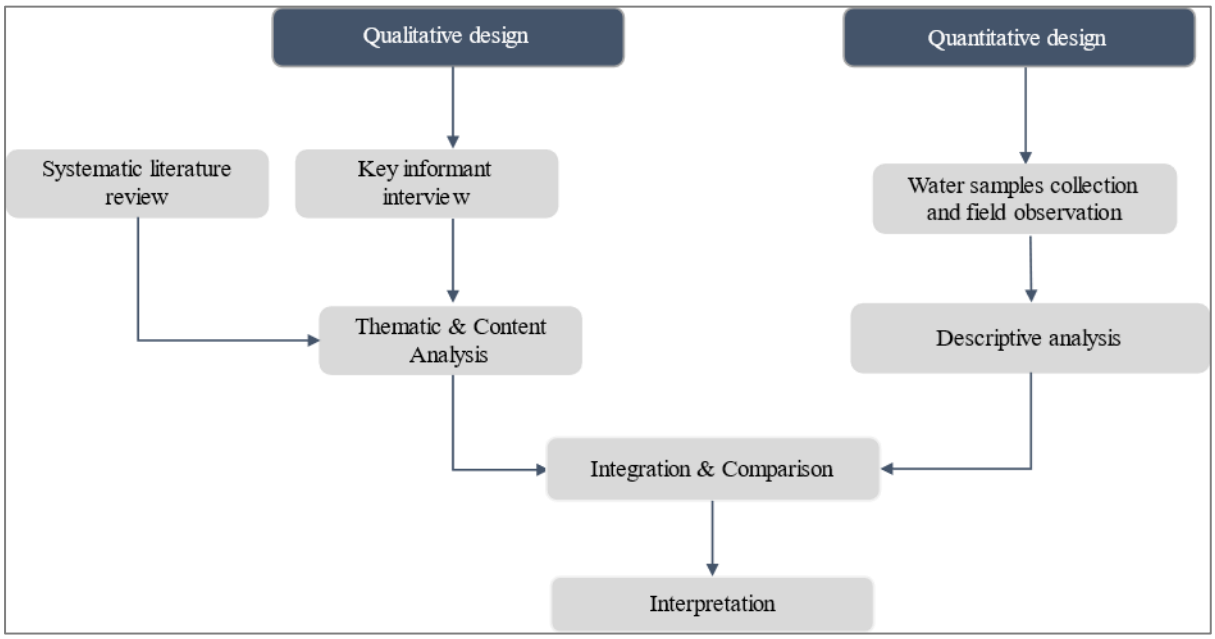

Figure 3.2 The concurrent mixed methods research design adopted for the study.

As shown in Figure 3.2, both qualitative and quantitative data collection and analysis methods were used. The data was collected at the same time from 29 February 2024 to 4 May 2024. The qualitative approach was included in order to gain in-depth insights into the experiences, perceptions and attitudes of stakeholders involved in the communities where abandoned coal mines exist. On the other hand, the quantitative research approach was included to capture numerical data that quantifies the extent of environmental and social consequences of abandoned coal mines. Specifically, this involved testing of water samples for pollution and recording of numerical observations e.g., number of disused dump sites, degraded sites, and contaminated water sources, among others. The mixed methods approach was adopted to capitalise on its ability to utilise the strengths from both qualitative and quantitative

approaches. As postulated by (Castro et al., 2010; König and Drebler, 2021), it distils the weaknesses of each of the research approaches by capitalising on the strengths of both.

3.4 Sampling and sample size

The purposive sampling approach was adopted as the strategy for selecting interview participants. This sampling approach is a non-probability sampling method in which the researcher subjectively selects participants based on a priori knowledge (Pace, 2021). The primary strength for anyone considering the purposive sample method is the idea that the researcher can use their expertise in conjunction with this technique to get information that otherwise might not be available from other sources and methods.

In this study, a total of 15 key informants were interviewed. Sample sufficiency tests reveal that the sample size was adequate to provide sufficient understanding of the environmental and socio-economic impacts of abandoned coal mines in Jackaroo Park. Figure 3.3 shows sample sufficiency test results depicted by the cumulative number of themes emerging as the number of interviewees cumulatively increase.

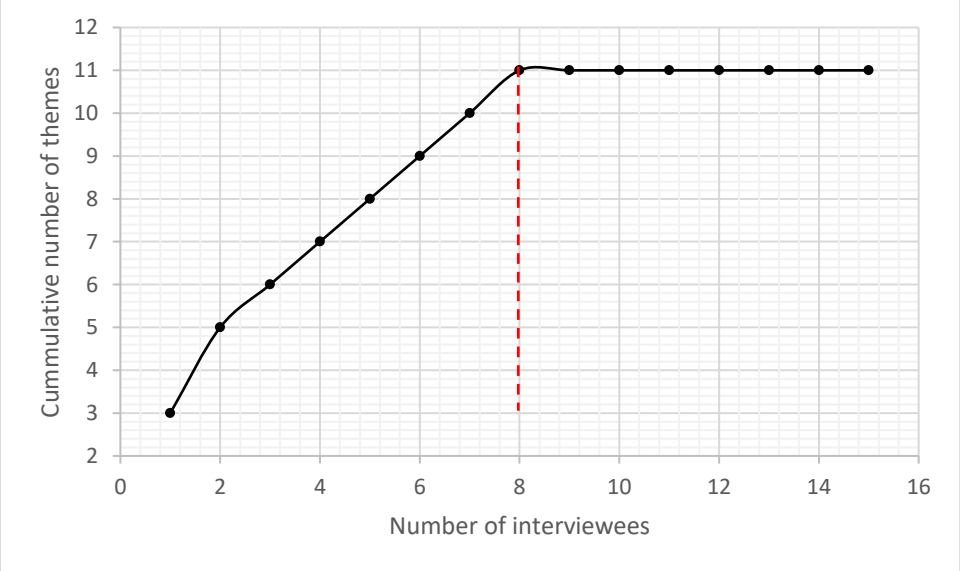

Figure 3.3 determination of Sample sufficiency

As shown in Figure 3.3, the cumulative number of new themes stopped increasing after interviewing 8 key informants. The other 7 key informants were repeating the themes that were already presented by the first 8 interviewees. This indicates that the sample size included

in this study was sufficient to cover all the aspects related to the environmental and socio-economic impacts of abandoned coal mines in Jackaroo Park.

3.5 Data collection and analysis

According to Kabir (2018) and Miles (2019), data collection is the process and activities for gathering data using a clearly designed instrument. The collected data is influenced by the objectives to be met and the variables that need to be addressed in the study. Data collection is essential for the success of research, as it provides a better understanding of the issues being investigated. Therefore, selecting the sources of data and the method of collection is one of the most critical judgments a researcher must make (Etikan et al., 2016). In this study, several data collection methods were employed to fulfil the requirements of a mixed-methods research design. These included field observations, interviews, systematic document analysis and water sample collection. Figure 3.4 shows the framework comprising the data collection methods, the data collection tools, and analysis and presentation methods used in this study.

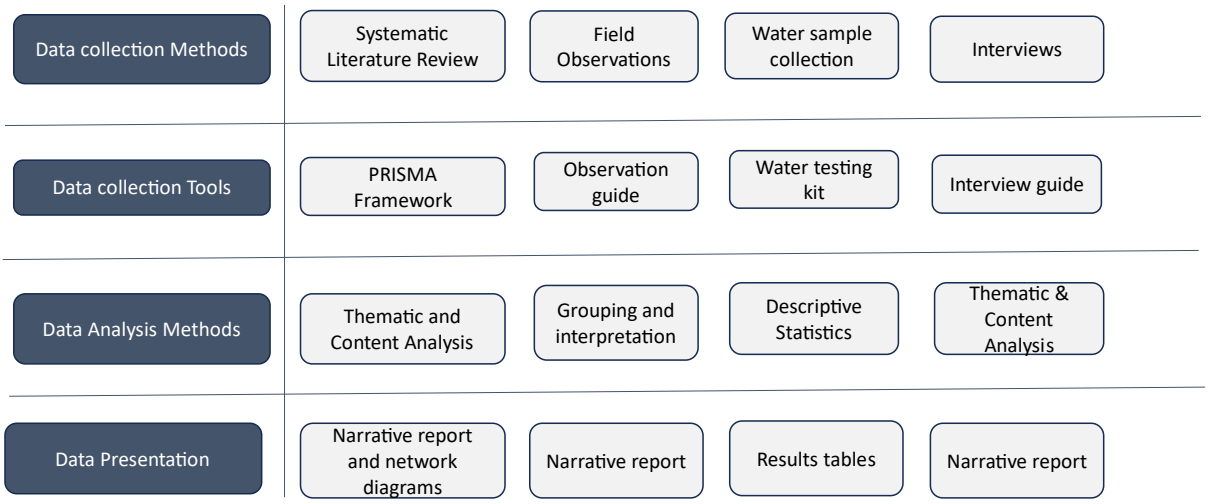

Figure 3.4 Methods and tools used in data collection and analysis.

3.5.1 Systematic literature review

Systematic literature review and analysis was done by adopting the Preferred Reporting Items for Systematic Meta-Analysis (PRISMA) methodology. The process included gathering documents from different sources that are likely to provide information regarding events or activities associated with abandoned coal mines and their impacts in Jackaroo Park. The documents were subjected to the screening process to ensure that only relevant documents

are considered for analysis. Table 3.1 shows the sources used, the number of documents per source and the total number of themes emerging from each type of source.

Table 3.1: Sources and documents used for literature analysis.

Information Source	Count	Total themes on impacts of abandoned coal mines
Electronic Newspaper	5	7
Print news media	1	3
Scientific publication	1	2
Website	2	3
Official report	1	2
Complaint registers	4	4
Total	14	21

NB: The themes shown in Table 3 overlap between information sources, for example, one theme may appear in more than 2 information sources.

As shown in Table 3.1, a total of 14 systematically identified secondary sources were used to extract information regarding the impacts of abandoned coal mines in Jackaroo Park. Electronic newspapers had the highest number of documents as well as themes that show the impacts. Reported cases, as indicated in the complaint registers obtained from eMalahleni municipality were the second most important source with a total of 4 themes related to the impacts of abandoned coal mines.

The literature screening process which resulted in the selection of the final 14 documents is shown in Figure 3.5.

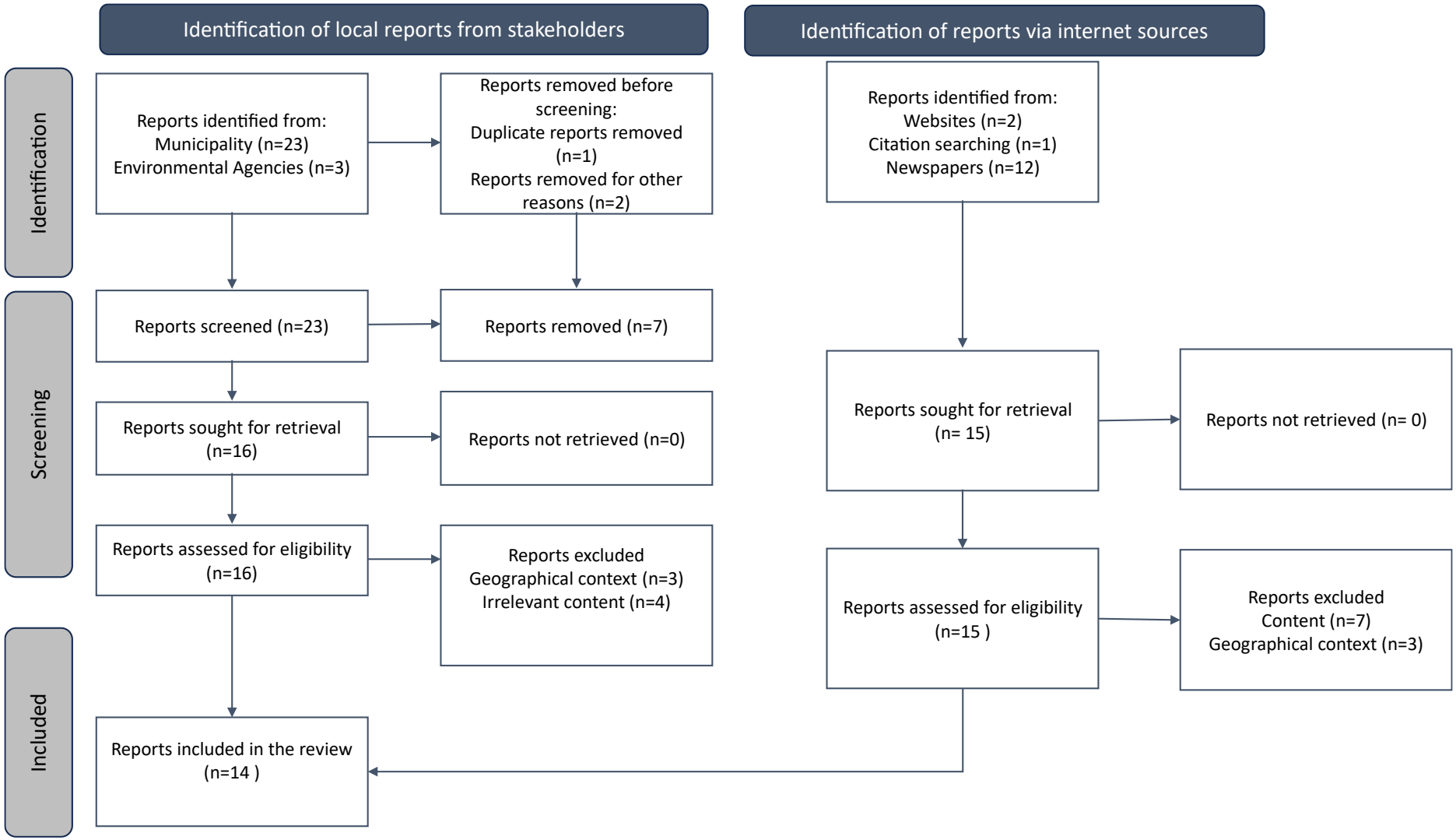

Figure 3.5: Document identification and screening flow diagram. Adapted from Page et al., (2020)

3.5.1.1 Document Review

The document analysis method is one of the methods used to collect data. The method involved a systematic review of printed and electronic material. (Morgan, 2022) put forward that the method is a reliable approach to gather data, analyse it, and interpret the findings to answer specific research questions. In this study, official local government documents, including policies and reports related to abandoned coal mines were examined to understand the context and background information. This approach was selected on the basis of its ability to provide access to a wide range of data that included historical perspectives of abandoned coal mines. In addition, the method does not involve interaction with participants, and this addresses the biases that come with self-reporting (Bowen 2009; Morgan 2022). More so, the method is cost effective and effectively complements other research methods used in this study (Bowen, 2009).

3.5.1.2 Document analysis procedure

Planning and preparation: Planning and preparation was the first step taken in the document analysis process. This involved understanding and refining the purpose and objectives of document analysis in the study, ensuring legal access to the documents and selection of relevant, and credible documents using a predetermined inclusion and exclusion criteria.

Data collection: This process included organisation of documents and systematically selecting the most relevant ones. In addition, the data collection process included reading the documents to identify content, and themes that provide answers to the study's research questions.

First, the complaint registers, reports and other local documents related to Jackaroo Park were collected from the eMalahleni local municipality. Permission from the municipality was sought and they assisted by providing documents with complaints from the community regarding the impacts of the abandoned mines. In addition, reports, complaint registers and other documents were retrieved from online newspaper articles. Only documents known to provide information about impacts related to the abandoned coal mines were retrieved.Second, all the complaints registers and documents were screened for eligibility using the following criteria:

i. Captures a complaint from a community member, or stakeholder from Jackaroo Park

ii. The complaint/ report is related to abandoned mines in Jackaroo Park

The decision on the suitability of the article was based on information captured in the title, abstract/introduction, key words and conclusion of the reports. The reason(s) for inclusion and exclusion were stated for each document or report. All documents meeting the inclusion criteria were retrieved and analysed to identify community concerns regarding abandoned coal mines. The document review process differentiated between local impacts confined to Jackaroo Park and those identified at regional level in eMalahleni to ensure that the impacts of abandoned mines are clearly linked to Jackaroo rather than to general conditions in the study area.

The identification of complaints from the complaint's registers, organisational reports, articles and other secondary documents and available literature partly addressed the first two objectives of the study, which aim to identify the environmental and social consequences of abandoned coal mines in the study area. Thus, complaints reported through written individual, community, pressure group, associations and organisational reports provided information about the major concerns of the community regarding the abandoned coal mines. This process led to the generation of a list of complaints from the community which were grouped into categories, depending on their effects.

Analysis

Analysis of the environmental and social consequences of abandoned coal mines from document review included grouping of the most significant issues. Significance was determined by the frequency and severity of the issues identified in the documents. Issues directly related to mine abandonment were identified.

3.5.2 Key informant interviews

After generating a list of the complaints in the community and their categories, open ended questions were designed to probe further information regarding the issues from key informants. Fifteen key informants were purposively selected to ensure that all the important stakeholders are well represented in the sample.

A criterion was set for the selection of key informants. For example, the selected key informant interviewee should have held their current position for at least 2 years or should have been working in a similar environment for more than 2 years. Four of the informants are local residents who have resided in the area for more than 20 years so that the changes that took

place since the pre-mining period can also be understood. This approach assisted in understanding the baseline conditions in the absence of environmental impact assessment reports that were generated before the commencement of mining activities. Table 3.2 shows the list of key informants

Table 3.2: List of key informants.

Category	**Number of interviewees**	**Males**	**Females**
Government officials	5	3	2
Local community leaders	6	4	2
Residents	4	2	2
Total	15	9	6

The interviews lasted between 26 and 45 minutes. Follow-up, probing questions were asked to get more details concerning the issues under discussion. An example of the interview questions and a probing question are as follows:

Main Question: *What environmental concerns do you have regarding coal mining adjacent to Jackaroo Park?*
Probing Question: *How do this impact you? Could you give some examples?*
The interview questions are included in Appendix 1.

The interviews focused on what the interviewees do on a daily basis, what they have seen happening, what they feel about what has been happening and what their peers in the community have been saying regarding what they see daily. In some cases, interviewees were given the opportunity to relate a story regarding an event which involved consequences associated with abandoned coal mines in Jackaroo Park, eMalahleni. The interviewees were asked about their perspectives on what should be done to address any of the concerns, and who should do it. The interviews were recorded, and notes written down.

Ethical considerations were taken into account where consent to participate in the interviews was sought prior to participation. Ethics clearance was obtained through the Wits ethics committee. The interviewees were informed about their right to withdraw from the interviews

at any point in time whenever they felt they cannot continue. Anonymity was maintained in all the records and confidentiality was also be reinforced.

3.5.2.1 Analysis of key informant interview data

The study adopted the thematic analysis approach. This was carried out systematically, commencing with data transcription and familiarisation. Figure 3.6 shows the process followed during the thematic analysis.

Figure 3.6 Data analysis procedure

The procedures depicted in Figure 3.6 were executed on all selected documents and interviews. Themes were refined and categorized based on their commonalities. Moreover, interpretation of findings was facilitated through the utilization of network diagrams and tables using excel software to enhance the clarity and effectiveness of result dissemination. The diagrams presented the connections between abandoned mine aspects and specific impacts whilst tables presented number of mentions of impacts per document.

In addition to thematic analysis, the data was further analysed by grouping the key environmental and social issues raised by each interviewee. The consequences of those issues were also grouped, and the recommendations provided for each consequence were noted. The persons or organisations responsible for implementing the specific recommendations were also noted. This analysis produced a list of grouped environmental and social issues and related consequences. The data on recommendations was used to address the third objective of making recommendations on how the environmental and social consequences of abandoned coal mines can be addressed.

3.5.3 Personal observations

Information obtained through secondary data sources and key informant interviews was buttressed by personal observation information. The researcher was a participant observer as they work in eMalahleni municipality's environmental department. An observation guide with predetermined environmental and socio-economic issues such as soil erosion, sinking ground,

water pollution, land pollution, land degradation, deforestation, health effects, deaths, loss of income and others was used to record the observations. The observation guide was also designed in a way that allowed the capturing of new observations that were not predetermined. A camera was used to capture some of the impacts for presentation in the results section. A total of 4 visits were done to the appropriate data collection sites and recurring observations as well as other significant events or incidents were recorded.

Observations were targeted at sites of identified impacts (as identified in the document review and through the interviews). To confirm specific observations, field measurements of specific phenomena were done, for example, to confirm water contamination, pH was measured using the mobile pH test meter. Tests for pH were done in 2 different seasons (dry and wet season). The sampling sites for pH include open pits where water is accumulated. In addition to pH, Water colour, and suspended solids were also determined.

3.5.3.1 Analysis of observation data

The observed phenomena were grouped and analysed to determine distribution, frequency, averages and descriptions of occurrences. Thus, descriptive narratives were used for variables that were appropriate.

3.5.4 Water sample collection and testing

Five water samples were collected from various sites near abandoned coal mines in Jackaroo Park, eMalahleni, to assess the extent of water contamination. The sites were selected based on proximity to abandoned mines, observable discharge points, and potential downstream impacts. Samples were collected in sterile polyethylene bottles, ensuring no prior contamination. Prior to collection, the bottles were rinsed three times with the sample water to condition them. The collection process adhered to standard sampling protocols to maintain the integrity of the samples.

Sampling was conducted during daylight hours to ensure safe access to the sites. Field parameters, including pH, temperature, and electrical conductivity, were measured on-site using portable meters. Each sample was labeled with a unique identifier, date, and time of collection, and immediately stored in a cooler box with ice packs to preserve their quality during transport to the laboratory.

All results were cross-referenced with baseline water quality standards to determine the level of contamination and assess potential environmental and health risks. Data were recorded systematically in field logbooks and later digitized for analysis.

3.6 Issue prioritisation

Data from different data collection methods were combined and analysed through prioritisation of major issues. A process of prioritisation was considered as it is essential to narrowing down findings, and once this is done, recommendations were developed that align with the most important findings. A prioritisation matrix was developed, and the key informants helped to rank the most important interventions for the area. The process led to a set of potential strategies or interventions to environmental and socio-economic problems.

3.7 Study limitations

Whilst this study provides important insights regarding the consequences of abandoned coal mines based on a mixed methods research design, which is quite comprehensive, the use of purposive sampling approach as well as a case study in one geographic region may introduce bias. Thus, the results may not be transferable to a wider and larger population or geographic area. The inclusion and exclusion criteria for documents, and key informants is solely decided by the researcher but based on a consistent methodology. This may also introduce subjectivity to the process, leading to biased results. However, the study remains key in alerting policy makers and development practitioners about the need to address challenges associated with abandoned coal mines and contributes significantly to the already existing body of knowledge.

3.8 Conclusion

The methodology outlined in this chapter provides a comprehensive framework for examining the impacts of abandoned coal mines in Jackaroo Park, eMalahleni. By employing a mixed methods research design, the study integrates quantitative and qualitative approaches to capture both measurable environmental parameters and the lived experiences of affected communities. The systematic collection and testing of water samples, combined with robust field observations and community engagement, ensures a thorough investigation of the environmental and socio-economic impacts.

The use of standardized protocols for sample collection and analysis enhances the reliability and validity of the findings, while the mixed methods approach enables a holistic

understanding of the complex interplay between environmental degradation and community well-being. This methodological approach ensures that the study generates actionable insights, contributing to evidence-based strategies for mitigating the impacts of abandoned coal mines and promoting sustainable development in the region.

CHAPTER 4 RESULTS

4.1 Introduction

This chapter presents the results and initial discussion derived from the analysis of the data obtained through a mixed methods approach. The results are presented per research question. The first section provides the history of Jackaroo Park including a map showing the extent of the site, the proximity to settlements, the location of the abandoned mines, and the mining infrastructure to provide context for the environmental and social impacts of abandoned coal mines.

4.2 Jackaroo park and the abandoned mines

The history of abandoned coal mines in Jackaroo Park, South Africa, is closely linked to the broader history of coal mining in the region. Coal mining in Jackaroo Park began in the late 1800s and quickly became a pivotal industry, driving both economic growth and the socio-economic development of the region (Cole et al., 2024). For over a century, the industry provided substantial employment opportunities for the local communities and significantly contributed to the regional economy.

However, alongside its economic benefits, coal mining also brought about considerable environmental degradation. The extraction processes led to pollution, habitat destruction, and a decline in the quality of natural resources. Despite these issues, the industry continued to flourish until recent decades (Ahmed, date). Over the past decade, the coal mining industry in Jackaroo Park experienced a significant decline. As mining activities dwindled, many mines were abandoned, resulting in a series of negative socio-economic and environmental consequences. The closure of these mines led to a sharp increase in unemployment and economic hardship for the local population (Syahrir et al., 2021).

The abandonment of the mines also left behind a legacy of environmental damage. Without proper maintenance and rehabilitation efforts, these abandoned sites contributed to widespread contamination of soil and water sources. This contamination has posed severe health risks to local communities, including increased incidences of respiratory illnesses and waterborne diseases (Mqotyana, 2022; Ahmed et al., 2022). The deterioration of air quality and water sources continues to threaten both human and wildlife health in the area, underscoring the urgent need for effective rehabilitation and management of these abandoned

mines. Figure 4.1 shows the location of Jackaroo Park and the abandoned coal mines adjacent to the park as well as the water sampling points.

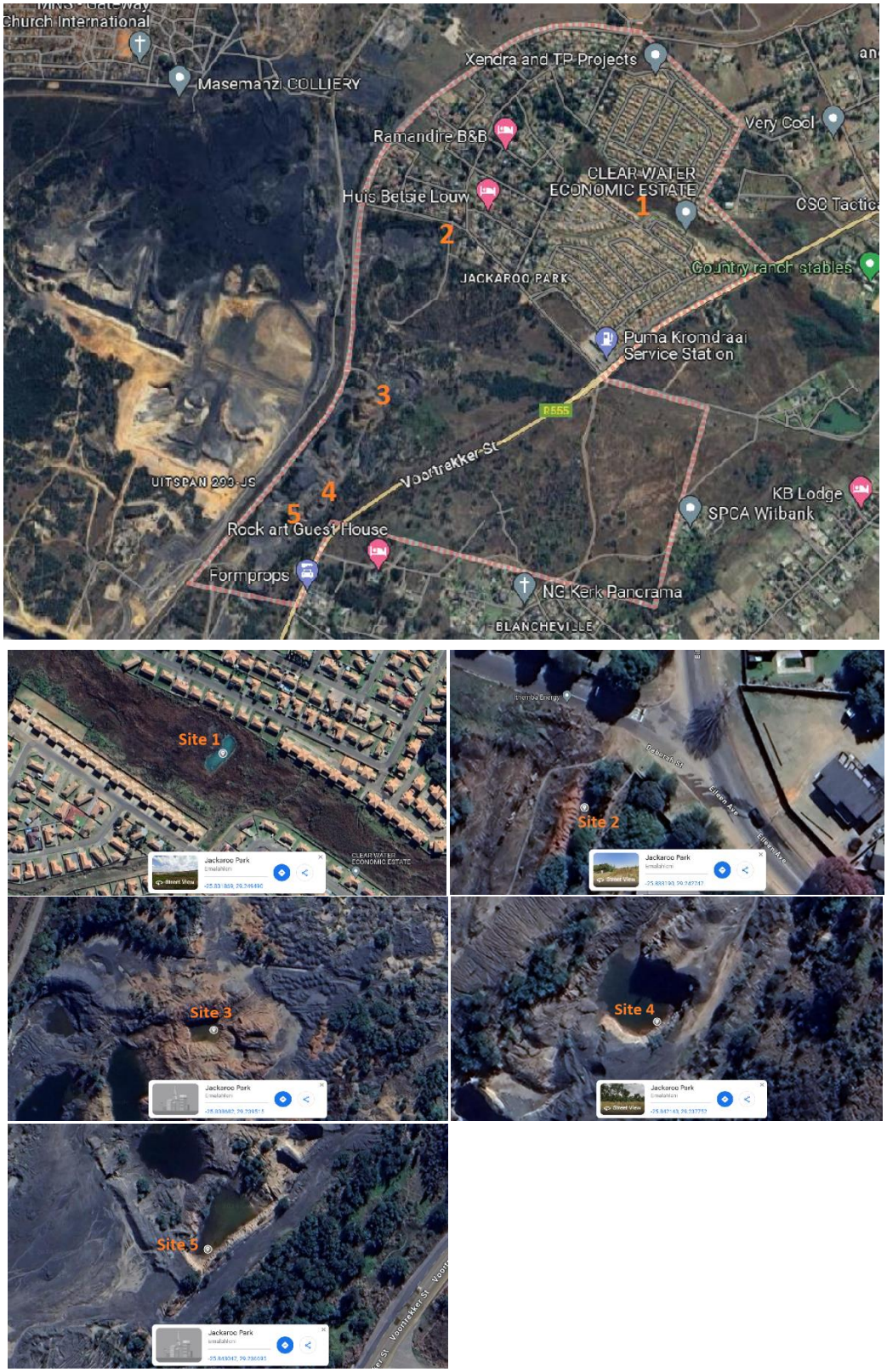

Figure 4.1 Jackaroo Park, abandoned coal mines and water sampling points.

As shown in Figure 4.1, abandoned mines are located in the vicinity of the residential areas in Jackaroo Park. Consequently, what happens in the abandoned mines directly and indirectly affects the communities. A plethora of environmental and socio-economic impacts have been experienced due to the close interaction of the park communities with the abandoned mine sites.

4.3 Environmental impacts of abandoned coal mines in Jackaroo

The findings of this investigation indicate that the abandoned mines in Jackaroo stem from operational discontinuities precipitated by financial insolvency, resource exhaustion, and inadequate closure strategies. These mines have been left in a state of neglect, presenting substantial environmental hazards. The jurisdiction encompassing Jackaroo Park has a historical pattern of abandoned mine sites, with approximately four such sites identified within the park's boundaries as of present. The absence of rehabilitation efforts on these abandoned mines poses a significant obstacle to the realization of SDGs, given their contribution exacerbating environmental degradation. These neglected mine sites inflict various forms of distress on the natural environment.

It emerged from the interviews and literature analysis that there are several environmental impacts of abandoned coal mines in Jackaroo Park, these impacts include water pollution, soil degradation, air pollution, land subsidence, loss of biodiversity, underground fire occurrences, and loss of aesthetic qualities of the land. Figure 4.2 shows the environmental impacts of abandoned coal mines in Jackaroo as well as the abandoned mine aspects linked to the specific impacts as reported by the key informants.

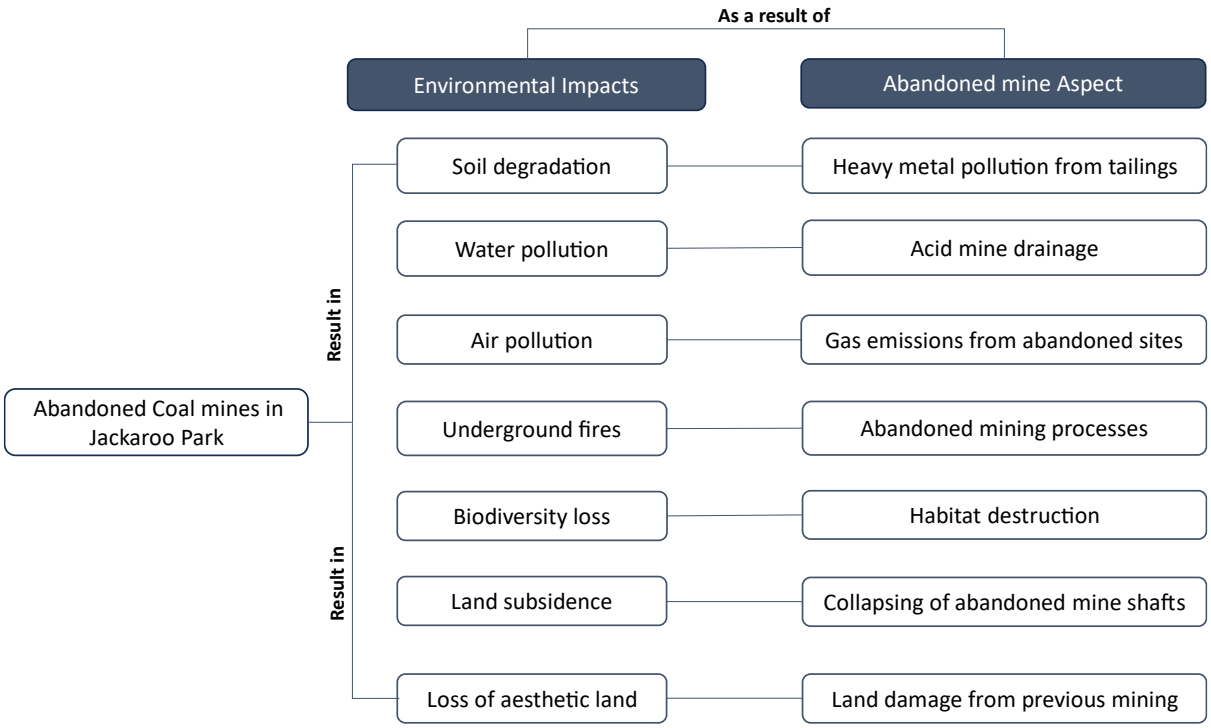

Figure 4.2 Environmental impacts of abandoned coal mines in Jackaroo Park, eMalahleni municipality, Mpumalanga

As shown in Figure 4.2, several environmental aspects were reported by the interviewees to be associated with abandoned coal mines.

Water pollution was reported as directly being influenced by acid mine drainage from the abandoned mine sites. There were indications from the interviews as well as electronic newspaper articles that air pollution in Jackaroo as a result of smoke being emitted from the abandoned sites, where some illegal mining activities are also taking place. Other impacts reported include underground fires, biodiversity loss, land subsidence and loss of aesthetic qualities of the land. These have been reported to be directly caused by various aspects of abandoned coal mines. The following sections discuss the impacts in more details.

Document analysis also confirmed the existence of various challenges associated with abandoned coal mines. The challenges were ranked based on their frequency of occurrence in the documents, which included complaint registers, published scientific articles, electronic newspapers, websites, print media and official reports. Table 4.1 shows the results from document analysis.

Table 4.1: Results from document analysis

Impact	Number of mentions	Document type(s)
Infrastructure damage	47	Complaint registers, print media, Electronic newspapers,
Water pollution	38	Published Scientific articles, electronic newspapers, official report
Soil degradation	32	Print media, Electronic newspapers, official reports
Land subsidence	22	Official report, Complaint registers, print media, Electronic newspapers
Biodiversity loss	12	Published scientific articles, Complaint registers, print media, Electronic newspapers
Air pollution	9	Print media, Electronic newspapers
Underground fire	5	Complaint registers, print media, Electronic newspapers
Loss of aesthetics	5	Complaint registers, print media, Electronic newspapers

4.3.1 Water pollution

The results show that water pollution is one of the major environmental concerns associated with abandoned coal mines.Mines generate AMD, which occurs when sulphide minerals are exposed to air and water, resulting in the formation of acidic runoff. This acidic water can dissolve heavy metals and other pollutants from the surrounding rock, leading to the contamination of both surface and groundwater sources. In Jackaroo Park, AMD has been reported to have severe impacts on aquatic life and pose significant risks to human health. Additionally, some road accidents along the R555 road have been linked to AMD from the abandoned coal mines. One key informant shared the following observation:

> "*The Overflow of acid mine drainage has also impeded the traffic flow and accidents along the R555 road. Furthermore, the effluent has reached the Olifants river system endangering the aquatic life*". (Local official: 17/01/2024)

A local resident also confirmed the problem of water pollution from abandoned coal mines and the health risks associated with exposure of residents to the polluted water the AMD:

"*We are not safe at all, almost all water surfaces in the Park are contaminated with acidic water. This is causing a lot of problems and health threats especially to our children who often come into contact with the water almost daily. The responsible authorities need to come to our rescue, its no longer safe here because of these old mining sites*" (Local resident: 17/01/2024).

The low pH of the water and the release of heavy metals associated with AMD poses a major problem to water users. Some key informants reported having experienced coloured water due to pollution. High levels of iron can cause the water to turn red, orange, yellow, brown and even black and stains open water sources. Although these stains are not responsible for any human health problems, they can give the impression to the users of the discoloured water that it is contaminated and cause the water to be avoided. Figure 4.3 shows coloured water found in abandoned mines in Jackaroo Park.

Figure 4.3 Coloured water due to abandoned mines in Jackaroo Park on 29 March 2024. Source: Author's field data, 2024

As shown in Figure 4.3, both pictures reflect heavy pollution from high levels of iron released from abandoned coal mines, turning water into red and yellow colour. The polluted water poses several health threats to the communities and exacerbates the scarcity of clean water sources in the area.

This study tested some water samples to verify the impact of abandoned coal mines on water quality. The sampled sites are water sources close to abandoned coal mines and the assumption

used in this study is that the closer the source of water is to an abandoned mine site the more it is likely to be affected by AMD released from the site. Table 4.2 shows the results from 5 sites which were sampled during the course of the study.

Table 4.2 Results of tested water parameters from sources close to abandoned coal mines in Jackaroo Park

	Results					
Water parameter	Site 1	Site 2	Site 3	Site 4	Site 5	RWQO Limit
pH	3	2,94	2,49	2,44	2,49	N/A
EC	135,6	166,7	0,501	0,388	0,363	≤111 mS/m
Turbidity	864	430	18	6,6	5,75	≤10
Manganese	1794	1901	8461	6618	7218	≤1300ug/l
TDS	881,4	1083,6	3,257	2,522	2,36	N/A
Iron as Fe	35400	54600	17000	15000	15000	N/A
Nitrate	2,3	4,3	350	480	330	≤4mg/l
Sulphate	504	611	1974	2683	1893	500mg/l
Fluoride	1,19	0,96	0,75	1,38	1,11	3mg/l
Copper	1200	2910	8945	6480	5980	8ug/l
Chloride	2,6	1,2	4,1	1,1	0	N/A
Zinc	0,2	0,45	300	254	300	0,036mg/l

The results presented in Table 4.2 confirm the submissions made through interviews that abandoned coal mines have contributed to the pollution of water sources in Jackaroo Park. As shown in Table 4.2, all the sources sampled are acidic, with a pH value far below 7, the neutral point. Acid mine water is known as water that has a pH lower than 5.5 and is produced when sulphides in rock are exposed to and react with air and water. This occurs in both underground and surface mining. Although the South African Department of Water Affairs and Forestry has legislated that the minimum acceptable stream pH is 6.5, this may be too high for some sensitive catchments and current water quality is often lower than this target.

The assessed parameters, such as electrical conductivity, turbidity, nitrates, sulphate, copper, and zinc show that at some of the sites, they go beyond the Receiving Water Quality Objectives (RWQO) limits. This is an indication that the water is polluted, and the abandoned coal mines are playing a contributory role as the abandoned sites show high levels of the measured parameters.

Confirming the problem of water pollution, one examined literature source indicated that: “The risks these mines pose are far reaching. Obviously, the most worrying fact is that water

resources are being poisoned. This not only makes the water unsafe for human consumption but can also poison the land which settlements are built on, affecting the agriculture, livestock, and people for years". Sibeko (2021). This provides more evidence indicating the impact of abandoned coal mines in Jackaroo and the surrounding areas, calling for the need for immediate action to rescue the community from the menace of abandoned coal mines.

4.3.2 Soil degradation

Secondary data analysis and interview data reveal that soil degradation is one of the most common impacts of abandoned coal mines in Jackaroo Park. The disturbance of soil during mining activities can lead to soil erosion and compaction. Abandoned mine sites, as indicated in Figure 4.4, are also left with large piles of waste material known as tailings, which can contaminate surrounding soils with heavy metals and other pollutants. Contaminated soil has the propensity to affect plant growth and biodiversity, further exacerbating ecological degradation in the area.

One interviewee had the following to say:

> "*Soils in Jackaroo are now useless for any agricultural activity due to these abandoned mines and the ongoing illegal mining activities within the abandoned sites are exacerbating the situation*……...". (Official, 17/01/2024)

> *"The land is badly eroded in many places, and the vegetation hasn't recovered. The streams and rivers are polluted, which affects not just our drinking water but also the wildlife. We've lost a lot of the natural beauty and biodiversity that used to be here. It's heartbreaking to see how the environment has deteriorated over the years."* (Resident, 18/01/2024)

Soil degradation was noted to be associated with pollution from tailings. A local official confirmed this in an interview as follows:

> "*The old mine sites with tailings, where pollution is rampant, are the most degraded parts of Jackaroo. The soils can no longer be used for any other economic activity*". (Local official, 17/01/2024)

Local residents weighed-in on this impact on Jackaroo Park, with one interviewee indicating that:

> "*The soils in Jackaroo are no longer usable for any other activity because the old mining activities have created dumps which heavily pollute the soils. This has created a huge problem for us residents as we are exposed to the polluted and degraded soils which are now good for nothing, except posing a health threat*" (Resident, 18/01/2024)

Personal observations reveal significant soil degradation, rendering the land aesthetically unappealing and unsuitable for further economic activities. Figure 4.4 presents fieldwork photographs illustrating severe soil degradation, evident from the numerous visible scars on the surface.

Figure 4.4: Land scars and rugged surfaces due to abandoned coal mines in Jackaroo Park. Photo taken by author on 29 March 2024.

Rehabilitation of land is one important process during mine closure, and this ensures that the soils can be used for other productive purposes. However, in Jackaroo Park, interviewees indicated that due to abandonment of the mines, no remedial work has been done to restore the quality of the soils and this has further degraded the soils, leading to them being highly unproductive.

4.3.3 Air pollution

The secondary data from literature, supported by some interview data reveal that although direct emissions from abandoned mines may decrease once mining activities cease, the release

of particulate matter and airborne pollutants can persist due to wind erosion of exposed mine surfaces. This situation has been reported in abandoned mine sites in Jackaroo Park. In addition, underground coal fires, which are common in abandoned mines in Jackaroo have been reported as emitting gases such as carbon monoxide and sulphur dioxide, contributing to air pollution and respiratory health issues for nearby communities.

While coal mining itself is a significant source of greenhouse gas emissions, abandoned mines in Jackaroo continue to emit methane, a potent greenhouse gas, through ongoing coal seam degasification and underground coal fires. Methane emissions from abandoned mines contribute to climate change and global warming if left uncontrolled. One interviewee said:

> *"The existence of abandoned coal mines in our localities is a cause for concern given the nature of some of their impacts……they pollute the air, but the pollution is invisible and people are already suffering from respiratory ailments". (Local resident, 22/01/2024)*

The above assertion indicates that some stakeholders in Jackaroo Park are aware of methane and carbon emissions from abandoned coal mines and are privy to their deleterious impacts.

4.3.4 Land subsidence

Results indicate the existence of sink holes due to land-subsidence. Underground coal mining often leads to the formation of voids and subsidence of the land surface. Abandoned mine shafts and tunnels can collapse over time, causing sinkholes and land subsidence, which can damage infrastructure and disrupt ecosystems. Land subsidence can also alter surface water flow patterns, leading to changes in hydrology and further exacerbating erosion and sedimentation issues.

According to two interviewees and information from secondary data sources, Mpumalanga Province is widely acknowledged as a major coal mining hub in South Africa. It is characterized by extensive underground and opencast coal mining operations. The presence of abandoned coal mines has resulted in land subsidence and the formation of sinkholes, particularly in urban areas. For example, the eMalahleni area has witnessed numerous sinkholes, posing risks to infrastructure, roads, and residential areas. This phenomenon not only disrupts local ecosystems but also presents significant threats to human safety and property. Jackaroo Park has not been spared from these catastrophes. Figure 4.5 shows a sink hole and disturbed land surface due to past mining activities.

Figure 4.5 Sink hole and land disturbances resulting from past mining activities. Photo taken by author on 1 June 2024.

4.3.5 Loss of biodiversity

It emerged from the interviews that there are areas that have experienced habitat destruction and loss of biodiversity in Jackaroo Park on abandoned mine sites due to illegal mining activities that are happening in the park. The disturbance and destruction of habitats caused by coal mining activities can result in the loss of biodiversity in affected areas. In Jackaroo Park, abandoned mine sites were left barren and inhospitable to native flora and fauna, leading to declines in species populations and overall ecosystem health. Reclamation efforts to restore biodiversity in these areas can be challenging and costly and the government has not done much to rehabilitate the ecosystems.

4.3.6 Summary of environmental impacts of abandoned coal mines

A word cloud analysis based on interview data and key themes emerging from the analysed literature shows a wide range of environmental impacts of abandoned coal mines. Figure 4.6 shows the word cloud highlighting the major impacts emerging in this study.

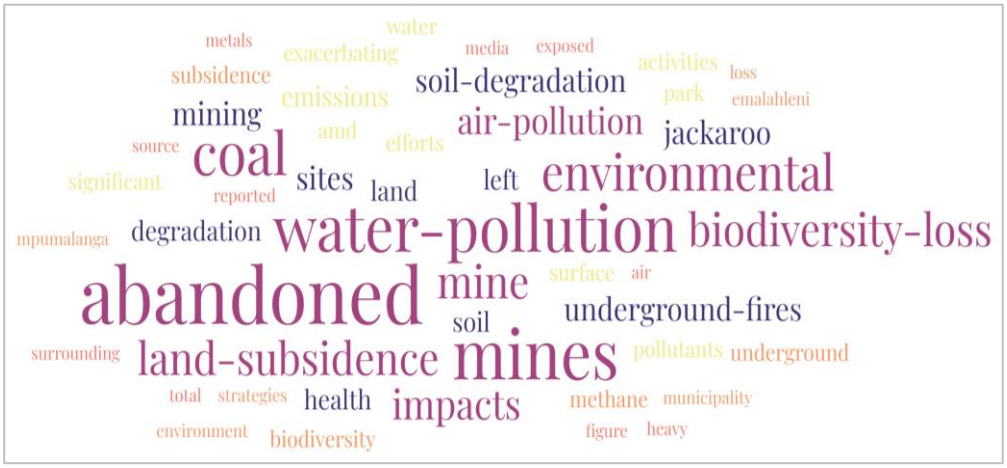

Figure 4.6: Environmental Impacts of abandoned coal mines in Jackaroo Park

As shown in Figure 4.6, the most visible terms are the ones that are most frequently mentioned from document analysis as well as in interviews. This shows the prominence of such terms and consequently the importance of the impacts. The terms water pollution, biodiversity loss, land subsidence, underground fires are respectively prominent, indicating that these are the most important environmental impacts associated with abandoned coal mines in Jackaroo Park.

Recommendations emerged from the analysis that addressing the environmental impacts of abandoned coal mines requires comprehensive strategies for mine reclamation, remediation, and ongoing monitoring. This includes efforts to mitigate water pollution through the treatment of AMD, stabilize mine structures to prevent land subsidence, rehabilitate disturbed landscapes, and implement measures to control methane emissions. Additionally, stakeholders must work together to ensure the long-term sustainability of affected ecosystems and minimize risks to human health and the environment.

4.4 Socio-economic impacts of abandoned coal mines in Jackaroo Park

The socio-economic impacts of abandoned coal mines in Jackaroo Park, eMalahleni represent a critical concern with far-reaching implications for both local communities and broader provincial development. Understanding the socio-economic impacts of abandoned coal mines is crucial, as they significantly affect not only the surrounding environment but also livelihoods, infrastructure, and socio-political dynamics. This section examines the various dimensions of these impacts in Jackaroo Park, highlighting the challenges faced by affected communities and suggesting strategies for sustainable mitigation and redevelopment.

It emerged in this study that several socio-economic impacts of abandoned coal mines are haunting Jackaroo Park, including health challenges, social dislocation, economic strain, socio-environmental challenges, and deaths. Figure 4.7 presents the socio-economic challenges found in this study and how they are linked with specific aspects of abandoned coal mines.

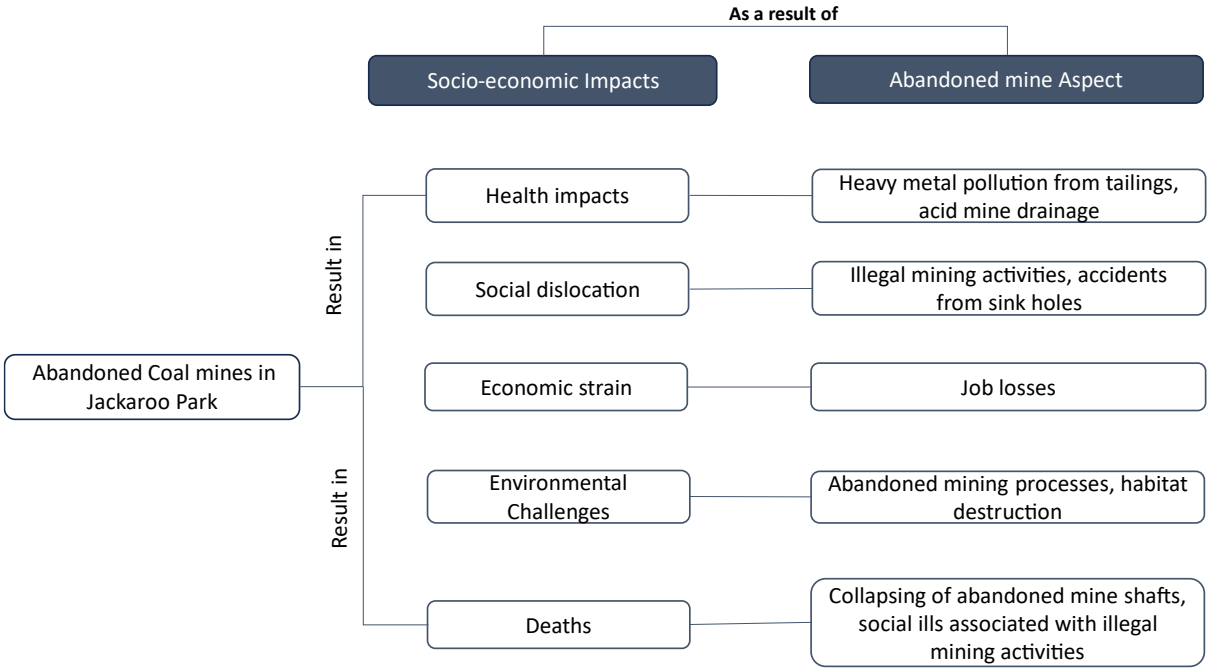

Figure 4.7 Socio-economic impacts of abandoned coal mines in Jackaroo Park, eMalahleni.

As illustrated in Figure 4.7, the socio-economic impacts of abandoned coal mines are intricately connected. The research instruments and data sources used in this study reveal that mine closures have far-reaching effects on the social and economic well-being of affected communities. The loss of jobs and resulting economic instability intensify social tensions, deepen inequalities, and weaken community cohesion. Additionally, the uncertainty and displacement associated with mine closures impose a significant psychological burden on residents, leading to mental health challenges and social fragmentation. The decline in social capital and community resilience further exacerbates the hardships faced by marginalized groups in these mining-affected areas. The subsequent section examines these impacts in greater detail.

4.4.1 Economic strain

Results indicate that the economic strain induced by abandoned coal mines on local communities in Jackaroo Park, eMalahleni represents a pressing issue with profound implications for the well-being and sustainability of these areas. Interviewees indicated that Jackaroo Park was once a bustling centre of industry and employment, but communities surrounding abandoned coal mines now grapple with the stark realities of economic decline and dislocation. The cessation of mining activities, whether due to exhaustion of resources or shifts in market dynamics, leaves behind a legacy of socio-economic challenges that profoundly impact the fabric of local life. Jackaroo Park comprises an intricate web of economic burdens borne by communities affected by the abandonment of coal mines. The is a nuanced interplay of factors such as unemployment, loss of revenue, and infrastructural decay in the park as one of the interviewees elaborated:

> "*It is sad to notice how the community has been dislocated and disenfranchised due to abandonment of mine sites by previous mine owners…all factors seem to be working together to downgrade the Park inhabitants, for example, pollution, infrastructure decay, loss of revenue and unemployment have become the norm". (Local Resident,18/01/2024)*

Document analysis indicate that abandoned coal mines left behind a legacy of infrastructure that is no longer maintained or utilized. This includes abandoned mine shafts, buildings, and roads, which pose safety hazards and limit future development opportunities in the park. The cost of rehabilitating and repurposing this infrastructure place an additional burden on already-strained local governments and communities.

4.4.2 Health impacts

It emerged from this study that the health impacts stemming from abandoned coal mines on local communities in Jackaroo Park stand as a grave concern, representing a silent yet pervasive threat to the well-being of residents. The communities were once vibrant during the period of active mines, but they now suffer from public health hazards left behind by defunct mines. The cessation of mining operations, often accompanied by inadequate rehabilitation efforts, has led to a host of health challenges ranging from respiratory ailments to water contamination and beyond. There is an increased prevalence of diseases associated with

contamination of air and water sources. Water parameter tests conducted by this study has established that the water sources are polluted, and this exposes the communities to diseases. Exposure to dust, particulate matter, and toxic pollutants released from abandoned mine sites are contributing to respiratory problems, cardiovascular diseases, and other health issues. Furthermore, the loss of healthcare services and support programs associated with mine closure have exacerbate health disparities in already vulnerable communities.

The health impacts of abandoned coal mines are clearly elucidated in the following interview extract:

> "*The presence of abandoned coal mines in eMalahleni in general, and Jackaroo in particular, in line with your question, poses a serious risk to public health, as evidenced by elevated rates of respiratory illnesses, waterborne diseases, and other health complications within affected communities*". (Local Official, 18/01/2024)

The above interview extract summarises the views of most of the respondents in this study and the literature surveyed, indicating that the communities in Jackaroo have experienced a plethora of health challenges associated with abandoned coal mines.

4.4.3 Safety impacts

The safety impacts of abandoned coal mines on local communities in Jackaroo Park represent a critical challenge. The abandoned shafts and structures pose imminent dangers to nearby populations. From the threat of collapse to the potential for toxic gas emissions, the hazards associated with abandoned coal mines loom large, jeopardizing the safety and well-being of individuals and communities. Document anaylsis indicated a variety of safety issues associated with abandoned coal mines in Jackaroo Park. The following extract was obtained from an interview published in a newspaper article (Sibeko, 2021); it puts into perspective the views of most of the interviewees as well as literature sources used in this study:

> "*There are also serious safety issues to consider. Some of the mines visited were not fenced off and there are no signs to warn the community of the danger they pose. Some of these abandoned mines have since filled up with rainwater, and children swim in them as they don't necessarily understand how unsafe it is. I have met with parents whose children drowned whilst swimming in these mines, deaths that were entirely preventable*". (Sibeko, 2021)

The above extract indicates the seriousness of safety concerns associated with abandoned coal mines in Jackaroo Park. During field work, It was observed that there were no fences to protect children from entering the abandoned mine sites, posing a serious safety threat to the communities in the park.

Land subsidence and the proliferation of illegal blasting in abandoned coal mines have also posed serious safety issues as housing and other infrastructures are weakened and cracking, posing a safety issue. Figure 4.8 shows cracking a cracking house and spillage of polluted water, posing health and safety threats in Jackaroo Park.

Figure 4.8 Polluted water spillages and cracking houses in Jackaroo Park. Photo taken by author on 1 June 2024

4.4.4 Environmental degradation

The interviewees in this study considered environmental degradation a social issue. They indicated that the environmental impacts of abandoned coal mines, such as water and air pollution, are indirectly affecting the socio-economic well-being of communities. Contaminated water sources are compromising access to clean drinking water and agricultural resources, while air pollution has resulted in the increase of the prevalence of respiratory illnesses and decrease the overall quality of life in the park.

4.4.5 Social dislocation

This study found that social dislocation impacts stemming from abandoned coal mines on local communities in Jackaroo Park represent a profound and often overlooked consequence of industrial decline. The communities in Jackaroo now bear the scars of economic abandonment, grappling with a myriad of social challenges that undermine the fabric of life.

From unemployment and poverty to social fragmentation and mental health issues, the repercussions of abandoned coal mines reverberate deeply within these neighbourhoods, exacerbating existing inequalities and straining social cohesion. Interview data revealed that the closure of coal mines disrupted social cohesion and stability within communities. Workers and their families were forced to migrate in search of employment opportunities elsewhere, leading to the breakup of social networks and the loss of community ties. This dislocation contributed to social isolation, mental health issues, and increased crime rates in Jackaroo.

It emerged from document analysis and interview data that addressing the socio-economic impacts of abandoned coal mines requires a coordinated effort involving government agencies, community organizations, and industry stakeholders. Strategies may include diversifying the local economy, providing alternative employment opportunities, investing in education and skills training programs, and implementing social support services to assist affected individuals and communities in transitioning to a post-coal economy. Additionally, efforts to remediate environmental damage and promote sustainable development practices can help mitigate the long-term impacts of coal mining on South African communities.

To summarise the nature of the impacts being experienced in Jackaroo Park from a local resident perspective, when asked to describe how the abandoned coal mines have affected their daily lives, a local resident said:

> "*The abandoned mines have drastically changed our lives here. The water from our taps is often dirty, and we have to boil it before using it. Many people in the community, including my own family, have developed health problems that we believe are linked to the contaminated water. It's hard to find work, and many of us rely on small-scale farming, but even the soil quality has deteriorated. It feels like we're constantly battling the consequences of the mining that took place here*."
> (local resident, 18/01/2024)

4.5 Strategies for addressing impacts of abandoned coal mines in Jackaroo Park

Developing effective strategies for addressing the environmental and socio-economic impacts of abandoned coal mines in Jackaroo Park is imperative for promoting sustainable development and safeguarding the well-being of affected communities. As relics of a bygone era of industrialization, abandoned coal mines present a myriad of challenges that extend far beyond their physical boundaries, impacting ecosystems, livelihoods, and social dynamics

alike. From land degradation and water pollution to economic decline and social dislocation, the legacy of coal mining casts a long shadow over the regions where these mines are located. Based on data collected from through systematic literature analysis, and interviews, this section examines the diverse array of strategies available for mitigating and remediating the environmental and socio-economic impacts of abandoned coal mines in Jackaroo. By exploring innovative approaches to rehabilitation, community empowerment, and policy intervention, it aims to provide insights into how stakeholders can work together to address the complex challenges posed by abandoned coal mines and pave the way towards a more sustainable and equitable future.

It emerged for the interviews and secondary data sources (e.g. Sibeko, 2021; Worlanyo and Jiangfeng, 2021) that several strategies can be implemented to address the challenges associated with the impacts of abandoned coal mines in Jackaroo Park. These strategies can be replicated in other areas experiencing similar impacts. The strategies include dedicated efforts towards mine site remediation and rehabilitation, community engagement and empowerment, community education and awareness, public-private partnerships dedicated to addressing and preventing impacts of abandoned coal mines, environmental monitoring and regulation and alternative economic development, among others as shown in Figure 4.9.

Figure 4.9 Proposed strategies for addressing impacts of abandoned coal mines in Jackaroo Park.

As shown in Figure 4.9, there are six major recommendations emerging from this study. The major highlights from the interviews were that these strategies should be implemented in an integrated manner to address any loopholes in the implementation framework.

The following interview extract reveals some suggested strategies by local residents:

> "*We need help to clean up the pollution and restore the land. I hope the government and other organizations will step in with projects to rehabilitate the environment and provide clean water. Economic support is also crucial. Things like job training programs and new business opportunities would make a huge difference. Most of all, I hope for a healthier and more prosperous future for our community, where we don't have to live in fear of the lingering effects of these abandoned mines.*" (Resident, 18/01/2024)

As indicated in the interview extract, remediation and rehabilitation work are key in resuscitating hopes for the residents of Jackaroo Park. Capacity building is also coming out as an important strategy for recovery. Figure 4.9 shows the key strategies suggested by key informants as well as the recommendations from the reviewed literature.

4.5.1 Mine site remediation and rehabilitation

This study found that mine site remediation and rehabilitation emerge as critical strategies for mitigating the environmental and socio-economic impacts caused by abandoned coal mines in Jackaroo Park and South Africa in general. Interviewees indicated that with the cessation of mining activities, these sites often remain scarred landscapes, characterized by ecological degradation, safety hazards, and economic dislocation. However, through systematic remediation and rehabilitation efforts, it is possible to reclaim these abandoned mine sites, restoring their ecological integrity, mitigating risks to human health and safety, and revitalizing local economies. There is a call to use best practices, innovative technologies, and policy frameworks, to foster environmental sustainability, promote socio-economic resilience, and pave the way for the transformation of former mining landscapes into thriving and vibrant ecosystems. The activities that may be implemented include stabilizing mine structures, re-vegetating disturbed areas, and treating acid mine drainage. This recommendation was clearly echoed by one of the interviewees who said:

> *"We need coordinated efforts in utilizing innovative technologies and best practices to address specific environmental challenges at each site, such as passive treatment systems for acid mine drainage or bio-remediation techniques for contaminated soils……. site remediation and rehabilitation is not even a choice but a must*". (Official, 22/01/2024)

The above extract shows that all other strategies that might be implemented to address the impacts of abandoned coal mines are best implemented as complimentary to mine remediation and rehabilitation.

4.5.2 Community engagement and empowerment

Most interviewees opined that community engagement and empowerment stand as essential pillars in addressing the multifaceted impacts of abandoned coal mines in Jackaroo Park. As repositories of local knowledge, resilience, and agency, communities affected by the legacy of coal mining play a pivotal role in shaping the trajectory of remediation and rehabilitation efforts. By fostering meaningful engagement and empowering local stakeholders, it is possible to harness the collective wisdom and resources necessary for addressing environmental degradation, socio-economic dislocation, and public health challenges associated with

abandoned coal mines. The following interview extract provides an enhanced picture of this recommendation:

> *"The transformative potential of community engagement and empowerment as a strategy for addressing the impacts of abandoned coal mines should not be undermined……. participatory approaches, and capacity-building initiatives underscore the importance of collaborative decision-making, inclusive governance, and bottom-up solutions in fostering sustainable development and social justice in affected communities*". (Official; 22/01/2024)

From the above assertion and the general recommendations emerging from literature and interviews in this study, involving local communities in decision-making processes related to mine site remediation and rehabilitation ensures their needs and concerns are addressed. It also provides opportunities for skills training, capacity building, and employment in remediation and restoration projects to enhance local economic development and empower communities affected by mine closures.

4.5.3 Alternative economic development

It emerged from interviews that alternative economic development is one of the key strategies that can be implemented to address the impacts of abandoned coal mines in Jackaroo Park. There is a general perception that, amidst the lingering impacts of abandoned coal mines in Jackaroo Park, alternative economic development emerges as a compelling strategy for fostering resilience, revitalization, and sustainability in affected communities. As the coal mining industry wanes, leaving behind a legacy of environmental degradation, economic decline, and social dislocation, the imperative to diversify local economies and create new pathways to prosperity becomes increasingly apparent. Alternative economic development offers a promising approach to address the multifaceted impacts of abandoned coal mines by fostering innovation, entrepreneurship, and inclusive growth.

An extract from document analysis indicated that there is potential for alternative economic development as a strategy for addressing the impacts of abandoned coal mines and this can be achieved by examining initiatives such as renewable energy projects, eco-tourism ventures, and agro-industrial enterprises. These can pave way for unlocking new opportunities, enhancing resilience, and promoting sustainable development in formerly mining-dependent areas. The government and other capable stakeholders should provide financial incentives,

grants, or tax breaks to attract businesses and stimulate economic growth in areas impacted by mine closures.

4.5.4 Environmental monitoring and regulation

This study established that environmental monitoring and regulation stand as indispensable tools in the concerted effort to address the pervasive impacts of abandoned coal mines in Jackaroo Park. The key informants indicated that, effective monitoring and stringent regulation are paramount in mitigating risks, safeguarding natural resources, and facilitating the transition towards sustainable land use practices. There is a need to establish rigorous environmental monitoring programs to track the long-term impacts of abandoned mine sites and ensure compliance with environmental regulations. On the other hand, there is a need to strengthen enforcement of existing environmental laws and regulations to hold responsible parties accountable for the remediation of abandoned mine sites and prevent future environmental degradation.

4.5.5 Public-private partnerships

In the wake of abandoned coal mines in Jackaroo Park, interviewees saw the pressing need for innovative solutions to address the far-reaching impacts on communities, economies, and the environment. Public-private partnerships (PPPs) emerge as a promising strategy for mobilizing resources, expertise, and collaboration to tackle the complex challenges posed by these defunct mining sites. By leveraging the strengths of both public and private sectors, PPPs offer a pathway towards sustainable remediation, rehabilitation, and revitalization of abandoned coal mines. The following interview extract summarises the general views amongst the key informants:

> "*Fostering collaboration between government agencies, private sector companies, non-profit organizations, and local communities to pool resources and expertise for mine site remediation and economic revitalization efforts is the sine quo non for addressing the impacts of abandoned coal mine…….there is a need to encourage private sector investment in abandoned mine reclamation projects through public-private partnerships, concession agreements, or tax incentives".(Official: 22/01/2024)*

4.5.6 Education and awareness

It emerged from thematic analysis of the available literature and interview data that education and awareness stand as indispensable pillars in addressing the multifaceted impacts of abandoned coal mines in Jackaroo Park. As communities grapple with the enduring legacy of environmental degradation, economic decline, and social dislocation, the need for informed action and collective engagement becomes increasingly evident. Interviewees highlighted that education serves as a catalyst for understanding the complex interplay of factors shaping the impacts of abandoned coal mines, while awareness-raising efforts empower individuals and communities to advocate for sustainable solutions and participate in decision-making processes.

There is a call for the provincial government to raise awareness among stakeholders, including local communities, government officials, and industry representatives, about the environmental and socio-economic impacts of abandoned coal mines. Efforts should also include providing education and training programs on sustainable land management practices, environmental stewardship, and alternative livelihood opportunities to promote long-term resilience and sustainability in affected communities. By implementing these strategies in a coordinated and collaborative manner, it is possible to address the environmental and socio-economic impacts of abandoned coal mines and pave the way for sustainable development in affected areas.

CHAPTER 5: DISCUSSION OF RESULTS

In the Northwest Province and in KwaZulu-Natal, researchers have found that poverty is among the reasons for risky scavenging from mine dumps and slimes dams. Poverty may motivate scavengers to take risks because currently, there are no economic incentives to promote more risk-averse behaviour (Mhlongo and Akintola, 2021). The mine dumps are part of the abandoned mines that comprise mainly derelict and degraded lands (Worlanyo and Jiangfeng, 2021). Several studies found that people were willing to enter such dangerous and degraded areas because of the economic opportunities offered by informal coal mining, despite the risks involved (Paltasingh and Satapathy, 2021; Achina-Obeng and Aram, 2022). This situation indicated that poor people were at risk of being both recipients and victims of pollution and other environmental and social problems associated with abandoned coal mines.

5.1 Environmental impacts of abandoned coal mines

The environmental impacts identified in the study include water pollution, soil degradation, air pollution, land subsidence, loss of biodiversity, underground fire occurrences, and loss of aesthetic land. The results of water parameter testing near abandoned coal mines in Jackaroo Park confirmed the pollution of water sources, with acidic pH levels and other parameters exceeding the Receiving Water Quality Objectives (RWQO) limits. Additionally, soil degradation was identified as a common impact of abandoned coal mines, leading to soil erosion, compaction, and contamination with heavy metals and other pollutants. These findings are consistent with broader literature e.g., (Ambani and Annegarn 2015; McCarthy 2011; Ochieng et al. 2010) which has indicated serious challenges associated with abandoned coal mining in other regions and countries.

5.1.1 Water pollution

Water pollution, through Acid Mine Drainage emerged as one of the most serious environmental problems affecting various other facets of life. This is in line with findings by Lee et al., (2012) and Lourenco & Curtis, (2021) which indicated that abandoned coal mines have an influence on water resources and downstream communities in addition to the mine site. Aquatic habitats have suffered greatly as a result, and local people' sources of drinking water have become contaminated. Because of the high concentration of hydrogen ions, which limits root uptake of water and mineral salts and respiration, most plants are unable to withstand low pH water.

Consistent with the findings of this study, Liu et al. (2021) determined that the coal mining industry affects regional water quality. Ma et al. (2021) further emphasized that the discharge of substantial volumes of coalmine water into the environment without adequate treatment can degrade water quality due to the accumulation of dissolved ions. The illegal mining activities occurring in the abandoned coal mines in Jackaroo Park result in the release of significant amounts of wastewater into the environment. Adjovu et al. (2023) noted that the accumulation of dissolved ions in effluent contributes to the total dissolved solids (TDS) concentration, which, when introduced into receiving water bodies, can impact the aquatic ecosystem. Elevated TDS levels can alter the ionic strength of surface water, potentially harming aquatic life.

Additionally, in accordance with the results of this study, Wang et al. (2021) asserted that AMD poses the most significant environmental threat associated with abandoned coal mines. The effects of AMD involve the release of large quantities of dissolved ions, which can detrimentally affect receiving water bodies through various mechanisms. These negative impacts include increased dissolved and suspended loads and toxicity, leading to the degradation of aquatic ecosystems (Kalita et al., 2022). Some studies in Gauteng confirm the findings of this study that the water in abandoned coal mines is often acidic and highly contaminated with heavy metals (Rezaie & Anderson, 2020; Wolkersdorfer and Mugova, 2022). The volume of water in some of these mine voids is so large that the quality and volume of surface water and groundwater in the surrounding area is impacted. The consequences of this impact are that the receiving rivers downstream also experience pollution with associated negative ecological effects.

Masood et al., (2020) reiterate that pollution for abandoned coal mines is associated with ecological effects that are more serious than usually reported because many such areas are informal human settlements using the river for drinking water, washing, and other activities. Animals are also negatively affected if they drink from these rivers. The risk of contamination of the food chain for humans has also been reported in some of these areas.

5.1.2 Air pollution

The reviewed literature, together with some data from interviews, shows that even though direct emissions from closed mines may go down after mining operations end, exposed mine surfaces may continue to erode by wind, which can result in the release of particulate matter and other airborne pollutants. Reports of this condition have come from Jackaroo Park's

abandoned mine sites. Furthermore, it has been stated that underground coal fires, which are frequent in Jackaroo's abandoned mines, release pollutants like sulfur dioxide and carbon monoxide into the atmosphere, endangering the respiratory systems of the populations nearby.

Consistent with the findings of this study (Nádudvari et al. 2021) indicate that particles resulting from the burning of coal, legally or illegally, not only contain some heavy metals but can also be coated with various organic compounds that can be carcinogenic, such as polycyclic aromatic hydrocarbons, dibenzopyrenes, or benzofluoranthenes, which are chemically very dangerous. Guo et al., (2021) weigh -in claiming that the organic substances adhering to the carbon particles that originate from coal combustion include toxic heavy metals susceptible to carcinogenic effects. Thus, the air in existing and abandoned mines is heavily polluted and exposes the adjacent communities to chronic toxicity.

5.1.3 Soil degradation

The findings on soil degradation in Jackaroo Park align closely with existing literature on the environmental impacts of abandoned coal mines. Studies have consistently shown that mining activities disturb soil structure, leading to compaction, erosion, and contamination by heavy metals and other pollutants from mine tailings (Finkelman et al., 2021; Mhlongo & Akintola, 2021). As highlighted in this study, the presence of tailings and the lack of post-closure rehabilitation contribute to significant soil degradation, rendering the land unsuitable for agriculture and other economic activities. This is consistent with observations by Ambani and Annegarn (2015), who noted that abandoned mines exacerbate soil erosion and reduce soil fertility, impacting local ecosystems and livelihoods.

The interview data corroborate findings from other studies that emphasize the cascading effects of soil degradation on biodiversity and community well-being. For example, Paltasingh and Satapathy (2021) observed that soil contamination from mining activities negatively affects plant growth and ecosystem functionality, echoing sentiments from local residents and officials in Jackaroo Park. The inability to use degraded soils for agriculture and other productive activities is a recurring theme in mining literature, with scholars such as Burton et al. (2018) highlighting how this impacts food security and economic resilience in mining-affected regions.

The psychological and socio-economic toll noted in the interviews further reflects broader trends documented in the literature. Communities dependent on agriculture or other land-based livelihoods suffer economic losses and social dislocation when soils are rendered unproductive (Marais et al., 2022). Additionally, the lack of rehabilitation, as emphasized by respondents, underscores gaps in governance and enforcement of environmental regulations, a challenge noted by Sovacool (2021) in similar contexts.

Personal observations of the physical landscape in Jackaroo Park, with visible scars and unappealing aesthetics, are consistent with descriptions in studies like McCarthy (2011), which report that abandoned mine sites often leave behind barren, degraded land. The lack of vegetation recovery, as highlighted by residents, aligns with findings from studies that stress the long-term ecological consequences of mining activities when no remedial actions are undertaken (Cornelissen et al., 2019).

In conclusion, the findings from Jackaroo Park are consistent with global and local studies on the impacts of abandoned coal mines on soil degradation. The situation highlights the critical need for comprehensive mine closure and rehabilitation programs to restore soil health and promote sustainable land use. Without such interventions, the long-term socio-economic and ecological viability of affected areas remains at risk.

5.2 Socio-economic challenges

The results of this study have shown socio-economic challenges associated with abandoned coal mines. The unplanned closure of mines and the resulting economic challenges in Jackaroo have directly and indirectly led to social disruption, increased crime rates, substance abuse, and other social issues. The loss of employment opportunities has contributed to the widespread of poverty, deterioration of standards of living, and outward migration as individuals seek better opportunities. Additionally, the abandonment of mines has led to a decrease in purchasing power and foreign investment, further affecting the local economy. These findings resonate with earlier studies in different geographical settings by (Marais & de Lange, 2021; Worlanyo and Jiangfeng, 2021) which show that abandoned coal mines have a plethora of social impacts which include economic, employment, livelihoods, health and demographic effects among others.

Considerable social stress is experienced in communities that depended on mining operations or related industries for employment. The loss of these jobs leads to increased

poverty within these communities (Shackel, 2023). When a community cannot maintain its quality of life, encompassing both material and social well-being, its members may suffer from depression, social alienation, or turn to alcohol and substance abuse (Marais et al., 2022). Numerous studies have shown that long-term poverty and associated mental health issues are closely linked to chronic unemployment as a significant source of social stress. Unemployed individuals face not only a loss of income but also diminished self-esteem, identity, and status, along with declining physical and mental health, and strained family relationships (Githiria and Onifade, 2020). Moreover, those living in poverty have limited access to social services that could help promote and maintain their physical and mental health and support their families during crises.

This study indicates that the social impacts of mine closures are very significant at local, levels. Some studies confirm that the impacts are also significant at regional and national levels (Syahrir et al., 2021). Consistent with the results of this study, Marais & de Lange, (2021) postulated that the negative social impacts at the community level include deterioration in public health due to an increase in waterborne illnesses, an increase in unemployment and poverty as the source of livelihood is lost, the breakdown in social infrastructure as the means for maintaining it is diminished, and the loss of cultural heritage or identity and sense of place as the community disintegrates. These social impacts typically are all interconnected, resulting in a considerable decline in the quality of life at the local community level (Syahrir et al., 2021). A perceived or real injustice in benefiting from mineral resource wealth while bearing the social and environmental externalities also often results in social unrest, conflict, or increased crime in local communities (Marais and de Lange, 2021).

Surface fires release a cocktail of toxins into the air. The most dangerous of these toxins is carbon monoxide, which is known as the "silent killer" since it is an odourless, colourless gas that acts very quickly. If exposed to low concentrations of CO for a long period, the gas causes headaches, dizziness, weakness, nausea, mental confusion, and death (Nnaji et al., 2023). Individuals who scavenge coal are risking their lives, and statistically, at least one person per week loses their life to the coal piles (Stretesky and Grimmer, 2020). Many more individuals are injured, and their lives are scarred as a result of these injuries (Marais & de Lange, 2021). The impact on the affected families is one of loss, pain, and suffering (Lahiri-Dutt, 2023; Noy, 2020). They are the ones who mourn the loss of a family member or must

care for an injured family member, as well as suffer the loss of income if the deceased was the breadwinner. The mining industry prospers, but at a great cost to these communities.

A large number of informal settlements have emerged in and around coal stockpiles, which are located predominantly on the mines' private properties but very close to the mine's perimeter (Ugo, 2021). Accidents and fatalities occur frequently from individuals attempting to scavenge coal, which is sold to other community members or used for heating and cooking. These activities are highly illegal, but with the high rate of poverty in the area, the community turns a blind eye to enforcement from the government, the mine, or the police (Schwartz et al., 2021; Shackel, 2023). The unique characteristic of an operating underground coal mine necessitates a high level of security around the mine property to prevent unauthorized access. In an underground mine, a fire can smoulder for up to three years before being detected and then can break out into a flaming fire.

Various strategies have been proposed to address the impacts of abandoned coal mines in Jackaroo, with broader implications for managing abandoned mines at the provincial and national levels. The study highlighted the importance of public-private partnerships (PPPs) as a promising approach for mitigating the impacts of abandoned coal mines. By leveraging the strengths of both public and private sectors, PPPs can facilitate the sustainable remediation, rehabilitation, and revitalization of these sites. Additionally, education and awareness were identified as crucial components in addressing the complex impacts of abandoned coal mines. Raising awareness among stakeholders and implementing education and training programs on sustainable land management practices and alternative livelihood opportunities are recommended to foster long-term resilience and sustainability in affected communities.

The study also highlights the importance of proactive and sustainable mine closure practices, as well as ongoing monitoring and management of legacy mine sites to minimize their environmental and socio-economic impacts. The findings of the study provide important policy recommendations that may support the implementation of principles that promote sound environmental management and protection of communities from the biophysical consequences associated with abandoned coal mines.

Furthermore, the study contributes to the existing global literature on abandoned mines and their impacts on environmental and socio-economic aspects of surrounding communities.

This provides an opportunity for the academic community to do a comparative analysis with other communities facing similar challenges. The findings and recommendations of the study are also useful for Environmental Non-Governmental Organizations, Government departments, and Community-based associations as they implement strategies to bring solutions to the communities living adjacent to abandoned coal mines.

In summary, the study's findings underscore the urgent need for proactive and sustainable mine closure practices, ongoing monitoring, and management of legacy mine sites to minimize their environmental and socio-economic impacts. The results align with existing literature on the environmental and socio-economic consequences of abandoned coal mines, emphasizing the importance of addressing these challenges through collaborative and informed action.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

The results of this study highlight the environmental and socio-economic impacts of abandoned coal mines in Jackaroo Park, eMalahleni Municipality, Mpumalanga Province, South Africa. The study utilized the mixed methods research design, which facilitated a nuanced understanding of the environmental and socioeconomic ramifications of abandoned coal mines. The data collection methods included document analysis, key informant interviews, and direct observations, which provided comprehensive insights into the impacts of abandoned mines.

This study comprised three specific objectives as follows:

To examine the environmental impacts associated with abandoned coal mines in Jackaroo Park, eMalahleni Municipality, Mpumalanga Province in South Africa.

To examine the socio-economic consequences of the abandoned coal mines on adjacent communities in Jackaroo Park eMalahleni Municipality, Mpumalanga Province in South Africa.

To make recommendations on appropriate action for addressing the local environmental and socio-economic impacts of abandoned coal mines in Jackaroo Park, eMalahleni Municipality, Mpumalanga Province in South Africa.

By examining the intricate nexus between industrial heritage, community dynamics, and environmental stewardship, the study sheds light on the complexities of post-mining landscapes and explores pathways towards mitigation and regeneration. The examination of socio-economic consequences of abandoned coal mines holds significant importance in addressing pressing societal concerns. By shedding light on the myriad challenges faced by communities impacted by these abandoned mines, the study serves as a catalyst for action among various stakeholders.

6.1 Environmental impacts of abandoned coal mines

Drawing on data from 15 key informant interviews, personal observations, and water quality testing, the study reveals a complex and pressing situation. The findings highlight the enduring impacts of industrial exploitation, which continue to shape both the lives of residents and the landscape they depend on.

The results of this study reveal that the presence of abandoned mines in Jackaroo Park is attributable to operational disruptions caused by financial insolvency, resource depletion, and inadequate closure strategies. These mines have been left neglected, resulting in significant environmental risks. Within the jurisdiction of Jackaroo Park, a historical trend of abandoned mine sites is evident, with approximately four sites where infrastructure was identified within its boundaries. The lack of rehabilitation efforts on these abandoned mines presents a considerable barrier to the achievement of SDGs, given their substantial contribution to environmental degradation. These derelict mine sites inflict various forms of harm on the natural environment.

Through interviews and a review of documents, several environmental impacts of abandoned coal mines in Jackaroo Park have been identified. These impacts encompass water pollution, soil degradation, air pollution, land subsidence, loss of biodiversity, occurrences of underground fires, and degradation of the landscape's aesthetic value.

The findings identify water pollution as a primary environmental issue linked to abandoned coal mines. It emerged that these mines generate AMD, a phenomenon wherein exposed sulphide minerals react with air and water, leading to the release of acidic runoff. This acidic water has the potential to extract heavy metals and other contaminants from the adjacent rock formations, subsequently contaminating surface and groundwater reservoirs. Within Jackaroo Park, instances of AMD have been documented to exert detrimental effects on aquatic ecosystems and pose hazards to human health. Reported incidents of road accidents along R555 have been attributed to the presence of AMD originating from the abandoned coal mines.

The results further indicate that soil degradation ranks among the predominant consequences of abandoned coal mines in Jackaroo Park. The disruption of soil integrity during mining operations often results in soil erosion and compaction. Moreover, the presence of extensive waste material, referred to as tailings, within abandoned mine sites poses a significant risk of soil contamination with heavy metals and other pollutants. Such contamination has the potential to impede plant growth and disrupt biodiversity, thereby exacerbating ecological degradation within the region.

It emerged from this study that although direct emissions from abandoned mines may decrease following the cessation of mining activities, the release of particulate matter and airborne pollutants can persist due to wind erosion of exposed mine surfaces. This scenario has been documented in abandoned mine sites within Jackaroo Park. Furthermore, underground coal

fires, prevalent in abandoned mines in Jackaroo, have been identified as sources of emissions such as carbon monoxide and sulphur dioxide, thereby exacerbating air pollution and respiratory health concerns for nearby communities. Moreover, while coal mining represents a notable source of greenhouse gas emissions, abandoned mines in Jackaroo continue to emit methane, a potent greenhouse gas, through ongoing coal seam degasification processes and underground coal fires. The uncontrolled release of methane emissions from abandoned mines contributes significantly to climate change and global warming, underscoring the urgency of implementing mitigation measures to address these environmental concerns.

The findings reveal the presence of sinkholes resulting from land subsidence—a common consequence of underground coal mining. The process of underground coal extraction frequently creates voids and leads to the gradual sinking of the land surface. Over time, abandoned mine shafts and tunnels may collapse, precipitating the formation of sinkholes and land subsidence, thereby posing risks to infrastructure and disrupting local ecosystems. Additionally, land subsidence can induce alterations in surface water flow patterns, thereby impacting hydrological systems and exacerbating issues related to erosion and sedimentation.

This study revealed impacts related to habitat destruction and loss of biodiversity within Jackaroo Park attributed to illegal mining activities occurring in the area. The disruption and degradation of habitats stemming from coal mining operations often precipitate declines in biodiversity within affected regions. In Jackaroo Park, abandoned mine sites have been left devoid of vegetation and unsuitable for indigenous wildlife, resulting in diminished species populations and compromised ecosystem integrity. Reclamation endeavours aimed at restoring biodiversity in these areas present significant challenges and financial burdens, exacerbated by a perceived lack of government intervention in ecosystem rehabilitation efforts.

Overall, it is the conclusion of this study that abandoned coal mines have been the driving force behind a plethora of environmental problems observed in Jackaroo Park.

6.2 Socio-economic impacts of abandoned coal mines

From a social perspective, the results indicate that the impacts of abandoned coal mines extend far beyond the economic realm, permeating through the social fabric of communities. The loss of livelihoods, health concerns stemming from pollution, and the erosion of traditional ways of life underscore the profound human toll of extractive industries. Addressing these challenges necessitates a holistic approach, one that prioritizes community empowerment, socio-economic diversification, and the preservation of cultural heritage.

The study highlights the health impacts resulting from abandoned coal mines on local communities within Jackaroo Park, presenting a significant threat to residents' well-being. Formerly vibrant communities, once sustained by active mining operations, now grapple with a myriad of public health hazards left in the wake of defunct mines. The cessation of mining activities, often coupled with inadequate rehabilitation measures, has precipitated a spectrum of health challenges encompassing respiratory ailments, water contamination, and beyond.

An escalation in the prevalence of diseases linked to air and water pollution has been observed, with water quality assessments conducted as part of this study corroborating the presence of pollution in local water sources, thereby heightening the risk of disease transmission within communities. Exposure to airborne pollutants, including dust, particulate matter, and toxic emissions emanating from abandoned mine sites, has been identified as a significant contributor to respiratory disorders, cardiovascular ailments, and various other health afflictions among residents.

Moreover, the discontinuation of healthcare services and support programs following mine closures has further exacerbated health disparities within already vulnerable communities, compounding the challenges faced by residents in accessing essential medical care and resources. Thus, the study underscores the urgent need for concerted efforts to address the health implications of abandoned coal mines in Jackaroo Park and safeguard the well-being of affected communities.

The study's conclusion highlights significant safety concerns linked to abandoned coal mines within Jackaroo Park. Notably, the absence of protective barriers such as fences around observed abandoned mine sites poses a substantial safety risk, particularly to children within the surrounding communities. This lack of physical deterrents increases the likelihood of

accidental entry into hazardous areas, thereby heightening the potential for injuries and other safety hazards among park residents.

More so, the results indicate that the closure of coal mines precipitated disruptions in social cohesion and stability within communities. Displaced workers and their families were compelled to seek alternative employment opportunities elsewhere, resulting in the fracturing of social networks and the erosion of community ties. This dislocation contributed to heightened levels of social isolation, exacerbated mental health issues, and correlated with an increase in crime rates within Jackaroo Park.

6.3 Actions for addressing impacts of abandoned coal mines.

This study also endeavoured to make recommendations on appropriate action for addressing the local environmental and socio-economic impacts of abandoned coal mines in Jackaroo Park. The results have indicated that the proposed strategies encompass a multifaceted approach aimed at mitigating the adverse impacts of abandoned coal mines in Jackaroo Park. Key components of these strategies include:

- Mine site remediation and rehabilitation: Implementing targeted initiatives to remediate and rehabilitate abandoned mine sites, restoring ecological integrity and minimizing environmental hazards.
- Community engagement and empowerment: Fostering active participation and empowerment of local communities in decision-making processes related to mine site remediation and addressing social challenges arising from industrial decline.
- Community education and awareness: Promoting community education and awareness campaigns to enhance understanding of the environmental and socio-economic consequences of abandoned coal mines, fostering a sense of collective responsibility and advocacy.
- Public-private partnerships: Facilitating collaborative partnerships between government agencies, private enterprises, and community stakeholders to mobilize resources and expertise towards addressing and preventing the impacts of abandoned coal mines.
- Environmental monitoring and regulation: Strengthening environmental monitoring efforts and regulatory frameworks to ensure compliance with environmental standards and mitigate ongoing risks posed by abandoned mine sites.

- Alternative economic development: Supporting the diversification of local economies through the promotion of sustainable alternative industries and job creation initiatives, reducing dependency on coal mining and fostering long-term economic resilience.

6.4 Study recommendations

In view of the results emerging from this study, several recommendations are proposed in order to improve the situation in Jackaroo Park. The recommendations can be generalised and applied to other sites across the world to address environmental and socio-economic problems emerging from abandoned coal mines. The major recommendation is that the policy makers, local communities, non-governmental organisations, private companies and other coal mining entities engage in a long-term intervention programme of resource mobilisation, planning and development of strategies to address the socio-economic and environmental plight of local communities.

A participatory approach will ensure that the affected people are part of the solution to the existential problems. The strategies include dedicated efforts towards mine site remediation and rehabilitation, community engagement and empowerment, community education and awareness, public-private partnerships dedicated to addressing and preventing impacts of abandoned coal mines, environmental monitoring and regulation and alternative economic development, among others.

The need to improve mine closure strategies cannot be overemphasized. To improve South Africa's National Mine Closure Strategy in the context of the impacts caused by abandoned coal mines, the following recommendations are proposed:

- Strengthen Enforcement of Rehabilitation Obligations: Ensure mining companies comply with existing regulations under the Minerals and Petroleum Resources Development Act (MPRDA) and National Environmental Management Act (NEMA) by increasing monitoring, audits, and penalties for non-compliance.
- Establish a Dedicated Mine Rehabilitation Fund: Create a centralized fund, financed by mining companies and government contributions, to support the rehabilitation of abandoned mines, particularly where original operators can no longer be held accountable.
- Adopt Community-Centric Closure Plans: Involve local communities in the planning and implementation of mine closure and rehabilitation to address socio-economic

impacts, such as job loss and livelihood disruptions, and to ensure sustainable land use post-mining.

- Integrate Ecological Restoration Practices: Focus on restoring soil health, biodiversity, and water quality in affected areas, leveraging technologies such as bioremediation and phytoremediation.
- Promote Economic Diversification: Develop programs to repurpose abandoned mines for alternative uses, such as renewable energy projects, tourism, or agriculture, to create long-term economic opportunities for local communities.
- Enhance Data Collection and Transparency: Establish a national database of abandoned mines, including their environmental and socio-economic impacts, to guide policy decisions and prioritize interventions effectively.

If the National Mine Closure Strategy addresses these areas, there will be a more robust and sustainable framework for mitigating the impacts of abandoned coal mines in South Africa.

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Appendix 1: Interview Guide

Question 1 1.Please tell me who you are and your daily interactions with Jackaroo Park?
Answer 1
Question 2 2. Do you experience or are you familiar with environmental problems in Jackaroo Park? Probe: What are these? Are the mines a problem? Which ones? How are they a problem? Probe for concerns related to dust, smoke, water, dumping, others
Answer 2
Question 3 3. Do you remember any negative incident related to local mines? where and when? Kindly explain what happened. **Did you report this? To whom and what was done?**
Answer 3
Question 4 4. Do you experience any social issues or concerns related to the mines? Please tell me about these. Probe: concerns around crime, health impacts, economic consequences. Are these fears or experiences?
Answer 4
Question 5 5.How would you want the current challenges associated with local mines be addressed? Probe: closure, rehabilitation, reopening and mining, no need to address these issues, other ideas?
Answer 5
Question 6 6. Who do you think should be responsible for this and why? Probe: local government, national government (DMRE, Environmental Affairs), previous mine owners, local community members, others?
Answer 6
Question 7 7. If there were no mines do you think life was going to be any different? Please explain.
Answer 7

Appendix 2: Certificate of competence in research ethics

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

SCHOOL OF ANIMAL, PLANT AND ENVIRONMENTAL SCIENCES ETHICS COMMITTEE
CONSTITUTED UNDER THE UNIVERSITY HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: HA2401**
PROJECT TITLE	The social and environmental consequences of abandoned coal mines in Jackaroo Park, eMalahleni Municipality, Mpumalanga Province in South Africa.
INVESTIGATOR	Johanna Phetla
SCHOOL/DEPARTMENT OF INVESTIGATOR	School of Animal, Plant and Environmental Sciences
DATE CONSIDERED	30 January 2024
DECISION OF THE COMMITTEE	Approved unconditionally
RISK LEVEL	MINIMAL RISK
EXPIRY DATE	Date of submission of the Research Report

ISSUE DATE OF CERTIFICATE 30 January 2024 **CHAIRPERSON** _____
(Dr Justice Muvengwi)

cc: Supervisor: Dr. Ingrid Watson

DECLARATION OF INVESTIGATOR

To be completed in duplicate and ONE COPY returned to the Chairperson of the School/Department ethics committee.

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 be contemplated from the research procedure as approved, I/we undertake to submit an amendment of the protocol to the Committee.

_____ 31/01/2024

Signature **Date**