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Title: Acid Mine Drainage treatment in South Africa: towards a harmonised policy framework

RESEARCH REPORT

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DECLARATION

I, Zanozuko Mbane, declare that this research report is my unaided work. This thesis is submitted in partial fulfilment of the requirements for the Degree of Master of Public Health at the University of the Witwatersrand, Johannesburg, South Africa. It has not been submitted before for any degree or examination at any other University.

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Signature

_____**19th** ________ day of ____**August**________________ **2025** in Johannesburg, South Africa.

DEDICATION

I want to dedicate this piece of my academic work to our grandfather "Langa Mbane" a commander and fighter during World War two. A man who has sacrificed his time and left his family for the better of his community and his country – "Ndiyabonga Jwarha, Mayarha, Khathithi, Salakulandelwa, Ngwe'dlamathole, mzukulwna KaTyefu, Khalipha". My late parents, "Qgibibhongo and Nosicabelo-maMbanjwa", both had a passion for education, although they had never had a formal education. May *Their Souls Rest in Eternal Peace*. To my wife, "Onesisa Mbane, Lisa, Jambase, Hlathi, Zaba, Zangomv'eweni", you have been a pillar of my strength; I do appreciate all your support throughout this period. You have sacrificed time when I sometimes felt so lonely, but you have never deserted me. I love you so dearly. To my dearest daughters, Asemahle, Abulele, and Inganathi, thank you, my baby girls, for your support and love. To my siblings, Mzukisi, Nompucuko and Philiswa. Lastly, to my mother-in-law, for all the prayers when the road was so steep, and I needed moral support; thank you, Mama.

God has been with me throughout the trials and tribulations of these studies. Without His Love and Wisdom, I would have been nothing today. Thank you, Dear Lord. Your name deserves praise all the time. James 1:12: "Blessed is the one who perseveres under trial because, having stood the test, that person will receive the crown of life that the Lord has promised to those who love him."

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Executive summary

Background: One of the well-known pollutants that could affect aquaculture, agriculture, the environment, and public health in general is acid mine drainage (AMD). This study report focuses on the creation of AMD, currently available therapies, and their management structure from a policy perspective.

Aim: This study aimed to develop recommendations for a harmonised treatment framework for acidic water generated by mines in South Africa.

Methodology: The study aimed to develop a harmonised policy framework for managing and treating acid mine drainage (AMD) in South Africa by synthesising secondary data through a three-stage iterative process. A systematic review approach was selected to gather information from the literature, with a focus on the South African context. A total of 391 articles from AJOL, ProQuest, and PubMed NCBI were sourced to evaluate various treatment options in South Africa, informing the development of a well inclusive and considerate framework for AMD treatment. The study focused on quantitative research using systematic reviews and meta-analyses, which combined data from multiple studies to provide high-quality, evidence-based conclusions. This approach ensured the use of credible, precise, and reproducible data, helping to compare various AMD treatment options and support the study's objectives. Only articles with specific keywords related to AMD in South Africa were included.

Results: The study reviewed a total of 391 articles. Of these, 209 (67.6%) had titles relevant to the study, while 182 (58.9%) were not relevant. After further screening, 127 articles (41%) had abstracts deemed relevant, and 82 (27%) were found to have irrelevant abstracts. Additionally, 29 duplicate articles (9.4%) were excluded as duplicates, resulting in 98 unique articles (31.7%) that were accepted for the study analysis.

Conclusion: Overall, this report has shown that a harmonised treatment policy can be the solution to prevent fragmentation between different government departments. Finally, a synergy among various treatment solutions for AMD and policies deserves more attention and in-depth exploration to address future impacts.

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GLOSSARY OF TERMS

AMD	Acid Mine Drainage
BDAS	Barium Carbonate Disperse Alkaline Substrate
CHPTAC	3-chloro-2-hydroxypropyl trimethylammonium chloride
Cr	Chromium
CR	Congo red dye
DFFE	Department of Forestry, Fisheries and the Environment
DMRE	Department of Mineral Resources and Energy
DWS	Department of Water and Sanitation
FA	Fly Ash
FeS_2	Ferrous disulfide
FeS2	Ion disulfide
GLD	The green liquor dress
GTMAC	Glycidyl trimethylammonium chloride
Hg	Mercury
HiPRO	High-Level Precipitation Reverse Osmosis
LCA	Life Cycle Assessment
LCCA	Life cycle cost analysis
MPRDA	Mineral and Petroleum Resource Development Act
NEMA	National Environmental Management Act
NWA	National Water Act
Pb	Lead
PES	Polyethersulfone
pH	Acidity or alkalinity scale level
TFS	Tailing Facility Storage
U	Uranium
V	Vanadium
WWTP	Wastewater treatment plant

CHAPTER ONE: INTRODUCTION

This chapter begins with an introduction to the origin of Acid Mine Drainage (AMD), its treatment processes, and the management thereof. The legislation from various departments, in line with the South African legislative framework, policies, and protocols, is also discussed, as well as the public health risks and outcomes associated with exposure to AMD, including environmental degradation. The problem statement and justification of the study are outlined, and the chapter ends by presenting the study's aim and objectives.

1.1 INTRODUCTION

Ever since the discovery of gold in South Africa in 1886, many decades ago, the mining sector has changed the picture of the economy, legislation, decision authorities and the social environment, including human and environmental health consequences (Adler et al., 2007). It is commonly acknowledged that AMD is a highly critical pollutant within the mining sector, especially from abandoned mines, without exclusion of current operational mining activities (Feris & Kotze, 2014).

Operations related to mining in the country's largest basin, the Witwatersrand basin, have caused extreme repercussions through secondary activities that created volumes of AMD that could not be neutralised by the buffering procedure of tailings (Tutu et al., 2008). Many processes are well known that lead to the development of AMD, mainly from the interaction between mineral pyrite Ion disulfide (FeS_2) with oxygenated water (McCarthy, 2011). Most AMD is reported to occur during a process of oxidation, which usually takes place over a bi-folded process from Ferrous disulfide (FeS_2) and sulphuric acid as well as additional sulphuric acid and orange-red ferric hydroxide (McCarthy, 2011).

Although it was thought to pose a concern to the environment, there is a particular risk to the republic's water supply, which may have a significantly negative impact on people’s health and well-being (Feris & Kotze, 2014). Approximately 270 tailing storage facilities (TFS) spanning a 400 km² area of the Witwatersrand are not properly rehabilitated and have inadequate lining, resulting in the leaching of acid mine drainage (AMD) into the environment (Mpanza et al., 2020). Occasionally, the TFSs play a crucial role in acid mine drainage, particularly in situations where mineral sulphide exposure to moisture and oxygen results, causing the production of AMD, which eventually seeps into rivers and streams (Nengovhela et al., 2006). In addition, other sources of AMD arise from open mine pits, including closed mines, but without proper control and management of wastewater (Akcil & Koldas, 2006).

Even though South Africa's gold mining sector has previously contributed significantly to the country's economy and still does, there are still concerns about the effects AMD is having on the environment and water supplies, especially regarding public health (Humphries et al., 2017). Across the board, there are numerous treatment options for AMD, ranging from active to passive approaches, which consequently reduce risk factors related to the environment, ecosystem, and public health. However, this depends on its complexities and cost-effectiveness (Masindi et al., 2022). The current treatment option recommended by the South African government through stipulated legislations, policies, reports, and other forums prefers pH neutralisation before the water is released into streams and rivers (Feris & Kotze, 2014).

While treatment options for AMD are perceived to be vital, they cannot be concluded alone without considering its management. The execution thereof by both the private sector and government varies, depending on the roles and responsibilities of various departments and lacks synergy along the way. Therefore, this study aims to contribute to the development of a harmonised policy framework for AMD treatment and its management.

1.2 PROBLEM STATEMENT

Globally, acid mine drainage (AMD) poses a significant environmental and socio-economic threat, particularly in regions with a long history of mining. The release of acidic, metal-contaminated water from abandoned or operational mines continues to degrade ecosystems, pollute water resources, and impose long-term remediation costs on governments and communities. In response, many countries have adopted policy frameworks that emphasize governance, scientific research, and sustainable treatment technologies to mitigate AMD impacts effectively.

In contrast, South Africa despite being one of the most mining intensive countries in the world continues to struggle with managing AMD comprehensively. The absence of a harmonised policy framework has led to fragmented responses across various government departments, including environmental, water, and mineral resources sectors. This institutional disconnection hampers coordinated decision-making and delays the implementation of sustainable, large scale AMD treatment solutions.

The lack of an integrated, evidence based national policy not only undermines efforts to protect South Africa's scarce water resources but also increases the risk of long-term environmental degradation and public health crises, especially in heavily mined arears. There is an urgent need to synthesise existing knowledge and best practices through a systematic, data-driven approach to support the development of a harmonised policy framework for treatment of AMD in South Africa.

Numerous data points suggest that AMD is one of the most significant contaminants affecting water quality, as it lowers the pH level of water resources, increases the risk of dissolved metals, and contributes to environmental degradation and public health issues. The residue from closed mines, including those still in operation, has contaminated soil and water sources. These residues are deposited into surface and groundwater ways, exacerbating the same dangers to public health. Because every department with an interest in the subject is working independently to address problems affecting AMD, there is no coordination among the measures used to control AMD in South Africa.

1.3 RESEARCH QUESTION

What will be an ideal policy framework for the treatment, management, and discharge of AMD in South Africa?

1.4 AIM

The study aims to recommend a model approach to a harmonised policy framework for the treatment, management, and discharge of AMD in South Africa.

1.5 OBJECTIVES

- To describe the evolution of the policy framework on AMD in South Africa;
- To identify various treatment options available for AMD;
- To propose a model approach for a harmonised policy framework for AMD treatment management and discharge in South Africa.

1.6 CHAPTER OVERVIEW

Chapter 1: This chapter covers the origin, treatment, management, and South African legislation related to AMD, as well as its associated health and environmental risks. It concludes with the problem statement, justification, and research aims.

Chapter 2: This chapter reviews the literature on age-related macular degeneration (AMD) in South Africa, covering its origins, impacts, and treatment methods, and highlights the need for improved policies and a unified framework to address public health and environmental risks.

Chapter 3: This chapter describes the study area, the data collection model, and the systematic literature review process, including information analysis, management, and storage. It also outlines criteria for article inclusion and exclusion, highlighting relevant and non-relevant sources.

Chapter 4: This chapter presents the findings obtained from the systematic review process patterns. The systematic review entails the synthesis of articles, reports, and policies using a template process that covers the name of the article, report, or policy, the author, the year of publication, the treatment option, relevance to the study, and its viability. Furthermore, this chapter will highlight the various management types of AMD, their cost-effectiveness, and the areas where they can be applied.

Chapter 5: This chapter compares the study's findings with previous research, discusses AMD treatment options, management, frameworks, and legislation, and evaluates their viability and cost-effectiveness.

Chapter 6: This chapter presents the study's conclusions, recommendations, and limitations.

1.7 JUSTIFICATION

Although the environmental and health implications of acid mine drainage (AMD) are well-established globally, and a range of treatment technologies has been explored in the literature, there is a marked deficiency in the integration of scientific knowledge into cohesive, actionable policy, particularly in the South African context. Existing research has largely focused on the technical and chemical dimensions of AMD treatment, while limited attention has been given to the governance, institutional coordination, and policy alignment needed for effective implementation. In South Africa, where AMD is an acute and persistent challenge due to the country's extensive mining legacy, government reliance on conventional pH neutralisation persists despite the availability of advanced treatment methods. Compounding this issue is the fragmentation between departments responsible for water, mining, and environmental management, resulting in disjointed responses that undermine public health and environmental protection.

Globally, AMD is a significant issue, particularly in areas with a high concentration of coal and gold mine operations (Kefeni et al., 2017). Following its creation, the environment may suffer, leading to a variety of effects such as water pollution and impeded aquatic creatures' and plants' capacity for reproduction (Nengovhela et al., 2006). The presence of heavy metals and sulphates continues to impact ground and surface water, as they result from the microbiological oxidation of certain minerals when these minerals interact with oxygen, leading to the formation of acidic mine water (Madzivire et al., 2011). These heavy metals, which dissolve in acidic water, are responsible for a variety of public health effects, including environmental degradation (McCarthy, 2011).

While there is common knowledge available to control, manage and treat AMD before it is discharged into rivers and streams, there are various other treatment options available, such as conventional neutralisation, chemical desalination membranes, High-Level Precipitation Reverse Osmosis (HiPRO) electrodialysis, vibration shear enhanced process as well as Ion exchange (Abiye & Ali, 2022).

In South Africa, the primary treatment option recommended by the government is the pH neutralisation process, as stipulated in government policies, legislation, and reports. However, the fragmentation experienced during the execution of such policies is a concern and threat to public health outcomes. Furthermore, a silo mentality by various departments responsible for the management and therapy of AMD act as a deterrent in fulfilling the public health obligations associated with AMD in South Africa (Feris & Kotze, 2014).

This study provides academic novelty by shifting the focus from purely technical solutions to a policy level synthesis that seeks to bridge the gap between scientific knowledge and institutional practice. By adopting a systematic review and meta-analytic approach, the research evaluates the effectiveness of various AMD treatment methods while also critically examining the policy and governance barriers that hinder their implementation. The development of a harmonised policy framework for AMD management in South Africa represents a novel contribution to the academic discourse, offering an interdisciplinary model that integrates environmental science, public health, and policy analysis in addressing one of the country's most pressing environmental challenges.

CHAPTER TWO: LITERATURE REVIEW

In this early chapter, we provide a concise overview of the academic literature on the history of AMD in South Africa and its origin. Various scholars have made a significant contribution by highlighting the origin of AMD, possible treatment methods, and their impact on public health and the environment. Furthermore, the articles indicate the considerable efforts required to bring various policies and legislations closer together, which are meant to manage AMD in South Africa. At the end of this chapter, a discussion is presented on the management of treatment options to formulate a harmonised policy framework on AMD, thereby aiming to address public health challenges and environmental degradation risks more effectively.

2.1 LITERATURE REVIEW

Residuals discharged from coal mine sites, whether abandoned, reclaimed, or currently operating, that contain water substantially more acidic than the surrounding environment continue to pose a global problem due to their diverse effects on ground and surface water quality. The cost and complexity of technologies needed to soften and treat such fluids increase, making AMD management more challenging (Acharya & Kharel, 2020).

According to global data by Bashar Bhuiyan et al., (2013)diseases linked to water pollution claim the lives of approximately 14,000 people every day. Of these, approximately 700 million Indians lack access to toilets, which contributes to the 1,000 documented cases of diarrheal illnesses every day (Bashar Bhuiyan et al., 2013). Subsequently, these studies show that an estimated 500 million population in China lack access to safe drinking water, and 90% of Chinese cities are severely afflicted by pollution. These occurrences are reported in both developed and developing nations (Bashar Bhuiyan et al., 2013). While some countries in the region have been mining solid minerals for a considerable time, there remains a scarcity of information and documentation regarding the effects of acid mine drainage (AMD) and its therapeutic methods, which has a detrimental impact on the ecosystem (Adeniyi et al., 2022).

Sulphates, iron, and heavy metals are among the waste products of mining operations that are referred to as AMD. AMD harms the environment, endangering people's health and preventing sustainable growth. The socioeconomic demands, including environmental challenges of the impacted population from specific locations, are not taken into consideration by any AMD remedial approaches (Thomas et al., 2022). One of the main issues brought on by mining operations, which is well-documented to have a ripple effect on the environment, is AMD. AMD has garnered considerable attention recently due to its devastating impacts on ecotoxicology, society, and the environment. Several nations with a strong mining industry, including South Africa, the United States, Canada, China, and Russia, are probably suffering from the effects of AMD (Masindi, et al., 2022).

The literature revealed that AMD is infamous due to its originality of mining activities, whereby the studies indicate that it happened through an interaction between pyrite solid rock with oxygenated water, creating the most harmful acidic water because of dissolved heavy metals and sulphate contaminants (McCarthy, 2011;Madzivire et al., 2011; Kefeni et al., 2015).

The primary cause of AMD is South Africa's history of abandoned mines and its consequential effects on the environment, aqua system, and public health, following years of mining which contributed to fulfilling economic opportunities in the country (Mhlongo & Amponsah-Dacosta, 2016). The tailings facility storages (TSF) are one of the areas where AMD takes place by means of mineral oxidation, particularly when it interacts with oxygen gas and water (Nengovhela et al., 2006).

Over many years since gold was discovered in South Africa, which without any dispute contributed immensely in economic ways and still is one area whereby the government is relying on certain minerals to be produced that assist the country to grow, the issue of acidic water from mines has never been fully addressed (McCarthy, 2011). Over time, several studies have contextualised how mine acid water was formed, including some repulse effects it has on the environment, ecosystem, and public health risks through precipitated heavy metals that are disposed of into rivers and streams across areas where there are abandoned mines, as well as active mines with poor control measures in place (Bell et al., 2002).

2.2 IMPACTS OF AMD

2.2.1 Environmental impacts

The toxicity of AMD, which is caused by excessive acidity and the presence of heavy metals and metalloids, is said to have disastrous consequences on the environment worldwide, putting humans, animals, and plants at serious risk (Du et al., 2022). Given the fluctuations in pH levels and the fact that aluminium (Al), one of the hazardous heavy metals on AMD, is present, acid mine drainage does have a detrimental environmental impact on river waters (Chamier et al., 2015). It was noted elsewhere that AMD exacerbates the amounts of erosion caused by abandoned mines, thus posing a global threat to environmental deterioration (Chen et al., 2015).

2.2.2 The impact on aquatics or ecological species

Certain fish species, which are crucial to the food supply of rural areas in the nation that rely on fish as a primary food source, are severely harmed by the heavy metals contained in the sediment of dams. This includes the polluted dams in South Africa that are the result of AMD (Lebepe et al., 2020). Where heavy metal concentrations are high, as in AMD, the long-term toxicity of these metals endangers aquatic systems, plants, soil, and human health (Simate & Ndlovu, 2014). The high concentration of total dissolved solids caused by AMD pollution in and around South African streams and dams continues to impact some aquatic species negatively, even though, at some point, the acid mine drainage is neutralised by sewage water through pH level changes (Lebepe et al., 2020). Furthermore, the research shows that this adverse effect extends to physico-chemical characteristics (Lebepe et al., 2020).

The evidence shown in this research underscores the toxicological risks associated with AMD, highlighting the need for stringent monitoring and remediation efforts to safeguard aquatic life and human health (Lebepe et al., 2020).

2.2.3 The impact on agricultural fields

Many predictions and reports indicate that South Africa is a dry area; therefore, AMD is seen as a potential source of water for agricultural and plant irrigation. However, low pH levels and high total dissolved solids from AMD's heavy metal could severely damage this. The agricultural sector is impacted by this phenomenon, as crops require water irrigation to develop and thrive (Munyai et al., 2022). Hence, AMD is mentioned as one of the main factors affecting the industry, along with other main obstacles that impact the availability of water, whether for household use or agricultural purposes (Munyai et al., 2022).

2.2.4 The Impact on health and well-being

As a by-product of mining operations that contain sulphates, iron, and heavy metals, acid mine drainage (AMD) seriously degrades the environment and endangers both human health and sustainable development. Phytoremediation is a potentially effective remediation strategy for areas afflicted by AMD, as it addresses the ecological, social, and economic demands of affected people in a comprehensive manner (Thomas et al., 2022).

2.3 MANAGEMENT OF AMD

Proper management of AMD does have positive implications for bringing pH levels to acceptable standards that the environment can tolerate without significant challenges (Akcil & Koldas, 2006). Although various methods have been introduced to prevent, manage, and treat AMD, the evidence shows that sulphate and iron concentrations point in the direction of pyrite as the significant factor of sulphite-rich mineral that tends to give problems in the management of AMD (Aphane & Vermeulen, 2015). The research indicates that rehabilitation and restoration are one element that is lacking from the management alternatives that can have a quantifiable influence on AMD. Therefore, green technology may become even more sophisticated while still meeting human and environmental needs. Moreover, phytoremediation is a technology found in mining equipment that provides a bioremediation treatment option in this industry (Thomas et al., 2022).

2.3.1 Models and frameworks for managing AMD

The provisions of the Constitution of the Republic of South Africa, particularly sections 24 and 27 of the Act, which examine the challenges South Africa has with AMD, must be observed appropriately. When these parts are combined, they express the right that everyone has the right to live in a safe environment free from health hazards, as specified in Section 24 of the Act (Sachs, 1996). While addressing environmental degradation is important, the acidic water discharged from abandoned mines into streams has the potential to contaminate rivers and exacerbate the challenges of water pollution. South Africa is well known to be a water-scarce country, even though Section 27 of the Constitution advocates for the provision of access to clean water as a fundamental right (Sachs, 1996).

When acidic water leaks into the environment, it becomes an issue that demands the Department of Environmental Affairs address or, alternatively, prosecute the perpetrators. However, the owners of mines that have been abandoned must pay a price, according to the Department of Minerals and Energy. Nevertheless, it can take years before these mines are eliminated altogether as a threat. The Department of Water Affairs seeks to fulfil its responsibility by combining two sections into a comprehensive framework for regulating AMD and controlling it, as provided for in the legislation. The inability of departments to handle AMD consequences effectively and efficiently due to their broad silo mentality and distinct areas of expertise raises serious concerns. Consequently, the goal of this study is to fill the gap by providing specific recommendations for a cohesive policy framework. Departments will be encouraged to collaborate on addressing AMD problems in South Africa in order to provide clean water to its citizens through its regulations. This initiative aims to address the risk factors for water-related diseases in consultation with the Department of Health.

2.3.2 Various AMD treatment Options

The negative impact of AMD experienced on some areas of Witwatersrand that run into the streams originates from the acidified water that seeps from the mine tailings dumps, whereby the pH is lowered, and heavy metals are deposited, causing tremendously high Ion hydroxide precipitation (Naicker et al., 2003). Further detrimental effects associated with AMD from abandoned mines are a known fact and require key fundamental intervention. In countries where drought and water shortages are common, acid mine drainage needs to be treated to a level where it does not pose a risk to the environment, including public health (Masindi et al., 2018).

Among other treatment methods, the life cycle assessment (LCA) method has been found helpful in areas where there is no power. It has the potential to address risks related to socioeconomic and health (Masindi et al., 2018). The extraordinary repercussions on environmental degradation caused by allowing untreated AMD to seed through permeable rock, which contains groundwater, as well as into streams, requires a strong response of treatment comprising active and passive methods (Westensee et al., 2018). The emphasis on addressing the scourge of acidic mine drainage requires various treatment options such as neutralising, stabilising, and removing contaminants through physical, chemical, and biological processes that can change water pH levels (Kefeni et al., 2017). Because cellulose-rich waste materials provide a less expensive approach to remediating AMD, scientists have recently developed alternative treatment techniques (Wasteness et al., 2018). It is essential that treatment options be implemented by both the government and the private sector to take responsibility, thereby containing AMD challenges through legislation, policies, and regulations (Feris & Kotze, 2014). At its worst, the increase in pH from AMD sources leads to the precipitation of heavy metals, which is a treatment measure that can be used to eliminate some of these metals, such as Fe and Al (Madzivire et al., 2011).

The pH scale is widely used globally, and South Africa is no exception in this treatment of AMD (Akcil & Koldas, 2006). Diverse alternative treatment strategies have been proposed and classified as either active or passive. Among these, the application of limestone and cow dung has been proven to be effective in addressing the rectification processes associated with AMD (Westensee et al., 2018). One of the treatment techniques discovered involved the active neutralization of AMD with fly ash over time, which produced alkaline solid residues, while the AMD was actively treated (Gitari et al., 2008). Alga Spirulina sp.: is another efficient AMD preferred treatment as it has been measured among most passive treatment systems (Van Hille et al., 1999).

Other scholars suggested using oxidation pre-treatment, which has proven effective in precipitating iron and manganese. For complete removal of heavy metals, a combination of lime and sulphide can be used to address the limitation of lime alone, which does not fully precipitate the metals (Feng et al., 2000). Apart from pH remediation treatment of AMD, using grass has been found as a potential passive treatment to be considered; however, it has cost challenges (Ramla & Sheridan, 2015). Wetlands generated near river flows, especially where there are high levels of metals from Acid Mine Drainage (AMD), provide an effective process to absorb several metals before they reach or mix with downstream waters, which is a well-recommended approach to establishing and protecting wetlands that play a crucial role in AMD treatment (Bell et al., 2002). Natural wetlands in areas with abandoned mines serve as a remedy. They require protection as they contribute to the outcomes of AMD management at the endpoint once the liquids have passed through the wetlands (Bell et al., 2002). Furthermore, Green Liquor Dress (GLD), which is the treatment process emanating from white liquor, is also recommended to neutralise AMD. However, there is not enough information in South Africa due to limited feasibility studies at Kraft mills (Sebogodi et al., 2020). A variety of other treatment options have been cited widely by various researchers, including, among others, the application of alkaline chemicals such as calcium hydroxide and barium calcium, the construction of wetlands and other solutions (Kefeni et al., 2017).

Chitosan-infused PES membrane is one of the recognised treatment options for AMD because of its demonstrated efficacy in producing favourable results (Mathaba & Daramola, 2020). This is achieved by using synthesis options to change chitin into chitosan (Mathaba & Daramola, 2020). In potato cultivars, fly ash and quicklime have been shown to have a significant effect on metabolite exudation, which can mitigate AMD. However, more research is necessary to confirm this (Munyai et al., 2022). To synthesise various adsorbents and metal oxides meant to filter water, sludge samples are necessary, especially those from synthetic AMD treated with green oxidants (Munyengabe et al., 2020).

2.4 RELEVANT LEGISLATION AND POLICIES ON AMD

South Africa has inherited a dangerous phenomenon called AMD (Feris & Kotze, 2014). The situation has worsened because of contestation and fragmentation between role players regarding the implementation of legislation and policies that were supposed to have taken owners of the abandoned mines, including current operational mining industries, into account (Feris & Kotze, 2014). Several government departments, including the National Environmental Act, which governs waste management, the Water Services Act, which controls access to potable water supplies, and the National Water Act, which oversees management and conservation, have specific overlapping roles and responsibilities regarding AMD, which makes it difficult to coordinate. Furthermore, the Mineral and Petroleum Resources Development Act (MPRDA) has a regulatory responsibility for AMD (Feris & Kotze, 2014). Collectively, these policies are key in the development of a harmonised policy framework to enforce compliance with the management of AMD (Naidoo, 2015). While there is uncertainty about where the responsibilities lie, the impacts of AMD worsen environmental degradation and similar public health risks. The strides made by various policies, legislations, and reports suggest that there are no collaborative efforts in addressing acid mine drainage risks to public health and environmental degradation, so this study aims to develop a harmonised policy framework for the treatment of AMD in South Africa. As part of this, it aims to address the silo mentality challenge posed by various government departments and private sector companies in dealing with matters of AMD in South Africa.

CHAPTER THREE: METHODOLOGY

This chapter begins with a description of the study area, followed by an explanation of the study design and model used to collect the data. It explains the information recorded during the systematic literature review and how the information was analysed. Furthermore, the chapter explains the management of the information before it is summarised to give a sense of what has been systematically reviewed. Lastly, it highlights the relevant and non-relevant articles and criteria for inclusion and exclusion in the study.

3. METHODOLOGY

3.1 Study Setting

The study took place in Johannesburg, Gauteng, in South Africa, as shown in Figure 1 below. The researcher reviewed articles and reports on AMD, with a focus on the South African perspective. Secondary data was extracted from various websites, including government information and communication websites, using Microsoft tools.

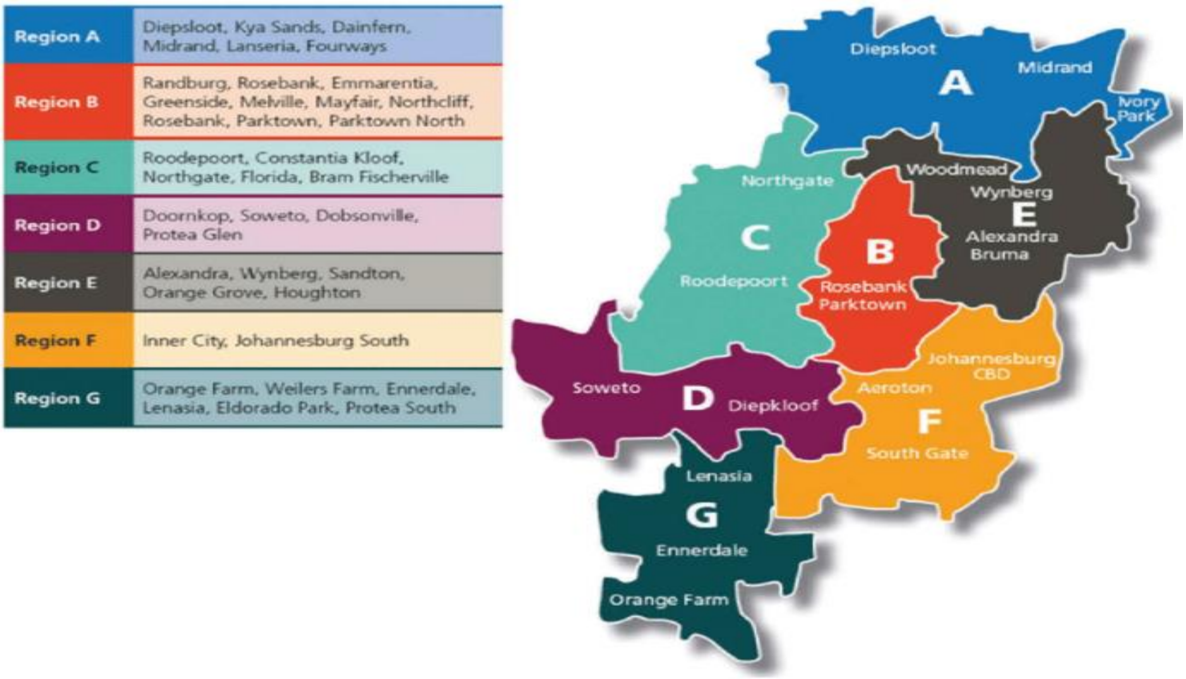

Figure 1: Geographical map of Johannesburg metropolitan area

3.2 STUDY DESIGN

The study is a systematic review that synthesises available secondary data to develop a harmonised policy framework for the treatment, management, and discharge of AMD in South Africa. This will be achieved by identifying articles and reports related to acidic mine water in

South Africa, and a three-stage iterative process will be undertaken. The research that used quantitative methodologies will be the source of the data collection. Systematic reviews and meta-analyses present conclusions by combining and analysing data from multiple studies conducted on similar research subjects. The strength of a systematic review lies in its use of clearly defined systematic methods to obtain answers to a specific question. Furthermore, the systematic reviews are at the top level of the evidence pyramid. The data comes from credible sources that are comprehensive, reproducible, and precise in stating the outcomes. This will assist with responding to the study objectives. In providing concise evidence, meta-analysis is a valid, objective, and scientific method of analysing and combining different results. The systematic review and meta-analysis provide a comparison between several AMD treatment options. The review of articles helps to extract more accurate and reliable data from the large amount of data generated from multiple articles. In this case, articles that had specific words were included in the study.

3.3 Study Population

The study involved no human element and relied solely on secondary data obtained through a systematic review of articles and reports.

3.4 SAMPLE SIZE

All articles and reports published within a ten-year period that addressed acidic mine water evolution in South Africa, as well as treatment options and management, were included in the study, with no time limit on their publication. A total of **90** articles from **AJOL** were retrieved, regardless of their relevance, by using the keywords "AMD*" [All Fields]. A total of **163** articles through **ProQuest** search were retrieved, irrespective of whether they were relevant or not relevant, which contained keywords (AMD*) and (South Africa). From the **PubMed** search, a total of **79** articles, irrespective of relevant or not relevant, were retrieved, and all those were guided by the keywords "AMD" and "South Africa" [All Fields]. A total of **59** articles were retrieved from **NCBI** using the keywords (AMD [MeSH Terms]) and South Africa.

3.5 Inclusion and exclusion criteria

The study included all peer-reviewed articles on AMD. Furthermore, only studies published in South Africa within the last 10 years and English studies were include and non-English studies were excluded (see Table 1). The search included not only peer-reviewed publications but also reports, dissertations, company profiles, scientific newsletters, and scientific conference presentations.

Table 1: Citation exclusion criteria

Exclusion criteria
Not AMD*
Location of study; and/or institution; and/or researcher(s); and/or funder are not South African
Non-English

3.6 STUDY DATA COLLECTION TOOL

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) were used to conduct the study. PRISMA is a minimum set of elements for reporting in systematic reviews and meta-analyses that are based on evidence. Primarily, it focuses on the reporting of reviews and evaluating the effects of interventions but can also be used as a basis for reporting systematic reviews with objectives other than evaluating interventions (e.g.) evaluating an aetiology, prevalence, diagnosis, or prognosis). Both the PRISMA and the flow diagram were used to conduct the study. Notably that this systematic review approach with Preferred Reporting Items for Systematic Reviews and Meta- Analyses (PRISMA 2020) guidelines, was done without a quantitative meta-analysis. The systematic review was designed to synthesise and evaluate published research on environmental and toxicological impacts of AMD, with particular attention to treatment options on metal contamination and human health risks. A comprehensive search strategy was used across multiple academic databases (AJOL, ProQuest, PubMed and NCBI), focusing on peer-reviewed articles published within the range of ten years with specific key words on acid mine drainage. The studies were selected based on predefined inclusion and exclusion criteria. These included relevance to AMD, environment, and health impact. Only English articles were considered.

To minimise the bias and assess the risk of bias, a tow step process was followed through, independent screening and duplicate removal were conducted by two reviewers to reduce selection bias. Disagreements were resolved through consensus or consultation with a third reviewer. Publication bias was considered by examining grey literature database and including unpublished theses and reports where applicable.

3.6.1 Materials and data collection

The Literature from the desktop search was uploaded and coded using EPPI-Reviewer (V.4.3.4). The data were then exported into Microsoft Excel, where a master database of potential study articles has been maintained (i.e., researchers and/or institutions involved in the production, importation, or utilisation of AMD in South Africa). The data required to meet objectives 1-3 was collected using the data collection tool (Appendix C).

3.7 DATA COLLECTION PROCEDURE

3.7.1 Stage 1: Desktop literature search

In consultation with information scientists, a sensitive search strategy was developed to identify all published research on AMD, as well as its causes, impact, and treatment conducted in South Africa, at a South African institution, or by a South African researcher. Search terms utilised both controlled vocabulary and free-text terms. No date limits were applied to the search strategy. Table 2 provides a summary of examples of the database search strategies to be used for each database.

Table 2: Summary of database search strategies

Database	Search Strategy
AJOL	“AMD*” [All Fields]
NCBI	(AMD [MeSH Terms]) and South Africa
ProQuest	all (AMD*) AND all (South Africa)
Pub Med	“AMD” and “South Africa” [All Fields]
RSC	Title “AMD*” and “South Africa”
Sabinet	((all text unstemmed: (“AMD*”) and all text unstemmed: (“South Africa”)) OR (ocr: (“AMD*”) and orc: (“South Africa”))
Science Direct	TITLE-ABST-KEY (“AMD*”) and TITLE-ABST-KEY (“South Africa”)
SCOPUS	TITLE-ABST-KEY (“AMD*” and “South Africa”)

Springer Link	(AMD*) AND (South Africa) [TITLE-ABST-KEY]
Web of Science	Topic= (AMD* and "South Africa"); Timespan = All years
Wired Space	Full-Text Search: "AMD*"

All citations identified, using the search strategy were uploaded into EPPI-Reviewer 4 (V.4.3.4). Using EPPI-Reviewer 4, all citations undergo title and abstract screening, during which the exclusion criteria (as summarised in Table 1) were applied. Screening was done independently and in duplicate (double-blinded) by at least two reviewers. Where differences between reviewers' opinions existed, citations were reconciled by a third reviewer (Appendix C): Article, Title, Author, Year of Publication, Treatment option, Article/Report and Relevancy to the study tool). The data was recorded in a Microsoft Excel worksheet by the lead researcher. Engagement and disapproval regarding the inclusion of articles and reports in the study were resolved through discussions between the supervisors and the researcher. The researcher then extracted data from the articles, synthesised the information, and created a summary template, including author, study design, country, and treatment options, management programme activities and graphs.

The analyses and syntheses of the selected data were conducted using quantitative methods. The results were summarised, and the limitations and future research opportunities thereof were highlighted. A total of 98 articles were identified as relevant to the study and included because they contained keywords in their titles or had abstracts that were related to the study's topic. Throughout the process, a rigorous review was conducted, excluding all duplicates and articles that were not relevant due to the absence of relevant keywords in their titles or abstracts.

3.7.2 Stage 2: Reviewed articles from various search websites

Figure 2 below provides an overview of the Desktop search strategy. From the full-text review, data was collected on the articles and reports. Information on funding sources for the publication was also collected. This information was consolidated into a primary database of institutions and researchers involved with AMD in South Africa. This was a primary objective of the desktop search: to develop a comprehensive database of articles and reports related to AMD in South Africa, which could then be listed in a table format for analysis of secondary data sources. This analysis requires an in-depth examination that will be used for future recommendations of this study.

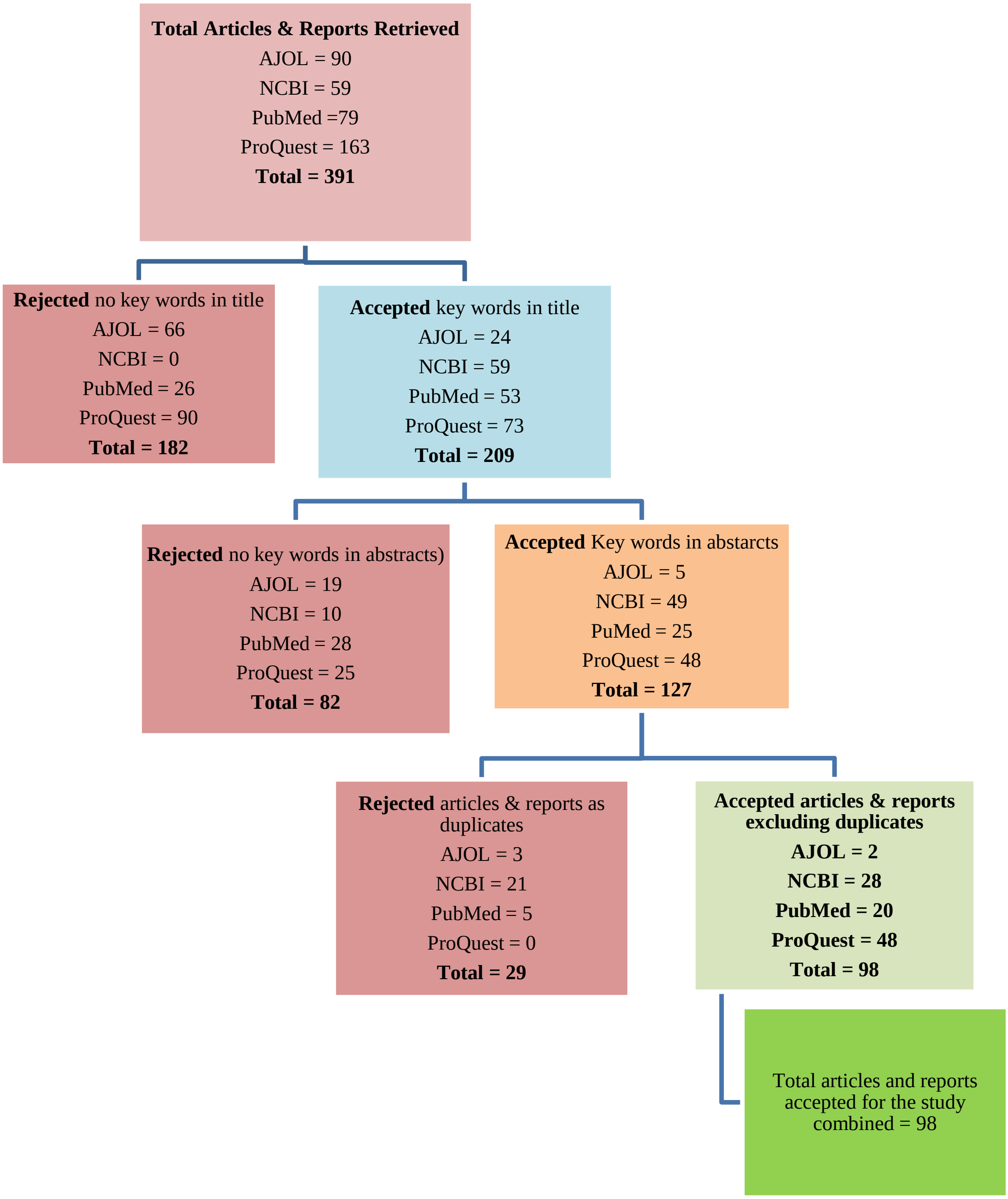

Figure 2: A schematic diagram following the PRISMA criterion for data collection

All citations that were not excluded have underwent full-text review to code citations and extract data. Soft copies of the citations were collected and uploaded onto the EPPI-4 reviewer platform. The first round of full-text reviews was conducted by two independent reviewers (in a double-blind process), and a third reviewer reconciled any discrepancies. This was to allow the team to identify any ambiguity that might have existed in the interpretation of the coding and data extraction frame. **Table 3** below provides a summary of the data variables extracted from the full text. In the end, the full coding frame and data extraction for analysis was done.

Table 3: Summary of data extracted from included citations

Variable
Date of publication
Title of the article
Treatment Option
Relevancy to the study

The first step of the systematic review showed that a total of 391 articles and reports were retrieved from various web search sites. A total of 24 articles were accepted from the AJOL search site, while 66 were rejected because they did not contain relevant keywords in their titles. A total of 59 articles were retrieved from NCBI, with zero articles rejected and all 59 accepted because they contained pertinent keywords in their titles. A total of 53 articles were retrieved from PubMed, with 28 rejected due to the absence of relevant keywords in their titles. A total of 73 articles were accepted from ProQuest, but 90 were ultimately dismissed due to a lack of keywords in their titles.

The second step of the systematic review identified a total of 209 articles and reports that were accepted because the keywords were present in the abstracts. A total of 184 articles and reports were rejected because the keywords were not included in the abstracts.

The third step of the systematic review resulted in the rejection of a total of 82 articles because their abstracts were not relevant to the study. In comparison, a total of 127 articles and reports were accepted because their abstracts were relevant to the study.

The fourth step of the systematic review revealed that a total of 127 articles and reports were accepted and reviewed for duplicates before being included in the study. Out of 127 articles and reports, 29 duplicate articles were excluded. A total of 98 articles were included and considered for treatment options available in South Africa.

3.8 DATA ANALYSIS

A description of research trends from the Desktop search was analysed in Microsoft Excel. These trends included an analysis of research output from various research institutions, funding streams and research focus areas. From the primary data collected by the leading researchers, review articles and reports were used as secondary data and analysed to describe the origin of AMD, its treatment options, and management, with a focus on the South African perspective. The variety of articles and reports generated were tabled according to the Title, Author, Date of publication, Treatment Options, and cost-effectiveness. All similar articles and reports with identical treatment options were clustered together and analysed for commonalities. Several government laws related to AMD, along with associated cost and risk evaluations, should be used to describe the current recommended treatment method in South Africa clearly.

3.9 VALIDITY AND RELIABILITY

The study focused on the South African context and included only literature published within the last ten years. All the articles included concentrated on AMD treatment, emphasising various options that can be used. The study can be repeated using the same method and is likely to produce the same or similar results; however, the conclusion may differ due to variations in sample size, inclusion, and exclusion criteria. The study's results do not yield a definitive conclusion on the best treatment option for AMD, leaving room for future studies to draw their determinations.

3.10 ETHICAL CONSIDERATION

Ethical clearance waiver was granted by the University of the Witwatersrand Human Research Ethics Committee, certificate number W-PR-230928-01 (see Appendix B). The waiver was issued as the study involved secondary data analysis of published papers and did not include human subjects or personal data. All relevant ethical principles were followed throughout the research.

CHAPTER FOUR: RESULTS

This chapter presents the findings obtained from the systematic review process patterns. The results are presented in a variety of graphs and tables that depict the number of articles reviewed, as well as showing which articles were relevant or irrelevant to the study. Furthermore, this chapter highlights the various management types of AMD, their cost-effectiveness, and the areas where they can be applied.

4. RESULTS OF ARTICLES, ABSTRACTS AND REPORTS REVIEWED

The results presented in Table 4 provide a detailed summary of the literature search process employed in this systematic review. Various reputable search websites were utilized to ensure comprehensive coverage of the existing literature. These databases included both multidisciplinary and specialized platforms relevant to the research topic. For each source, the total number of articles retrieved during the search phase was recorded to demonstrate the initial scope and breadth of the literature pool. This process formed the foundation for systematic screening and selection of studies aligned with the aims and objectives of the review.

A structured screening process was applied to determine the relevance of the identified literature. Articles were first reviewed based on their titles, where a distinction was made between titles relevant to the study and those deemed not applicable. This initial filter helped narrow the pool to those articles most likely to contribute meaningful insights. The second level of screening involved evaluating the abstracts of the remaining articles. Here again, abstracts were classified according to their relevance, allowing for the identification of studies whose objectives, methods, or findings aligned with the research questions. Abstracts that did not reflect pertinent information were excluded at this stage.

Further refinement of the dataset was conducted by eliminating duplicate entries articles that appeared more than once across different databases or during repeated searches. The number of such duplicates was recorded separately to illustrate the extent of redundancy in the initial pool. Following the removal of duplicates, the final set of articles accepted for full review comprised only those that were both relevant and unique. These accepted studies formed the basis for deeper thematic analysis and synthesis of findings. Table 4 thus serves as a transparent account of the systematic filtering process, ensuring the rigor and reproducibility of the literature review methodology.

Table 4: Illustration of number of articles received per search website

Item	Search website	Total number of articles reviewed	Number of articles reviewed with titles relevant to the study	Number of articles reviewed with titles not relevant to the study	Number of articles reviewed with abstracts relevant to the study	Number of articles reviewed with abstracts not relevant to the study	Number of articles rejected from the study with duplicates	Number of articles accepted without duplicates
1.	AJOL	90	24	66	5	19	3	2
2.	NCBI	59	59	0	49	10	21	28
3.	ProQuest	163	73	90	50	25	0	48
4.	PubMed	79	53	26	25	28	5	20
5.	RSC	0	0	0	0	0	0	0
6.	Sabet	0	0	0	0	0	0	0
7.	SCOPUS	0	0	0	0	0	0	0
8	Springer Link	0	0	0	0	0	0	0
9.	Web of Science	0	0	0	0	0	0	0
10	Wired Space	0	0	0	0	0	0	0
Total		391	209 (67.6%)	182 (58.9%)	127 (41%)	82 (27%)	29 (9.4%)	98 (31.7%)

Overall, about 391 articles underwent a systematic review using the PRISMA approach. The publications were obtained from several search engines, including ProQuest, PubMed, RSC, Scopus, Web of Science, and Wired Space. As a result, **Error! Reference source not found.** shows that 90 (29.1%) articles were found using the AJOL search database.

Considering the availability of the key terms "AMD*" [All Fields]" from their titles, a total of 24 publications out of the 90 were pertinent to the study. However, due to the absence of essential words in their titles, 66 out of the 90 articles were irrelevant.

The NCBI search page then yielded 59 (15.1%) papers whose titles contained the keywords "(AMD [MeSH Terms]) and South Africa," making them either pertinent or unrelated to the study.

There were no articles detected that were not relevant due to keywords in their titles, and the remaining 59 were all relevant because of the accessible keywords in their titles. There were 163 (41.7%) articles about AMD in the ProQuest search database.

Out of 163 papers, 73 had the pertinent keywords "all (AMD*) and all (South Africa)" in their titles. The remaining 90 articles, however, did not have any key terms in their titles and were, therefore, unrelated to the study. When searching for publications on AMD using the keywords "AMD" and "South Africa" [All Fields]," the PubMed search page turned up 79 results, or 20.2% of the total.

Fifty-three publications pertinent to the study, which included key terms in their titles, were identified among the 79 articles reviewed by this website. Because crucial phrases were absent from the titles of 26 papers, they were deemed irrelevant to the study.

Zero articles were found on the remaining research websites from the Web of Science, RSC, Sabet, SCOPUS, SpringerLink, and Wired Space, in that order.

Of the ten search websites on which articles were found, four accounted for most of the acceptable articles. These websites are NCBI, ProQuest, AJOL, and PubMed.

A total of **391 articles** were systematically reviewed using the **PRISMA approach**, drawn from ten online databases. However, only **four databases** which are: **ProQuest, PubMed, NCBI, and AJOL have** yielded relevant results. The remaining six databases (Web of Science, RSC, Sabet, SCOPUS, SpringerLink, and Wired Space) did not produce any usable literature, highlighting a **limitation in search coverage** or relevance within those search engines for this study title.

The observation throughout these databases shows that :

- **ProQuest** had contributed the **highest volume** (163 articles: 41.7%), with **73 articles (44.8%)** containing relevant keywords in their titles. Despite its volume, it also had the highest number of irrelevant articles (90), suggesting a **broad but less targeted index**.
- **NCBI** was highly effective, retrieving **59 relevant articles (100%)** with no irrelevant titles—demonstrating strong keyword relevance and a **high retrieval precision**.
- **PubMed** provided **79 articles (20.2%)**, with **53 relevant titles (67.1%)** and a moderate level of irrelevant ones (26), indicating **balanced performance**.
- **AJOL** yielded **90 articles (29.1%)**, but only **24 (26.7%)** were relevant, pointing to a **lower relevance rate** despite a substantial count.

Overall, **209 articles (67.6%)** had relevant titles, and **127 (41%)** had relevant abstracts. This filtering process reflects the **rigorous application of inclusion criteria**, ensuring quality and topic specificity. However, **29 duplicate articles** were later removed, leaving **98 unique, accepted studies**.

Strengths:

- **Effective filtering via PRISMA** ensured that only relevant, high quality articles were retained.
- Databases like **NCBI and PubMed** demonstrated strong specificity and precision.
- The process enabled a **clear synthesis of article relevance by title and abstract content**.

Limitations:

- **High number of irrelevant articles** in AJOL and ProQuest reduced screening efficiency.

- **No relevant output** from six databases limited diversity and comprehensiveness of sources.
- Duplicate entries, especially from overlapping databases (e.g., NCBI and PubMed), **affected data efficiency**.

Synthesis:

The findings show that **NCBI and ProQuest** were the most productive in terms of both volume and relevance, followed by **PubMed**. The use of precise keywords significantly improved retrieval accuracy, particularly in AMD related databases. However, the disparity in database performance emphasizes the need for **targeted database selection** and **refined search strategies** in systematic reviews.

The number of accepted papers on each search website for the study is shown in Figure 3 below. The term "AMD in South Africa" appeared in the titles and abstracts of the articles.

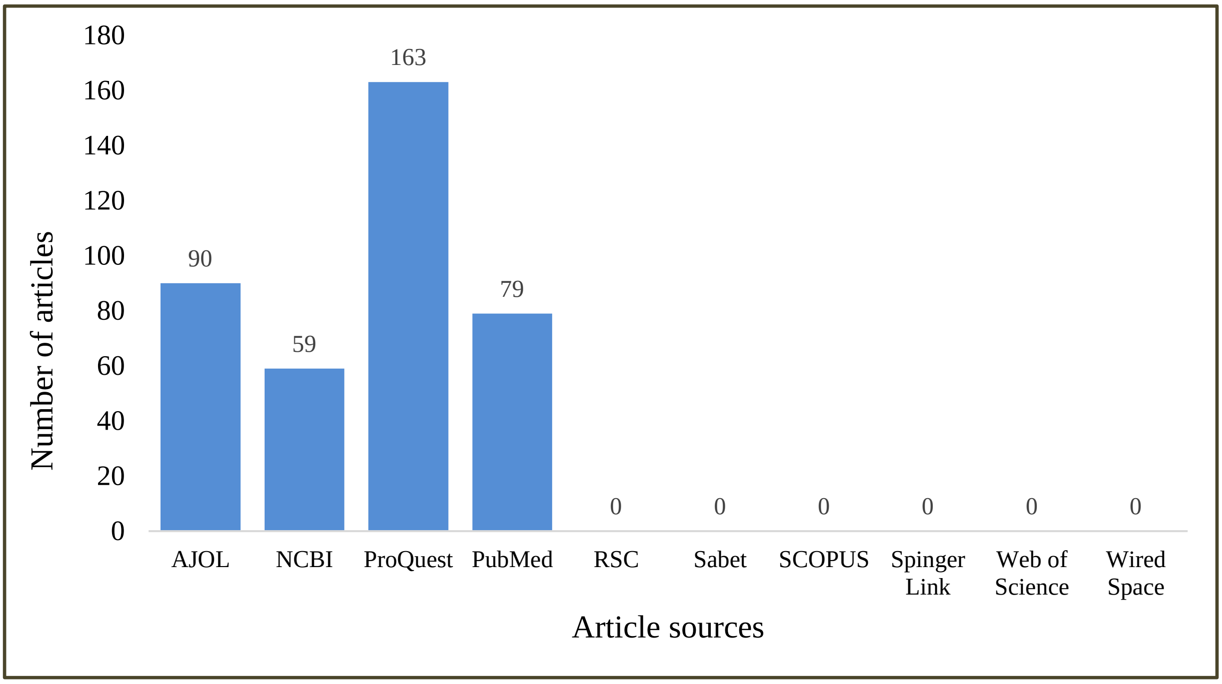

Figure 3: Total number of articles reviewed relevant to the study of AMD treatment in South Africa

Specific key terms were used to search for articles across all the study's designated websites. After their abstracts were reviewed, the articles that were accepted for the study are shown in Figure 4 below. The primary sources of these articles were AJOL, NCBI, PubMed, and

ProQuest. The bar chart presented illustrates the distribution of articles sourced from four different academic databases during the systematic review process. These sources include AJOL (African Journals Online), NCBI (National Centre for Biotechnology Information), PubMed, and ProQuest. The vertical axis represents the number of articles retrieved, while the horizontal axis lists the respective databases.

From the chart, ProQuest yielded the highest number of articles, with a total of 73 articles identified. This indicates that ProQuest had a broader or more accessible range of publications relevant to the study topic. NCBI followed with 59 articles, suggesting its significance in contributing scientifically rigorous content. PubMed, another biomedical-focused database, provided 53 articles, reflecting its strong alignment with health-related content, though slightly less than NCBI. AJOL, a regional database focusing on African journals, contributed the fewest articles, with only 24 retrieved, likely due to a narrower scope or fewer publications on the subject of interest.

Overall, the figure underscores the importance of diversifying search sources in a systematic review. It also highlights the dominant role of international databases such as ProQuest and NCBI in providing extensive literature coverage, while emphasizing the need to include region-specific platforms like AJOL to ensure local context and relevance in health and social research.

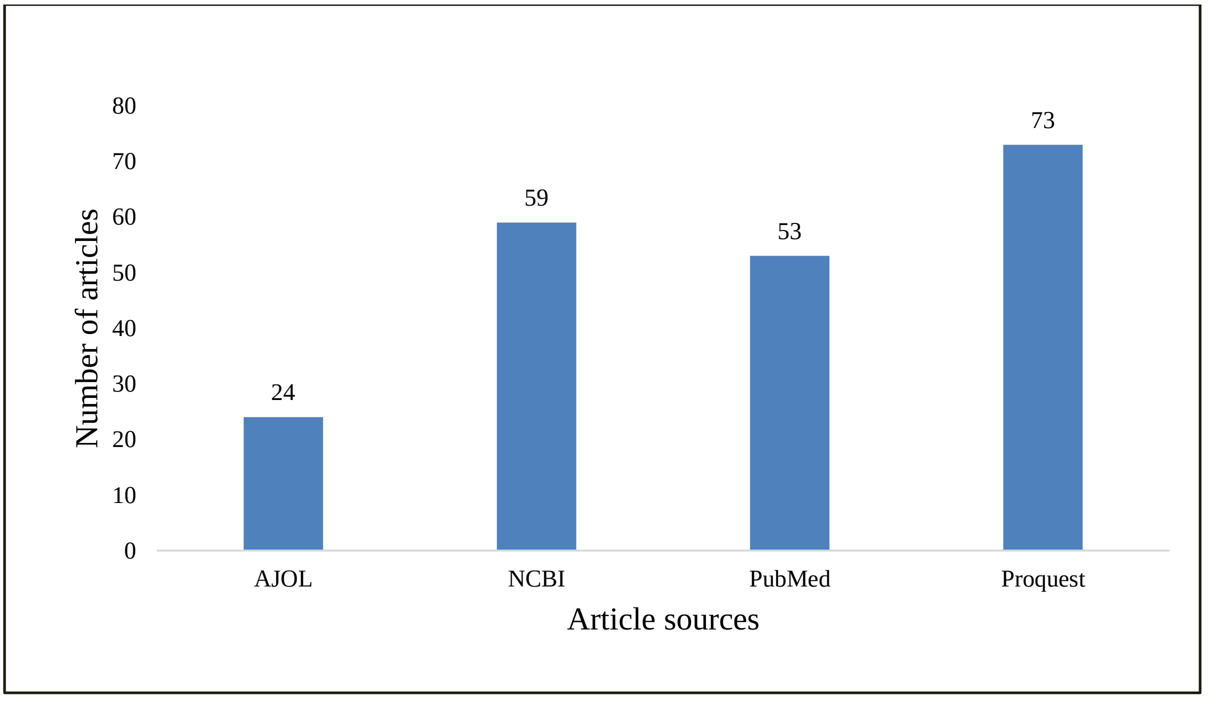

Figure 4: Articles reviewed with titles relevant to the study

Articles that have keywords in their abstracts were considered relevant to the research. Figure 5 below shows those articles totalling 127 articles. These articles were then reviewed to eliminate duplicates.

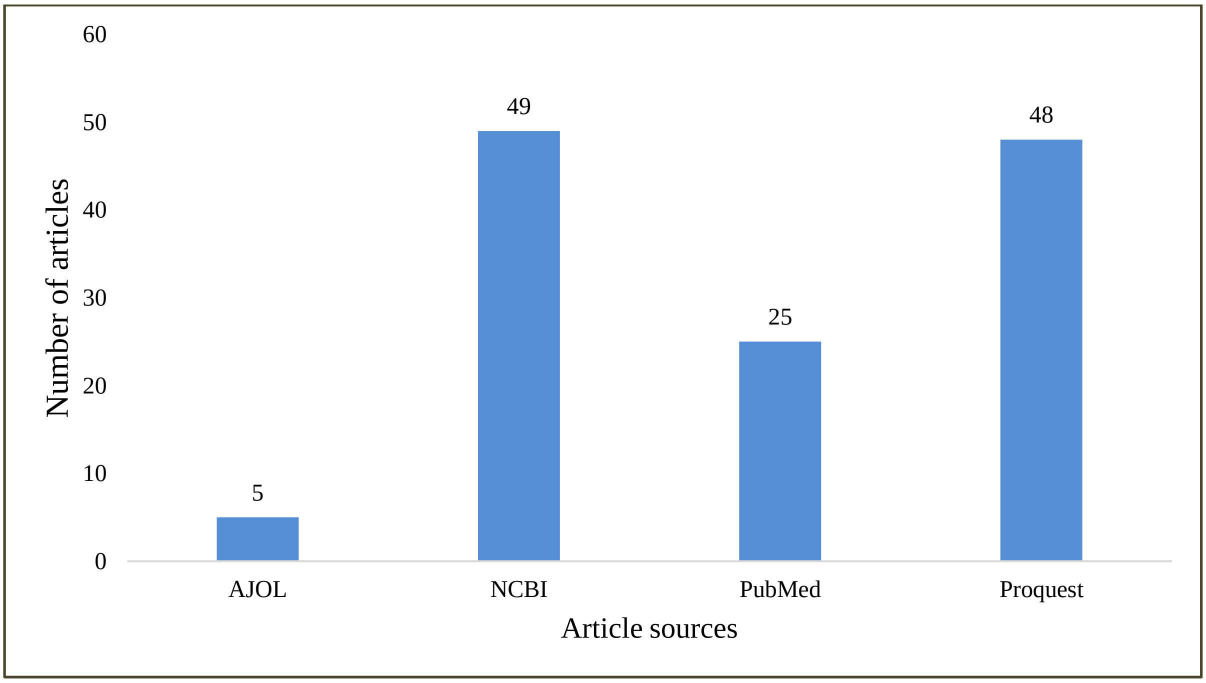

Figure 5: Articles reviewed with abstracts relevant to the study

It was necessary to reject all of the 82 articles with no keywords in their abstracts to determine the final number of articles to be considered in the study. A total of rejected articles without keywords in abstracts, which were eliminated from the study, are shown in Figure 6 below.

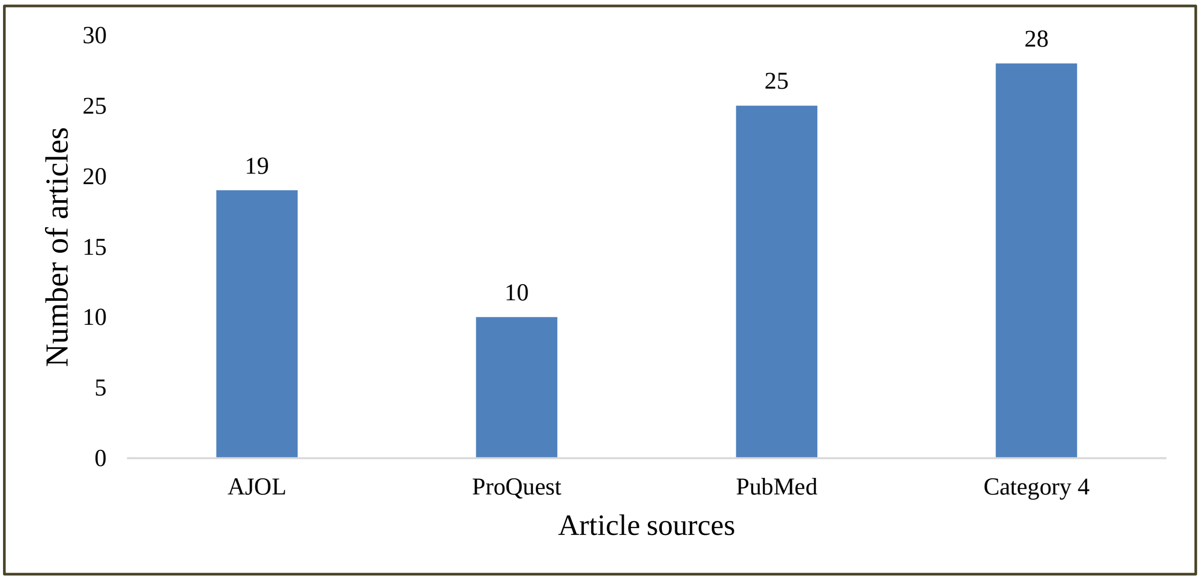

Figure 6: Articles reviewed with abstracts not relevant to the study

After consideration of duplicates among the reviewed articles, it was necessary to remove all duplicates from the four search engines: AJOL, NCBI, PubMed, and ProQuest. A total of 29 articles as rejected duplicates are shown in Figure 7 below.

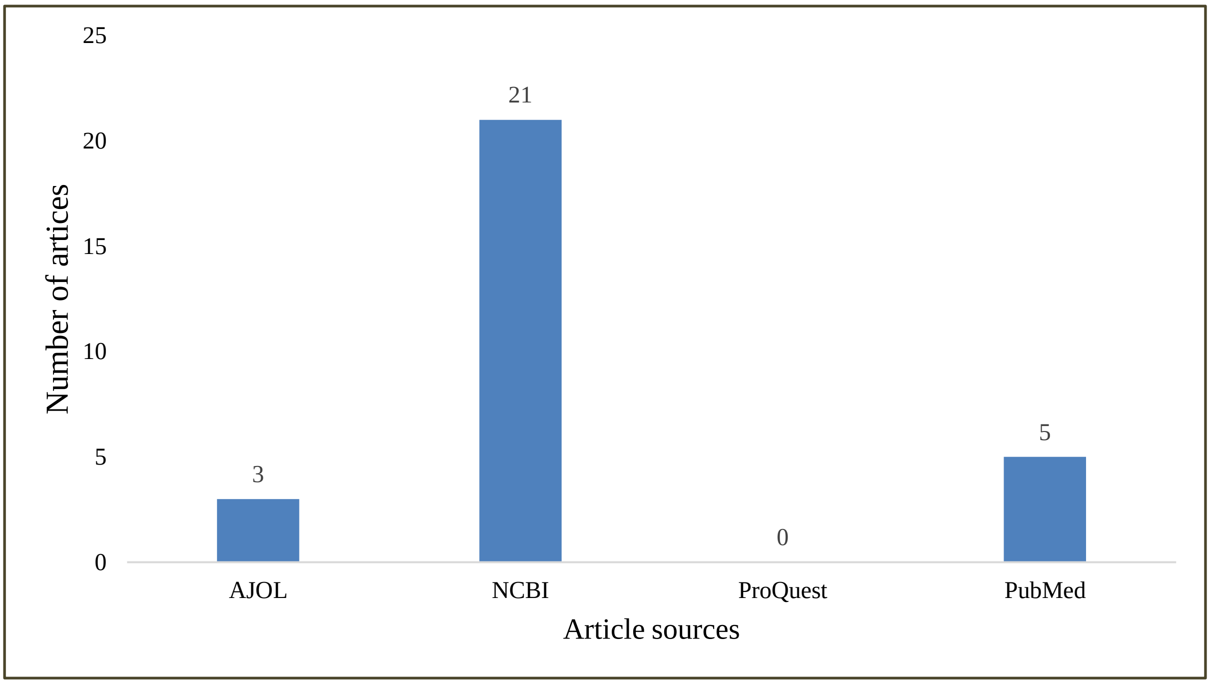

Figure 7: Articles rejected from the study with duplicates

The articles accepted without duplicates were predominantly from the four leading websites: AJOL, NCBI, PubMed, and ProQuest. This is illustrated in Figure 8 below are the study results.

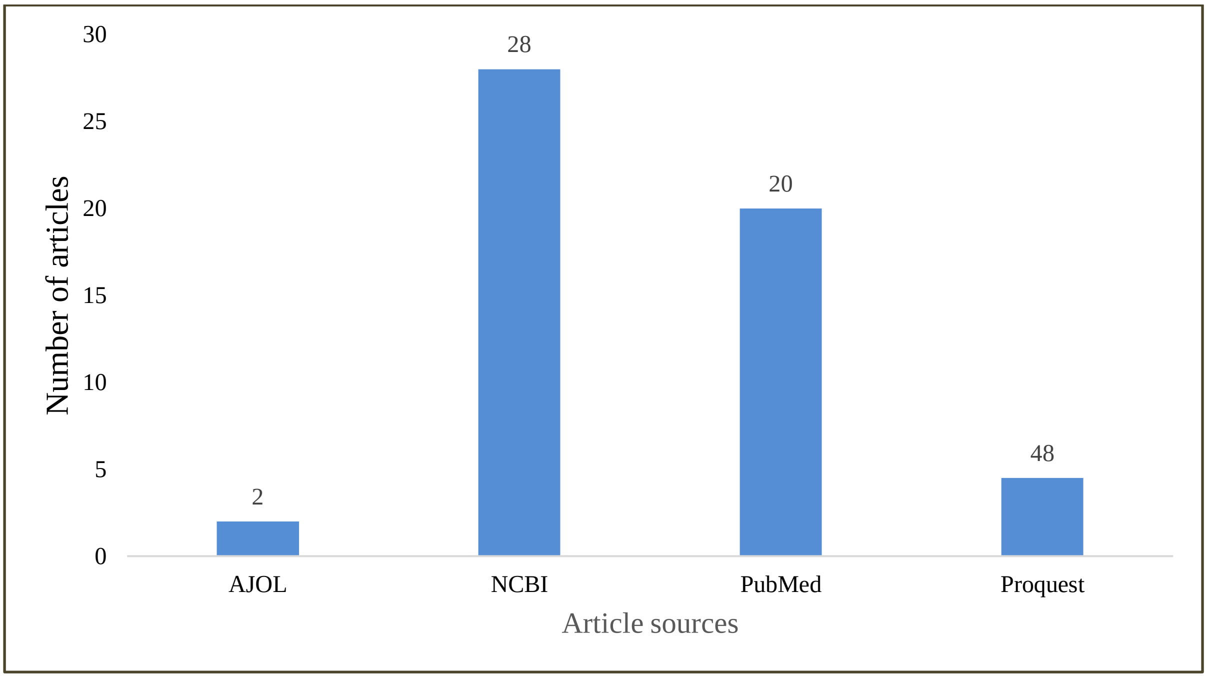

Figure 8: Articles accepted without duplicates

Error! Reference source not found. below shows that the articles are clustered according to t heir website source. These clusters include articles with keywords, considered abstracts with keywords, accepted articles without duplicates, abstracts without keywords, and articles rejected as duplicates.

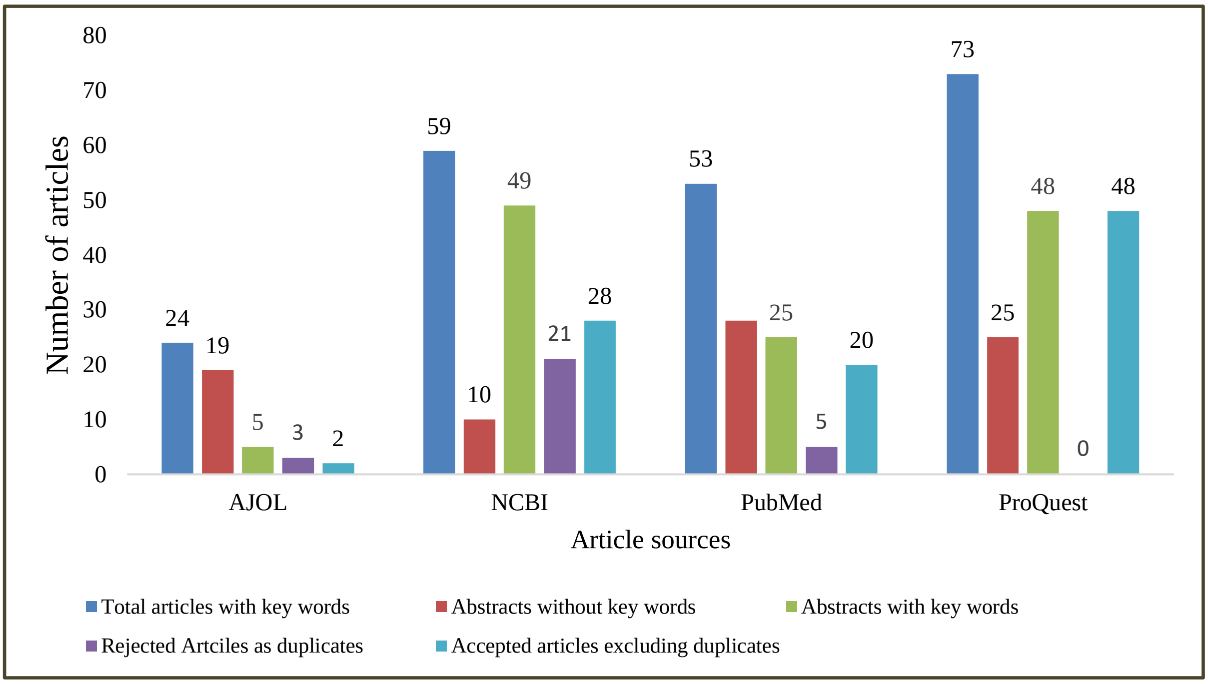

Figure 9: The number of articles reviewed with keywords, abstracts with keywords, articles accepted excluding duplicates, abstracts not having keywords and rejected articles as duplicates

The series of bar graphs collectively represent the systematic review process of 391 articles across multiple databases, following PRISMA methodology. Each graph visualizes a specific stage of the article screening, filtering, and selection process for a study involving AMD (Acid Mine Drainage) in South Africa.

The systematic review process analyzed the contribution of various academic databases, beginning with the total number of articles retrieved. ProQuest had the highest yield, contributing 163 articles (41.7%), followed by AJOL (90), PubMed (79), and NCBI (59). Notably, six databases RSC, Sabet, SCOPUS, SpringerLink, Web of Science, and Wired Space yielded zero results, suggesting either limited indexing for the specific topic or lower relevance. This outcome underscores the critical role of targeted database selection in literature reviews, especially when exploring niche or region-specific themes.

When refining results based on keyword presence in titles and abstracts, ProQuest, NCBI, and PubMed consistently emerged as strong contributors. ProQuest led in articles with relevant keywords in the title (73), reflecting its strength in volume. NCBI (59) and PubMed (53) followed, suggesting better-targeted relevance. AJOL's title relevance was considerably lower, with only 24 articles. For keywords in abstracts, NCBI (49) and ProQuest (48) remained dominant, while PubMed (25) and AJOL (5) trailed behind. However, NCBI had the most articles (28) where abstracts lacked key terms, raising concerns about content alignment despite its title strength. PubMed (25) and AJOL (19) also showed noticeable mismatches between titles and abstracts. ProQuest, in contrast, showed a better match between title and abstract content, indicating consistency in keyword usage.

The filtering process further examined duplicate articles and final accepted entries, refining the pool significantly. NCBI had the most duplicates (21), likely due to overlap with PubMed and similar platforms. In contrast, ProQuest had zero duplicates, reinforcing its contribution of unique content. Post-duplicate removal, ProQuest still led with 48 accepted articles, followed by NCBI (28), PubMed (20), and AJOL with only 2 accepted entries reflecting a high rejection rate. The summary graph (Graph 9) visually confirms these trends, showing that ProQuest and NCBI outperformed at almost every stage, except in duplicate management for NCBI. AJOL's contribution diminished significantly through the filtering stages, while PubMed maintained a moderate but balanced presence, albeit with a higher proportion of abstracts lacking keywords. This detailed review highlights ProQuest's comprehensive strength in both volume and relevance, and NCBI is strong but sometimes redundant yield.

Table 5: Overall Comparison and Insights

Database	Strengths	Limitations
ProQuest	Highest volume, high number of accepted articles, no duplicates	High number of irrelevant titles
NCBI	High precision in titles and abstracts, strong final acceptance	High duplication rate
PubMed	Moderate relevance, good number of accepted articles	Many abstracts lacked key terms
AJOL	Initially high volume	Low keyword presence, very low final acceptance

Conclusion

- NCBI and ProQuest emerged as the most effective databases in terms of both quantity and quality of relevant, unique articles.
- AJOL and PubMed played supporting roles, with AJOL contributing very little in final accepted studies.
- The data underscores the importance of targeted database selection and careful keyword filtering in systematic reviews.

4.1 TREATMENT SOLUTIONS FOR AMD

Numerous academics have researched and proposed several acid mine drainage treatment solutions. These solutions work by either removing heavy metals from acidic water or by adjusting the pH, and they are suitable for use in industrial or semi-industrial settings. Several of the therapy alternatives from the 98 papers in the study are detailed here, along with explanations to provide a clearer understanding of how each one works. Additionally, a preference between pH adjustment and heavy metal removal is highlighted in the treatment alternatives to stabilise water content. A few of these therapy alternatives include, but are not limited to, those that are briefly described below.

4.2.1 Phytoremedial treatment option

Phytoremediation is defined as the use of plants, microbiota, amendments, and/or agronomic techniques to contain or render contaminants harmless. It is applied for the remediation of soil, sediment, and water resources. This option uses plants that are resistant to absorbing metals and storing them in the soil while preventing contaminated soil from eroding. With the development of phytoremediation research, various challenges, and limitations to its application in real-world scenarios have been identified. The most pressing obstacles towards successful implementation are: 1) inefficiencies in plant performance – their ability to take up or stabilise metals and to do so in multi-contaminant conditions, 2) the need for better economic evaluation and opportunity – While the raw materials are less expensive than those using traditional, industrial remediation techniques, there is a need for more economic incentives to offset the amount of time it takes for complete remediation, and 3) the somewhat contradicting need for more unified nomenclature but also interdisciplinary research because with this treatment option, metals are not removed from the water (Thomas et al., 2022).

4.2.2 Algae, biochar, and bacteria treatment option

The sorption of heavy metals by algae is a complex process. Usually, there are two phases involved. Extracellular sorption is the first. It happens quickly and is presumably passive (see Figure 10). The following mechanisms are involved in this process, which occurs immediately after algae encounter metals: covalent bonding between metal ions and proteins and other polymers, micro-precipitation, surface complexation, and the interaction between metal ions and anionic cell ligands. Intracellular accumulation is the second stage. This is thought to be active since it moves more slowly than the first stage. The species-specific mechanisms at play include the formation of metal complexes by Phyto chelation (Du et al., 2022).

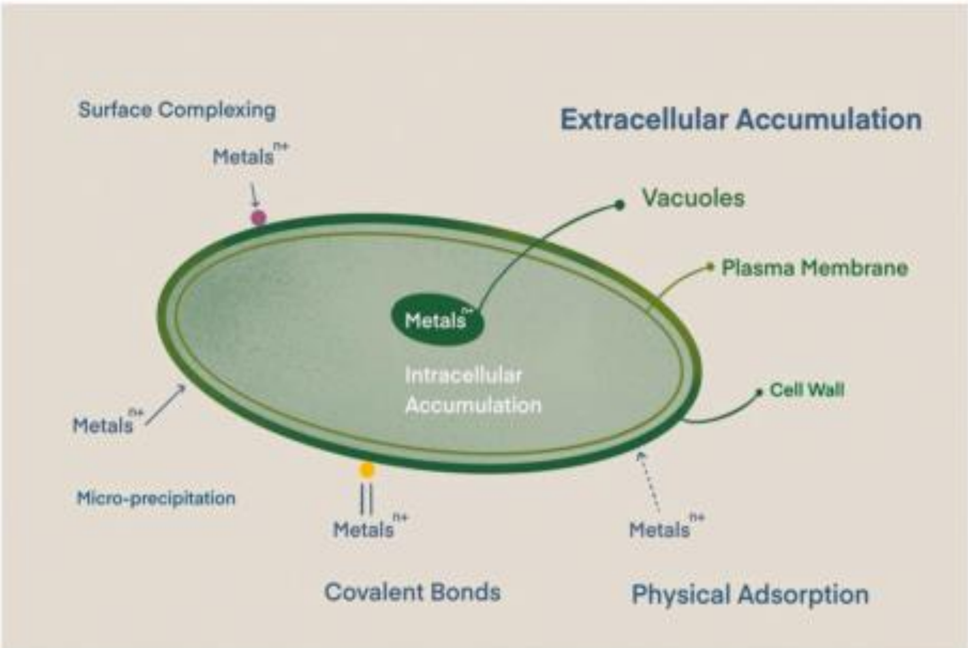

Figure 10: The mechanisms of heavy metal removal by algae (Du-Tianhao 2011)

The use of algae in AMD treatment is influenced by pH, Ion concentration, and temperature variations. This further complicates the process of metal removal during treatment. Physical sorption, Ion exchange, precipitation, complexation, and electrostatic interactions are some of the processes by which biochar is used in metal removal. However, the use of biochar may not be efficient in the presence of algae, and it also works differently under varying pH conditions(Oberholzer et al., 2022).

4.2.3 Fluidised-bed reactor treatment option

The primary method of using a fluidised-bed reactor involves inoculating aerobic sludge, which is removed from wastewater treatment plants, and packing it with silica sand (see Figure 11). The biological treatment occurs through a heating process at a temperature of 300°C to isolate and monitor physicochemical, nutrient, organic carbon, and metal parameters during the initial phases. At the same time, the process is observed to assess the contribution of abiotic processes to sulphate and chemical oxygen demand (COD) removal from acid mine drainage (AMD).

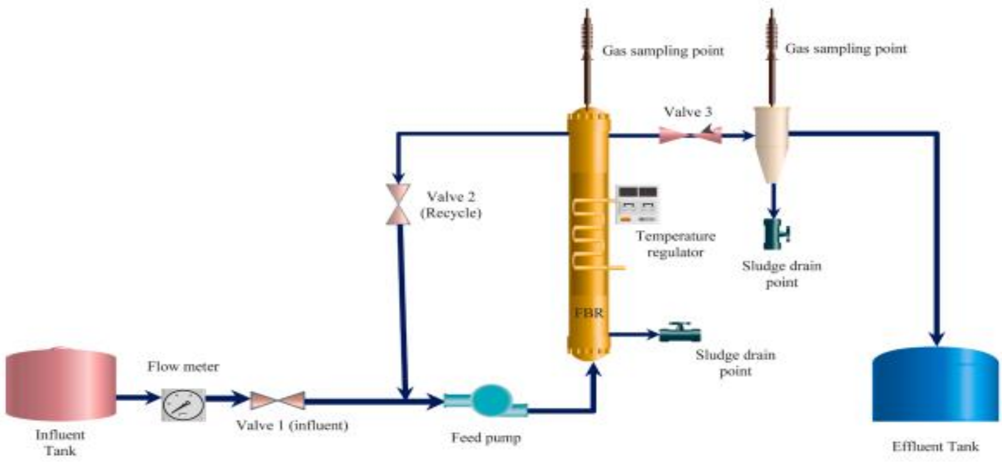

Figure 11: Fluidised-bed reactor treatment option (Makhathini TP, 2011)

4.2.4 Membrane coating treatment option and challenges

The manufactured membranes were coated using a method previously documented. In this treatment method, polyvinyl alcohol (PVA) is dissolved in deionised water. One of the difficulties with membrane applications is the decrease in membrane performance resulting from fouling (Ntshangase et al., 2021). Membrane filtration or coating treatment options varies depending on the surface properties of a membrane. Normally the surface properties assist to ascertain which type of nanofiltration to be used in the case of separation process for Ion from acid water (Agboola et al., 2017).

4.2.5 Cultivars Irrigated with Fly Ash treatment option

Use of lime, phosphorous rock, artificial wetlands, and the reverse osmosis process. The cost of the methods used for decontaminating AMD water varies, as some methods, such as fly ash (FA), are less expensive and can enhance the irrigation water supply compared to liming, which is more costly (Raletsena et al., 2022).

4.2.6 Cellulose cationised using CHPTAC and GTMAC treatment option

Cellulose cationised using 3-chloro-2-hydroxypropyl trimethylammonium chloride (CHPTAC) and glycidyl trimethylammonium chloride (GTMAC) were found to be effective sorbents for the removal of Cr (VI) ions from synthetic and actual samples of mine contaminated water. Cellulose cationised using GTMAC showed greater removal capacities at pH 4, probably due to its higher ionisation efficiency, as determined by elemental analysis. However, the challenge with this type of option is that the adsorbents were also found to have significant antimicrobial properties, thereby inducing the production of reactive oxidative species and reducing the viability of E. coli cells from ~77% to ~56% (Etale et al., 2021).

4.2.7 Congo red dye (CR) adsorption treatment option

This method involved the adsorption of Congo red dye (CR) by a polycationic Fe/Al Di-metal nanostructured composite (PDFe/Al), which was created using Fe (III) and Al (III) recovered from real AMD (Muedi et al., 2022).

4.2.8 Quicklime and fly ash treatment option

This is a combined method using CO_2, soda ash, lime, and magnetite, which is employed at a semi-industrial scale of treatment. Based on a life cycle cost analysis (LCCA) of coal mines in South Africa, it proved to be feasible and economical. The treatment could lower mineral recovery while maintaining the pH level of the AMD (Munyai et al., 2022).

4.2.9 Chitosan membranes coated with polyamide

Polyethersulfone (PES) membranes coated with a polyamide layer and infused with chitosan have been utilised as AMD therapy options. A chitin is defined as the natural polymer found in fungi cell walls, exoskeletons of insects, and the shells of crustaceans. Several heavy metals have been reported to be removed through this type of option, although some fouling membrane processes have also been observed. No observations were encountered around the adjustment of pH during this processing, thus making it more effective towards the metal removal process (Mathaba & Daramola, 2020).

4.2.10 Sludge treatment option

Sludge samples are composed of several salts and minerals that share the same chemical composition as the thermonatrite, vonsenite, halite, and hematite or magnetite groups. To reduce the acidity of the water to an acceptable level, this kind of treatment works by removing heavy metals from AMD (Munyengabe et al., 2020).

4.2.11 The metabolomics phenomenon

This treatment option involved using metabolites found in potatoes to detect the presence of untreated AMD and other fly ash-treated AMD solutions. There is not much metal recovery from this process, together with high probabilities of water pH neutrality (Munyai et al., 2022).

4.2.12 Bacterial Reduction treatment option

The approach of bacterial reduction is a feasible choice because it is environmentally friendly and economical. This is so because of the biogeochemical behaviour of uranium bioremediation U(VI), which usually functions more effectively during the reduction process. This sort of treatment also depends on the pH level, which is less than 5.5. The challenge of this treatment option is that it cannot work well if the pH is higher than 5.5. (Calisto et al, 2023). The use of high-density sludge, it has been reported that certain heavy metals may be removed but not in totality with the combination of wetland assistance

4.2.13 The Life cycle assessment (LCA) treatment method

This method has the potential to address the risks associated with socioeconomic issues and health. This kind of treatment option happens in semi-industrial areas. Essentially, using an integrated process that involves a soda ash, magnesite, lime, and CO_2 bubbling treatment. In South Africa, AMD, like other pollution factors, has the potential to cause detrimental effects on the environment, human health, access to clean water, economic impacts, and socioeconomic instability. Through this treatment option, AMD is expected to affect the metal recovery model, thereby demonstrating some level of viability due to its low-cost treatment system. LCA is a quantitative technique used to evaluate the environmental impact of a process, product, or service. The method considers all energy and raw material inputs, accounts for solid, liquid, and gaseous wastes, and performs ‘cradle-to-gate’ analysis. The LCA condenses hundreds of engineering inputs into a manageable set of indicators related to environmental and human health. The data can then be shown by the LCA practitioner to highlight the system's hotspots or to contrast the outcomes with those of other similar processes (Masindi et al., 2018).

4.2.14 Neutralising, stabilising, and removing contaminants through physical, chemical, and biological processes

Heavy metals carried by rivers and streams, and ultimately into the aquatic environment, are removed from contaminated sediments using this type of treatment approach. These heavy metals have gathered to contaminate the water at the sediment compartment level. Therefore, to recover the heavy metals from the aquatic environment, a variety of methods must be used to transform them into a soluble phase (Lucas et al., 2021).

4.2.15 Cellulose-rich waste products

This treatment occurs through the possible remediation of AMD using cellulose-rich waste products. The products are generated from natural feedstock from highland areas. The contribution of AMD from abandoned mines makes it easier for feedstock to grow as natural products, primarily where water is continually discharged into streams or natural wetlands. When the AMD reaches these celluloses, it neutralises the free acidity and suspended particles. The resultant effluent is free of heavy metals, thus ensuring that the stream meets the environmental discharge requirements proposed by legislation. The predominant pollutant in mine water is usually sulphate, which can react with other salts to form a range of compounds that increase the salinity close to the discharge site. Therefore, to adhere to discharge regulations, cellulose-rich waste products decrease the sulphate concentration through treatment (Simate & Ndlovu, 2014).

4.2.16 Limestone and cow manure treatment option

The study indicates a notable increase in pH levels and a notable decrease or elimination of sulphate metals, such as Al, Fe, Zn, and Mn, when employing limestone and cow dung as a treatment option for AMD. Therefore, the elimination of these heavy metals highlights the importance of cow manure and limestone in the treatment process of the value chain. By a process of precipitation, the limestone settles after each addition. The rectification techniques for AMD have proven to be persuasive (Vadapalli et al., 2015).

4.2.17 Feedstock treatment option

In place of first-generation feedstock derived from edible crops, this enters the fray with second-generation feedstock, such as cellulose plant materials like woody crops, agricultural leftovers, and grass, including raw materials for biotechnological manufacturing. Locally, bagasse from sugarcane, mielie mill products, grass, and the rest are used as second-generation feedstock. For the intended use, all of these appeared effective (Westensee et al., 2018).

4.2.18 The Barium Carbonate Disperse Alkaline Substrate (BDAS) treatment system

The procedure clarified how AMD entered the reactor, including calcite combined with an organic matrix and moved gravitationally throughout the system. At this stage, it neutralises and precipitates oxyhydroxy sulphate, which is a trivalent metal similar to Fe and Al. The water is now alkalinised after passing through the reactor, which contains a mixture of organic matrix and barium carbonate (BaCO3). At the same time, salts (like Ca and Mg) and divalent metals like (Zn and Mn) immobilise as BaSO4 and neo-formed carbonate minerals, respectively. After that, the water passes through the cascade and the decanter (van Wyk et al., 2022).

4.2.19 Chemical neutralisation using lime or limestone

This type of treatment option results in a sludge. At this point, metals are released into the environment through the disposal of sludge. However, the challenge with this type is that it causes potential environmental pollution. Consequently, the sludge produced in a process requires storage facilities and disposal mechanisms to minimise the risk of environmental pollution. Therefore, making the treatment option is not viable for some areas due to its expensive costs. There is a need for a specialised design for such treatment options (Kefeni, 2015)

4.2.20 Wetland and carbonate rocks drain treatment option

This serves as a passive treatment option. The carbonate rocks are used to raise or lower the acidity or alkalinity scale level (pH) and limit metal solubility. The metals continue to move but as insoluble suspended particulates. Then the wetlands reduce the sulphate content, which the carbonate rocks do not have control over. This type of option is viable and requires good programmes to protect the wetlands and proper education on its importance as a natural solution (Humphries, 2016).

4.2.21 Abundant cellulose-rich waste product

This can be used in rural, semi-rural, semi-industrial, and urban areas. The option is quite viable and less costly (Westensee, 2018)

4.2.22 pH adjustment treatment option

Increasing the pH alters the number of metals available in the water – depending on the geochemical environment that surrounds the AMD source (Akcil & Koldas, 2006).

4.2.23 Biological and chemical treatment option

The use of sulphate-reducing bacteria facilitated the biological process, while the chemical process involved the use of lime and limestone. This option is expensive, considering that lime needs to be sourced before it can be utilised. As a result, the use of coal fly ash (FA) becomes a viable alternative for metal removal and pH adjustment (Thisani et al., 2022).

4.2.24 Second-generation feedstocks (lignocellulosic biomass)

This was achieved by utilising grass as a feedstock and subsequently converting the acid-pre-treated grass into valuable bio-products. This is the result of the high carbon content found in the bio-refineries. Through this option, some of the heavy metals can be removed from AMD. An overview of the above treatment alternatives typically suggested during the treatment process reveals that most choices involve removing heavy metals from AMD. Of the 24 therapy methods, 14 (58.3%) are recommended for the elimination of heavy metals. Table 6 indicates that while 4 out of 24 (16.7%) treatment options remove both heavy metals and adjust pH simultaneously, there are also 6 (25%) treatment options recommended for adjusting pH (Westensee et al., 2018).

Table 6: Different types of treatment options (removal of heavy metals treatment options and the pH adjustment treatment options including Article Authors).

No.	***Treatment option***	***Treatment purpose***		
		Metal Removal	**pH Adjustment**	**Articles Authors**
1.	Phytoremedial	**Yes**	**Yes**	**Thomas et al, 2021**
2.	Algae, biochar, and bacteria		**Yes**	**Oberholster et al, 2019**
3.	Fluidised-bed reactor	**Yes**		**Makhathini et al, 2011**

4.	Membrane coating	**Yes**		**Ntshangase et al, 2021**
5.	Cultivars Irrigated with Fly	**Yes**		**Raletsena et al, 2022**
6.	Cellulose cationised using CHPTAC and GTMAC	**Yes**		**Elate et al, 2021**
7.	Congo red dye (CR) adsorption	**Yes**		**Khathutshelo et al, 2022**
8.	Quicklime and fly ash	**Yes**	**Yes**	**Ogola et al, 2024**
9.	Chitosan membranes coated with polyamide	**Yes**		**Mathaba & Daramola, 2020**
10.	Sludge treatment option		**Yes**	**Munyengabe et al, 2020**
11.	The metabolomics phenomenon	**Yes**		**Munyai et al, 2022**
12.	Bacterial Reduction		**Yes**	**Castillo et al, 2023**
13.	Life cycle assessment (LCA) methodology	**Yes**		**Masindi et al, 2018**
14.	Neutralising, stabilising, and removing contaminants through physical, chemical, and biological processes	**Yes**	**Yes**	**Lucas et al, 2021**
15.	Cellulose-rich waste products	**Yes**		**Simate &Ndlovu 2014**
16.	Limestone and cow manure		**Yes**	**Vadapalli et al, 2015**
17.	Feedstock remedial treatment	**Yes**		**Westensee et al, 2018**
18.	The BDAS	**Yes**		**Van Wyl et al, 2022**
19.	Chemical neutralisation using lime or limestone		**Yes**	**Kefeni, 2015**
20.	Wetland and carbonate rock drains	**Yes**		**Humphries, 2020**
21.	Abundant cellulose-rich waste product	**Yes**		**Westensee, 2018**
22.	pH adjustment		**Yes**	**Akcil& Koldas, 2006**
23.	Biological and chemical	**Yes**	**Yes**	**Thisani et al, 2022**
24.	Second-generation feedstocks (lignocellulosic biomass)	**Yes**		**Westensee et al, 2018**

4.2 THE FRAMEWORK FOR MANAGING AMD

The most used method for managing AMD is groundwater neutralisation with lime or passive treatment options (ref). To prevent substantial harm to the ecosystem, the basins reduce the impact of effluent to levels that the ecosystem can tolerate. Various departments are required by law to carry out their distinct tasks in the AMD management system that is now in place in South Africa.

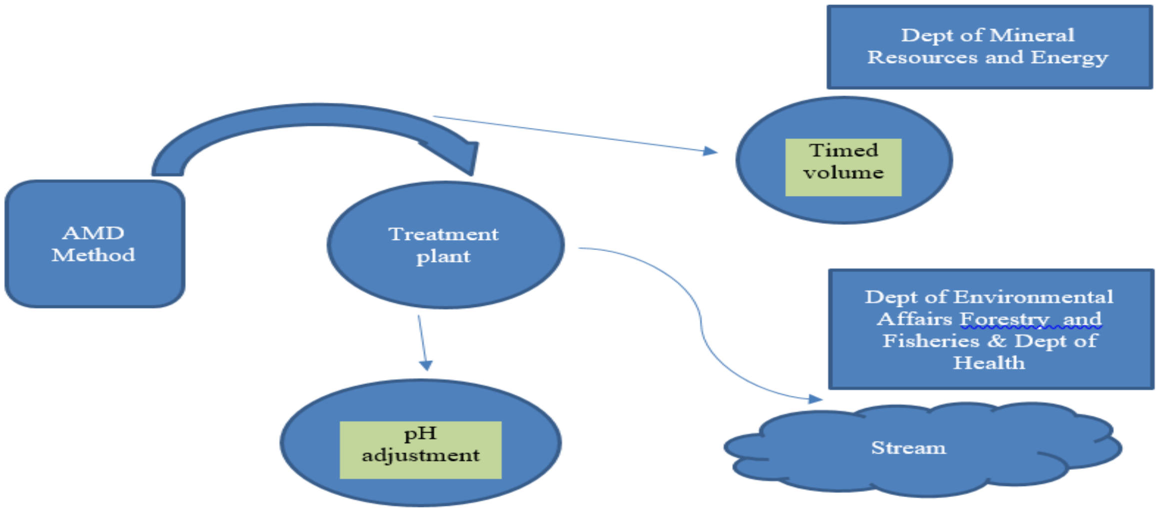

Figure 12: Illustration of current AMD treatment framework in South Africa

Figure 12 above illustrates how AMD is deposited at the treatment plant and subsequently discharged into the streams without pH or timed volume adjustment, resulting in different government departments being responsible for various interests. The current framework, which incorporates several policies aimed at addressing the challenges of managing acid mine drainage in South Africa, is illustrated in the figure above. AMD is first released or discharged from mines that are either closed or still in operation, typically containing heavy metals and low-pH water. The treatment plant receives acidic water for stabilisation and pH adjustment. From this point on, the water volume is timed and is typically observed by the Department of Mineral Resources and Energy.

Before the water is released into the streams, the Departments of Environmental Affairs, Forestry, Fisheries, and Health monitor their interests by activating applicable laws. Thereafter, no department monitors the pH level when the water is released, which makes it hazardous and can have multiple negative effects on the environment. Therefore, this supports the study's aim, which is to address the differences or discrepancies among government departments.

4.3 AMD LEGISLATION AND POLICY FRAMEWORK

Section 24(a) of The Republic of South African Constitution, 1996, enshrines the right of everyone "to an environment that is not harmful to their health or well-being," while Section

24(b) states that everyone has the right: “to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that (1) prevent pollution and ecological degradation; (2) promote conservation; and (3) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.” (The Constitution of RSA, Chapter 2 Section 24, 1996).

Section 19 of the National Water Act deals with the prevention and remedying the effects of water pollution by a land user for any activity as stated in sub-section (1) paragraph (b) “any other situation exists, which causes, has caused or is likely to cause pollution of a water resource, must take all reasonable measures to prevent any such pollution from occurring, continuing, or recurring.” Such person/land user company if they do not comply with the Department, “… may recover all costs incurred because of having to implement remedial steps to deal with any resulting pollution due to non-compliance to a departmental directive under Section 19” (National Water Act, Chapter 3, Section 19).

Accordingly, the MPRDA also has a liability provision, which is more imperative in the AMD phenomenon. Section 38(1)(d) states that a mine must, "as far as it is reasonably practicable, rehabilitate the environment affected by the prospecting or mining operations to its natural or predetermined state or to a land use which conforms to the generally accepted principle of sustainable development" (Feris and Kotze). It further stipulates that a mine is also "responsible for any environmental damage, pollution or ecological degradation as a result of his or her reconnaissance prospecting or mining operations which may occur inside and outside the boundaries of the area to which such right, permit or permission relates" (Feris and Kotze).

Several provisions are made under the National Environmental Management Act and the National Water Act, which focus on waste-related activities that affect water resources, thereby exacerbating challenges related to acid mine drainage (AMD). This is covered in Section 1 of the Act, which defines waste as “any substance, whether or not that substance can be reduced, reused, recycled and recovered (a) that is surplus, unwanted, rejected, discarded, abandoned or disposed of; or (b) which the generator has no further use for production; (c) that must be treated or disposed of; or (d) that is identified as waste by the Minister by notice in the Gazette and includes waste generated by the mining, medical or another sector” (Feris and Kotze).

CHAPTER FIVE: DISCUSSION

This chapter discusses and contrasts the findings reported in this study with those of previous studies conducted elsewhere, highlighting the similarities and differences between them. Furthermore, it highlights the in-depth differences between various AMD options, their management, framework, and associated legislation. The discussion highlights the viability of some of these treatment options and their cost-effectiveness. The chapter concludes with a discussion of the limitations and recommendations for future research to advance the relevance of the study.

5. DISCUSSION

This study aims to recommend a model approach for a harmonised policy framework on the treatment, management, and discharge of AMD in South Africa. The study had specific objectives to achieve, namely:

Objective 1: To describe the evolution of the policy framework on AMD in South Africa. The aim is achieved by following the current legislation on AMD in South Africa, within which several departments are responsible for managing AMD in different ways. Such departments have a specific, limited interest in AMD due to their legislative mandates.

Objective 2: To identify the various treatment options available for AMD. This objective was achieved through a rigorous process of reviewing secondary data from relevant articles and reports on AMD using multiple search engines. These were systematically screened following a PRISMA model until all relevant abstracts were included in the study.

Objective 3: To propose a model approach for a harmonised policy framework for AMD treatment management and discharge in South Africa. This objective was achieved through a proposed harmonised AMD treatment framework that can be recommended to suit the South African context.

5.1.1 AMD policy evolution in South Africa

Understanding the history, causes, and current treatments of AMD is essential for addressing the issue holistically in South Africa. The current study indicates that South Africa is well known for being at the centre of global mining activity. Consequently, the environment and public health continue to bear the brunt of AMD from closed mines, particularly those that generate gold and coal.

The literature states that AMD is formed through processes that involve underground water coming into contact with pyrite rock and becoming oxygenated, resulting in acid due to the presence of heavy metals. As this process unfolds, the water seeps into the environment, resulting in various undesirable conditions.

Therefore, the government must guarantee that human beings live in a safe environment and must safeguard its inhabitants from public health threats. Numerous departments assign themselves a set of duties to address AMD in one way or another. The departments working on legislation related to AMD management are the Department of Health, the Department of Fisheries, the Department of Mineral Resources and Energy, and the Department of Environmental Affairs and Development Planning.

By developing policies that align with these agencies' responsibilities, the claim identified during the AMD development process demonstrates a notable advancement in addressing the issue at hand. Though each department tries to address the issue, some regions are left out, and the situation worsens while stakeholders wait for a response. This remains the primary source of the problem.

5.1.2 Effectiveness and efficiency of AMD treatment options within South Africa

Often, AMD is recognised as a significant water challenge that requires specialised treatment procedures. Numerous academics have investigated various treatment approaches that can be implemented in standard sewage treatment plants located in industrial or semi-industrial areas. These treatment approaches are versatile and vary in their effectiveness and efficiency. The analysis in the current study mainly focused on South Africa. A methodological review process, which provided a more uncontested backdrop, validated the quality and dependability of the facts gathered during this process flow. A comprehensive overview of various AMD treatments investigated in South Africa was provided by the 98 publications that were analysed during this procedure. The findings covered in the results chapter indicate that differences and commonalities have been conceived using synergies and tables.

Evidence was presented along the way to support the theory that AMD originated from mines that are currently in operation, as well as from others that are no longer operational. In South

Africa, significant efforts have been made to mitigate the impacts of AMD through various laws and policies, as it has been demonstrated over time that AMD has detrimental effects on the environment, aquatic systems, agriculture, and public health.

However, due to the chaotic implementation of these regulations, it has not been feasible to achieve the desired results fully. This is probably because some legal limitations and boundaries must be respected. The examined literature provided an overview of potential courses of action depending on the features of different urban and semi-urban settings, such as the size and capacity of wastewater treatment plants to manage acid mine drainage (AMD).

The current study's findings indicate that there is evidence to support the ability of treatment alternatives to either remove heavy metals from AMD or neutralise the water by adjusting its pH values. Several AMD treatment options are available in South Africa. These treatment methods are either active or passive in their approach, depending on the type of treatment plant. For the acid water to be acceptable for various uses, it becomes essential for it to be well treated by either removing the heavy metals or through pH adjustment processes. Since it is a known fact that AMD predominantly originates from abandoned mines, this justifies the presence of heavy metals in these waters, which could have ripple effects on public health and environmental degradation. The numerous research papers that were reviewed found that the most popular methods for stabilising water acidity include the use of sludge treatment, pH adjustment, natural wetland vegetation, and heavy metal removal. The effectiveness and efficiency of these treatment options depend on factors such as the type of treatment plant, whether it is located in an industrial or semi-industrial area, and whether the processes are cost-effective. The more advanced treatment options, which operate in well-established industrial areas, may have the potential to remove heavy metals that can be repurposed as a helpful resource. However, this requires further investigation, as it is not within the scope of this study. The evidence, however, of heavy metals in acidic water does exist, as observed on the riverbanks of red streams and wetlands. The treatment options vary according to the cost-effectiveness, efficiency, and contribution to a green economy.

5.1.3 Economical implications of AMD in South Africa

A critical piece of foundational data about AMD must be addressed using an active or passive process system as soon as it is released into the environment at an untreated stage. Several researchers who have examined the literature investigated possibilities that demonstrate evidence that treating AMD is quite expensive and demands that many resources have to be employed successfully (Westensee et al., 2018). After several thoroughly investigated AMD therapy approaches from different domains were tried and tested for viability, the expense and capital required to complete the task continued to be a challenge. Therefore, in comparison to active preferences, the passive options appear to be superior. Low-cost treatment facilities are willing to use these passive methods (Ramla & Sheridan, 2015).

Due to the abundance of treatment choices, only a specific sewage plant from both urban and semi-urban areas can be used for the process. The only thing the government can do to help with the process is enact laws to establish control mechanisms (McCarthy, 2011). These laws are burdensome because they demand greater capabilities from human resources, as well as other types of equipment, to test and analyse the samples taken from the rivers and streams surrounding the mining belt areas. A decision to treat AMD using various treatment options is one of the costly exercises, especially when negligence by owners has left the mine unattended, contrary to legislative requirements. Consequently, it is imperative to practice the correct measures by avoiding and treating AMD if all other systems do not work. To safeguard ecosystems and downstream water use (in compliance with discharge, surface, or groundwater quality regulations), AMD treatment may be necessary. Reusing water on-site, such as by purifying it to reduce operating expenses, is another option. Maintaining costly or necessary on-site infrastructure in this manner can help reduce operating expenses.

5.1.4 Proposed harmonized and treatment option in South Africa

The study results demonstrate a clear and persistent pattern of fragmentation and silo mentality among the several departments tasked with handling AMD in South Africa. The Departments of Water Affairs, Energy, and Mineral Resources, as well as the Departments of Environmental Affairs, Forestry, and Fisheries, including Health, all have regulations in place. Each of these departments has distinct interests, which contribute to the level of disarray in how the impacts of AMD in South Africa are addressed holistically. A unified framework or appropriate design structure can provide several advantages that should be investigated to reap financial rewards and support the green economy (Feris & Kotze, 2014).

Several active and passive remediation treatment approaches have been established for AMD. The problem persists in the fragmented policies that are in place to address the challenges that arise (Feris & Kotze, 2014). To accommodate all government agencies and provide a consistent approach to problem-solving, this study aims to establish a unified AMD framework policy.

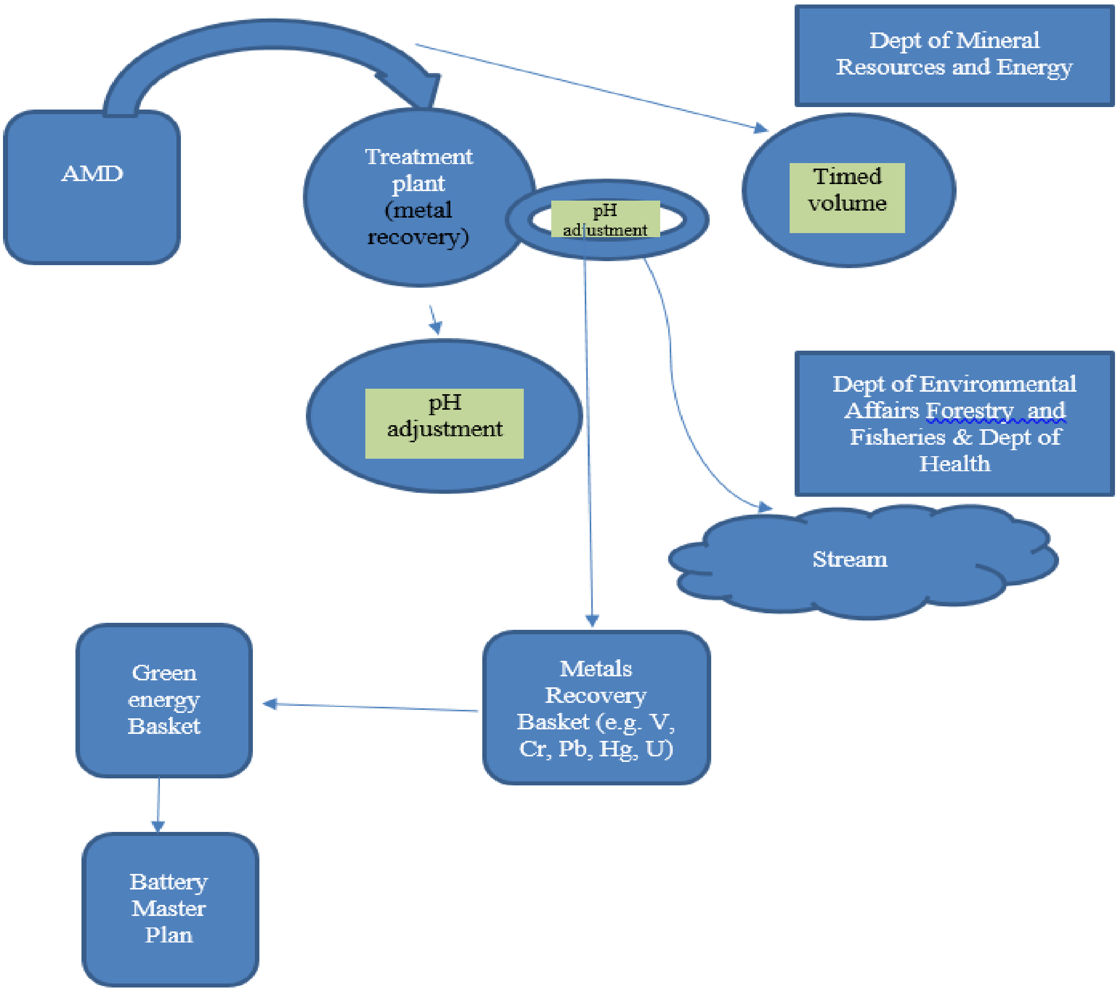

Figure 13: Illustration of proposed harmonised treatment option framework for AMD in South Africa

The inadequacies and required actions to rectify South Africa's disjointed AMD treatment strategy are illustrated in Figure 13 above. Three crucial phases encompass some of the issues the mining industry faces with AMD control, namely, pH adjustment, pH adjustment with metal removal, and timed volume.

Once the corrosive water reaches the treatment facility, it must undergo a programmed volume process to allow the heavy metals to settle. Subsequently, the Department of Mineral Resources and Energy should make suggestions for heavy metal recovery based on water testing results.

To ensure that the acidic water is safe to discharge into streams and the environment, tests must be conducted by the Department of Environmental Affairs, the Department of Forestry and Fisheries, and the Department of Health (see Table 6).

Table 7: The departments involved in AMD treatment and management

Department	Departmental Role in AMD Treatment & Management	Legal Mandate
Department of Water and Sanitation (DWS)	- Monitor water quality and quantity in mining areas - Regulate the discharge of contaminated water - Issue water use licences - Enforce remediation measures to protect water resources	**National Water Act (NWA), 1998** - Section 19: Duty of care to prevent and remedy water pollution - Chapter 4: Regulates water use, including disposal of waste and effluent
Department of Forestry, Fisheries and the Environment (DFFE) -	- Oversee environmental impact assessments (EIAs) - Set norms and standards for environmental protection - Coordinate national policy on waste and pollution - Hold parties accountable for environmental degradation	**National Environmental Management Act (NEMA), 1998** - Section 28: Duty of care and remediation of environmental damage - EIA Regulations: mandatory for mining activities
National Environmental Management Act (NEMA), 1998	- Oversee environmental impact assessments (EIAs) - Set norms and standards for environmental protection - Coordinate national policy on waste and pollution	**National Water Act (NWA)** - Responsible for water use and licencing and water quality impacted by AMD

	- Hold parties accountable for environmental degradation - Section 28: Duty of care and remediation of environmental damage - EIA Regulations: Mandatory for mining activities	**Mineral and Petroleum Resources Development Act (MPRDA)** - Governs mining right but must exercise it in line with NEMA's environmental obligation
Department of Mineral and Petroleum Resources and Development Act (MPRDA)	- Grant mining rights and permits - Require environmental management programmes (EMPs) and mine closure plans - Monitor mine compliance with environmental standards	**Mineral and Petroleum Resources Development Act (MPRDA), 2002** - Section 38: Requires EMPs for environmental protection - Section 43: Mine closures and post-mining environmental responsibility **National Environmental Management: Waste Act (NEMA)**: - Regulates AMD-related waste handling and disposal, including permitting of waste
National Environmental Management Waste Act	- Manages classification, storage, and disposal of AMD-related waste. - Ensures safe handling of	**National Environmental Management: Waste Act (NEMA):**

	hazardous sludge and residues from AMD treatment	- Regulates AMD-related waste handling and disposal, including permitting of waste treatment facilities.

Supposing that the test results indicate that recovering heavy metals is now imperative, during a technique, the heavy metal complexes V, Cr, Pb, Hg, and U are usually detected and must be utilised effectively. Such optimism could be beneficial to the country's green, renewable energy sources. The South African economy is known to be significantly impacted by heavy metals. Thus, unleashing it should only occur when there is a deep understanding of the typical heavy elements recovered from AMD. The Republic of South Africa's battery master plan, which is dependent on acid water, is one of the benefits to be explored. In summary, the proposed integrated framework should eliminate residual generation. **Step 1**: AMD collected and pumped to an AMD treatment facility. **Step 2**: PH adjustment to precipitate the metals. **Step 3**: Aeration to change metals from liquid to solid. **Step 4:** Ensure that metal sedimentation and mine water are free from metal flows from the top of metal sediment. **Step 5**: Ensure that metal recovery is for industrial application and use. **Step 6**: Reuse AMD-treated water for a mining water need.

5.1.5 What these heavy metals may offer, including the consequence of the recovery process

Vanadium (V) is an element that is often regarded as rare but has high value because it is costly to extract. It is utilised as a catalyst, a pigment for superconducting magnets, and in glass and ceramic manufacturing. A crucial mineral, chromium (Cr), plays a role in how insulin regulates the body's blood sugar levels. Asthma, eye irritation and damage, ruptured eardrums, and respirator irritation are possible side effects of exposure to chromium. Batteries, paints, ammo, cable sheathing, lifting weights, driving weight belts, lead crystal glass, radiation protection, and certain solders are among the many products that include lead (Pb). Furthermore, chromium helps store corrosive liquids due to its characteristic of resisting corrosion. It can impact the brain and central nervous system at high exposure levels, leading to unconsciousness, seizures, and even death. In the Earth's crust, coal deposits and other minerals contain mercury (Hg), a naturally occurring chemical element that is also found in rock and coal deposits. Unfortunately, it does not benefit the human body. Still, it is utilised in numerous industries to produce caustic soda and chlorine gas, and it is also employed in the manufacture of batteries, electrical switches, thermometers, and barometers.

5.1.6 Limitations

Firstly, the use of secondary data from websites chosen by the author to collect data for the study presented various limitations. Not many websites have titles and abstracts that include all the necessary terms. The maximum number of search engines utilised as sources for this article was four.

Secondly, the therapeutic options suggested by the examined articles did not overlap. AMD treatment in South Africa remains a fundamental challenging issue despite few attempts having been made to acquire the information available from the numerous departments involved in AMD.

Thirdly, from a public health perspective, all relevant departments should collaborate within a single, cohesive framework, considering the environmental issues associated with AMD. Lastly, future, in-depth studies on the synthesis of treatment policies may be sparked by this research.

CHAPTER SIX: CONCLUSION

This chapter gives a comprehensive analysis of the study conducted. Subsequently, it includes recommendations and limitations that affected the study throughout its progress. Such recommendations may be used for further research studies or to close the gaps encountered along the way.

6. SUMMARY OF FINDINGS

The treatment of AMD in South Africa is still difficult and lacks a unified, well-coordinated strategy among government agencies. There are several treatment options studied and recommended by researchers that aim to either remove or stabilise acidic water so it can be used for other activities without adverse effects. The different types of heavy metals that need to be removed from acidic water may play a crucial role in the country's economic state. However, there is a chance that this phenomenon can be addressed through several treatment options that have been researched, either by neutralising acidic water so it can be used for other purposes, such as agriculture, or by removing heavy metals, which could improve the nation's economic situation. In conclusion, future research is recommended to investigate the impact of water quality aspects following the removal of heavy metals and the neutralisation process. Harmonised policy frameworks are crucial for tackling AMD in South Africa and eliminating the department's silo mentality.

6.1 CONCLUSION

6.2.1 Objective One

The Desktop review process had included the search engines to seek existing literature. Search engines which were used included AJOL, NCBI. ProQuest and PubMed. Only articles that are peer reviewed were included in the Desktop review. The first step in the Desktop review was searching for articles with titles that include the following key words; acid mine drainage, treatment options, acid drain management policies and legislation, acid drain impacts, acid mine drainage on environment and public health. Articles that contain one or more key word were included to the next step. The second step was done through by screening the selecting articles that have abstracts which contain the key words; acid mine drainage, acid mine drainage impact, acid mine drainage treatment options, acid mine drainage policy, acid mine drainage legislation, acid mine drainage management, acid mine drainage legislation and regulations. The articles which had abstracts containing these key words were included in the next step. The third step was reviewing the selected articles, reading through them, and selecting articles that were relevant to the study and were used for analysis. The total of these articles were 98 articles.

6.2.2 Objective Two

On the review literature the focus databases were centred on secondary data regarding environmental and public health impacts. First database was focusing on the evolution of acid mine drainage in South Africa. Second database was focusing on available treatment options including the legislation and policies on environmental degradation and public health by acid mine drainage.

6.2.3 Objective Three

Data obtained from objective 1 and 2 was imported in a risk assessment methodology to the severity of acid mine drainage. Through a comparison of various options and what was available or used in South Africa in which a decision needed to be drawn on the harmonised acid mine drainage framework policy.

6.3 RECOMMENDATIONS

To effectively address the environmental and public health hazards posed by Acid Mine Drainage (AMD) in South Africa, a unified and collaborative approach is essential. A harmonised regulatory framework, jointly enforced by key governmental departments such as the Department of Water and Sanitation, Department of Mineral Resources and Energy, and the Department of Environment, Forestry and Fisheries should be urgently developed and implemented. This framework will enable improved coordination of AMD treatment, permitting, monitoring, and compliance. All reintegration of treated AMD into the environment or industrial use must strictly align with existing water quality standards to ensure safety and sustainability.

Furthermore, AMD can be transformed from an environmental liability into a valuable economic resource through innovation and investment. Incentivizing the recovery of metals like copper, zinc, and rare earth elements from AMD can offset treatment costs and attract private sector participation. Simultaneously, research and development into integrating passive and active treatment technologies such as wetlands, reverse osmosis, and lime dosing should be prioritized to enhance treatment performance and reduce long-term operational costs. These hybrid solutions can be tailored to various AMD profiles, promoting ecological balance while improving treatment efficiency.

In addition, mandatory Environmental Impact Assessments (EIAs) should be enforced for all new AMD treatment plants, ensuring early identification of potential risks and the development of mitigation strategies. Community-based and sustainable solutions must also be explored, including the use of bioremediation through sulfate-reducing bacteria, bioreactors, constructed wetlands, and algae-based neutralization. Promoting these low-cost, low-energy remediation technologies encourages innovation and long-term environmental stewardship. Together, these recommendations enable a strategic, integrated, and sustainable response to AMD challenges in South Africa.

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APPENDIX A: PLAGIARISM DECLARATION

SENATE PLAGIARISM POLICY:

I, Zanozuko Mbane, Student Number 511055, am a student enrolled in the Master of Public Health program for the academic year 2025.

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.
- I have included as an appendix a report from "Turnitin" (or other approved plagiarism detection) software, indicating the level of plagiarism in my research document.

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UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG	HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

Office of the Deputy Vice-Chancellor (Research & Innovation)

28/09/2023

Ref: W-PR-230928-01

TO WHOM IT MAY CONCERN

Waiver: This certifies that the following research does not require clearance from the Human Research Ethics Committee (Medical)

Investigator: Mr Z Mbane
Student No. (if appropriate): 511056
Staff No. (if appropriate):

Supervisor: Dr DM Masekameni

School: Public Health
Department:
Division:

Medical School
University

Project title: *Acid mine drainage treatment in South Africa: towards a harmonized policy framework*

Reason: Review of information in the public domain
No human participants will be involved in the study

Professor P Ruff
Chairperson: Human Research Ethics Committee (Medical)

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APPENDIX C: TURNITIN REPORT

Goitsemang Keretetse
Co-supervisor
20/05/2025

Prof MD Masekameni
Supervisor

Zanozuko Mbane Final Research Report MPH 18 March 2025-5.docx

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SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

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2	Fonseka, Charith. "Selective Recovery of Rare Earth Elements and Valuable Metals from Mining Wastewater by Membrane/Adsorption Hybrid Systems", University of Technology Sydney (Australia), 2024 Publication	1%
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APPENDIX D: LANGUAGE EDITORS CERTIFICATE

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PROOFREADING AND EDITING CERTIFICATE

This is to certify that **Busy Bee Editing** has diligently proofread and edited the research report titled:

Acid Mine Drainage treatment in South Africa: towards a harmonised policy framework

Author: Zanozuko Mbane
Student Number: 511055
Institution: University of the Witwatersrand

A research report submitted in partial fulfilment of the requirements for the degree of Master of Public Health in Exposure and Health. In the Faculty of Health Sciences, School of Public Health.

Scope of Editing

Our editing process included:
✓ Ensuring consistency in spelling, hyphenation, numerals, fonts, and capitalisation
✓ Correcting spelling, grammar, punctuation, and syntax
✓ Refining sentence structure and improving coherence
✓ Ensuring appropriate paraphrasing and academic tone
✓ Verifying formatting, layout, and references to the best of our ability

Disclaimer

Busy Bee Editing's role concluded upon delivery of the final version of this dissertation to Zanozuko Mbane. Any changes made thereafter—including amendments to grammar, spelling, or formatting—are beyond our responsibility. As the author, Zanozuko Mbane retains full discretion to accept or reject our suggestions and remains responsible for reviewing all edits and ensuring the accuracy and originality of the final submission.

Hugo Chandler - BA Psychology and Drama (UCT)
Proofreader and Editor at Busy Bee Editing

Brenda van Rensburg
Proofreader and Editor at Busy Bee Editing

Date of Completion: 14 June 2025

We are proud to have contributed to Zanozuko Mbane's academic journey and wish him every success in his future endeavours.

APPENDIX E: DATA COLLECTION TOOL

Table 8: Summary of secondary data collection from articles and reports on PubMed, ProQuest, AJOL and NCBI search websites:

No.	ProQuest Article Details, title, author, year.	Author	Year published	Treatment option	Article or report	Relevancy to the study
1.	The influence of a high-density sludge acid mine drainage (AMD) chemical treatment plant on water quality along the Blesbokspruit Wetland, South Africa Lourenco, Mauro; Curtis, Chris. **Water S.A; Gezina** Vol. 47, Iss. 1, (Jan 2021): 35-44.	Lourenco, Mauro; Curtis, Chris	Jan 2021	Plant and wetland treatment use. - Heavy metal removal	Article	Relevant
2.	Sustainable Co-Management of Acid Mine Drainage with Struvite Synthesis Effluent: Pragmatic Synergies in Circular Economy Masindi, Vhahangwele; Mbhele, Ryneth; Foteinis, Spyros. **Environments; Basel** Vol. 10, Iss. 4, (2023): 60.	Masindi, Vhahangwele; Mbhele, Ryneth; Foteinis	2023	Struvite - Heavy metal removal	Article	Relevant
3.	The assessment of diffuse pollution from acid-mine drainage using an updated and revised diatom assessment procedure as an added-value bio-monitoring tool Archibald, CGM; Taylor, J C. **Water Science and Technology; London** Vol. 55, Iss. 3, (Feb 2007): 151-160.	Archibald, CGM; Taylor, J C.	2007	Diatom Assessment - Heavy metal removal	Article	Relevant
4.	Characterization of Two Nanofiltration Membranes for the Separation of Ions from Acid Mine Water Agboola, Oluranti; Mokrani, Touhami; Sadiku, Emmanuel Rotimi; Kolesnikov, Andrei; Olukunle, Olubiyi Isola; et al. **Mine Water and the Environment; Dordrecht** Vol. 36, Iss. 3, (Sep 2017): 401-408.	Agboola, Oluranti; Mokrani, Touhami; Sadiku, Emmanuel Rotimi; Kolesnikov, Andrei; Olukunle, Olubiyi Isola; et al	Sep 2017	Nanofiltration membrane - Heavy metal removal	Article	Relevant
5.	Efficiency of a flocculent consisting of bentonite clay and fly ash for the removal of pollutants in AMD	Ntwampe, I O	Mar 2022	Flocculant	Article	Relevant

	Ntwampe, I O. **Water Practice and Technology; London** Vol. 17, Iss. 3, (Mar 2022): 661-674.			- Heavy metal removal		
6.	Techno-Economic Analysis of the Reclamation of Drinking Water and Valuable Minerals from Acid Mine Drainage Shingwenyana, Rhulani; Shabalala, Ayanda N; Mbhele, Ryneth; Masindi, Vhahangwele. **Minerals; Basel** Vol. 11, Iss. 12, (2021): 1352.	Shingwenyana, Rhulani; Shabalala, Ayanda N; Mbhele, Ryneth; Masindi, Vhahangwele.	2021	Magnesite softening and reverse osmosis	Article	Relevant
7.	Measurement of pore volume, connectivity and clogging of the pervious concrete reactive barrier used to treat acid mine drainage Ekolu, Stephen O; Solomon, Fitsum; de Beer, Frikkie; Bitandi, Louisette; Kilula, Rais N; et al. **Environmental Science and Pollution Research; Heidelberg** Vol. 29, Iss. 37, (Aug 2022): 55743-55756.	Ekolu, Stephen O; Solomon, Fitsum; de Beer, Frikkie; Bitandi, Louisette; Kilula, Rais N; et al	Aug 2022	Pervious concrete	Article	Relevant
8.	Microbial Community Diversity as a Potential Bioindicator of AMD and Steel Plant Effluent in a Channelled Valley Bottom Wetland Staebe, K; Botes, M; Madlala, T; Oberholster, P J; Cloete, T E. **Water, Air and Soil Pollution; Dordrecht** Vol. 229, Iss. 12, (Dec 2018): 1-15.	Staebe, K; Botes, M; Madlala, T; Oberholster, P J; Cloete, T E	Dec 2018	Microbial community - Heavy metal removal	Article	Relevant
9.	Application of Response Surface Methodology and Desirability Function in the Optimization of Adsorptive Remediation of Arsenic from Acid Mine Drainage Using Magnetic Nanocomposite: Equilibrium Studies and Application to Real Samples Gugushe, Aphiwe Siyasanga; Nqombolo, Azile; Nomngongo, Philiswa N. **Molecules; Basel** Vol. 24, Iss. 9, (2019): 1792.	Gugushe, Aphiwe Siyasanga; Nqombolo, Azile; Nomngongo, Philiswa N.	2019	Adsorptive remediation - Heavy metal removal	Article	Relevant
10.	The Treatment of Acid Mine Drainage Using Vertically Flowing Wetland: Insights into the Fate of Chemical Species	Beauclair Nguegang; Masindi, Vhahangwele; Titus	2021	Vertical Flowing wetland	Article	Relevant

	Beauclair Nguegang; Masindi, Vhahangwele; Titus Alfred Makudali Msagati; Tekere, Memory. **Minerals; Basel** Vol. 11, Iss. 5, (2021): 477.	Alfred Makudali Msagati; Tekere, Memory				
11.	<u>Effectiveness of Fly Ash and Red Mud as Strategies for Sustainable Acid Mine Drainage Management</u> Keller, Viktoria; Stopić, Srećko; Buhle Xakalashe; Ma, Yiqian; Ndlovu, Sehliselo; et al. **Minerals; Basel** Vol. 10, Iss. 8, (2020): 707.	Keller, Viktoria; Stopić, Srećko; Buhle Xakalashe; Ma, Yiqian; Ndlovu, Sehliselo; et al.	2020	Fly ash and Red Mud	Article	Relevant
12.	<u>[1]H-NMR and LC-MS Based Metabolomics Analysis of Potato (*Solanum tuberosum* L.) Cultivars Irrigated with Fly Ash Treated Acid Mine Drainage</u> Raletsena, Maropeng V; Mdlalose, Samukelisiwe; Bodede, Olusola S; Assress, Hailemariam A; Woldesemayat, Adugna A; et al. **Molecules; Basel** Vol. 27, Iss. 4, (2022): 1187.	Raletsena, Maropeng V; Mdlalose, Samukelisiwe; Bodede, Olusola S; Assress, Hailemariam A; Woldesemayat, Adugna A; et al	2022	Fly ash	Article	Relevant
13.	<u>Assessing Alternative Supporting Organic Materials for the Enhancement of Water Reuse in Subsurface Constructed Wetlands Receiving Acid Mine Drainage</u> Oberholzer, Martha M; Oberholster, Paul J; Ndlela, Luyanda L; Botha, Anna-Maria; Truter, Johannes C. **Recycling; Basel** Vol. 7, Iss. 3, (2022): 41.	Oberholzer, Martha M; Oberholster, Paul J; Ndlela, Luyanda L; Botha, Anna-Maria; Truter, Johannes C.	2022	Organic material	Article	Relevant
14.	<u>The removal of pollutants and natural organic compounds from acid mine drainage using a combination of bentonite clay and $MgSO_4$</u> Ntwampe, I O. **Water Practice and Technology; London** Vol. 16, Iss. 2, (Apr 2021): 490-503.	Ntwampe, I O.	Apr 2021	Combination of bentonite clay and $MgSO_4$	Article	Relevant
15.	<u>Carbothermal Reduction of Barium Sulfate-Rich Sludge from Acid Mine Drainage Treatment</u> Alternate title: Carbothermische Reduktion von bariumsulfatreichem Schlamm bei der Behandlung von sauren Grubenwässern	Molopo, Jean; Motaung, S.	Mar 2014	Sludge process	Article	Relevant

	Mulopo, Jean; Motaung, S. **Mine Water and the Environment; Dordrecht** Vol. 33, Iss. 1, (Mar 2014): 48-53.					
16.	<u>Effect of Silica Sodalite Functionalization and PVA Coating on Performance of Sodalite Infused PSF Membrane during Treatment of Acid Mine Drainage</u> Ntshangase, Nobuhle C; Sadare, Olawumi O; Daramola, Michael O. **Membranes; Basel** Vol. 11, Iss. 5, (2021): 315.	Ntshangase, Nobuhle C; Sadare, Olawumi O; Daramola, Michael O.	2021	Silica Sodalite and PVA coating	Article	Relevant
17.	<u>Effective Adsorption of Congo Red from Aqueous Solution Using Fe/Al Di-Metal Nanostructured Composite Synthesised from Fe (III) and Al (III) Recovered from Real Acid Mine Drainage</u> Khathutshelo Lilith Muedi; Masindi, Vhahangwele; Johannes Philippus Maree; Haneklaus, Nils; Brink, Hendrik Gideon. **Nanomaterials; Basel** Vol. 12, Iss. 5, (2022): 776.	Khathutshelo Lilith Muedi; Masindi, Vhahangwele; Johannes Philippus Maree; Haneklaus, Nils; Brink, Hendrik Gideon	2022	Adsorption of Congo and Aqueous solution	Article	Relevant
18.	<u>Acid Mine Drainage as Habitats for Distinct Microbiomes: Current Knowledge in the Era of Molecular and Omic Technologies</u> Lukhele Thabile; Selvarajan Ramganesh; Nyoni Hlengilizwe; Mamba, Bheki B; Msagati Titus A M. **Current Microbiology; New York** Vol. 77, Iss. 4, (Apr 2020): 657-674.	Lukhele Thabile; Selvarajan Ramganesh; Nyoni Hlengilizwe; Mamba, Bheki B; Msagati Titus A M.	Apr 2020	Traditional culture-based techniques	Article	Relevant
19.	<u>Lime Treatment of Acid Mine Water and Associated Solids/Liquid Separation</u> Bosman, D J. **Water Science and Technology; London** Vol. 15, Iss. 2, (Feb 1983): 71-84.	Bosman, D J.	Feb 1983	Lime treatment	Article	Relevant
20.	<u>Application of neural network techniques to predict the heavy metals in acid mine drainage from South African mines</u> John Kabuba *; Maliehe, Andani Valentia. **Water Science and Technology; London** Vol. 84, Iss. 12, (Dec 2021): 3489-3507.	John Kabuba *; Maliehe, Andani Valentia.	Dec 2021	Neural network technique	Article	Relevant

21.	Synthesis of Poly-Alumino-Ferric Sulphate Coagulant from Acid Mine Drainage by Precipitation Mwewa, Brian; Stopić, Srećko; Ndlovu, Sehliselo; Simate, Geoffrey S; Buhle Xakalashe; et al. **Metals; Basel** Vol. 9, Iss. 11, (2019): 1166.	Mwewa, Brian; Stopić, Srećko; Ndlovu, Sehliselo; Simate, Geoffrey S; Buhle Xakalashe; et al.	2019	Synthesis of Poly-Alumino-Ferric Sulphate Coagulant	Article	Relevant
22.	Assessment of selected macroalgae for use in a biological hybrid system for treating sulphur in acid mine drainage (AMD) Oberholster, Paul J; Cheng, Po-Hsun; Botha, Anna-Maria; Hobbs, Philip; Hill, Liesl. **Journal of Applied Phycology; Dordrecht** Vol. 30, Iss. 2, (Apr 2018): 1361-1370.	Oberholster, Paul J; Cheng, Po-Hsun; Botha, Anna-Maria; Hobbs, Philip; Hill, Liesl	Apr 2019	Use of selected macroalgae	Article	Relevant
23.	Using Periphyton Assemblage and Water Quality Variables to Assess the Ecological Recovery of an Ecologically Engineered Wetland Affected by Acid Mine Drainage After a Dry Spell Oberholster, Paul Johan; Schoeman, Yolandi; Johannes Christoff Truter; Botha, Anna-Maria. **Processes; Basel** Vol. 10, Iss. 5, (2022): 877.	Oberholster, Paul Johan; Schoeman, Yolandi; Johannes Christoff Truter; Botha, Anna-Maria.	2022	Using Periphyton Assemblage	Article	Relevant
24.	Optimising Brewery-Wastewater-Supported Acid Mine Drainage Treatment vis-à-vis Response Surface Methodology and Artificial Neural Network **Processes; Basel** Vol. 8, Iss. 11, (2020): 1485.		2020	Optimising Brewery-Wastewater-Supported	Article	Relevant
25.	Integrated treatment of acid mine drainage using cryptocrystalline magnesite and barium chloride Masindi, Vhahangwele. **Water Practice and Technology; London** Vol. 12, Iss. 3, (Aug 2017): 727-736.	Masindi, Vhahangwele.	2017	using cryptocrystalline magnesite and barium chloride	Article	Relevant
26.	Exploring the Use of Tobacco Waste as a Metal Ion Adsorbent and Substrate for Sulphate-Reducing Bacteria during the Treatment of Acid Mine Drainage Dovorogwa, Hamilton; Harding, Kevin. **Sustainability; Basel** Vol. 14, Iss. 21, (2022): 14333.	Dovorogwa, Hamilton; Harding, Kevin.	2022	Using tobacco waste (dust and stem)	Article	Relevant

27.	The Use of Acid Mine Drainage (AMD) in the Flotation of a Platinum-Group-Minerals-Bearing Merensky Ore Taguta, Jestos; Peku, Zandile; Nthapo Sehlotho; Corin, Kirsten. **Minerals; Basel** Vol. 12, Iss. 10, (2022): 1259.	Taguta, Jestos; Peku, Zandile; Nthapo Sehlotho; Corin, Kirsten.	2022	Flotation of a Platinum-Group-Minerals-Bearing	Article	Relevant
28.	Effect of Chitosan's Degree of Deacetylation on the Performance of PES Membrane Infused with Chitosan during AMD Treatment Mathaba, Machodi; Daramola, Michael Olawale. **Membranes; Basel** Vol. 10, Iss. 3, (2020): 52.	Mathaba, Machodi; Daramola, Michael Olawale	2021	Use of chitosan's degree of deacetylation	Article	Relevant
29.	The potential utilisation of Indigenous South African grasses for acid mine drainage remediation Ramla, Binita; Sheridan, Craig. **Water S.A., suppl. Special Edition: WISA 2014; Gezina** Vol. 41, Iss. 2, (2014): 247-252.	Ramla, Binita; Sheridan, Craig.	2022	Use of Indigenous grass	Article	Relevant
30.	Assessment of locally available reactive materials for use in permeable reactive barriers (PRBs) in remediating acid mine drainage Shabalala, Ayanda N. **Water S.A; Gezina** Vol. 39, Iss. 2, (Apr 2013): 251-256.	Shabalala, Ayanda N.	2020	Use of reactive materials	Article	Relevant
31.	Passive neutralization of acid mine drainage using basic oxygen furnace slag as neutralization material: experimental and modelling Zvimba, John N; Siyakatshana, Njabulo; Mathye, Matlhodi. **Water Science and Technology; London** Vol. 75, Iss. 5, (Mar 2017): 1014-1024.	Zvimba, John N; Siyakatshana, Njabulo; Mathye, Matlhodi.	Aug 2017	Passive neutralisation using oxygen furnace slag	Article	Relevant
32.	Characterisation of Mg-Al Hydrotalcite and Surfactant-Modified Bentonite Nano Clays for the Treatment of Acid Mine Drainage Gumede, Silindile; Musonge, Paul. **Sustainability; Basel** Vol. 14, Iss. 15, (2022): 9501.	Gumede, Silindile; Musonge, Paul.	2022	Characterisation of Mg-Al Hydrotalcite and Surfactant-Modified	Article	Relevant

				Bentonite Nano Clay		
33.	Assessment of Growth, Tuber Elemental Composition, Stomatal Conductance and Chlorophyll Content of Two Potato Cultivars Under Irrigation with Fly Ash-Treated Acid Mine Drainage Nemutanzhela, Maropeng Vellry; Modise, David Mxolisi; Siyoko, Kotose Joseph; Kanu, Sheku Alfred. **American Journal of Potato Research; Orono** Vol. 94, Iss. 4, (Aug 2017): 367-378.	Nemutanzhela, Maropeng Vellry; Modise, David Mxolisi; Siyoko, Kotose Joseph; Kanu, Sheku Alfred.	2022	Using Cultivars	Article	Relevant
34.	Synergism Red Mud-Acid Mine Drainage as a Sustainable Solution for Neutralizing and Immobilizing Hazardous Elements Lucas, Hugo; Stopić, Srećko; Buhle Xakalashe; Ndlovu, Sehliselo; Friedrich, Bernd. **Metals; Basel** Vol. 11, Iss. 4, (2021): 620.	Lucas, Hugo; Stopić, Srećko; Buhle Xakalashe; Ndlovu, Sehliselo; Friedrich, Bernd.	2021	Synergism Red Mud	Article	Relevant
35.	LC-MS Based Metabolomics Analysis of Potato (*Solanum tuberosum* L.) Cultivars Irrigated with Quicklime Treated Acid Mine Drainage Water Munyai, Rabelani; Raletsena, Maropeng Vellry; Modise, David Mxolisi. **Metabolites; Basel** Vol. 12, Iss. 3, (2022): 221.	Munyai, Rabelani; Raletsena, Maropeng Vellry; Modise, David Mxolisi.	2022	Using cultivars with quicklime	Article	Relevant
36.	Assessing leaf spectral properties of Phragmites australis impacted by acid mine drainage van Deventer, Heidi; Cho, Moses A. **South African Journal of Science; Pretoria** Vol. 110, Iss. 7/8, (Jul/Aug 2014): 1-12.	van Deventer, Heidi; Cho, Moses A	Jul/Aug 2014	Using leaf spectral properties	Article	Relevant
37.	The formulation of synthetic domestic wastewater sludge medium to study anaerobic biological treatment of acid mine drainage in the laboratory van den Berg, M Francis; Botes, Marelize; Cloete, T Eugene. **Water S.A; Gezina** Vol. 42, Iss. 2, (Apr 2016): 350-354.	van den Berg, M Francis; Botes, Marelize; Cloete, T Eugene.	Apr 2016	Domestic wastewater sludge	Article	Relevant

38.	Co-remediation of Acid Mine Drainage and Industrial Effluent Using Passive Permeable Reactive Barrier Pre-Treatment and Active Co-Bioremediation Thisani, Sandisiwe Khanyisa; Daramy Vandi Von Kallon; Byrne, Patrick. **Minerals; Basel** Vol. 12, Iss. 5, (2022): 565.	Thisani, Sandisiwe Khanyisa; Daramy Vandi Von Kallon; Byrne, Patrick.	2022	Biological treatment – removal of heavy metals	Article	Relevant
39.	Adsorptive removal of lead from acid mine drainage using cobalt-methyl imidazolate framework as an adsorbent: kinetics, isotherm, and regeneration Nqombolo, Azile; Mpupa, Anele; Gugushe, Aphiwe S; Moutloali, Richard M; Nomngongo, Philiswa N. **Environmental Science and Pollution Research; Heidelberg** Vol. 26, Iss. 4, (Feb 2019): 3330-3339.	Nqombolo, Azile; Mpupa, Anele; Gugushe, Aphiwe S; Moutloali, Richard M; Nomngongo, Philiswa N.	Feb 2019	Using cobalt-methylimidazolate with removal of heavy metals	Article	Relevant
40.	Heavy Metals and Radioactivity Reduction from Acid Mine Drainage Lime Neutralized Sludge Mashifana, T; Sithole, N. **IOP Conference Series. Earth and Environmental Science; Bristol** Vol. 120, Iss. 1, (Mar 2018).	Mashifana, T; Sithole, N.	Mar 2018	Chemical treatment through Lime neutralised and AMD sludge	Article	Relevant
41.	Effective Desalination of Acid Mine Drainage Using an Advanced Oxidation Process: Sodium Ferrate (VI) Salt Munyengabe, Alexis; Zvinowanda, Caliphs; Ramontja, James; Zvimba, John Ngoni. **Water; Basel** Vol. 13, Iss. 19, (2021): 2619.	Munyengabe, Alexis; Zvinowanda, Caliphs; Ramontja, James; Zvimba, John Ngoni.	2021	Desalination using Sodium Ferrate (VI) Salt	Article	Relevant
42.	Long-term sustainability in the management of acid mine drainage wastewaters - development of the Rhodes BioSURE Process Rose, Peter. **Water S.A; Gezina** Vol. 39, Iss. 5, (Oct 2013): 583-592.	Rose, Peter.	Oct 2021	Sewage sludge	Article	Relevant
43.	The removal of turbid materials from AMD using bentonite clay, Fe or Al salt, $MgCO_3$ and flocculent with varying agitations	Ntwampe, I O.	Sep 2020	Using bentonite clay	Article	Relevant

	Ntwampe, I O. **Water Practice and Technology; London** Vol. 15, Iss. 3, (Sep 2020): 580-597.					
44.	Effects of Contact Time and Flow Configuration on the Acid Mine Drainage Remediation Capabilities of Pervious Concrete Thisani, Sandisiwe Khanyisa; Daramy Vandi Von Kallon; Byrne, Patrick. **Sustainability; Basel** Vol. 13, Iss. 19, (2021): 10847.	Thisani, Sandisiwe Khanyisa; Daramy Vandi Von Kallon; Byrne, Patrick.	2021	Pervious Concrete	Article	Relevant
45.	A Fixed Bed Pervious Concrete Anaerobic Bioreactor for Biological Sulphate Remediation of Acid Mine Drainage Using Simple Organic Matter Thisani, Sandisiwe Khanyisa; Daramy Vandi Von Kallon; Byrne, Patrick. **Sustainability; Basel** Vol. 13, Iss. 12, (2021): 6529.	Thisani, Sandisiwe Khanyisa; Daramy Vandi Von Kallon; Byrne, Patrick.	2021	Pervious Concrete	Article	Relevant
46.	Synthesis and performance evaluation of PES/chitosan membranes coated with polyamide for acid mine drainage treatment Machodi, Mathaba J; Daramola, Michael O. **Scientific Reports (Nature Publisher Group); London** Vol. 9, (Nov 2019): 1-14.	Machodi, Mathaba J; Daramola, Michael O.	Nov 2019	PES/Chitosan membranes	Article	Relevant
47.	Synthesis of PES and PES/chitosan membranes for synthetic acid mine drainage treatment Machodi, Mathaba J; Daramola, Michael O. **Water S.A; Gezina** Vol. 46, Iss. 1, (Jan 2020): 114-122.	Machodi, Mathaba J; Daramola, Michael O.	Jan 2020	PES/chitosan membranes	Article	Relevant
48.	Quality of water recovered by treating acid mine drainage using pervious concrete adsorbent Shabalala, AN; Ekolu, SO. **Water S.A; Gezina** Vol. 45, Iss. 4, (Oct 2019): 638-647.	Shabalala, AN; Ekolu, SO.	Oct 2019	Pervious concrete	Article	Relevant
	AJOL Articles					

49.	14 Aug 2013**...** * To whom **all** correspondence should be addressed. ☎ +27 82 801-1353; e... contaminated **acid mine drainage water**. Patent: RSA 99/4586; USA. Evaluation of the genotoxic potential of water impacted by **acid mine**... www.ajol.info › index.php › wsa › article › view.	Oluwafikemi T Iji1, Emmanuel Mfotie Njoya1, Balungile Madikizela1, Jan G Myburgh1 and Lyndy J McGaw1	Oct 2021	Use of natural wetlands (passive) or conventional physical and chemical pH-neutralised processes	Article	Relevant
50.	03 Sept 2010**...** logical **areas** through the **field**... **acid mine drainage,** although low transmissivities will in **all** probability prevent decant after back-filling is... Passive remediation of **acid mine drainage using** cryptocrystalline... www.ajol.info › index.php › wsa › article › view	Vhahangwele Masindi1,3*, Mugera Wilson Gitari1, Hlanganani Tutu2 and Marinda De Beer4	Oct 2015	Using cryptocrystalline magnesite – a geochemical approach removing heavy metals	Article	Relevant
	PubMed Articles				Article	Relevant
51.	Assessing the sustainability of **acid mine drainage** (AMD) treatment in **South Africa**. Masindi V, Chatzisymeon E, Kortidis I, Foteinis S. Sci Total Environ. 2018 Sep 1; 635:793-802. doi: 10.1016/j.scitotenv.2018.04.108. Epub 2018 Apr 24. PMID: 29710603 The environmental sustainability of **acid mine drainage** (AMD) treatment at a semi-industrial scale is examined by means of the life cycle assessment (LCA) methodology...In terms of environmental sustainability, 29.6 kg CO(2eq) are emitted per treated m (3) AMD …	Masindi V, Chatzisymeon E, Kortidis I, Foteinis S	Sep 2018	Using life cycle assessment (LCA) methodology	Article	Relevant

52.	Improving **acid mine drainage** treatment by combining treatment technologies: A review. Mosai AK, Ndlovu G, Tutu H. Sci Total Environ. 2024 Apr 1; 919:170806. doi: 10.1016/j.scitotenv.2024.170806. Epub 2024 Feb 12. PMID: 38350575 Review. The **mining** and processing of some minerals and coal result in the production of **acid mine drainage** (AMD), which contains elevated levels of sulphate and metals, which tend to pose serious environmental issues...	Mosai AK, Ndlovu G, Tutu H	Feb 2024	Combined use of technologies	Article	Relevant
53.	Effective treatment of **acid mine drainage** using a combination of MgO-nanoparticles and a series of constructed wetlands planted with Vetiveria zizanioides: A hybrid and stepwise approach. Nguegang B, Masindi V, Msagati Makudali TA, Tekere M.J Environ Manage. 2022 May 15; 310:114751. doi: 10.1016/j.jenvman.2022.114751. Epub 2022 Feb 24. PMID: 35220100 In this novel study, **acid mine drainage** (AMD) was treated using a hybrid approach that comprises a nano-and-biotic system synergistically integrated in a stepwise and modular fashion....Finally, the product water conformed to the prescribed standards for effluent…	Nguegang B, Masindi V, Msagati Makudali TA, Tekere M.	Feb 2022	Using a combination of MgO-nanoparticles and a series of constructed wetlands	Article	Relevant
54.	Co-treatment of **acid mine drainage** and municipal wastewater effluents: Emphasis on the fate and partitioning of chemical contaminants. Masindi V, Foteinis S, Chatzisymeon E.J Hazard Mater. 2022 Jan 5; 421:126677. doi: 10.1016/j.jhazmat.2021.126677. Epub 2021 Jul 21. PMID: 34332476	Masindi V, Foteinis S, Chatzisymeon E.	Jul 2022	Co-treatment and wastewater effluents	Article	Relevant

	Here, the co-treatment of real municipal wastewater (MWW) and **acid mine drainage** (AMD) is comprehensively examined. Under the identified optimum co-treatment condition, i.e., 15 min contact time, 1:7 AMD to MWW liquid-to-liquid ratio, and ambient temperature …					
55.	Iron-mineral accretion from **acid mine drainage** and its application in passive treatment. Florence K, Sapsford DJ, Johnson DB, Kay CM, Wolkersdorfer C. Environ Technol. 2016;37(11):1428-40. doi: 10.1080/09593330.2015.1118558. Epub 2016 Jan 23. PMID: 26675674 **Free PMC article.** This study demonstrates substantial removal of iron (Fe) from **acid mine drainage** (pH 3) in a passive vertical flow reactor (VFR) with an equivalent footprint of 154 m (2) per L/s **mine** water and residence times of >23 h...Heterogeneous precipitation …	Florence K, Sapsford DJ, Johnson DB, Kay CM, Wolkersdorfer C	Jan 2023	Using a passive vertical flow reactor (VFR) removing heavy metals	Article	Relevant
56.	Insights into mechanisms governing the passive removal of inorganic contaminants from acid mine drainage using a permeable reactive barrier. Shabalala A, Masindi V.J Environ Manage. 2022 Nov 1; 321:115866. doi: 10.1016/j.jenvman.2022.115866. Epub 2022 Aug 16. PMID: 35985264 The permeable reactive barrier has been deemed as the most prudent and pragmatic way to passively manage and remediate AMD. Herein, insights into mechanisms governing the removal of inorganic contaminants from AMD using a permeable reactive…	Shabalala A, Masindi V.	Nov 2022	Using permeable reactive barrier removing heavy metals	Article	Relevant

57.	Passive co-treatment of phosphorus-depleted municipal wastewater with **acid mine drainage**: Towards sustainable wastewater management systems. Masindi V, Shabalala A, Foteinis S.J Environ Manage. 2022 Dec 15; 324:116399. doi: 10.1016/j.jenvman.2022.116399. Epub 2022 Oct 6. PMID: 36206654 Here, wastewater from a phosphorus recovery system (chemical precipitation) was co-treated with AMD. Specifically, phosphorus-rich municipal wastewater was treated with hydrated lime to synthesise a wastewater-derived phosphorus product…	Masindi V, Shabalala A, Foteinis S.	Oct 2022	Passive co-treatment of phosphorus-depleted wastewater – treated with lime and removal of heavy metals	Article	Relevant
58.	The potential of using alkaline gold **mine** tailing as a cover material to mitigate AMD formation from acidic gold **mine** tailing pile at Sabie-Pilgrim's Rest Goldfields, **South Africa**. van Wyk N, Eloka-Eboka AC, Fosso-Kankeu E. Environ Sci Pollut Res Int. 2022 Dec;29(60):90178-90190. doi: 10.1007/s11356-022-22106-9. Epub 2022 Jul 22. PMID: 35867300 **Acid mine drainage** (AMD) caused by the oxidation of sulphide minerals found in **mine** waste is a global environmental concern, especially in water-restricted countries with heavy **mining** industries...This study evaluated the **acid** generation …	van Wyk N, Eloka-Eboka AC, Fosso-Kankeu E	Jul 2022	Soil covers and blends	Article	Relevant
59.	Emerging remediation potentiality of struvite developed from municipal wastewater for the treatment of **acid mine drainage**. Masindi V, Fosso-Kankeu E, Mamakoa E, Nkambule TTI, Mamba BB, Naushad M, Pandey S. Environ Res. 2022	Masindi V, Fosso-Kankeu E, Mamakoa E, Nkambule TTI, Mamba BB, Naushad M, Pandey S	Feb 2022	Using synthesised struvite and removal of metals	Article	Relevant

	Jul;210:112944. doi: 10.1016/j.envres.2022.112944. Epub 2022 Feb 17. PMID: 35183518 The optimum conditions for the synthesis of struvite were 60 min of mixing, 300 rpm mixing speed, 1 g of activated magnesite and room temperature, while optimum conditions for the treatment of **acid mine drainage** (AMD) using the synthesised struvite were 45 m …					
60.	Sulfidogenic fluidized-bed bioreactor kinetics for co-treatment of hospital wastewater and **acid mine drainage**. Makhathini TP, Mulopo J, Bakare BF. Biotechnol Rep (Amst). 2021 Oct 14;32: e00683. doi: 10.1016/j.btre.2021.e00683. eCollection 2021 Dec. PMID: 34745909 **Free PMC article.** A passive co-treatment of **acid mine drainage** and hospital wastewater has previously demonstrated a promising bioremediation approach for both toxic streams.	Thobeka Pearl Makhathini 1 2, Jean Mulopo 1, Babatunde Femi Bakare 2	Dec 2021	Using a sulfidogenic fluidised-bed reactor – adjusting the pH level	Article	Relevant
61.	Comparison of individual and ensemble machine learning models for prediction of sulphate levels in untreated and treated **Acid Mine Drainage**. Hasrod T, Nuapia YB, Tutu H. Environ Monit Assess. 2024 Mar 2;196(4):332. doi: 10.1007/s10661-024-12467-8.PMID: 38429461 **Free PMC article.** Machine learning was used to provide data for further evaluation of the potential extraction of octathiocane (S(8)), a commercially valuable by-product, from **Acid Mine Drainage** (AMD) by predicting sulphate levels in an AMD water quality dataset...	Hasrod T, Nuapia YB, Tutu H	Mar 2024	Use of machine leaning models for the extraction of heavy metals	Article	Relevant

62.	Synthesis and application of cationised cellulose for removal of Cr (VI) from **acid mine-drainage** contaminated water. Etale A, Nhlane DS, Mosai AK, Mhlongo J, Khan A, Rumbold K, Nuapia YB.AAS Open Res. 2021 Jan 21;4:4. doi: 10.12688/aasopenres.13182.1. eCollection 2021.PMID: 33623862 **Free PMC article.** Background: **Acid mine drainage** (AMD) leads to contamination of surface and groundwater by high levels of toxic metals, including chromium...Methods: Cationised hemp cellulose was prepared by etherification with two quaternary ammonium salts: 3-chloro-2-hydr …	Elate A, Nhlane DS, Mosai AK, Mhlongo J, Khan A, Rumbold K, Nuapia YB	Jan 2021	Use of cationised cellulose for removal of metals	Article	Relevant
63.	Development of a diatom-based multimetric index for **acid mine drainage** impacted depressional wetlands. Riato L, Leira M, Della Bella V, Oberholster PJ. Sci Total Environ. 2018 Jan 15; 612:214-222. doi: 10.1016/j.scitotenv.2017.08.181. Epub 2017 Sep 1. PMID: 28850840 **Acid mine drainage** (AMD) from coal **mining** in the Mpumalanga Highveld region of **South Africa** has caused severe chemical and biological degradation of aquatic habitats, specifically depressional wetlands, as mines use these wetlands for sto …	Riato L, Leira M, Della Bella V, Oberholster PJ.	Sep 2017	Use of wetlands	Article	Relevant
64.	Performance of microbial community dominated by Bacillus spp. in **acid mine drainage** remediation systems: A focus on the high removal efficiency of SO (4) (2Al (Cd (3Cu (Mn (2Pb (Cu(2Sr (Mn(2+), Pb(2+), and Sr(2). Akinpelu EA, Ntwampe SKO, Fosso-Kankeu E, Nchu F, Angadam JO. Heliyon. 2021 Jun 7;7(6): e07241. doi:	Akinpelu EA, Ntwampe SKO, Fosso-Kankeu E, Nchu F, Angadam JO	Jun 2021	Use of consortium of microbial community for removal of heavy metals	Article	Relevant

	10.1016/j.heliyon.2021.e07241. eCollection 2021 Jun. PMID: 34189300 **Free PMC article.** A consortium of microbial community was used for the treatment of **acid mine drainage** wastewater laden with sulphate and heavy metals...					
65.	Passive neutralization of **acid mine drainage** using basic oxygen furnace slag as neutralization material: experimental and modelling. Zvimba JN, Siyakatshana N, Mathye M. Water Sci Technol. 2017 Mar;75(5-6):1014-1024. doi: 10.2166/wst.2016.579.PMID: 28272031 This study investigated the passive neutralisation of acid mine drainage using basic oxygen furnace slag as a neutralisation material over 90 days, with monitoring of the quality parameters and assessment of their removal kinetics...The study findings provide in …	Zvimba JN, Siyakatshana N, Mathye M	Mar 2017	Using basic oxygen furnace slag as neutralisation material, pH adjustment	Article	Relevant
66.	Mathematical modelling of Pb (2Cu (Ni (2Zn (Cr (2+), Cd ((2+), Cr (6+) and Cd (2+) ions adsorption from a synthetic acid mine drainage onto chitosan derivative in a packed bed column. Igberase E, Osifo P, Ofomaja A. Environ Technol. 2018 Dec;39(24):3203-3220. doi: 10.1080/09593330.2017.1375027. Epub 2017 Sep 19. PMID: 28866961	Igberase E, Osifo P, Ofomaja A	Sep 2017	Mathematical modelling of heavy metals	Article	Relevant
67.	Magnetite and cobalt ferrite nanoparticles are used as seeds for acid mine drainage treatment.	Kefeni KK, Mamba BB, Msagati TAM.J	Mar 2017	Chitosan process through mathematical modelling process	Article	Relevant

	Kefeni KK, Mamba BB, Msagati TAM.J Hazard Mater. 2017 Jul 5; 333:308-318. doi: 10.1016/j.jhazmat.2017.03.054. Epub 2017 Mar 27. PMID: 28376359 In this study, magnetite and cobalt ferrite nanoparticles were used as seeds for **acid mine drainage** (AMD) treatment at a pH of 7.05 to 3.5. Duplicate samples of AMD, one without heating and another with heating at 60 °C were treated under continuous stirring for 1 h. …			to remove heavy metals		
68.	Facile thermal activation of non-reactive cryptocrystalline magnesite and its application on the treatment of **acid mine drainage**. Magagane N, Masindi V, Ramakokovhu MM, Shongwe MB, Muedi KL. J Environ Manage. 2019 Apr 15; 236:499-509. doi: 10.1016/j.jenvman.2019.02.030. Epub 2019 Feb 13. PMID: 30771670 In this study, the authors report a facile thermal activation of non-reactive cryptocrystalline magnesite and explore its application in the treatment of **acid mine drainage** (AMD). The primary aim was to optimise the calcination-water interface reactive condition…	Magagane N, Masindi V, Ramakokovhu MM, Shongwe MB, Muedi KL	Feb 2019	Using of non-reactive cryptocrystalline magnesite for pH adjustment and metal removal	Article	Relevant
69.	Pervious concrete reactive barrier for removal of heavy metals from **acid mine drainage -** column study. Shabalala AN, Ekolu SO, Diop S, Solomon F.J Hazard Mater. 2017 Feb 5;323(Pt B):641-653. doi: 10.1016/j.jhazmat.2016.10.027. Epub 2016 Oct 14. PMID: 28340907 This paper presents a column study conducted to investigate the potential use of pervious concrete as a reactive barrier for	Shabalala AN, Ekolu SO, Diop S, Solomon F.	Oct 20216	Pervious concrete reactive	Article	Relevant

	treating water impacted by **mine** waste. The study was done using **acid mine drainage** (AMD) collected from a gold **mine** …					
70.	Characterization and reusability suggestions of the sludge generated from a synthetic **acid mine drainage** treatment using sodium ferrate (VI). Munyengabe A, Zvinowanda C, Zvimba JN, Ramontja J. Heliyon. 2020 Oct 13;6(10): e05244. doi: 10.1016/j.heliyon.2020.e05244. eCollection 2020 Oct. PMID: 33088977 **Free PMC article.** **Mining** activities are the leading cause of the generation of voluminous sludge waste, loaded with metals precipitated from the treatment of **acid mine drainage** (AMD), and this is always disposed to the landfill...	Munyengabe A, Zvinowanda C, Zvimba JN, Ramontja J	Oct 2020	Sludge treatment process, metal removal	Article	Relevant
	NCBI Articles					
71.	Bacterial communities shift and influence the treatment of acid mine drainage using a barium carbonate-dispersed alkaline substrate system. Castillo J, Alom J, Gomez-Arias A, Cebekhulu S, Matu A, Cason E, Valverde A. Sci Total Environ. 2023 Aug 10; 885:163526. doi: 10.1016/j.scitotenv.	Castillo J, Alom J, Gomez-Arias A, Cebekhulu S, Matu A, Cason E, Valverde A.	Aug 2023	Using a barium carbonate-dispersed alkaline substrate system.	Article	Relevant
72.	Assessing the sustainability of acid mine drainage (AMD) treatment in South Africa. Masindi V, Chatzisymeon E, Kortidis I, Foteinis S. Sci Total Environ. 2018 Sep 1; 635:793-802. doi: 10.1016/j.scitotenv.2018.04.108. Epub 2018 Apr 24. PMID: 29710603	Masindi V, Chatzisymeon E, Kortidis I, Foteinis S.	Apr 2018	Sludge process treatment – removal of metals	Article	Relevant

73.	Co-cropping vetiver grass and legume for the phytoremediation of an acid mine drainage (AMD) impacted soil. Thomas G, Sheridan C, Holm PE. Environ Pollut. 2024 Jan 15; 341:122873. doi: 10.1016/j.envpol.2023.122873. Epub 2023 Nov 8. PMID: 37949161	Thomas G, Sheridan C, Holm PE.	Nov 2023	Vetiver grass and legume for phytoremediation	Article	Relevant
74.	Diversity and functional profile of bacterial communities at Lancaster acid mine drainage dam, South Africa, as revealed by 16S rRNA gene high-throughput sequencing analysis. Lukhele T, Selvarajan R, Nyoni H, Mamba BB, Msagati TAM. Extremophiles. 2019 Nov;23(6):719-734. doi: 10.1007/s00792-019-01130-7. Epub 2019 Sep 13. PMID: 31520125	Lukhele T, Selvarajan R, Nyoni H, Mamba BB, Msagati TAM.	Sep 2019	Bacterial communities	Article	Relevant
75.	The availability of second-generation feedstocks for treating acid mine drainage and enhancing South Africa's bio-based economy. Westensee DK, Rumbold K, Harding KG, Sheridan CM, van Dyk LD, Simate GS, Postma F. Sci Total Environ. 2018 Oct 1;637-638:132-136. doi: 10.1016/j.scitotenv.2018.04.410. Epub 2018 May 8. PMID: 29751295	Westensee DK, Rumbold K, Harding KG, Sheridan CM, van Dyk LD, Simate GS, Postma F.	May 2018	Second-generation Feedstocks	Article	Relevant
76.	Implication of biofilms in the sustainability of acid mine drainage and metal dispersion near coal tailings. Pandey S, Fosso-Kankeu E, Redelinghuys J, Kim J, Kang M. Sci Total Environ. 2021 Sep 20; 788:147851. doi: 10.1016/j.scitotenv.2021.147851. Epub 2021 May 20. PMID: 34034167	Pandey S, Fosso-Kankeu E, Redelinghuys J, Kim J, Kang M	May 2021	Biofilms and metal dispersion	Article	Relevant
77.	High-throughput amplicon sequencing datasets of the microbial community in soils irrigated by quicklime and fly ash-treated acid mine drainage water.	Ogola HJO, Munyai R, Selvarajan R.	Fe 2024	Quicklime and Fly ash	Article	Relevant

	Ogola HJO, Munyai R, Selvarajan R. Data Brief. 2023 Nov 26; 52:109849. doi: 10.1016/j.dib.2023.109849. eCollection 2024 Feb. PMID: 38093854 **Free PMC article.**					
78.	Co-treatment of acid mine drainage and municipal wastewater effluents: Emphasis on the fate and partitioning of chemical contaminants. Masindi V, Foteinis S, Chatzisymeon E. J Hazard Mater. 2022 Jan 5; 421:126677. doi: 10.1016/j.jhazmat.2021.126677. Epub 2021 Jul 21. PMID: 34332476	Masindi V, Foteinis S, Chatzisymeon E.	Jul 2021	Partitioning of chemical contaminants	Article	Relevant
79.	Effective treatment of acid mine drainage using a combination of MgO-nanoparticles and a series of constructed wetlands planted with Vetiveria zizanioides: A hybrid and stepwise approach. Nguegang B, Masindi V, Msagati Makudali TA, Tekere M. J Environ Manage. 2022 May 15; 310:114751. doi: 10.1016/j.jenvman.2022.114751. Epub 2022 Feb 24. PMID: 35220100	Nguegang B, Masindi V, Msagati Makudali TA, Tekere M. Nguegang B, Masindi V, Msagati Makudali TA, Tekere M.	Feb 2022	Using a combination of MgO-nanoparticles and a series of constructed wetlands planted with Vetiveria zizanioides	Article	Relevant
80.	A clay-coal fly ash-based dual hydraulic-reactive liner for controlling acid mine drainage. Mafoko B, Gwenzi W, Chaukura N. Bull Environ Contam Toxicol. 2023 Jun 7;110(6):102. doi: 10.1007/s00128-023-03743-3. PMID: 37284872	Mafoko B, Gwenzi W, Chaukura N.	Jun 2023	A clay-coal fly ash-based dual hydraulic-reactive liner	Article	Relevant
81.	Continuous fixed-bed column study and adsorption modelling removal of Ni2+, Cu2+, Zn2+ and Cd2+ ions from synthetic acid mine drainage by nanocomposite cellulose hydrogel. Banza M, Rutto H.	Banza M, Rutto H.	Feb 2022	Using nanocomposite cellulose hydrogel	Article	Relevant

	J Environ Sci Health A Tox Hazard Subst Environ Eng. 2022;57(2):117-129. doi: 10.1080/10934529.2022.2036552. Epub 2022 Feb 9. PMID: 35137674			for the removal of heavy metals		
82.	Acid mine drainage neutralisation in a pilot sequencing batch reactor using limestone from a paper and pulp industry. Vadapalli VR, Zvimba JN, Mathye M, Fischer H, Bologo L. Environ Technol. 2015;36(19):2515-23. doi: 10.1080/09593330.2015.1036786. Epub 2015 Apr 27. PMID: 25846482	Vadapalli VR, Zvimba JN, Mathye M, Fischer H, Bologo L.	Apr 2015	Using limestone from a paper and pulp industry for pH adjustment	Article	Relevant
83.	Synthesis of Stabilised Iron Nanoparticles from Acid Mine Drainage and Rooibos Tea for Application as a Fenton-like Catalyst. Kimpiab E, Kapiamba KF, Folifac L, Oyekola O, Petrik L. ACS Omega. 2022 Jul 6;7(28):24423-24431. doi: 10.1021/acsomega.2c01846. eCollection 2022 Jul 19. PMID: 35874212 **Free PMC article.**	Kimpiab E, Kapiamba KF, Folifac L, Oyekola O, Petrik L.	Jul 2022	Synthesis of Stabilised Ion	Article	Relevant
84.	Comparative analysis of brewing wastewater and lactate as carbon sources for microbial community treating acid mine drainage in anaerobic MBBR systems. Akinpelu EA, Ntwampe SKO, Fosso-Kankeu E, Waanders F. Environ Technol. 2021 Nov;42(25):3955-3962. doi: 10.1080/09593330.2020.1771431. Epub 2020 Jun 2. PMID: 32419642	Akinpelu EA, Ntwampe SKO, Fosso-Kankeu E, Waanders F.	Jun 2020	Analysis of brewing wastewater and lactate as carbon source	Article	Relevant
85.	Polymeric Ion exchanger supported ferric oxide nanoparticles as adsorbents for toxic metal ions from aqueous solutions and acid mine drainage. Dlamini CL, De Kock LA, Kefeni KK, Mamba BB, Msagati TAM. J Environ Health Sci Eng. 2019 Jul 1;17(2):719-730. doi: 10.1007/s40201-019-00388-5. eCollection 2019 Dec. PMID: 32030146 **Free PMC article.**	Dlamini CL, De Kock LA, Kefeni KK, Mamba BB, Msagati TAM.	Dec 2019	Polymers Ion exchange	Article	Relevant
86.	Reaction dynamics of bentonite clay, FeCl3, Al2(SO4)3 and Na2CO3 dosage in AMD using varying dispersion techniques.	Ntwampe IO, Moothi K	Oct 2018	Using bentonite clay for the	Article	Relevant

	Ntwampe IO, Moothi K. J Environ Manage. 2019 Feb 1; 231:552-561. doi: 10.1016/j.jenvman.2018.07.019. Epub 2018 Oct 28. PMID: 30388652 Review.			removal of heavy metals		
87.	Performance of microbial community dominated by *Bacillus* spp. in acid mine drainage remediation systems: A focus on the high removal efficiency of SO4 2-, Al3+, Cd2+, Cu2+, Mn2+, Pb2+, and Sr2. Akinpelu EA, Ntwampe SKO, Fosso-Kankeu E, Nchu F, Angadam JO. Heliyon. 2021 Jun 7;7(6): e07241. doi: 10.1016/j.heliyon.2021.e07241. eCollection 2021 Jun. PMID: 34189300 **Free PMC article.**	Akinpelu EA, Ntwampe SKO, Fosso-Kankeu E, Nchu F, Angadam JO.	Jun 2021	Microbial community dominated by Bacillus species	Article	Relevant
88.	Trace metal content prediction along an AMD-contaminated stream draining a coal mine using VNIR-SWIR spectroscopy. Abrahams JR, Carranza EJM. Environ Monit Assess. 2023 Oct 2;195(11):1261. doi: 10.1007/s10661-023-11837-y. PMID: 37782376 **Free PMC article.**	Abrahams JR, Carranza EJM.	Oct 2023	VNIR-SWIR spectroscopy	Article	Relevant
89.	Mathematical modelling of Pb2+, Cu2+, Ni2+, Zn2+, Cr6+ and Cd2+ ions adsorption from a synthetic acid mine drainage onto chitosan derivative in a packed bed column. Igberase E, Osifo P, Ofomaja A. Environ Technol. 2018 Dec;39(24):3203-3220. doi: 10.1080/09593330.2017.1375027. Epub 2017 Sep 19. PMID: 28866961	Igberase E, Osifo P, Ofomaja A.	Sep 2017	Using chitosan derivative as a mathematical modelling process to remove heavy metals	Article	Relevant
90.	Effective removal of arsenate from wastewater using aluminium-enriched ferric oxide-hydroxide recovered from authentic acid mine drainage. Muedi KL, Brink HG, Masindi V, Maree JP. J Hazard Mater. 2021 Jul 15; 414:125491. doi: 10.1016/j.jhazmat.2021.125491. Epub 2021 Feb 23. PMID: 33652214	Muedi KL, Brink HG, Masindi V, Maree JP.	Feb 2021	Using aluminium-enriched ferric oxide-hydroxide by adjusting pH	Article	Relevant
91.	Investigation of as(V) removal from acid mine drainage by iron (hydro) oxide modified zeolite.	Nekhunguni PM, Tavengwa NT, Tutu H.	Apr 2017	Using iron (hydro) oxide-	Article	Relevant

	Nekhunguni PM, Tavengwa NT, Tutu H. J Environ Manage. 2017 Jul 15; 197:550-558. doi: 10.1016/j.jenvman.2017.04.038. Epub 2017 Apr 15. PMID: 28419977			modified zeolite to remove heavy metal		
92.	Effect of Chitosan's Degree of Deacetylation on the Performance of PES Membrane Infused with Chitosan during AMD Treatment. Mathaba M, Daramola MO. Membranes (Basel). 2020 Mar 24;10(3):52. doi: 10.3390/membranes10030052. PMID: 32213825 **Free PMC article.**	Mathaba M, Daramola MO.	Mar 2020	Using PES Chitosan's Degree of Deacetylation	Article	Relevant
93.	Novel hybrid metal-loaded chelating resins for removal of toxic metals from acid mine drainage. Dlamini CL, De Kock LA, Kefeni KK, Mamba BB, Msagati TAM. Water Sci Technol. 2020 Jun;81(12):2568-2584. doi: 10.2166/wst.2020.285. PMID: 32857744	Dlamini CL, De Kock LA, Kefeni KK, Mamba BB, Msagati TAM.	Jun 2020	Novel hybrid metal-loaded chelating resins	Article	Relevant
94.	Selection of Clostridium spp. in biological sand filters neutralising synthetic acid mine drainage. Ramond JB, Welz PJ, Le Roes-Hill M, Tuffin MI, Burton SG, Cowan DA. FEMS Microbial Ecol. 2014 Mar;87(3):678-90. doi: 10.1111/1574-6941.12255. Epub 2013 Dec 11. PMID: 24251832	Ramond JB, Welz PJ, Le Roes-Hill M, Tuffin MI, Burton SG, Cowan DA.	Dec 2013	Selection of Clostridium species in biological sand	Article	Relevant
95.	Destabilisation dynamics of clay and acid-free polymers of ferric and magnesium salts in AMD without pH adjustment. Ntwampe IO, Waanders FB, Bunt JR. Water Sci Technol. 2016;74(4):861-75. doi: 10.2166/wst.2016.259. PMID: 27533861	Ntwampe IO, Waanders FB, Bunt JR.	2916	Destabilisation dynamics of clay and acid-free polymers	Article	Relevant
96.	The potential of selected macroalgal species for treatment of AMD at different pH ranges in temperate regions. Oberholster PJ, Cheng PH, Botha AM, Genthe B.	Oberholster PJ, Cheng PH, Botha AM, Genthe B	Apr 2014	The potential of selected macroalgal species	Article	Relevant

	Water Res. 2014 Sep 1; 60:82-92. doi: 10.1016/j.watres.2014.04.031. Epub 2014 Apr 24. PMID: 24835955					
97.	Fungal and metabolome diversity of the rhizosphere and endosphere of *Phragmites australis* in an AMD-polluted environment. Kalu CM, Oduor Ogola HJ, Selvarajan R, Tekere M, Ntushelo K. Heliyon. 2021 Mar 8;7(3):e06399. doi: 10.1016/j.heliyon.2021.e06399. eCollection 2021 Mar. PMID: 33748472 **Free PMC article.**	Kalu CM, Oduor Ogola HJ, Selvarajan R, Tekere M, Ntushelo K.	Mar 2021	Fungal and metabolome diversity of the rhizosphere and endosphere of Phragmites australis	Article	Relevant
98.	A critical review of phytoremediation for acid mine drainage-impacted environments. Thomas G, Sheridan C, Holm PE. Sci Total Environ. 2022 Mar 10; 811:152230. doi: 10.1016/j.scitotenv.2021.152230. Epub 2021 Dec 8. PMID: 34896134 Review.	Thomas G, Sheridan C, Holm PE.	Dec 2021	phytoremediation	Article	Relevant