

Systematic Review

Environmental Degradation from Zama-Zama Illegal Mining in South Africa: Policy Implementation and Governance Challenges

Benett Siyabonga Madonsela , Thabang Maphanga *  and Xolisiwe Sinalo Grangxabe

Department of Environmental and Occupational Studies, Faculty of Applied Sciences, Cape Peninsula University of Technology, Corner of Hanover and Tennant Street, Zonnebloem, Cape Town 8000, South Africa

* Correspondence: maphangat@cput.ac.za

Abstract: In Africa, the legacy of mining has not only contributed to economic growth, employment, and prosperity but also brought risks to pollution exposure associated with detrimental health effects, ecological degradation, and social upheaval, such as the rapid Zama-Zamas. Due to this, illegal mining on the African continent has numerous environmental implications. While illegal mining operations have an adverse impact on the environment, government and academic research into the Zama-Zamas in South Africa has focused mainly on the socio-economic aspects of the illegal mining aspect, so environmental factors have been overlooked. Most government reports and academic literature on illegal mining activities in the country typically emphasize the socio-economic impact with little or no environmental consideration. Zama-Zamas have a major socioeconomic impact; however, their adverse impact on the environment cannot be ignored as well. This is especially true with Zama-Zamas' illegal activities, which result in environmental pollution that may affect the entire ecosystem as a result. Based on this background, the purpose of this paper is to explore the significant environmental implications of Zama-Zama's illegal mining in the South African context. The current study has discovered that there is little documentation regarding the environmental implications of illegal mining within communities where it occurs within South Africa's mining sector, despite its infiltration by Zama-Zamas illegal mining activities. This is a cause for concern, especially within countries like South Africa where illegal mining has become a national crisis, yet the environmental impacts of illegal mining from the literature point of view are not well documented. The limited literature on this issue highlights the need for urgent attention to the environmental damage caused by illegal mining. Thus, this appraisal advocates for the inclusion of environmental impact studies alongside the socio-economic impacts widely reported on illegal mining. For a country striving to achieve sustainable development, understanding the holistic potential risks of illegal mining activities by Zama-Zama is essential.

Keywords: illegal mining activities; environmental degradation; Zama-Zamas; environmental impact; mining governance; mining policy



Academic Editor: Cun Zhang

Received: 6 March 2025

Revised: 30 March 2025

Accepted: 2 April 2025

Published: 11 April 2025

Citation: Madonsela, B.S.; Maphanga, T.; Grangxabe, X.S. Environmental Degradation from Zama-Zama Illegal Mining in South Africa: Policy Implementation and Governance Challenges. *Sustainability* **2025**, *17*, 3418. <https://doi.org/10.3390/su17083418>

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

African mining has been responsible for substantial economic growth and development through millions of dollars of foreign investments [1], deeming it an indispensable economic cornerstone for the African member states that have access to abundant minerals [2]. The mining sector involves the extraction and processing of minerals, in addition to precious metals from under the earth [3]. The extraction of minerals and precious

stones under the earth has played a crucial role in the social and economic development of numerous African member states [4]. For instance, the process of mining minerals has provided significant socioeconomic development as well as employment opportunities across African nations such as Ghana, Tanzania, Zimbabwe, Niger, Madagascar, and Mali, just to mention a few [5]. Similarly, South Africa has always seen mining as the backbone of its economy [6]. This dates back to the 1886 Witwatersrand Gold Rush, which began with the discovery of gold resources near Pilgrim's Rest and Barberton. Historic archives indicate that this was South Africa's largest gold discovery [7]. Since the late 19th century, mining has directly contributed to the foundation of the Johannesburg Stock Exchange and contributed immensely to the gross domestic product of South Africa. Thus, mining has had a positive effect or impact in shaping South Africa politically, culturally, and economically. Economically, the mining industry is accountable for employing more South Africans than any other industry after agriculture [8]. To this extent, Davenport [9] argues that mining has become a social fabric for South Africa, especially since the country is enriched with a plethora of minerals that could be mined. Thus, it has received an iconic status of being recognized as the global leader in the mining industry [10].

To date, mining is still fundamental to South Africa's economy. This accentuates the importance of the mining industry across the country. For example, previously the industry provided 500,000 direct and 800,000 indirect jobs and contributed 16% to the country's gross domestic product [11]. Similarly, recently in the year 2021, the industry was reported to contribute millions of US dollars to the country's GDP, employing a workforce of 458,954 people in the process [12]. This excludes the whopping USD 816 million worth of gold profit reported to be annually generated by Zama-Zamas [13]. Against this background information, it is evident that the mining sector brings about inherent economic benefits in the country. However, since it is associated with the economic aspect of sustainable development, its impact is not devoid of challenges in the other two dimensions of the sustainable development pillars, namely social and environmental [14]. Furthermore, illicit mining has the potential to undermine the efforts and strides that the country has made toward achieving sustainable development. For instance, numerous challenges associated with illicit mining have been detailed in the local communities where there are mineable minerals [15]. As Durand [16] posits, the legacy of mining has not only contributed to economic growth, employment, and prosperity, but also to pollution, detrimental health effects, ecological degradation, and social upheaval such as the rapid rise of Zama-Zamas.

Zama-Zamas in isiZulu simply refers to the hustlers who take their chances by engaging in illegal mining activities [17]. Therefore, the word Zama-Zama is a colloquial term used within the South African mining industry to describe illegal miners working with gold or other precious metals [18]. Ledwaba and Nhlengetwa [10] profile Zama-Zamas as "miners that operate outside the regulatory framework, and usually target old, unused gold shafts in the Witwatersrand and Welkom areas". It is important to note that at the time when Ledwaba and Nhlengetwa [10] made their submissions, the issue of Zama-Zamas was predominantly limited within the two mentioned geographical areas, which are mainly urban areas due to their economic developments.

However, in recent times, driven by unemployment and poverty, the scourge of Zama-Zamas has been reported even in the deep rural areas of the country [19]. This transpires amidst a stagnant economy exacerbated by COVID-19, thus, the increase in illegal mining activities in recent times. Mkodzongi and Spiegel [20] accentuate that amid the economic crisis, illegal mining in rural areas becomes a source of revenue. This observation is in line with that of Munakamwe [11] and eNCA [21] that within the South African context, a decline in job opportunities has a direct bearing on the increase in illegal mining activities. Similarly, even in countries outside South Africa, it has been corroborated that at the

root of illegal mining is the decline of economic conditions embodied by poverty and unemployment [22].

The Rapid Rise of Zama-Zama Illegal Activities Presents Growing Environmental and Social Threat Challenges in South Africa

In recent times, amid the rise of illegal mining operations in the West and East Rand of Gauteng, South Africa, most of the media outlets in the country have reported on the social and economic impacts of the Zama-Zamas that compromise the safety of the citizens as well as the mining industry. However, it is surprising, and a major cause for concern that there is not much coverage and reporting on the impact of the Zama-Zamas' activities on the natural environment and the resources associated with it. As a matter of fact, in South Africa, illegal mining research and the risks associated with it are very limited [8,23]. The activities of the Zama-Zamas have a significant impact on the environment engendering environmental pollution, which has the potential to alter the entire ecosystem, especially given the prominent environmental impact of mining activities associated with the acid mine drainage, uranium contamination, and discharge of air pollutants from mine dumps that negatively impact plant growth.

To this end, Awotwi et al. [24] have discovered that Zama-Zama's illegal activities and environmental pollution in other places significantly alter the hydrological regime, thus constituting a threat to the natural ecosystems. Therefore, to minimize the gap of limited research within the South African context of illegal mining and its environmental implications, the present study focuses on the prospective impact associated with the illegal activities of the Zama-Zamas on the fundamental pillar of the sustainable element, which is the environment. While it is indispensable to document the role of illegal miners in society, the adverse impact on the environment should not be ignored. Given that illegal mining has adverse impacts on the environment, it might compromise the ability of the natural environment to continue to provide humanity with endless opportunities. Thus, the current study aims to review the existing literature on the impact of illegal mining (Zama-Zamas) activities on the degradation of the environment in South Africa.

2. Literature Methods

2.1. Search Strategy

The current study carried out an exploratory literature review aiming at holistically summarizing themes of illegal mining operations' implications on the environment. Subsequently, papers were selected to inform the review by extensively searching the range of multiple reputable scientific databases. In these databases, thematic search terms such as illegal mining, Zama-Zamas mining activities, environmental impact of illegal mining operations, and causes of illegal mining activities were used to narrow down the search within the relevant scope of illegal mining context. This systematic search was designed to capture a broad range of academic papers and any other reports thereof within the illegal mining sector, thus avoiding comprehensively capturing all studies that may not be directly related to illegal mining activities. As such the preferred reporting items for systematic reviews and meta-analyses (PRISMA) reporting was fundamental to achieving this systematic search. Moreover, a Supplementary Material has been added which includes relevant information on the screening and eligibility process depicted in the PRISMA diagram. Thus, in the current study, PRISMA, as depicted in Figure 1, facilitated the identification and inclusion of pertinent literature and reports. In this study, a comprehensive analysis was conducted on a total of 327 review papers.

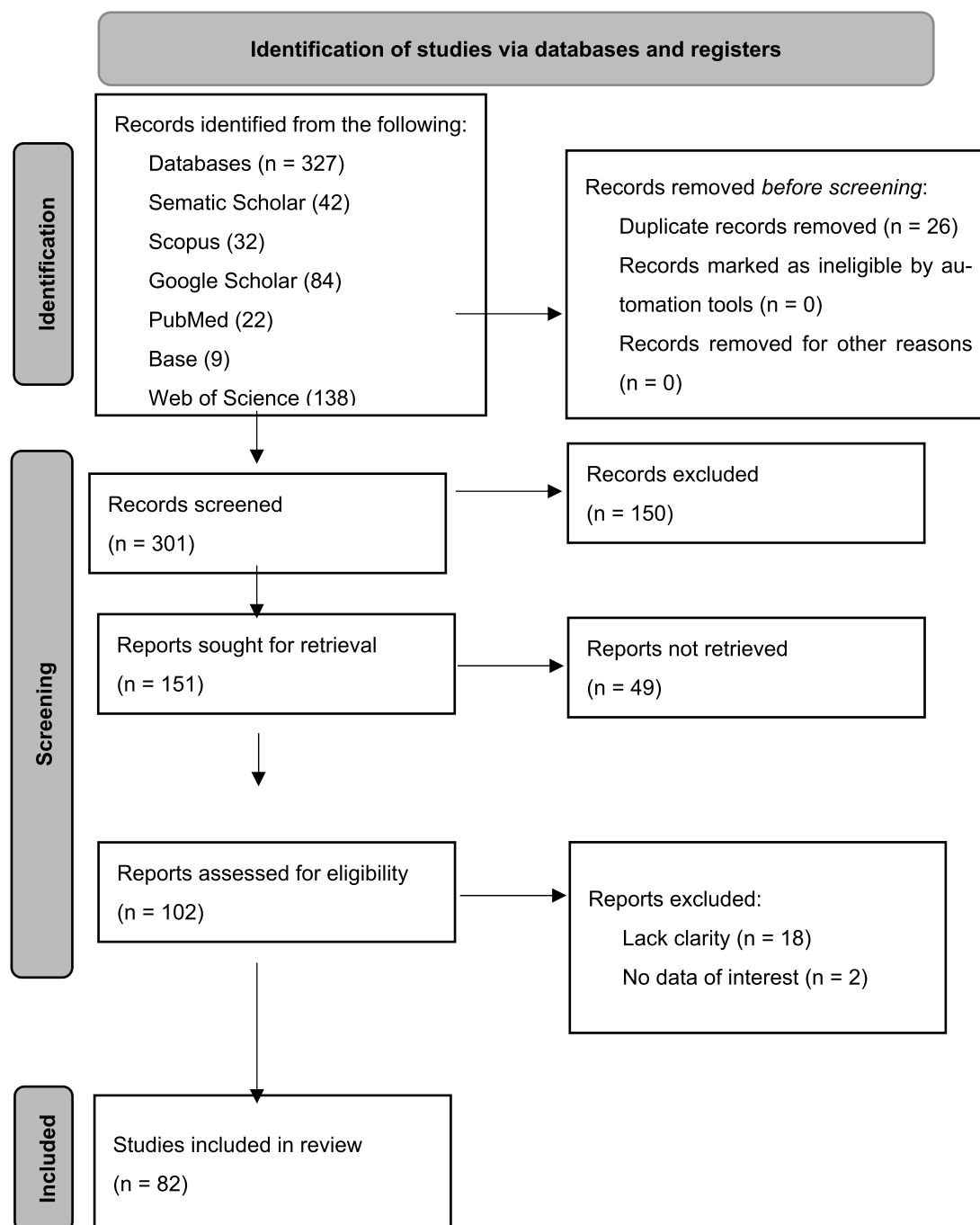


Figure 1. The preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines for degradation of the environment caused by illegal mining.

By utilizing the global databases, the authors successfully identified records that could potentially be relevant. As demonstrated in Figure 1, a dataset was identified, and the database search produced 327 records. The authors opted to employ four distinct reputable databases, namely Sematic Scholar (42), Scopus (32), Google Scholar (84), PubMed (22), Base (9), and Web of Science (138). Subsequently, the data were stratified and examined using the reference manager program EndNote 21 throughout data processing as suggested by Madonsela et al. [25]. EndNote 21 facilitated the elimination of duplicate papers, the categorization of articles through labeling, and the organization of papers into subgroups. During the removal of duplicates process, twenty-six duplicates were excluded before screening, as shown in Figure 1. Furthermore, post this bureaucratic process in-

tended to maintain the objectivity, transparency, and reliability of research, the Grangxabe et al. [26] and Madonsela [27] methodology framework of reading, analyzing, evaluating, and summarising scholarly materials related to the review was undertaken. To this end, an explanatory research approach was used to explain the implications of Zama-Zamas, illegal miners within the South African context.

2.2. Data Extraction and Selection of Studies

Authors of this review performed relevance checking in the records screening process, which consisted of title and abstract reading for relevance, and out of 301 records, 150 records were excluded, leading to 151 reports that were sought for retrieval in the screening process. Two reviewers performed the data extraction from the included studies which consists of the full-text reading stage; 82 studies were finally included in the review due to 49 being excluded because full papers could not be retrieved and 20 reports excluded from the 102 studies retrieved and assessed for eligibility reports as they did not meet the eligibility criteria for a variety of reasons such as lack of clarity and no data of interest.

Moreover, given the limited number of scholarly materials associated with the environmental impact of “illegal mining” as the keyword; this research study went a step further to illustrate the lack of research within the context of “illegal mining environmental impact” and searched the Web of Science database for “mining environmental impact”. The search indicated that the environmental impacts of mining activities it is well documented globally.

That is, through the extensive literature search, over 7000 publications associated with “mining environmental impacts” were retrieved, in contrast to a meagre 138 articles linked to the environmental impacts of illegal mining. It is important to note that in the global context, 138 publications are a minimal number. This is a cause for concern, especially within countries like South Africa, where illegal mining has become a national crisis, yet the environmental impacts of illegal mining are not documented and well-known. As such, this research aims at bridging the gap. The overall analysis associated with illegal mining environmental impacts published articles was performed using the specialized software VOSViewer 1.6.20. Subsequently, an enhanced visual representation of environmental impacts associated with mining activities was produced, as shown in Figure 2.

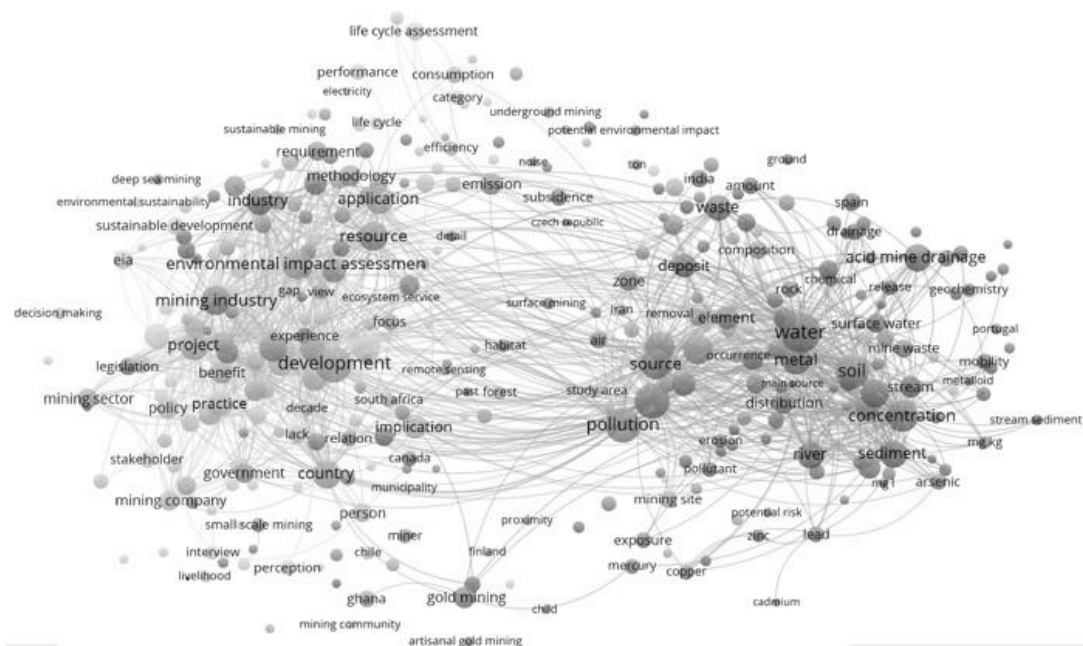


Figure 2. Structure of research in Web of Science using specialized VOSviewer tool software.

2.3. Factors Contributing to Illegal Mining Activities in South Africa

Illegal mining is characterized as a problem in gold-stricken nations [28]. These nations comprise Zimbabwe, Ghana, and Niger, just to mention a few [5]. Driven by the world's demand for gold, numerous authors indicate that illegal mining is on the rise and across the globe [29,30]. To this effect, the situation is no different in Southern Africa, where illegal mining continues to turn into a major problem across the South African provinces. For example, the illicit mining activities in the old, defunct mines, have in recent times become a major challenge for the Department of Mineral Resources, mining companies, and local authorities [8]. As a result, in South Africa, currently, illegal mining activities have become more prevalent such that they pose multiple challenges associated with the environmental, economic, and societal contests beyond the mining sector that require urgent attention. Stewart et al. [17] corroborate that illegal mining activities take place within the declining mining infrastructures. Subsequently, pervasive evidence of illegal mining activities associated with the Zama-Zamas has been discovered in the infrastructure of some old gold mines [5].

Similarly, Mhlongo and Amponsah-Dacosta [31] concur that it is the abandoned mines that have become the nexus of Zama-Zama's illegal mining activities. In South Africa, abandoned mines are those for which a closure certificate has not been granted and for which no party can be located to bear liability for their obligations [32]. Apparently, before the Zama-Zamas could begin with the illegal mining activities, they first focused on the steel infrastructure, which they stripped and sold as scrap metal. Any infrastructure still in place is then typically randomly vandalized. Illegal mining operations may start there after all of the valuable material has been taken [5]. Thus, the *modus operandi* of the Zama-Zamas is often to mine and process minerals in abandoned or closed excavations. However, in recent times, it has emerged that illegal mining is not only limited to abandoned mines. According to MCSA [33], it equally occurs in both active and inactive mines, where illegal miners frequently work in hazardous conditions. Thus, the scope of illegal mining in South Africa has expanded to include the surface and underground at closed, abandoned, and operating mines.

Despite the hazardous conditions and highly involved manual processes, Zama-Zamas brave these conditions and continue to mine. The bravery and courage, according to Owusu and Dwomoh [34], emanate from poverty. It is for this reason that Hilson [35] characterizes illegal mining as the result of being trapped in poverty. Thus, across developing countries, more than 13 million people are involved in illegal mining activities [36]. Citing the Minerals Council South Africa, du Plessis [33] highlights the shrinkage of employment in the mining sector. Between the years 2013 and 2019, the mining industry shed 56,366 jobs [33]. Thus, there is a general perspective that the current socioeconomic conditions in many parts of South Africa drive many people to engage in illegal mining activities [6], especially since the activities of the Zama-Zamas have been recognized as an essential source of livelihood that is prominent in developing countries [37]. Ref. [37] states that "there is no shortage of men with mining experience to apply to be Zama-Zamas or to impart their knowledge to younger generations. Secondly, because of the social crisis caused by the layoffs, when unemployed men are offered work, legal or illegal, many are willing to take their chances".

Furthermore, Field [13] contends that due to a loss of formal employment in the mining industry and a lack of alternative employment opportunities, Zama-Zamas resort to illegal mining as a permanent livelihood strategy, albeit fraught with risks. To this end, Chuma [38] posits that the persistent economic decline, retrenchments, high unemployment, and population growth have crippled livelihoods that have given birth to the proliferation of illegal mining. Similarly, MSCA [33] argues that the retrenchment of thousands of miners could only spell the proliferation of these unprecedented illegal mining practices. Moreover,

there are technical aspects of mining that exacerbate the issue of Zama-Zamas. However, CMSA [39] posits that whilst some illegal miners act out of economic desperation, it cannot be overlooked that illegal mining activities are directly linked to lucrative illicit trade in precious metals and diamonds. According to Jara [40], these include, amongst others, a lack of access to mineral rights because South Africa has an onerous mineral licensing regime, a lack of access to finance and funding mainly because financing agents such as banks are unlikely to participate in mining ventures which provide limited security and financial returns, and lack of appropriate structures to assist the small mining developments. This speaks directly to the absence of assistance from the state or business.

Thus, Havey [41] asserts that SADC countries such as Lesotho, Swaziland, Malawi, Zimbabwe, and Mozambique essentially contribute to the regional poverty that ultimately accounts for the cumulative supply of illegal miners in South Africa. It is for this reason that most of the Zama-Zamas' activities in South Africa are associated with illegal immigrants from these preceding SADC countries. In addition to poverty and illegal migrants contributing to the issue of Zama-Zamas, Havey [41] points out the demand for illegally mined minerals. There seems to be a huge thriving financial market for illegally mined minerals. This corroborates Field's earlier submission that illegal mining in South Africa is a profitable industry with estimated millions of US dollars' worth of gold per annum [13]. However, it is alarming that such a profitable industry does not absorb more employees to crowd out opportunities for illegal mining [41].

2.4. Reactive Policy Implementation and Governance Directed Towards Mitigating the Impacts of Illegal Mining

The South African government is cognizant that the upsurge of Zama-Zama's illegal miners has implications for the country. Thus, the Minister in the office of Mineral Resources and Energy posits that illegal mining is the criminal element that contravenes the laws of the country and equally forms part of many other economic-related crimes that are afflicting our society. In addition to the economic aspects affected by the Zama-Zamas, the illegal activities have a negative impact on the environment which has become the bedrock of the economic development which concerns the Minister. To this end, given that illegal mining practices are associated with crime, the South African Police Service is always incorporated to arrest the Zama-Zamas. However, this practice is yet to yield a positive outcome considering that it follows a reactive approach. Moreover, it does not thwart the environmental impact as by the time the police force is reactive the contamination of the sensitive segment of the environment would have already transpired. For instance, the SAPS is currently not mandated to monitor and investigate mining permit holders which is the function of another department.

On the other hand, incorporating this function within the jurisdiction of SAPS, for example, "would give law enforcement greater latitude and oversight to spot trends, undertake proactive due diligence on permit applicants, and monitor the business activity of criminally exposed entities" [42]. This, in the process, would minimize the potential impact of illegal mining activities on the environment, as law enforcement would be capacitated to be proactive and spot any irregularities, in contrast to being reactive. As things stand currently, the police officers are only expected to react to the highly trained illegal miners equipped with militant weapons who do not surrender to arrest like civilians. This has on numerous occasions led to the shedding of blood. Consequently, in an attempt to enhance the strategies that seek to mitigate the impact of illegal miners and to transition towards the proactive approach, the office of the Minister of Mineral Resources and Energy has in recent times lobbied for the establishment of a specialized cooperative unit.

This comes after the brutal gang rape of eight women near a disused mine in Gauteng province. However, at this point and time, the functions and confines of the purported

specialized cooperative unit are not clear. Nevertheless, the Minister did suggest that “the unit is expected to be multi-disciplinary and will draw in skills from other departments”. The multidisciplinary approach that integrates various departments might prove to be a shrewd move which if well-coordinated might mitigate some of the enablers of illegal mining activities [42]. It is important to note that in some instances, the adoption of an integrated environmental management approach, which draws from the different departments, has yielded positive outcomes, given that everyone gets involved to resolve a specific challenge. However, in this case, it is not clear who will make up the specialized cooperative unit.

2.5. Environmental Rehabilitation Challenges Amidst Illegal Mining Impact

The inclusion of the multidisciplinary approach and or integrated environmental management might be fundamental in presenting strategic views associated with clearly assigning responsibilities that seek to redress the inefficiency of the current rehabilitation framework on the rehabilitation of derelict and ownerless mines, which contravenes the National Environmental Management Act (Act 105 of 1998). It is important to note that even though the principles for cooperative environmental governance are articulated in the National Environmental Management Act (Act 105 of 1998), as emphasized in Table 1, the enforcement of these regulations is always found wanting, especially in mitigating the environmental degradation attributed to Zama Zamas. Illegal mining operations continue owing to inadequate enforcement and insufficient cooperation among regulatory agencies. This enforcement gap not only exacerbates environmental degradation but also prevents attempts to build sustainable governance structures. Therefore, enhancing supervision and ensuring the effective implementation of environmental regulations is essential for mitigating the adverse effects of unlawful mining. For example, in as much as the financial contributions are made by legitimate miners’, rehabilitation to date remains an illusion. At the center of this is the issue of the potentially high cost associated with rehabilitation [31]. However, given that illegal mining is a lucrative illegitimate business model that yields millions of dollars annually [42], a willing government committed to curbing illegal mining and protecting the segment of the environment could re-mine the abandoned mine and channel the majority of the earnings towards rehabilitation programs that seeks to restore the environment back to better states and to ample ecosystem. This could spell a fundamental paradigm shift in circumventing further environmental pollution due to illegal mining activities and reinstating the disturbed environment to its original and ample ecological state. The lack of rehabilitation post-mining operation affects land use and perpetuates long-term contamination of the environment. For it is the requirement of section 24 of NEMA, that the holder of a prospecting right, mining right, or mining permit must provide acceptable financial provision for the rehabilitation, closure, and ongoing post-decommissioning management of negative environmental impacts. Whilst it may not have been a matter of emergency to rehabilitate all debilitated mines previously as highlighted by Cornelissen [43], now it has proved to be an emergency given that it has become a gateway for Zama-Zamas that have no regard for the immediate environment. For example, in the environment in which the Zama-Zamas operate, members of the parliamentary portfolio committees conducted an oversight in the area, only to discover that some of the people’s homes are on the verge of collapsing due to land degradation [44]. This discovery communicates the incidences interconnected with the environmental impact because of illicit mining activities [45]. Regrettably, the environmental degradation effect will have a far-reaching indirect bearing on the soil quality of the area as it will result in the loss of fertile land, thus rendering the soil less productive within the agricultural space. This has a lethal environmental impact on rural communities that mostly depend on subsistence

farming. Given that soil contamination because of the released toxic elements such as metals during mining proceedings is a serious environmental problem [46]. Especially since these toxic elements have a lengthy residence duration or life span in the soil and are not easily biodegradable [47,48]. Most of these toxic elements that contaminate the soil such as mercury and cadmium are produced during the extraction phases of the precious mineral resources argues Terrones-Saeta et al. [46]. However, it is important to note that in most cases, some of these environmental impacts associated with illegal mining activities are overlooked given that they occur on a smaller scale [49]—even though these mining activities are a direct threat with the potential to deplete a water resource for instance [15]. Hence, environmental pollution of surface and groundwater is attributable to the processes of illicit mining activities in spaces where there are abandoned mines as highlighted in Table 1 [50], such that water is identified as the “mining’s most common victim” [51]. Thus, illegal mining is capable of polluting water sources nearby and depleting freshwater supplies within the jurisdiction of the mine. Mensa and Darku [52] detailed how illicit mining affected the ecosystem and the water resources in rural communities, by arguing that the water resources instantly became unsuitable for human use the moment illegal miners commenced their operations.

Table 1. South African legislations that govern the mining industry.

Country	Policy/Law	Objective
South Africa	Mineral and Petroleum Resources Development Act, Act No. 28 of 2002 (MPRDA)	Transferred mineral rights from private holders to government as guardians of peoples of S.A. and made provision to benefit Historically Disadvantaged South Africans (HDSAs).
South Africa	Mineral and Petroleum Resources Development Amendment Act, Act No. 49 Of 2008	Bill enhances provisions related to the regulation of the mining industry through the beneficiation of minerals and the promotion of national energy security to streamline administrative processes and align them with previous Acts.
South Africa	Mine Health and Safety Act, No 29 of 1996	Provide for the protection of the health and safety of employees and other persons.
South Africa	Constitution Act, Act No. 108 of 1996	Section 24 protects everyone’s health and well-being by preventing pollution and ecological degradation.
South Africa	National Environmental Management Act, Act	Provide for co-operative environmental governance by establishing principles for decision-making on matters affecting the environment, institutions that will promote co-operative governance and procedures for coordinating environmental functions by an organ of the state.
South Africa	Precious Metals Act, Act No. 37 of 2005	Provide for the development of precious metals in the best interest of the people of South Africa.
South Africa	National Environmental Management: Waste Amendment Act, Act No. 26 of 2014	Provide for the regulation of mine residue and stockpiles under NEMA. DMRE is the competent authority in terms of the National Environmental Management Laws Amendment Act, Act No. 25 of 2014 (NEMLA).
South Africa	National Water Act, Act No. 36 of 1998	Provide for fundamental reform of the law relating to water resources.

Source: MCSA [33].

2.6. Existing South African Legislative Framework That Safeguards the Mineable Environment

The change in the political landscape in 1994 ushered in a paradigm shift in the context of mining South African minerals. Through the enactment of the policies to regulate the mining of minerals in the country, including the complex system of mining rights, the policies were enacted to give effect to the democratic constitution which recognizes the rights of everyone to an environment that is not hazardous. Consequently, numerous statutes, as stipulated in Table 1, regulate mining and any activities associated with it in the Republic of South Africa. For instance, the Mineral and Petroleum Resources Development Act (MPRDA) (Act 28 of 2002) provides the main legislative framework for the entire mining activities in South Africa. This move is consistent with the International Council for Mining and Metals which has urged countries to amend their laws to allow for small-scale mining permits [53]. However, the challenges are that the licensing requirements for artisanal miners are generally the same as those for industrial miners, including the daunting process of submitting online applications and mining work programs that demonstrate the applicant's financial resources and the technical ability to conduct the proposed mining operation optimally [54].

Therefore, these bureaucratic processes might be a deterrent for small strides directed at mitigating the illicit mining practices that present hazardous risks to the environment. Thus, currently, in South Africa, this is viewed as some practical element that makes it difficult to obtain mineral rights that could be argued as the enablers of Zama-Zamas illicit mining that potentially contaminates the environment. The issue of mining rights negatively contributes to some of the challenges that restrict the potential integration of Zama-Zamas into the formal mining sector. The formal sector, in this instance, is recognized as artisanal and small-scale mining as gazetted by the Minister. The incorporation of Zama-Zamas into these entities has the potential to mitigate the environmental impacts emanating from the illicit activities, as these entities are regulated, expected, and required to comply with the environmental management acts guided by NEMA.

In addition to the policy bureaucratic processes of obtaining mining rights, most of the workforce involved in illegal mining would not be eligible for the above technical process which Jara [40] regards as cumbersome for obtaining mining rights, given that the workforce of the Zama-Zamas is largely composed of undocumented illegal migrants. As Steenkamp and Clark-Mostert [5], and Brits et al. [55] contend that Zama-Zamas are caused by undocumented illegal migrants. Most of the workforce involved in illegal mining would be not eligible for the above technical process which Jara [40] regards as cumbersome for obtaining mining rights, given that the workforce of the Zama-Zamas is largely composed of undocumented illegal migrants [56]. Steenkamp and Clark-Mostert [5] and Brits et al. [55] are convinced that Zama-Zamas are caused by undocumented illegal migrants.

The MPRDA encompasses the control and mitigation of four broad categories of mining that comprises surface mining, shallow underground mining, deep underground mining, and offshore mining [6]. To this effect, section 3 of the MPRDA in its current form affirms the state as the custodianship of mineral resources for the benefit of all South Africans—that is, the state through the Department of Mineral Resources and Energy (DMRE) may grant authorizations contemplated in MPRDA, including the prospecting and mining rights, mining permits, and environmental authorizations. Furthermore, to regulate all possible dealings with metals and ore, the legislation prohibits the holding or trading of certain metals in an unwrought state without a permit. This is regulated by the Precious Metals Act (Act 37 of 2005), as highlighted in Table 1.

The Act falls under the authority of the Minister of Mineral Resources and Energy; however, the implementation of all the policies and procedures contemplated by the Act is managed by the South African Diamond and Precious Metals Regulator established

by the Diamonds Act (Act 56 of 1986) [57]. Informal mining activities operating outside this legal framework constitute illegal mining. However, the enactors of the policies could not foresee the uprising of the illegal mining activities currently experienced in the country. It is the current rise of illegal mining activities throughout the country that has recently prompted the Minister of Mineral Resources and Energy to gazette Artisanal and Small Scale-Mining Policy 2022 for implementation in terms of the Mineral and Petroleum Resources Development Act of 2002. Recently, the Minister of Minerals Resources and Energy has made the pronouncement that illegal mining poses a “threat to national security, government authority and socio-economic development” [58]. Again, the absence of emphasis on the illegal mining impact on the third pillar of sustainability (environment) was noticeable. The Minister of Minerals Resources and Energy believes that illegal mining is a criminal activity. “This criminal activity is in contravention of our laws” most notably referring to the contravention of the Mineral and Petroleum Resources Development Act.

Thus, South African authorities view illegal miners primarily as criminals who must be suppressed with the help of the law [54]. However, scholars argue that it is not clear what legislation is available to criminalize Zama-Zamas [8,59], given that currently, illegal mining is not defined as an offense in terms of South African legislation [60]. Therefore, those apprehended cannot be charged with illegal mining operations. However, Wellsted [60] acknowledges that common methods in illegal mining do include practices that are illegal and prohibited by law. These, for example, comprise the following:

- (a) Theft and possession of gold-bearing materials.
- (b) Contravention of the Mine Health and Safety Act.
- (c) Petroleum Products Amendment Act.
- (d) Trespass Act.
- (e) Mineral and Petroleum Resources Development Act.

As a result, when illegal miners are arrested, they are primarily charged with trespassing and often escape prosecution for the criminal offenses they commit in South Africa [60]. To some extent, Thornton [59] criticizes the practice of persecuting Zama-Zamas under the banner of trespassing. Thornton [59] argues that whilst illegal miners are viewed as they are often trespassing on the mine-owned property, this same property is crisscrossed with pathways that are used by everyone in the vicinity to get to work or to visit the shop, friends, and relatives. And of course, South African laws that pertain to the surface do not govern the underground resources.

Furthermore, Wellsted [60] posits that illegal miners cannot be held responsible for the theft of gold materials unless they are discovered in possession of the stolen goods. Discrediting, poking holes, and casting doubt on the South African mining legal framework; Thornton [59] states that in as much as “it is illegal to own or trade in raw gold and other ‘precious metals’ but until the final process that results in refined metallic gold, the material they deal in is just dust and dirt”. This argument buttresses the earlier argument that the state does not have a watertight case that promotes persecuting the Zama-Zamas under trespassing. Therefore, the current enforcement and policy responses, which criminalize illegal miners might be misguided the author suggests. Hence, the arrests of illegal miners might not be viewed as a sustainable exercise that could be deemed as strategic to curb illegal mining, especially if the miners are not in the position of illegal explosives—as in some instances, they use the rudimentary process to mine for gold-bearing materials. However, Thornton’s [59] argument is baseless given that Zama-Zamas are mining without the required statutory authorization as prescribed by the Mineral and Petroleum Resources Development Act (Act 28 of 2002). Section 5A of the aforesaid act stipulates that

“No person may prospect for or remove, mine, conduct technical co-operation, operations, reconnaissance operations, explore for and produce any mineral or petroleum or commence with any work incidental thereto on any area without:

- (a) an environmental authorisation.
- (b) a reconnaissance permission, prospecting right, permission to remove, mining right, mining permit, retention permit, technical co-operation permit, reconnaissance permit, exploration right or production right, as the case may be and
- (c) giving the landowner or lawful occupier of the land in question at least 21 days written notice”.

Therefore, by virtue, illegal mining operations are a criminal activity as stipulated in section 5A of the act. Moreover, Kabai [53], contends that Zama-Zamas have a history of using very irresponsible and non-environmentally friendly purification processes and materials, which might result in irreversible environmental harm. As a result, because any breach of environmental legislation constitutes an environmental crime, Zama-Zama's activities are clearly within the scope of environmental crime as defined by the National Environmental Management Act (NEMA), 1998 (Act No. 107 of 1998).

2.7. Characterizing the Illegal Miners' Mining Apparatus with the Potential to Contaminate the Environment

In the context of South African mining, explosives are currently synonymous with illegal mining activities. More often than not, whenever Zama-Zamas are apprehended in the illicit act, they are always busted with explosives. For instance, recently, a total number of 40 blasting cartridges were confiscated by the members of the South African Police Service (SAPS) from illegal miners [61]. To this end, SAPS [62] posits that substances such as the detonation cord, blasting cartridges, explo gel, detonators, and blasting caps are commonly found with illegal miners. Characterizing the explosives, SAPS [62] suggests that “the energy from a single blast has the potential to create significant damage to the ground or surrounding infrastructure, which could collapse”. These are smuggled explosives that are believed to sustain illegal mining activities [63]. Moreover, the SAPS [62] indicates that the modus operandi for illegal miners is characterized by refiners, as well as smelters [62]. Moreover, according to Puglisi [64], illegal miners concede to chemical exposure during the mining and processing of minerals. They expose themselves and their communities to mercury and other poisonous gases in their amalgamation and extraction of gold. Mercury is a ubiquitous contaminant that poses a risk to the environment as it circulates through the air, water, sediment, soil, and living organisms [65].

On the other hand, because of human activity, cyanide is a chemical that is extensively disseminated across the environment. This chemical is used in the majority of industrial processes to manufacture products like electroplating or gold extraction [66]. This is not alarming as the application of chemicals such as cyanide and mercury is largely recorded across illegal mining. Techniques like amalgamation and cyanidation are used to refine gold. Around the globe, numerous illicit individuals mine for gold using the amalgamation method. This method creates an amalgam by combining rocks with mercury in water media using tiny gold trommel/spindles [67]. According to United Nations [68], illegal miners are accountable for “the largest global use of mercury, and the largest source of mercury releases”. Utembe et al. [2] state that the application of cyanide and mercury chemicals during the extraction of gold is very popular in South Africa. These chemicals are used to extract gold from the host rock. This is a cause for concern given that South Africa ranks high in the number of countries that use mercury [69,70]. Therefore, the use of smuggled mercury across the sector of illegal mining in South Africa is not helping the cause, it is a hazardous practice that must be discouraged [6]. It is for this reason that

chemicals used in mining and processing minerals have been widely documented to have a negative influence on the environment, especially when released into the soil, water, and air [71].

2.8. Implications of Illegal Mining Operations on the Environment

The environment and its natural resources are fundamental for human survival. However, illegal mining operations across countries with pervasive mining activities (Ghana and South Africa) pose significant risks to the very same environment [72]. Despite the impact of the legal mining sector on the environment, Zama-Zamas generally aggravate substantial changes in the environment [29]. While some could argue that all mining has risky side effects, illicit mining footprint has more significant effects on the environment. Given that illegal mining practices do not adhere to the same rules that legitimate mining practices do. The risks of the Zama-Zamas on the environmental aspect are consistent with the use of potentially toxic purifying processes and the use of substances to extract the gold from the host ore during the mining phases. The disregard and inconsideration for regulations such as the National Environmental Management Act (Act 107 of 1998) associated with regulating mining activities further exacerbate the illicit mining's impact on the environment. Ali [50] states that illicit miners without any legal permits have no regard for the environment, and it is for this reason that environmental damages occur to a high degree.

Numerous scholars reckon that this is aggravated by the lack of advanced technology that prompts illegal miners to resort to the exploitation techniques of mineral deposits using rudimentary tools and primitive mining processing that contaminate the environment [30,34,73–76]. However, others contend that it is the lack of educational background that is to blame for the absence of consideration for the consequences of their actions on the environment [77,78]. To this effect, at the current rate of illegal mining unprecedented incidences, South Africa is at risk of the ripple effect of water pollution, air pollution, as well as the loss of biodiversity and other numerous forms of pollution [79]. In light of the above, the subsequent paragraphs present the several sectors of the environment that are at risk of environmental pollution in South Africa if illegal mining is not abated.

Through direct and indirect mining activities, illegal mining may have an impact on the environment which could possibly cause soil erosion locally, water pollution regionally as well as climate change internationally. The consequences may include soil erosion, sinkholes, biodiversity loss, and pollution of surface, ground, and freshwater resources by chemicals released during mining operations [36]. Mining is a naturally invasive operation that can alter the landscape over a much larger area [80,81]. Moreover, Suresh and Jain [81] corroborate that land degradation, soil erosion as well as dust pollution are byproducts of illicit mining activities. For instance, the activities of illicit mining are responsible for leaving open pits within the jurisdiction of the illegal mining activities [15]. At the enter of this is the illegal mining modus of operandi that starts with the excavation of the gold-bearing sediments. This operation makes use of rudimentary machinery tools in the form of picks and shovels [82]. As such, one of the most frequent characteristic types of illegal mining remnants is an open pit, which involves material being removed from an open mining pit. This transpires when Zama-Zamas dig up sediments that are believed to contain gold.

To this end, Mhlongo [32] corroborates that the digging of gold-bearing sediments leaves behind extensively degraded land with dangerous shallow pits. This type of mining is particularly damaging to the environment because strategic minerals are often only available in small concentrations, which increases the number of open pits needed to be mined to extract the minerals. Hence, abandoned open pit scars are characterized as the by-product of the illegal mining operation [82]. Furthermore, the indiscriminate excavations as a result of illegal mining activities not only cause deterioration of the land, but also equally play a significant role that leads to deforestation and the disturbance of the soil structure [32]. For example, in recent times in a village in the Limpopo province (Northern part of South Africa), illegal miners began excavating a residential area leaving unrehabilitated hazardous trenches behind [44]. This transpires as the issue of Zama-Zamas in mining moves towards the South African rural communities.

Moreover, the pollution of the soil is not only limited to these incidences. Mulenga [83] posits that “mining practices such as the open pit mining that leads to the creation of dumps (or black mountains) or tailing dams also lead to the pollution of the soil”. This pollution is mainly exacerbated by the fact that Zama-Zamas have no regard for specific environmental management acts such as NEMA that seek to mitigate the pollution emanating from the mining processes including soil pollution. To this extent, the creation of mine dumps is primarily responsible for air pollution. Mine dumps are formed when the material extracted from abandoned mine sites is processed in the vicinity of the mines. It is for this reason that it has been reported that communities within the vicinity of illegal mining activities complain about the increased level of dust [84]. This is a cause for concern, especially since dust from the mines has been reported to contain elevated levels of metal concentrations. In addition, the processes of illegal mining also affect the atmosphere from the emissions of carbon which influence the quality of the biodiversity [36]. In some instances, the illicit mining practices ignite fires that consistently burn, releasing fly ash and smoke laden with greenhouse gasses and toxic chemicals [85]. Likewise, Asamoah et al. [86] submit that during the processing of gold material within illegal mining practices, mercury is added to gold particles in concentrates to create an ‘amalgam’. The amalgam consists of rather large balls of the mixture. The amalgam is subsequently subjected to heat or combustion to vaporize and release both the mercury and any other contaminants, resulting in the extraction of a comparatively pure gold product. This process exacerbates environmental air pollution which anguishes vulnerable neighboring poor communities which tend to be historically marginalized. A similar incident has been reported in the Mpumalanga province in the Emalahleni area just outside Duvha Park, infested by illegal mining activities [87].

Furthermore, the veracity of the illegal miner’s impact on scarce water resources cannot be overlooked. This has since coerced some communities in Mpumalanga within the jurisdiction of the illegal miners to search for alternative water resources given the degree of water pollution in the rivers, streams, and lakes. Kuffour et al. [76] argue that the contamination of water sources is because of the chemicals utilized by illegal miners. The chemicals utilized by illegal miners comprise mercury and cyanide [88]. Uppal et al. [89] suggest that illegal miners utilize mercury and cyanide which are heavy metals and potentially hazardous substances, in their mining operations. According to Gonçalves et al. [90] and Tomiyasu et al. [91] mercury which is used in the processes of illegal mining prominently impacts the environment in numerous ways.

To this end, Aristide and Ernest [92] highlight that the contamination of the environment by cyanide and mercury chemicals presents risks for the water bodies as well as the living organisms within the water resource. To this extent, the literature indicates that numerous studies qualify the environmental impact of cyanide and mercury trace metals on

the environment and the living species associated with them [93–96]. Moreover, according to Marshall et al. [30] in addition to pollution of aquatic systems, these chemicals further contribute to siltation in streams and rivers. According to Mhlongo and Akintola [97], the material extracted from abandoned mine sites is often treated on-site or in neighboring rivers using the sluicing process, depending on the water availability; thus, the construction of sluicing sites along the riverbank is associated with siltation.

This has a cumulative impact on the sedimentation that tends to be deposited in streambeds and can potentially choke off streams, destroying the habitat [81]. Likewise, sedimentation and spill erosion due to illegal mining are some of the ways that characterize illegal mining activities that affect surface and groundwater [98]. To an extent, elevated levels of toxic metals as a result of sluicing sites associated with illegal mining activities have been reported to exceed prescribed limits in river sediments. In addition, the impact of illegal mining activities leads to the alteration of the river morphology [97,98]. Without a say, these harm the natural environment and put in jeopardy the achievement of sustainable development to ensure that current and future generations have access to resources; by compromising the already scarce water resources and subjecting South African water systems to severe stress.

South African literature indicates that there are few environmental damages reported across the country regarding illegal mining. Sadly, the present study notes that across the country the implications of illegal miners on the environment are generally under-reported. Table 1 below summarises the few incidences that reported the environmental impacts associated with illegal mining across the South African provinces. Furthermore, the present study notes the absence of this information within the peer-reviewed publication spaces.

2.9. Research Studies Exploring the Impacts of Illegal Mining (Zama-Zamas) Activities in South Africa

Table 2 below details the research studies that to date have investigated and documented the impacts of illegal mining practices in South Africa. As such, Table 2 comprises a total number of thirty research studies included in the current review. These research studies provide the spatial scourge of illegal mining activities across the country. This Table highlights information about the aim of the study, the country of origin, as well as the objective of the study to assess and link environmental impact with illegal mining practices.

In contextualizing the findings of Table 2, it is evident that in as much as there is extensive documentation of environmental impacts associated with legal mining activities; the degradation of the environment associated with illegal mining practices is not prioritized by South African researchers. It is for this reason that in the current study, ~80% of research studies never intended to ascertain the environmental impacts associated with illegal mining practices (Table 2). Most of the research studies' focal point was directed on either on economic or social impacts of the illegal mining practices. This observation is elucidated further in Figure 3.

Table 2. Research studies that have investigated the impacts of illegal mining in South Africa.

South African Authors	Matshusa and Leonard [99]	Madimu [100]	Mabaso [57]	Ojakorotu [101]	Mhlongo [32]	Sekwadi et al. [102]	Bester [103]	Bester and Uys [104]	Lebitso and Mabudusha [105]	Mazikana [36]
Aim of study	The purpose of this study was to develop a strategy that can be used for emergency preparation and rescue efforts associated with disasters caused by abandoned mines and illegal gold mining.	This study examines unregulated gold-mining activities prevalent at disused mines and decommissioned shafts at operating mines in post-apartheid South Africa.	This study examines the past and present legislative framework that resulted in legacy mine shafts and dumps and how communities find themselves living next to these mine sites, which results in social and environmental problems.	To examine the effects of illegal mining on the socio-economic development of Northwest province.	This study discusses the physical hazards of abandoned mines with a special focus on the situation of these mines in South Africa.	To assess a prolonged outbreak of enteric fever associated with illegal miners in the City of Matlosana, South Africa.	Develop the artisanal mining sector for broader socio-economic opportunities through corporate social responsibility.	Exploring the drivers of artisanal gold mining in South Africa	To explore the increasing numbers of illegal mining activities in South Africa	This research explores Informal gold miners with mercury toxicity
The focal point of the research study	Economic and social impacts	Economic	Economic, social, and environmental impacts	Socio-economic impacts	Economic and social impacts	Enteric fever associated with illegal miners	Economy	Social and economic impact	Social impact	Economic impact

Table 2. Cont.

South African Authors	Matshusa and Leonard [99]	Madimu [100]	Mabaso [57]	Ojakorotu [101]	Mhlongo [32]	Sekwadi et al. [102]	Bester [103]	Bester and Uys [104]	Lebitso and Mabudusha [105]	Mazikana [36]
Country of origin	Gauteng (Ekurhuleni Metropolitan Municipality)	South Africa	Gauteng (Witwatersrand)	North–West (South Africa)	Tanzania (Dar es Salaam)	Motlasana City (Northwest)	South Africa	South Africa	South Africa	South Africa
South African authors	Makhetha [106]	Carry and Müller [107]	Mzondi [108]	Ledwaba and Mutumeri [109]	Mhangara et al. [110]	Zondo [111]	Dyan [112]	Jinnah [113]	Sibiya [114]	Williams [115]
Aim of study	To understand Basotho miners and Zama Zama's role in disused commercial gold mines in Gauteng Province, South Africa.	Investigates environmental injustices in South African artisanal gold mining.	The article focuses on the second development by applying two Ubuntu values and a Christocentric approach to compare gold mine companies and the Zama Zama enterprises in the region.	This research aims to examine the institutional frameworks that have been put in place to facilitate the development of the ASM sector.	Aimed to quantify changes in vegetation cover, bare soil, and mined open pits from 2014 to 2018 due to the impacts of ASM.	This study, therefore, contributes to this gap because it documents the lived experiences of individuals and community members engaged in traditional artisanal mining in Blaauw-bosch.	This research examines whether the current legislative framework regulating access to South Africa's mineral resources provides for the mandate to protect South Africa's mineral resources from illegal mining activities.	To outline in detail the process of informal gold mining.	The purpose of this study is to explore the environmental and social impact of illegal gold mining on the surrounding communities of Welkom.	This paper examines unregulated gold-mining activities prevalent at disused mines and decommissioned shafts at operating mines in post-apartheid South Africa.

Table 2. Cont.

South African Authors	Matshusa and Leonard [99]	Madimu [100]	Mabaso [57]	Ojakorotu [101]	Mhlongo [32]	Sekwadi et al. [102]	Bester [103]	Bester and Uys [104]	Lebitso and Mabudusha [105]	Mazikana [36]
Focal point of the research study	Economic impact	Environmental and social impact	Economic and social impact	Economic impact	Environmental impact	Economic and social impact	Economic impact	Economic and social impact	Environmental and social impact	Economic and social impact
Country of origin	South Africa	South Africa	West Rand District Municipality	South Africa	South Africa	Blaauwbosch (KwaZulu-Natal)	South Africa	South Africa	Welkom (Free State)	South Africa
South African authors	Mphokane [116]	Mkhize [8]	Chimukoko [117]	Wilson [118]	Yende [119]	Stoddard [120]	Heiberg [121]	Phala et al. [122]	Riukulehto [123]	Bester [103]
Aim of study	To understand the complexity related to illegal gold mining in Barberton.	Reappraising illegal artisanal mining in South Africa.	To explore the lived experiences of undocumented immigrants participating in illegal gold mining.	Unshackling South African artisanal miners.	To ascertain illegal mining escalation in Limpopo.	To comprehend illegal miners and fouled waterways in Mpumalanga.	The study assessed if South Africa has protected residents from gold mine pollution.	Community Safety to explore socio-economic, and policing implications of illegal mining.	This research establishes dangerous, frightening, and homely of living in close proximity to illegally mined areas.	Develop the artisanal mining sector for broader socio-economic opportunities through corporate social responsibility.

Table 2. Cont.

South African Authors	Matshusa and Leonard [99]	Madimu [100]	Mabaso [57]	Ojakorotu [101]	Mhlongo [32]	Sekwadi et al. [102]	Bester [103]	Bester and Uys [104]	Lebitso and Mabudusha [105]	Mazikana [36]
Focal point of the research study	Economic and social impact	Economic impacts	Economic and social impact	Economic impact	Environmental impact	Environmental impact	Economic impact	Economic and social impact	Environmental and social impact	Social impact
Country of origin	South Africa	South Africa	South Africa	South Africa	Moolhoek (Limpopo)	Emalahleni (Mpumalanga)	Johannesburg (Gauteng)	South Africa	West Rand (Gauteng)	Johannesburg (Gauteng)

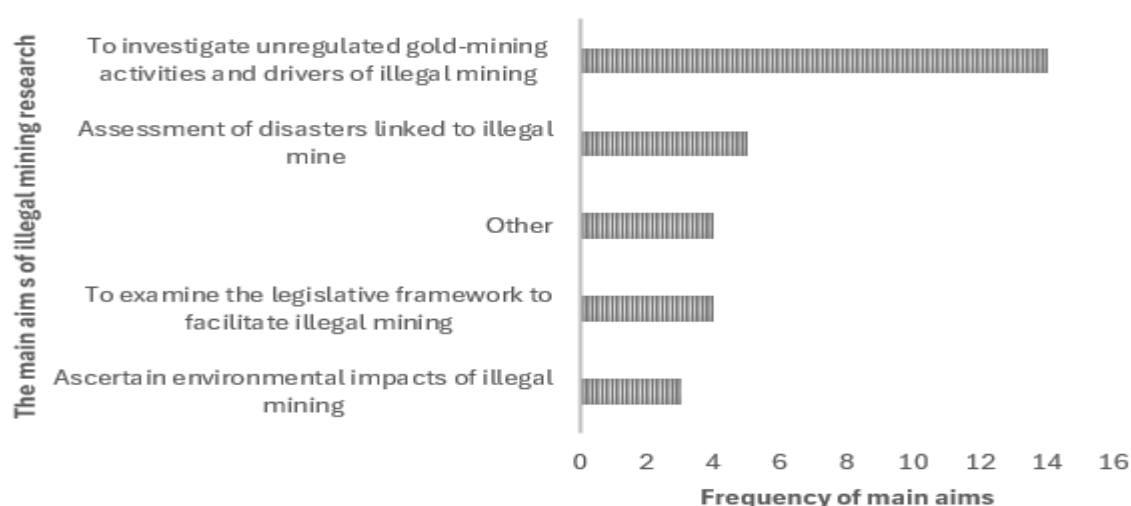


Figure 3. Overview aims of the South African research studies that have undertaken illegal mining studies.

Across the country, five sets ($n = 5$) of objectives that characterize the main drive of South African illegal mining research were scrutinized and visually illustrated as shown in Figure 3. The visuals suggest that the objectives, as illustrated in Figure 3, are characterized by a high degree of contrast. To this end, the illustration indicates that the majority of South African scholars undertake Zama-Zamas' related studies to investigate unregulated gold mining activities and drivers of illegal mining (47%). Whilst, the studies that seek to comprehend the environmental impacts of illegal mining are almost five-fold lower than the investigations of unregulated gold-mining activities and drivers of illegal mining. Below are the objectives that influence illegal mining-related investigations characterized according to their proportion.

(a) Ascertain the environmental impacts of illegal mining	10%
(b) To examine the legislative framework to facilitate illegal mining	13%
(c) Other	13%
(d) Assessment of disasters linked to illegal mining	17%
(e) To investigate unregulated gold-mining activities and drivers of illegal mining	47%

It is startling that the investigations of environmental degradation only account for 10% given that there is extensive documentation of environmental degradation associated with legal mining activities. These discoveries raise serious concerns for environmental sustainability, given that illegal mining activities are often uncontrolled and executed without environmental protection. Consequently, they exert significant impacts on ecosystems, including depleting vegetation, water pollution, and degradation of habitats, thus impacting flora and fauna. The absence of research suggests that this deterioration is likely to continue without documentation risking biodiversity and ecological systems that are fragile. This is a concern given that the meager of studies that have conducted the main drive of South African illegal mining research associated with environmental degradation have discovered that Zama-Zamas' illegal mining practices by far contaminate the water resources (42%), followed by the environmental degradation (25%), as highlighted in Figure 4.

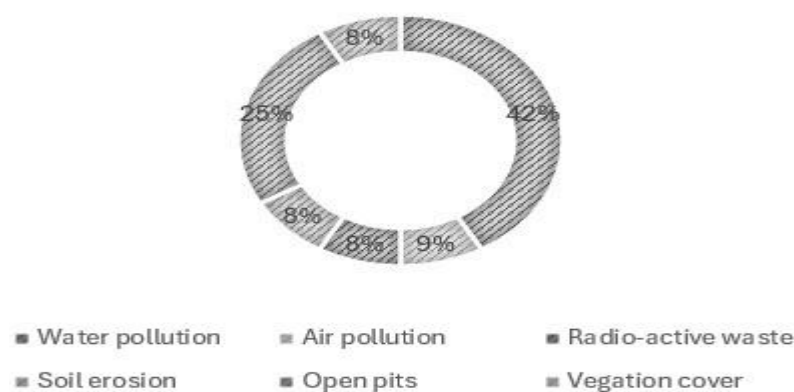


Figure 4. The environmental degradation impacts of Zama-Zamas.

3. Discussion and Implications

The environmental degradation risks as a result of Zama-Zamas' illegal mining activities are overshadowed by social and economic risk factors in South Africa. This transpires despite that illegal mining practices are generally known to exert environmental degradation and deplete limited natural resources thus causing water pollution (42%) as indicated in Figure 4. To this end, Emmanuel et al. [15] posit that Zama-Zamas' mining activities are a direct threat with the potential to deplete a water resource given the absence of water pollution mitigation measures. It is for this reason that in some instances environmental pollution of surface and groundwater has been attributed to the processes of illegal mining activities in spaces where there are abandoned mines as highlighted in Table 2 [50]. Such that water is identified as the "mining's most common victim" [51]. This is concerning given that although adverse environmental effects of illegal mining are evident, there has been minimal research into how Zama-Zama activities contribute to a greater extent to the environmental degradation as illustrated in Figure 4. This discovery contradicts the documented instances of extensive environmental degradation associated with legal mining activities in South Africa [124,125]. This gap in South African academic and governmental studies poses a significant challenge to understanding the full scope of illegal mining's impact. Moreover, this contrasts with the observation of the studies conducted in other African countries that to date have conducted extensive research on this domain. For instance, in other African countries such as Ghana, the destruction of surface and ground water due to chemical contamination, pollution from mud and sediments, air and noise pollution, and the loss of biodiversity, including native plants, animals, and aquatic species, are some of the documented drawbacks of illegal mining [79]. While in the South African context, the emphasis is skewed towards the socio-economic drawbacks. As Mhlongo and Amponsah-Dacosta [31] suggest this observation calls for more intensive environmental degradation research-based studies to understand the magnitude of the problem that consequently causes social problems. Given that environmental pollution caused by these illegal activities, especially in South Africa's mining sector, could affect the entire ecosystems and lead to long-term environmental risks that hinder sustainable development [126–128], the current study advocates for a more comprehensive approach to studying illegal mining, one that includes environmental impact assessments alongside socio-economic considerations. For a country like South Africa, which is seeking sustainable development, it is essential to understand the broader risks posed by illegal mining to both people and the environment. It is for this reason that the present study emphasizes the need for holistic research and policy frameworks that recognize the environmental harm caused by Zama-Zamas, thus suggesting that future studies must address the environmental dimension to ensure the country's long-term sustainability goals are met.

4. Conclusions

The current study has discovered that the legacy of mining has not only contributed to economic growth, employment, and prosperity, but also to pollution, with detrimental health risks and ecological degradation. Therefore, the current upsurge of illegal mining activities in South Africa if not strategically abated is on course to undermine and reverse the efforts as well as the strides that have been made towards achieving sustainable development. The recent policy development of Artisanal and Small Scale-Mining Policy 2022 for implementation in terms of the Mineral and Petroleum Resources Development Act (Act 22 of 2002) is acknowledged. However, it might not be enough to deter Zama-Zama's illegal mining operations. Given the bureaucratic procedures and the fact that the majority of the Zama-Zamas' workforce consists of undocumented immigrants who are present in the country illegally and ineligible to get mining rights. The current review has discovered that the indiscriminate operations of illicit mining present environmental implications in addition to the prioritized socio-economic issues. Therefore, the paucity of research on the environmental effects of the mining industry in South Africa is alarming. To an extent that even government reports and academic literature prioritize the socio-economic aspect to the detriment of the environmental segment. Whilst a lot of literature associated with the illegal miner's impacts on the environment is pervasively accessible across other African countries within the mining sector, there remains a notable literature gap for the South African mining sector. To an extent, only 10% of studies across the country have attempted to account for environmental impacts associated with the Zama-Zamas' activities, while a whopping 47% focused on unregulated gold-mining activities and drivers of illegal mining. As a result, the current study advocates for the undertaking of environmental impact-related studies associated with the operations of Zama-Zamas' illegal miners within the South African context.

Future Studies

- There is a need for research studies to conduct comprehensive environmental impact assessments associated with Zama-Zamas.
- Government institutions must invest in strengthening environmental regulations associated with rehabilitation post-mining.
- Research on illegal mining's hazardous consequences on the environment can enhance public consciousness and inform communities about the environmental severity associated with these practices.
- Collaborative research given that illegal mining and its environmental consequences are not unique to South Africa. Collaborating with international environmental organizations can provide South Africa with access to technical expertise, funding, and innovative solutions.
- Research on the environmental impacts of illegal mining can help raise public awareness about the seriousness of the illegal mining impacts.
- In addition to comprehensive environmental impact assessment associated with Zama-Zamas. Future research studies should expand the scope of studies to include a thorough analysis of the commission of illegal mining activities as crimes.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su17083418/s1>, PRISMA 2020 Checklist [127].

Author Contributions: Conceptualization, T.M., B.S.M. and X.S.G.; methodology, T.M. and X.S.G.; software, X.S.G.; validation, X.S.G. and B.S.M.; formal analysis, T.M. and X.S.G.; investigation, B.S.M.; writing—original draft; writing—review and editing, T.M., X.S.G. and B.S.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare that they have no known conflicts of interest or personal relationships that could be perceived as having influenced the work described in this paper.

References

1. Zhang, H.; Wilkes, A. *Trends in Chinese Trade and Investment in Africa's Mining Sector*; Chinese Academy of Land Resources and Economy: Beijing, China, 2010.
2. Utembe, W.; Faustman, E.M.; Matatiele, P.; Gulumian, M. Hazards identified and the need for health risk assessment in the South African mining industry. *Hum. Exp. Toxicol.* **2015**, *34*, 1212–1221. [CrossRef]
3. Akabzaa, T.; Darimani, A. Impact of Mining Sector Investment in Ghana: A Study of the Tarkwa Mining Region. *Third World Netw.* **2001**, *11*, 47–61.
4. Carvalho, F.P. Mining industry and sustainable development: Time for change. *Food Energy Secur.* **2017**, *6*, 61–77. [CrossRef]
5. Steenkamp, N.C.; Clark-Mostert, V. Impact of illegal mining at historic gold mine locations, Giyani Greenstone Belt area, South Africa. In Proceedings of the 9th International Mining History Congress, Johannesburg, South Africa, 17–20 April 2012; pp. 1–10.
6. Love, J. *Report of the SAHRC Investigative Hearing-Issues and Challenges in relation to Unregulated Artisanal Underground and Surface Mining Activities in South Africa*; South African Human Rights Commission: Johannesburg, South Africa, 2015.
7. Rosenthal, A.K.; Rosenthal, E. *Gold! Gold! Gold!: The Johannesburg Gold Rush*; Scribner Book Company: New York, NY, USA, 1970.
8. Mkhize, M.C. Reappraising illegal artisanal mining in South Africa. *S. Afr. Crime Q.* **2017**, *61*, 67–75. [CrossRef]
9. Davenport, J. *Digging Deep: A History of Mining in South Africa*; Jonathan Ball Publishers: Johannesburg, South Africa, 2013.
10. Ledwaba, P.; Nhlengetwa, K. When policy is not enough: Prospects and challenges of artisanal and small-scale mining in South Africa. *J. Sustain. Dev. Law Policy* **2016**, *7*, 25–42. [CrossRef]
11. Munakamwe, J. The interface between the legal and illegal mining processes: Unpacking the value chain of illegally mined gold. In *Centre for Sustainability in Mining and Industry (CSMI) Artisanal and Small-Scale Mining (ASM) Seminar Series*; FL-CIO: Washington, DC, USA, 2015; Volume 11.
12. Statista. Number of People Employed by South Africa's Mining Industry in 2021 by Commodity. 2021. Available online: <https://www.statista.com/statistics/241420/south-african-mining-key-facts/> (accessed on 11 September 2022).
13. Field, T.L. Artisanal Gold Mining in South Africa Is out of Control. 2022. Available online: <https://www.wits.ac.za/news/latest-news/opinion/2022/2022-08/artisanal-gold-mining-in-south-africa-is-out-of-control.html> (accessed on 20 September 2022).
14. Edwards, D.P.; Sloan, S.; Weng, L.; Dirks, P.; Sayer, J.; Laurance, W.F. Mining and the African environment. *Conserv. Lett.* **2014**, *7*, 302–311. [CrossRef]
15. Emmanuel, A.Y.; Jerry, C.S.; Dzigbodi, D.A. Review of environmental and health impacts of mining in Ghana. *J. Health Pollut.* **2018**, *8*, 43–52. [CrossRef]
16. Durand, J.F. The impact of gold mining on the Witwatersrand on the rivers and karst system of Gauteng and North West Province, South Africa. *J. Afr. Earth Sci.* **2012**, *68*, 24–43. [CrossRef]
17. Stewart, P.; Bezuidenhout, A.; Bischoff, C. Safety and health before and after Marikana: Subcontracting, illegal mining and trade union rivalry in the South African mining industry. *Rev. Afr. Political Econ.* **2020**, *47*, 27–44. [CrossRef]
18. Khan, M. Dealing with illegal miners. *Inside Min.* **2017**, *10*, 34–35.
19. SABC (South African Broadcasting Channel). Limpopo Residents Express Concern About Scourge of Illegal Mining in Muyexe Village. 2022. Available online: <https://www.sabcnews.com/sabcnews/limpopo-residents-express-concern-about-scourge-of-illegal-mining-in-muyexe-village/> (accessed on 20 September 2022).
20. Mkodzongi, G.; Spiegel, S.J. Mobility, temporary migration and changing livelihoods in Zimbabwe's artisanal mining sector. *Extr. Ind. Soc.* **2020**, *7*, 994–1001. [CrossRef]
21. eNCA. Illegal Mining | The Queen Who Loves Gold. Available online: <https://www.enca.com/opinion/illegal-mining-queen-who-loves-gold> (accessed on 24 September 2022).
22. Kervankiran, I.; Dziwornu, M.G.; Temurcin, K. *Illegal Mining as Threat to Sustainable Development in Ghana: A Political Ecology Approach*; Zeitschrift für die Welt der Türken: Ankara, Türkiye, 2016.
23. Mutemeri, N.; Petersen, F.W. Small-scale mining in South Africa: Past, present and future. In *Natural Resources Forum*; Blackwell Publishing Ltd.: Oxford, UK; Boston, MA, USA, 2002; Volume 26, pp. 286–292.
24. Awotwi, A.; Anornu, G.K.; Quaye-Ballard, J.A.; Annor, T.; Nti, I.K.; Odai, S.N.; Arhin, E.; Gyamfi, C. Impact of post-reclamation of soil by large-scale, small-scale and illegal mining on water balance components and sediment yield: Pra River Basin case study. *Soil Tillage Res.* **2021**, *211*, 105026. [CrossRef]
25. Madonsela, B.S.; Semenya, K.; Shale, K. A review of indigenous knowledge systems and their application in sustainable solid waste management. *World* **2024**, *12*, 219–239. [CrossRef]

26. Grangxabe, X.S.; Madonsela, B.S.; Maphanga, T.; Gqomfa, B.; Phungela, T.T.; Malakane, K.C. An overview of waste management practices of street vendors in sub-saharan africa: A meta-analysis. *J. Environ. Manag.* **2024**, *364*, 121464. [CrossRef]
27. Madonsela, B.S. A meta-analysis of particulate matter and nitrogen dioxide air quality monitoring associated with the burden of disease in sub-Saharan Africa. *J. Air Waste Manag. Assoc.* **2023**, *73*, 737–749. [CrossRef]
28. Susanti, T.; Utami, W.; Hidayat, H. The negative impact of illegal gold mining on the environmental sector in Batang Asai, Jambi. *Sustinere J. Environ. Sustain.* **2018**, *2*, 128–143. [CrossRef]
29. Obeng, E.A.; Oduro, K.A.; Obiri, B.D.; Abukari, H.; Guuroh, R.T.; Djagbletey, G.D.; Appiah, M. Impact of illegal mining activities on forest ecosystem services: Local communities' attitudes and willingness to participate in restoration activities in Ghana. *Heliyon* **2019**, *5*, e02617. [CrossRef]
30. Marshall, B.G.; Veiga, M.M.; da Silva, H.A.; Guimarães, J.R.D. Cyanide contamination of the puyango-tumbes river caused by artisanal gold mining in portovelo-zaruma, Ecuador. *Curr. Environ. Health Rep.* **2020**, *7*, 303–310. [CrossRef] [PubMed]
31. Mhlongo, S.E.; Amponsah-Dacosta, F. A review of problems and solutions of abandoned mines in South Africa. *Int. J. Min. Reclam. Environ.* **2016**, *30*, 279–294. [CrossRef]
32. Mhlongo, S.E.; Amponsah-Dacosta, F.; Magodi, R.; Sithole, K.C. Artisanal Gold Mining and its Environmental Stress at Abandoned Louis Moore Mine in the Limpopo Province of South Africa. In Proceedings of the ASM Conference 2018 Fostering a Regional Approach of ASM Transformation in Sub-Saharan Africa, Johannesburg, South Africa, 10–11 September 2018; pp. 181–193.
33. Mineral Council South Africa (MCSA). Illegal Mining. 2022. Available online: <https://www.mineralscouncil.org.za/work/illegal-mining> (accessed on 16 August 2022).
34. Owusu-Boateng, G.; Kumi-Aboagye, E. An assessment of the status of pollution of the Lake Amponsah in the Bibiani-Anhwiaso-Bekwai District, Ghana. *Am. J. Sci. Ind. Res.* **2013**, *4*, 499–511.
35. Hilson, G. "Creating" rural informality: The case of artisanal gold mining in Sub-Saharan Africa. *SAIS Rev. Int. Aff.* **2013**, *33*, 51–64. [CrossRef]
36. Mazikana, A.T. *Assessing the Impact of Illegal Mining on the Environment: A CASE of Ward 59 of Mt Darwin South District*; SSRN: Rochester, NY, USA, 2022.
37. Hinton, J.J.; Veiga, M.M.; Beinhoff, C. Women, mercury and artisanal gold mining: Risk communication and mitigation. *J. De. Phys. IV* **2003**, *107*, 617–620. [CrossRef]
38. Chuma, M. *Understanding Context and the Legal Regulation of Asgm in South Africa in Constituting Various Livelihood Assets*; SSRN: Rochester, NY, USA, 2022.
39. Chamber of Mines of South Africa (CMSA). Integrated Annual Review 2016. Available online: <https://www.mineralscouncil.org.za/reports/2016/#home> (accessed on 15 September 2022).
40. Jara, A. Insights following Junior Indaba 2022. *Inside Min.* **2022**, *15*, 22–23.
41. Havey, R. The Economics of Illegal Mining. 2014. Available online: <https://saiaa.org.za/research/the-economics-of-illegal-mining/> (accessed on 17 August 2022).
42. ISS. Solving South Africa's Violent and Costly Zama Zama Problem. 2019. Available online: <https://www.defenceweb.co.za/security/human-security/iss-solving-south-africas-violent-and-costly-zama-zama-problem/> (accessed on 13 November 2024).
43. Cornelissen, H.; Watson, I.; Adam, E.; Malefetse, T. Challenges and strategies of abandoned mine rehabilitation in South Africa: The case of asbestos mine rehabilitation. *J. Geochem. Explor.* **2019**, *205*, 106354. [CrossRef]
44. Mahopo, Z. Zama Zamas Make Life Unbearable for Limpopo Villagers. 2022. Available online: <https://www.sowetanlive.co.za/news/south-africa/2022-09-19-Zama-Zamas-make-life-unbearable-for-limpopo-villagers/> (accessed on 15 October 2022).
45. Kozińska, P.; Górniak-Zimroz, J. A review of methods in the field of detecting illegal open-pit mining activities. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *942*, 012027. [CrossRef]
46. Terrones-Saeta, J.M.; Suárez-Macías, J.; Bernardo-Sánchez, A.; Álvarez de Prado, L.; Menéndez Fernández, M.; Corpas-Iglesias, F.A. Treatment of Soil Contaminated by Mining Activities to Prevent Contamination by Encapsulation in Ceramic Construction Materials. *Materials* **2021**, *14*, 6740. [CrossRef]
47. Ghazaryan, K.A.; Movsesyan, H.S.; Khachatryan, H.E.; Ghazaryan, N.P. Geochemistry of potentially toxic trace elements in soils of mining area: A case study from Zangezur Copper and Molybdenum Combine, Armenia. *Bull. Environ. Contam. Toxicol.* **2018**, *101*, 732–737. [CrossRef]
48. Okonkwo, S.I.; Idakwo, S.O.; Ameh, E.G. Heavy metal contamination and ecological risk assessment of soils around the pegmatite mining sites at Olode area, Ibadan southwestern Nigeria. *Environ. Nanotechnol. Monit. Manag.* **2021**, *15*, 100424. [CrossRef]
49. Alvarez-Berríos, N.L.; Aide, T.M. Global demand for gold is another threat for tropical forests. *Environ. Res. Lett.* **2015**, *10*, 014006. [CrossRef]
50. Ali, M.I. The Consequences of Illegal Mining in the Environment: Perspectives Behavioral, Knowledge and Attitude. *Int. J. Environ. Eng. Educ.* **2019**, *1*, 25–33. [CrossRef]
51. Weleabzgi, B.; Alemayehu, T.; Estifanos, S. Assessing the Environmental Impact of Artisanal Gold Mining Activities on the Waters and Sediments Around Meli, Northwestern Tigray, Ethiopia. *Momona Ethiop. J. Sci.* **2021**, *13*, 281–299. [CrossRef]

52. Mensah, E.O.; Darku, E.D. The impact of illegal mining on public health: A case study in kenyasi, the ahafo region in Ghana. *Tech. Soc. Sci. J* **2021**, *23*, 1.
53. Kabai, M. Illegal Gold Mining Activities in South Africa: ‘Zama Zamas’. 2020. Available online: <https://newjurist.com/illegal-gold-mining-activities-in-south-africa-zama-zamas/> (accessed on 20 September 2022).
54. Martin, A. Uncovered: The dark world of the Zama Zamas. *ENACT*, 23 April 2019.
55. Brits, D.M.; Steyn, M.; Hansmeyer, C. Identifying the unknown and the undocumented: The Johannesburg (South Africa) experience. In *Forensic Science and Humanitarian Action: Interacting with the Dead and the Living*; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2020; pp. 681–692. [CrossRef]
56. Strydom, E. Illegal Mining. 2016. Available online: <http://www.mineralscouncil.org.za/reports/2016/download/CM-IR16-focus-illegal-mining.pdf> (accessed on 15 September 2022).
57. Mabaso, S.M. Legacy gold mine sites & dumps in the Witwatersrand: Challenges and required action. *Nat. Resour.* **2023**, *14*, 65–77.
58. South African Government News Agency (SANGA). Government Is Committed to Eliminating Illegal Mining. 2022. Available online: <https://www.sanews.gov.za/south-africa/government-committed-eliminating-illegal-mining> (accessed on 20 September 2022).
59. Thornton, R. Zamazama, “illegal” artisanal miners, misrepresented by the South African Press and Government. *Extr. Ind. Soc.* **2014**, *1*, 127–129. [CrossRef]
60. Welsted, J. Combatting Illegal Mining. 2022. Available online: <https://www.SSW-FS20-combatting-illegal-mining%20.pdf> (accessed on 20 September 2022).
61. Yende, S.S. Illegal Mining Escalates in Limpopo to Feed Chinese Market. 2022. Available online: <https://www.news24.com/citypress/news/illegal-chrome-mining-escalates-in-limpopo-to-feed-the-chinese-market-20221016> (accessed on 16 October 2022).
62. South African Police Service (SAPS). Illicit Mining North West. 2022. Available online: https://www.parliament.gov.za/storage/app/media/Pages/2022/7-August/8-08-2022/Ministerial_Briefing_Illegal_Mining/session2/North_West.pdf (accessed on 22 September 2022).
63. Chelin, M.; Els, W. Smuggled Explosives Keep Illegal Mining Syndicates in Business. 2021. Available online: <https://issafrica.org/iss-today/smuggled-explosives-keep-illegal-mining-syndicates-in-business> (accessed on 16 September 2022).
64. Puglisi, F. South Africa’s Illegal Miners Risk Everything for Gold. 2020. Available online: <https://www.voanews.com/a/africa-south-africas-illegal-miners-risk-everything-gold/6195605.html> (accessed on 16 September 2022).
65. Mosa, K.A.; Saadoun, I.; Kumar, K.; Helmy, M.; Dhankher, O.P. Potential biotechnological strategies for the cleanup of heavy metals and metalloids. *Front. Plant Sci.* **2016**, *7*, 303. [CrossRef]
66. Lovasoa, C.R.; Hela, K.; Harinaivo, A.A.; Hamma, Y. Bioremediation of soil and water polluted by cyanide: A review. *Afr. J. Environ. Sci. Technol.* **2017**, *11*, 272–291. [CrossRef]
67. Syamsussabri, M. Mercury and Cyanide Pollution on the Aquatic Organism in Sekotong People Gold Mining. *J. Phys. Conf. Ser.* **2019**, *1414*, 012032.
68. United Nations (UN). Global Mercury Supply, Trade and Demand. United Nations Environmental Programme. 2017. Available online: <https://www.unep.org/resources/report/global-mercury-supply-trade-and-demand> (accessed on 4 October 2022).
69. Pacyna, E.G.; Pacyna, J.M.; Sundseth, K.; Munthe, J.; Kindbom, K.; Wilson, S.; Steenhuisen, F.; Maxson, P. Global emission of mercury to the atmosphere from anthropogenic sources in 2005 and projections to 2020. *Atmos. Environ.* **2010**, *44*, 2487–2499. [CrossRef]
70. Driscoll, C.T.; Mason, R.P.; Chan, H.M.; Jacob, D.J.; Pirrone, N. Mercury as a global pollutant: Sources, pathways, and effects. *Environ. Sci. Technol.* **2013**, *47*, 4967–4983. [CrossRef]
71. Mantey, J.; Nyarko, K.; Owusu-Nimo, F.; Awua, K.; Bempah, C.; Amankwah, R.; Akatu, W.; Appiah-Effah, E. Influence of illegal artisanal small-scale gold mining operations (galamsey) on oil and grease (O/G) concentrations in three hotspot assemblies of Western Region, Ghana. *Environ. Pollut.* **2020**, *263*, 114251. [CrossRef]
72. Asiedu, J.B.K. Technical report on reclamation of small scale surface mined lands in Ghana: A landscape perspective. *Am. J. Environ. Prot.* **2013**, *1*, 28–33. [CrossRef]
73. Nyamunda, T.; Mukwambo, P. The state and the bloody diamond rush in Chiadzwa: Unpacking the contesting interests in the development of illicit mining and trading, c.2006–2009. *J. S. Afr. Stud.* **2012**, *38*, 145–166. [CrossRef]
74. Veiga, M.M.; Angeloci-Santos, G.; Meech, J.A. Review of barriers to reduce mercury use in artisanal gold mining. *Extr. Ind. Soc.* **2014**, *1*, 351–361. [CrossRef]
75. Boafo, J.; Paalo, S.A.; Dotsey, S. Illicit Chinese small-scale mining in Ghana: Beyond institutional weakness? *Sustainability* **2019**, *11*, 5943. [CrossRef]
76. Kuffour, R.A.; Tiimub, B.M.; Agyapong, D. Impacts of illegal mining (galamsey) on the environment (water and soil) at Bontefufuo area in the Amansie West district. *J. Environ. Earth Sci.* **2018**, *8*, 98–107.

77. Kessey, K.D.; Arko, B. Small scale gold mining and environmental degradation, in Ghana: Issues of mining policy implementation and challenges. *J. Stud. Soc. Sci.* **2013**, *5*, 12–30.
78. Mudyazhezha, S.; Kanhukamwe, R. Environmental monitoring of the effects of conventional and artisanal gold mining on water quality in Ngwabalozi River, southern Zimbabwe. *Int. J. Eng.* **2014**, *4*, 8269. [CrossRef]
79. Suglo, P.; Effah, P.; Acheampong, A.A.; Sunkari, R.; Yeboah, A. Effects of Illegal Mining on the Environment, Economy, and Agricultural Productivity. *Biochem. Mol. Biol.* **2021**, *6*, 79. [CrossRef]
80. Massachusetts Institute of Technology (MIT). Environmental Risks of Mining. 2016. Available online: <https://web.mit.edu/12.000/www/m2016/finalwebsite/problems/mining.html> (accessed on 12 October 2022).
81. Suresh, M.; Jain, K. Change detection and estimation of illegal mining using satellite images. In Proceedings of the 2nd International conference of Innovation in Electronics and communication Engineering ICIECE-2013, Guru Nanak Institutions, Hyderabad, India, 9–10 August 2013.
82. Chakuya, J.; Munkuli, N.; Mutema, C.; Gandiwa, E. An assessment of the impact of illegal artisanal gold mining on the environment in parts of Chewore Safari Area, Northern Zimbabwe. *Environ. Res. Commun.* **2023**, *5*, 075005. [CrossRef]
83. Mulenga, C. Soil governance and the control of mining pollution in zambia. *Soil Secur.* **2022**, *6*, 100039. [CrossRef]
84. Mpanza, M.; Adam, E.; Moolla, R. Perceptions of external costs of dust fallout from gold mine tailings: West Wits Basin. *Clean Air J.* **2020**, *30*, 1–12. [CrossRef]
85. Dontala, S.P.; Reddy, T.B.; Vadde, R. Environmental aspects and impacts its mitigation measures of corporate coal mining. *Procedia Earth Planet. Sci.* **2015**, *11*, 2–7. [CrossRef]
86. Asamoah, E.O.; Xu, W.; Huang, W.; Yang, W. Environmental Impacts of Artisanal Gold Mining: A case study of Nkaseim Community-Ghana. *J. Environ. Earth Sci.* **2018**, *8*, 116–130.
87. Land Portal Foundation (LPF). Illegal Miners Started Mpumalanga Coal Mine Fire Weeks Ago—It’s Still Burning Today. 2022. Available online: <https://landportal.org/node/102377#:~:text=%E2%80%9CIllegal%20mining%20and%20blasting%20activities,surrounding%20communities%20and%20the%20environment.%E2%80%9D> (accessed on 20 October 2022).
88. Alfonso, P.; Anticoi, H.; Yubero, T.; Bascompta, M.; Henao, L.; Garcia-Valles, M.; Palacios, S.; Yáñez, J. The importance of mineralogical knowledge in the sustainability of artisanal gold mining: A mid-south Perú case. *Minerals* **2019**, *9*, 345. [CrossRef]
89. Uppal, H.; Tripathy, S.S.; Chawla, S.; Sharma, B.; Dalai, M.; Singh, S.; Singh, N. Study of cyanide removal from contaminated water using zinc peroxide nanomaterial. *J. Environ. Sci.* **2017**, *55*, 76–85. [CrossRef]
90. Gonçalves, A.O.; Marshall, B.G.; Kaplan, R.J.; Moreno-Chavez, J.; Veiga, M.M. Evidence of reduced mercury loss and increased use of cyanidation at gold processing centers in southern Ecuador. *J. Clean. Prod.* **2017**, *165*, 836–845. [CrossRef]
91. Tomiyasu, T.; Kodamatani, H.; Hamada, Y.K.; Matsuyama, A.; Imura, R.; Taniguchi, Y.; Hidayati, N.; Rahajoe, J.S. Distribution of total mercury and methylmercury around the small-scale gold mining area along the Cikaniki River, Bogor, Indonesia. *Environ. Sci. Pollut. Res.* **2017**, *24*, 2643–2652. [CrossRef]
92. Aristide, Y.K.S.; Ernest, A.K. Assessment of Mercury (Hg) and Cyanide (CN) Pollution in Surfacewaters, Groundwaters and Sediments around Industrial Mining Sites in the Department of Divo (Ivory Coast). *J. Water Resour. Prot.* **2021**, *13*, 75–91. [CrossRef]
93. Diop, M.; Howsam, M.; Diop, C.; Goossens, J.F.; Diouf, A.; Amara, R. Assessment of trace element contamination and bioaccumulation in algae (*Ulva lactuca*), mussels (*Perna perna*), shrimp (*Penaeus kerathurus*), and fish (*Mugil cephalus*, *Saratherondon melanotheron*) along the Senegalese coast. *Mar. Pollut. Bull.* **2016**, *103*, 339–343. [CrossRef]
94. Suhadi, S.; Sueb, S.; Muliya, B.K.; Ashoffi, A.M. A Pollution of mercury and cyanide soils and plants in surrounding in the Artisanal and Small-Scale Gold Mining (ASGM) at Sekotong District, West Lombok, West Nusa Tenggara. *Biol. Environ. Pollut.* **2021**, *1*, 30–37. [CrossRef]
95. ulul Ningtyas, A.; Suhadi, S.; Dharmawan, A. Absorption of Heavy Metal Mercury (Hg) in Long Bean (*Vigna unguiculata* L. Walp) with Variation of Planting Period and Planting Medium. *J. Ilmu Hayat* **2021**, *5*, 80–89. [CrossRef]
96. Fahmi, A.G.; Abidin, Z.; Kusmana, C.; Noor, E. Versatile synthesis of activated carbon from coconut shells: A method for cyanide adsorption in artisanal and small-scale gold mining wastewater. *J. Degrad. Min. Lands Manag.* **2022**, *9*, 3685–3693. [CrossRef]
97. Mhlongo, S.E.; Akintola, G.O. Artisanal and small-scale mining activities as post-mining land use in abandoned mine sites: A case of Giyani and Musina areas, Limpopo Province of South Africa. *J. Degrad. Min. Lands Manag.* **2021**, *8*, 2815. [CrossRef]
98. Ugya, A.Y.; Ajibade, F.O.; Ajibade, T.F. Water pollution resulting from mining activity: An overview. In Proceedings of the 2018 Annual Conference of the School of Engineering & Engineering Technology (SEET), The Federal University of Technology, Akure, Nigeria, 17–19 July 2018; pp. 17–19.
99. Matshusa, K.; Leonard, L. Exploring strategies for management of disasters associated with illegal gold mining in abandoned mines: A case study of Ekurhuleni Metropolitan Municipality. *Jambá-J. Disaster Risk Stud.* **2022**, *14*, 1237. [CrossRef] [PubMed]
100. Madimu, T. ‘Illegal’ gold mining and the everyday in post-apartheid South Africa. *Rev. Afr. Political Econ.* **2022**, *49*, 436–451.
101. Ojakorotu, V. The Effects of Illegal Mining on Socio-Economic Development of North West Province, South Africa. *Zhongguo Kuangye Daxue Xuebao* **2024**, *29*, 353–362.

102. Sekwadi, P.; Smith, A.M.; Maruma, W.; Mongologa, G.; Tsele, G.; Ngomane, M.; Tau, N.; Williams, S.; Disenyeng, B.; Sebilane, M.; et al. A prolonged outbreak of enteric fever associated with illegal miners in the City of Matlosana, South Africa, November 2020–September 2022. In *Open Forum Infectious Diseases*; Oxford University Press: Oxford, MI, USA, 2024; Volume 11, p. ofae118.
103. Bester, V. A corporate social responsibility conceptual framework to address artisanal gold mining in South Africa. *Resour. Policy* **2022**, *79*, 103030. [CrossRef]
104. Bester, V.; Uys, T. Artisanal mining and its drivers in the South African context. *Extr. Ind. Soc.* **2023**, *15*, 101278. [CrossRef]
105. Lebitso, B.T.; Mabudusha, A. Entrenched Violence and Vulnerability in Illegal Mining Activities: A Policing Dilemma in South Africa. *Int. J. Soc. Sci. Res. Rev.* **2023**, *6*, 346–360.
106. Makhetha, E. ‘Zama Zama’ and leftovers: The recycling of ore in abandoned gold mines in South Africa. *Extr. Ind. Soc.* **2023**, *14*, 101272.
107. Carry, I.; Müller, M. Addressing environmental injustices in South African artisanal gold mining. In *Governing Natural Resources for Sustainable Peace in Africa*; Routledge: London, UK, 2023; pp. 77–100.
108. Mzondi, A.M.M. An Ubuntu-Christocentric Comparison of Gold Mine Companies and the Zama Zama Enterprise in the West Rand District Municipality. *Pharos J. Theol.* **2022**, *103*. [CrossRef]
109. Ledwaba, P.F.; Mutemeri, N. Institutional gaps and challenges in artisanal and small-scale mining in South Africa. *Resour. Policy* **2018**, *56*, 141–148. [CrossRef]
110. Mhangara, P.; Tsoeleng, L.T.; Mapurisa, W. Monitoring the development of artisanal mines in South Africa. *J. S. Afr. Inst. Min. Metall.* **2020**, *120*, 299–306. [CrossRef] [PubMed]
111. Zondo, N.M. Rethinking Artisanal Mining: The Lived Experiences of Rural Artisanal Mining Communities in South Africa. *J. Soc. Dev. Sci.* **2024**, *14* (Suppl. S2), 1–12. [CrossRef] [PubMed]
112. Dyan, C.I. South Africa’s Stolen Gold: A Legal Analysis of the Impact of Illegal Mining on South Africa’s National Security. Master’s Thesis, Faculty of Commerce, Law and Management, University of the Witwatersrand, Johannesburg, South Africa, 2022.
113. Jinnah, Z. The Miners. In *Informal Livelihoods and Governance in South Africa: The Hustle*; Springer International Publishing: Cham, Switzerland, 2022; pp. 23–43.
114. Sibiya, R.P. Environmental and Social Impact of Illegal Gold Mining on Surrounding Communities: A Case Study of Welkom. Ph.D. Thesis, University of the Free State, Bloemfontein, South Africa, 2014.
115. Williams, T.G. Illegal Mining’s Effect on the Sustainability of a South-African Gold Mine. Ph.D. Thesis, North West University, Potchefstroom, South Africa, 2019.
116. Mphokane, S.D. Curbing Illegal Gold Mining in Barberton. Ph.D. Thesis, Faculty of Commerce, Law and Management, University of the Witwatersrand, Johannesburg, South Africa, 2018.
117. Chimukoko, J. Lived Experiences of Illegal Immigrant Gold Miners Residing in Lindelani Informal Settlement. Master’s Thesis, University of Johannesburg, Johannesburg, South Africa, 2017.
118. Wilson, L.A. Unshackling South African Artisanal Miners: Considering Burkina Faso’s Legislative Provisions as a Guideline for Legalisation and Regulation. Master’s Thesis, Faculty of Law, Department of Private Law, University of Cape Town, Cape Town, South Africa, 2018.
119. Yende, S.S. Lily Mine Disaster Report Says Prosecute. 2018. Available online: <https://www.fin24.com/Economy/lily-mine-disaster-report-says-prosecute-20180826-2> (accessed on 26 August 2023).
120. Stoddard, E.D. Illegal Miners and Fouled Waterways in Mpumalanga Underscore Coal’s Toxic Legacy. 2022. Available online: <https://www.dailymaverick.co.za/article/2022-05-24-illegal-miners-and-fouled-waterways-in-mpumalanga-underscore-coals-toxic-legacy/> (accessed on 12 September 2022).
121. Heiberg, T. South Africa Hasn’t Protected Residents from Gold Mine Pollution: Harvard Report. 2016. Available online: <https://www.reuters.com/article/us-safrica-environment-mining/south-africa-hasnt-protected-residents-from-gold-mine-pollution-harvard-report-idUKKCN12C1ZP> (accessed on 24 September 2022).
122. Phala, A.; Mistry, M.; Maatlala, R. Implications of illegal mining in Gauteng Province. *Int. J. Humanit. Soc. Sci.* **2017**, *6*, 53–56.
123. Riukulehto, S. Dangerous, frightening, homely: Home experiences of those living on the goldmines of the Far West Rand. *New Contree* **2022**, *89*, 19. [CrossRef]
124. Weissenstein, K.; Sinkala, T. Soil pollution with heavy metals in mine environments, impact areas of mine dumps particularly of gold-and copper mining industries in Southern Africa. *Arid Ecosyst.* **2011**, *1*, 53–58. [CrossRef]
125. Laker, M.C. Environmental impacts of gold mining—With special reference to South Africa. *Mining* **2023**, *3*, 205–220. [CrossRef]
126. Worlanyo, A.S.; Jiangfeng, L. Evaluating the environmental and economic impact of mining for post-mined land restoration and land-use: A review. *J. Environ. Manag.* **2021**, *279*, 111623. [CrossRef]

127. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* **2021**, *372*, n71. [CrossRef]
128. Maphanga, T.; Madonsela, B.S. Land degradation associated with illegal sand mining in rural areas and lack of formalization of the industry in South Africa: A review. *Int. J. Environ. Impacts* **2023**, *6*, 251–256. [CrossRef]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.