The Journal of Accounting and Management

Accounting for Waste by the Zimbabwean Gold Mining Sector

Moses Nyakuwanika[1], Huibrecht Margaretha van der Poll[2], John Andrew van der Poll[3]

Abstract: The disposal of gold mining waste is a major cause of land degradation and forest loss in Zimbabwe. Although the mining sector is a key driver of the Zimbabwean economy, substantial volumes of wastewater, waste rocks, tailings, and slag are produced. The research aimed to establish how the Zimbabwean gold mining sector accounts for waste. Twelve in-depth interviews were conducted among selected key gold mines in Zimbabwe. It was found that some gold mines adopted international environmental accounting standards as strategies to minimise waste and move towards zero waste generation, and that waste can be converted into economic value. However, most solutions were found to be sectoral. It is recommended that holistic approaches are needed to address the challenges of waste management within the gold mining sector of Zimbabwe. Raw materials should be utilised effectively, and waste reduced to facilitate profit generation by the mining sector. Considering the potential conflicts of gold mining, we suggest a comprehensive, integrated waste management strategy consistent with other land uses. Remedial action is recommended to protect the environment. Future research may investigate ways to minimise waste through environmental management accounting practices. Interdisciplinary research may also assist as the challenges cut across several disciplines, such as accounting for the financial flows of waste and engineering for the physical flows of waste.

Keywords: environment; gold mining; mine waste; sustainable mining; waste management

JEL Classification: M400, M410, M480, Y4

1. Introduction

The demand for gold has always been high in the jewellery, investment, electronic, and medical industries due to its unique physical characteristics (Munagamage et al., 2021; Birich et al., 2023; Rao et al., 2023). However, mining activity has generally been described as a threat to ecosystem integrity (Kalamandeen et al., 2020; Timsina et al., 2022; König et al., 2023). It is the main cause of environmental degradation through the use of toxic chemicals such as mercury and the removal of

[1] Department of Management, College of Accounting Sciences (CAS), University of South Africa, Muckleneck, South Africa, Address: Preller Street, Muckleneuk Ridge, Pretoria, E-mail: nyakuwanikam@gmail.com.
[2] Graduate School of Business Leadership (SBL), Sustainable Livelihoods, Midrand, University of South Africa, South Africa, Corresponding author: vdpolhm@unisa.ac.za.
[3] Graduate School of Business Leadership (SBL), Digital Transformation and Supply Chain Management, Midrand, University of South Africa, South Africa, E-mail: vdpolja@unisa.ac.za.

forest cover (Markham & Sangermano, 2018; Pisconte et al., 2024). This calls for managers to monitor any change related to landscape use and thereby develop strategies to manage the environment (Stoll et al., 2022; Quash, Kross & Jaeger, 2024).

Globally, legislation has been passed to protect, monitor, and manage the environment (Orimoloye & Ololade, 2020; Nandiyanto et al., 2023) as a response to research indicating that human activities primarily contribute to environmental degradation (Guerry et al., 2015). Furthermore, mining operations, including mineral extraction, agricultural expansion, and urban development, are some of the human activities that negatively impact the loss and degradation of biodiversity of the ecosystem (Epule et al., 2014; Tegegne et al., 2016; Korhonen-Kurki et al., 2019). For example, gold mining activity causes substantial damage to the ecosystem by contaminating water bodies, thereby destroying natural habitats (Palacios-Torres, de la Rosa & Olivero-Verbel, 2020; Escobar-Segovia et al., 2021; Córdoba-Tovar et al., 2023). Therefore, environmental accountability is essential for the gold mining sector to achieve its sustainability goals.

During gold mining processes, mercury and cyanide are regularly released into the environment (Veiga et al., 2014; Ilyas & Lee, 2018; Manzila & Moyo, 2021). Environmental degradation is believed to be caused mainly by mining processes and waste disposal practices (Spiegel et al., 2018; Orimoloye et al., 2019). According to Orimoloye and Ololade (2020), mining tailings and waste are the most toxic and can harm humans and animals if they are not contained. Due to the relative nature of mine waste, the distance of the mining industry from the population, and occasionally apparent success in mine waste management, it is less recognised by the mining industry than by municipal councils and chemical and manufacturing industries (Mudd, 2007; Voncken & Buxton, 2019; Baker et al., 2020).

Mineral production has increased substantially while ore grades have been declining, and this, coupled with a shift from underground to open-cast mining, has increased the production of waste rock (Mudd, 2007). According to Mudd, the global increase in mineral demand will likely leave an ecological footprint, which may pose challenges in meeting various law obligations, social expectations, corporate standards, and environmental constraints.

Due to the effects of gold mining on the environment, climate change, and the socioeconomic position of local communities, it remains controversial in developing nations (Orimoloye & Ololade, 2020). Furthermore, the current utilisation of gold mine waste in developing countries is very low compared to developed countries (Oluwasola *et al.*, 2014). Therefore, it is essential to establish how the Zimbabwean gold mining sector accounts for gold waste so that key stakeholders can devise strategies to reduce its environmental footprint. This research aims to establish how waste is accounted for within the Zimbabwean gold mining sector.

The article's layout is as follows: Section 1.1 justifies the research, and Section 1.2 defines the research questions (RQs). Section 2 presents the literature review, whereas Section 3 provides the research methodology that underpins this research. The findings are discussed in Section 4. Section 5 provides the conclusion and future work. The article concludes with a list of references.

1.1. Problem Statement

The main driving force for this research is exploring how Zimbabwe's gold mining sector accounts for waste. This aligns well with the early views that waste management is essential for the mining sector

to optimise profits (Munagamage et al., 2021). For example, a trucker was paid to haul the waste away, but discovered that the waste was a valuable fertiliser that became an additional source of revenue for the entire industry (Kalamandeen et al., 2020). The research has also been motivated by the growing scarcity of valuable resources and the continued depletion of metal ores. Oluwasola et al. (2014) provide that the use of mine waste in developing countries is below expectations compared to advanced countries, and rapid global population growth and expansion of the mining sector have caused significant mining waste production.

1.2. Research Question

The following question was raised to investigate waste generation in the Zimbabwean gold mining sector:

How does the gold mining sector account for waste?

The researchers aimed to answer this question to provide useful information on how the Zimbabwean gold mining sector accounts for waste, which would promote greener gold mining in Zimbabwe.

The work reported in this article stems from a Doctoral thesis of the lead author.

2. Literature Review

Sustainability has been defined as addressing the requirements of the present without sacrificing the capacity of future generations to address their own needs (Mensah, 2019; Purvis et al., 2019; Hariram et al., 2023). Hence, mineral deposits are considered unsustainable since it is a limited or non-renewable resource (Mudd, 2007). However, the gold mining sector has expanded considerably due to liberalisation, with more foreign mining organisations and artisanal miners investing in the sector, particularly open pit mining (Amoako et al., 2018). Amoako et al. (2018) further add that expanding gold production has raised numerous environmental concerns and challenges due to the activities used in gold processing. Therefore, this calls for the mining sector to be accountable for environmental issues and reduce its footprint so future generations can also benefit.

Mining is one of the sectors that significantly contributes to the aggregate mining countries' per capita gross domestic product (GDP) (Ericsson & Löf, 2019; Gochero & Boopen, 2020; Mufandaedza, 2021; Benita & Gaytán-Alfaro, 2024). In Zimbabwe, the sector contributes at least 8% of the country's GDP (Manyuchi, Mbohwa & Muzenda, 2019). Though the mining sector positively contributes to a country's economic development, the detrimental legacy left by gold tailings and slag harms the environment (Mashifana & Sithole, 2021). Mashifana and Sithole indicated that the gold mining sector is related to contaminated subsurface works, sinkholes, and tailing dams. Fourteen billion tons of tailings are anticipated to be produced annually on a global scale (Maruthupandian, Chaliasou & Kanellopoulos, 2021; Araya, Kraslawski & Cisternas, 2020; Baker et al., 2020; Cacciuttolo & Atencio, 2022; Sarker et al., 2022).

Research conducted by Rembuluwani, Dacosta and Gumbo (2014) on environmental risk and management related to gold tailings has revealed that the tailings were acidic and heavy metal-laden, with a pH of between 3 and 6. Furthermore, acid mine drainage (AMD), which results from mining chemicals being exposed underground, is a prominent signal of the environmental problem that gold mining activities are causing (Uchenna, 2017; Candeias et al., 2019; Mensah, 2021; Cacciuttolo &

Atencio, 2022; Ata et al., 2024). A global issue is the mining industry's consequences on the environment, the economy, and the government (Ros-Tonen et al., 2021). Consequently, the gold mining sector may need to account for waste, which poses environmental risks to animals and humans.

Mining operations result in large amounts of waste containing toxic chemicals that may pollute the environment (Kaniki & Tumba, 2019). Kaniki and Tumba argued that the mining sector has long been considered a waste driver, creating a significant risk to the environment, animals, and inhabitants near the mine. In Zimbabwe, one of the sources of solid waste is the gold mining industry (Mutsvanga, Mapira & Ngaza, 2018). Recent studies have indicated that waste tailings from mining operations contain metallic trace elements, which are difficult to degrade and threaten the well-being of people (Banza et al., 2009; Mwaanga et al., 2019).

Much waste is generated during the mining process, depending on the mining method and technology being applied, as well as the geology of the mining site (Manyuchi et al., 2019). Therefore, a good waste management strategy is needed to prevent environmental damage (Mapira, 2017; Hove, Rathaha & Mugiya, 2020; Mubonderi, 2023). There should be coordination between waste management and a country's legislation, and in the case of Zimbabwe, it is the Environmental Management Act. Waste should be stored, collected, transported, and disposed of on time to curb the spread of disease, forest fires, and water body contamination, and keep the ecosystem close to its natural state.

An extensive volume of water is used and discharged during mining (Northey et al., 2016; Thomashausen, Maennling & Mebratu-Tsegaye, 2018; Turunen et al., 2020; Wolkersdorfer & Mugova, 2022). National and international communities are calling for the understanding and effective utilisation of natural resources as the driver for sustainable resource use and management (Thomashausen, Maennling & Mebratu-Tsegaye, 2018; Wolkersdorfer & Mugova, 2022). More attention has recently been placed on economic development by the mining sector, which has been at the expense of sustainable development (Mutsvanga et al., 2018). The unregulated flow of mining waste into rivers and on land represents a significant environmental challenge related to waste disposal (Woźniak & Pactwa, 2018). Therefore, owing to humanity's increased demands on the ecosystem (Palacios-Torres, de la Rosa & Olivero-Verbel, 2020), it is essential to estimate the environmental footprint of the resources being used (Ilyas & Lee, 2018). In this regard, an understanding of the management of water, being a scarce resource, appears to be limited (Cosgrove & Loucks, 1969; Liu et al., 2017; Molden, 2020; Ricart et al., 2021), making it hard to determine what degree of water use and discharge by a mining organisation is appropriate (Northey et al., 2019).

Gold-mining waste includes occupied land during stockpiling, dumping, and disposal, which endangers the ecosystem, including the air, water, and soil (Mutsvanga et al., 2018). Calls for an integrated and interdisciplinary approach to waste management have been made to generate new economic value, move toward zero waste generation, and leave little or no trace of one's existence on the environment (Tayebi-Khorami et al., 2019). Backfilling has been suggested as a remedy for the environmental degradation caused by gold tailings and slag (Mashifana & Sithole, 2021) and many nations have begun investigating paste backfill technology as a novel and innovative method to deal with mine waste (Cheng et al., 2019). Since this research is generally concerned with waste management and not backfill technology, further discussion of the latter is beyond the scope of this work. From a risk management perspective, waste accounting is an essential governance matter in the gold-mining process, emphasising control of the process throughout the gold-mining process value chain (Ghorbani & Nwaila, 2020). Therefore, proper waste management may create new economic value for the gold-mining sector, greatly increasing its profitability.

Most mining tailings are disposed of in tailing dams, of which filled dams have caused significant spillage issues (Oluwasola et al., 2014). According to Oluwasola et al. prominent examples are the breakdown of the Merriespruit tailing dam in South Africa in 1994, which resulted in fatalities and extensive damage to residential structures, and the evacuation of 250 residents in the Philippines in 2002 due to the tailing spilling into the Mapanuepe Lake. The modern view of the mining sector is towards sustainable mining, which represents a shift away from a narrow view of a particular mine and towards an overall perspective of the sector and its role in the development of society (Mudd, 2007). Mudd adds that reclamation of disused mining areas has been lacking, which calls for the modern mining industry to move towards improved sustainability performance and reporting. Hence, an integrated waste management approach would go a long way in mitigating some of these problems.

Since mining produces a lot of waste per ore of mineral that is extracted, concentrated in the form of spent heap leach pads, tailings, storage facilities, or waste rock dumps, reclamation and post-reclamation are crucial factors in the valuation of mining assets (Espinoza & Morris, 2017). The size of current mining operations and the volume of waste they produce dwarf all other industrial waste management efforts, and these may be the largest obstacle to sustainability (Schneider, 2017; Ogunseitan, 2023; Wilson, 2023). The issue is worsened because the waste produced by the chemical methods used to extract minerals from ore (for instance, gold employs cyanide-rich solutions as a leaching agent) can be highly hazardous (Espinoza & Morris, 2017). According to Espinoza and Morris, these leaching processes occur via industrial procedures that dump fine ground tailings in storage facilities earmarked for tailings. Therefore, the remaining sulphide minerals in tailing storage are vulnerable to oxidation, leading to AMD, which is detrimental to the environment and human health (Nieva, Borgnino & García, 2018; Masindi et al., 2022; Si et al., 2023). By its very nature, mining is a transient industry that produces income for a brief time. However, it may also result in obligations that may remain forever (Masindi et al., 2022; Ogunseitan, 2023; Si et al., 2023). Therefore, the country's culture should develop mechanisms to prevent wasting the important resources being mined and prepare for a day when those resources will not be available anymore (Espinoza & Morris, 2017). The following section presents materials and methods underpinning this research.

3. Materials and Methods

This research aimed to establish how the Zimbabwean gold-mining sector accounts for waste. The researchers adopted the research onion of Saunders, Lewis, and Thornhill (2019) to develop the research methodology. The researchers conducted 12 in-depth interviews with personnel from five chosen gold mines in Zimbabwe. A qualitative multimethod research choice aligned with the interpretivist philosophy was chosen for this research, with a research strategy that involved qualitative surveys. The researchers made generalisations using deductive reasoning. The data collection technique and analysis were conducted through in-depth interviews. Personnel from the identified gold mines in Kadoma, Bindura, and Gwanda in Zimbabwe were contacted for in-depth interviews. A participant information sheet explaining the goals of the research and the interview subjects' rights was given to each participant. Interviewees signed an informed consent before taking part in the study.

Additionally, the interviewees were assured that their answers would remain anonymous. Annexure 1 presents the interview questions. The next section presents the findings.

4. Findings and Discussion

Data were gathered during the interviews. Twelve interviews were conducted and transcribed by a transcriber who signed a confidentiality agreement. The section that follows presents the questions asked and responses from the interviewees. Interviewees were asked how the Zimbabwean gold mining sector was accounting for waste. This was essential to establish how waste was being accounted for, since waste can affect the environment. The findings of the interviews on how the Zimbabwean gold mining sector accounts for waste are discussed below.

The first question was, "How does the gold mining sector account for waste? Is waste identified separately or assigned to overheads? Explain."

A synthesis of responses from the interviewees pointed to the following themes:

- **Accounting for waste**

  Large quantities of waste are produced annually, which calls for accounting for it and its environmental impact. For example, the land occupied by waste rock during dumping and tailing dams should be accounted for.

- **Recording of waste**

  Waste should not be assigned to overheads as it is moved at a cost, and the volume of waste within a rift or ore determines the profits to be generated. When an acceptable percentage of waste exists within the rift, an organisation can profit. To emphasise the importance of waste management and accounting, P1 stated:

  "*To us, it's necessary because waste is moved at a cost. And at the end of the day, it also makes us know the ratio between our rift and the waste."*

- **Waste governance**

  Waste accounting is a governance matter with the environmental regulators (Environmental Management Agency and the Ministry of Mines) in Zimbabwe.

- **Responsible gold mining waste disposal**

  Waste disposal was identified as a threat to the environment (harmful to animals and humans) if not properly accounted for. Effluent water from plants is pumped, recirculated, and used in the plant to avoid flowing downstream and contaminating water bodies; however, there are instances when it overflows from tailing dams into the environment. Furthermore, mining organisations are working on minimising their footprint on the environment by adopting internationally accepted environmental standards on waste management. Effective utilisation of waste by converting it into other economic value addition was viewed as sustainable development.

- **Association between waste accounting and organisational culture, mission, and operating environment**

  Several participants indicated that waste accounting aligns with the organisation's culture, mission, and operating environment. Participants stated that employees would take waste management seriously if it were an organisational culture and stated within its mission statement. P5 stated:

> "*…all about culture, it is all about efficiency of technology of what the industry has begun, the legislation also comes into play, competence also comes into play, consumer pressure also comes into play, community demand, and management awareness come into play. We are looking at the growth perception of your interested or affected parties on how the operations in terms of influence to go green."*

The preceding discussions support the idea that gold mining is expanding due to the growing population. This results in environmental challenges due to large quantities of waste being produced. Markham & Sangermano (2018) observed waste as the main cause of environmental disasters through the release of toxic chemicals. Orimoloye and Ololade (2020) supported the above and argued that mining tailings could be toxic to humans and animals if not well contained. Munagamage et al. (2021) indicated that gold-mining chemicals were chief contaminators of the environment. This also aligns well with the argument provided by Mudd (2007) that gold mining should move towards improved sustainability performance and reporting to minimise environmental disasters resulting from gold mining waste.

The second question that was posed was, "Do you think knowing the volume of waste generated by the gold mining process is going to assist the industry in any way? Explain."

Although the answers provided by the participants to the question differed, a summary of their responses revealed the following themes:

- **Knowing the volume of waste and strategies for reducing it**

  In large mines, waste is an asset that should be properly accounted for. Therefore, a tail's report should be provided, and the information should be readily available to management to be utilised when needed.

  Though other types of waste can be converted to other uses, knowing the volume of waste assists in decision-making by developing strategies to reduce waste. Knowing the volume of waste being produced would help to decide on the disposal site and the cost of moving the waste, as well as assisting in deciding how the waste can be converted into other uses. For example, when mining hard rock, a lot of waste rock is generated, which can be crushed into quarry stones used for building purposes. This can be a strategy to manage waste by converting it into building materials that generate other income for the mining organisation. Knowing volume would assist in ascertaining its impact on the environment, which would likely assist in developing mitigatory strategies.

- **Asset versus waste**

  What might be considered waste in other mining organisations could be regarded as an asset by others. What is regarded as waste is built up in tales that become assets to the mining organisations as they await gold to be extracted.

  To emphasise the importance of knowing the volume of waste produced by the gold-mining process and how it was going to assist the industry, P2 stated:

  "*…the waste in gold is your tailings, and though gold could have been extracted within the tales, gold is never exhausted. As you extract it, whatever waste you throw away, you dump it somewhere. As new mining methods are discovered, you still revisit that waste, which now sits as an asset, and retreat that dump to get more gold."*

It was revealed that no technology is currently available in Zimbabwe that could extract all the gold in the ore or the rift.

The themes above align with the belief that reliable waste data is critical for internal decision-making (Strand & Syberfeldt, 2020; Esposito et al., 2024). In addition, Orimoloye and Ololade (2020) believe that knowing the volume of waste is essential since it is related to profits. This also aligns with (Lin et al., 2013; Abdel-Shafy & Mansour, 2018; Das et al., 2019), who revealed that depending on the quality and volume of waste generated, it could be converted into other products that can provide the organisation with additional revenue.

The third question posed was, "Is there any relationship or linkage between waste reduction and the performance of a gold mining company in terms of the economy and the environment? Explain"

A synthesis of responses from the interviewees indicated a linkage between waste reduction and the performance of a mining organisation in terms of economy and the environment. The interviewees' responses pointed to the following themes:

- **Waste reduction for increased profitability**

  A relationship between waste reduction and a goldmine's performance is essential. Goldmines should work towards reducing the volume of waste if they want to generate a profit. Waste management should be taken seriously, and avenues for creating new economic value should be pursued to move towards zero waste generation, which could drive profits upward. Hence, waste reduction implies cost savings and increased profitability.

- **The rift determines the amount of waste**

  It is not always easy to reduce waste since waste generation is due to the nature of the rift being mined. If the rift being mined is wider, the volume of waste to be moved becomes minimal; however, if it is narrow, more waste will be generated, thereby diluting gold percentage returns.

- **Improved production processes**

  Waste reduction can result in an improvement in gold production processes. P4 mentioned that:

  "*In our efforts to reduce waste, we may end up optimising our processes. If we optimise our processes, we are going to use less of inputs per gold output or the ore processed, which means we improve our efficiencies, which improves our productivity, so the bottom line would be increased. So, as we increase our bottom line, we also reduce our waste, thereby optimising our processes. This is very key."*

  Waste management could not be separated from production processes; hence, improving the production process would generate minimal waste.

- **Driver for economic growth**

  We need to examine and understand how natural resources like water could be used sustainably to drive economic growth.

These themes align with the argument that waste reduction supports eco-efficiency decisions and increases an organisation's economic and environmental performance (Comăniță et al., 2018; Puertas

et al., 2022; Daraio, Di Leo & Simar, 2024). In addition, Comăniță et al. (2018) and Daraio, Di Leo and Simar (2024) indicated that there had been calls by the communities of the mining sector to understand and devise an effective utilisation of natural resources as a driver for economic development and sustainable resource use, as well as management.

The fourth question posed was, "Do you have a waste reduction strategy? If not, why not? If yes, how has this been implemented, and how has it been of help to you?"

The synthesis of the responses highlighted the following themes:

- **Waste reduction strategy**

  Large gold-mining organisations have a waste-reduction strategy, while smaller gold mines operate without a strategy. The strategy of managing waste was integrated into the business model.

- **Utilising waste**

  Though some large gold mines are converting waste rock into quarry stones, the utilisation of gold mine waste was slow in the Zimbabwean gold mines.

- **Environmental management plans**

  Though they submitted environmental management plans to the regulator, small gold mines rarely followed them.

  P6, in support of the above sentiment, responded as follows to the question that had been raised:

  "*Here, we don't have a documented management plan in place. Yes, we are legally required to manage and protect the environment, but we cannot say we have an environmental management plan in place."*

The findings of this research contradicted the belief that the waste storage area, its architecture, and long-term plans for waste instability after mining closure should be included in the waste management strategies to be implemented (Manyuchi, et al., 2019). However, a section of the findings agreed with the views of Oluwasola et al. (2014), who provided that the utilisation of waste in developing countries is rather slow and lagging.

The fifth question posed was, "Which accounting system is used within your organisation? Do you think the current accounting system can capture the entire flow of waste within the gold processing? Explain."

The following themes were identified after a synthesis of responses from participants:

- **Accounting system and eco-efficiency decisions**

  Interviewees (P8, P9, P10, and P11) argued that the accounting system does not support eco-efficiency decisions. They attributed this to the nature of the reports required by the environmental regulator, which did not support eco-efficiency decisions. P10 and P11 stated that waste accounting supports eco-efficiency decisions since the waste dumping site should be built in an environmentally friendly manner to avoid spillage into water bodies and the environment. In the end, gold-mining organisations are complying with the regulation. To emphasise the above, P11 stated:

"*We only subscribe to EMAg, which is the environmental regulator. They have what they call quarterly reports, and they also raise invoices for specific environmental impacts and assessments that have to do with mining activities."*

It was revealed by several interviewees (P8, P9, P10, and P11) that the accounting systems being used by most organisations focused on financial accounting issues and not the environment. P9 had to emphasise by saying:

"The accounting system in use handles accounting issues only. It does not have other modules even to use by HR or plant processing, and hence it is just for accounting purposes."

- **Accounting system and measuring of environmental performance**

  P10 and P11 revealed that waste information was regarded as an investment, and even though the accounting system had limitations, it assisted in measuring environmental performance, keeping track, and comparing progress on projections.

The findings from this aspect of the research were found to be contrary to the views of various researchers, who asserted that waste management was essential for the mining sector to optimise profits and that the accounting system should provide waste information if the profit optimisation goal is to be realised (Alves, Ferreira & Azurem, 2017; Iacovidou et al., 2017; Zvarivadza, 2018; Nwaila et al., 2022).

The sixth question was, "Do you subscribe to any standard that prescribes to waste management? If yes, how has the standard been of assistance to you? How has the standard assisted you in making available waste information?"

A synthesis of responses from interviewees revealed the following themes:

- **Adherence to waste management standards**

  Most large gold-mining organisations subscribe to standards that prescribe waste management, while others do not. Small gold mines were not subscribing to standards prescribing waste management due to a lack of resources, and in the end, these mines only subscribed to EMAg standards, which are the regulators.

  Participants indicated that they subscribe to ISO4001, ISO 18001, and Orchards 45001. ISO4001 prescribes how gold-mining organisations should manage the environment. To emphasise the importance of subscribing to standards, P8 stated that:

  "ISO18001 and Orchards 45001 are recent standards, so they are good in terms of environmental management, and they are being checked every year. The guys come down usually to do the resubscription process, and compliance with standards is key to being given an operating license."

- **Resource availability and best practice**

  Most respondents from large gold-mining organisations indicated that due to the availability of resources, they had done a lot in terms of best practices, from employing international standards to aiming to achieve excellence and living in excellence, unlike other small gold-mining organisations that try to achieve legal compliance.

- **Minimising the environmental footprint**

Most respondents revealed that mining organisations are working on minimising their footprint on the environment by adopting internationally accepted environmental standards. To this end, interviewees indicated that it is within their mission statement that they work towards reducing their footprint on the environment.

Interviewees from large gold-mining organisations indicated that to minimise their footprint on the environment, they had adopted internationally accepted standards to which they are certified by a German company, GDS. Respondents added that they work with a strategic plan.

- **Strategic plan to reduce environmental impact**

  Each year, mining organisations try to determine their possible impacts on the environment and develop programmes to reduce them. Respondents indicated that they work with targets, such as no chemical spills into the environment, and that the organisation's strategic vision is zero harm to the environment.

The above discussion of adopting international standards to manage waste agrees with the position of Mashifana and Sithole (2021) that the gold-mining sector is associated with tailing dams, sinkholes, and contaminated underground workings, which require the adoption of international standards to manage them and avoid leaving a detrimental legacy that may impact negatively on the environment.

The seventh question posed was, "Do you provide any waste-related information to management for waste-reduction decision-making? If not, why? If yes, how has the information been rated?"

On the provision of waste-related information to management, a synthesis of responses from the interviewees revealed the following themes:

- **Waste-related information**

  Several gold-mining organisations provided their management with waste-related information, which was rated as good. Waste-related information was essential to management because it assists in devising a more cost-effective way to extract gold in the future, as gold is never exhausted.

  P11 emphasised that:

  "*Yes, we provide management with waste information since the same information is required by EMAg, the regulator. The information we provide to management helps us not to be caught on the wrong side of the law.*"

- **Regulator requirement**

  Waste-related information, a requirement of the Environmental Management Agency (EMA), the regulator, had to be provided to management so that everyone knew and could not be found wanting. The gold-mining process uses many chemicals like cyanide, and how this was managed was essential for decision-making and to avoid punitive fines from the regulator.

- **Economy, society, and the environment**

  Attention has of late been directed to the gold-mining industry's performance in terms of the economy, society, and the environment, which has necessitated the need for waste accounting data.

The last question posed was, "Are there barriers in the provision of gold process waste information? If yes, which strategies have been adopted to try and address them?"

A summary of the responses pointed to the following themes:

- **Lack of resources to invest in new technology**

  The lack of resources to invest in current technologies was cited as the major barrier. Participants pointed to the economic meltdown and sanctions as issues that have hindered the importation of new technologies that could be used in providing waste-related information. On strategies that have been adopted to try and address the barrier, it was stated that some gold-mining organisations have tried to enter into partnership agreements with would-be investors from countries with advanced technologies, with the hope that when they invest, they bring them advanced technologies from their countries which could assist in making waste related information available.

- **Dust generation and pollution**

  It was revealed that much dust is generated during the crushing of rocks to extract gold, and much water is used to suppress the dust to avoid pollution and contamination of employees.

This aligns with the view that mining activities result in environmental damage and ecological degradation, like air pollution, destruction of the landscape, loss of biodiversity, water acidification, and loss of fertile soils (Gupta & Paul, 2015; Praveen, Ganguly & Wakchaure, 2017; Adla et al., 2022). Some respondents revealed that they treat cyanide using chemicals, and some of it is destroyed naturally by exposing it to the sun to acceptable levels before discharging effluent water into downstream operations.

5. Conclusion and Future Research

The article aimed to establish how the gold-mining sector in Zimbabwe accounts for waste by conducting in-depth interviews within the sector. It was found that the mining sector is a significant generator of solid waste, including tailings and waste rock. Gold-mining waste was identified as an environmental threat if not properly accounted for. The findings further indicate that some Zimbabwean gold mines have strategically embarked on international environmental accounting standards to address their waste challenges, aimed at zero-waste operations. One effective strategy is to transform waste generation into value generation, which may be considered sustainable development. Easy-accessible waste can be beneficial in creating value-added construction materials, aiding in resolving environmental issues that the gold-mining industry is facing. The solutions proposed in the literature were found to be sector-specific; consequently, based on their findings, the researchers call for an integrated and holistic approach to address waste generation challenges in the Zimbabwean gold-mining industry. Such approaches should be consistent with challenges around other land uses. Conflicts may result, but arguably can only be fully resolved when the effects of gold-mining waste are acknowledged, and all stakeholders are involved in devising measures to address them.

Addressing the challenge of waste starts with effectively utilising raw materials. Doing so may improve gold mining companies' profit margins. Apart from preventative measures, investigations

aimed at addressing already compromised environmental conditions, especially the challenge of waste in the form of tailings resulting from mining activities, should be launched.

Future research may be conducted along several avenues. As indicated, ways to utilise environmental management accounting practices to address waste resulting from tailings in the goldmine sector should be investigated. A lucrative EMA practice is material flow cost accounting. Examining cutting-edge technology that Zimbabwean gold mines can employ to reduce waste and boost waste processing could yield vital new knowledge. Research could be conducted to assess the feasibility and potential consequences of using technologies like hydrometallurgical processes or bioleaching. More comprehensive waste management solutions may result from understanding how to collaborate with mining firms, regulatory agencies, and local populations. Best practices and lessons learnt could be found through comparative research with other gold mining regions, especially those that have effectively adopted zero waste initiatives. This will provide a more comprehensive framework for understanding Zimbabwe's unique challenges and opportunities. Owing to the interdisciplinary nature of waste management in gold mining, research is also needed regarding the physical flows of waste at the intersection of gold mining, financial aspects, and engineering.

This study differs from others in that it focuses on the gold mining sector in Zimbabwe, providing localised insights crucial for effective policy formulation and implementation. This contrasts with many other studies that address gold mining waste in a broader sense. Additionally, in-depth interviews with important stakeholders in the mining industry offer a nuanced understanding of waste management challenges and procedures that quantitative studies may overlook. Unlike studies that focus on technical or economic issues, this research advocates for a comprehensive, integrated approach to waste management that considers social, economic, and environmental factors. In contrast to most of the extant literature, the proposal for interdisciplinary approaches encourages collaboration amongst fields such as engineering, economics, and environmental research.

Conflicts of Interest

The authors declare no conflict of interest.

References

Abdel-Shafy, H.I., & Mansour, M.S.M. (2018). Solid waste issue: Sources, composition, disposal, recycling, and valorization, *Egyptian Journal of Petroleum*, 27(4), 1275–1290.

Adla, K., Dejan, K., Neira, D., & Dragana, S. (2022). Chapter 9 - Degradation of ecosystems and loss of ecosystem services, *One Health: Integrated Approach to 21st Century Challenges to Health*. Prata, J.C., Ribeiro, A.I. & Rocha-Santos, T. Eds., Academic Press, 281-327.

Alves, W., Ferreira, P., & Araújo, M. (2021). Challenges and pathways for Brazilian mining sustainability, *Resources Policy,*

74.

Amoako, Y. K., Gordon, C., Sakyi, P.A., & Gyimah, R. (2018). Carbon footprint of the large scale gold mining industry of Ghana, *West African Journal of Applied Ecology*, 26, 242–260.

Araya, N., Kraslawski, A., & Cisternas, L.A. (2020). Towards mine tailings valorization: Recovery of critical materials from Chilean mine tailings, *Journal of Cleaner Production,* 263.

Ata, A.A.E-S.M., Aly, M.H., Hussein, H., Eid, M.H., Abukhadra, M.R., El-Sherbeeny, A.M., Bellucci, S., & Gad, M. (2024). Hydrogeochemical characteristics and air quality risks associated with gold mining operations in Egypt using geochemical

modeling and risk indices, *Heliyon*, 10(11), 31086.

Baker, E. (2020). Chapter II. Mine Tailings Facilities: Overview and Industry Trends', *Towards Zero Harm: A Compendium of Papers Prepared for the Global Tailings Review;* Oberle, B., Brereton, D. & Mihaylova, A., Eds, 14-25. Available at: https://globaltailingsreview.org/wp-content/uploads/2020/09/GTR-TZH-compendium.pdf.

Banza, C.L.N. (2009). High human exposure to cobalt and other metals in Katanga, a mining area of the Democratic Republic of Congo, *Environmental Research*, 109(6), 745-752.

Benita, F., & Gaytán-Alfaro, D. (2024). A linkage analysis of the mining sector in the top five carbon emitter economies, *Regional Science Policy and Practice*, 16(4), 1-16.

Birich, A., Gao, Z., Vrucak, D., & Friedrich, B. (2023). Sensitivity of Gold Lixiviants for Metal Impurities in Leaching of RAM Printed Circuit Boards, *Metals*, 13(5).

Cacciuttolo, C., & Atencio, E. (2022). Past, Present, and Future of Copper Mine Tailings Governance in Chile (1905–2022): A Review in One of the Leading Mining Countries in the World, *International Journal of Environmental Research and Public Health*, 19(20).

Candeias, C., Ávila, P., Coelho, P., & Teixeira, J.P. (2019). Mining activities: Health impacts, *Encyclopedia of Environmental Health*, 415-435.

Cheng, H., Wu, S., Zhang, X., & Li, J. (2019). A Novel Prediction Model of Strength of Paste Backfill Prepared from Waste-Unclassified Tailings, *Advances in Materials Science and Engineering*, 2019(Ml).

Comăniță, E., Cozma, P., Simion, I.M., Roșca, M., & Gavrilescu, M. (2018). Evaluation of eco-efficiency by multicriteria decision analysis. Case study of eco-innovated and eco-designed products from recyclable waste, *Environmental Engineering and Management Journal*, 17(8), 1791-1804.

Córdoba-Tovar, L., Marrugo-Negrete, J., Ramos Barón, P.A., & Díez, S. (2023). Ecological and human health risk from exposure to contaminated sediments in a tropical river impacted by gold mining in Colombia, *Environmental Research*, 236.

Córdoba-Tovar, L., Marrugo-Negrete, J., Ramos Barón, P.A., Calao-Ramos, C.R., & Díez, S. (2023). Toxic metal(loids) levels in the aquatic environment and nuclear alterations in fish in a tropical river impacted by gold mining, *Environmental Research*, 224.

Cosgrove, W.J. & Loucks, D.P. (1969). Water Resources Research, *Journal of the American Water Resources Association*, 5(3), 2-2.

Daraio, C., Di Leo, S. & Simar, L. (2024). Viable eco-efficiency targets for waste collection communities, *Scientific Reports*, 14(1), 1-15.

Das, S., Lee, S.-H., Kumar, P., Kim, K-H., Lee, S.S., & Bhattacharya, S.S. (2019). Solid waste management: Scope and the challenge of sustainability, *Journal of Cleaner Production*, 228, 658-678.

Epule, E.T., Peng, C., Lepage, L., & Chen, Z. (2014). Policy options towards deforestation reduction in Cameroon: An analysis based on a systematic approach, *Land Use Policy*, 36, 405-415.

Ericsson, M., & Löf, O. (2019). Mining's contribution to national economies between 1996 and 2016, *Gornaya Promyshlennost*, 2019(6), 84-93.

Escobar-Segovia, K., Jiménez-Oyola, S., Garcés-León, D., Paz-Barzola, D., Navarrete, E.C., Romero-Crespo, P., & Salgado, B. (2021). Heavy metals in rivers affected by mining activities in Ecuador: Pollution and human health implications, *WIT Transactions on Ecology and the Environment*, 250, 61-72.

Espinoza, R.D., & Morris, J.W.F. (2017). Towards sustainable mining (part II): Accounting for mine reclamation and post reclamation care liabilities, *Resources Policy*, 52(January), 29-38.

Esposito, P., Antonucci, G., Palozzi, G., & Fijałkowska, J. (2024). Cognitive systems for improving decision-making in the workplace: an explorative study within the waste management field, *Management Decision*.

Ghorbani, Y., & Nwaila, G.T. (2020). Systematic Framework toward a Highly Reliable Approach in Metal Accounting, *Mineral Processing and Extractive Metallurgy Review*, 43(5), 1-15.

Gochero, P. & Boopen, S. (2020). The effect of mining foreign direct investment inflow on the economic growth of

Zimbabwe, *Journal of Economic Structures*, 9(1).

Guerry, A.D., Polasky, S., & Lubchenco, J. (2015). Natural capital and ecosystem services informing decisions: From promise to practice, *Proceedings of the National Academy of Sciences of the United States of America*, 112(24), 7348-7355.

Gupta, A.K. & Paul, B. (2015). Ecorestoration of Coal Mine Overburden Dump to Prevent Environmental Degradation: A Review, *Research Journal of Environmental Sciences*, 9(7), 307-319.

Hariram, N.P., Mekha, K.B., Suganthan, V. & Sudhakar, K. (2023). Sustainalism: An Integrated Socio-Economic-Environmental Model to Address Sustainable Development and Sustainability, *Sustainability*, 15(13).

Hove, G., Rathaha, T. & Mugiya, P. (2020). The Impact of Human Activities on the Environment, Case of Mhondongori in Zvishavane, Zimbabwe, *Journal of Geoscience and Environment Protection*, 8(10), 330-349.

Iacovidou, E., Velis, C.A., & Purnell, P. (2017). Metrics for optimising the multi-dimensional value of resources recovered from waste in a circular economy: A critical review, *Journal of Cleaner Production*, 166, 910-938.

IIyas, S., & Lee, J. (2018). Artisanal Gold Mining and amalgamation. *Gold Metallurgy and the Environment,* S. IIyas and J. Lee, Eds. Boca Raton: CRC Press.

Kalamandeen, M., Gloor, E., & Johnson, I. (2020). Limited biomass recovery from gold mining in Amazonian forests, *Journal of Applied Ecology*, 57(9), 1730-1740.

Kaniki, A.T. & Tumba, K. (2019). Management of mineral processing tailings and metallurgical slags of the Congolese Copperbelt: Environmental stakes and perspectives, *Journal of Cleaner Production*, 210(December 2018), 1406-1413.

König, L.A., Medina-Vega, J.A., & Longo, R.M. (2023). Restoration success in former Amazonian mines is driven by soil amendment and forest proximity, *Philosophical Transactions of the Royal Society B: Biological Sciences*, 378(1867).

Korhonen-Kurki, K., Brockhaus, M., & Sehring, J. (2019). What drives policy change for REDD+? A qualitative comparative analysis of the interplay between institutional and policy arena factors, *Climate Policy*, 19(3), 315-328.

Lin, C.S.K., Pfaltzgraff, L.A., & Herrero-Davila, L. (2013). Food waste as a valuable resource for the production of chemicals, materials and fuels. Current situation and global perspective, *Energy and Environmental Science*, 6(2), 426-464.

Liu, J., Yang, H., & Gosling, S.N., (2017). Water scarcity assessments in the past, present, and future, *Earth's Future*, 5(6), 545-559.

Manyuchi, M.M., Mbohwa, C., & Muzenda, E. (2019). Mining waste management for sustainable mining practices, *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 137-142.

Manzila, A.N. (2021). *A study of alternative techniques to mercury amalgamation for gold extraction in artisanal and small-scale gold mining. Master Thesis*. University of Cape Town, Cape Town.

Mapira, J. (2017). The mining industry in Zimbabwe: Challenges for sustainable development, *European Journal of Social Sciences Studies*, 2, 314.

Markham, K.E., & Sangermano, F. (2018). Evaluating Wildlife Vulnerability to Mercury Pollution From Artisanal and Small-Scale Gold Mining in Madre de Dios, Peru, *Tropical Conservation Science*, 11.

Maruthupandian, S., Chaliasou, A., & Kanellopoulos, A. (2021). Recycling mine tailings as precursors for cementitious binders – Methods, challenges and future outlook, *Construction and Building Materials,* 312, 125333.

Mashifana, T., & Sithole, T. (2021). Clean production of sustainable backfill material from waste gold tailings and slag, *Journal of Cleaner Production*, 308, 127357.

Masindi, V., Foteinis, S., & Renforth, P. (2022). Challenges and avenues for acid mine drainage treatment, beneficiation, and valorisation in circular economy: A review, *Ecological Engineering*, 183(July), 106740.

Masunda, S. & Choga, I. (2021). Impact of trade liberalization on technical efficiency of mining sector: A case of selected SADC countries. Problems and Perspectives in Management, 19(4), 362-374.

Mensah, A.K. (2021). *Arsenic contamination and remediation of active and abandoned gold mining spoils in Ghana, Doctoral Thesis*. http://hss-opus.ub.ruhr-unibochum.de/opus4/frontdoor/index/.

Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action:

Literature review, *Cogent Social Sciences*, 5(1).

Molden, D. (2020). Scarcity of water or scarcity of management?, *International Journal of Water Resources Development*, 36(2-3), 258-268.

Mubonderi, J. (2023). Environmental Protection and Economic Development in Zimbabwe, *Journal of Environmental and Public Health*, 1-7.

Mudd, G.M. (2007). Sustainability and Mine Waste Management – A Snapshot of Mining Waste Issues, *Waste Management & Infrastructure Conference - IIR Conferences*, (January), 1-12.

Munagamage, S., Harshana, D., & Asvini, I. (2021). Hydrometallurgical Approach to Investigate the Recovery Potential of Gold Available in Waste PCBs, *International Symposium on Earth Resources Management & Environment (ISERME)*, (December), 114-119.

Mutsvanga, T., Mapira, J., & Ngaza, N. (2018) Gold ore waste management challenges at Renco Mine, Zimbabwe, *European Journal of Social Sciences Studies*, 3, 18-34.

Mwaanga, P., Silondwa, M., & Kasali, G. (2019). Preliminary review of mine air pollution in Zambia, *Heliyon*, 5(9), e02485.

Nandiyanto, A.B.D., Ragadhita, R., & Al Husaeni, D.N. (2023). Research trend on the use of mercury in gold mining: Literature review and bibliometric analysis, *Moroccan Journal of Chemistry*, 11(1), 1-19.

Nieva, N.E., Borgnino, L. & García, M.G. (2018). Long term metal release and acid generation in abandoned mine wastes containing metal-sulphides, *Environmental Pollution*, 242, 264-276.

Northey, S.A., Mudd, G.M., & Saarivuori, E. (2016). Water footprinting and mining: Where are the limitations and opportunities?, *Journal of Cleaner Production*, 135, 1098-1116.

Northey, S.A., Mudd, G.M., & Werner, T.T. (2019). Sustainable water management and improved corporate reporting in mining, *Water Resources and Industry*, 21, 100104.

Nwaila, G.T., Frimmel, H.E., & Zhang, S.E. (2022). The minerals industry in the era of digital transition: An energy-efficient and environmentally conscious approach, *Resources Policy*, 78(June), 102851.

Ogunseitan, O.A. (2023). The Environmental Justice Agenda for E-Waste Management, *Environment*, 65(2), 15-25.

Oluwasola, E.A., Hainin, M.R., & Haziz, M.M.A. (2014). Potentials of steel slag and copper mine tailings as construction materials, *Materials Research Innovations*, 18(December).

Orimoloye, I.R., Mazinyo, S.P., & Kalumba, A.M. (2019). Wetland shift monitoring using remote sensing and GIS techniques: landscape dynamics and its implications on Isimangaliso Wetland Park, South Africa, *Earth Science Informatics*, 12(4), 553-563.

Orimoloye, I.R., & Ololade, O.O. (2020). Potential implications of gold-mining activities on some environmental components: A global assessment (1990 to 2018), *Journal of King Saud University - Science*, 32(4), 2432-2438.

Palacios-Torres, Y., de la Rosa, J.D., & Olivero-Verbel, J. (2020). Trace elements in sediments and fish from Atrato River: an ecosystem with legal rights impacted by gold mining at the Colombian Pacific, *Environmental Pollution*, 256.

Pisconte, J.N., Vega, C.M., & Sayers, C.J. (2024). Elevated mercury exposure in bird communities inhabiting Artisanal and Small-Scale Gold Mining landscapes of the southeastern Peruvian Amazon, *Ecotoxicology*, 33(4-5), 472-483.

Praveen, K., Ganguly, S., & Wakchaure, R. (2017). Environmental pollution and safety measures: International issues and its global impact, *Global progress in development of sustainable environment*, (July), Khan, M.M.A.A., Abid, M., Haider, R., Omer, A.M. & Maheshwar, R.K. Eds. 40-65.

Puertas, R., Guaita-Martinez, J.M., & Carracedo, P. (2022). Analysis of European environmental policies: Improving decision making through eco-efficiency, *Technology in Society*, 70(March).

Purvis, B., Mao, Y., & Robinson, D. (2019). Three pillars of sustainability: in search of conceptual origins, *Sustainability Science*, 14(3), 681-695.

Quash, Y., Kross, A., & Jaeger, J.A.G. (2024). Assessing the impact of gold mining on forest cover in the Surinamese Amazon from 1997 to 2019: A semi-automated satellite-based approach, *Ecological Informatics*, 80(August 2023), 102442.

Rao, M. D., Meshram, P., Abhilash, K. S., & Kamalesh, K. S. (2023). Validation of Bromide Leaching through Response Surface Methodology and Separation of Gold from Waste Printed Circuit Boards, *Minerals*, 13(4).

Rembuluwani, N., Dacosta, F.A., & Gumbo, J.R. (2014). Environmental Risk Assessment and Risk Management Strategies for Abandoned New Union Gold Mine in Malamulele, Limpopo, South Africa, *An Interdisciplinary Response to Mine Water Challenges*, pp. 367-373. http://www.imwa.de/docs/imwa_2014/IMWA2014_Rembuluwan_367.pdf.

Ricart, S., Villar-Navascués, R.A., & Hernández-Hernández, M. (2021). Extending natural limits to address water scarcity? The role of non-conventional water fluxes in climate change adaptation capacity: A review, *Sustainability*, 13(5), 1-31.

Ros-Tonen, M.A.F., Aggrey, J.J., & Somuah, D.P. (2021). Human insecurities in gold mining: A systematic review of evidence from Ghana, *Extractive Industries and Society*, 8(4), 100951.

Sarker, S.K., Haque, N., & Bhuiyan, M.(2022). Recovery of strategically important critical minerals from mine tailings, *Journal of Environmental Chemical Engineering*, 10(3), 107622.

Saunders, M.N.K., Lewis, P. & Thornhill, A. (2019). *Research methods for business students*. 8th ed. London: Pearson.

Schneider, M. (2017). Wasting the rural: Meat, manure, and the politics of agro-industrialization in contemporary China, *Geoforum*, 78, 89-97.

Si, M., Chen, Y., & Li, C. (2023). Recent Advances and Future Prospects on the Tailing Covering Technology for Oxidation Prevention of Sulfide Tailings, *Toxics*, 11(1), 1-13.

Spiegel, S.J., Agrawal, S., & Mikha, D. (2018). Phasing Out Mercury? Ecological Economics and Indonesia's Small-Scale Gold Mining Sector, *Ecological Economics*, 144(July 2017), 1-11.

Stoll, E., Roopsind, A., & Maharaj, G. (2022). Detecting gold mining impacts on insect biodiversity in a tropical mining frontier with SmallSat imagery, *Remote Sensing in Ecology and Conservation*, 8(3), 379-390.

Strand, M. & Syberfeldt, A. (2020). Using external data in a BI solution to optimise waste management, *Journal of Decision Systems*, 29(1), 53-68.

Tayebi-Khorami, M., Edraki, M., & Corder, G. (2019). Re-Thinking Mining Waste through an Integrative Approach Led by Circular Economy Aspirations. *Minerals*, 9(5), 286.

Tegegne, Y. T., Lindner, M., & Kalame, F. (2016). Evolution of drivers of deforestation and forest degradation in the Congo Basin forests: Exploring possible policy options to address forest loss. Land Use Policy, 51, 312-324.

Thomashausen, S., Maennling, N., & Mebratu-Tsegaye, T. (2018). A comparative overview of legal frameworks governing water use and waste water discharge in the mining sector, *Resources Policy*, 55(November 2017), 143-151.

Timsina, S., Hardy, N.G., & Woodbury, D.J. (2022). Tropical surface gold mining: A review of ecological impacts and restoration strategies, *Land Degradation and Development*, 33(18), 3661-3674.

Turunen, K., Räsänen, T., & Hämäläinen, E. (2020). Analysing Contaminant Mixing and Dilution in River Waters Influenced by Mine Water Discharges, *Water, Air, and Soil Pollution*, 231(6).

Uchenna, G. (2017). Abandoned gold mine tailing: Mineralogy, environmental hazards, valorization, and remediation strategies – A multidisciplinary approach. Thesis, University of Johannesburg, Johannesburg.

Veiga, M.M., Angeloci-Santos, G. & Meech, J.A. (2014). Review of barriers to reduce mercury use in artisanal gold mining, *Extractive Industries and Society*, 1(2), 351-361.

Voncken, J.H.L., & Buxton, M.W.N. (2019). Sustainability in Mining, *World Scientific Series in Current Energy IssuesCritical Materials*, 251-263.

Wilson, D.C. (2023). Learning from the past to plan for the future: An historical review of the evolution of waste and resource management 1970–2020 and reflections on priorities 2020–2030 – The perspective of an involved witness, *Waste Management and Research*, 41(12), 1754-1813.

Wolkersdorfer, C., & Mugova, E. (2022). *Effects of Mining on Surface Water*. 2nd ed, *Encyclopedia of Inland Waters, Second Edition*. 2nd ed. Elsevier Inc.

Woźniak, J., & Pactwa, K. (2018). Responsible mining-the impact of the mining industry in Poland on the quality of atmospheric air, *Sustainability*, 10(4).

Zvarivadza, T. (2018). Artisanal and Small-Scale Mining as a challenge and possible contributor to Sustainable Development, *Resources Policy*, 56(October 2014), 49-58.

Annexure 1: Interview Protocol

1. How does the gold mining sector account for waste? Is waste identified separately or assigned to overheads? Explain.
2. Do you think knowing the volume of waste generated by the gold-mining process is going to assist the industry in any way? Explain.
3. Is there any relationship or linkage between waste reduction and performance of a gold mining organisation in terms of the economy and the environment? Explain.
4. Do you have a waste reduction strategy? If not, why not? If yes, how has this been implemented, and how has it been of help to you?
5. Which accounting system is used within your organisation? Do you think the current accounting system is able to capture the entire flow of waste within the gold processing? Explain.
6. Do you subscribe to any standard that prescribes to waste management? If yes, how has the standard been of assistance to you? How has the standard assisted you in making available waste information?
7. Do you provide any waste-related information to management for waste-reduction decision-making? If not, why? If yes, how has the information been rated?
8. Are there barriers in the provision of gold process waste information? If yes, which strategies have been adopted to try and address them?