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CHALLENGES OF WASTE MANAGEMENT AT JENA MINE, KWEKWE, ZIMBABWE AND THEIR POSSIBLE SOLUTIONS

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Abstract:
In Zimbabwe, gold mining dates back to the pre-colonial era and has remained one of the major economic activities in the country. In recent years, the industry is predominantly conducted by small-scale operators and informal gold panners scattered around the country. Recently, the government has recognized the contribution of these people and has advised them to sell their product to Fidelity Printers. Through the Zimbabwe Mining Development Corporation (ZMDC), the government has encouraged small-scale gold mining in different parts of the country. Jena mine which is located in Silobela 80km from Kwekwe district is a member of the ZMDC and has caused several environmental challenges, which are discussed in this paper. The mine produces waste materials in the form of overburden and tailings which have found their way into the environment surrounding Silobela. In a research conducted during the period between 2016 and 2017 (using both qualitative and quantitative research methods), this paper reviews some of the challenges affecting the mine. Some of the problems, which the company is facing in its waste management programmes include financial constraints, poor infrastructural capacity and environmental pollution. This study notes that Jena mine needs to resuscitate its infrastructure and enhance its security to prevent illegal mining on mine dumps which are contributing greatly to environmental pollution.

Keywords: mine waste management, challenges, solutions, Zimbabwe

1. Introduction

Zimbabwe is a mineral rich country which produces over forty minerals including gold, platinum, iron, coal and diamonds (Mapira, 2017b). The gold mining industry is the biggest in the country and has realized numerous proceeds from its operations. Gold mining dates back to the pre-colonial era (Bulpin, 1968) and has continued to play a significant role in the country's economy (Munowenyu, 1996). In 2009, gold production

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hit a historic 700 tonnes (*Gold Producers' Association*, 2014). Fifteen tonnes of gold were produced in 2012 which accounted for US$17.1 million in foreign currency (*Zimbabwe Mines Chief Executive Officer*, Kwese, 2014). Annually gold exports account for 15% of the total national exports (*ZimTrade*, 2016) and 34% of the total minerals produced (Chamber of mines, 2015).

The ZMDC was established by an Act of Parliament Number 31 of 1982 with the aim of creating a vibrant and versatile mining power house necessary to transform Zimbabwe's mineral wealth to world class standards (Makichi in *The Herald* of November 18, 2016). The ZMDC currently acts as a parastatal company and has subsidiary companies under its name which include Jena Mine in Silobela.

However, the gold mining industry has been facing financial hurdles and has posed some environmental challenges to ecosystems, humans, fauna and flora. These issues emanate from the waste management methods and un-controlled panning activities around the mining area. Such issues provide the main thrust of this article and focus on how waste management at Jena mine is affecting the financial and environmental aspects of Silobela in Kwekwe.

In the *Financial Gazette* of October, 17, 2017, Kunambura claims that JENA Gold Mine, has a capacity of producing 45kgs of gold per day if properly managed. In 2012, the mine produced 309kgs of gold which amounted to US$16.1 million (Kunambura, 2017). It consists of four operational shafts, which include: Termite, Stump, N15 and Lioness. The mine has employed over 400 people who reside in Crossroads in Silobela (as indicated in the unpublished report of the Human Resources Department of August 2017). It is considered an economic hub of Silobela area and many families rely on the mine activity.

The mining process initially involves the extraction phase which is the removal of ore from the earth. This is mainly achieved by drilling and blasting methods which produce loads of primary waste in the form of soils and fragments of parent rock. Jerrie and Sibanda (2010) indicate that of the ore extracted, it is estimated that only 0.00001% is actually refined into gold and the rest is mine waste material. Overburden (which is the major waste from extraction) is the primary waste produced. Then follows tailings which result from secondary processes such as beneficiation whereby chemicals like mercury, cyanide and lime are added to the ore. Tailings and overburden are a major source of contamination in the Gweru River which passes through Silobela. Gweru River is a source of water around the area and Campbell (1998) notes that mine waste can result in water pollution. In Zimbabwe, most gold deposits are found within the Great Dyke which stretches from Mberengwa to Shamva (Figure 1).

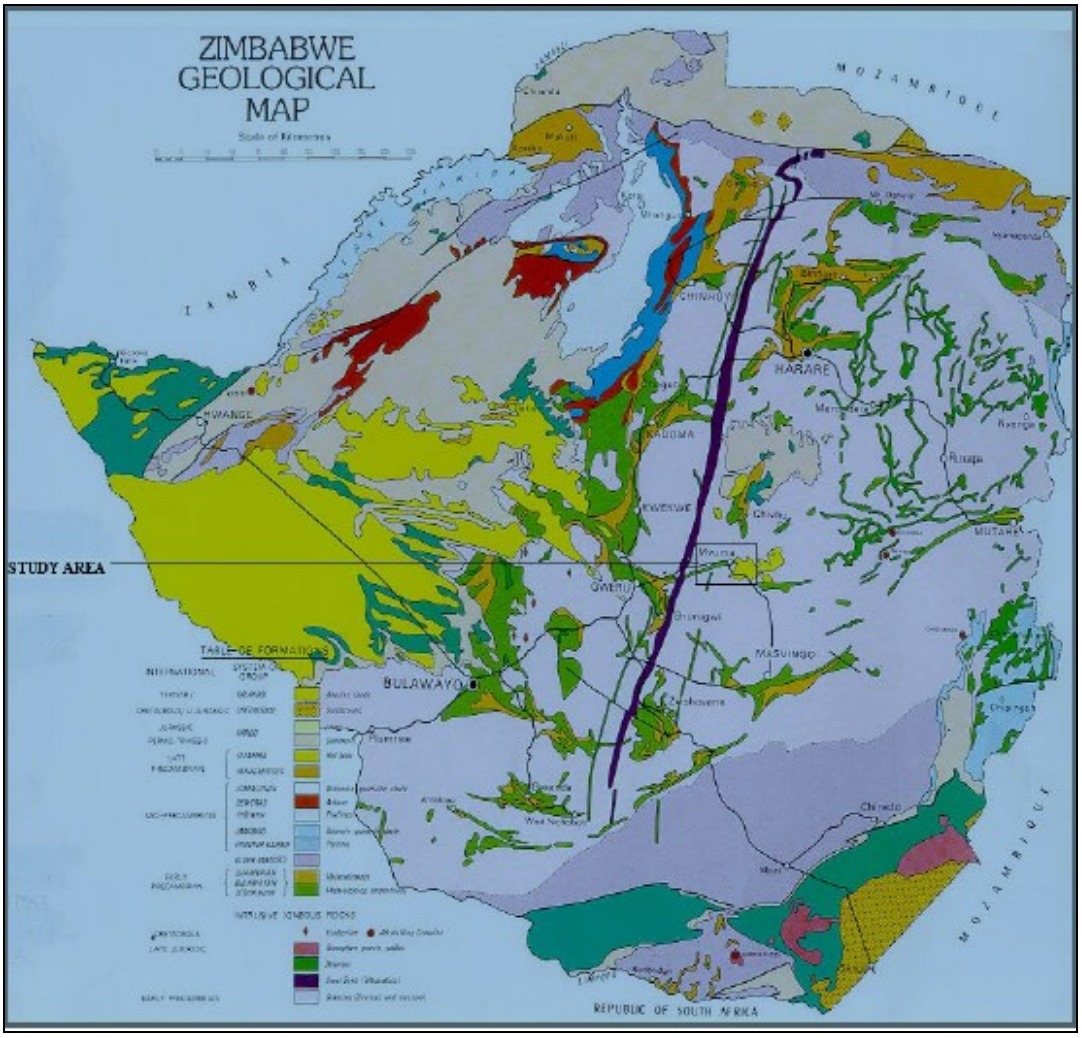

Figure 1: Geology of Zimbabwe

2. Research Methods

Several research methods were employed in this study. They included a pilot study, literature reviews, questionnaires and interviews. The first method to be conducted was a literature review. It involved the perusal of textbooks, journals, newspapers, and government documents such as Acts of Parliament and Mine Annual Reports. As a secondary research method, literature review provided a theoretical foundation for the whole study. Later on, a pilot study was conducted. It involved several visits and observations at Jena Mine, the focus of the study. Several issues were conducted during the visits. They included surveys of the mine environment with a view to establishing major problems bedeviling the area. Features such as mine dumps, tailings and dams were observed including any evidence of liquid and solid waste. The next stage involved the administration of interviews and questionnaires on key members of the mining community. The information derived from these exercises was in the form of both qualitative and quantitative information. The data which was collected from the above methods were then analyzed in order to provide the views that are expressed in this paper.

3. The Legislative Framework of Mining in Zimbabwe

The Industrial Waste Management Project in Zimbabwe was conceived out of the initiatives of the Rio de Janeiro United Nations Conference on the Environment and Development of June 1992 (Ngwenya, 2001).This conference which was attended by Zimbabwean representatives from the highest level, brought to the fore issues of the environment in the country. The Ministry of Environment and Tourism, through the Department of Natural Resources, spearheaded environmental issues. It is through one such initiative, "Industry and Environment in Zimbabwe" undertaken in the Midlands Province in1992 that issues of improper management of industrial wastes were revealed. This gave birth to the Mines and Minerals Act Chapter16:05, which is administered by the Ministry of Mines and Mine Development. It provides the main legislative framework for all mining activities in Zimbabwe. While the Act did not inhibit the development of small-scale mining, it is not seen as promotional either. The Act was complemented by 18 pieces of legislation administered by eight other ministries, which covered the usage and management of natural resources, a situation that sometimes led to conflicts. For example, the Natural Resources Act set the limit for cultivation on river banks at 30m while the Forest Act sets the limit at 100m. There was a need to harmonise the pieces of legislation to make easy administration of mining operations. The effectiveness of the Ministry of Mines and Mining Development in administering the Act was constrained by lack of human and financial resources. Chapter 165 made it possible for all interested parties to extensively explore the mineral potential of the country. In its application, it eliminated the need for direct negotiations over the minerals rights between landowners and potential miners, as was the case with other countries for example South Africa (Sunga and Marinda 1998). However, the Act is quite eloquent in the protection of the rights of the precedent activity such as farming activities and basic infrastructure, state assets and private property. The condition contributed largely to setting a base for dialogue between the owners of properties and the miners and created the basis for mutual understanding and co-existence though this presented some problems between the parties involved (*The Mines and Minerals Act 21:05* of 1996).The requirements of the Act involve the registration of a mining concession for the purposes of acquiring mining rights. In doing so issues have to be observed, namely: the acquisition of a prospectors license at a nominal fee, the appointment of an approved prospector who will perform the statutory pegging and registration of the area sought after, notification of Government agencies of the area concerned, a sitting or works plan should be produced for approval by the authorities in the Ministry of Mines and Mining Development, a comprehensive environmental impact assessment (EIA) of the proposed mining project must be produced and approved. In order to facilitate the administration of the Act, various advisory and regulatory boards including the Mining Commissioners, Geologists, Metallurgy and Mining Engineering are integrated into the process. All these departments are accessible to all classes of miners; however, lack of human and financial resources is a limiting

factor to their effectiveness. There are other supporting regulations enacted to assist the Act. These are: the mining (Health and Sanitation) Regulations, 1977, which regulate the provision of adequate health and sanitation facilities on a mine, the Mining (Management and Safety) Regulations of 1990, which seek to control health and safety in and about a mine; and the mining (Alluvial gold) (Public Streams) Regulations of 1991 which seek to deal with small-scale gold panning activities in the country. Besides the Mines and Minerals Act there are other pieces of legislation, which govern the usage, and management of natural resources and these are: the Natural Resources Act (1975), the Hazardous Substances and Articles Act (1971), the Forestry Act (1982), the Water Act (1976), the Atmospheric Pollution Prevention Act (1975), the Parks and Wildlife Act (1975), the National Museums and Monuments Act (1972), the Pneumoconiosis Act and the Interim EIA Policy (1995) (Chimonyo and Mupfumi, 2008; Gambara, 2006).

The pieces of legislation contribute towards the management of mining operations. They rely upon the conventions joined by Zimbabwe with efforts to move towards sustainable development. However, in 2002 a new Act of Parliament was enacted in order to co-ordinate all environmental issues in the country. This is the Environmental Management Act (CAP 20:27), which is now in charge of environmental issues in the country. Five years later in 2007, an Environmental management Agency (EMA) was developed in order to be the environmental watch dog agency in Zimbabwe. This development addressed the problem of fragmentation, which had been prevalent during previous decades, when environmental issues often led to inter-ministerial conflicts (Mapira and Mungwini, 2005).

4. Waste Management / Disposal Methods at Jena Mine

The wastes being generated by the mining industry occur mainly during the process of extraction, beneficiation and processing of minerals. Extraction is the first phase that consists of the initial removal of ore from the earth's crust is done by the process of blasting which results in the generation of large volumes of waste such as soil, debris and other material which is useless for the industry and is just stored in big piles within the mine lease area, and sometimes, on public land (Das and Choudhury, 2013). This is one of the ways by which large amounts of waste is generated by the process.These are a set of management practices employed with the aim of eradicating mine waste accumulating as production continues, but it is important to first indicate the types of waste that are generated at Jena mine.

5. Types of Wastes

Two types of waste include: waste rock/overburden, and tailings.

A. Waste rock/Overburden

Jena mine extracts gold using a shaft that digs deep into the ground after processes like blasting have been done. Gold alongside with parental rock debris are extracted and separated, then the waste rock is dumped at different places around the mine. Waste rock is generally stored indefinitely in a landfill site which, for economic reasons associated with transport costs, is located in the immediate vicinity of the main mining centre (Charbonnier, 2001). The quantity of mining waste that can be stored at a mining centre varies considerably and mainly depends on the selectivity of the mining method. As a rule, opencast pits and quarries generate much more mining waste than an underground mine. The main type of waste rock is generated by surface (or barren rock) stripping to expose the shallow ore. This is rock that is weathered to varying degrees, although increasingly fresh with depth and showing the geological characteristics of the local surrounding material. Its composition is similar to the rocks of the sector. The largest quantity of barren rock comes from stripping for opencast mines (Maruza, 2016). In underground mines, these barren rocks are generated by the passages (shafts and crosscuts), which is the case at Jena mine. Overburden created is mainly in the form of parental rock materials containing sulphur trace elements. .

B. Tailings (processing waste)

When gold is extracted, it goes through a process entitled beneficiation when the gold particles are mixed with chemicals such as cyanide and mercury. The resulting end-product contains a solution with both these chemicals and is then deposited in a tailing dam or in water bodies. At a mine, an ore mill normally abuts on the extraction centre to produce the first marketable products (metallic concentrates, sorted ore, and ingots). The technological processes are very different depending on the type of substance mined, and the modernity of the technologies employed (floatation, leaching, and biotechnology).These units produce various types of waste, which include: aqueous solutions from cyanide (Charbonnier, 2001).

Below is a diagram that shows the types of waste generated through mining (Figure 2).

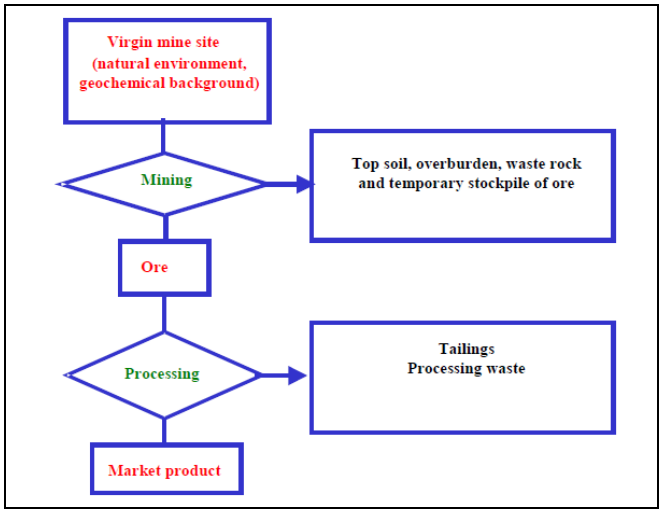

Figure 2: Mine waste types common at Jena mine

6. The Disposal of Mining Waste and Tailings

The disposal of coarse mining waste involves the coverage of large areas with dumps or infilling abandoned open-pits. Usually the waste in the form of overburden is stored in heaps which are scattered around the mine area (Bhebhe, 2008). At Jena mine most waste is dumped around and there is a lot of existing panning on these dumps since most local people believe that there are traces of gold still present. The heaps are left desolate over time and unattended creating the risk of acid ground water accumulation over time. By order of importance, the disposal of tailings is generally by the following:

a. Terrestrial impoundment

Terrestrial deposition is the predominant method for tailings disposal. It concerns fine waste and slurries such as mill tailings. The main purpose of dams (or ponds) is to dispose of the tailings in an accessible condition that provides for their future reprocessing once improved technology or a significant increase in price makes it profitable (Jerrie & Sibanda, 2010). At Jena mine, tailings are deposited into ponds where they will be released in the environment at spots around the mine.

b. Deep water disposal

The disposal of tailings and solid waste directly into bodies of water although sometimes used in past operations, is rapidly becoming non-authorised as a standard practice due to the significant pollution effects it can have on the receiving waters and the possible subsequent impacts on the livelihoods of the local communities. This method requires specific conditions and specific impact assessments (Bhebhe, 2008). At Jena mine, tailings are feared to be released along the basins of Gweru River which provides a source of living for the local people. There seems to be a consensus among scientists that an appropriately designed underwater disposal of sulphuric tailings is the ideal solution from an environmental point of view in the short-term with control of the level of water. The sulphur in gold mines is released after a reaction involving sulphur containing rocks from the parent material and oxygen producing a weak sulphuric acid.

c. Pond and open water bodies

In this method, the exhausted open pit mines are refilled with the tailings.

d. Dry staking

The dewatering of tailings is done using vacuums and filters which save the water and reduces the impact on the environment. This is done in the exhausted underground mines which are a truly complex method (Olivia, 2013).

e. Recycling

Coarse mining waste and especially barren rock (overburden) is sometimes considered as materials for roads, building foundations or cement factories, depending on its geotechnical and geochemical characteristics. A deposit of overburden materials at Jena mine at road systems has attracted a significant positive reaction from the communities around (Charbonnier, 2001). The road network is predominantly dust roads which need

frequent attention before potholes emanate. However, recycling is not classified as disposal.

7. Waste Management Challenges at Jena Mine

The company is currently facing financial constraints and this has turned the attention to shifting funds to recapitalize it. According to an article in *The Herald* by Makichi (2017), it is clear that the ZMDC secured close to US$6 million from Fidelity Printers and other private sources for the recapitalization of Jena Mine. The US$6 million was part of plans by the mining company to revamp production and improve efficiency. Priorities have been shifted and as a result, mine dumps have been left desolate and unattended creating a small community that is primarily surviving on the panning of these dumps. Tailing facilities need rehabilitation, and this calls for a significant fund. The dumps have the potential to spill sulphuric acid which can be traced to underground sources and pose a threat to the general public. The illegal mining has created a situation in which traces of mercury have been discovered in water bodies such as Gweru River which is nearby.

8. Environmental Implications of Mine Waste Produced at Jena Mine

Waste mine substances produced at Jena mine affect the environment in a number of ways.

A. Ground water contamination

The sulphuric acid produced as a result of a reaction of water and sulphur containing rock can be traced to underground sources of water. The company does not have any leachate catchment dams for such contamination and it is believed that all the weak acid produced finds its way into underground sources. In the long run, the contamination if unattended to may expose the local community to risks as it depends mainly on ground water.

B. Endangering human life

Waste in the form of dust originates at transfer points or when the conveyor belt experiences shakes. This has negative implications on humans. Large amounts of heat which are produced in the plant during crushing and smelting processes result in occupational health problems to the exposed workers. Cyanide, borax, sodium nitrate, hydrochloric acid and lime are the chemicals used in mineral processing. These chemicals are hazardous to the human body. Accidental spillages of those chemicals on skin or inhalation and ingestion of those chemicals results in health problems to the employees. Moran (2000) argues that chemical substances for example cyanide which is used as a solvent for metals like gold results in stomach, heart and brain problems as well as death. The frequency of exposure to the dangerous chemicals also indicates the severity of a chemical hazard.

There are also mechanical hazards in the plant area because some workers have to work on raised platforms thereby risking their lives through possible falls from these great heights. In addition to that, conveyor belts pose a danger to workers who handle them accidentally when they are in motion.

C. Disturbance of the landscape

Waste materials from the mine particularly overburden take a lot of space and the heaps that are laid idle disturb the use of the landscape. Much space is put to waste and the environmental use is greatly reduced.

D. Pollution of the environment

The litter generated by illegal mining leaves the mine dirty with litter all around. Litter is often left for long periods and the mine dump area remains dirty thereby posing an environmental threat to natural ecosystems. The litter also endangers livestock especially plastic bags which when consumed have the potential to kill local livestock. Recently, the United Nations Environment Programme (UNEP) headquarters in Nairobi banned the use of plastic bags in coastal areas where they pose a threat to aquatic life (Mapira, 2017c).

E. Endangering plant and animal life

Chemical spills on terrestrial lands pose a danger to plant life and animals which are an essential element of the environment. The chemical tailings which at times are left on surfaces, expose the environment to risks. Previous researches have revealed how mining operations threaten natural landscapes of the surrounding communities. For example, during the period from 1952 to 1996, the landscape around Buchwa Mine in Mberengwa was so damaged that it disturbed both animal and plant species. Obviously, some animals lost their habitats leading to either migration or extinction (Mapira and Zhou, 2006).

8. Current Waste Management Methods at Jena Mine

Jena mine has recently adopted five main waste management methods which include: regulation, education, terrestrial disposal, hydro disposal, destruction and tailing dams.

A. Regulation

This is the main thrust of the management programme and it is dependent on government legislation on mining. The company fully complies with the regulations. The regulation governs the treatment, disposal and handling of hazardous substances and aims at maintaining environmental integrity.

B. Education

The company always educates its staff on the effects of chemicals and how they must be handled. There are numerous training seminars done yearly and some of them highlight current trends of sustainable mining which do not negatively affect the environment. Environmental education (EE) has proved to be an effective method of instilling environmental awareness among the public over the years (Fien, 1993).

C. Terrestrial Disposal

About 90% of waste generated at Jena mine is disposed on landscapes as heaps. These heaps include waste in the form of rock particles of different sizes that are produced through blasting and extraction methods. The heaps are scattered around the mine areas. Some of the rock particles are spread along the road network linking Kwekwe (the nearest town) and the mine.

D. Hydro-Disposal

Some liquid waste deposited into the Gweru River pose a threat to the environment and they lead to the contamination of the river.

E. Destruction

Some of the waste is burnt and this includes chemical substances like mercury which are burnt beyond their boiling point making them less poisonous. This includes waste generated from other departments such as plastics, paper and debris scattered around the mine.

F. Tailing dams

The mine has constructed tailing dams which store and process waste before it is disposed. However, the tailing dams have been damaged and are recommended for repair for them to fully perform their function.

9. Suggested Alternative Waste Management Methods

Alternative methods which the company can adopt and their results are indicated below (Figure 3). They include recycling, water treatment, modern tailings and transportation.

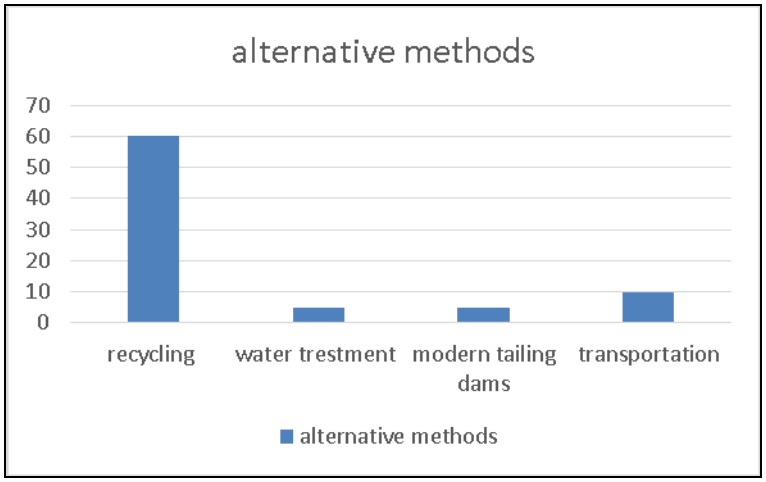

Figure 3: Alternative methods

A. Recycling

Recycling is a sustainable method that can be adopted. Instead of the company disposing these products, it can recycle them into products which can benefit the mine. A recent study in the city of Masvingo has shown that some people in the informal

sector recycle plastic paper to produce floor polish which they market to other people (Ngaza, Mandiudza and Mapira, 2018).

B. Water Treatment

The company can treat its water in order to make the substances less harmful before it can be disposed it into the environment.

B. Modern tailing dams

The need for the company to improve its tailing dams and make ones which meet the modern requirements can also be considered. This would reduce the chances of the current tailing dams from cracking, and limit the amount of ground water contamination.

C. Transportation

The company can transport other waste products to secure areas rather than letting them to just accumulate in-situ. This is possible for materials like overburden which are not harmful to humans and animals.

10. Major Challenges of Waste Management

The major problematic wastes at Jena Mines are tailings, overburden, chemical spills, leachate and littering. The results concur with the findings of Bhebhe (2008) which also show similar problematic substances and materials from gold mining in Gwanda, Zimbabwe. The overburden materials are as a result of extraction processes or blasting which creates a lot of rock materials which are derived from the parent rock. The extraction index from the process is 1:1000 000 meaning that one particle of gold comes along with 1000 000 parts of rock debris which is not useful and is regarded as waste. Overburden is a problem affecting other mines and generally, the rock waste materials are dumped in areas around the mine. Examples of huge mine dumps are found at Mvuma, Mashava and Zvishavane. Researchers claim that overburden disturbs the landscape and may affect the value of a physical landscape as well as its use (Ngwenya, 2006). These results also supported by Bhebhe (2008), are a major problem in mining in Zimbabwe and many companies like Jena do not have enough infrastructure to handle and treat these tailings before they pose an environmental threat. Jena mine produces loads of tailing which are temporally stored in tailing dams. However, these dams are not stable and there is a greater risk of these tailing finding their way to underground water sources. Some of the tailings which are considered to be weak are deposited into Gweru River. Waste spills (chemical) within the company have also been reported to have caused health problems among employees. The results also concur with the findings of Olivia (2013) which highlighted that gold mining produces a lot of chemical substances which are harmful to humans. The chemical waste should be treated with caution to reduce their effect on human life. Littering being another waste generated at Jena mine by illegal panning has effects on the environment and human health. As outlined by Olivia (2013) in her findings on the effects of illegal mining in Gwanda, littering is problematic as it affects animals like cattle which can be killed by materials

such as plastics. The dirt on the environment can be a source of disease outbreaks and needs to be controlled. When the illegal miners finish their activities, they leave their used materials lying on the ground which becomes the responsibility of the mine since the activities take place within the jurisdiction of the mine.

The waste substances and materials produced have damaging effects on the environment which have been highlighted as endangering human life, ground water contamination, contamination at Gweru River, disturbing the landscapes and endangering plant and animal life. The results are supported by Muraza (2016) who in his research on gold panning in Kwekwe indicated that there are reports of contamination of water bodies and ground water from mining activities in Kwekwe. There were reports of sulphiric acid formulation on rocks containing sulphur when they reacted with water. The accumulation of the sulphiric acid can indicate that there has been ground water contamination by mining in Silobela. However, some of the information has been affected by politics since the company is owned by the government which tries to protect the integrity of the company. This explains why there is little evidence in such reports. As Olivia (2013) outlined, there are other ethnic challenges such as prostitution which result from illegal mining and Jena mine should put more efforts on stopping illegal mining from dumps by putting in place a waste disposal program which does not accumulate loads of overburden with gold traces around the mine.

11. Possible Solutions

Several solutions can be recommended for the promotion of sustainable gold production at Jena mine. Firstly, Jena mine can seek financial assistance through banks and relevant stakeholders in order to recapitalize production and repair the tailing dams which need urgent repair. Secondly, it can also develop its tailing facilities to modern standards which have been designed to reduce the draining of tailings into underground water. The mine is using tailing dams which date back to the 1980s. Jena mine can also adopt the recycling and re-use of waste materials and substances rather than just relying on disposing them. This involves the use of mine overburden to mend roads. It can also recycle mercury and cyanide through modern techniques of reuse in the beneficiation process.

Jena mine can increase the security on mine dumps to prevent illegal mining around these areas. This can be in the form of increasing personnel and also reducing entry areas through fencing and use of danger warning signs. It can further adopt the use of educational campaigns (EE) within the local communities and also in the plant highlighting the effects of waste on the environment. These can include public awareness campaigns at schools and public places and within departments in the company. There is also a need to further the research by targeting on how illegal mining can be controlled and managed and also its implications on the environment stipulating on how each chemical poses the threat in detail.

12. Conclusions

Jena is one of the gold mines in Kwekwe that have been reported to have generated waste materials and substances that have negative implications on the environment. The major waste materials are tailings and overburden which result from beneficiation and extraction processes respectively. These waste products have damaging effects on the environment in a number of ways which include the pollution of water bodies (both open and underground), threatening human health, polluting the biophysical environment and also endangering plant and animal life. The mine has adopted several methods of managing wastes which are primarily governed by the legislation of Zimbabwe (Ministry of Mines and Mining Development). The management programme seeks to ensure that the waste does not pose any environmental threats. Besides having put in place a management protocol, the company faces environmental challenges emanating from the waste products. However, the mine has been affected by financial constraints which have resulted in poor infrastructure development for waste management. Much of the company's attention is now focusing on raising capital to resuscitate the company's activities. Jena mine has plenty of options which can assist in its successful waste management program which include seeking financial aid, increasing its security levels, forming partnerships with the community and training its personnel to adopt new methods which are available on the mining markets through research.

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