An Appraisal of Environmental Management Systems in Small Scale Mines of the Midlands Province of Zimbabwe: The Case of Indarama Mine

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Abstract
Most industries in developing countries are playing a major role in depleting the environment through the release of dangerous and toxic substances. These substances not only affect plants, animals and soils but also the health and activities of human beings. This study evaluated the environmental management practices at Indarama mine in Midlands province of Zimbabwe.

Levels of iron, cyanide, sulphur and antimony in effluent were established through two sets of 20 samples taken from various parts of Indarama mine and compared with wastewater and effluent discharge standards. The environmental management practices at the mine were also evaluated.

The findings of the study showed that levels of cyanide, iron, sulphur and antimony were outside the recommended levels of the Water and Waste Disposal regulations of 2000.

The findings of this research point to the need to establish comprehensive environmental policies in which treatment of effluent prior to discharge should be considered integral to promote environmental sustainability.

Keywords: Effluent, gold, Environmental sustainability, Indarama mine, Zimbabwe

Introduction
Zimbabwe’s mining sector continues to be significant to the country’s development endeavors. Over the years, this sector has accounted for about 4% of the country’s Gross Domestic Product (GDP) (Zimtrade 1998). Gold production in particular has proved to be an important source of foreign currency to the economy contributing about 30% of the total foreign currency earnings. It is estimated that on average, gold exports accounted for about 15% of all export proceeds in any given year.
Despite the eminent role played by gold exports to the economy, a number of constraints have been affecting gold productivity. Ajusa (2003) identified factors affecting gold production to include the ever rising costs of production, lack of foreign currency, lack of new processing technologies, complexity of the remaining gold ores and the depletion of free milling ores. As a result gold production, which normally constitutes 52% of the total mineral production, suffered a major slump in the period 1999-2001. Total production reduced from 22 tonnes in 2000 to 18 tonnes in 2001 in comparison with 28 tonnes produced in 1999. In addition, a significant proportion of the local gold is smuggled into other countries. Estimates indicate that the value of gold pilfered from the country is approximately 3000kg (NECF, 2003).

Focus in the mining sector has not only been placed on the economic aspect but also on sustainable environmental management. This is part of the integrated global efforts for environmentally friendly production processes. These processes should release effluent that minimize the impact on the environment and should contain a minimal level of toxic substances that are below the stipulated levels both locally and internationally. This study analyses solid and liquid waste (effluent) released at Indarama mine located in Kwekwe of the Midlands province in Zimbabwe and the environmental practices that are in operation. This is against the background of cases of pollution, which have been linked to human health problems, and the decimation of biodiversity species that have characterized the Midlands province of Zimbabwe. Conditions at the mine are typical of small-scale mines found in the province.

The broad objective of the study is to make an analysis of the effluent released at Indarama mine and evaluating the environmental management systems that are operating.

**Literature Review**

**Overview of Indarama Processing Plant**
The Indarama processing plant is made up of three major sections, the Mill complex, the Bioleach plant and the Tails treatment plant.

**Mill Complex**
Metallurgical procedures practiced at the mill complex include initial crushing (primary and secondary) and milling of the ore followed by classification, amalgamation and flotation. At an average gold grade of 4-7g/t the mill complex processes approximately 57tpd of underground ore.

**Crushing**
Crushing involves reduction of ore in a double stage process i.e. primary and secondary crushing. Ore of size +30cm or –30cm is delivered to a rough ore bin through a grizzly from where its gravity fed into a Telsmith primary jaw crusher. The crusher has a reduction ratio of 1:4 and comprises of a pair of heavy
metal jaws, a swinging and a stationary jaw. The swinging action of the moving jaw against the stationary jaw reduces the ore into smaller fractions. The crushed product is conveyed to a stockpile for temporary storage by means of a 465mm belt conveyor.

The primary crushed product is fed onto 520mm belt conveyor to a single deck screen with small apertures after passing under a magnet for the removal of ferromagnetic objects. The screen vibrates by means of rotating weights on either side. These vibrations cause the ore to move over the deck thus separating undersize and oversize ore. Oversize ore is conveyed by means of a 540mm return belt to a 36" Telsmith Gyratory crusher and returned to the screen. The crusher has a reduction ratio of 1:6. Undersize material drops into a 150t capacity fine ore bin where it’s temporarily stored.

**Milling**

Milling involves further reduction of the already partially comminuted rock by subjecting it to the breaking action of bodies tumbling freely in a gyrating container. At Indarama milling is done in a two-stage process.

Ore is discharged from the fine ore bin by means of a gravity chute and conveyed at a rate of approximately 3 tonnes per hour to the mill on a 467mm belt conveyor. For metallurgical accounting, tonnage is monitored every hour using a 1m-belt cut. Primary and secondary grinding in closed circuit is accomplished by a 2x1.9m Hardinage ball mill and 2x1.2m Tube mill respectively. The ball mills have rectangular plain ribbed manganese steel liners that protect the shell and are replaceable when out. Grinding takes place with the help of 100mm forged steel balls at a rotational speed of 25rpm.

During rotation, the load consisting of the pulp and grinding media is carried up the rising side of the mill to a height that is dependant on the speed of rotation and degree of slip between the mill shell and the load. The falling balls introduce impact-causing grinding of the pulp. Pulp (60-70% solids) is produced through a continuous flow of water in the ball mill and is discharged onto a trommel screen with 4mm apertures.

Pulp from the primary ball mill is gravity fed through a screen into a discharge sump and is pumped by a direct transfer vertical pump into the primary hydrocyclone. The hydrocyclone consists of a vortex finder
that aids in the separation of fine and coarse pulp. Coarse and heavier material in the cyclone underflow returns to the tube mill for secondary grinding whilst the overflow comprising of light and fine particles enters the gravity concentration circuit.

**Biological Leaching Process**
The biological leaching technology oxidizes sulphidic concentrates biologically by the use of bacteria. Since the ores are refractory i.e. gold mineralizations in which gold is encapsulated in sulphides or silica, feeding of the sulphides by the bacterium liberates the locked metal.

The preparatory stages of sulphidic concentrates received the mill complex consist of classification and regrinding. The concentrates are pumped into two acid conditioning tanks for tonnage accounting before entering the feed preparation circuit.

The feed preparation circuit consists of a concentrate repulper feeding a 1.7x1.4m ball mill in closed circuit with a spiral classifier. The concentrates are repulped in the repulper and fed to the ball mill for regrinding.

The basic reasons for regrinding are:

1. It increases the surface area on which the bacteria can act on as the particles are reduced to ultra fine particles.
2. It exposes the locked gold by removing the impervious coating which make the gold metal impermeable to leach reagents and which may be toxic to bacteria.
3. It increases the efficiency of gold by cyanidation.

The classifier receives the ultra fine particles and separates them according to particle size and specific gravity. The classifier overflow has a high percentage of water and fine solids that are pumped to a de-watering thickener. The underflow consisting of coarse particles returns to the repulper and is fed to the ball mill for further regrinding.

Classifier fines are thickened in a continuously agitated thickener by addition of a flocculent called Young’s flocculent. The thickener increases density of the solids by reducing the percentage of water in the concentrates. Toxic reagents are also removed by addition of water that overflows to a water pond.

The thickened concentrates are stored in three storage tanks called STOs in continuous agitation with Wallace agitators. A detergent is added into the tanks to emulsify hydrocarbons (oils and grease) smeared on gold surfaces and also hydrogen peroxide to render cyanides and thiocyanates ineffective, as they will destroy bacteria in the biological leaching circuit.
In order to minimize soluble toxins, the aqueous solution is decanted leaving the thickened concentrates. These concentrates are then pumped to a surge, which can contain the concentrates in the three small tanks. The tank provides continuous feed to the biological leaching circuit via the primary reactor at a specific gravity of 55% solids and a flow rate of 0.125 L/s. Nutrients i.e. 1.7 kg/t nitrogen as ammonium sulphate and 0.3 kg/t phosphorous as phosphoric acid are added in the tank for bacterial cell metabolism. Sulphuric acid is also added to reduce the pH to below 1.8.

The biological leaching circuit consists of rubber lined and heat resistant reactors placed in series i.e. one primary, two secondary and two tertiary reactors.

The primary reactor with a capacity of 110 m$^3$ has a Pachuca orientation and is fitted with a recessed impeller vortex pump that draws material from the cone apex and delivers into the top of the reactor. Air pressure of about 60 kPa is delivered into the tank at a point two thirds of the cone height using blowers and compressors. This allows agitation in the tank and is also necessary in the subsequent sulphide oxidation process.

Sulphide oxidation in the primary reactor is directly proportional to the feed sulphur grade and varies between 45-75%. The feed sulphur grade varies between 8-22%. The primary reactor overflows into the secondary and tertiary reactors with a capacity of 33 m$^3$. These reactors are continuously agitated through pitch blades, blowers and compressors. The product of the tertiary reactors overflows into the first of two continuous thickeners where wash water is added to minimize dissolved salts.

It requires approximately six days for a given mass of concentrates to pass through the biological leaching circuit to accomplish adequate sulphide oxidation by the mesophilic bacterial culture.

**Fundamentals of Biological Leaching**

Bacterial oxidation through the biological leaching process utilizes a chemolithotrophic (rock eating) and acidophilic mesophile bacterial culture to oxidize inorganic minerals and ferrous ions thus liberating the locked gold. A chemolithotroph bacterium has the capacity to derive energy by oxidizing inorganic materials. The metabolic energy acquired by the bacteria is vital for growth and cell maintenance.

Oxygen and carbon dioxide are essential for the bacterial sulphide oxidation process. Carbon dioxide provides the building blocks for the organic body composition. The bacteria are therefore autotrophs since they can use carbon dioxide as their energy source. Oxygen in the atmosphere as well as from the compressors serves as an oxidant thus the bacterium is aerobic. Being acidophiles the bacteria operate under highly acidic conditions (pH below 1.8).
The mixed bacterial culture comprising of *Thiobacillus ferooxidans*, *Thiobacillus thiooxidans*, *Leptospirillum ferrooxidans* and a fourth species still to be named accelerates sulphide mineral oxidation. The characteristics of the bacteria are outlined in the table below.

**Table 1: Ndarama bacterial species**

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>Shape and size (Micrometers)</th>
<th>Optimum temp Range</th>
<th>Optimum pH range</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Thiobacillus ferooxidans</em></td>
<td>Bacilli 0.5x1.7</td>
<td>28-35°C</td>
<td>1.5-1.8</td>
</tr>
<tr>
<td><em>Thiobacillus thiooxidans</em></td>
<td>Bacilli 0.5x1.2</td>
<td>28-30°C</td>
<td>1.3-1.8</td>
</tr>
<tr>
<td><em>Leptospirillum ferrooxidans</em></td>
<td>Spirilli 0.8x1.2</td>
<td>25-35°C</td>
<td>1.6-1.8</td>
</tr>
</tbody>
</table>

There are also many other factors that affect bacterial oxidation and these include nutrient addition, temperature, toxic reagents, grind size etc.

Pulp from the biological leaching circuit is washed in two semi-continuous thickeners in series. Continual washing with process water removes some of the arsenic and sulphiric acid accumulated in the biological leaching circuit. This raises the pH of the slurry thus reducing the consumption of lime in the pre-aeration tank. Acid washing also reduces the concentration of dissolved salts in the slurry that may precipitate on gold bearing particles by the use of lime in the pre-aeration tank.

In the pre-aeration tank, pulp is fed from the second continuous thickener for neutralization. Neutralization is accomplished by the addition of lime to a pH of between 8.5-9.5. This pH range prevents the formation of dangerous hydrocyanic acid as a result of the reaction between hydrogen ions and cyanide in the cyanidation circuit. This alkaline environment also destroys elemental sulphur that causes high cyanide consumption. Lead nitrate is also added and acts as an oxidizing agent and avoids the consumption of oxygen.

**Research Methodology**

**Study site**

The study was carried out at Indarama mine located 17km outside Kwekwe in the Midlands province of Zimbabwe. The mine particularly focuses on gold extraction that is marketed both locally and internationally. As for the assessment of the impact on the environment samples were taken from nearby streams and rivers to ascertain the level of toxic substances present.
Water and pulp samples
Pulp and water samples were collected into clean 500ml plastic bottles. The bottles were sealed tight and kept in a safe cool place. All the pulp samples collected were analyzed for iron, cyanide, antimony, sulphur, and arsenic. The water samples collected were also tested for the same elements. All the samples collected for cyanide analysis were stored in a dark place to minimize the natural decomposition of cyanide and other complexes. However, most of the samples were prepared and analyzed whilst still fresh.

Cyanide strength analysis
This is used to test for the amount of free cyanide ions in the sample. The term free cyanide is used to indicate the equivalent, in terms of potassium cyanide or sodium cyanide, all of the cyanogens present as simple cyanide of the alkalis and the alkaline earth metals such as calcium and barium.

The experiment requires a standard silver nitrate solution made from 13.08g of silver nitrate dissolved in one liter of distilled water. Furthermore, potassium iodide made from 5g of potassium iodide crystals dissolved in 50ml distilled water was used.

Calculation: Percentage cyanide (%CN) = titre [Ag (NO₃)₂] x 0.04

Determination of Sulphur: Sulphur is determined in solution by the gravimetric method of analysis. The method has a turnaround time of three days and its detection limit is about 0.1%.

Calculation: Total sulphur in solution = weighed BaSO₄ x 0.1375 x 1000

Original aliquot

The total sulphur is usually reported as grams per liter or parts per million (ppm).

Determination of Antimony, arsenic and Iron
This analysis does not involve filtration of the samples but acid digestion to place the required elements into solution. This method can be used for base metals such as copper, lead, nickel and antimony.

Water analysis
Water was sampled from various points of the river. This is because the river is a main water supply for domestic, agricultural and industrial use. The analysis was a way of determining the impact of the effluent that was being released into the river. The toxic chemicals pose dangerous effects to the health of animals, humans and all manner of biodiversity.
The samples were taken from various points along the river and at different depths. This was to ensure that the results are not biased towards a single part or few points along the river and streams.

_Determination of sulphur_

The sulphur content in the river water was determined as the sulphate ion. In nature usually sulphur is oxidized to the sulphate ion thus the test was done to ascertain the level of the sulphate ion by the turbidimetric method of analysis.

_Cyanide determination_

The method involves oxidation of the cyanide in water, followed by distillation and titration.

**Results and Discussions**

**Table 2:** Zones in which each of the elements falls

<table>
<thead>
<tr>
<th>Element</th>
<th>Blue zone</th>
<th>Green zone</th>
<th>Yellow zone</th>
<th>Red zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron (Fe)</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Sulphur (S)</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Antimony (Sb)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cyanide (CN⁻)</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

**Table 3:** Characterization of the management systems at Indarama Mine

<table>
<thead>
<tr>
<th>Dumpsite category</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Near residential area and is placed on the eastern side</td>
</tr>
<tr>
<td>Walls</td>
<td>Dumpsite walls are being built at a slower rate than rate of effluent discharge</td>
</tr>
<tr>
<td>Vegetation</td>
<td>No plants on the dumpsite to prevent surface run off and avoiding the wind from blowing the dried effluent mud.</td>
</tr>
<tr>
<td>Discharge</td>
<td>Effluent is being discharged directly into the environment</td>
</tr>
<tr>
<td>Management</td>
<td>Good paddock system established to manage the dumpsite. Some of the dumpsites are being rehabilitated</td>
</tr>
<tr>
<td>Stability</td>
<td>The dumpsites are very stable. No collapse of dumpsites has been recorded to date.</td>
</tr>
</tbody>
</table>
The deviations in the concentration of effluent recorded were minimal in both sets of data except for sulphur. The general trend showed that there were relatively high concentrations of each constituent in the effluent as compared to the limits of the Waste and Effluent Disposal Regulations of 2000.

The average cyanide level in the effluent is high. The figure ($\bar{X} = 0.358$ ppm) falls in the red zone of the Waste and Effluent Disposal Regulations of 2000. The high cyanide levels can be attributed to the fact that cyanide is used in high amounts as a means of dissolving gold in leaching tanks. Such levels have potential effects on the environment in the short and long term because cyanide is very toxic even at low concentrations.

Cyanide is toxic to aquatic life and if disposed in water streams it can disturb the whole aquatic food chain. In warm-blooded animals its toxic characteristics cause rapid death due to suffocation. It also hinders the proper transfer of blood from the lungs to the tissues by forming a ligand with iron, which normally forms bonds with oxygen. Relatively low concentrations (LD$_{50}$ for ingestion is 1-3mg/kg of body weight) of cyanide can be highly toxic to humans. Cyanide can reach the water table by leaching from areas where it’s used. As a result, some traces of cyanide have been detected in borehole water in areas where cyanide is not used at all. The results of this study are consistent with Zhou (2003) who confirmed the high level of cyanide in the effluent released at Indarama mine.

The average level of sulphur was found to be high in the effluent and the figure ($\bar{X} = 399.35$ ppm) falls in the red zone of the Waste and Effluent Disposal Regulations of 2000. In the case of sulphur, it is concentrated in the ore mined at Indarama and is usually associated with gold. Sulphur encapsulates the gold thus making the ore refractory i.e. impermeable by conventional gold extraction processes. As a result of the high concentration of in the ore, there were generally high levels recorded in the effluent released.

The danger with high levels of sulphur is that it can form bonds that are damaging to the environment and can cause great effects on human health e.g. disturbance of blood circulation, heart damage etc.

The average level of antimony ($\bar{X} = 4.966$ ppm) was also found to be high, although the Waste and Effluent Disposal Regulations of 2000 had no established limits for this element. Antimony is also highly concentrated within the ore at Indarama mine therefore high amounts were found in the effluent. The low levels also recorded can be as a result of varying compositions of the antimony within the ore. Antimony is hazardous because it’s a heavy metal. Heavy metals tend to bioaccumulate i.e. its concentration in a biological organism tends to increase over time compared to the chemical’s concentration in the environment. Exposure to high levels of antimony for short periods causes vomiting, nausea and diarrhea. The element is also suspected to be a human carcinogen. In the time past, the mine used
differential flotation which removed antimony concentrates also it became obsolete with the advent of bulk flotation.

The effluent was also found to contain high levels of arsenic and the average figure (\( \bar{X} = 0.725 \text{ppm} \)) fell into the red zone of the Waste and Effluent Disposal Regulations of 2000. Arsenic is also highly concentrated within the ore mined at Indarama and forms precipitates. Due to the fact that antimony is toxic at low concentration, the potential effect on the environment can be great in the long and short term. Like antimony, arsenic is also a heavy metal that accumulates in living organisms.

Iron was also found to be in high levels with the average value (\( \bar{X} = 7.56 \)) falling in the red zone of the Waste and Effluent Disposal Regulations of 2000. Iron is one of the most abundant elements on the earth, which can explain the high levels in the effluent. It can only be hazardous to the environment in the form of iron (III)-0-arsenite. This chemical persists in the environment.

In the evaluation of the environmental management practices, a number of shortcomings were identified as with most small-scale mines in the Province. The dumpsites, which form part of the environmental management system, have been placed on the eastern side of residential areas. Instead best environmental management practices require the location of the dumpsites on the western side because in Zimbabwe winds usually blow from the east to the western or southern sides. The residential areas are also very close (within 20m) to the dumpsites. This poses a great threat to the health of children who frequent the dumpsites and overall to the whole community. Best environmental management practices require that disposal sites should be far away from residential areas for health reasons.

The discharge pipes from the dumpsites also releases effluent directly into the environment. There is no established system to either treat the effluent prior to release into the environment or to return it for use in the process.

**Fig 2:** Effluent release into the environment at Indarama Mine
This poses a potential threat in the short and long term to animals, humans and plants. Usually animals like cattle can drink the effluent water resulting in their death or people can deliberately cause their animals to drink the effluent water so as to get compensation for death of their livestock. Plants are visibly drying as a result of direct discharge of the effluent into the environment. Best environmental management practices require that effluent containing toxic substances should be treated prior to release into the environment. Furthermore, the dumpsites can be fenced to prevent access by animals and people who are not authorized by the company. This can be implemented to reduce the effect on the environment and humans.

The construction of dumpsite walls to prevent spillage of effluent into the environment was not effective. Ideally the walls should not allow any effluent to spill into the environment. This has however been experienced because the rate at which the walls are built does not exceed the rate of effluent discharge onto the dumpsites. Best environmental management practices require proper construction of dumpsite walls to prevent any spillages of effluent into the environment. Improper construction of the walls can also result in collapse of the dumpsites.

Another visible anomaly is that there is no vegetation that has been planted on the dumpsites. The vegetation avoids wind from blowing off dust and reduces the surface run off as a result of rain. Despite the identified weaknesses the dumpsites are currently utilizing the efficient paddock system to manage effluent discharge. The system requires a lot of planning and management commitment to environmental issues although, large amounts of effluent have been released on the dumpsites they have shown great stability.

Conclusion and Recommendations

Conclusions
There were generally high levels of each chemical constituent that was evaluated both in the effluent. As a result of the high levels of the chemical constituents in the effluent their average values fell into the red zone of the Waste and Effluent Disposal Regulations of 2000. They were shortcomings in the environmental management system, which did not conform to best industrial practices.

Recommendations:
The effluent should be treated prior to discharge. A three-stage process that involves the following steps can remove the heavy metals:

1. Firstly a bonding agent is added to the wastewater to bind the heavy metal. The bonding agent should be able to rapidly bind the metal and have high selectivity. Zeolites which are made by the crystallization of an alluminosilicate gel form very uniform structures and have been developed to remove heavy metals such as arsenic, antimony etc.
2. The loaded bonding agent is separated by ultra filtration or micro filtration.
3. The bonding agent can be regenerated and the heavy metal can be returned into the system.

This innovative and cost effective approach will minimize environmental impact from wastewater and prevent potential damage to health as a result of heavy metals. Antimony can also be removed by reintroducing differential flotation, which removes antimony concentrates in the processing of pulp. This system can be used in combination with the bulk flotation circuit that is currently in use.

The cyanide contained in the wastewater can be removed by implementing cyanide destruction techniques. The hydrogen peroxide process can be used to reduce the level of cyanide. The process involves oxidation followed by acidification to produce substances that are not harmful.

\[
\begin{align*}
\text{CN}^- & + \text{H}_2\text{O}_2 & \rightarrow & \text{CNO}^- & + \text{H}_2\text{O} \\
\text{CNO}^- & + 2\text{H}^+ & + & \text{H}_2\text{O} & \rightarrow & \text{CO}_2 & + \text{NH}_4^+
\end{align*}
\]

If excess hydrogen peroxide is left in the treated water it rapidly decomposes to form water and oxygen. Furthermore, the process is economical because of its lower capital and operating cost. It is also simple in terms of process flow and control and can be applied to a wide range of operations. Adding iron sulphate to the effluent that forms a complex with iron can also reduce cyanide.

As for sulphur research can be made to find whether it can be used in the pharmaceutical industry for instance for the production of sulphur ointment. The research can also be vital for other industries that use sulphur as a raw material. Research can also be done for iron to find out whether it can be used as a source for industries who may be in dire need of it.

The dumpsites should be relocated and placed far away from the residential areas and on the western side. This prevents children from playing around the sites and the wind from blowing dust to the residential areas. In addition, there should be fencing around the dumpsites to prevent livestock from drinking the toxic effluent water. This will reduce the chance of people driving their livestock deliberately to the dumpsites as a means of obtaining compensation from the company. A variety of hazing can be used to keep away birds e.g. lights.

In order to prevent discharge of effluent directly into the environment, the effluent water can be re-used in the production process. This is because the effluent water contains cyanide that can be re-used and thereby reduce the amount of cyanide added to the process.

The dumpsite walls should be built at a rate that is faster than the discharge of effluent to prevent spillages into the environment. Measures should be put in place to monitor construction of the walls together with rate of discharge. Vegetation should also be planted on the dumpsites to prevent surface
run-off as a result of rain and to avoid dust from being blown by the wind. Despite the stability of the dumpsites cofferdams must be put in place to guard against any collapse that might occur. Collapse of the dumpsites can result in mine closure.

The above-mentioned recommendations for the dumpsites are part of the requirements for best environmental management practices that should be implanted to protect the environment against industrial effluent.

References:


Water (Waste and Effluent Disposal) Regulations 2000
