ARD MANAGEMENT AT GEITA GOLD MINE[1]

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Abstract: The Geita Gold Mine (GGM) is located approximately 4km west of Geita in the Mwanza Region of northern Tanzania. The mine is situated at the headwaters of the Mtakuja River that drains into Lake Victoria approximately 20km north west of plant site. GGM is owned and managed by AngloGold Ashanti Limited which is one of the major gold producer companies in the world. GGM alone produces up to 610,000 oz of gold per year moving towards 880,000 oz in 2007.

GGM has sound environmental practices and Acid Rock Drainage (ARD) is one of the main issues of concern. This paper describes the management of ARD at GGM which is mostly done through proper identification and handling of potentially acid forming waste material from all operating five pits. The procedure for ARD management involves: producing a waste model for the life of mine for each pit; validating of waste models using in-pit geological mapping; selective handling and placement of waste in designated areas of the waste rock dump and the tailings dam embankments; validating placement of waste within the waste rock dump and tailings dam embankment; monitoring the placement using piezometers within the waste rock dump, tailings embankment and downstream of these facilities; regular technical reviews and implementing the mentioned procedures for the life of mine. Our rehabilitation programme further enhances the combat of ARD and has been recognised in the Tanzanian mining industry as being the benchmark.

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Introduction

Acid Rock Drainage (ARD) is one of the major issues of concern in the mining industry. As such Geita Gold Mine (GGM) has taken the issue seriously and it was discussed even before mining during the environmental impact assessment (EIA) time and the recommendations put into practice during the mining phase. Being the leader in environmental management, GGM considers ARD to be the issue of great concern and therefore its management is taken to be of high priority as will be seen in the following parts of this paper.

The Geita Gold Mine

Geita District is located in northwest Tanzania, 295 Kilometres and 590 Kilometres west of Serengeti National Park and Mount Kilimanjaro respectively, see Fig. 1 below. Geita Gold Mine is situated in the Geita District, approximately 25km from the southern shores of Lake Victoria. Geita Gold Mine is one of the 25 operations in 11 countries and in 4 continents owned by Anglogold Ashanti Limited.

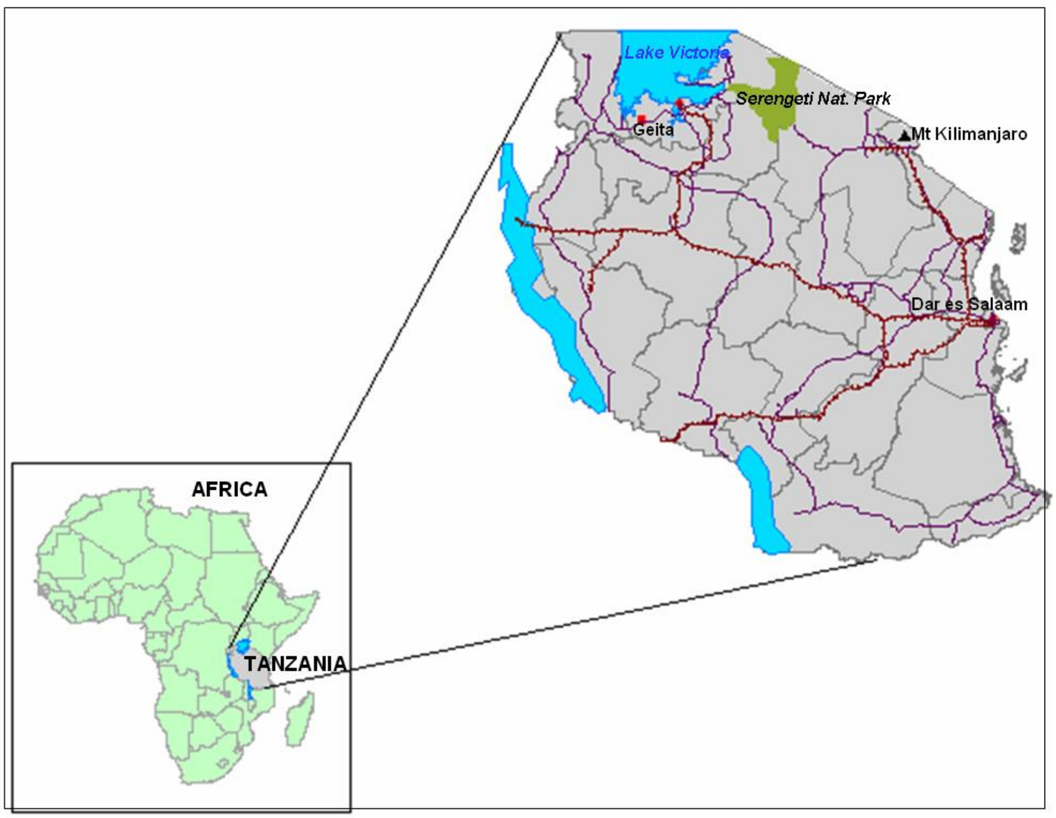

Figure 1: General location map

Historical mining in the area has taken place for many years; with the last major operation being the Geita Underground Mine which operated from the 1930's through to the 1960's and produced nearly 1 million ounces (Moz) of Au. Ongoing small-scale mining continues to this day at different places within Geita district.

The modern Geita Gold Mine has been operating since mid-1999, with processing of ore commencing in mid-2000. The mine operates under a Special Mining License that was granted in June 1999 in accordance to section 39 of the Tanzania Mining Act, 1998. The mine draws water from Lake Victoria through a Water Right granted by the Ministry of Water and which gives authority to extract up to 15,000 m^3 per day. Geita Gold Mine is supplied with power from the 40-megawatt predominantly heavy fuel oil (HFO) fuelled power station located on site. The mine maintains a workforce of around 2400 people including contractors. In addition to mining activities within its Special Mining License area, the company has been conducting exploration in a number of areas around the mine lease area.

Geita Gold Mine currently operates five open pits. The open pit mines are operated with conventional techniques using excavators and trucks mining flitches, up to 3.5m high. Most material requires blasting, ranging from “paddock blasting” in soft laterites and oxides, to hard rock blasting in sulfides. To date almost 76 million bank cubic metres (189 Million tonnes) have been mined from the five pits. The yearly target is in excess of 23 million bank cubic meters (60 million tonnes)

In complying with the requirements of the “Mining (Environmental Management and Protection) Regulations, 1999” Geita Gold Mine has established environmental management systems and processes.

At the international level, Geita Gold Mine has achieved and retained certification to the ISO14001 (an international standard code of practice for Environment Management) since 2001 the basis of which is its established Environment Management system.

Geita Geology And Mineralogy

The Geita deposits are hosted in Archaean-age rock formations characterised by banded iron formation (BIF), felsic volcanics and andesite/diorite lithologies. The BIF outcrops in all of the high ground in the area while felsic volcanics occur in the lower flanks of the ridges and are either inter-bedded within the BIF or occur on either side of the BIF. The other main lithology in the Geita area is a trachyandesite, which encompasses a suite of volcanic rock types ranging from basalt to diorite in composition. The trachyandesite units are commonly interbedded and folded with the BIF. The volcanics, which host the Au mineralisation, have been metamorphosed to lower greenschist facies. At Nyankanga the principal waste rock comprises microdiorite and BIF. The Kukuluma host waste rock sequence is more variable and includes mafic to felsic volcanics, BIF and metasediments. The metamorphic facies is uncertain and may possibly be retrograde amphibolite facies.

Gold mineralisation is associated with quartz veins (inner belts) and disseminated sulfides (outer belt) in quartz-carbonate-chlorite shear zones replacing and crosscutting magnetite-rich BIF. Gold mineralisation also occurs within the Geita Mining field associated with massive and disseminated sulfide bodies on contacts between felsic tuffs and BIF.

The principal sulfide present in the shear and vein hosted deposits is pyrite with minor pyrrhotite and trace arsenopyrite, chalcopyrite, galena, and sphalerite. Gold occurs as free native Au in quartz veins and as inclusions or surface adherents to Fe sulfides.

Carbonate minerals that are present in the mine sequence are dominated by calcite with accessory dolomite, ankerite and siderite. The carbonates occur as fine-grained pervasive mineralisation in the altered BIF matrix and as coarser grained calcite in veins.

The supergene mineral assemblage is dominated by oxyhydrates of Fe and Al together with very reactive fine-grained Fe mono-sulfides.

A description of the ARD process

Acid Rock Drainage occurs when the sulfide bearing rocks are exposed to air and water. The mining activities disturb rocks and expose the sulfide minerals present in rocks to air (O_2) and water which react and form reaction products that are easily solubilized and can form a low pH solution (H_2SO_4) characteristic of ARD. It is strongly associated with mobilisation of heavy metals and hence the environmental consequences are of higher significance, should ARD not be contained.

Management of ARD is therefore achieved by either stopping the oxidation process from occurring (break contact between sulfides and O_2) or to treat the acidic water once it has been formed. A combination of both management techniques is undertaken at GGM. In terms of the former, PAF (potentially acid forming) material is encapsulated within NAF (non-acid forming material). The prevention of leachate exiting the lease is done by utilising the natural hill/valley topography to form a series of catchment dams. In some cases where testing shows leachate and run-off to have an unacceptable level of contaminants, water is also treated before being discharged from site.

Mining Activities And ARD Management

The mining activities at Geita involve a series of procedures to ensure that the ore and waste materials are mined and handled to their respective final destinations in a controlled manner. Before mining commences, ore and NAF/PAF waste models are produced for the life of mine for each pit to get a clear picture of their position and sizes/volumes before mining. During mining the waste rock management procedure continues progressively as follows:

- Validating the waste model using in-pit geological mapping;
- Selective handling and placement of waste in designated areas of the waste rock dump and the tailings dam embankments;
- Validating placement of waste within the waste rock dump and tailings dam embankment;
- Monitoring for success of placement using piezometers within the waste rock dump, tailings embankment and downstream of these facilities;
- Regular technical reviews monthly (internal), three to six monthly (external);
- Implementing these procedures for life of mine.

Modelling

ARD modelling is carried out using 3-dimensional wire-frame models of sulfide mineralisation interpreted within 3% sample cut off envelope. These wire-frame models are developed from drill-logged sections in the geology department. Because Au mineralisation in this area is associated with sulfide mineralisation, a large portion of the sulfides fall within the mineralisation body.

In-pit geological mapping and grade control drilling

As part of increasing the understanding of the geology of the ore body, detailed in-pit geological mapping is carried out by geologists on each production bench. This exercise focuses mainly on the lithological contacts, structural features, alterations and sulfide mineralization. Using the mapped areas of sulfide mineralisation, the risk of the material falling into the PAF category is assessed. A direct field-testing method to establish the reactivity of the rock using H_2O_2 is used when visual identification of PAF material from sulfide content is unable to be established. By using these maps, delineation of PAF/NAF material is done and thereafter demarcated on the ground before being hauled to their respective destinations.

The waste model is updated using information gathered from the field (Fig. 2). In this way, the model may be reconciled against actual dump volumes to establish a defensible position where GGM can demonstrate correct handling of this material.

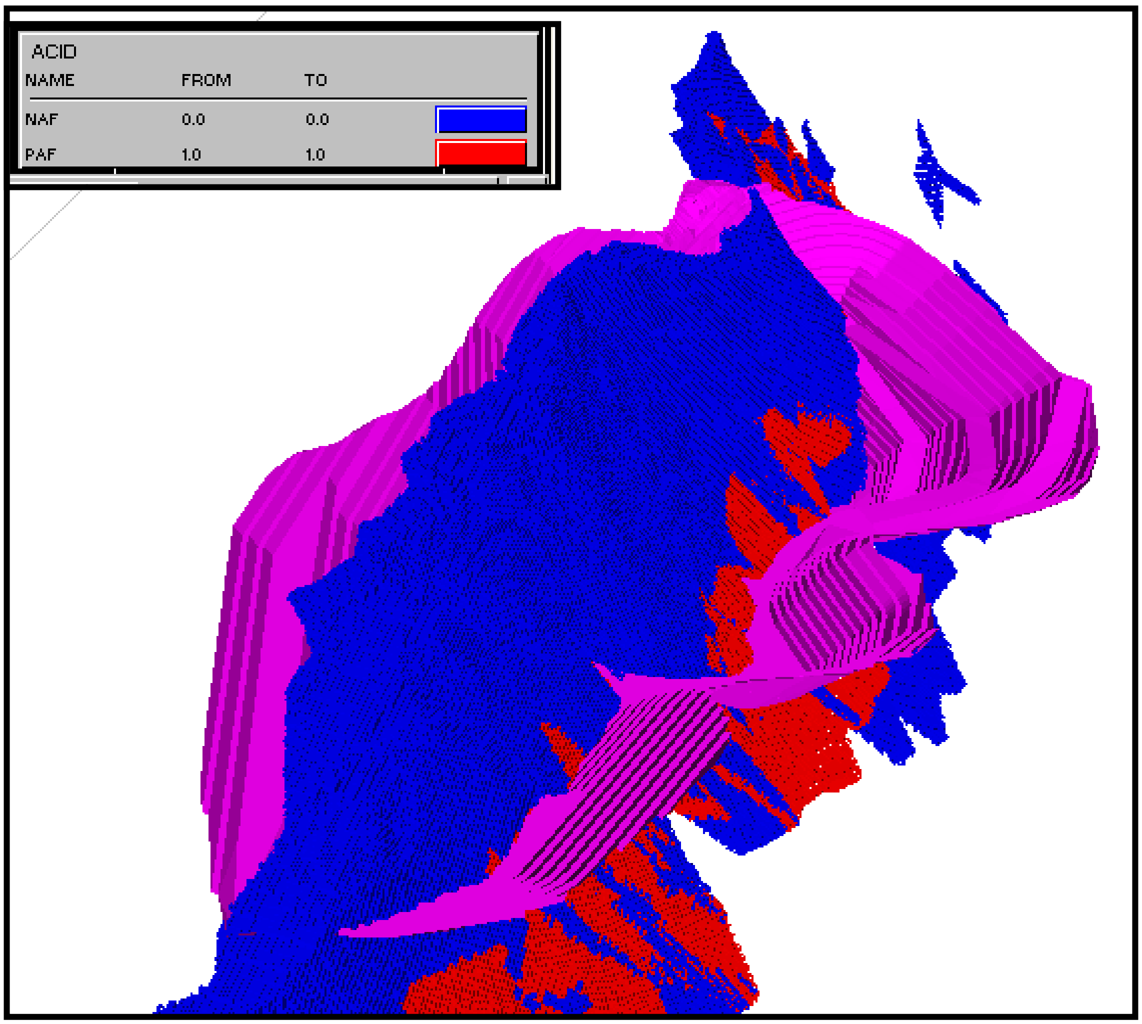

Figure 2: Example of a prepared PAF/NAF model for a section of Geita hill pit

Waste Mining, Segregation And Encapsulation

Following blasting, the blasted materials are identified by the geologist and marked as ore, PAF and NAF. Mining and hauling these materials is accomplished using excavators and 100t and 240t trucks which carry the materials to the designated areas i.e. ore to the crusher, and NAF/PAF to the specially-designed waste rock dumps and part used for tailings storage facility (TSF) wall construction. The bottom of these waste dumps and the TSF are underlain by the hardpan ferricrete layer, which does not allow penetration or seepage of water to the underground aquifers. To date, more than 190million cubic meters of waste material has been mined from seven (7) open pits and more than 7 waste rock dumps have been constructed.

Segregation of waste in the pit continues until their final destination on the waste dumps, where the PAF and NAF are dumped separately. The designs of the waste dumps encapsulate the PAF materials in the middle and the leave the outer layer of between 80m to 100m on each dump lift comprising NAF material. Tipping of material is usually done at 35° to 37° batter angle depending on type of material (oxides to fresh), interspersed with 36m wide berms at 20m vertical increment lifts and the final batter angle is less than 20°. Compaction of materials occurs as dumping progresses and therefore minimises the infiltration of water into the dump.

Figure 3 shows the placement of NAF and PAF wastes on the waste dump

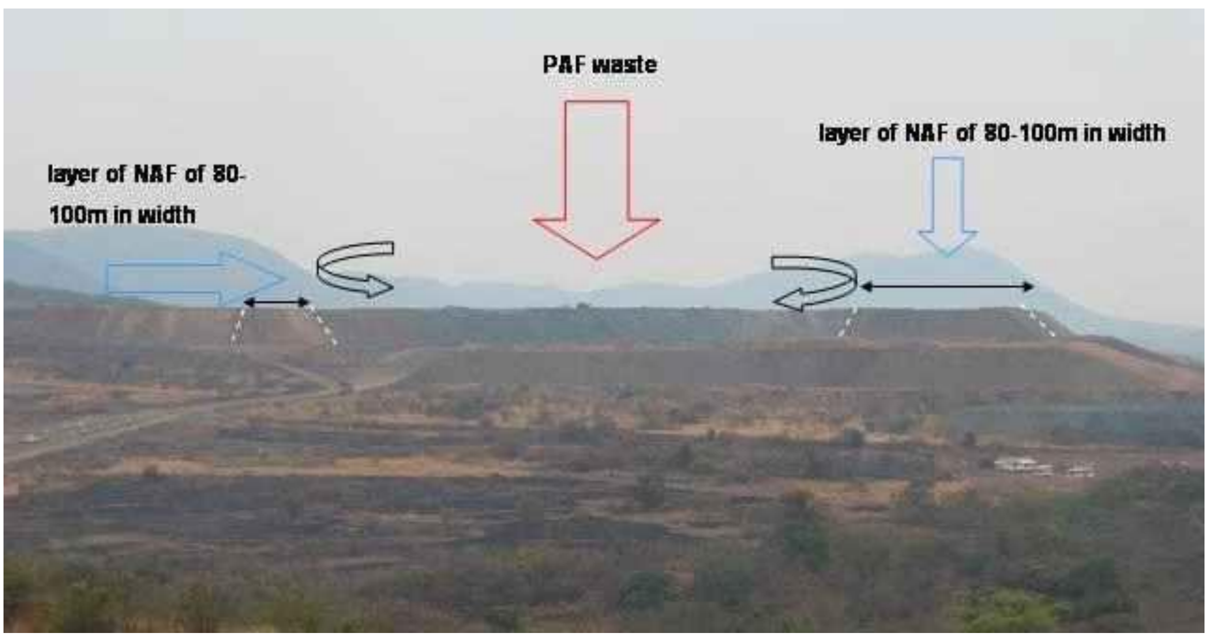

Figure 3: Nyankanga Waste dump 1

Water Management And Kinetic Tests

On all the waste dumps, drainage channels are in place to immediately drain away storm water to prevent infiltration through the material (Fig. 5). The waste dumps slope and drainage channel design and construction (Fig. 4) enhance smooth and safe collection and transportation of water away from the dumps minimising infiltration of water into the dump. In addition to the drainage systems, the vegetation cover that is established on the slopes minimises the infiltration of water and prevents the silt from being released to the environment.

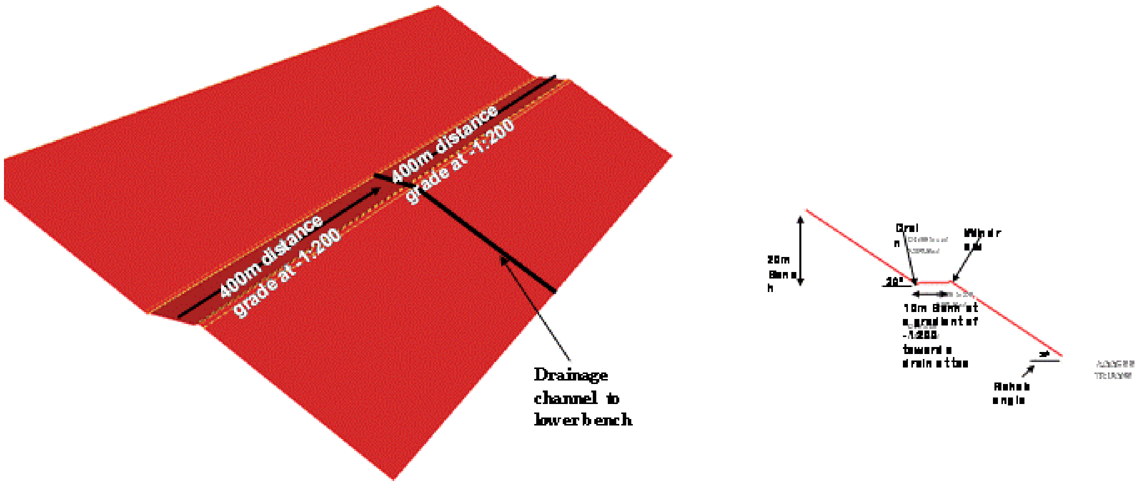

Figure 4: Details of dump dewatering designs

Figure 5: Nyankanga Waste dump showing one of the drainage channels that drain water off the dump slope

Downstream of each dump and Tailing Storage Facility (TSF), a series of boreholes have been placed to monitor groundwater and ensure that its quality remains the same (Fig. 6). In addition to the boreholes, monitoring is done on all identified surface waters within the mine site and outside including a point at Lake Victoria (about 25km away) on quarterly bases. No significant changes against baseline data have been noticed so far on the quality of water of all the monitoring sites including the sites downstream of waste dumps and TSF. This is an indication of the proper handling of acid forming wastes and other kind of wastes generated on site.

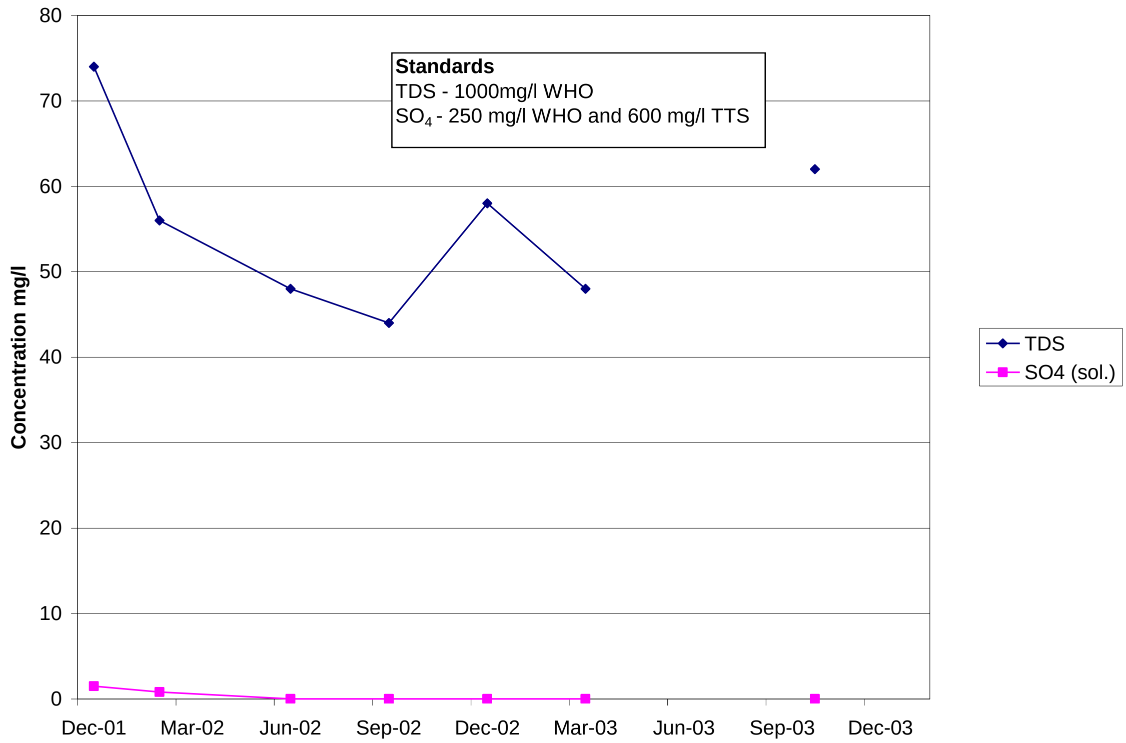

Figure 6: Water results of one of the boreholes (GW33E) that is located downstream of the largest waste rock dump WD1

The kinetic test has been set to assess the changes of different types of rocks when exposed to the environment. Column methods have been adopted at GGM where by eight (8) columns with different rock types and sulfide percentage have been operated. The wastes include NAF and PAF of both micro diorite (MD) and banded Fe formation (BIF) type, and ore. The columns are of 200 litres volume each, are set outside on open space (to simulate the condition at the waste rock dump) where they are exposed to air and rainfall. The columns configuration includes a bottom layer (150mm deep) of clean quartz material that acts as a filter bed, followed by the rock sample (750mm deep) as shown in Fig. 7 below.

The columns have been running for more than 36 months and the findings to date indicate that the SO_4^{-2} concentration in leachate from the columns (expressed in mg/L) decreased from the commencement of the test or remained static.

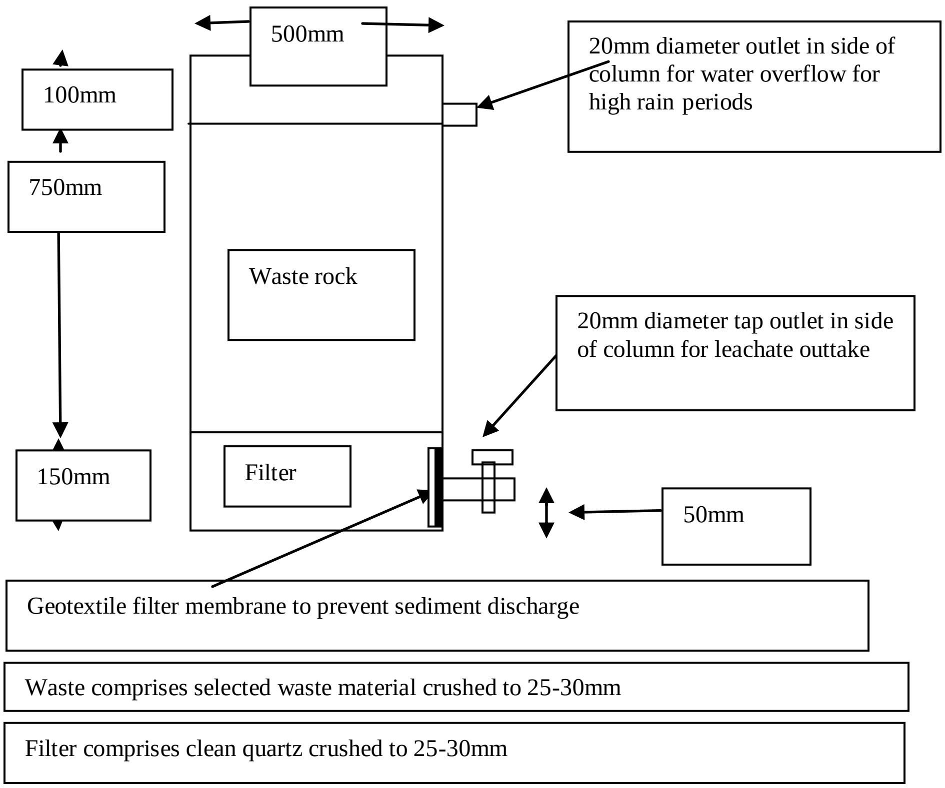

Figure 7: Kinetic column configuration

The initial elevated concentrations would normally relate to existing oxidation within the samples. The highest SO_4^{-2} concentration in leachate was recorded from Column C7 (Ore BIF with sulfides >1%) that had SO_4^{-2} concentrations ranging from 3734 mg/L at the commencement of the test period to 1334mg/L after 36 weeks. The data does indicate that under the testing regime SO_4^{-2} is being released.

The pH for all waste rocks remained around 7 while Fe and As remain below the detection limits i.e. <0.5 and <0.01mg/l respectively. Calcium and Mg have been released and their presence is the indication of acid buffering by rock weathering. Monitoring of the columns will continue to further observe the trend. As the samples under observation are fresh rock with coarse pyrite, the oxidation is likely to take much longer time to have the ARD.

Rehabilitation And Closure Of Waste Dumps

Rehabilitation and revegetation of waste dumps is a final stage after completing the dumping process of wastes. Planning for ultimate closure of the waste dumps at Geita Gold Mine takes into account the Legal Requirements which under the Regulation 26 of The Mining Act, 1998 it stipulates that "…waste dumps shall be reclaimed to ensure:

- long term stability;
- water quality released from waste rock dumps to the receiving environment is of a standard specified in the Fifth schedule to the Regulations; and
- land use and productivity objectives are achieved…"

GGM thus considers the following during the waste dumps designs in addition to the ARD aspects explained above:

- surface and structural integrity of the dumps
- surrounding landforms and topography
- visual values
- cover treatments and rehabilitation

At GGM, rehabilitation is done concurrently with active mining so as to limit rehabilitation required at the end of mine life. The waste dump land forms are designed in such a manner they are similar to the surrounding landforms (Fig. 8). The faces are battered to a slope of less than 20 degrees to ensure that the dump face is stable and not too steep to be eroded easily. After battering, topsoil of 20cm depth is spread on top and cross-ripped to form 50cm deep ridges. This further reduces erosion of topsoil and provides some roughness that assist in the better performance of vegetation. The vegetation cover is the final stage that follows after topsoil and this is the most important one in achieving a stable structure as the vegetation holds the soil together and makes the cover more stable.

Figure 8: Ongoing contoured rehabilitation on Waste dump 8 at Kukuluma pit.

To date, more than 200ha have been successfully rehabilitated since 2002, with 183,770 tree seedlings (only indigenous species of more than 40 species) transplanted on the areas, more than 700kg of seeds being collected either broadcasted and direct sown on different places. The use of indigenous species ensures a sustainable ecosystem and maintaining the natural beauty of the areas that existed before disturbance.

Conclusion

Geita Gold Mine is a leader in the environmental field on the African Continent. The close proximity to the second largest lake on earth as well as its location within the Geita Forest Reserve makes environmental management and pollution control non-negotiable.

The commitment of resources and adherence to systems ensures the continued success in this field. The continuous management of ARD and the exceptional focus on environmental issues will ensure that closure liabilities are minimised.

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