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Lehating Manganese Mine

Acid Rock Drainage and Geochemical Report

SLR Project No.: 710.20011.00002

Report No.: v1

February 2012

Lehating Mining (Pty) Limited

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ACID ROCK DRAINAGE AND GEOCHEMICAL REPORT

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ACRONYMS AND ABBREVIATIONS

Below a list of acronyms and abbreviations used in this report.

Acronyms / Abbreviations	Definition
ABA	Acid Base Accounting
AD	Acid Drainage
AMD	Acid Mine Drainage
AP	Acid Potential
ARD	Acid Rock Drainage
ARLP	Acid Rain Leach Procedure
DRC	Democratic Republic of Congo
EPA	Environmental Protection Agency
IFC	International Finance Corporation
NNP	Net Neutralizing Potential
NP	Neutralizing Potential
NPR	Neutralization Potential Ratio
PAF	Potentially Acid Forming
TSF	Tailings Storage Facility
WHO	World Health Organisation

EXECUTIVE SUMMARY

SLR Consulting (Africa) Pty Limited (SLR) have been appointed by Lehating Mine (Pty) Limited (Lehating) to undertake geochemical assessment and provide technical input for the preparation of an Acid Rock Drainage (ARD) Management Plan for the proposed Lehating Manganese Mine in the Northern Cape Province of South Africa.

Four samples that represent all material likely to be encountered during the mining operation were collected from site and geochemical investigations undertaken to determine the potential for acid production. The test work undertaken as part of this report includes ABA and NAG tests along with leach tests. Based on the laboratory results, it was concluded that all four samples were non-acid forming with sufficient neutralising potential to compensate any potentially generated acidity. Based on the available data, the quality of the leachate produced would not be acceptable for discharge (when compared to relevant chemical water quality standards) into the environment without treatment, however it is noted that these conclusions are based on four samples and it is recommended that further test work be undertaken (specifically on waste rocks and tailing material) to substantiate the result and to better understand the potential for acid generation and metal leaching at Lehating Mine.

ACID ROCK DRAINAGE AND GEOCHEMICAL REPORT

1 INTRODUCTION

SLR Consulting (Africa) Pty Limited (SLR) has been appointed by Lehating Mine (Pty) Limited (Lehating) to carry out geochemical test work related to proposed manganese mining operations at Lehating Mine in the Northern Cape Province of South Africa.

Geochemical investigations were undertaken on four samples collected for site during exploratory drilling work in December 2012 and represent all material likely to be encountered during the mining operation to determine the potential for acid production. The four samples consisted of the following material; the Kalahari Sands, Dwyka formation, Ongeluk Lava and manganese ore.

A first order risk assessment was undertaken based on the results retrieved from the geochemical test works which link a potential source (i.e. tailing storage facility or waste rock dump) directly to a potential receptor (i.e. human beings or the environment), by comparing the leachate quality results to relevant water quality standards (physical parameter).

This report provides a summary of the geochemical investigations undertaken as part of this assessment and is in accordance with the IFC Guidelines for Mining (IFC 2007) that recommend mining operations undergo geochemical characterization of ores and mine wastes in order to properly manage potentially acid generating materials and Acid Rock Drainage (ARD) (also referred to as Acid Drainage (AD) and Acid Mine Drainage (AMD)). This report also provides appropriate recommendations arising from the geochemical testing.

1.1 OBJECTIVES

The objectives of this report are to:

- Geochemically characterise all material likely to be encountered during the mining operations which include the Kalahari sands, Dwyka formation, Ongeluk Lava and manganese ore;
- Identify which material has the highest polluting potential through the mining operations;

1.2 REGULATORY REQUIREMENT

The International Network for Acid Prevention (INAP) sponsored the development of the Global Acid Rock Drainage (GARD) Guide, which outlines current international best practice for the prediction, prevention and management of acid rock drainage, including the development of ARD management plans. This report follows this guideline.

In accordance with the 'Equator Principles', any discharges from site would also have to comply with the International Financial Corporation (IFC) Discharge Guidelines for Mining.

1.3 REPORT STRUCTURE

The report has been divided accordingly:

- Section 2 briefly summarised the general site setting.
- Section 3 summarises the waste rock characterisation of the site as determined from the geochemical analysis.
- Section 4 summarises and concludes the report

2 SITE SETTING

This section briefly summarises the site setting, geology, climate and groundwater regime of the Lehating Manganese Mine which have been discussed in depth in previous reports.

2.1 SITE LOCATION

The Lehating Mine Site is located in the Northern Cape Province, approximately 1km north-east of the R380 national road which connect the town of Kuruman to the Botswana border. The nearest town to the site is Black Rock, approximately 10km to the south of the site. Figure 2-1 presents the site location.

The mine will be located between topographic elevations of 1003 and 1009 meters above mean sea level (mamsl). The topography falls towards the Kuruman River.

Due to the low rainfall the typical flora found on site is mostly scares, however grasses and acacia are found to grow on the investigated site of Lehating (Metago, 2011).

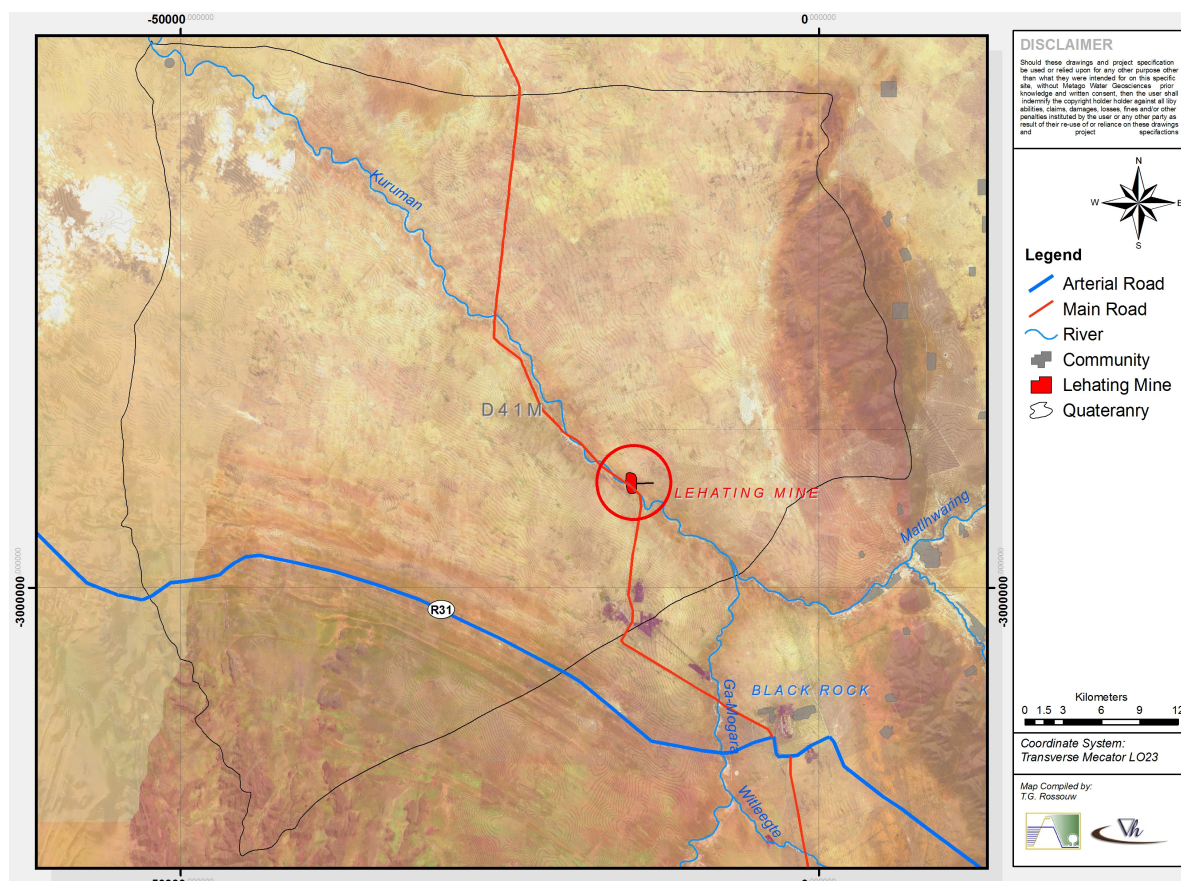


FIGURE 2-1: LOCALITY OF LEHATING MINE SITUATED IN QUATERNARY CATCHMENT D41M.

2.2 OPERATIONS

Lehating Mine is a prospective manganese mine looking to exploit the Kalahari Manganese Field (KMF) in the Northern Cape Province of South Africa.

The KMF is a large land-based manganese deposit and consists of low grade sedimentary Mamatwan-type ore (constitutes about 97% of the ore reserves) and high grade Wessels-type ore (constitutes about 3% of the known reserves), and occurs in the north-western part of the main Kalahari deposit.

Lehating is located in the north-western part of the KMF and is a graben structure which houses the Wessels-type high grade ore.

2.3 GEOLOGY

Full details on the regional and local geology are presented in previous reports (Metago, 2011), but mainly consist of the Kalahari Formation (terrestrial sediments), the Dwyka formation (Karoo Supergroup), the Hotazel Formation (Transvaal Supergroup) and the Ongeluk Formation (Transvaal Supergroup).

The Olifantshoek Formation outcrops 30km to the south-west of the site and forms a geological boundary and the Asbestoss Hill Formation (Transvaal Supergroup) outcrops 20km to the east of the site.

The Hotazel Formation is approximately 20 metres thick in the area of investigation and contains important commodities for the mining industry. Lehating Mine will exploit the Hotazel Formation for the rich manganese and iron bands.

2.4 GROUNDWATER REGIME

Based on previous investigations and geological interpretations (Metago, 2011) the following is understood;

- The Kalahari aquifer is an unconfined aquifer
- The Dwyka is a confined aquifer;
- The Hotazel / Ongeluk aquifer is a deeper fractured aquifer.

Of major importance for regional groundwater flow is the continuous presence of an impermeable or semi-permeable interface between the upper unconfined Kalahari aquifer and the deeper, confined Dwyka aquifer. This layer prevents rapid vertical drainage of the Kalahari aquifer on a regional scale, thus permitting lateral groundwater flow in the Kalahari aquifer driven by topographic gradients. Vertical infiltration across this interface is controlled by the existence of permeable zones such as areas with the absence of clay minerals

3 SAMPLE COLLECTION

Four samples of various materials likely to be mined at Lehating Mine (the Kalahari sands, Dwyka formation, Ongeluk Lava and manganese ore) were collected by a project geologist during exploratory drilling in December 2011 and sent to an accredited laboratory in Pretoria for geochemical analysis.

4 WASTE CHARACTERISATION METHODOLOGIES

The laboratory tests to determine the potential of rock samples to produce Acid Rock Drainage (ARD) are generally grouped into two categories; static and kinetic tests. The static tests are relatively simple, inexpensive and rapid, whereas kinetic tests may take several months. Kinetic tests are typically carried out if the results of the static tests are not conclusive or the samples are flagged as potentially acid generating and kinetic reaction rates are required for geochemical models

The following laboratory testing was undertaken on the Lehating sample:

- **Acid Base Accounting (ABA) analysis** was undertaken on to determine the acid neutralising potential (NP) and the acid generating potential (AP) of the tailing sample;
- **Total Sulphur and Inorganic Carbon Content** was determine to assess the potential to generate acidity and the potential to neutralise the acid;
- **Net Acid Generation (NAG) analysis** was undertaken to determine the acid generating potential of sulphur minerals in a sample by oxidation with hydrogen peroxide (H_2O_2); and
- **Synthetic Precipitation Leaching Procedure (SPLP)** was undertaken on the sample to provide an indication of the metals and salts that could be leached from the waste products.

4.1 SUMMARY OF METHODOLOGY

4.1.1 ACID BASE ACCOUNTING (ABA)

Acid–Base Accounting (ABA) is an internationally accepted analytical procedure that was developed to screen the acid-producing and acid-neutralizing potential of rocks. . It is a static procedure and provides no information on the rate with which acid generation or neutralisation will proceed, which is usually determined by kinetic weathering or leaching tests The ABA methodology assumes conservatively that all sulphur in the sample will react to form sulphuric acid. However, should a significant part of the total sulphur occur as sulphate sulphur instead of sulphide sulphur, the overall risk of acid generation is reduced; therefore an assessment of the sulphur speciation is also required.

4.1.2 TOTAL SULPHUR SPECIATION AND INORGANIC CARBON CONTENT

The ABA methodology assumes conservatively that all sulphur in the sample will react to form sulphuric acid, while some of the sulphur may also be present in non-acid producing sulphates, organic or elemental sulphur. If a significant part of the total sulphur occurs as sulphate sulphur instead of sulphide sulphur, the overall risk of acid generation is reduced. Acid generation of samples with sulphide sulphur content below 0.3 % is considered short term (Price & Errington 1995, Soregaroli & Lawrence 1998). In general, the use of total sulphur for the determination of the maximum potential acidity is considered

more reliable (Brady, 1990), therefore an assessment of sulphur speciation is undertaken to allow a better characterisation of the acid *generating* potential, which is related to the type of sulphur minerals present.

The acid *neutralising* potential of a rock / tailings sample, predominantly from carbonates and exchangeable alkali and alkali earth cations, is further characterised by the inorganic carbon content (as an estimate of carbonate contents in the tailing material) of the sample.

4.1.3 NET ACID GENERATION TESTS (NAG)

Net Acid Generation (NAG) tests directly determine the acid generating potential of sulphur minerals in a rock sample by oxidation with hydrogen peroxide (H_2O_2). The final NAG pH after complete oxidation of the sample is used as a screening criterion for the acid generation potential. The pH value indicates the following:

- pH values below 3.5 indicate a high risk of acid generation;
- pH values between 3.5 and 5.5 a low risk of acid generation; and
- pH values above 5.5 indicate no risk of acid generation.

The supernatant of the test is titrated to a pH of 4.5 and 7.0 and the net acid potential in the form of kilograms of sulphuric acid produced per tonne of tailing sample ($kg\ H_2SO_4/t$) calculated.

4.1.4 LEACH TESTS

The potential leachate quality emanating from various waste infrastructures on site is characterised using a modified Synthetic Precipitation Leaching Procedure (SPLP, EPA Method 1312) with varying pH values. The SPLP is a laboratory extraction method designed to determine the leachability of both organic and inorganic determinands present in soils, and wastes. The solid phase is extracted over 18 hours with an extraction fluid (pH dependent), and liquid-to-solid ratio of 20:1. Following extraction, the liquid extract is separated from the solid phase by filtration (combined with any potential initial liquid portion) and analysed.

The SPLP is a procedure to assess run-off from on-site fresh waste rock stockpiles or tailing storage facilities where rainwater is the only external factor influencing leachate generation. The chosen pH values for the extraction fluid furthermore allow the evaluation of the leachate quality under potential acid-rock drainage (pH3) or neutral (pH7) rock drainage conditions. It falls however short to characterise the actual site-specific liquid-to-solid ratio and provides therefore only a first screening criteria of the likely leachate quality.

As part of this assessment, SPLP tests were undertaken using the following extraction fluids with the appropriate pH value:

- distilled water pH7 To represent 'best case' or neutral drainage scenario;
- Sulphuric Acid (H₂SO₄) pH4 To represent potential acid rock conditions.

A first order risk assessment is undertaken based on the results retrieved from the above specified tests. First order risk assessments link a potential source (i.e. tailing storage facility or waste rock dump) directly to a potential receptor (i.e. human beings or the environment), by comparing the leachate quality results to following water quality standards (physical parameter):

- World Health Organisation (WHO) Guidelines for drinking-water quality (WHO, 2006);
- International Finance Corporation (IFC) Guidelines for Mining Effluents (IFC, 2007); and
- South African National Standards (SANS) 241 Guidelines for Drinking Water Standards.

While the drinking water standards are for obvious reasons very stringent, the less stringent effluent discharge guidelines specify permissible limits for effluent that can be discharged from a mining facility into the receiving environment (stream / rivers) and must be met during the operational and post closure phases. There are no generally accepted Department of Water Affairs (DWA) guidelines for mining effluent. Ambient groundwater and surface water conditions must be considered in evaluating the potential impacts of mine discharges. Note that exceedences of the highest standard value for each element are highlighted in the result tables and discussed in the text below. Depending on the element, the highest limit may be the effluent limit (e.g. manganese) or drinking water (e.g. sulphate) standards.

The IFC effluent guidelines are applicable for any site run-off and treated effluents or discharges to surface waters and should be achieved, without dilution, at least 95 % of the time that the plant or unit is operating. Site-specific discharge levels may be established based on the availability and conditions of publicly operated treatment systems or on the receiving water use classification.

A first order risk assessment does not consider potential dilution and/or retardation along a pathway (e.g. ground or surface water pathways) but serves to provide a high level screening mechanism of potential risks. It is noted however that such an assessment can provide only an initial screening tool of potential risks, but is by no means accurate and should be followed up by site-specific ground- and surface water models, which calculate environmental concentrations at a higher confidence. If the client proceeds to a detailed source-pathway-receptor risk assessment, the information gained from this study might be used as a source term for waste rocks

5 RESULTS AND DISCUSSION

5.1.1 ACID BASE ACCOUNTING (ABA)

The ABA results for the Lehating samples are presented in Table 5-1.

The ABA test results suggest that all four samples are **non-acid forming** and that the leachate produced from mining at Ruashi Mine would not be of an acidic nature, although mitigation measure would be required to ensure concentrations remained below the relevant water quality standards.

- The paste pH value for all four samples was above 5.5 which suggest that there was no acid generation prior to analysis for all four samples or that it was already neutralised.
- The total sulphur content for all four samples (all less than 0.05%) is low, which suggests a limited potential to generate acidity.
- For the manganese ore sample, a higher proportion of the total sulphur content occurs as sulphate sulphur (0.04%) instead of the potential acid generating sulphide sulphur (0.01%), therefore the overall risk of acid generation is reduced. The other samples were recorded as less than (<) 0.01% sulphide sulphur (limit of detection), regardless of the total sulphur content. A quantifiable relationship (i.e. increasing sulphide sulphur content with total sulphur content) can therefore not be established.
- For all four samples, a higher proportion of the total carbon content occurs as inorganic carbon rather than organic carbon, which suggest the samples have sufficient acid neutralising potential available.
- The net neutralising potentials (NNP) are positive for all four samples as a result of the limited sulphur content and sufficient acid neutralising potential (inorganic carbon content) and suggests that samples have the potential to neutralise any acidity produced by the limited sulphur content. In addition, the sulphide sulphur content is below 0.3 % therefore the potential acid generation of all samples is considered short term (Price & Errington 1995, Soregaroli & Lawrence 1998). Figure 5-1 below presents a plot of the sulphide sulphur (%) against the NPR and shows that all samples are non-acid generating.

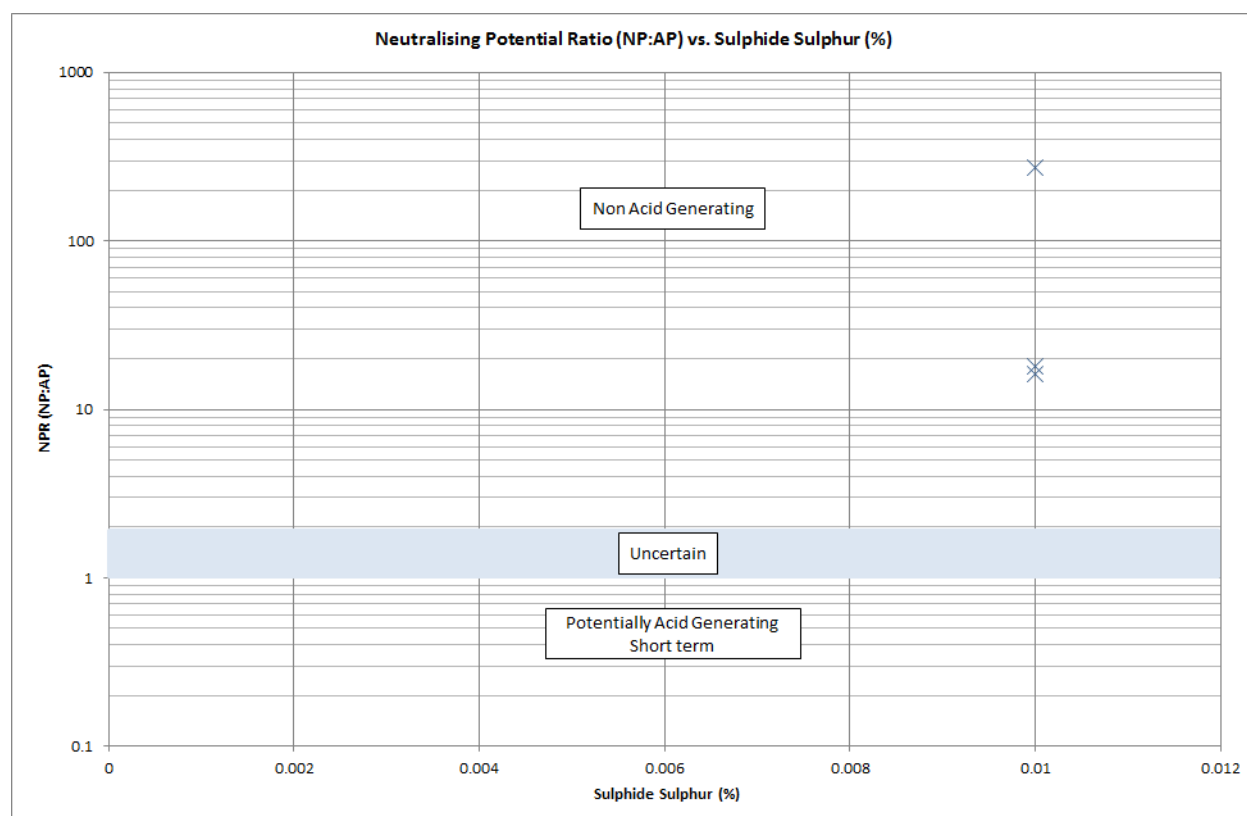


FIGURE 5-1: SULPHUR SPECIES (%) VERSUS NEUTRALIZING POTENTIAL RATIO (NP:AP) PLOT

5.1.2 NET ACID GENERATION TESTS (NAG)

The Net acid Generation (NAG) results are presented in Table 5-1. A review of Table 5-1 shows that:

- The Kalahari formation and Dwyka formation samples, along with the manganese ore sample recorded a NAG pH above pH 5.5 which suggest there is no risk of acid generation.
- The Ongeluk Lava sample recorded a pH between 3.5 and 5.5 (4.18) which suggest there is a low risk of acid generation.

TABLE 5-1: SUMMARY OF ABA AND SULPHUR SPECIATION RESULTS FOR THE LEHATING MINE SAMPLES

Laboratory Test	Kalahari Formation	Dwyka	Ongeluk Lava	Mn Ore
NAG pH:	6.72	6.8	4.18	6.45
NAG(kg H ₂ SO ₄ /t)	<0.01	<0.01	1.176	<0.01
Paste pH	7.2	7.7	8	6.9
Total Sulphur (%)	<0.01	Repeat Analysis	<0.01	0.05
Sulphate (SO ₄ ²⁻) Sulphur (%)	<0.01	Repeat Analysis	<0.01	0.04
Sulphide (S ²⁻) Sulphur [%]	0.01	Repeat Analysis	<0.01	<0.01
Acid Potential (AP) [kg CaCO ₃ /t]	0.31	8.46	0.31	1.44
Total Carbon (%)	1.94	1.55	0.03	0.12
Organic Carbon (%)	0.05	0.46	0.01	<0.01

Laboratory Test	Kalahari Formation	Dwyka	Ongeluk Lava	Mn Ore
Inorganic Carbon (%)	1.89	1.09	0.02	0.11
Neutralizing Potential (NP) [kg CaCO ₃ /t]	85.82	39.2	5.59	23.5
Net Neutralizing Potential NNP (=NP-AP)	85.51	30.73	5.28	22.06
Neutralizing Potential Ratio NPR (=NP/AP)	274.62	4.63	17.88	16.32
Assessment	Non-Acid Forming	Non-Acid Forming	Non-Acid Forming	Non-Acid Forming

5.1.3 LEACH TEST

The results of the SPLP tests undertaken on the Lehating samples under varying pH values are presented in Appendix A. Numerous metalliferous elements including aluminium (Al), arsenic (As), boron (B), barium (Ba), chromium (Cr), iron (Fe), manganese (Mn), molybdenum (Mo) and nickel (Ni) recorded in the SPLP leachate exceeded acceptable drinking water and/or mining effluent limits.

Review of the data show that the concentration of calcium increases as the pH decreases (increase in acidity), which is to be expected as this mineral becomes more mobile as it is dissolved from the rock matrix under acidic conditions.

A number of other metals, including aluminium, boron, and iron show decreasing concentrations with an increase in acidity (decreasing pH), which would suggest that these minerals are less mobile under acidic conditions. Such behaviour is typically not observed for metalloids (they generally become more soluble and mobile under acidic conditions) and suggests sample heterogeneities, i.e. variable initial metal contents in the tested samples. It is therefore recommended to initiate additional leach tests using samples composited from a larger core section to ensure representative results. Until new results become available, the maximum leached concentrations under neutral or acidic conditions should be used for the assessment.

- Concentrations of **calcium** within the leachate of the Kalahari, Dwyka and Manganese Ore samples are low under pH7 conditions (17mg/L, 11mg/L and 14mg/L respectively) and increase under pH4 conditions (165mg/L, 132mg/L and 56mg/L). Concentrations within the leachate from the Ongeluk Lava are low under both pH7 and pH4 conditions which is typical for the rock type. Concentrations generally remain below the relevant water quality standards with the exception of the Kalahari sample under pH4 conditions (165mg/L) which exceeds the SANS 241 Class I Limit;
- Concentrations of **aluminium** within the leachate of two samples (Dwyka and Ongeluk) decreased from 17mg/l and 7.85mg/L respectively under pH7 conditions to 0.13mg/L and below laboratory detection limit (<0.1mg/l) respectively under pH4 conditions. Concentrations of these two samples exceeded the WHO Standard for Drinking Water Quality under pH7 conditions but remained below it under pH4 conditions;

- The concentration of **arsenic** within the leachate of the Dwyka sample decreased from 0.022mg/L under pH7 conditions to below laboratory detection limit (0.01mg/L) under pH4 conditions. The concentration recorded under pH7 conditions exceeded the WHO Standard for Drinking Water Quality and the SANS 241 Class II Lower limit (both 0.01mg/L);
- Concentrations of **boron** within the leachate of the Dwyka sample and the manganese ore sample exceeded the WHO Drinking Water Standards (0.5mg/l) under both pH4 and pH7 conditions. The concentration recorded within the leachate from the Dwyka sample decreased from 1.55mg/L (pH7) to 0.56mg/L (pH4). The concentration's recorded within the leachate from the manganese ore sample increased slightly from 0.787mg/L (pH7) to 0.798mg/L (pH4);
- The concentration of **barium** recorded in the leachate of the manganese ore sample exceeded the WHO Drinking Water Standard (0.7mg/L) under both pH7 and pH4 conditions and increased from 0.75mg/L (pH7) to 3.54mg/L (pH4). The concentrations recorded in the leachate of the Kalahari sample also increased from 0.154mg/L under pH7 conditions (below WHO Drinking Water Standards) to 0.86mg/L under pH4 conditions which exceed the WHO Drinking Water Standards. Concentrations recorded in leachate of the Dwyka and Ongeluk decreased with an increase in acidity although concentrations remained below the WHO Drinking Water Standards under both pH conditions;
- Concentrations of **chromium** recorded in leachate from all four samples were predominately below the laboratory detection limit of <0.025mg/L for both pH7 and pH4 conditions. The concentration recorded within the leachate from the Dwyka sample exceeded the WHO Drinking Water Sample of 0.05mg/L under pH7 conditions but decreased under pH4 conditions to below laboratory detection limits
- Concentrations of **iron** recorded in the leachate of all four samples decreased with a decrease in pH (i.e. increase in acidity). Concentrations recorded in leachate from the Dwyka and Ongeluk Lava samples (32mg/L and 6.93mg/L respectively) under pH7 conditions exceeded the SANS 241 Class II Upper Limit (2mg/L) and the IFC Mining effluent Standards (2mg/l). Concentrations reduced under pH4 conditions (0.16mg/L and 0.28mg/L respectively) with only the concentration of the Ongeluk Lava exceeded a Drinking Water Sample (SANS 241 Class II Lower Limit (0.2mg/L);
- Concentrations of **manganese** within the four samples exceeded the relevant Drinking Water Standards under both pH7 (SANS 241 Class II Limits) and pH4 conditions (WHO Drinking water Standards) with the exception of the concentrations recorded in the Kalahari sample under pH7 conditions which remained below all standards. An increase in concentration was recorded in the Kalahari, Ongeluk Lava and Mn Ore samples and a decrease recorded in the Dwyka sample.
- **Nickel and molybdenum** concentrations were generally below the laboratory detection limit of <0.025mg/L under both pH4 and pH7 conditions for all four samples. Concentrations of both

determinands recorded in the leachate from the Dwyka sample (0.095mg/L and 0.084mg/L) exceeded the WHO Drinking Water Standards (both of 0.07mg/L) under pH7 conditions and decreased to below this standard under pH4 conditions;

- **Antimony** concentrations recorded in the leachate of all four samples were below the laboratory detection limit of <0.01mg/L under both pH7 and pH4 conditions with the exception of the Kalahari sample where a concentration of 0.027mg/L was recorded and exceeded the WHO Drinking Water Standard of 0.02mg/L and the SANS 241 Class II Lower Limit of 0.01mg/L;
- Concentrations of **sulphate and chloride** recorded in all four samples under both pH7 and pH4 conditions were low and remained below all relevant water quality standards. Concentrations recorded under pH7 conditions generally decrease to below laboratory detection limit under pH4 conditions

TABLE 5-2:SPLP LEACHATE ANALYSIS RESULTS (IN MG/L) UNDER PH7 CONDITIONS FOR LEHATING MINE SAMPLES

Sample ID	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe	K	Li	Mg	Mn	Mo	Na	Ni	P	Pb	Sb	Se	Si	Sn	Sr	Ti	V	W	Zn	Zr	Alkalinity as CaCO ₃	Chloride as Cl	Sulphate as SO ₄	Nitrate as N	Fluoride as F	pH	EC		
Unit	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
WHO Standard for Drinking Water	N/A	0.2	0.01	0.5	0.7	N/A		300		N/A	0.05	2	N/A	N/A	N/A	N/A	0.4	0.07	200	0.07	N/A	0.01	0.02	0.01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A			250	400	10	1.5	N/A		
IFC Mining Effluent	N/A	N/A	0.1	N/A	N/A	N/A		N/A		N/A	N/A	0.3	2	N/A	N/A	N/A	N/A	N/A	N/A	0.5	N/A	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.5			N/A	N/A	N/A	N/A	N/A	N/A	
SANS for Drinking Water - Class I	N/A	0.3	0.01	N/A	N/A	N/A		150	0.005	0.5	0.1	1	0.2	50	N/A	70	0.1	N/A	200	0.15	N/A	0.02	0.01	0.02	N/A	N/A	N/A	N/A	N/A	0.2	N/A	5			200	400	10	1	5 - 5.9		
SANS for Drinking Water - Class II	N/A	0.5	0.05	N/A	N/A	N/A		300	0.01	1	0.5	2	2	100	N/A	100	1	N/A	400	0.35	N/A	0.05	0.05	0.05	N/A	N/A	N/A	N/A	N/A	0.5	N/A	10			600	600	20	1.5	4-10		
Kalahari Formation	<0.025	<0.100	<0.010	0.031	0.152	<0.025	<0.025	17	<0.005	<0.025	<0.025	<0.025	0.030	3.2	<0.025	8	0.034	<0.025	9	<0.025	<0.025	<0.020	<0.010	<0.020	14.6	<0.025	0.068	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	92	<5	11	<0.2	0.5	8.3	18.8	
Dwyka	0.081	17	0.022	1.55	0.032	<0.025	<0.025	11	<0.005	<0.025	0.073	0.029	32	5.7	0.027	16	1.37	0.095	57	0.084	0.179	<0.020	<0.010	<0.020	16.1	<0.025	0.256	0.079	0.146	0.034	0.060	<0.025	132	27	52	<0.2	0.7	8.9	33		
Ongeluk Lava	0.093	7.85	<0.010	0.274	0.099	<0.025	<0.025	2	<0.005	<0.025	<0.025	<0.025	6.92	7.6	<0.025	3	0.384	<0.025	21	0.052	<0.025	<0.020	<0.010	<0.020	11.3	<0.025	0.049	0.090	0.100	0.035	<0.025	<0.025	<0.025	76	<5	7	<0.2	0.3	9.6	11.8	
Mn Ore	<0.025	<0.100	<0.010	0.787	0.753	<0.025	<0.025	14	<0.005	<0.025	<0.025	<0.025	0.062	<1.0	<0.025	<2	1.57	<0.025	3	<0.025	<0.025	<0.020	<0.010	<0.020	<0.2	<0.025	0.921	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	28	12	<5	<0.2	<0.2	8.1	10.2	

Note: Colour coding indicated exceedences of relevant water quality standards

TABLE 5-3: SPLP LEACHATE ANALYSIS RESULTS (IN MG/L) UNDER PH 3 CONDITIONS FOR LEHATING MINE SAMPLES

Sample ID	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe	K	Li	Mg	Mn	Mo	Na	Ni	P	Pb	Sb	Se	Si	Sn	Sr	Ti	V	W	Zn	Zr	Alkalinity as CaCO ₃	Chloride as Cl	Sulphate as SO ₄	Nitrate as N	Fluoride as F	pH	EC	
Unit	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
WHO Standard for Drinking Water	N/A	0.2	0.01	0.5	0.7	N/A		300		N/A	0.05	2	N/A	N/A	N/A	N/A	0.4	0.07	200	0.07	N/A	0.01	0.02	0.01	N/A	N/A	N/A	N/A	N/A	N/A	N/A			250	400	10	1.5	N/A		
IFC Mining Effluent	N/A	N/A	0.1	N/A	N/A	N/A				N/A	N/A	0.3	2	N/A	N/A	N/A	N/A	N/A	N/A	0.5	N/A	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.5			N/A	N/A	N/A	N/A	N/A	N/A	
SANS for Drinking Water - Class I	N/A	0.3	0.01	N/A	N/A	N/A		150	0.005	0.5	0.1	1	0.2	50	N/A	70	0.1	N/A	200	0.15	N/A	0.02	0.01	0.02	N/A	N/A	N/A	N/A	0.2	N/A	5			200	400	10	1	5 - 5.9		
SANS for Drinking Water - Class II	N/A	0.5	0.05	N/A	N/A	N/A		300	0.01	1	0.5	2	2	100	N/A	100	1	N/A	400	0.35	N/A	0.05	0.05	0.05	N/A	N/A	N/A	N/A	0.5	N/A	10			600	600	20	1.5	4-10		
Kalahari Formation	<0.025	<0.100	<0.010	<0.025	0.858	<0.025	<0.025	165	<0.005	<0.025	<0.025	<0.025	0.028	3.8	<0.025	28	0.951	<0.025	3	<0.025	<0.025	<0.020	0.027	<0.020	9.0	<0.025	0.280	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	536	<5	<5	<0.2	<0.2	7.4	90
Dwyka	<0.025	0.130	<0.010	0.557	<0.025	<0.025	<0.025	132	<0.005	<0.025	<0.025	<0.025	0.161	6.1	<0.025	12	0.753	<0.025	22	0.035	<0.025	<0.020	<0.010	<0.020	5.0	<0.025	1.57	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	404	<5	<5	<0.2	<0.2	7.3	71.1
Ongeluk Lava	<0.025	<0.100	<0.010	0.078	<0.025	<0.025	<0.025	5	<0.005	<0.025	<0.025	<0.025	0.280	7.5	<0.025	2	0.423	<0.025	8	<0.025	<0.025	<0.020	<0.010	<0.020	3.3	<0.025	0.089	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	76	<5	<5	<0.2	<0.2	8.5	10.3
Mn Ore	<0.025	<0.100	<0.010	0.798	3.54	<0.025	<0.025	56	<0.005	<0.025	<0.025	<0.025	0.033	<1.0	<0.025	<2	24	<0.025	<2	<0.025	0.035	<0.020	<0.010	<0.020	1.0	<0.025	0.975	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	196	<5	<5	<0.2	<0.2	7.7	34

Note: Colour coding indicated exceedences of relevant water quality standards

6 SUMMARY AND CONCLUSION

SLR Consulting (Africa) Pty Limited (SLR) have been appointed by Lehating Mine (Pty) Limited (Lehating) to undertake geochemical assessment and provide technical input for the preparation of an Acid Rock Drainage (ARD) Management Plan for the proposed Lehating Manganese Mine in the Northern Cape Province of South Africa.

Geochemical investigation was undertaken on four samples collected from site representing all material likely to be encountered during the mining operation to determine the potential for acid production

Based on various analytical tests it is concluded that all four types of material are non-acid forming. However, the quality of leachate produced would not be acceptable for discharge into the environment without treatment when compared to relevant water quality standards. It is noted however that this assessment is based on one sample of each rock type and is deemed insufficient in providing statistically significant results as well as a comprehensive geochemical assessment for the likely tailing quality / waste material for the entire ore body. It is recommended that further static tests be undertaken on additional tailings samples originating from different ore sections as well as on the waste rocks from the site as the project progresses to further assess the potential of acid rock drainage from the entire Lehating Mine operations.

Acid Rock Drainage Potential

- Based on Acid Base Account (ABA) testing for the sub-sectioned all four samples are classified as potentially non-acid generating.

Leachate Quality:

- The results suggest that a number of constituents within the leachate that would emanate from waste material at site would exceed WHO drinking water standards.
- The SPLP results under neutral conditions (pH7) identified the following constituents of concern; aluminium, arsenic, boron, barium, chromium, iron, manganese, molybdenum and nickel.
- The SPLP results under acidic conditions (pH3) identified the following constituents of concern; antimony, boron, barium and manganese.

7 REFERENCES

Metago Water Geosciences (Pty) Ltd (January 2011) *Groundwater Report – Lehating 225*. Metago Ref.: WGC-110.

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APPENDIX A: LABORATORY CERTIFICATES



RECORD OF REPORT DISTRIBUTION

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