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EXM Environmental Advisory (Pty) Ltd

KOLOMELA GEOCHEMICAL ASSESMENT AND WASTE CLASSIFICATION
FINAL REPORT

SPECIALIST DECLARATION

This report has been drafted as per the latest requirements for specialist reports as set by the Department of Environmental Affairs and listed in Government Gazette No. 40713, dated 24 March 2017 and Government Gazette No. 40772 dated 07 April 2017 in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA).

I, Tobias Loubser, hereby declare that:

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, Regulations and all other applicable legislation;
- I have not, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- All the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.



Tobias Loubser (Pr. Sci. Nat)
Managing Director for LWRC

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Acronyms and abbreviations

Acronym / abbreviations	Definition
ABA	Acid Base Accounting
AMD	Acid Mine Drainage
AP	Acid Potential
ARD	Acid Rock Drainage (similar to AMD)
BH	Borehole
CMB	Chloride Mass Balance
DEA	Department of Environmental Affairs
DEM	Digital Elevation Model
DWAF	Department of Water Affairs and Forestry (previous name)
DWS	Department of Water and Sanitation (also referred to as Department of Human Settlements, Water and Sanitation)
EC	Electrical conductivity
EIA	Environmental Impact Assessment
EMPR	Environmental Management Program Report
GN	Government Notice
ha	Hectares
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometer
ICP-MS	Inductively coupled plasma mass spectrometry
ℓ (ℓ/s)	Litre (Litres Per Second)
LC	Leach concentration in mg/ℓ
LCT	Leach concentration threshold in mg/ℓ
LOI	Loss on ignition (percentage)
LOM	Life of Mine
LWRC	Loubser Water Resources Consult (Pty) Ltd
m³ (m³/d)	Cubic metres (cubic meters per day)
mamsl	Meters Above Mean Sea Level
mbg	Meters below ground
mbsl	Meters below static water level
mg/kg	Milligram per kilogram
mg/ℓ	Milligram per litre
NP	Neutralising potential
NPR	Neutralising potential ratio
NEM:WA	National Environmental Management: Waste Act, Act 59 of 2008, as amended
NWA	National Water Act, Act 39 of 1998, as amended
PAG	Potentially acid generating
PCD	Pollution control dam
T	Transmissivity
TC	Total concentration in mg/kg
TCT	Total concentration threshold in mg/kg

TDS	Total dissolved salts
SANAS	South African National Accreditation System
SANS	South African National Standards
SoW	Scope of Work
WGS	World Geodetic System
XRD	X-ray Diffraction
XRF	X-ray Fluorescence
µS/cm	Micro Siemens per centimetre

KOLOMELA GEOCHEMICAL ASSESMENT AND WASTE CLASSIFICATION

PRJ21-010

1. INTRODUCTION**1.1 Background**

Loubser Water Resources Consult (Pty) Ltd (LWRC) was appointed by EXM Advisory Services (Pty) Ltd (EXM) to conduct a geochemical characterisation and waste classification for Kolomela Mine near Postmasburg in the Northern Cape.

The primary objective of this geochemical assessment and waste classification, is to determine the chemical nature and character of the waste rock dump (WRD) and tailings storage facility (TSF) material and to determine their pollution generating potential (including AMD / ARD).

Fines from the DMS plant will be placed on top of the current Leeuwfontein North WRD. Thin layered disposal of 'wet cake' in waste rock containment cells was seen as the most probable disposal methodology as it results in limited interaction between tailings and waste rock disposal (cPod Consulting (Pty) Ltd).

Relevant sections of Kolomela include Leeuwfontein North & South, Kapsteveld and Klipbankfontein. The Heuningkranz section is excluded. The DMS Plant is located directly northeast of the Leeuwfontein WRD.

1.2 Objectives

The key objective of the geochemical assessment is to determine the geochemical characteristics of the waste material in terms of their risk to mobilize trace metals into the surrounding water resources and to provide guidance on disposal requirements.

The waste classification will assess the subject waste streams for disposal / storage purposes and will be conducted according to the National norms and Standards for the Assessment of Waste for Landfill Disposal (DEA 2013a - GNR635). The system is based on the Australian State of Victoria's waste classification system for disposal, which uses the Australian Standard Leaching Procedure (ASLP) to determine the leachable concentrations (LCs) of pollutants in a particular waste (DEA, 2013a). In addition to the above, the total concentrations (TCs) of the constituents of concern need to be determined and compared to specified total concentration threshold (TCT) values (DEA, 2013a). The main objectives in summary entail:

- Assess the waste material for disposal / storage purposes in terms of the GNR 635 of August 2013 (National Norms and Standards for the Assessment of Waste for Landfill Disposal). The analysis procedure is based on the Australian Standard Leaching Procedure (ASLP) to determine leachable concentrations (LC's). Total Concentrations (TC's) also need to be determined.
- Determine the mineralogy and the potential to generate acid mine drainage and to further establish the pollution generating potential. Analysis includes, amongst others, X-ray Diffraction (XRD) and X-ray fluorescence spectrometry (XRF), Acid-base Accounting (ABA) and sulphur speciation.

This assessment is required for authorisation and licensing purposes, as well as engineering designs.


2. SAMPLE COLLECTION






2.1 Sampling and Laboratory Analysis

Six (6) WRD samples and two (2) fines samples were taken and made into a composite sample (KCD01) to represent fines disposal within cells in the WRD footprint (**Figure 2.a** and **Table 2.a**). Sampling, in summary, included:

- Three (3) Leeuwfontein WRD samples (LF1-3);
- Three (3) Klipbankfontein WRD samples (KF1-3);
- One (1) wet fines sample from DMS Plant (DMS Wet);
- One (1) dry fines sample from DMS Plant (DMS Dry)

Table 2.a: Sample summary

Sample ID	Latitude	Longitude	Facility / MRD	Photo
	WGS84			
DMS Dry	-28.385553	22.974834	DMS Plant - Fines	
DMS Wet	-28.371395	22.985050	DMS Plant - Fines	
KF1	-28.399101	22.966696	Klipbankfontein WRD	

KF2	-28.401136	22.967655	Klipbankfontein WRD	
KF3	-28.402271	22.966080	Klipbankfontein WRD	
LF1	-28.383266	22.978111	Leeuwnfontein WRD	
LF2	-28.382134	22.978376	Leeuwnfontein WRD	
LF3	-28.381416	22.978901	Leeuwnfontein WRD	

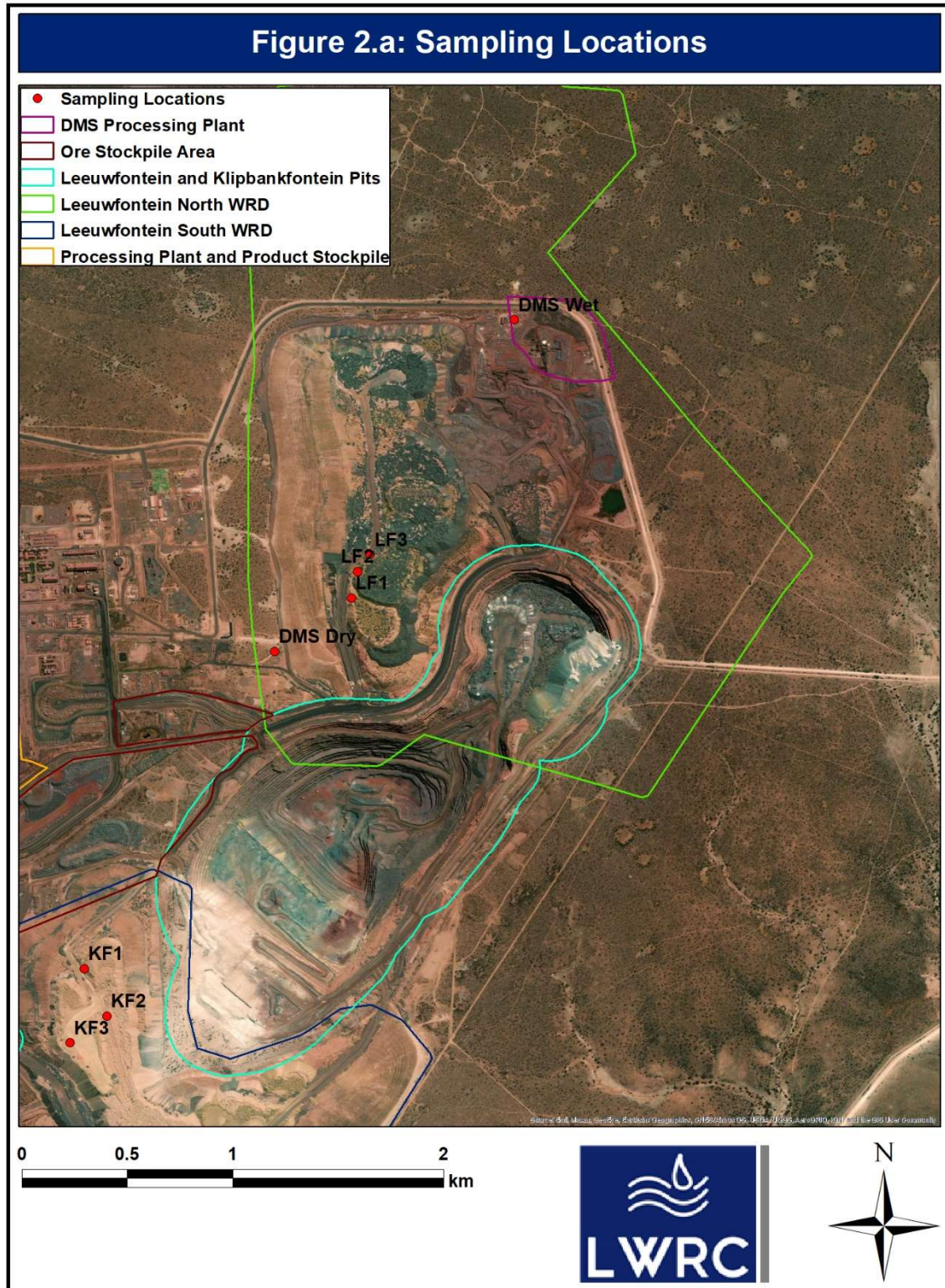


Figure 2.a: Sampling locations

2.2 Analysis conducted

The KCD01 composite sample were submitted to UIS Laboratory, a SANAS accredited laboratory for the following analysis:

- Distilled water leach (1:20) followed by the analyses of the leach solution for the listed metals and anions as per the DEA's "National Norms and Standards for the Assessment of Waste for Landfill Disposal" (GNR 635).
- Analyses of the total concentrations of metals and anions of concern as listed in the DEA's "National Norms and Standards for the Assessment of Waste for Landfill Disposal", including an analysis of the Total Fluoride and Total Cr VI.
- XRD analysis to determine the mineralogical composition of the materials;
- XRF analysis to determine the major oxides and trace elements;
- Acid Base Accounting and sulphur speciation to determine the Acid Mine Drainage (AMD) potential;
- Toxicity Characteristic Leaching Procedure (TCLP).

The sample were not analysed for any organic constituents, including pesticides, as it is highly unlikely that it would contain any organic constituents due to the nature of the operations.

The laboratory certificates are attached in **Appendix A**.

3. **PREVIOUS INVESTIGATIONS**

Results from previous geochemical and hydrogeological investigations were assessed and used to compare the LWRC (2021) results against. The following studies were reviewed and compared (more in **Chapter 7**):

- CPod Consulting (Pty) (2020). Ltd_Kolomela Mine DMS Plant_Tailings Disposal Management - Feasibility Study Interim Feedback & Discussion Presentation_CPod Consulting (Feb 2020)
- Jones & Wagener (Pty) Ltd (J&W) (2017). Heuningkranz Waste Assessment_Rep No. JW198/17/G393_Rivonia
Note_Heuningkranz is excluded from the current SoW but J&W did analyse a tailings sample and discard (waste rock) sample from the process plant at Kolomela.
- Golder Associates (2016). Kolomela Mineral Waste Streams Assessment and Mining Residue Facilities Impact Report. Rep No. 127024-29903-1. Pretoria.
- EXM Environmental Advisory (Pty) Ltd (2021). Expansion of Activities at Kolomela Mine near Postmasburg, Northern Cape. DMRE Ref No. NC069MR. Bryanston.

4. **LWRC ASSESSMENT RESULTS**

4.1 **XRD Analysis**

The mineralogy of the composite sample (KCD01) was determined through X-Ray diffraction (XRD). It should be noted that the amorphous phases, if present, are not taken into account in the quantification.

The results from the XRD analyses of the minerals for the composite sample are presented in **Table 4.a**. With reference to this table, the following is noted:

- Dolomite and quartz make up more than 60% of the sample's mineralogical composition;
- Hematite and calcite are also observed to make up notable weight (%) contribution, as expected for the site geological conditions.

Table 4.a: XRD Analyses summary

Mineral	Chemical composition	Sample (weight %)
		KCD01
Calcite	CaCO ₃	10.8
Chlorite	(Mg,Fe ⁿ) ₁₀ Al ₂ (Si, _{Al}) ₈ O ₂₀ (OH,F) ₁₆	3.7
Dolomite	CaMg(CO ₃) ₂	31.3
Hematite	Fe ₂ O ₃	14
Palygorskite	(Mg,Al) ₂ Si ₄ O ₁₀ (OH)·4(H ₂ O)	3.2
Quartz	SiO ₂	30.3
Smectite	(Na,Ca) _{0.33} (Al,Mg) ₂ (Si ₄ O ₁₀)(OH) ₂ ·nH ₂ O	6.7

4.2 XRF Analysis

The element specific concentrations were obtained from the XRF analyses. Samples are illuminated by X-rays or gamma rays, resulting in excitation of electrons. The radiative decay of the electrons results in emission of secondary (fluorescent) X-ray's, characteristic of the energy levels of each atomic species, which serves as a spectroscopic fingerprint for each element in the sample. Results are included in **Table 4.b**. With reference to this table, the following is noted:

- As expected, silicon, expressed as silica (XRD = quartz), was dominant in terms of the major elements in the composite sample, followed by ferric (iron) oxide (XRD = hematite);
- Dolomite and calcite are also making up a notable weight (%) contribution to the composite sample, which is expected for the geological terrain in which the study area is located.

Table 4.b: XRF Analysis and Major Element Concentrations

Mineral	Major element concentration (wt %) [s]
	KCD01
Fe ₂ O ₃	17.04
SiO ₂	34.6
Al ₂ O ₃	5.96
K ₂ O	0.48
P ₂ O ₅	0.07
Mn ₃ O ₄	0.31
CaO	13.34
MgO	8.39
TiO ₂	0.32
Na ₂ O	0.23
V ₂ O ₅	0.007

Mineral	Major element concentration (wt %) [s]
	KCD01
BaO	0.06
Cr ₂ O ₃	0.02
SrO	0.01
ZrO ₂	0.009
MnO	0.29
LOI	19.7

4.3 Alloway Crustal Abundances

Table 4.c indicates the total concentrations (TCs) of selected, detected, metals in the composite sample. Also indicated in the table are the Alloway Crustal Abundance concentrations of the particular elements, which indicates the average abundance of an element in the earth's crust (Alloway et al, 1995). By calculating the ratio of the trace element concentrations to the average composition of the earth's crust an indication can be obtained whether the concentration of an element is raised above the average crustal abundance. Enrichment does not necessarily indicate that the element is an environmental risk.

Based on the results obtained (**Table 4.c**), arsenic is observed to be the major element in the composite sample (KCD) that is elevated above the crustal abundances. The only other notable element that is elevated is manganese.

Table 4.c: Total Concentrations and Alloway Abundance Ratios

Element	Crustal Abundance (mg/kg)	ELEMENT RATIO
		KCD01 (ratio)
As	1.5	3.8 (2.5)
Ba*	425	102 (0.24)
Co	20	8.34 (0.4)
Cu	50	15 (0.3)
Mn	950	1280 (1.3)
Ni	80	9.26 (0.12)
V	160	34 (0.2)
Zn	75	8.5 (0.1)

5. ACID BASE ACCOUNTING

5.1 ABA Assessment Methods

Acid-base accounting (ABA) is used to determine the net potential of the waste material to produce acidic drainage.

Acid rock drainage (ARD) is produced through the natural oxidation of sulfidic minerals by air and water, accelerated by bacterial action (*thiobacillus*). Therefore, exposed sulphide-bearing tailings/discard (and waste rock) are prone to ARD generation.

The resulting acid leaches other heavy and toxic metals into the ARD (Weisener et al., 2003). Mining activities sometimes expose pyrite to oxidising agents such as oxygen and ferric iron (Fe^{3+}). During the oxidation process of sulphide ores, the sulphidic component (S^{2-}) in pyrite is oxidised to sulphate (SO_4^{2-}); acidity (H^+) is generated and ferrous iron (Fe^{2+}) ions are released.

Leaching from carbonaceous material and sulphides will allow for oxidation and hydration resulting in the generation of acidity (H^+), sulphates (SO_4^{2-}) and ferric (Fe^{3+}) and ferrous (Fe^{2+}) iron species and the movement of other conservative contaminants with groundwater in a downgradient direction from the source.

The resulting acidity will mobilise reactive metal contaminants which will create a pollution plume and can migrate in a downgradient direction polluting aquifers and surfacing at seepage points, contaminating surface waters along the way. Within wetland systems, oxidation of Fe^{2+} to Fe^{3+} will result in the precipitation of ferric hydroxide (FeOH), typically as a gel, which can coat the reactive surfaces of the plants and sediment, thereby greatly reducing the ability of the wetland to remove pollutants by adsorption. In addition, the high salt load is often toxic to aquatic life.

The percentage sulphur, the Acid Potential (AP), the Neutralization Potential (NP) and the Net Neutralization Potential (NNP) of the rock material are determined in this test, as an important first order assessment of the potential leachate that could be expected from the rock material.

In this study, the potential for AMD (also referred to as Acid Rock Drainage or ARD) generation from the samples was assessed using the MEND method (Price, 1997). This method is widely used in the industry and is internationally accepted. The MEND method entails determining the AMD potential by calculating the Neutralising Potential Ratio (NPR) by dividing the neutralising potential (NP) with the acid generation potential (AP)

The subsequent ratio interpretation is as follows:

- NPR < 1: Potentially acid-generating (PAG);
- 1 < NPR < 2: Uncertain potential for acid-generation; and
- NPR > 2: Non-acid-generating (NAG).

5.2 ABA Results

For the material to be classified in terms of their acid-rock drainage potential, the ABA results can be screened in terms of its NNP, %S and NP:AP ratio as follows:

- A rock with NNP < 0 kg CaCO_3/t theoretically has a net potential for acidic drainage;
- A rock with NNP > 0 kg CaCO_3/t has a net potential for the neutralization of acidic drainage.

From uncertainty related to the exposure of the carbonate minerals and the interpretation of whether a rock will be net acid generating or neutralizing, the following was noted:

- From research, a range from -20 kg CaCO_3/t to 20 kg CaCO_3/t is defined as “uncertain” in determining the net acid generation or neutralization potential of a rock. Material with an NNP above this range is classified as Rock Type IV (No Potential for Acid Generation), and material with an NNP below this range as Rock Type I (Likely Acid Generating).

Table 5.a summarises the deduced acid generating potential based on the net neutralising potential (NNP).

Table 5.a: NNP guideline

Net neutralising potential (NNP) NNP = NP-AP	Acid generating potential
< -20.0	Likely to be acid generating.
> 20.0	Not likely to be acid generating.
Between -20.0 and 20.0	Uncertain range.

Table 5.b summarises the criteria against which the acid forming potential is measured based on the neutralisation potential ratio (NPR) as proposed by Price (1997).

Table 5.b: NPR guidelines (Price, 1997)

Potential for acid generation	NP: AP screening criteria	Comments
Rock Type I. Likely Acid Generating.	< 1:1	Likely AMD generating.
Rock Type II. Possibly Acid Generating.	1:1 – 2:1	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides.
Rock Type III. Low Potential for Acid Generation.	2:1 – 4:1	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficient reactive NP
Rock Type IV. No Potential for Acid Generation. >4:1 No further AMD testing required unless materials are to be used	> 4.1	No further AMD testing required unless materials are to be used as a source of alkalinity.

From Li (2006) and Soregaroli and Lawrence (1998), the following is inferred:

- Material with a %S of above 0.3%, is classified as Rock Type I - Likely Acid Generating;
- Material with a %S of 0.2-0.3% is classified as Rock Type II – Potential Acid Forming
- Material with a %S of 0.1-0.2% is classified as Rock Type III - Intermediate; and
- Material with a %S below 0.1% is classified as Rock Type IV - No Potential for Acid Generation (**Table 5.c**).

Table 5.c: Rock classification according to %S (Li, 2006)

Classification	Acid forming potential	Criteria
Type I	Likely acid generating	Total S (%) > 0.3%
Type II	Potential acid forming	Total S (%) 0.2 - 0.3%
Type III	Intermediate	Total S (%) 0.1 - 0.2%
Type IV	No potential for acid generation	Total S (%) <0.1 %

Net-acid Generating (NAG) testing is an assessment of the potential for a material to produce acid, after exposure to an oxidant is provided. Hydrogen peroxide (H₂O₂) is used to oxidize sulfide minerals to predict the acid generation potential of the sample. The NAG test can also be used to refine the results of the ABA predictions.

The NAG involves the addition of H₂O₂ to a specific sample weight in a conical flask or similar. The sample is covered and placed in a fume hood in a well-ventilated area for about 2 hours. Once "boiling" ceases, the solution is allowed to cool to room temperature and the final pH (NAG pH) is determined. A quantitative estimation of the amount of net acidity remaining (the NAG capacity) in the sample is determined by titrating it with sodium hydroxide (NaOH) to pH 4.5 (and/or pH 7.0) to obtain the NAG Value. In order to determine the acid generation potential of a sample, the screening method of Miller et al. (1997) is used (**Table 5.d**).

Table 5.d: NAG test screening method

Rock Type	NAG pH	NAG Value (H ₂ SO ₄ kg/t)	NNP (CaCO ₃ kg/t)
Rock Type Ia. High Capacity Acid Forming.	< 4.5	> 10	Negative
Rock Type Ib. Lower Capacity Acid Forming.	< 4.5	≤ 10	-
Uncertain, possibly Ib.	< 4.5	> 10	Positive
Uncertain.	≥ 4.5	0	Negative (Reassess mineralogy) *
Rock Type IV. Non-acid Forming.	≥ 4.5	0	Positive

The ABA analysis, NAG tests as well as sulphur speciation results are summarised in **Table 5.e** and **Table 5.f**.

Table 5.e: Acid – Base Accounting Results

Acid – Base Accounting Modified Sobek (EPA-600)	KCD01
Paste pH	8.27
Total sulphur (%)	0.045
Total Sulphide (%)	0.022
Acid Potential (AP) (kg/t)	1.42
Neutralization Potential (NP) (kg/t)	275
Nett Neutralization Potential (NNP) (kg/t)	273
Neutralising Potential Ratio (NPR) (NP : AP)	194

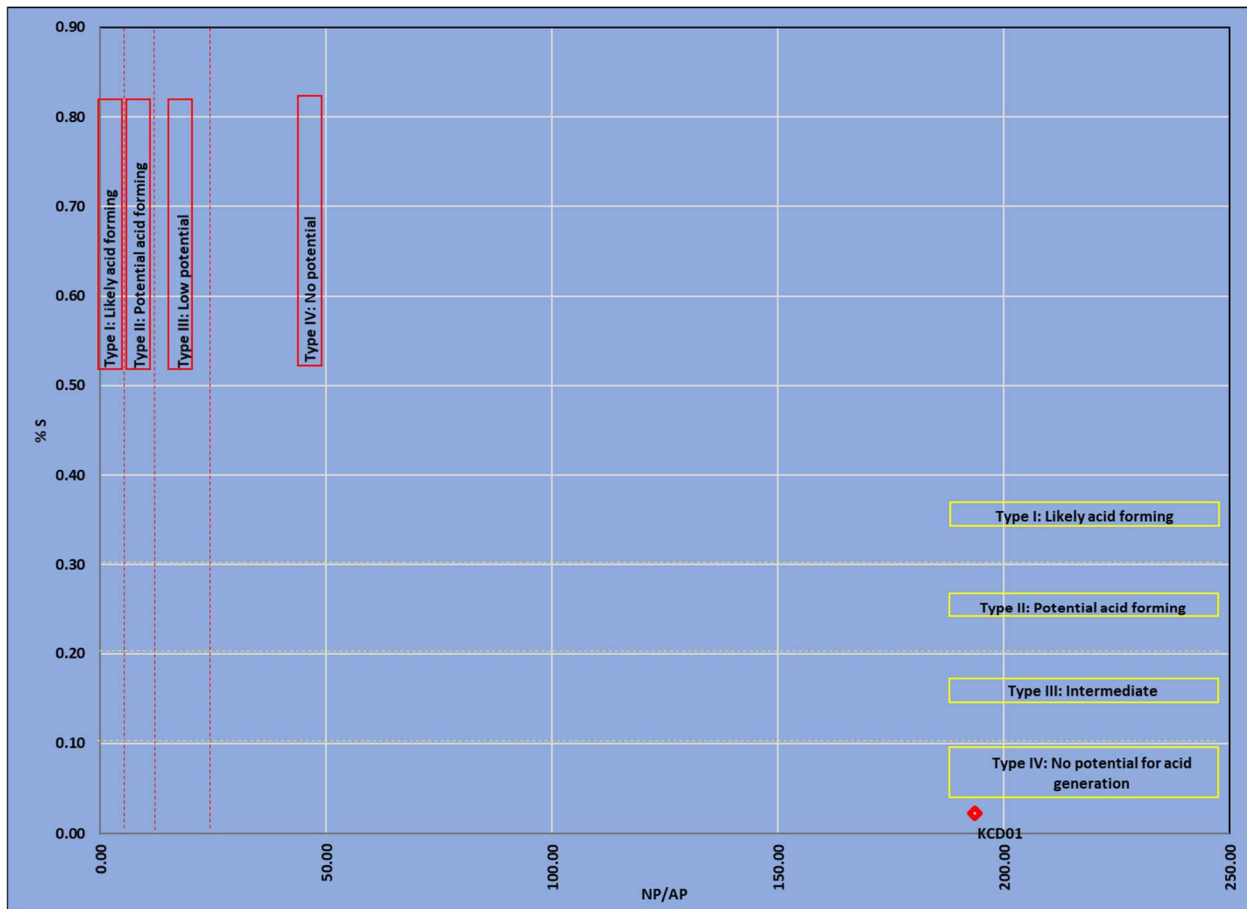
Table 5.f: NAG test results summary

Sample ID	NAG pH: (H ₂ O ₂)	NAG pH 4.5 (kg H ₂ SO ₄ /t)	NAG pH 7.0 (kg H ₂ SO ₄ /t)
KCD01	7.22	<0.01	<0.01

Refer to **Table 5.g** and **Figure 5.a** for a summary of AMD potential per lithology. It is evident that the composite sample (KCD01) classify as Rock Type IV with no potential for acid mine drainage / acid generation. This can be ascribed to the high neutralisation potential (NP) and low sulphide concentrations. In summary, there exist insufficient oxidisable sulphides to sustain long term acid generation. Refer to **Figure 5.a** for a graphic illustration of the AMD potential, NPAG, considering NP / AP and sulphide (%).

Table 5.g: Summary table on ARD/AMD results

Sample id	%S > 0.3	%S > 0.3	%S < 0.1 - 0.3	%S < 0.1 - 0.3	%S < 0.1	%S < 0.1
	NP/AP < 2.0	NP/AP > 2.0	NP/AP < 2.0	NP/AP > 2.0	NP/AP < 2.0	NP/AP > 2.0
KCD01						
Potential for ARD	Likely/possibly acid generating. High salt load.	Medium potential for acid generation. Medium to high salt load	Low to medium potential for acid generation. Low to medium salt load.	Very low potential for acid generation. Very low to low salt load.	No potential for acidic drainage. Very low/no salt load.	No potential for acidic drainage. Very low/no salt load.


Figure 5.a: NP / AP plotted against %S

6. WASTE ASSESSMENT AND CLASSIFICATION

6.1 Introduction

Waste is defined in the National Water Act (NWA) as “any solid material or material that is suspended, dissolved or transported in water (including sediment) and which is spilled or deposited on land or into a water resource in such volume, composition or manner as to cause, or to be reasonably likely to cause, the water resource to be polluted”.

The waste classification was conducted according to the National norms and Standards for the Assessment of Waste for Landfill Disposal (DEA 2013a - GNR635), as the DWS also uses this procedure to determine leach potential. Barrier systems are prescribed in GNR636 (National Norms and Standards for Disposal of Waste to Landfill)

6.2 Toxicity Characteristic Leaching Procedure (TCLP)

TCLP (by US EPA), is a static testing and sample extraction procedure and similar to the acetic leach procedure in the Australian Standards. It is used as an analytical method to simulate leaching through a waste body, landfills and more.

The sample was added to a shake flask at a solid to liquid ratio of 1:20 and agitated for 24 hours. Accordingly, inductively coupled plasma optical emission spectrometry (ICP-OES) technique were utilised to analyse the composition of elements in samples obtained from the distilled water extraction. Refer to **Table 6.a**.

Table 6.a: TCLP and DWL results for sample KCD01

Elements (mg/l)[ppm]	DWL (1:20)	TCLP
Metals	mg/L	mg/L
As	0.003	<0.01
B	0.06	0.2
Ba	0.18	7.8
Cd	<0.001	<0.001
Co	<0.025	0.08
Cr (total)	<0.025	<0.025
Cr(VI)	<0.05	<0.05
Cu	<0.01	0.2
Hg	<0.001	<0.001
Mn	<0.025	27
Mo	<0.025	<0.025
Ni	<0.025	0.63
Pb	<0.001	0.002
Sb	<0.001	<0.001
Se	0.002	<0.001
V	<0.025	<0.03
Zn	<0.025	0.05
Anions		
F	0.17	0.6
Cl	2.0	50.1
NO ₃ as N	0.7	<5.0
SO ₄	7.5	176.7
CN	<0.07	<0.07
TDS	20	6996

6.3 Waste Classification Overview

The waste assessment system that was used is based on the Australian State of Victoria's waste classification (for disposal), which uses the Australian Standard Leaching Procedure (ASLP) to determine the leachable concentrations (LCs) of pollutants in a particular waste (DEA, 2013a).

As part of the above, the total concentrations (TCs) of the constituents of concern was determined and compared to specified total concentration threshold (TCT) values (DEA, 2013a). The approach for the assessment of the waste is as follows (**Table 6.b**):

Table 6.b: GN. R 635 Classification Explained

GN R. 635 Classification Summary	Type 0 Waste	Type 1 Waste	Type 2 Waste	Type 3 Waste	Type 4 Waste
Classification	$LC > LCT3$ or $TC > TCT2$	$LCT2 < LC \leq LCT3$ or $TCT1 < TC \leq TCT2$	$LCT1 < LC \leq LCT2$ and $TC \leq TCT1$	$LCT0 < LC \leq LCT1$ and $TC \leq TCT1$	$LC \leq LCT0$ and $TC \leq TCT0$
Risk Class	Extremely hazardous	Highly hazardous	Moderate hazardous	Low hazardous	Near inert
Disposal Requirements	Requires treatment before disposal	Class A landfill (Hh / HH)	Class B landfill (GLB+)	Class C landfill (GLB +)	Class D landfill No with formal barrier (GLB-)

- Wastes with all element or chemical substance leachable concentration levels for metal ions and inorganic anions below or equal to the LCT0 limits are considered to be Type 3 wastes, irrespective of the TCs of elements or chemical substances in the waste, provided that:
 - All chemical substance concentration levels are below the total concentration limits for organics and pesticides;
 - The inherent physical and chemical character of the waste is stable and will not change over time; and,
 - The waste is disposed of to landfill without any other waste.

6.4 Waste Classification Results

The results of the De-Ionised Water Leach Test and Total Concentration analysis of the composite sample (KCD01) are shown in **Table 6.c**. The following is noted regarding the results:

- In terms of the LC's, none of the Threshold 0 (LCT0) values are exceeded;
- In terms of the TC's the concentrations of barium and manganese exceed their respective Total Concentration Threshold 0 (TCT0) values;
- Based on the *National Norms and Standards for the Assessment of Waste for Landfill Disposal*, the KCD01 sample is therefore assessed as a Type 3 waste (low hazardous waste).

Consideration should be given to site climatic and geological conditions in determining disposal (barrier) requirements and mitigation measures. The area is characterised by low rainfall and high evaporation trends which already has a mitigating effect when considering potential for leachate production and contamination migration. The shallow calcretes and low permeability clays also limits any potential contamination migration to underlying aquifers.

Table 6.c: De-ionised Water Leach test and Total Concentration Result: KCD01 versus LCT and TCT

Elements	Sample KCD01			LCT0 (mg/ℓ)	TCT0 (mg/kg)	LCT1 (mg/ℓ)	TCT1 (mg/kg)	LCT2 (mg/ℓ)	TCT1 (mg/kg)	LCT3 (mg/ℓ)	TCT2 (mg/kg)	
	LC in mg/ℓ	TC in mg/kg	Limit of Report for LC (mg/ℓ)									
As	0.003	3.8	0.01	0.01	5.8	0.5	500	1	500	4	2 000	
B	0.06	<32	0.025	0.5	150	25	15 000	50	15 000	200	60 000	
Ba	0.2	102	0.025	0.7	62.5	35	6 250	70	6 250	280	25 000	
Cd	<0.001	6.2	0.003	0.003	7.5	0.15	260	0.3	260	1.2	1 040	
Co	<0.025	8.3	0.025	0.5	50	25	5 000	50	5 000	200	20 000	
Cr (total)	<0.025	23.4	0.025	0.1	46 000	5	800 000	10	800 000	40		
Cr(VI)	<0.05	<2.0	0.01	0.05	6.5	2.5	500	5	500	20	2 000	
Cu	<0.01	15	0.025	2	16	100	19 500	200	19 500	800	78 000	
Hg	<0.001	<0.8	0.001	0.006	0.93	0.3	160	0.6	160	2.4	640	
Mn	<0.025	1280	0.025	0.5	1 000	25	25 000	50	25 000	200	100 000	
Mo	<0.025	<6.4	0.025	0.07	40	3.5	1 000	7	1 000	28	4 000	
Ni	<0.025	9.3	0.025	0.07	91	3.5	10 600	7	10 600	28	42 400	
Pb	<0.001	<3.2	0.01	0.01	20	0.5	1 900	1	1 900	4	7 600	
Sb	<0.001	<3.2	0.02	0.02	10	1	75	2	75	8	300	
Se	0.002	<6.4	0.01	0.01	10	0.5	50	1	50	4	200	
V	<0.025	34	0.025	0.2	150	10	2 680	20	2 680	80	10 720	
Zn	<0.025	8.5	0.025	5	240	250	160 000	500	160 000	2000	640 000	
Inorganic Anions				Type 4 Waste LC ≤ LCT0 and TC ≤ TCT0		Type 3 Waste LCT0 < LC ≤ LCT1 and TC ≤ TCT1		Type 2 Waste LCT1 < LC ≤ LCT2 and TC ≤ TCT1		Type 1 Waste LCT2 < LC ≤ LCT3 or TCT1 < TC ≤ TCT2		Type 0 Waste (LC > LCT3 or TC > TCT2)
TDS	20		10	1 000		12 500		25 000		100 000		
Chloride	2.0		5.0	300		15 000		30 000		120 000		
Sulphate	7.5		3.0	250		12 500		25 000		25 000		
NO3 as N	0.7		0.20	11		550		1 100		4 400		
Fluoride	0.17	4.0	0.20	1.5	100	75	10 000	150	10 000	600	40 000	
Cyanide	<0.07	<1.6	0.050	0.07	14	3.5	10 500	7	10 500	28	42 000	

7. PREVIOUS STUDIES RESULTS COMPARISON

Table 7.a below summarises and compares the LWRC (2021) results against relevant previous geochemical assessments and waste classifications conducted at Kolomela Mine. Only samples collected from waste rock or tailings (fines) storage facilities are included in the comparison.

The results from the studies largely agree on the mineralogy, ABA and the observed TC's and LC's. The mineralogy of the waste rock and tailings is dominated by silica (quartz), ferric oxide (hematite), aluminium oxide and dolomite. In terms of acid generating potential all studies agree that the potential is low to zero for the waste rock or tailings material.

The TC's are also similar in the studies in that the elements observed to exceed TCT values are mostly barium, copper and manganese. The LC's are observed to be similar as well. The investigations all classed the waste rock and tailings as Type 3 Waste.

Table 7.a: Previous investigations results comparison

Investigation	Facility material /	Mineralogy	ABA	TC's Exceeding TCT0	LC's Exceeding LCT0	Waste Classification
LWRC - 2021	Fines & Waste Rock Composite	Silica (quartz) dominant, also hematite & dolomite	Rock Type IV, no potential for AMD	Ba, Mn	None	Type 3 Waste
J&W 2017	Tailings	Quartz & hematite dominant	Not performed	Ba, Cd, F	Fe	Type 3 Waste
	Discard	Quartz & hematite dominant	Not performed	Ba, Cd, F	Fe	Type 3 Waste
Golder 2016	Kapsteveld WRD Composite	Silica, iron oxide (ferric oxide) & aluminium oxide dominant	Not Potentially Acid Generating (non-PAG), near neutral-low metal leachate	As, Ba, Cu, Mn	None	Type 3 Waste (according to GNR 635 Waste Assessment) and Type 3 to Type 4 waste according to the geochemical model
	Leeuwfontein South WRD Composite	Silica & iron oxide (ferric oxide) dominant	Not Potentially Acid Generating (non-PAG), near neutral-low metal leachate	As, Ba, Cu, Mn	None	
	Leeuwfontein North WRD Composite	Silica & iron oxide (ferric oxide) dominant	Not Potentially Acid Generating (non-PAG), near neutral-low metal leachate	As, Ba, Cu, Mn	None	
	TSF Composite	Iron oxide (ferric oxide) Silica & iron oxide (ferric oxide) dominant	Not Potentially Acid Generating (non-PAG), near neutral-low metal leachate	Ba	None	

Golder Associates (2016) concluded that none of the base (model) scenarios for the Waste Rock Dumps final profiles have $LC > LCT_0$, but all have at least one $TC > TCT_0$ – thus whilst they are not Type 4 waste, they do not meet the complete definition of Type 3 waste ($LC > LCT_0$ so low risk from leachable concentrations) and this indicates that it is reasonable to consider not applying a Class C barrier system, which is prescribed for Type 3 waste

In addition, Golder Associates (2016) concluded that the impact on water resources from the MRF's will be minimal, one of the reasons being the very low annual TDS load to groundwater (without Class C liner systems). Furthermore, Golder Associates (2016) also indicated manganese seepage loads of $0.07 \text{ kg}\cdot\text{a}^{-1}$ (Kapsteveld), $4.94 \text{ kg}\cdot\text{a}^{-1}$ (Leeuwfontein North) and $0.06 \text{ kg}\cdot\text{a}^{-1}$ (Leeuwfontein South).

The calculations were based on a 27% recharge figure, an annual precipitation of $294 \text{ mm}\cdot\text{a}^{-1}$ and a resulting recharge volume through the WRD's of $79 \text{ mm}\cdot\text{a}^{-1}$.

8. RECOMMENDATIONS

Based on the outcomes of the assessment the following actions are recommended:

- i. It is recommended that the proposed co-disposal facilities must contain the appropriate mitigation systems to manage and minimise migration of contaminants.
- ii. The composite waste sample analysed (LWRC, 2021) suggest that the material can be classed as a Type 3 waste (low hazardous waste) and should be managed accordingly. However, also considering the Golder (2016) model findings that the waste rock varies between Type 3 and Type 4 Waste (not one of these two Types specifically), a Class C liner may not be required. This will, however, also need to be discussed with the relevant authorities.

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Ferdinand Mostert (Pr. Sci. Nat)
Hydrogeologist / project manager



Tobias Loubser (Pr. Sci. Nat)
Hydrogeologist / project director

APPENDIX A

ANALYTICAL CERTIFICATES

FINAL CERTIFICATE OF ANALYSIS
REVISION: 0

TO: Charlene du Toit
 CLIENT NAME: UIS Sediba Laboratory (Pty) Ltd
 CLIENT ADDRESS: Unit 5 Carrera House, Route 21 Corporate Park, Irene

FROM: UIS Analytical Services
 XRF Laboratory
 ADDRESS: 13 Esdoring Nook, Highveld Technopark, Centurion

TEL: +27 12 345 1004
 MOBILE: +27 82 309 8373
 EMAIL: charlenes@uisol.co.za

TEL: +27 12 665 4291
 FAX: +27 12 665 4294
 REQUEST DATE:
 DATE REQUIRED:

ANALYSED GRADE PERCENTAGES

		Fe ₂ O ₃	SiO ₂	Al ₂ O ₃	K ₂ O	P ₂ O ₅	Mn ₂ O ₃	CaO	MgO	TiO ₂	Na ₂ O	V ₂ O ₅	BaO	Cr ₂ O ₃	SrO	ZrO ₂	MnO	LOI	Total (XRF)	
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
CLIENT SAMPLE ID	UIS SAMPLE ID																			
AMIS 0571	CENTERED VALUE	9.490	56.000	10.200	1.330	0.100	0.205	6.900	8.870	0.770	2.170			0.150			0.190	3.000		
	MEASURED VALUE	9.745	55.891	10.359	1.347	0.107	0.207	7.063	8.854	0.780	2.079	0.025	0.011	0.153	0.009	0.009	0.192	3.205	99.844	
12809/08/Jun/21/Soil/KDC/0/Kolomela/Mine	783495	17.038	34.568	5.961	0.488	0.073	0.312	13.343	8.392	0.322	0.230	0.007	0.062	0.020	0.011	0.009	0.290	19.714	100.551	
12809/08/Jun/21/Soil/KDC/0/Kolomela/Mine	783495 QC	17.031	34.509	5.962	0.489	0.066	0.312	13.329	8.398	0.328	0.227	0.006	0.061	0.014	0.011	0.009	0.290	19.780	100.532	

NOTES:
 *The results relate specifically to the items as tested
 *The report shall not be reproduced except in full, without the written approval of the laboratory

Identification of test method: Major and Minor Elements by XRF
 UIS method identification: UIS-XF-T007
 Instrument model: ARL ADVANTX SERIES
 Asset number: UIS-AS 0285

Identification file: UIS 38379_Report
 Authorisation date: 13-Jul-2021
 Authorised by: NAME: I Aphane
 DESIGNATION: Technician

ANALYTICAL REPORT: Acid / Base Accounting (ABA)



To: UIS Sediba Laboratory (Pty) Ltd
Attention: Charlene du Toit
Ref No:
Site Location:
Order No: 5304

Date of Request: 09/06/2021

UIS Analytical Services
 Analytical Chemistry
 Laboratories 4, 6
 Fax: (012) 665 4294

Certificate of analysis: 38379

Lims ID **Sample ID** Note: No unauthorised copies may be made of this report.

		Paste pH	Total Sulphur %	Acid Potential (AP) kg CaCO3/t	Neutralization Potential (NP) kg CaCO3/t	Nett Neutralization Potential (NNP) kg CaCO3/t	Neutralising Potential (NPR) (NP : AP) Ratio NP:AP	Total Carbon %						
783495	12809/08/Jun/21/Soil/KDC/0/Kolomela/Mine	8.27	0.045	1.42	275	273	194	4.85						
783495 QC	Duplicate	8.27	0.043	1.33	277	276	208	4.82						

Note: Negative NP values are obtained when the volume of NaOH(0.1N) titrated (pH:8.3) is greater than the volume of HCl(1N) to reduce the pH of the sample to 2.0-2.5. Any negative NP values are corrected to 0.00

Date:	25.06.2021	Chemical elements:	ABA
Analysed by:	L van der Walt	Instrument:	Methohm Titrino, LECO CS 230
		Method:	EPA 600 Modified Sobek
		Date:	28.06.2021
		Authorised :	JJ Oberholzer

ANALYTICAL REPORT: Net Acid Generation (NAG)



To:	UIS Sediba Laboratory (Pty) Ltd	Date of Request:	09/06/2021	UIS Analytical Services
Attention:	Charlene du Toit			Analytical Chemistry
Ref No:				Laboratories 4, 6
Site Location:				Fax: (012) 665 4294
Order No:	5304			

Certificate of analysis: 38379

Lims ID	Sample ID	Note: No unauthorised copies may be made of this report.												
		NAG pH: (H ₂ O ₂)	NAG at pH 4.5	NAG at pH 7.0										
			kg H ₂ SO ₄ / t	kg H ₂ SO ₄ / t										
783495	12809/08/Jun/21/Soil/KDC/0/Kolomela/Mine	7.22	<0.01	<0.01										
783495 QC	Duplicate	7.44	<0.01	<0.01										
		Note: Analysis done on sample as received												

		Chemical elements:	Net Acid Generation (NAG)
		Instrument:	Methohm Titrino
		Method:	Single addition NAG test
Date:	25.06.2021	Date:	28.06.2021
Analysed by:	L van der Walt	Authorised :	JJ Oberholzer

ANALYTICAL REPORT: Sulphur Speciation



To: UIS SEDIBA
Attention: Charlene du Toit
PO: 5304
Site Location:
Order No:

Request Date: 09.06.2021

UIS Analytical Services
 Analytical Chemistry
 Laboratories 4, 6
 Fax: (012) 665 4294

Certificate of analysis: 38379

Lims ID	Sample ID	Note: No unauthorised copies may be made of this report.													
		Total Sulphur	S (sulphide)	S (sulphate)											
		%	%	%											
783495	12809/08/Jun/21/Soil/KDC/0/Kolomela/Mine	0.045	0.022	0.020											
783495 QC	Duplicate	0.043	0.020	0.021											

		Chemical elements:	S (total), S (sulphide), S (sulphate)
		Instrument:	ICP-OES LECO CS 230
Date:	2021.06.28	Date:	2021.06.28
Analysed by:	SS Nel	Authorised :	JJ Oberholzer

CLIENT: UIS-Sediba
DATE: 14 June 2021
SAMPLES: 1 Sample (Request Sediba-12809)
ANALYSIS: Qualitative and quantitative XRD

The material was prepared for XRD analysis using a back loading preparation method. Diffractograms were obtained using a Malvern Panalytical AERIS diffractometer with PIXcel detector and fixed slits with Fe filtered Co-K α radiation. The phases were identified using X'Pert Highscore plus software
The relative phase amounts (weight %) were estimated using the Rietveld method.

Comment:

- In case the results do not correspond to results of other analytical techniques, please let me know for further fine tuning of XRD results.
- Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group.
- Due to preferred orientation and crystallite size effects, results may not be as accurate as shown.
- Smectite, lizardite (serpentine), chlorite and kaolinite peaks overlap and further test would be necessary to distinguish. Identification is largely based on peak shapes and positions.
- Traces of additional phases may be present.
- Amorphous phases, which may be present, were not taken into consideration during quantification.

If you have any further queries, kindly contact me.

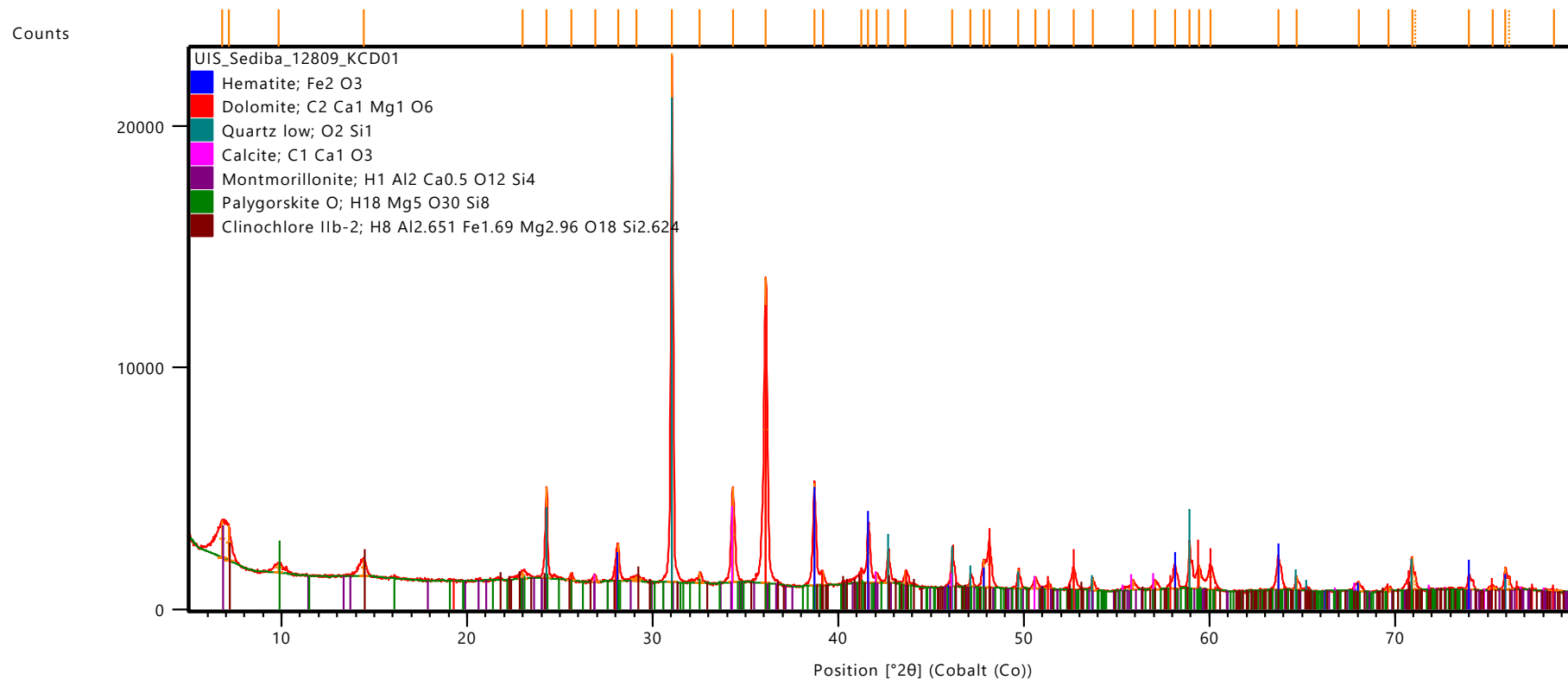


Dr. Sabine Verryn (Pr.Sci.Nat)

Samples will be stored for 3 months after which they will be discarded.

	Smectite	Hematite	Dolomite	Quartz	Calcite	Palygorskite	Chlorite
UIS_Sediba_12809_KCD01	6.7	14.0	31.3	30.3	10.8	3.2	3.7

0 = n.d. – not detected above the detection limit of 0.5-3 weight per cent
Montmorillonite = smectite (swelling clay)



Phase	Chemical Formula
Hematite	Fe ₂ O ₃
Dolomite	C ₂ Ca ₁ Mg ₁ O ₆
Quartz low	O ₂ Si ₁
Calcite	C ₁ Ca ₁ O ₃
Montmorillonite	H ₁ Al ₂ Ca _{0.5} O ₁₂ Si ₄
Palygorskite O	H ₁₈ Mg ₅ O ₃₀ Si ₈
Clinocllore 11b-2	H ₈ Al _{2.651} Fe _{1.69} Mg _{2.96} O ₁₈ Si _{2.624}



Client Information

Company: Gradient Consulting
Attention: Ferdinand Mostert
Tel: (073) 344 3021
Fax: N/A
Address: 14 Barnstable Road
Lynnwood Manor
0081

Analysis Report

Lab No: 13248

Test Information: Waste Assessment for Disposal, GNR 635 (Gazette No. 36784), Australian Standard Leaching, AS4439 - 1997

Sample Information

Matrix: Distilled Water
Sample ID: KCD01

Date Received: 2021/08/02
Date Completed: 2021/08/31
Date Issued: 2021/08/31

Parameters	Results
	DW
pH - Leach Fluid	N/A
pH - Sample	7.39
	Metals
	mg/l*
As - Arsenic	0.003
B - Boron	0.062
Ba - Barium	0.176
Cd - Cadmium	< 0.001
Co - Cobalt	< 0.025
Cr Total - Chromium Total	< 0.025
Cr (VI) - Chromium (VI) *	< 0.05
Cu - Copper	< 0.01
Hg - Mercury *	< 0.001
Mn - Manganese	< 0.025
Mo - Molybdenum	< 0.025
Ni - Nickel	< 0.025
Pb - Lead	< 0.001
Sb - Antimony	< 0.001
Se - Selenium	0.002
V - Vanadium	< 0.025
Zn - Zinc	< 0.025
	Anions (Discrete Analyser)
	mg/l*
Fluoride - F	0.17
Chloride - Cl	2.03
Nitrate as NO3	3.29
NO3 as N	0.74
Sulphate - SO4	7.54
CN - Total Cyanide *	< 0.07
	Total Dissolved Solids
	mg/l*
TDS	20

Type Assessment, based on inorganic results only, and not detection limits
Highest Total Concentration Value
Highest Leachable Concentration Value excluding Boron from the Borax leaches
Final Waste Type Classification

Authorized Signatory
M. Kannemeyer



Disclaimer:

- The results relate only to the test items provided, in the condition as received.
- UIS Sediba Laboratory takes no responsibility for sample/s prior to submission: this includes sampling, sample container, storage and shipping to our testing facility. The sample is analysed per customer request for analysis.
- This report may not be reproduced, except in full, without the prior written approval of the laboratory.
- Parameters marked " * " are not included in the SANAS Schedule of Accreditation for this laboratory. Analysis marked " ** " have been outsourced.
- UTD - Unable to determine, NR - Not Requested, RTF - Results to Follow
BDL - Below Detection Limit (Please note that if the results is BDL, it does not indicate that the sample is clean or that the analyte result is equal to zero)
- Storage Conditions: Fridge @ 0-6°C
- Methods: UISSL-WL-001 (Conductivity), UISSL-WL-002 (Alkalinity), UISSL-WL-003 (pH), UISSL-WL-004 (TDS), UISSL-WL-005 (Anions by IC), UISSL-WL-006 (Cations by IC), UISSL-WL-007 (Metals), UISSL-WL-008 (Cr(VI)), UISSL-WL-009 (TOC), UISSL-WL-010 (Hg by DMA), UISSL-WL-011 (Anions by Discrete Analyser), UISSL-HPLC-001 (Formaldehyde)
- Uncertainty of measurement for all methods included in the SANAS Schedule of Accreditation is available on request.



Client Information

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 Address: 14 Barnstable Road
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 0081

Analysis Report

Lab No: 12809

Test Information: Waste Assessment for Disposal, GNR 635 (Gazette No. 36784), Australian Standard Leaching, AS4439 - 1997

Sample Information

Matrix: Solid-TCLP
 Sample ID: KCD01

Date Received: 2021/06/03
 Date Completed: 2021/07/02
 Date Issued: 2021/07/02

Parameters	Results		TCT*	LCT*
	Solids	TCLP		
pH - Leach Fluid	N/A	2.87		
pH - Sample	9.56	5.66		
Metals				
As - Arsenic	mg/kg	mg/liter **	< TCT0	< LCT0
B - Boron	< 32	0.216	< TCT0	< LCT0
Ba - Barium	101.6	7.84	< TCT1	< LCT1
Cd - Cadmium	6.15	< 0.001	< TCT0	< LCT0
Co - Cobalt	8.34	0.084	< TCT0	< LCT0
Cr Total - Chromium Total	23.37	< 0.025	< TCT0	< LCT0
Cr (VI) - Chromium (VI) *	< 2	< 0.05	< TCT0	= LCT0
Cu - Copper	14.96	0.191	< TCT0	< LCT0
Hg - Mercury **	< 0.8	< 0.001	< TCT0	< LCT0
Mn - Manganese	1280	27	< TCT1	< LCT2
Mo - Molybdenum	< 6.4	< 0.025	< TCT0	< LCT0
Ni - Nickel	9.26	0.628	< TCT0	< LCT1
Pb - Lead	< 3.2	0.002	< TCT0	< LCT0
Sb - Antimony	< 3.2	< 0.001	< TCT0	< LCT0
Se - Selenium	< 6.4	< 0.001	< TCT0	< LCT0
V - Vanadium	33.96	< 0.025	< TCT0	< LCT0
Zn - Zinc	8.52	0.046	< TCT0	< LCT0
Anions (Discrete Analyser)				
Fluoride - F	mg/kg *	mg/liter	< TCT0	< LCT0
Chloride - Cl	4.08	0.62	N/A	< LCT0
Nitrate as NO3	N/A	50.1	N/A	N/A
NO3 as N	N/A	< 22.2	N/A	< LCT0
Sulphate - SO4	N/A	< 5	N/A	< LCT0
CN - Total Cyanide *	N/A	176.7	< TCT0	< LCT0
	< 1.55	< 0.07	< TCT0	= LCT0
Total Dissolved Solids				
TDS	mg/kg	mg/liter	N/A	< LCT1
	N/A	6996		

Type Assessment, based on inorganic results only, and not detection limits		
Highest Total Concentration Value		≤ TCT 1
Highest Leachable Concentration Value	excluding Boron from the Borax leaches	≤ LCT 2
Final Waste Type Classification		Type 2

Authorized Signatory

M. Kannemeyer



Disclaimer:

- The results relate only to the test items provided, in the condition as received.
- UIS Sediba Laboratory takes no responsibility for sample/s prior to submission: this includes sampling, sample container, storage and shipping to our testing facility. The sample is analysed per customer request for analysis.
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- UTD - Unable to determine, NR - Not Requested, RTF - Results to Follow
BDL - Below Detection Limit (Please note that if the results is BDL, it does not indicate that the sample is clean or that the analyte result is equal to zero)
- Storage Conditions: Fridge @ 0-6°C
- Methods: UISSL-WL-001 (Conductivity), UISSL-WL-002 (Alkalinity), UISSL-WL-003 (pH), UISSL-WL-004 (TDS), UISSL-WL-005 (Anions by IC), UISSL-WL-006 (Cations by IC), UISSL-WL-007 (Metals), UISSL-WL-008 (Cr(VI)), UISSL-WL-009 (TOC), UISSL-WL-010 (Hg by DMA), UISSL-WL-011 (Anions by Discrete Analyser), UISSL-HPLC-001 (Formaldehyde)
- Uncertainty of measurement for all methods included in the SANAS Schedule of Accreditation is available on request.