



Future Flow

GROUNDWATER & PROJECT MANAGEMENT SOLUTIONS

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Client Reference:

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Attention: Tanja Bekker

KHUMANI IRON ORE MINE

WASTE CHARACTERISATION PROJECT

Good day Tanja,

Please see attached the updated report on the outcomes of the waste characterisation tests that were performed for the Khumani Project.

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Please do not hesitate to contact me should you require any additional information.

Best regards,

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KHUMANI IRON ORE MINE
WASTE CHARACTERISATION PROJECT

For
African Rainbow Minerals

On behalf of
EnviroGistics

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**KHUMANI IRON ORE MINE
WASTE CHARACTERISATION PROJECT**

For

African Rainbow Minerals

on behalf of

EnviroGistics

Report Issue	Final		
Reference Number	EGS.15.008		
Title	Khumani Waste Characterisation Project – Laboratory Test Result Assessment		
	Name	Signature	Date
Author	Thabile Mgwebi		18 September 2015
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EXECUTIVE SUMMARY

Introduction and terms of reference

Future Flow GPMS cc was asked to perform waste characterisation testing for the Khumani Iron Ore Mine. The aim of the testing was to classify the material in terms of the waste classification guidelines set by the Department of Environmental Affairs (DEA) and published in the Government Gazette during August 2013. The particular guidelines that have reference include:

- R. 634 National Environmental Management: Waste Act (59/2008): Waste Classification and Management Regulations;
- R. 635 National norms and standards for the assessment of waste for landfill disposal;
- R. 636 National norms and standards for disposal of waste to landfill.

In addition to this, the waste is classified for hazardous substances according to SANS 10234.

The sample material was submitted to SGS in Johannesburg South Africa, which is a SANAS accredited laboratory, for the analyses. Tests the sample was subjected to include:

- Total concentration; and
- Leachable concentration.

Following a review of the analysis results it was decided to verify the analysis results by re-submitting two of the samples to an alternative laboratory for analysis.

Total concentration and leachable concentration test results

The obtained results were compared to the total concentration and leachable concentration threshold guidelines set out in Regulation 635. The waste classification guidelines are based on the various Total Concentration Threshold (TCT) and Leachable Concentration Threshold (LCT) values. Exceeding a certain TCT or LCT value has implications for waste management and waste facility lining requirements.

The Total Concentration Threshold (TCT) means the total concentration threshold limit of a particular element or chemical substance in a waste, expressed as mg/kg. A range of guideline values exist:

- TCT0: Where available TCT0 limits have been obtained from SA Soil Screening Values that are protective of water resources. If not available, the State of Victoria value for ill material (EPA Victoria, Classification Wastes, has been selected. If limits were not available in these references a conservative value was obtained by dividing the TCT1 value by 100.
- TCT1: Derived from the land remediation values for commercial / industrial land determined by the Department of Environmental Affairs, March 2012. If South African TCT1 limits are



unavailable, reference is made to the limits published by the Environmental Protection Agency, Australian State of Victoria.

- TCT2: These limits were derived by multiplying TCT1 by a factor of 4.

The Leachable Concentration Threshold (LCT) means the leachable concentration threshold limit for particular elements and chemical substances in a waste, expressed as mg/L. A range of guideline values exist:

- LCT0: Where possible, the lowest value of the standard for human health effects listed for drinking water in South Africa (DWAF, SANS) were used. If no standard was available in South Africa then the limits given by the WHO or other appropriate drinking water standards were used.
- LCT1: Where possible, the LCT1 values were derived from the lowest value of the standard for human health effects listed for drinking water (LCT0) in South Africa by multiplying with a Dilution Attenuation Factor (DAF) of 50 as proposed by the Australian State of Victoria, June 2009. If no standard was available in South Africa then the limits given by the WHO or other appropriate drinking water standards were used.
- LCT2: These values were derived by multiplying the LCT1 value with a factor of 2.
- LCT3: These values were derived by multiplying the LCT2 value with a factor of 4.

The factors represent a conservative assessment of the decrease in risk achieved by the increase in environmental protection provided by more comprehensive liner designs in higher classes of landfill and landfill operating requirements.

Initial round of testing

Total concentration test results

The test results for the total concentrations (TC) show that hexavalent chromium (King and Parsons waste material); manganese (Parsons waste material) and lead (King and Bruce waste material) exceed the TCT0 guidelines in some of the samples. Barium and arsenic exceed the TCT0 guidelines in all the samples. All the samples comply with the TCT1 guidelines.

It should be noted that all elements that exceed the TCT0 guideline values still comply with the TCT1 guideline values.

Leachable concentration test results

In general the elements comply with the LCT0 guidelines, except nitrate (King and Bruce waste material), barium (King, Bruce and Parsons waste material), manganese (King Paste) and zinc (King waste material).

It should be noted that all elements that exceed the LCT0 guideline values still comply with the LCT1 guideline values.



Verification round of testing

Total concentration test results

There are some discrepancies in the results from the two rounds of analysis:

- Arsenic concentrations from the verification testing are much lower than the initial round of testing, and do not exceed the TCT0 guideline value of 5.8 mg/L;
- Fluoride concentrations from the verification testing are much higher than the initial round of testing, and exceed the TCT0 guideline value of 100 mg/L;
- Cadmium concentrations from the verification testing are much higher than the initial round of testing, and exceed the TCT0 guideline value of 7.5 mg/L;
- Manganese concentrations from the verification testing are much lower than the initial round of testing, and do not exceed the TCT0 guideline value of 5.8 mg/L

The reason for these discrepancies is not known with certainty, but is most probably associated with the difference methods used by the two laboratories. Factors of variance include acids used, temperatures at which the testes were done, time to completion of tests, and other laboratory management factors.

There are a number of elements that exceed the TCT0 guideline values, including fluoride, barium, cadmium, lead.

Leachable concentration test results

- The barium concentration exceeds the LCT0 guideline value, but not in the same sample. In addition, the boron, lead and selenium concentrations also exceed the LCT0 guideline value.

Discussion of leach test analysis results

At the Bruce WRD facility the average barium concentration in leachate exceeds the LCT0 guideline values only slightly (by 0.145 mg/L), and it would be reasonable to assume that dilution with groundwater in the underlying and surrounding aquifers will reduce the leachate concentration to below that LCT0 guideline value, assuming that the barium concentration in the natural groundwater complies with the LCT0 guidelines in the first place – no information on this is available.

Facilities where additional studies have to be performed to determine whether dilution of the leachate with groundwater will yield a combined groundwater quality compliant with LCT0 are:

- King WRD;
- King Paste;
- Bruce BC11; and
- Parsons Discard.



These studies would include:

- Determining the natural groundwater quality in the area in terms of barium concentrations;
- Possibly a basic groundwater contaminant model to determine the cumulative impact of leachate from the facilities on the underlying and surrounding aquifers should the natural barium and manganese concentrations in the groundwater be below LCT0 guideline values.

Waste classification based on TC and LC test analyses

Based on the above, the material from all the different sites is classified as Type 3 Waste following the GN 635 classification system.

This classification is mostly based on the results of the total concentration testing results where there are elements that exceed the TCT0 guidelines for all the samples. As discussed in Section 3.3 the Bruce WRD facility may not be impacted when taking into consideration dilution with natural groundwater based on the leach concentration results.

Natural groundwater quality

In order to determine the natural groundwater quality in the area, the groundwater quality data was collected from seven monitoring boreholes as found in the Khumani EIA report (Ivuzi Water, Environmental and Earth Sciences Consultants, 2006).

The groundwater in the Khumani area is naturally high in nitrate with concentrations ranging between 30 mg/L and 81 mg/L in the majority of the monitoring boreholes.

The sulphate concentrations in monitoring boreholes BK12 and BK17 are measured at 300 and 279 mg/L respectively. These values exceed the LCT0 guideline value of 250 mg/L.

Manganese and zinc form part of the 4 main elements to be considered when assessing the impact of leachate from the surface facilities towards the aquifers. The measured concentrations from all the samples comply with the LCT0 guideline values. The manganese concentrations are mostly in the order of 0.001 to 0.006 mg/L with BK36 showing a concentration of 0.11 mg/L. Zinc concentrations are consistently below detection limit (<0.005 mg/L).

Natural barium concentrations in the area fall below detection limit (<0.001 mg/L) as can be seen from the 2016 sampling data. The borehole at the paste disposal area shows an elevated barium concentration which can be attributable to the nearby paste facility. The barium concentration in this borehole is measured at 0.835 mg/L, which is one order of magnitude less than the source concentration at the paste facility. This indicates the influence of dilution of the source fluids with uncontaminated natural groundwater.



Comparison of natural groundwater quality to the expected leach quality

Based on the available groundwater quality data and the leach test results little impact is expected on the groundwater quality in the underlying and surrounding aquifers, except:

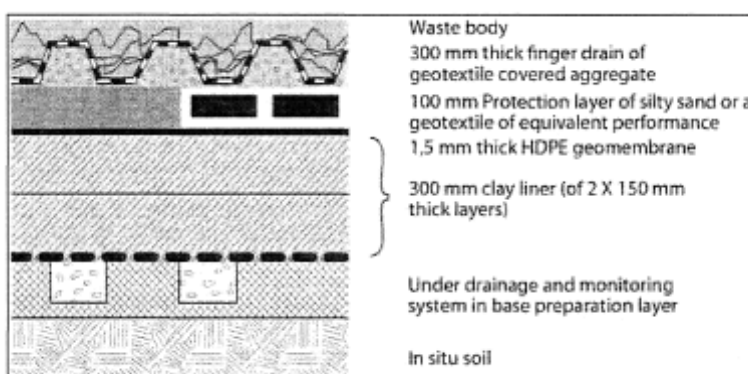
- All facilities have the potential to increase the aluminium and sodium concentrations due to seepage into the underlying aquifers. The resultant water will still comply with LCT0 guideline values;
- All facilities, except the BC11 facility, can be expected to have an impact on the barium concentrations in the groundwater. The barium concentrations are expected to increase up to 1.7 to 2.3 mg/L over time as the plumes develop and ultimately the barium concentrations will exceed the LCT0 guidelines;
- At the King WRD potassium concentrations could increase. There are no LCT0 guideline values to compare it against;
- The King Paste facility could pose some risk of increasing the manganese concentration in the underlying aquifers up to 1.7 mg/L. This value exceeds the LCT0 guideline value;
- The Bruce BC11 and King WRD facilities could cause an increase in the zinc concentrations in the underlying aquifers. At the King WRD facility the leachate could exceed the LCT0 guideline value slightly (0.085 mg/l vs 0.07 mg/L). At the Bruce BC11 facility the impact could be more prominent, with concentrations increasing to 0.175 mg/L (a factor of 2.5).

It has to be reiterated that due to a lack of information on barium concentrations in the natural groundwater the impact of one of the most prominent leach elements cannot be evaluated.

Landfill site recommendation

Following the GN 636 guideline, the material from all the facilities may only be disposed of at a Class C landfill designed in accordance with Section 1(1) and (2) of the GN 636 Norms and Standards, or, subject to Section 3(4) it may be disposed of at a landfill site designed in accordance with the requirements for a GLB+ landfill as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAf, 1998).

A class C landfill design require:





Summary of risk from leachate to the environment

Facility	Risk of leachate to environment				Leach element (% greater than LCT0)	Leach comparison to natural groundwater concentrations
	No risk	Marginal	Definite			
Bruce WRD		X		Barium (20%)	Aluminium >1000% - Still comply with LCT0 guideline Barium >1000% - Do not comply with LCT0 guideline Sodium 900% - Still comply with LCT0 guideline	
King WRD			X	Barium (250%) Zinc (21%)	Aluminium >1000% - Still comply with LCT0 guideline Barium >1000% - Do not comply with LCT0 guideline Sodium 900% - Still comply with LCT0 guideline Zinc – 21 % - Still comply with LCT0 guideline	
King Paste			X	Barium (300%) Manganese (350%)	Aluminium >1000% - Still comply with LCT0 guideline Barium >1000% - Do not comply with LCT0 guideline Sodium 900% - Still comply with LCT0 guideline Manganese >1000% - Do not comply with LCT0 guideline	
Bruce BC11			X	Zinc (250%)	Aluminium >1000% - Still comply with LCT0 guideline Sodium 900% - Still comply with LCT0 guideline Zinc 250% - Still comply with LCT0 guideline	
Parsons discard			X	Barium (250%)	Aluminium >1000% - Still comply with LCT0 guideline Barium >1000% - Do not comply with LCT0 guideline Sodium 900% - Still comply with LCT0 guideline	

No risk – Leach concentration of all elements are below LCT0 guideline values

Marginal risk – Leach concentration of individual elements exceed LCT0 guideline values by less than 25%

Definite risk – Leach concentration of individual elements exceed LCT0 guideline values by more than 25%



SANS 10234 classification

Physical hazards

- The rock material stored on site is not considered to be explosive. In addition to this, the water used in the process on site is not explosive;
- The rock material stored on site is not considered to be a flammable gas. In addition to this, the water used in the process on site is a flammable gas;
- The material stored on site is not considered to be flammable. In addition to this, the water used in the process on site is not a flammable aerosol. Therefore, the material does not have to be considered for classification as flammable aerosols;
- Neither the rock material stored on site, nor the water used in the process, is an oxidising gas;
- Neither the rock material stored on site, nor the water used in the process, is a gas under pressure;
- Neither the rock material stored on site, nor the water used in the process, is considered to be flammable liquids;
- Neither the rock material stored on site, nor the water used in the process, are flammable solids;
- Neither the rock material stored on site, nor the water used in the process, is considered to be self-reactive;
- Neither the rock material stored on site, nor the water used in the process, is considered to be pyrophoric;
- As can be deduced from the fact that the material has been stored on site for years and no spontaneous combustion has taken neither the rock material stored on site, nor the water used in the process, is considered to be prone to self-heating and spontaneous combustion;
- Neither the rock material stored on site, nor the water used in the process, is considered to be prone to emit flammable gasses on contact with water;
- Neither the rock material stored on site, nor the water used in the process, is considered to be an oxidising substance;
- Neither the rock material stored on site, nor the water used in the process, is classified as organic peroxides;
- Neither the rock material stored on site, nor the water used in the process is corrosive to metals;
- The various material stored on site do not pose physical hazards as grouped or classed in the SANS 10234 guideline. Neither the rock material, nor the water used in the wash process, poses an explosive, oxidising, flammable or other risk. Therefore, the material is **classified as non-hazardous** in terms of physical hazards.

Health hazards

- The acute toxicity estimate according to the oral route can be calculated for the waste rock and the slimes (paste) material:



- Waste rock: 0.062; and
- Slimes: 0.092
- From the above both mixtures are classified as Category 1 (the highest toxicity category) for acute health effects;
- In order to determine the skin corrosion and irritant hazard the 1 % concentration rule is applied, from this aluminium, iron, and potassium have to be include in the assessment. In addition, other chemicals re considered to be an irritant based on literature publications. These include sulphate, nitrate, cyanide, hexavalent chromium, arsenic, bismuth, calcium, cobalt, magnesium, sodium, nickel, selenium, uranium, zinc, and chloride. The calculated sum of concentrations of the elements listed above are summarised below for each of the mixtures:
 - Waste rock: 20.8 %; and
 - Paste (Slimes): 19.8 %.
- From the above results both mixtures are classified as hazardous in terms of skin corrosion or irritation;
- To determine the risk for eye damage and irritation the 1 % concentration rule is again applied. In addition, reference is made to elements that have been identified as a risk based on research. The elements to be included in the assessment are aluminium, iron, potassium, sulphate, nitrate, cyanide, hexavalent chromium, silver, arsenic, bismuth, calcium, cobalt, lithium, magnesium, sodium, nickel, antimony, selenium, vanadium, and chloride. The calculated sum of concentrations of the elements listed above are summarised below for each of the “mixtures”:
 - Waste rock: 4.8 %; and
 - Slimes (paste): 20.2 %.
- From the above results both mixtures are classified as Category 1 hazardous to the eye.
- For each mixture there are individual substances (elements) that are classified as a skin or a respiratory sensitizer and are present at, or above, the concentration limits shown in Table 5.7. These elements can be summarised:
 - Skin & respiratory sensitizers ≥ 0.1 and < 1.0 %:
 - Waste rock: none;
 - Slimes: potassium;
 - Skin & respiratory sensitizers ≥ 1.0 %:
 - Waste rock: iron, potassium; and
 - Slimes: iron.
- From the above both the waste rock and slimes or paste material “mixtures” can be classified as hazardous in terms of respiratory and skin sensitization hazards.
- The following mutagens are identified:
 - Category 1 mutagen (ingredient concentration ≥ 0.1):
 - Waste rock: aluminium, iron, potassium;
 - Slimes: aluminium, iron, potassium;
 - Category 2 mutagen (ingredient concentration ≥ 1.0):
 - Waste rock: None; and
 - Slimes: None.



- Although Category 1 carcinogens are present, none of the mixtures contain known carcinogens at concentrations ranging from 0.1 % and above. Therefore, none of the mixtures are classified as being carcinogenic;
- Both mixtures show the presence of Category 1 reproductive toxicants:
 - Category 1 reproductive toxicants ≥ 0.1 % and < 0.3 %:
 - Waste rock: none;
 - Slimes (paste): none.
 - Category 1 reproductive toxicants ≥ 0.3 %:
 - Waste rock: aluminium; and
 - Slimes (paste): aluminium.
- Both mixtures contain specific target organ – single exposure toxicants:
 - Category 1 (≥ 1.0 % and < 10 %):
 - Waste rock: None;
 - Slimes (paste) material: None
 - Category 1 (≥ 10 %):
 - Waste rock: None;
 - Slimes (paste) material: None.
 - Category 2 (≥ 1.0 % and < 10 %):
 - Waste rock: aluminium (4.8 %), potassium (1.1 %);
 - Slimes (paste) material: aluminium (1.8 %);
 - Category 2 (≥ 10 %):
 - Waste rock: iron (15 %); and
 - Slimes (paste) material: iron (15 %);
- Both mixtures contain specific target organ – repeated exposure toxicants:
 - Category 1 (≥ 1.0 % and < 10 %):
 - Waste rock: None;
 - Slimes material: None
 - Category 1 (≥ 10 %):
 - Waste rock: None;
 - Slimes material: None.
 - Category 2 (≥ 1.0 % and < 10 %):
 - Waste rock: aluminium (4.8 %);
 - Slimes material: aluminium (1.8%);
 - Category 2 (≥ 10 %):
 - Waste rock: iron (15 %); and
 - Slimes material: iron (15 %).

Aquatic toxicity

Laboratory testing shows that the material is non-hazardous to the aquatic environment from both an acute and a chronic toxicity point of view.



Validity of classification

It should be noted that the hazard classification is influenced by the locality where the material is stored or used. The classification is applicable to the conditions are Black Rock as they are now.

Should the material be used off site, the material be used for some other purpose, or moved to within close range of surface water bodies (for example the calcrete may be sold off-site for use somewhere else in construction where it could be located close to, or within a surface stream) the classification will have to be revisited to ensure it is still applicable.



TABLE OF CONTENTS

1. Introduction and terms of reference	1
2. Methodology	1
2.1. Scope of work	1
2.2. Sample description	2
3. Test results	2
3.1. Initial round of testing	3
3.1.1. Total concentration test results	3
3.1.2. Leachable concentration test results	4
3.2. Verification round of testing	8
3.2.1. Total concentration test results	8
3.2.2. Leachable concentration test results	8
3.3. Discussion of leach test analysis results	12
3.4. Waste classification based on TC and LC test analyses	14
3.5. Natural groundwater quality	15
3.6. Comparison of natural groundwater quality to the expected leach quality	16
3.7. Summary of risk from leachate to the environment	19
4. Landfill site recommendation	21
5. SANS 10234 classification	22
5.1. Physical hazard	23
5.1.1. Explosives	23
5.1.2. Flammable gasses	23
5.1.3. Flammable aerosols	23
5.1.4. Oxidising gasses	24
5.1.5. Gasses under pressure	24
5.1.6. Flammable liquids	24
5.1.7. Flammable solids	25
5.1.8. Self-reactive substances and mixtures	25
5.1.9. Pyrophoric substances	25
5.1.10. Self-heating substances and mixtures	26
5.1.11. Substances and mixtures that, on contact with water, emit flammable gasses	26
5.1.12. Oxidising substances and mixtures	26
5.1.13. Organic peroxides	27
5.1.14. Corrosive to metals	27
5.1.15. Summary of physical hazards	27
5.2. Health hazard	28
5.2.1. Acute toxicity	28
5.2.2. Skin corrosion and skin irritation	30
5.2.3. Serious eye damage and eye irritation	32
5.2.4. Respiratory sensitisation and skin sensitisation	34
5.2.5. Germ cell mutagenicity	35
5.2.6. Carcinogenicity	36
5.2.7. Reproductive toxicity	36



5.2.8.	Specific target organ toxicity – single exposure	39
5.2.9.	Specific target organ toxicity – repeated exposure.....	40
5.2.10.	Health hazard classification summary	42
5.3.	Hazards to the aquatic environment.....	44
5.4.	Material safety data sheet.....	48
5.4.1.	Total concentrations	48
5.4.2.	Leachable concentrations	49
5.4.3.	Material safety data sheet (MSDS)	50
6.	Conclusions	51
6.1.	Initial round of testing.....	51
6.1.1.	Total concentration test results	51
6.1.2.	Leachable concentration test results.....	51
6.2.	Verification round of testing.....	51
6.2.1.	Total concentration test results	51
6.2.2.	Leachable concentration test results.....	52
6.3.	Discussion of leach test analysis results	52
6.4.	Waste classification based on TC and LC test analyses	52
6.5.	Natural groundwater quality	53
6.6.	Comparison of natural groundwater quality to the expected leach quality	53
6.7.	Landfill site recommendation	54
6.8.	SANS 10234 classification.....	54
6.8.1.	Physical hazards.....	54
6.8.2.	Health hazards	55
6.8.3.	Hazards to the aquatic environment.....	57
6.8.4.	General comment	57



LIST OF TABLES

Table 2.1: Sample description.....	2
Table 3.1: Total concentration test results.....	5
Table 3.2: Leachable concentration test results	7
Table 3.3: Total concentration test results – Verification round of testing	10
Table 3.4: Leachable concentration test results – Verification round of testing.....	11
Table 3.5: Waste stream classification	15
Table 3.6: Natural groundwater quality compared to LCT guideline values	20
Table 5.1: Categories and classification criteria for flammable gasses.....	23
Table 5.2: Categories and classification criteria for flammable liquids.....	24
Table 5.3: Categories and classification criteria for flammable solids.....	25
Table 5.4: Cut-off values / concentration limits of the ingredients of a mixture classified as skin Category 1, 2, or 3 that classify classification of the mixture as hazardous to the skin	31
Table 5.5: Cut-off values / concentration limits of the ingredients of a mixture classified for which the additivity approach does not apply, that trigger classification of the mixture as hazardous to skin	31
Table 5.6: Cut-off values / concentration limits of the ingredients of a mixture classified as Category 1 for skin effects and/or Category 1 or 2 for eye effects that trigger classification of the mixture as hazardous to the eye	33
Table 5.7: Cut-off values / concentration limits of the ingredients of a mixture classified as skin sensitizers or respiratory sensitizers that trigger classification of a mixture	34
Table 5.8: Cut-off values / concentration limits of ingredients of a mixture classified as germ cell mutagens that trigger classification of the mixture.....	35
Table 5.9: Cut-off values / concentration limits of ingredients classified as carcinogens that trigger classification of the mixture	36
Table 5.10: Cut-off values / concentration limits of ingredients of a mixture classified as reproductive toxicants or for effects on, or via, lactation that trigger classification of the mixture...	38
Table 5.11: Concentration limits / cut-off values of ingredients of a mixture classified as a specific target organ toxicant that trigger classification of the mixture	39
Table 5.12: Cut-off values / concentration limits of the ingredients of a mixture classified as a specific target organ toxicant – repeated exposure that trigger classification of the mixture	41
Table 5.13: Health hazard criteria and categories for individual substances.....	43
Table 5.14: Toxicity Units (after Tonkes and Baltus, 1997)	45
Table 5.15: Hazard categories of acute toxicity for substances hazardous to the aquatic environment.....	46
Table 5.16: Hazard categories of chronic toxicity for substances hazardous to the aquatic environment.....	46
Table 5.17: Screening acute toxicity test results	47
Table 5.18: Cut-off values / concentration limits for hazard classes	48
Table 5.19: Summary of total concentrations compared to SANS 10234 generic guidelines.....	49



APPENDICES

Appendix A: Laboratory analysis certificates – Initial Round of testing

Appendix B: Laboratory analysis certificates – Verification Round of testing

Appendix C: Laboratory analysis certificates – Aquatic toxicity testing

Appendix D: Material safety data sheet



1. Introduction and terms of reference

Future Flow GPMS cc was asked to perform waste characterisation testing for the Khumani Iron Ore Mine. The aim of the testing was to classify the material in terms of the waste classification guidelines set by the Department of Environmental Affairs (DEA) and published in the Government Gazette during August 2013. The particular guidelines that have reference include:

- R. 634 National Environmental Management: Waste Act (59/2008): Waste Classification and Management Regulations;
- R. 635 National norms and standards for the assessment of waste for landfill disposal;
- R. 636 National norms and standards for disposal of waste to landfill.

In addition to this, the waste is classified for hazardous substances according to SANS 10234.

The sample material was submitted to SGS in Johannesburg South Africa, which is a SANAS accredited laboratory, for the analyses. Tests the sample was subjected to include:

- Total concentration; and
- Leachable concentration.

Following a review of the analysis results it was decided to verify the analysis results by re-submitting two of the samples to an alternative laboratory for analysis.

2. Methodology

2.1. Scope of work

As part of the methodology the guidelines as set out in GN R 635 were followed. This included:

- Sampling of the waste rock material (sampled by representatives of Khumani);
- Analysis of the material to determine the total concentrations (TC) and leachable concentrations (LC) of the elements and chemical substances in the waste;
- The TC and LC limits of the chemical substances in the sampled material is compared to the threshold limits for total concentrations (TCT limits) and leachable concentrations (LCT limits) of specific elements and chemical substances specified in the R635 guideline documentation;
- Based on the TC and LC limits of the elements and chemical substances in the material exceeding the corresponding TCT and LCT limits respectively, the specific type of waste for disposal to landfill are determined in terms of Section 7 of the R 635 norms and standards;
- From the above classification the lining requirements for each facility is determined using R636; and
- Classification of the material according to SANS 10234.



The total concentration and leach tests that were done followed the GN 635 guideline and included metal ions, inorganic anions, and organics. From the list of organic elements a selection was made to include petroleum hydrocarbons as this could be introduced during the transport of the material. Other organics such as benzene and associated derivatives, phenols and xylenes are not included as it is considered that there are no processes on site that can introduce these chemical substances. Note that the material stored on the waste rock dumps undergo no processing, and the material stored within the King Paste facility is crushed and washed using clean water during the process, therefore no chemical substances are introduced into the system during the processing. Similarly, there are no processes that can introduce pesticides, and therefore pesticides were excluded from the analyses.

In addition to the above tests the natural groundwater quality in monitoring boreholes were compared to the expected quality of the seepage emanating from the storage facilities to determine whether there will be a negative impact on the groundwater qualities.

2.2. Sample description

The samples were collected in a manner to ensure representative sampling from the waste rock material. This represents the typical material that will be deposited. A summary description of the material collected as part of each sample is included in Table 2.1 below.

Table 2.1: Sample description

Sample ID	Waste Stream	Material	Comment
King WRD A	King Waste Rock Dump KM01	Waste Rock	Geology not same as Bruce, therefore tested separately
King WRD B			
Bruce WRD A	Bruce Waste Rock Dump	Waste Rock	Geology not same as King, therefore tested separately
Bruce WRD B			
King Paste	King Paste Disposal Facility	Paste	Tailings from Parsons plant
Bruce BC11A	Bruce BC11	Low grade, normal waste rock	Old waste rock dump, mined by Kumba
Bruce BC11B			
Parsons Discard A	Parson Discard Dump (aka Low Grade RoM Stockpile)	Low grade, normal waste rock	Combination of Bruce and King
Parsons Discard B			

3. Test results

The samples were submitted for analysis and the obtained results were compared to the total concentration and leachable concentration threshold guidelines set out in Regulation 635. The waste classification guidelines are based on the various Total Concentration Threshold (TCT) and Leachable Concentration Threshold (LCT) values. Exceeding a certain TCT or LCT value has implications for waste management and waste facility lining requirements.

The Total Concentration Threshold (TCT) means the total concentration threshold limit of a particular element or chemical substance in a waste, expressed as mg/kg. A range of guideline values exist:



- TCT0: Where available TCT0 limits have been obtained from SA Soil Screening Values that are protective of water resources. If not available, the State of Victoria value for ill material (EPA Victoria, Classification Wastes, has been selected. If limits were not available in these references a conservative value was obtained by dividing the TCT1 value by 100.
- TCT1: Derived from the land remediation values for commercial / industrial land determined by the Department of Environmental Affairs, March 2012. If South African TCT1 limits are unavailable, reference is made to the limits published by the Environmental Protection Agency, Australian State of Victoria.
- TCT2: These limits were derived by multiplying TCT1 by a factor of 4.

The Leachable Concentration Threshold (LCT) means the leachable concentration threshold limit for particular elements and chemical substances in a waste, expressed as mg/L. A range of guideline values exist:

- LCT0: Where possible, the lowest value of the standard for human health effects listed for drinking water in South Africa (DWA, SANS) were used. If no standard was available in South Africa then the limits given by the WHO or other appropriate drinking water standards were used.
- LCT1: Where possible, the LCT1 values were derived from the lowest value of the standard for human health effects listed for drinking water (LCT0) in South Africa by multiplying with a Dilution Attenuation Factor (DAF) of 50 as proposed by the Australian State of Victoria, June 2009. If no standard was available in South Africa then the limits given by the WHO or other appropriate drinking water standards were used.
- LCT2: These values were derived by multiplying the LCT1 value with a factor of 2.
- LCT3: These values were derived by multiplying the LCT2 value with a factor of 4.

The factors represent a conservative assessment of the decrease in risk achieved by the increase in environmental protection provided by more comprehensive liner designs in higher classes of landfill and landfill operating requirements.

3.1. Initial round of testing

3.1.1. Total concentration test results

The test results for the total concentrations (TC) are summarised in Table 3.1. From the table it can be seen that hexavalent chromium (King and Parsons waste material), manganese (Parsons waste material) and lead (King and Bruce waste material) exceed the TCT0 guidelines in some of the samples. Barium and arsenic exceed the TCT0 guidelines in all the samples. All the samples comply with the TCT1 guidelines.

It should be noted that all elements that exceed the TCT0 guideline values still comply with the TCT1 guideline values.



3.1.2. Leachable concentration test results

The leachable concentration test results are summarised in Table 3.2. From the table it can be seen that in general the elements comply with the LCT0 guidelines, except nitrate (King and Bruce waste material), barium (King, Bruce and Parsons waste material), manganese (King Paste) and zinc (King waste material).

It should be noted that all elements that exceed the TCT0 guideline values still comply with the TCT1 guideline values.



Table 3.1: Total concentration test results

Constituent	Units	TCT Guidelines Values			King WRD A	King WRD B	Bruce WRD A	Bruce WRD B	King Paste	Bruce BC11A	Bruce BC11B	Parsons Discard A	Parsons Discard B
		TCT0	TCT1	TCT2									
Nitrate	mg/kg	N/L	N/L	N/L	171	222	164	220	29	<5	<5	21	21
Sulphate	mg/kg	N/L	N/L	N/L	74	84	25	32	56	<5	<5	82	66
Fluoride	mg/L	100	10 000	40 000	0.68	0.52	0.43	0.37	0.26	0.26	0.27	0.21	<0.2
Hexavalent Chromium	mg/kg	6.5	500	2 000	12	<0.4	<0.4	<0.4	<0.4	2.1	<0.4	2.6	8.7
TPH Banded C10-C28 Total	mg/kg	N/L	N/L	N/L	<142	NA	<142	NA	NA	NA	NA	NA	NA
TPH Banded C10-C40 Total	mg/kg	N/L	N/L	N/L	<182	NA	<182	NA	NA	NA	NA	NA	NA
TPH Banded C28-40	mg/kg	N/L	N/L	N/L	<40	NA	<40	NA	NA	NA	NA	NA	NA
Aluminium	ppm	N/L	N/L	N/L	56 000	55 000	71 000	68 000	18 000	39 000	39 000	38 000	16 000
Barium	ppm	62.5	6 250	25 000	1 586	2 013	425	461	693	248	223	218	453
Calcium	ppm	N/L	N/L	N/L	1 000	1 000	800	700	400	400	300	300	300
Chromium	ppm	46 000	800 000	N/A	121	78	157	150	81	135	107	105	34
Copper	ppm	16	19 500	78 000	<0.5	<0.5	6.9	6.3	<0.5	0.6	<0.5	<0.5	<0.5
Iron	ppm	N/L	N/L	N/L	>150 000	>150 000	>150 000	>150 000	>150 000	>150 000	>150 000	>150 000	>150 000
Potassium	ppm	N/L	N/L	N/L	17 000	16 000	21 000	19 000	4 000	3 200	3 400	3 300	4 600
Lithium	ppm	N/L	N/L	N/L	258	223	39	41	27	12	13	13	22
Magnesium	ppm	N/L	N/L	N/L	1 200	1 300	1 400	1 200	300	500	400	400	200
Manganese	ppm	1 000	25 000	100 000	484	547	459	500	709	220	187	180	1 645
Sodium	ppm	N/L	N/L	N/L	500	400	400	400	200	200	200	200	300
Phosphorus	ppm	N/L	N/L	N/L	465	539	568	618	372	455	446	375	311
Sulphur	ppm	N/L	N/L	N/L	500	600	300	300	300	200	200	200	200
Strontium	ppm	N/L	N/L	N/L	232	280	410	473	296	292	294	292	143
Titanium	ppm	N/L	N/L	N/L	2 100	2 100	3 500	3 900	700	1 400	1 300	1 300	500
Vanadium	ppm	150	2 680	10 720	98	96	142	129	82	89	87	85	59
Zinc	ppm	240	160 000	640 000	46	39	28	23	20	17	17	16	14
Zirconium	ppm	N/L	N/L	N/L	136	147	164	159	30	59	58	58	39
Silver	ppm	N/L	N/L	N/L	1.3	0.4	0.6	0.5	<0.3	0.3	0.8	0.4	<0.3
Arsenic	ppm	5.8	500	2 000	101	120	50	45	39	24	23	26	23
Beryllium	ppm	N/L	N/L	N/L	1.1	1.3	1.3	1.4	0.4	0.7	1.2	0.5	0.5
Bismuth	ppm	N/L	N/L	N/L	0.86	0.74	6.4	1.5	0.49	0.76	0.81	0.29	0.26
Cadmium	ppm	7.5	260	1 040	0.08	0.04	0.05	0.04	0.04	0.04	0.05	0.02	0.05
Cerium	ppb	N/L	N/L	N/L	82	103	122	122	43	62	59	41	30
Cobalt	ppm	50	5 000	20 000	6.2	7.3	11	11	4.4	3.4	3.1	5.1	4.6
Caesium	ppm	N/L	N/L	N/L	1.7	1.8	2.3	2.2	0.51	0.48	0.47	0.43	0.34
Dysprosium	ppm	N/L	N/L	N/L	7.1	8	5.6	6.1	1.6	4	3.7	1.5	1.5
Erbium	ppm	N/L	N/L	N/L	3.6	4.4	3.2	3.3	0.91	2.3	2.2	0.94	0.92
Europium	ppm	N/L	N/L	N/L	2.2	2.5	2.1	2.3	0.65	1.3	1.2	0.61	0.44
Gallium	ppm	N/L	N/L	N/L	13	13	18	17	4.5	8.7	8.5	4.2	3.3
Gadolinium	ppm	N/L	N/L	N/L	8	9.3	7.7	8.1	2.1	5	4.7	2.2	1.6
Germanium	ppm	N/L	N/L	N/L	2.5	2.7	1.1	0.6	0.2	0.8	2.2	0.3	0.4
Hafnium	ppm	N/L	N/L	N/L	3.8	4.9	4.5	4.2	0.82	1.8	1.7	0.95	0.98
Holmium	ppm	N/L	N/L	N/L	1.2	1.4	0.97	0.92	0.15	0.63	0.59	0.15	0.14
Indium	ppm	N/L	N/L	N/L	0.06	0.06	0.07	0.06	0.02	0.04	0.04	0.02	<0.02
Lanthanum	ppb	N/L	N/L	N/L	44	55	65	65	20	32	31	21	16
Lutetium	ppm	N/L	N/L	N/L	0.5	0.62	0.42	0.43	0.15	0.34	0.33	0.15	0.15



Constituent	Units	TCT Guidelines Values			King WRD A	King WRD B	Bruce WRD A	Bruce WRD B	King Paste	Bruce BC11A	Bruce BC11B	Parsons Discard A	Parsons Discard B
		TCT0	TCT1	TCT2									
Molybdenum	ppm	40	1 000	4 000	1.7	1.9	1.8	1.8	2	1	1.6	1.3	1.2
Niobium	ppm	N/L	N/L	N/L	14	16	17	19	1.8	4.1	4	2	2.7
Neodymium	ppm	N/L	N/L	N/L	39	49	51	55	14	28	27	15	11
Nickel	ppm	91	10 600	42 400	28	26	47	45	35	24	23	14	12
Lead	ppm	20	1 900	7 600	33	35	38	37	14	20	20	16	13
Praseodymium	ppm	N/L	N/L	N/L	10	13	14	15	3.9	7.4	7	4.3	3
Rubidium	ppm	N/L	N/L	N/L	63	61	67	63	13	11	12	20	13
Antimony	ppm	10	75	300	7.5	8.9	3.6	2.9	2.4	2.5	2.3	2.2	2
Scandium	ppm	N/L	N/L	N/L	9.4	11	14	13	5.1	10	9.7	4.3	3.5
Selenium	ppm	10	50	200	<2	<2	<2	<2	<2	<2	<2	<2	<2
Samarium	ppm	N/L	N/L	N/L	7.6	8.9	9.1	9.4	2.4	5.6	5.2	2.6	1.8
Tin	ppm	N/L	N/L	N/L	3.4	3.7	5.2	4.7	0.7	2.1	2	0.8	0.5
Tantalum	ppb	N/L	N/L	N/L	1.9	1.7	2.2	1.8	0.2	0.52	0.52	0.23	0.32
Terbium	ppm	N/L	N/L	N/L	1.2	1.4	1	1.1	0.19	0.65	0.59	0.2	0.13
Tellurium	ppm	N/L	N/L	N/L	1.2	1.5	0.47	0.38	0.17	0.19	0.12	0.23	0.11
Thorium	ppm	N/L	N/L	N/L	10	10	13	13	3.1	7.7	7.4	3.3	2.6
Thallium	ppm	N/L	N/L	N/L	0.4	0.4	0.3	0.3	<0.02	<0.02	<0.02	<0.02	<0.02
Thulium	ppm	N/L	N/L	N/L	0.42	0.55	0.34	0.31	<0.05	0.21	0.17	<0.05	<0.05
Uranium	ppm	N/L	N/L	N/L	1.5	1.5	1.7	1.6	0.65	1.1	1.1	0.3	0.27
Tungsten	ppm	N/L	N/L	N/L	2.8	2.1	13	2.9	0.2	0.5	0.3	<0.1	<0.1
Yttrium	ppm	N/L	N/L	N/L	33	41	27	27	8.6	21	20	9.1	9
Ytterbium	ppm	N/L	N/L	N/L	2.5	3.1	2.1	2.2	0.7	1.8	1.6	0.7	0.7
Mercury	ppm	0.93	160	640	0.31	0.13	0.12	0.13	0.09	0.17	0.18	0.07	0.08
Boron	ppm	150	15 000	60 000	18	20	22	25	27	18	29	21	23
Chloride	ppm	N/L	N/L	N/L	<500	<500	<500	<500	<500	<500	<500	<500	<500
Total Cyanide	mg/kg	14	10 500	42 000	<0.01	0.05	0.04	0.05	<0.01	0.025	<0.01	0.06	<0.01

 Exceed TCT0 guideline value



Table 3.2: Leachable concentration test results

Constituent	Units	LCT Guidelines Values				King WRD A	King WRD B	Bruce WRD A	Bruce WRD B	King Paste	Bruce BC11A	Bruce BC11B	Parsons Discard A	Parsons Discard B
		LCT0	LCT1	LCT2	LCT3									
Final pH	-	N/L	N/L	N/L	N/L	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
Sulphate	mg/L	250	12 500	25 000	100 000	3.9	3.2	0.99	1.1	2.1	0.13	0.28	1.2	1.8
Nitrate	mg/L	11	550	1 100	4 400	11	7.9	4.	17	1.6	<0.1	<0.1	1.2	0.4
Total Cyanide	mg/L	0.07	3.5	7	28	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Hexavalent Chromium	mg/L	0.05	2.5	5	20	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Fluoride by ISE	mg/L	1.5	75	150	600	0.1	0.08	0.05	0.05	0.08	0.06	0.07	<0.05	<0.05
Silver	mg/L	N/L	N/L	N/L	N/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Aluminium	mg/L	N/L	N/L	N/L	N/L	0.21	0.28	0.31	0.19	0.26	0.32	0.39	0.35	0.29
Arsenic	mg/L	0.01	0.5	1	4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	mg/L	0.5	25	50	200	0.04	0.05	0.03	0.03	0.03	0.02	0.02	0.02	0.02
Barium	mg/L	0.7	35	70	280	1.8	1.7	0.77	0.92	2.2	0.48	0.44	1.2	2.3
Beryllium	mg/L	N/L	N/L	N/L	N/L	0.0022	0.0023	0.001	0.0006	0.001	0.001	0.0012	0.0008	0.0009
Bismuth	mg/L	N/L	N/L	N/L	N/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Calcium	mg/L	N/L	N/L	N/L	N/L	24.	19.	11.	21.	8.8	5.2	7.5	2.1	2.
Cadmium	mg/L	0.003	0.15	0.3	1.2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/L	0.5	25	50	200	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	mg/L	0.1	5	10	40	<0.002	<0.002	<0.002	<0.002	0.02	<0.002	<0.002	<0.002	0.002
Copper	mg/L	0.2	100	200	800	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Iron	mg/L	N/L	N/L	N/L	N/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lanthanum	mg/L	N/L	N/L	N/L	N/L	NA	NA	NA	NA	NA	NA	NA	NA	NA
Potassium	mg/L	N/L	N/L	N/L	N/L	11.	13.	7.3	8.3	4.7	3.9	4.2	5.8	4.8
Lithium	mg/L	N/L	N/L	N/L	N/L	0.015	0.038	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Magnesium	mg/L	N/L	N/L	N/L	N/L	11.	7.8	4.1	7.8	2.7	1.9	2.5	0.97	0.68
Manganese	mg/L	0.5	25	50	200	0.1	0.19	0.16	0.18	1.7	0.08	0.09	0.27	0.39
Molybdenum	mg/L	0.07	3.5	7	28	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sodium	mg/L	N/L	N/L	N/L	N/L	224	204	204	164	164	184	154.	144	144
Nickel	mg/L	0.07	3.5	7	28	0.005	<0.005	0.006	<0.005	0.007	0.005	0.006	<0.005	<0.005
Phosphorus	mg/L	N/L	N/L	N/L	N/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Lead	mg/L	0.01	0.5	1	4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
Sulphur	mg/L	N/L	N/L	N/L	N/L	1.3	1.3	0.42	0.54	0.93	0.17	0.18	0.52	0.84
Antimony	mg/L	0.02	1.0	2	8	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Selenium	mg/L	0.01	0.5	1	4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon	mg/L	N/L	N/L	N/L	N/L	3	3	3	3	2	2	2	<1	<1
Tin	mg/L	N/L	N/L	N/L	N/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/L	N/L	N/L	N/L	N/L	0.19	0.16	0.096	0.1	0.11	0.06	0.059	0.048	0.042
Tellurium	mg/L	N/L	N/L	N/L	N/L	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Thorium	mg/L	N/L	N/L	N/L	N/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Titanium	mg/L	N/L	N/L	N/L	N/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Thallium	mg/L	N/L	N/L	N/L	N/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	mg/L	N/L	N/L	N/L	N/L	0.02	0.02	0.01	0.03	0.02	0.03	<0.01	<0.01	<0.01
Vanadium	mg/L	0.2	10	20	80	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tungsten	mg/L	N/L	N/L	N/L	N/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Yttrium	ppb	N/L	N/L	N/L	N/L	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zinc	ppm	0.07	3.5	7	28	0.13	0.04	0.03	0.03	0.04	0.04	0.31	0.02	0.03
Zirconium	ppm	N/L	N/L	N/L	N/L	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18
Mercury	ppm	0.006	0.3	0.6	2.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chloride	ppm	300	15 000	30 000	120 000	<5	<5	<5	<5	<5	<5	<5	<5	6
Evaluation pH	ppm	N/L	N/L	N/L	N/L	6.6	6.4	7	7.2	6.6	7.1	6.6	6.2	5.9

Exceed LCT0 guideline value



3.2. Verification round of testing

During this verification round of testing two samples were selected for testing at another laboratory. The samples were:

- Bruce Waste Dump 1; and
- Bruce BC11

The samples were selected based on:

- Results from initial round of testing;
- Availability of crushed, but un-analysed, sample from the initial laboratory.

3.2.1. Total concentration test results

The results from the total concentration tests are summarised in Table 3.3. Also included in the table are the results from the initial round of testing for the respective elements. From the table it can be seen that there are some discrepancies in the results from the two rounds of analysis:

- Arsenic concentrations from the verification testing are much lower than the initial round of testing, and do not exceed the TCT0 guideline value of 5.8 mg/L;
- Fluoride concentrations from the verification testing are much higher than the initial round of testing, and exceed the TCT0 guideline value of 100 mg/L;
- Cadmium concentrations from the verification testing are much higher than the initial round of testing, and exceed the TCT0 guideline value of 7.5 mg/L;
- Manganese concentrations from the verification testing are much lower than the initial round of testing, and do not exceed the TCT0 guideline value of 5.8 mg/L

The reason for the discrepancies in results between the two laboratories is not known with certainty, but is most probably associated with the difference methods used by the two laboratories. Factors of variance include acids used, temperatures at which the testes were done, time to completion of tests, and other laboratory management factors.

There are a number of elements that exceed the TCT0 guideline values, including fluoride, barium, cadmium, lead.

3.2.2. Leachable concentration test results

The results from the verification round of testing are summarised in Table 3.4. Also included in the table are the results from the original round of testing for the specific elements for comparative purposes.



From Table 3.4 it can be seen that the similar to the original round of testing the barium concentration exceeds the LCT0 guideline value, but not in the same sample. In addition, the boron, lead and selenium concentrations also exceed the LCT0 guideline value.

The results from the leachable concentration tests between the two laboratories (initial and verification rounds of testing) are relatively similar, except for the pH which is a function of the test done as per Regulation 635 where a spot test is done to determine the approximate pH, and then the test is regulated near 9.2 or 5.0. The initial test laboratory performed the test near a pH of 7.0, and the verification laboratory near 9.2.



Table 3.3: Total concentration test results – Verification round of testing

Constituent	Units	TCT Guidelines Values			Verification round of testing		Initial round of testing	
		TCT0	TCT1	TCT2	Bruce WRD A	Bruce BC11A	Bruce WRD A	Bruce BC11A
Arsenic	mg/kg	5.8	500	2 000	4.80	<4	50	24
Boron	mg/kg	150	15 000	60 000	70	17	22	18
Barium	mg/kg	62.5	6 250	25 000	398	226	425	248
Cadmium	mg/kg	7.5	260	1 040	21	28	0.05	0.04
Cobalt	mg/kg	50	5 000	20 000	<10	<10	11	3.4
Chromium	mg/kg	46 000	800 000	N/A	135	102	157	135
Copper	mg/kg	16	19 500	78 000	<10	<10	6.9	0.6
Mercury	mg/kg	0.93	160	640	<0.4	<0.4	0.12	0.17
Manganese	mg/kg	1 000	25 000	100 000	36	84	459	220
Molybdenum	mg/kg	40	1 000	4 000	<10	<10	1.8	1
Nickel	mg/kg	91	10 600	42 400	47	17	47	24
Lead	mg/kg	20	1 900	7 600	29	<4	38	20
Antimony	mg/kg	10	75	300	<4	<4	3.6	2.5
Selenium	mg/kg	10	50	200	<4	<4	<2	<2
Vanadium	mg/kg	150	2 680	10 720	90	47	142	89
Zinc	mg/kg	240	160 000	640 000	20	23	28	17
Hexavalent Chromium	mg/kg	6.5	500	2 000	<5	<5	<0.4	2.1
Fluoride	mg/kg	100	10 000	40 000	274	178	0.43	0.26
Total Cyanide	mg/kg	14	10 500	42 000	<0.01	<0.01	0.04	0.025

 Exceed TCT0 guideline value



Table 3.4: Leachable concentration test results – Verification round of testing

Constituent	Units	LCT Guidelines Values				Verification round of testing		Original round of testing	
		LCT0	LCT1	LCT2	LCT3	Bruce WRD A	Bruce BC11A	Bruce WRD A	Bruce BC11A
Arsenic	mg/L	0.01	0.5	1	4	<0.01	<0.01	<0.01	<0.01
Boron	mg/L	0.5	25	50	200	7	<0.025	0.03	0.02
Barium	mg/L	0.7	35	70	280	<0.025	1	0.77	0.48
Cadmium	mg/L	0.003	0.15	0.3	1.2	<0.003	<0.003	<0.001	<0.001
Cobalt	mg/L	0.5	25	50	200	<0.025	<0.025	<0.005	<0.005
Chromium	mg/L	0.1	5	10	40	<0.025	<0.025	<0.002	<0.002
Hexavalent Chromium	mg/L	0.05	2.5	5	20	<0.01	<0.01	<0.02	<0.02
Copper	mg/L	0.2	100	200	800	0.11	0.071	<0.02	<0.02
Mercury	mg/L	0.006	0.3	0.6	2.4	<0.001	<0.001	<0.1	<0.1
Manganese	mg/L	0.5	25	50	200	<0.025	<0.025	0.16	0.08
Molybdenum	mg/L	0.07	3.5	7	28	<0.025	<0.025	<0.005	<0.005
Nickel	mg/L	0.07	3.5	7	28	<0.025	<0.025	0.006	0.005
Lead	mg/L	0.01	0.5	1	4	<0.01	0.025	<0.01	<0.01
Antimony	mg/L	0.02	1.0	2	8	<0.02	<0.02	<0.02	<0.02
Selenium	mg/L	0.01	0.5	1	4	<0.01	0.017	<0.01	<0.01
Vanadium	mg/L	0.2	10	20	80	<0.025	0.076	<0.001	<0.001
Zinc	mg/L	0.07	3.5	7	28	0.038	<0.025	0.03	0.04
Chloride	ppm	300	15 000	30 000	120 000	<2	<2	<5	<5
Sulphate	mg/L	250	12 500	25 000	100 000	<2	<2	0.99	0.13
Nitrate	mg/L	11	550	1 100	4 400	1.3	<0.1	4.	<0.1
Fluoride by ISE	mg/L	1.5	75	150	600	0.3	0.2	0.05	0.06
Total Cyanide	mg/L	0.07	3.5	7	28	<0.01	<0.01	<0.005	<0.005
Evaluation pH	mg/L	N/L	N/L	N/L	N/L	9.4	9.4	7	7.1

 Exceed LCT0 guideline value



3.3. Discussion of leach test analysis results

The leach test results are summarised in Table 3.2 and Table 3.4, and discussed in Sections 3.1.2 and 3.2.2. The results show that in general the elements comply with the LCT0 guidelines. Some exceptions do occur:

- Initial tests (Section 3.1.2) - barium at all the sample points (except the Bruce BC11 facility); nitrate at King WRD A and Bruce WRD B; Manganese at King Paste; and Zinc at King WRD A exceed the LCT0 values;
- Verification round of testing (Section 3.2.2) - the barium concentration at the Bruce BC11A point exceeds the LCT0 guideline value. In addition, the boron at the Bruce WRD A, and the lead and selenium concentrations at the Bruce BC11 also exceeds the LCT0 guideline value.
 - Only 2 samples were taken for the verification testing, of which only 1 showed elevated boron, barium, lead and selenium concentrations. Therefore, it is not possible to come to any definite conclusions regarding the prevalence of elevated lead and selenium concentrations in the area based on the verification round of testing. Results from the initial testing do not show elevated boron, lead and selenium concentrations at any of the sampling points, which points towards the results from the verification round being an anomaly. No comments will be made regarding the boron, lead and selenium concentrations;
 - Barium concentrations in the initial tests also regularly exceeded the LCT0 guideline values and this can be used to confirm the results from the verification round of testing.

It should be noted that the above concentrations do not take into account:

- Differences in leach concentrations measured for different samples taken from the same surface facility;
- Dilution of the leachate with uncontaminated groundwater underlying, and around the surface stockpiles.

Analysis of the elements that are expected to exceed the LCT0 guidelines show:

- Barium (LCT0 guideline value of 0.7 mg/L):
 - The average barium concentration for the “King WRD” facility calculated from “King WRD A” and “King WRD B” is at 1.75 mg/L, which exceed the LCT0 guideline value of 0.7 mg/L by a factor of 2.5;
 - The average barium concentration for the “Bruce WRD” facility calculated from “Bruce WRD A” and “Bruce WRD B” is at 0.845 mg/L, which exceed the LCT0 guideline value of 0.7 mg/L by only 0.145 mg/L;
 - The barium concentration of 2.2 mg/L at the “King Paste” facility exceed the LCT0 guideline value by a factor of 3;



- The average barium concentration for the “Parsons Discard” facility calculated from “Parsons Discard A” and “Parsons Discard B” is at 1.75 mg/L, which exceed the LCT0 guideline value of 0.7 mg/L by a factor of 2.5;
- Nitrate (LCT0 guideline value of 11 mg/L):
 - The average nitrate concentration for the “King WRD” facility calculated from “King WRD A” and “King WRD B” is at 9.45 mg/L, which complies with the LCT0 guideline value;
 - The average nitrate concentration for the “Bruce WRD” facility calculated from “Bruce WRD A” and “Bruce WRD B” is at 10.5 mg/L, which complies with the LCT0 guideline value.
- Manganese (LCT0 guideline value of 0.5 mg/L):
 - The manganese concentration at the King Paste facility is 1.7 mg/L. This exceeds the LCT0 guideline value by a factor of 3.5;
- Zinc (LCT0 guideline value of 0.07 mg/L)
 - The average zinc concentration at the “King WRD” facility calculated from “King WRD A” and “King WRD B” is calculated to be 0.085 mg/L. This exceeds the LCT0 guideline value by only 0.015 mg/L; and
 - The average zinc concentration at the “Bruce BC11” facility calculated from “Bruce BC11 A” and “Bruce BC11 B” is calculated to be 0.175 mg/L. This exceeds the LCT0 guideline value by a factor of 2.5.

From the above, at the Bruce WRD facility the average barium concentration in leachate exceeds the LCT0 guideline values only slightly (by 0.145 mg/L), and it would be reasonable to assume that dilution with groundwater in the underlying and surrounding aquifers will reduce the leachate concentration to below that LCT0 guideline value, assuming that the barium concentration in the natural groundwater complies with the LCT0 guidelines in the first place – no information on this is available.

Facilities where additional studies have to be performed to determine whether dilution of the leachate with groundwater will yield a combined groundwater quality compliant with LCT0 are:

- King WRD;
- King Paste;
- Bruce BC11; and
- Parsons Discard.

These studies would include:

- Determining the natural groundwater quality in the area in terms of barium concentrations;
- Possibly a basic groundwater contaminant model to determine the cumulative impact of leachate from the facilities on the underlying and surrounding aquifers should the natural barium and manganese concentrations in the groundwater be below LCT0 guideline values.



3.4. Waste classification based on TC and LC test analyses

The waste classification as defined in GN 635 (Section 7) are summarised as:

- Wastes with any element or chemical substance concentration above LCT3 or TCT2 limits ($LC > LCT3$ or $TC > TCT2$) are Type 0 Wastes;
- Wastes with any element or chemical substance concentration above the LCT2 but below or equal to the LCT3 limits, or above the TCT1 but below or equal to the TCT2 limits ($LCT2 < LC < LCT3$ or $TCT1 < TC < TCT2$), are Type 1 Wastes;
- Wastes with any element or chemical substance concentration above the LCT1 but below or equal to the LCT2 limits, and all concentrations below or equal to the TCT1 limits ($LCT1 < LC < LCT2$ or $TC < TCT1$), are Type 2 Wastes;
- Wastes with any element or chemical substance concentration above the LCT0 but below or equal to the LCT1 limits, and all concentrations below or equal to the TCT1 limits ($LCT0 < LC < LCT1$ or $TC < TCT1$), are Type 3 Wastes; or
- Wastes with all elements and chemical substance concentration levels for metal ions and inorganic anions below or equal to the LCT0 and TCT0 limits ($LC \leq LCT0$ and $TC \leq TCT0$), and with all chemical substance concentration levels also below the relevant concentration limits for organics and pesticides, are Type 4 Wastes (no organics or pesticides are included in the waste rock material and therefore that requirement is not applicable);
- If a particular chemical substance in a waste is not listed with corresponding LCT and TCT limits in the norms and standards, and the waste has been classified as hazardous in terms of regulation 4(2) of the Regulations based on the health or environmental hazard characteristics of the particular element or chemical substance, the waste is considered to be Type 1 Waste (not applicable to this study);
- If the TC of an element or chemical substance is above the TCT2 limit, and the concentration cannot be reduced to below TCT2 limit, but the LC for the particular element or chemical substance is below the LCT3 limit, the waste is considered Type 1 Waste;
- Wastes listed in item (2)(b) of Annexure 1 to the regulations are considered to be Type 1 Waste, unless assessed and determined otherwise in terms of the Norms and Standards;
- Wastes with all element or chemical substances leachable concentration levels for metal ions and inorganic anions below or equal to the LCT0 limits are considered to be Type 3 Waste, irrespective of the total concentration of elements or chemical substances in the waste provided that:
 - The concentration levels are below the relevant limits for organics and pesticides;
 - The inherent waste 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.

Based on the above, the material from all the different sites is classified as Type 3 Waste following the GN 635 classification system.

This classification is mostly based on the results of the total concentration testing results where there are elements that exceed the TCT0 guidelines for all the samples. As discussed in Section



3.3 the Bruce WRD facility may not be impacted when taking into consideration dilution with natural groundwater based on the leach concentration results.

Table 3.5: Waste stream classification

Waste Stream	Classification
King WRD	Type 3
Bruce WRD	Type 3
King Paste	Type 3
Bruce BC11	Type 3
Parsons Discard	Type 3

3.5. Natural groundwater quality

In order to determine the natural groundwater quality in the area, the groundwater quality data from seven monitoring boreholes, as found in the Khumani EIA report (Ivuzi Water, Environmental and Earth Sciences Consultants, 2006) as referenced. In addition, groundwater samples were collected from the current available boreholes on site for barium analysis. This barium analysis was done because barium is not included in the available chemical analysis results and barium was one of the elements that exceed the LCT and TCT guidelines discussed in Sections 3.2 and 3.2. The data is presented in Table 3.6 and is compared to the Regulation 635 LCT guidelines. All elements that are expected to exceed the LCT guidelines are highlighted.

From Table 3.6 it can be seen that the groundwater in the Khumani area is naturally high in nitrate with concentrations ranging between 30 mg/L and 81 mg/L in the majority of the monitoring boreholes.

The sulphate concentrations in monitoring boreholes BK12 and BK17 are measured at 300 and 279 mg/L respectively. These values exceed the LCT0 guideline value of 250 mg/L.

Manganese and zinc form part of the 4 main elements to be considered when assessing the impact of leachate from the surface facilities towards the aquifers. The measured concentrations from all the samples comply with the LCT0 guideline values. The manganese concentrations are mostly in the order of 0.001 to 0.006 mg/L with BK36 showing a concentration of 0.11 mg/L.

Zinc concentrations are consistently below detection limit (<0.005 mg/L).

Natural barium concentrations in the area fall below detection limit (<0.001 mg/L) as can be seen from the 2016 sampling data. The borehole at the paste disposal area shows an elevated barium concentration which can be attributable to the nearby paste facility. The barium concentration in this borehole is measured at 0.835 mg/L, which is one order of magnitude less than the source concentration at the paste facility. This indicates the influence of dilution of the source fluids with uncontaminated natural groundwater.



3.6. Comparison of natural groundwater quality to the expected leach quality

The leachable concentrations as determined during the leach testing are compared to the natural groundwater quality in order to determine the expected impact on the groundwater quality in the aquifers underlying and adjacent to the various surface stockpiles.

The leachable concentrations are used because although the total concentrations are higher, not all the minerals in the rock material will go completely into solution and therefore using the total concentration will lead to an overestimation of the impact. The leachable concentrations provide a realistic indication of the element concentrations that can be expected in the leachate that will emanate from the surface stockpiles.

The leach test results are summarised in Table 3.2 and Table 3.4, and discussed in Sections 3.1.2 and 3.2.2, as well as Section 3.3. The available natural groundwater qualities are summarised in Table 3.6. The results show that:

- Chloride concentrations in the groundwater generally range between 5 and 45 mg/L. Monitoring point BK17 indicate a chloride concentration of 162 mg/L. Leach concentrations in all the samples except “Parsons Discard B (6 mg/L) are below 5 mg/L. From this it can be said that it is not expected that the leachate will negatively impact on the chloride concentrations in the aquifers;
- Sulphate concentrations in the groundwater generally range between 5 and 20 mg/L. Monitoring points BK12 and BK17 indicate sulphate concentrations of 300 and 279 mg/L respectively. Leach concentrations in the samples range between 1 and 4 mg/L. It is not expected that the leachate will negatively impact on the sulphate concentrations in the aquifers;
- Nitrate concentrations in the groundwater generally range between 30 and 80 mg/L. Leach concentrations in the majority of the samples are <0.1 mg/L. In some samples it ranges up to 4 mg/L. It is not expected that the leachate will negatively impact on the nitrate concentrations in the aquifers;
- Fluoride concentrations in the groundwater range between <0.1 and 0.8 mg/L. Leach concentrations in the samples range between 0.05 and 0.1 mg/L. It is not expected that the leachate will negatively impact on the fluoride concentrations in the aquifers;
- Silver concentrations in the groundwater was measured at <0.1 mg/L for all the samples. Leach concentrations in all the samples are measured at <0.002 mg/L. It is not expected that the leachate will negatively impact on the silver concentrations in the aquifers;
- Aluminium concentrations in all the groundwater monitoring points are measured at <0.009 mg/L, except BK37 and BK36 (0.03 and 0.1 mg/L respectively). Leach concentrations in the samples range between 0.2 and 0.4 mg/L. It is expected that the leachate could have a negative impact on the aluminium concentrations in the aquifers;
- Barium concentrations in the natural groundwater are below detection limit (0.001 mg/L). Leach concentrations range between 0.7 and 2.3 mg/L. it is expected that the leachate will negatively impact on the barium concentrations in the aquifers;



- Calcium concentrations in the groundwater range between 50 and 150 mg/L. Leach concentrations in the majority of the samples range between 2 and 24 mg/L. It is not expected that there will be a negative impact on the calcium concentrations in the groundwater;
- Copper concentrations in the groundwater was measured at <0.005 mg/L for all the samples. Leach concentrations in all the samples are measured at <0.02 mg/L. It is not expected that the leachate will negatively impact on the copper concentrations in the aquifers;
- Iron concentrations in the groundwater generally range between 0.002 and 0.2 mg/L. Leach concentrations in all of the samples are <0.05 mg/L. It is not expected that the leachate will negatively impact on the iron concentrations in the aquifers;
- Potassium concentrations in the groundwater generally range between 0.1 and 6.5 mg/L. Leach concentrations in all of the samples range between 4 and 13 mg/L. It is not expected that the leachate will negatively impact on the potassium concentrations in the aquifers;
- Magnesium concentrations in the groundwater range between 30 and 100 mg/L. Leach concentrations in the majority of the samples range between 0.6 and 4 mg/L. Some individual samples indicate concentrations of 11 (King WRD A), and 7.8 mg/L at both King WRD B and Brice WRD B. At King WRD the average magnesium concentration is calculated at 9.4 mg/L. It is not expected that the leachate will have a negative impact on the magnesium concentrations in the aquifers;
- Manganese concentrations in the groundwater range between <0.001 and 0.006 mg/L in the majority of the samples. BK36 indicates a concentration of 0.11 mg/L. Leach concentrations in the majority of the samples range between 0.1 and 0.4 mg/L. The King Paste sample indicates a concentration of 1.7 mg/L. It is expected that the leachate could have a negative impact on the magnesium concentrations in the aquifers, especially at the King Paste facility;
- Sodium concentrations in the groundwater generally range between 2 and 40 mg/L, with 85 mg/L measured at BK12, and 79 mg/L measured at BK17. Leach concentrations range between 140 and 220 mg/L. It is expected that the leachate will have a negative impact on the sodium concentrations in the aquifers;
- Nickel concentrations in the groundwater was measured at <0.003 mg/L for all the samples, except BK36 (0.005 mg/L). Leach concentrations in the majority of samples are measured at <0.005 mg/L, with some individual samples showing concentrations of 0.006 (Bruce WRD A and Bruce BC11 B) and 0.007 mg/L (King Paste). It is not expected that the leachate will have a notable negative impact on the nickel concentrations in the aquifers;
- Lead concentrations in the groundwater was measured at <0.01 mg/L for all the samples. Leach concentrations in all the samples are measured at <0.01 mg/L. It is not expected that the leachate will negatively impact on the lead concentrations in the aquifers;
- Vanadium concentrations in the majority of the groundwater monitoring points was measured at <0.002 to 0.006 mg/L. BK31 and BK37 showed concentrations of 0.02 and 0.01 mg/L respectively. Leach concentrations in all the samples are measured at <0.001 mg/L. It is not expected that the leachate will negatively impact on the copper concentrations in the aquifers; and



- Zinc concentrations in the groundwater was measured at <0.005 mg/L for all the samples. Leach concentrations were measured at 0.02 to 0.04 mg/L in the majority of the samples. Bruce BC11B showed a concentration of 0.31 mg/L. Together with Bruce BC11A an average zinc concentration of 0.175 mg/L is calculated for the Bruce BC11 facility. King WRD A show a concentration of 0.13 mg/L. Together with the King WRD B sample an average zinc concentration of 0.085 mg/L is calculated for the King WRD facility. It is expected that the leachate will negatively impact on the zinc concentrations in the aquifers, especially around the Bruce BC11 and King WRD facilities.

The above can be summarised to conclude that based on the available groundwater quality data and the leach test results little impact is expected on the groundwater quality in the underlying and surrounding aquifers, except:

- All facilities have the potential to increase the aluminium and sodium concentrations due to seepage into the underlying aquifers. The resultant water will still comply with LCT0 guideline values;
- All facilities, except the BC11 facility, can be expected to have an impact on the barium concentrations in the groundwater. The barium concentrations are expected to increase up to 1.7 to 2.3 mg/L over time as the plumes develop and ultimately the barium concentrations will exceed the LCT0 guidelines;
- The King Paste facility could pose some risk of increasing the manganese concentration in the underlying aquifers up to 1.7 mg/L. This value exceeds the LCT0 guideline value;
- The Bruce BC11 and King WRD facilities could cause an increase in the zinc concentrations in the underlying aquifers. At the King WRD facility the leachate could exceed the LCT0 guideline value slightly (0.085 mg/l vs 0.07 mg/L). At the Bruce BC11 facility the impact could be more prominent, with concentrations increasing to 0.175 mg/L (a factor of 2.5). These values still comply with the LCT0 guideline value of 5.0 mg/L.



3.7. Summary of risk from leachate to the environment

Facility	Risk of leachate to environment				Leach concentrations compared to natural groundwater concentrations (% greater than natural concentration)
	No risk	Marginal	Definite	Leach element > LCT0 (% greater than LCT0)	
Bruce WRD		X		Barium (20%)	Aluminium >1000% - Still comply with LCT0 guideline Barium >1000% - Do not comply with LCT0 guideline Sodium 900% - Still comply with LCT0 guideline
King WRD			X	Barium (250%) Zinc (21%)	Aluminium >1000% - Still comply with LCT0 guideline Barium >1000% - Do not comply with LCT0 guideline Sodium 900% - Still comply with LCT0 guideline Zinc – 21 % - Still comply with LCT0 guideline
King Paste			X	Barium (300%) Manganese (350%)	Aluminium >1000% - Still comply with LCT0 guideline Barium >1000% - Do not comply with LCT0 guideline Sodium 900% - Still comply with LCT0 guideline Manganese >1000% - Do not comply with LCT0 guideline
Bruce BC11			X	Zinc (250%)	Aluminium >1000% - Still comply with LCT0 guideline Sodium 900% - Still comply with LCT0 guideline Zinc 250% - Still comply with LCT0 guideline
Parsons discard			X	Barium (250%)	Aluminium >1000% - Still comply with LCT0 guideline Barium >1000% - Do not comply with LCT0 guideline Sodium 900% - Still comply with LCT0 guideline

No risk – Leach concentration of all elements are below LCT0 guideline values

Marginal risk – Leach concentration of individual elements exceed LCT0 guideline values by less than 25%

Definite risk – Leach concentration of individual elements exceed LCT0 guideline values by more than 25%



Table 3.6: Natural groundwater quality compared to LCT guideline values

Analysis	Units	LCT0 Guideline value	LCT1 Guideline value	Natural groundwater quality – Previous studies							Groundwater quality – 2016 sampling						
				BK12	BK13	BK30	BK31	BK17	BK37	BK36	Kraal	PBW1	PBW4	PBE1	BKM3D	BKM04	Paste Disposal Borehole
pH		N/L	N/L	7.5	7.4	7.6	7.6	7.2	7.5	7.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Electrical Conductivity (EC)	mS/m	N/L	N/L	118	89.1	57.5	72.1	158	69.3	89.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total dissolved solids (TDS)	mg/L	<1 000	12 500	848	640	438	624	1 132	476	652	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkalinity (Alk)	mg/L	N/L	N/L	228	340	180	336	396	264	444	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chloride (Cl)	mg/L	<300	15 000	40	43	12.8	24	162	19.7	5.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulphate (SO ₄)	mg/L	<250	12 500	300	18.4	14.2	12.3	279	16.6	5.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrate (NO ₃)	mg/L	<11	550	3.6	56	65	61	30	81	5.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fluoride (F)	mg/L	<1.5	75	0.8	0.2	<0.1	0.1	0.7	0.1	<0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ammonium (NH ₄)	mg/L	N/L	N/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Orthophosphate (PO ₄ ³⁻)	mg/L	N/L	N/L	0.6	<0.1	0.6	1	0.9	0.6	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Silver (Ag)	mg/L	N/L	N/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aluminium (Al)	mg/L	N/L	N/L	<0.009	<0.009	<0.009	<0.009	<0.009	0.03	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Calcium (Ca)	mg/L	N/L	N/L	113	74	53	66	152	66	96	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Copper (Cu)	mg/L	<2.0	100	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iron (Fe)	mg/L	N/L	N/L	0.04	0.04	0.18	0.19	0.002	0.006	0.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Potassium (K)	mg/L	N/L	N/L	6.5	1.8	0.1	2.3	3.7	1.7	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium (Mg)	mg/L	N/L	N/L	46	64	29	43	98	40	64	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Manganese (Mn)	mg/L	<0.5	25	<0.08	<0.001	0.002	0.001	0.002	0.006	0.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sodium (Na)	mg/L	N/L	N/L	85	22	18.3	40	79	23	8.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nickel (Ni)	mg/L	<0.07	3.5	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lead (Pb)	mg/L	<0.01	0.5	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Silicon (Si)	mg/L	N/L	N/L	11.5	28	30	38	20	33	15.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vanadium (V)	mg/L	<0.2	10	<0.002	0.006	0.005	0.02	<0.002	0.01	<0.002	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zinc (Zn)	mg/L	<5.0	250	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Barium	mg/L	<0.7	35	N/D	N/D	N/D	N/D	N/D	N/D	N/D	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.835

N/L: Not listed in Regulation 635

N/A: Not analysed

N/D: No data

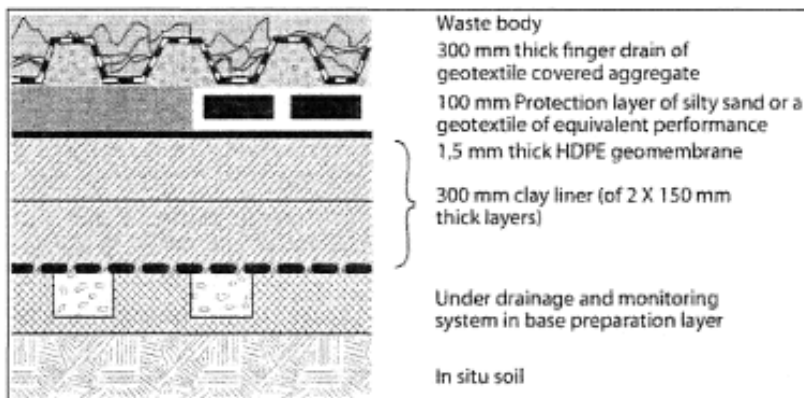
Exceed the LCT0 guideline value
 Exceed the LCT1 guideline value



4. Landfill site recommendation

Following the GN 636 guideline, the material from all the facilities may only be disposed of at a Class C landfill designed in accordance with Section 1(1) and (2) of the GN 636 Norms and Standards, or, subject to Section 3(4) it may be disposed of at a landfill site designed in accordance with the requirements for a GLB+ landfill as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998).

A class C landfill design require:





5. SANS 10234 classification

The SANS 10234 standard covers the harmonized criteria for the classification of hazardous substances and mixtures, including waste, for their safe transport, use at the workplace or in the home according to their health, environmental and physical hazards, for example acute toxicity and flammability. It gives the harmonized communication elements for labelling and safety data sheets.

The hazards evaluated according to SANS 10234 include:

- Physical hazards (Section 5.1 of this report):
 - Explosives;
 - Flammable gasses;
 - Flammable aerosols;
 - Oxidising gases;
 - Gases under pressure;
 - Flammable liquids;
 - Flammable solids;
 - Self-reactive substances and mixtures;
 - Pyrophoric substances;
 - Self-heating substances and mixtures;
 - Substances and mixtures that, on contact with water, emit flammable gases;
 - Oxidising substances and mixtures;
 - Organic peroxides;
 - Corrosive to metals;
- Health hazards (Section 5.2 of this report):
 - Acute toxicity;
 - Skin corrosion and skin irritation;
 - Serious eye damage and eye irritation;
 - Respiratory sensitization and skin sensitization;
 - Germ cell mutagenicity;
 - Carcinogenicity;
 - Reproductive toxicity;
 - Specific target organ toxicity – single exposure;
 - Specific target organ toxicity – repeated exposure;
 - Aspiration hazards;
- Hazards to the aquatic environment (Section 5.3 of this report):
 - Acute aquatic toxicity;
 - Bioaccumulation;
 - Degradation (abiotic or biotic) for organic chemicals; and
 - Chronic aquatic toxicity.



5.1. Physical hazard

5.1.1. Explosives

Explosives are defined in SANS 10234:

- An explosive substance is a solid substance or a liquid substance, or a mixture of substances, which is in itself capable, by chemical reaction, of producing gas at such a temperature, pressure and speed as to cause damage to the surroundings. Pyrotechnic substances are included even when they do not evolve gases;
- An explosive article is an article containing one or more explosive substances or mixtures;
- A pyrotechnic substance is a solid substance or a liquid substance, or a mixture of substances, designed to produce an effect by heat, light, sound, gas or smoke, or a combination of these, as the result of non-detonative self-sustaining exothermic chemical reactions; and
- A pyrotechnic article is an article containing one or more pyrotechnic substances or mixtures.

The rock material stored on site is not considered to be explosive. In addition to this, the water used in the process on site is not explosive.

5.1.2. Flammable gasses

Flammable gasses are defined:

A flammable gas is classified in one of two categories as indicated in Table 5.1.

Table 5.1: Categories and classification criteria for flammable gasses

Category	Classification criteria
1	Gases that, at 20 °C and a standard pressure of 101.3 kPa: a) are ignitable when in a mixture of 13 % or less, by volume, in air; or b) have a flammable range with air of at least 12 percentage points regardless of the lower flammable limit.
2	Gases that, at 20 °C and a standard pressure of 101.3 kPa, have a flammable range while mixed in air.

The rock material stored on site is not considered to be a flammable gas. In addition to this, the water used in the process on site is a flammable gas.

5.1.3. Flammable aerosols

- An aerosol shall be considered for classification as flammable if it contains any component classified as flammable in accordance with Section 5.1.2 (flammable gasses), Section 5.1.6 (flammable liquids), or Section 5.1.7 (flammable solids);



- Flammable components do not cover pyrophoric substances, self-heating substances (see 5.1.10) or water-reactive substances (see 5.1.11) as they are never used as contents for aerosols.
- A flammable aerosol is classified in one of two categories on the basis of its components, its chemical heat of combustion and, if applicable, of the results of the foam test (for foam aerosols), and of the ignition distance tests and the enclosed space test (for spray aerosols), in accordance with Part III, Section 31 of the United Nations.' *Manual of tests and criteria*.

The material stored on site is not considered to be flammable in accordance with Section 5.1.2 (flammable gasses), Section 5.1.6 (flammable liquids), or Section 5.1.7 (flammable solids). In addition to this, the water used in the process on site is not a flammable aerosol. Therefore, the material does not have to be considered for classification as flammable aerosols.

5.1.4. Oxidising gasses

Neither the rock material stored on site, nor the water used in the process, is an oxidising gas.

5.1.5. Gasses under pressure

Gases under pressure are defined in SANS 10234 as gases that are contained in a receptacle at a pressure not less than 280 kPa at 20 °C or as refrigerated liquids.

Neither the rock material stored on site, nor the water used in the process, is a gas under pressure.

5.1.6. Flammable liquids

A flammable liquid is classified in one of four categories as indicated in Table 5.2:

Table 5.2: Categories and classification criteria for flammable liquids

Category	Classification criteria
1	Closed-cup flash point < 23 °C and initial boiling point < 35 °C
2	Closed-cup flash point < 23 °C and initial boiling point > 35 °C
3	Closed-cup flash point > 23 °C and < 60 °C
4	Closed-cup flash point > 60 °C < 93 °C

Neither the rock material stored on site, nor the water used in the process, is considered to be flammable liquids.



5.1.7. Flammable solids

Solids are classified in one of two categories as indicated below:

Table 5.3: Categories and classification criteria for flammable solids

Category	Classification criteria
1	a) Substances or mixtures other than metal powders: Burning time < 45 s or burning rate > 2.2 mm/s, and the wetted zone does not stop flame propagation for at least 4 min. b) Metal powders: burning time < 5 min.
2	a) Substances or mixtures other than metal powders: Burning time < 45 s or burning rate > 2.2 mm/s, and the wetted zone stops flame propagation for at least 4 min. b) Metal powders: burning time > 5 min and < 10 min.

Neither the rock material stored on site, nor the water used in the process, are flammable solids.

5.1.8. Self-reactive substances and mixtures

- The decomposition of self-reactive substances or mixtures can be initiated by friction, impact or heat, or by contact with catalytic impurities, for example acids, heavy metal compounds and heavy metal bases.
- The rate of decomposition increases with temperature and varies with the substance or mixture. Decomposition, particularly if no ignition occurs, can result in the evolution of toxic gases or vapours. In the case of certain self-reactive substances, the temperature has to be controlled. Some self-reactive substances or mixtures can decompose explosively, particularly if confined; this characteristic can be modified by the addition of diluents or by the use of appropriate packaging.
- Some self-reactive substances or mixtures burn vigorously. Self-reactive substances include some of the following types of compounds:
 - aliphatic azo compounds (-C-N=N-C-);
 - organic azides (-C-N₃);
 - diazonium salts (CN₂+Z-);
 - N-nitroso compounds (-N-N=O); and
 - aromatic sulfohydrazides (SO₂-NH-NH₂).

As can be deduced from the fact that the material has been stored on site for years and no self-reactive burning has taken place, neither the rock material stored on site, nor the water used in the process, is considered to be self-reactive.

5.1.9. Pyrophoric substances

- Pyrophoric liquids ignite within 5 min when added to an inert carrier and exposed to air, or it ignites or chars a filter paper on contact with air within 5 min; and
- Pyrophoric solids ignites within 5 min of coming into contact with air



As can be deduced from the fact that the material has been stored on site for years and no pyrophoric ignition has taken place neither the rock material stored on site, nor the water used in the process, is considered to be pyrophoric.

5.1.10. Self-heating substances and mixtures

Self-heating of substances or mixtures is caused by reaction of the substance or mixture with oxygen in the air and when the heat that develops is not conducted away rapidly enough to the surroundings. Spontaneous combustion occurs when the rate of heat production exceeds the rate of heat loss and the auto-ignition temperature is reached. Some substances can emit toxic gases when they are involved in a fire.

As can be deduced from the fact that the material has been stored on site for years and no spontaneous combustion has taken neither the rock material stored on site, nor the water used in the process, is considered to be prone to self-heating and spontaneous combustion.

5.1.11. Substances and mixtures that, on contact with water, emit flammable gasses

Certain substances, on contact with water, emit flammable gases that can form explosive mixtures with air. Such gas mixtures are easily ignited by ordinary sources of ignition, for example naked flames, sparking hand tools or unprotected light bulbs. The resulting blast wave and flames can endanger people and the environment.

Neither the rock material stored on site, nor the water used in the process, is considered to be prone to emit flammable gasses on contact with water.

5.1.12. Oxidising substances and mixtures

SANS 10234 provides the following guideline on oxidising substances and mixtures:

- Although oxidizing substances are not necessarily combustible, they can, either by yielding oxygen or by similar processes cause, or contribute to, the combustion of other materials with which they come into contact.
- Depending on the amount and nature of combustible impurities they might contain, certain oxidizing substances are sensitive to impact, friction or a rise in temperature.
- Some mixtures of oxidizing substances and combustible material, for example hydrocarbons are so readily ignited that friction or impact can cause ignition. Such a mixture can burn with explosive force.
- There will be a violent reaction between most oxidizing substances and strong liquid acids, resulting in the emission of highly toxic gases. Such gases can also be emitted when certain oxidizing substances are involved in a fire.



Neither the rock material stored on site, nor the water used in the process, is considered to be an oxidising substance.

5.1.13. Organic peroxides

- Organic peroxides are liquid or solid organic substances that contain the bivalent -O-O structure and can be considered derivatives of hydrogen peroxide where one, or both, of the hydrogen atoms has been replaced by organic radicals;
- Organic peroxides are thermally unstable substances or mixtures that can undergo exothermic decomposition at normal or elevated temperatures. The decomposition can be initiated by heat, friction, impact or contact with impurities, for example acids, heavy metal compounds and amines. The rate of decomposition increases with a rise in temperature and can vary with different formulations (mixtures) of the same organic peroxide;
- Most organic peroxides burn rapidly and decomposition of the substance or mixture can result in the evolution of harmful, or flammable, gases and vapours;
- Contact of organic peroxides with the eyes and skin should be avoided since they can cause serious injury to the cornea even after brief contact, and they can be corrosive to skin;
- An organic peroxide is regarded as possessing explosive properties when, in laboratory testing, the formulation is liable to detonate, to deflagrate rapidly or to show a violent effect when heated under confinement.

Neither the rock material stored on site, nor the water used in the process, is classified as organic peroxides.

5.1.14. Corrosive to metals

Corrosive metals have a corrosion rate on steel or aluminium surfaces that exceeds 6.25 mm/year at a test temperature of 55 °C.

Neither the rock material stored on site, nor the water used in the process is corrosive to metals.

5.1.15. Summary of physical hazards

The various material stored on site do not pose physical hazards as grouped or classed in the SANS 10234 guideline. Neither the waste rock and paste material nor the water used in the wash process, poses an explosive, oxidising, flammable or other risk. Therefore, the material is **classified as non-hazardous** in terms of physical hazards.



5.2. Health hazard

There are various health hazards that are considered in SANS 10234. A summary of each of the health hazards, as well as a rating or discussion of the hazards are provided in the following sub-sections.

In geology and largely in chemistry as well, “rock” material which includes the waste rock and slimes material handled on site, are technically classified as “mixtures”. Based on this, the hazard characteristics for each individual substance (element) is taken into account when calculating the hazard rating of the “mixture” or rock / lithological material.

Table 5.13 provides a summary of the hazard characteristics for each individual substance (or chemical element) based on information as obtained from published literature. This information, together with results from the total concentration and leach testing, is used as background to the health hazard calculations done for the rock material. For example, results from the total concentration testing provides guidance on the elements that have to be included in the acute toxicity testing (typically elements with concentrations > 1%), while information on skin corrosion or serious eye damage from each individual substance (element) provides guidance on which elements have to be included in the hazard rating calculations for the “mixture” (rock material).

Please note that for this study the majority of the parameters analysed for during the total concentration and leach testing that was done (please refer to Section 3) were taken into account. However, some of the minor elements are excluded. These parameters include silicon, tin, strontium tellurium, thorium, titanium, thallium, tungsten, yttrium, and zirconium.

The hazard rating criteria and calculations for the “mixtures” are discussed in more detail in the following sub-sections. A summary discussion on the findings is provided in Section 5.2.10.

5.2.1. Acute toxicity

The LD₅₀ values that are available for the various elements analysed for are summarised in Table 5.13. The values listed are from the oral pathway and are based on experiments performed on rats as specified in SANS 10234. The LD₅₀ values are used to classify each individual element into a hazard rating category. Each of these categories is associated with a converted acute toxicity estimate (ATE) value that is used in the ATE calculation for the “mixture” as a whole. These converted ATE estimates are:

- Category 1: 0.5;
- Category 2: 5;
- Category 3: 100;
- Category 4: 500; and
- Category 5: 2 500.



SANS 10234 specifies that the classification of “mixtures” is based on the lethal dose data. However, for the classification of mixtures it is necessary to obtain, or derive, information that allows the criteria to be applied to the mixture. The classification of mixtures for acute toxicity can be carried out for each route of exposure but is only needed for one route of exposure, provided that the same route of exposure is followed for all the ingredients.

In order to make use of all available data for purposes of classifying a mixture, certain assumptions have been made and should be applied where appropriate in the tiered approach:

- The ingredients relevant for the classification of a mixture are the ingredients present in concentrations greater than or equal to 1 %, (by mass for solids, liquids, dusts, mists and vapours, and by volume for gases). However, an ingredient present at a concentration of less than 1 % can be used for classification purposes if there is reason to suspect that the substance is relevant for the classification of the mixture for acute toxicity, in particular when untested mixtures contain ingredients that are classified in category 1 and category 2; and;
- Where a classified mixture is used as an ingredient of another mixture, the actual or derived acute toxicity estimate (ATE) for that mixture may be used when calculating the classification of the new mixture using the formula (where data is available on all ingredients in the mixture):

$$\frac{100}{ATE_{mix}} = \sum_n \frac{C_i}{ATE_i}$$

Where:

- ATE_{mix} = acute toxicity estimate of the mixture;
- C_i = the concentration of element i (please refer to Table 3.1);
- ATE_i = the converted acute toxicity estimate of ingredient i (please refer to Table 23 in the SANS 10234 guideline document and listed above.

Based on the above, and in conjunction with Table 3.1, Table 3.2 and Table 5.13, it can be seen that the following elements should be included in the acute toxicity calculations:

- Elements with a concentration of > 1% in any of the lithologies:
 - Aluminium (waste rock and paste);
 - Iron (waste rock and paste);
 - Potassium (waste rock);
- Elements preliminary classified as Acute Toxicity Category 1:
 - Phosphorus, Selenium, Mercury;
- Elements preliminarily classified as Acute Toxicity Category 2:
 - Cyanide, hexavalent chromium, cobalt, total chromium, nickel, sulphur, vanadium.



By applying the above formula, and using the relevant data for the elements mentioned above, the acute toxicity estimate according to the oral route can be calculated for the waste rock and the slimes material:

- Waste rock: 0.062; and
- Slimes: 0.092.

From the above, both mixtures are classified as Category 1 (the highest toxicity category) for acute health effects.

5.2.2. Skin corrosion and skin irritation

Where the mixture itself has not been tested to determine its skin corrosion properties or its skin irritation properties, but there are sufficient data on the individual ingredients and similar tested mixtures to adequately characterize the hazards of the mixture, these data shall be used in accordance with the bridging principles as given in 10.2.2.2.2 to 10.2.2.2.7 of the SANS 10234 guideline. This ensures that the available data are used to the greatest extent possible in characterizing the hazards of the mixture without the necessity for additional animal testing.

In order to make use of all available data for purposes of classifying a mixture for skin corrosion or skin irritation, the tiered approach shall be followed where appropriate.

The ingredients of a mixture relevant for classification purposes are those ingredients present in concentrations of 1 % (by mass for solids, liquids, dusts, mists and vapours and by volume for gases) or greater. However, an ingredient present at a concentration of less than 1 % can still be relevant for classification of the mixture as corrosive or irritating to the skin.

When skin corrosion or skin irritation data are available for the components of a mixture, but not for the mixture as a whole, classification of the mixture shall be based on the theory of additivity. This is when each corrosive or irritant component contributes to the overall irritant or corrosive properties of the mixture in proportion to its potency and concentration. A weighting factor of 10 is used for corrosive components when they are present at a concentration below the concentration limit for classification in Category 1, but are at a concentration that will contribute to the classification of the mixture as an irritant. The mixture is classified as corrosive or irritant when the sum of the concentrations of such components exceeds a cut-off concentration limit as shown in Table 5.4.



Table 5.4: Cut-off values / concentration limits of the ingredients of a mixture classified as skin Category 1, 2, or 3 that classify classification of the mixture as hazardous to the skin

Sum of ingredients classified as:	Cut-off values / concentrations limits of the ingredients that trigger classification of a mixture % (by mass for solids, liquids dusts mists and vapours and by volume for gases)		
	Skin corrosive	Skin irritant	
	Category 1	Category 2	Category 3
Skin category 1	≥ 5	≥ 1 but ≤ 5	
Skin category 2		≥ 10	10 > C ≥ 1
Skin category 3			≥ 10
(10 x skin category 1) + skin category 2		≥ 10	10 > C ≥ 1
(10 x skin category 1) + skin category 2 + skin category 3			≥ 10

Particular care shall be taken when classifying certain types of chemicals such as acids and bases, inorganic salts, aldehydes and phenols. The classification procedures given above are not applicable to these types of substances as they are often corrosive or irritant at concentrations of less than 1 %. The pH value shall be used for the classification of mixtures containing strong acids or strong bases, since the pH value is a better indicator of corrosion than the concentration limits given in the table above. A mixture that contains corrosive or irritant components and that cannot be classified in accordance with the additivity approach (summarised in the table above) because of chemical characteristics, shall be classified as indicated in Table 5.5.

A mixture shall be classified as corrosive or irritant, as appropriate, when data show that (an) ingredient(s) of the mixture is corrosive or irritant at a concentration of less than 1 % for corrosives and less than 3 % for irritants.

Table 5.5: Cut-off values / concentration limits of the ingredients of a mixture classified for which the additivity approach does not apply, that trigger classification of the mixture as hazardous to skin

Properties of the ingredient	Cut-off values / concentration limits that trigger classification of the mixture %	Classification of mixture as hazardous to skin
Acid with pH ≤ 2	≥ 1	Category 1
Alkali with pH ≥ 11.5	≥ 1	Category 1
Other corrosive (category 1) ingredients for which additivity does not apply.	≥ 1	Category 1
Other irritant (category 2) ingredients for which additivity does not apply, including acids and bases.	≥ 3	Category 2



There are no strong acids or bases present in the material stored on site (water and rock or soil material). Therefore reference should be made to the guidelines set out in Table 5.4.

Applying the 1 % concentration rule the following elements should be taken into account in the classification:

- Aluminium (waste rock and slimes);
- Iron (waste rock and slimes); and
- Potassium (waste rock).

As summarised in Table 5.13 there are other chemicals that are considered to be an irritant, or potentially an irritant, to the skin which are present at < 1 % concentration that have to be taken into account. These include sulphate, nitrate, cyanide, hexavalent chromium, arsenic, bismuth, calcium, cobalt, magnesium, sodium, nickel, selenium, uranium, zinc, and chloride.

The calculated sum of concentrations of the elements listed above are summarised below for each of the mixtures:

- Waste rock: 20.8 %; and
- Paste (Slimes): 19.8 %.

From the above results each of the waste rock and paste (slimes) material is classified as hazardous in terms of skin corrosion.

5.2.3. Serious eye damage and eye irritation

In order to avoid unnecessary animal testing, the classification of substances and mixtures for serious eye damage and eye irritation is based on a tiered testing and evaluation scheme that combines pre-existing information on serious eye damage and eye irritation. Such data relate to historical human or animal experience, considerations on SAR or SPR, and the results obtained from validated *in vitro* tests.

In order to make use of all available data for purposes of classifying a mixture for eye irritation or serious eye damage properties, a tiered approach shall be followed.

The ingredients of a mixture relevant for classification are those ingredients which are present in concentrations of 1 % (by mass for solids, liquids, dusts, mists and vapours, and by volume for gases) or greater. However, an ingredient present at a concentration of less than 1 %, for example a corrosive ingredient, can still be relevant for the classification of a mixture for eye irritation or serious eye damage.

When data are available on the components, but not on the mixture as a whole, classification of a mixture as an eye irritant or as seriously damaging to the eye is based on the theory of additivity



where each corrosive or irritant component contributes to the overall irritant or corrosive properties of the mixture in proportion to its potency and concentration.

A weighting factor of 10 is used for corrosive components when they are present at a concentration below the concentration limit for classification in category 1, but are at a concentration that will contribute to the classification of the mixture as an irritant. A mixture is classified as seriously damaging to the eye or as a severe eye irritant when the sum of the concentrations of such components exceeds a threshold cut-off concentration limit (please refer to Table 5.6 below).

Table 5.6: Cut-off values / concentration limits of the ingredients of a mixture classified as Category 1 for skin effects and/or Category 1 or 2 for eye effects that trigger classification of the mixture as hazardous to the eye

Sum of ingredients classified as:	Cut-off values/concentration limits of the ingredients that trigger classification of a mixture %	
	Irreversible eye effects	Reversible eye effects
	Category 1	Category 2
Eye or skin Category 1	≥ 3	3 > C ≥ 1
Eye category 2A		≥ 10
(10 x eye category 1) + eye category 2A		≥ 10
Skin category 1 + eye Category 1	≥ 3	3 > C ≥ 1
10 x (Skin Category 1 + eye Category 1) + eye Category 2A or 2B.		≥ 10

Applying the 1 % concentration rule the following elements should be taken into account in the classification:

- Aluminium (waste rock and paste / slimes);
- Iron (waste rock and paste / slimes); and
- Potassium (waste rock).

As summarised in Table 5.13 there are other chemicals that are considered to be an irritant, or which can cause eye effects which are present at < 1 % concentration that have to be taken into account. These include sulphate, nitrate, cyanide, hexavalent chromium, silver, arsenic, bismuth, calcium, cobalt, lithium, magnesium, sodium, nickel, antimony, selenium, vanadium, and chloride.

The calculated sum of concentrations of the elements listed above are summarised below for each of the “mixtures”:

- Waste rock: 4.8 %; and
- Slimes (paste): 20.2 %.

From the above results both mixtures are classified as Category 1 hazardous to the eye.



5.2.4. Respiratory sensitisation and skin sensitisation

When reliable and good quality evidence from human experience or appropriate animal studies is available for a mixture, then the mixture can be classified by weight of evidence evaluation of these data. However, when evaluating data on mixtures, care should be exercised that the dose used does not render the results inconclusive.

A mixture shall be classified as a respiratory sensitizer or a skin sensitizer, as applicable, when at least one ingredient has been classified as a respiratory sensitizer or a skin sensitizer and is present at, or above, the concentration limits as shown in Table 5.7.

Table 5.7: Cut-off values / concentration limits of the ingredients of a mixture classified as skin sensitizers or respiratory sensitizers that trigger classification of a mixture

Ingredient classified as:	Concentration of the mixture that triggers classification of the mixture %		
	Skin sensitizer	Respiratory sensitizer	
	All physical states	Solid or liquid	Gas
Skin sensitizer	≥ 0.1 (see Note 1)	-	-
	≥ 1.0 (see Note 2)	-	-
Respiratory sensitizer	-	≥ 0.1 (see Note 3)	≥ 0.1 (see Note 5)
	-	≥ 1.0 (see Note 4)	≥ 2.0 (see Note 6)

NOTE 1 If a skin sensitizer is present in a mixture at a concentration between 0.1 % and 1.0 %, both an SDS and a label should be provided.
 NOTE 2 If a skin sensitizer is present in a mixture at a concentration of ≥ 1.0 %, both an SDS and a label should be provided.
 NOTE 3 If a solid or liquid respiratory sensitizer is present in a mixture at a concentration between 0.1 % and 1.0 %, both an SDS and a label should be provided.
 NOTE 4 If a solid or a liquid respiratory sensitizer is present in the mixture at a concentration of ≥ 1.0 %, both an SDS and a label should be provided.
 NOTE 5 If a gaseous respiratory sensitizer is present in the mixture at a concentration between 0.1 % and 0.2 %, both an SDS and a label should be provided.
 NOTE 6 If a gaseous respiratory sensitizer is present in the mixture at a concentration of ≥ 0.2 %, both an SDS and a label should be provided.

From the combined Table 5.7, Table 5.13 and Table 3.1 it can be seen that for each mixture there are individual substances (elements) that are classified as a skin or a respiratory sensitizer and is present at, or above, the concentration limits shown in Table 5.7.

These elements can be summarised:

- Skin & respiratory sensitizers ≥ 0.1 and < 1.0 %:
 - Waste rock: none;
 - Slimes: potassium;
- Skin & respiratory sensitizers ≥ 1.0 %:
 - Waste rock: iron, potassium; and
 - Slimes: iron.



Please note that all elements that exceed 1.0 % concentration by definition also exceed 0.1 % concentration.

From the above both the waste rock and slimes or paste material “mixtures” can be classified as hazardous in terms of respiratory and skin sensitization hazards.

5.2.5. Germ cell mutagenicity

This hazard class covers chemicals that cause mutations in the germ cells of humans and that can be transmitted to the progeny. The term “mutation.” applies both to heritable genetic changes that can be manifested at the phenotypic level and to the underlying DNA modifications when known including, for example, specific base pair changes and chromosomal translocations. The terms “mutagenic.” and “mutagen.” are used for agents giving rise to an increased occurrence of mutations in populations of cells or organisms (or both).

Where the mixture itself has not been tested to determine its germ cell mutagenicity hazard, but there are sufficient data on the individual ingredients and similar tested mixtures to adequately characterize the hazards of the mixture, these data shall be used in accordance with the bridging principles given in SANS 10234. This ensures that the available data are used to the greatest extent possible in characterizing the hazards of the mixture without the necessity for additional animal testing.

A mixture shall be classified as a mutagen when at least one ingredient has been classified as a category 1 or a category 2 mutagen and is present at, or above, the appropriate concentration limit as shown in Table 5.8.

Table 5.8: Cut-off values / concentration limits of ingredients of a mixture classified as germ cell mutagens that trigger classification of the mixture

Ingredient	Concentration of the ingredients that triggers classification of the mixture ^a	
	%	
	Category 1 mutagen	Category 2 mutagen
Category 1 mutagen	≥ 0.1	-
Category 2 mutagen	-	≥ 1.0

^aThe concentration limits apply to solids and liquids (expressed in % by mass) and to gases (expressed in % by volume).

From the above criteria in conjunction with Table 3.1 and Table 5.13 it can be seen that the following mutagens can be identified:

- Category 1 mutagen (ingredient concentration ≥ 0.1):
 - Waste rock: aluminium, iron, potassium;
 - Slimes: aluminium, iron, potassium;
- Category 2 mutagen (ingredient concentration ≥ 1.0):



- Waste rock: None; and
- Slimes: None.

5.2.6. Carcinogenicity

Classification of a substance as carcinogenic is based on the inherent properties of a substance and does not provide information on the level of the human cancer risk which the use of the substance may present.

Where the mixture itself has not been tested to determine its carcinogenic potential, but there are sufficient data on the individual ingredients and similar tested mixtures to adequately characterize the hazards of the mixture, these data shall be used in accordance with the agreed bridging principles given in 10.6.2.2.2 to 10.6.2.2.4 of SANS 10234. This ensures that the available data are used to the greatest extent possible in characterizing the hazards of the mixture without the necessity for additional animal testing.

A mixture shall be classified as a carcinogen when at least one ingredient has been classified as a category 1 or category 2 carcinogen and is present at, or above, the appropriate concentration limit as shown in Table 5.9.

Table 5.9: Cut-off values / concentration limits of ingredients classified as carcinogens that trigger classification of the mixture

Ingredients classified as:	Cut-off values / concentration limits of the ingredients that triggers classification of the mixture	
	%	
	Category 1 carcinogen	Category 2 carcinogen
Category 1 carcinogen	≥ 0.1	-
Category 2 carcinogen	-	≥ 0.1 ^a
	-	≥ 1.0 ^b

^a If a category 2 carcinogen ingredient is present in the mixture at a concentration between 0.1 % and 1 %, a regulatory authority could require information on the SDS for a product. Some authorities might choose a warning on the label when the ingredient is present in the mixture between 0.1 % and 1 %, while other authorities would normally not require a label in this case.

^b If a category 2 carcinogen ingredient is present in the mixture at a concentration of ≥ 1 %, both an SDS and a label would generally be expected.

From the above criteria, Table 3.1 and Table 5.13 it can be seen that although Category 1 carcinogens are present (please refer to Table 5.13); none of the mixtures contain known carcinogens at concentrations ranging from 0.1 % and above as shown in Table 3.1. Therefore, none of the mixtures are classified as being carcinogenic.

5.2.7. Reproductive toxicity

Some reproductive toxic effects cannot be clearly assigned to either impairment of sexual function and fertility or to developmental toxicity. Nevertheless, chemicals with these effects should be classified as reproductive toxicants with a general hazard statement.



Adverse effects on sexual function and fertility include, but are not be limited to, alterations to the female and male reproductive system, adverse effects on onset of puberty, gamete production and transport, reproductive cycle normality, sexual behaviour, fertility, ability to give birth, pregnancy outcomes, premature aging, or modifications in other functions that are dependent on the integrity of the reproductive systems.

Adverse effects on, or via, lactation are also included in reproductive toxicity. However, for classification purposes such effects are treated separately so that a specific hazard warning about this effect can be provided for lactating mothers.

Developmental toxicity includes any effect which interferes with normal development of the offspring, either before or after birth and that results from exposure of either parent prior to conception, or exposure of the developing offspring during prenatal development, or postnatally, to the time of sexual maturation. However, developmental toxicity is primarily intended to provide a hazard warning for pregnant women, and for men and women of reproductive capacity. Therefore, for purposes of classification, developmental toxicity essentially means adverse effects induced during pregnancy, or as a result of parental exposure. These effects can be manifested at any point in the life span of the organism. The major manifestations of developmental toxicity include:

- Death of the developing organism,
- Structural abnormality,
- Altered growth, and
- Functional deficiency.

Where the mixture itself has not been tested to determine its reproductive toxicity, but there are sufficient data on the individual ingredients and similar tested mixtures to adequately characterise the hazards of the mixture, these data shall be used in accordance with the bridging principles given in 10.7.3.2.2 to 10.7.3.2.4 of the SANS 10234 guidelines. This ensures that the available data are used to the greatest extent possible in characterizing the hazards of the mixture without the necessity for additional animal testing.

A mixture shall be classified as a reproductive toxicant when at least one ingredient has been classified as a category 1 or a category 2 reproductive toxicant and is present at, or above, the appropriate concentration limit as shown in Table 5.10.



Table 5.10: Cut-off values / concentration limits of ingredients of a mixture classified as reproductive toxicants or for effects on, or via, lactation that trigger classification of the mixture

Ingredients classified as:	Cut-off values / concentration limits of the ingredients that triggers classification of the mixture		
	%		
	Category 1 reproductive toxicant	Category 2 reproductive toxicant	Category 3 reproductive toxicant
Category 1 reproductive toxicant	≥ 0,1 (see NOTE 1)	-	-
	≥ 0,3 (see NOTE 2)	-	-
Category 2 reproductive toxicant	-	≥ 0,1 (see NOTE 3)	-
	-	≥ 3,0 (see NOTE 4)	-
Additional category for effects on, or via, lactation	-	-	≥ 0,1 (see NOTE 1)
	-	-	≥ 0,3 (see NOTE 1)

NOTE 1 If a category 1 reproductive toxicant or a substance classified in the additional category for effects on, or via, lactation is present in the mixture at a concentration between 0.1 % and 0.3 %, an SDS is required for such a product. However, a warning on the label is optional.
 NOTE 2 If a category 1 reproductive toxicant or a substance classified in the additional category for effects on, or via, lactation is present in the mixture at a concentration equal to or more than 0.3 %, an SDS is required for such a product as well as a warning on the label.
 NOTE 3 If a category 2 reproductive toxicant is present in a mixture at a concentration between 0.1 % and 3.0 %; an SDS is required for such a product. However, a warning on the label is optional.
 NOTE 4 If a category 2 reproductive toxicant is present in a mixture at a concentration equal to or more than 3.0 %, an SDS is required for such a product as well as a warning on the label.

A mixture shall be classified for effects on, or via, lactation when at least one ingredient has been classified for effects on, or via, lactation and is present at or above the appropriate cut-off value/concentration limit as shown in Table 5.10.

From the criteria in Table 5.10, the reproductive toxicity for individual elements (Table 5.13), and the concentrations summarised in Table 3.1 it can be seen that both mixtures show the presence of Category 1 reproductive toxicants:

- Category 1 reproductive toxicants ≥ 0.1 % and < 0.3 %:
 - Waste rock: none;
 - Slimes (paste): none.
- Category 1 reproductive toxicants ≥ 0.3 %:
 - Waste rock: aluminium; and
 - Slimes (paste): aluminium.

From the above it can be said that both mixtures can be classified as reproductive toxicants.



5.2.8. Specific target organ toxicity – single exposure

When no reliable evidence or test data are available on a mixture and the bridging principles (see 10.8.3.3.2 to 10.8.3.3.7 of the SANS 10234 guidelines) cannot be used for classification, the classification of the mixture shall be based on the classification of the ingredient substances. In such a case, the mixture shall be classified as a target organ toxicant (specific organ specified), following single exposure or repeated exposure (or both), when at least one ingredient:

- Has been classified as a category 1 or a category 2 target organ systemic toxicant, and
- Is present at, or above, the appropriate cut-off/concentration limit as given in Table 5.11 for hazard category 1 and hazard category 2 respectively.

The cut-off values/concentration limits and consequent classifications as given in Table 5.11 shall be applied equally and appropriately to both single- and repeated-dose target organ toxicants.

A mixture shall be classified for single- or repeated-dose toxicity (or both) independently.

When toxicants that affect more than one organ are combined, the potentiation or synergistic interactions should be considered as certain substances cause target organ toxicity at concentrations lower than 1 % when other ingredients in the mixture might be known to potentiate its toxic effect.

Care should be exercised when extrapolating the toxicity of a mixture that contains (an) ingredient(s) of hazard category 3. A cut-off value/concentration limit of 20 % has been suggested; however, it should be recognized that the cut-off value/concentration might be higher or lower depending on the hazard category 3 ingredient(s). Some effects such as respiratory tract irritation might not occur below a certain concentration while other effects such as narcotic effects might occur below the 20 % value. It is therefore necessary that expert judgement be exercised.

Table 5.11: Concentration limits / cut-off values of ingredients of a mixture classified as a specific target organ toxicant that trigger classification of the mixture

Hazard category of the ingredients	Cut-off values / concentration limits of ingredients of a mixture that trigger classification as a specific target organ toxicant .– single exposure	
	%	
	Category 1	Category 2
Category 1	≥ 1,0 (see NOTE 1) ≥ 10 (see NOTE 2)	-
Category 2	-	≥ 1,0 (see NOTE 3) ≥ 10 (see NOTE 4)
NOTE 1 If a category 1 specific target organ toxicant is present in the mixture at a concentration between 1.0 % and 10 %; an SDS is required for such a mixture. However, a warning on the label is optional. NOTE 2 If a category 1 specific target organ toxicant is present in the mixture at a concentration equal to or more than 10 %, an SDS is required for such a mixture as well as a warning on the label. NOTE 3 If a category 2 specific target organ toxicant is present in the mixture at a concentration between 1.0 % and 10 %; an SDS is required for such a mixture. However, a warning on the label is optional. NOTE 4 If a category 2 specific target organ toxicant is present in the mixture at a concentration equal to or more than 10 %, an SDS is required for such a mixture as well as a warning on the label.		



Reference to Table 5.11, Table 5.13, and Table 3.1 show that both mixtures contain specific target organ – single exposure toxicants:

- Category 1 ($\geq 1.0\%$ and $< 10\%$):
 - Waste rock: None;
 - Slimes (paste) material: None
- Category 1 ($\geq 10\%$):
 - Waste rock: None;
 - Slimes (paste) material: None.
- Category 2 ($\geq 1.0\%$ and $< 10\%$):
 - Waste rock: aluminium (4.8 %), potassium (1.1 %);
 - Slimes (paste) material: aluminium (1.8 %);
- Category 2 ($\geq 10\%$):
 - Waste rock: iron (15 %); and
 - Slimes (paste) material: iron (15 %).

Based on the above it can be said that both mixtures contain specific target organ toxicants of Category 2.

5.2.9. Specific target organ toxicity – repeated exposure

Mixtures are classified for specific target organ toxicity – repeated exposure by using the same criteria as for substances, or alternatively, as described in 10.9.3.2 to 10.9.3.4 of the SANS 10234 guideline document.

Where the mixture itself has not been tested to determine its target organ toxicity, but there are sufficient data on the individual ingredients and similar tested mixtures to adequately characterize the hazards of the mixture, these data can be used in accordance with the bridging principles given in 10.9.3.3.2 to 10.9.3.3.7 of the SANS 1024 guideline document. This ensures that available data are used to the greatest extent possible in characterizing the hazards of the mixture without the necessity of additional animal testing.

When no reliable evidence or test data are available on a mixture and the bridging cannot be applied, classification of the mixture shall be based on the classification of the ingredient substances. In such a case, the mixture shall be classified as a target organ toxicant (specific organ specified), following single exposure, repeat exposure, or both, when at least one ingredient:

- Has been classified as a category 1 or a category 2 target organ toxicant, and
- Is present at or above the appropriate cut-off values/concentration limits as given in Table 5.12.



Table 5.12: Cut-off values / concentration limits of the ingredients of a mixture classified as a specific target organ toxicant – repeated exposure that trigger classification of the mixture

Hazard category of the ingredient classified as a specific target organ system toxicant	Cut-off values/concentration limits of the ingredients of a mixture that triggers classification of a mixture as a target organ toxicant .– repeated exposure %	
	Category 1	Category 2
Category 1	≥ 1,0 (see NOTE 1)	-
	≥ 10 (see NOTE 2)	-
Category 2	-	≥ 1,0 (see NOTE 3)
	-	≥ 10 (see NOTE 4)

NOTE 1 If a category 1 target organ toxicant is present in the mixture at a concentration between 1.0 % and 10 %; an SDS is required for such a mixture. However, a warning on the label is optional.
 NOTE 2 If a category 1 target organ toxicant is present in the mixture at a concentration equal to or more than 10 %, an SDS is required for such a mixture as well as a warning on the label.
 NOTE 3 If a category 2 target organ toxicant is present in the mixture at a concentration between 1.0 % and 10 %, an SDS for such a mixture is required. However, a warning on the label is optional.
 NOTE 4 If a category 2 target organ toxicant is present in the mixture at a concentration of equal to or more than 10 %, an SDS is required for such a mixture as well as a warning on the label.

The cut-off values/concentration limits and consequent classification shall be applied equally and appropriately to both single- and repeated-dose target organ toxicants.

Mixtures shall be classified for single- or repeated-dose (or both) toxicity independently.

When toxicants affecting more than one organ system are combined, the potentiation or synergistic interactions shall be taken into account since certain substances cause target organ toxicity at concentrations less than 1 % when other ingredients in the mixture are known to potentiate its toxic effect.

Reference to Table 5.12, Table 5.13, and Table 3.1 show that all the mixtures contain specific target organ – repeated exposure toxicants:

- Category 1 (≥ 1.0 % and < 10 %):
 - Waste rock: None;
 - Slimes material: None
- Category 1 (≥ 10 %):
 - Waste rock: None;
 - Slimes material: None.
- Category 2 (≥ 1.0 % and < 10 %):
 - Waste rock: aluminium (4.8 %);
 - Slimes material: aluminium (1.8%);
- Category 2 (≥ 10 %):
 - Waste rock: iron (15 %); and
 - Slimes material: iron (15 %).



Based on the above it can be said that both mixtures contain specific target – repeated exposure organ toxicants of Category 2.

5.2.10. Health hazard classification summary

Based on the results discussed in Section 5.2.1 to 5.2.9 it can be seen that both the mixtures (waste rock and slimes/paste material) present a health hazard in one form or another.



Table 5.13: Health hazard criteria and categories for individual substances

Parameter	Acute toxicity LD ₅₀ value	Acute toxicity Classification	Skin corrosion and irritation	Eye damage & irritation	Respiratory & skin sensitisation	Germ cell mutagenicity	Carcinogenicity	Reproductive toxicity	Organ toxicity - single exposure	Organ toxicity - repeated exposure
Sulphate	1 200	Category 3	Irritant	Category 2	Category 1	N/A	N/A	N/A	Category 2	Category 2
Nitrate	1 600-9 000	Category 3	Irritant	Category 2	Category 1	N/A	Category 1B	Category 1B	Category 2	Category 2
Total Cyanide	8	Category 2	Irritant	Category 2	Category 1	N/A	N/A	Category 1B	Category 2	Category 2
Hexavalent Chromium	20-250	Category 2	Irritant	Category 2	Category 1	Category 1B	Category 1A	Category 1B	Category 2	Category 2
Fluoride	125	Category 3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Silver	50-100	Category 3	N/A	Category 2	Category 1	N/A	N/A	N/A	N/A	N/A
Arsenic	760	Category 4	Possible irritant	Category 2	Category 1	N/A	N/A	N/A	N/A	N/A
Boron	400-700	Category 4	N/A	N/A	N/A	No impact	No impact	Category 1B	Category 2	Category 2
Aluminium	200-1 000	Category 3	N/A	N/A	N/A	Category 1B	N/A	Category 1B	Category 2	Category 2
Barium	118 - 800	Category 3	N/A	N/A	N/A	No impact	No impact	No impact	Category 1	Category 1
Beryllium	120	Category 3	N/A	N/A	Category 1	N/A	Category 1A	Category 1B	Category 1	Category 1
Bismuth	5 000	Category 5	Possible irritant	Category 2	Category 1	N/A	N/A	N/A	N/A	Category 2
Calcium	6 450	Category 5	Possible irritant	Category 2	Category 1	N/A	N/A	N/A	Category 1	Category 1
Cadmium	350-3 500	Category 4	N/A	N/A	N/A	N/A	No impact	N/A	Category 2	Category 2
Cobalt	40-3 700	Category 2	Irritant	Category 2	Category 1	N/A	Category 1A	N/A	Category 2	Category 1
Chromium	20-250	Category 2	N/A	N/A	N/A	Category 1A	Category 1A	N/A	Category 1	Category 1
Copper	>2 000	Category 5	N/A	N/A	Category 1	N/A	Category 1B	Category 1A	N/A	N/A
Iron	30 000	Category 5	Possible irritant	Category 2	Category 1	N/A	N/A	N/A	Category 2	Category 2
Potassium	2 600	Category 5	Possible irritant	Category 2	Category 1	N/A	N/A	N/A	Category 2	Category 2
Lithium	526-1 530	Category 4	N/A	Category 2	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	2 800-5 440	Category 5	Irritant	Category 2	Category 1	N/A	N/A	N/A	Category 1	Category 1
Manganese	330-1 082	Category 4	N/A	N/A	N/A	Category 1B	N/A	Category 1B	Category 2	Category 1
Molybdenum	190 - 670	Category 3	No impact	No impact	No impact	N/A	Category 1A	Category 1A	Category 2	Category 1
Sodium	3 000	Category 5	Possible irritant	Category 2	Category 1	N/A	N/A	Category 1A	Category 2	Category 1
Nickel	39 - > 3 650	Category 2	Irritant	Category 2	Category 1	N/A	No impact	Category 1B	Category 2	Category 2
Phosphorus	3	Category 1	N/A	N/A	Category 1	N/A	N/A	N/A	N/A	N/A
Lead	70	Category 3	N/A	N/A	N/A	N/A	Category 1A	Category 1A	Category 1	Category 1
Sulphur	17	Category 2	N/A	N/A	Category 1	N/A	N/A	Category 1A	N/A	Category 2
Antimony	115	Category 3	N/A	Category 2	Category 1	Category 1B	Category 1A	Category 1B	Category 2	Category 2
Selenium	4.8-3 700	Category 1	Irritant	Category 2	Category 1	N/A	No impact	Category 1B	N/A	N/A
Uranium	114	Category 3	Irritant	N/A	Category 1	N/A	Category 1A	Category 1A	Category 1	Category 1
Vanadium	10-470	Category 2	No impact	Category 2	Category 1	No impact	N/A	Category 1A	Category 2	Category 2
Zinc	240-1 700	Category 3	Possible irritant	N/A	Category 1	Category 1B	Category 1B	Category 1A	Category 1	Category 1
Mercury	0.23	Category 1	N/A	N/A	N/A	Category 1B	Category 1A	Category 1A	Category 1	Category 1
Chloride	3 000	Category 5	Possible irritant	Category 2	N/A	Category 1B	N/A	N/A	N/A	N/A

N/A = not available

Where LD₅₀ values form a range that spans more than one guideline range specified in SANS 10234 the most severe category is chosen for acute toxicity classification



5.3. Hazards to the aquatic environment

The primary objective for the classification of substances and mixtures as hazardous to the environment is to alert the user to the hazards these substances and mixtures present to ecosystems. Although the present criteria refer by and large to aquatic ecosystems, it is known that certain substances and mixtures simultaneously, or alternatively, affect other ecosystems that range from soil microflora to primates.

The basic elements used for the classification of substances and mixtures as hazardous to the aquatic environment are:

- Acute aquatic toxicity;
- Bioaccumulation;
- Degradation (abiotic or biotic) for organic chemicals; and
- Chronic aquatic toxicity.

Substances or mixtures hazardous to the aquatic environment can be allocated to three hazard categories of acute toxicity (please refer to Table 5.15) and four hazard categories of chronic toxicity (please refer to Table 5.16). The hazard categories of acute toxicity and the hazard categories of chronic toxicity are applied independently. The classification of a substance or mixture in hazard categories 1 to 3 of acute toxicity is based on acute toxicity data only (EC_{50} or LC_{50}). The classification of a substance or mixture in hazard categories 1 to 4 of chronic toxicity combines two types of information, that is, acute toxicity data and environmental fate data (degradability and bioaccumulation data).

Following SANS 10234 (11.2.1.4), the lowest of the available toxicity values shall be used for the allocation of (a) hazard category(ies). There might be circumstances, however, when a weight of evidence approach needs to be used. Acute toxicity forms the basis for classification of substances or mixtures as hazardous to the environment since the data are readily available and the test methods are standardized.

Acute toxicity represents a key property in defining the hazard where transport of large quantities of a substance or mixture might give rise to short-term dangers arising from accidents or major spillages.

A packaged substance or mixture that has an acute toxicity ($L(E)C_{50}$) equal to or less than 1 mg/L can be considered as hazardous to the environment. At toxicity levels above 1 mg/L, the short-term toxicity does not reflect the hazards that arise from low concentrations causing effects over a longer time scale. As chronic toxicity data are not available for many substances and mixtures, it is necessary to use available acute toxicity data to estimate chronic toxicity. The intrinsic properties of a lack of rapid degradability or a potential to bio-concentrate (or both) in combination with acute toxicity can be used to assign a substance or mixture to a chronic hazard category. Classification of a substance or mixture in a chronic hazard category is not necessary if the NOECs is greater



than 1 mg/L. Likewise, a chronic toxicity $L(E)C_{50}$ greater than 100 mg/L is considered as insufficient to warrant classification.

The assignment of a chronic hazard category is based on acute toxicity data in combination with a lack of rapid degradation or a potential to bio-accumulate (or both).

The “relevant components” of a mixture are those components present at a concentration $\geq 1\%$, by mass, unless there is a presumption (for example, in the case of highly toxic components) that a component at a concentration less than 1%, by mass, is still relevant for classification of the mixture as hazardous to the aquatic environment.

The aquatic toxicity testing that was done on sample “Bruce WRD A” (details of the sample can be obtained from Table 2.1) included a screening test to determine whether the material is potentially hazardous. Should the screening test results indicate that the material is potentially hazardous definitive testing is done in order to determine the LC_{50}/EC_{50} values.

The screening tests that were performed as part of this project included:

- *Vibrio fischeri* bioluminescent test, (EN ISO 11348-3. 2007);
- *Selenastrum capricornutum* growth inhibition test, (OECD Guideline 201. 2006);
- *Daphnia pulex* acute toxicity test, (US EPA. 2002); and
- *Poecilia reticulata* acute toxicity test. (US EPA. 1996).

The screening test results are used to calculate the toxicity unit (TUa) for each test. The TUa is calculated as 100 % (full strength effluent expressed as percentage) divided by the effective concentration or LC_{50} expressed as percentage sample dilution (e.g. *Daphnia pulex* and *Poecilia reticulata* acute toxicity tests) and EC_{50} (e.g. *Vibrio fischeri* bioluminescent test and *Selenastrum capricornutum* growth inhibition test) (Tonkes & Baltus, 1997). If there is not sufficient toxicity in a sample to enable the determination of an EC_{50}/LC_{50} value, then an acute toxicity unit of <1 is assigned to the sample.

Table 5.14: Toxicity Units (after Tonkes and Baltus, 1997)

Toxicity Unit	Conclusion
<1	Limited to Not Acutely Toxic
1 – 2	Negligibly Acutely Toxic
2 – 10	Mildly Acutely Toxic
10 – 100	Acutely Toxic
>100	Highly Acutely Toxic

The screening test results are summarised in Table 5.17. The screening test results show toxicity unit (TUa) values of < 1 for all tests. This shows that the material is non-hazardous to the aquatic environment from both an acute and a chronic toxicity point of view.



Table 5.15: Hazard categories of acute toxicity for substances hazardous to the aquatic environment

Hazard category of acute toxicity	Classification criteria
1	96 h LC_{50} (for fish) ≤ 1 mg/L 48 h EC_{50} (for Crustacea) ≤ 1 mg/L 72 h or 96 h ErC_{50} (for algae or other aquatic plants) ≤ 1 mg/L
2	96 h LC_{50} (for fish) > 1 to ≤ 10 mg/L and/or 48 h EC_{50} (for Crustacea) > 1 to ≤ 10 mg/L and/or 72 h or 96 h ErC_{50} (for algae or other aquatic plants) > 1 to ≤ 10 mg/L
3	96 h LC_{50} (for fish) > 10 .– ≤ 100 mg/L and/or 48 h EC_{50} (for Crustacea) > 10 .– ≤ 100 mg/L and/or 72 h or 96 h ErC_{50} (for algae or other aquatic plants) > 10 .– ≤ 100 mg/L

Table 5.16: Hazard categories of chronic toxicity for substances hazardous to the aquatic environment

Hazard category of chronic toxicity	Classification criteria
1	a) 96 h LC_{50} (for fish) ≤ 1 mg/L; and/or b) 48 h EC_{50} (for Crustacea) ≤ 1 mg/L; and/or c) 72 h or 96 h ErC_{50} (for algae or other aquatic plants) ≤ 1 mg/L; and d) the substance is not rapidly degradable; and/or e) the $\log Kow$ ≥ 4 (unless the BCF < 500).
2	a) 96 h LC_{50} (for fish) > 1 to ≤ 10 mg/L and/or b) 48 h EC_{50} (for Crustacea) > 1 to ≤ 10 mg/L; and/or c) 72 h or 96 h ErC_{50} (for algae or other aquatic plants) > 1 to ≤ 10 mg/L; and d) the substance is not rapidly degradable; and/or e) the $\log Kow$ ≥ 4 (unless the BCF < 500); f) unless the chronic NOECs are > 1 mg/L
3	a) 96 h LC_{50} (for fish) > 10 to ≤ 100 mg/L; and/or b) 48 h EC_{50} (for Crustacea) > 10 to ≤ 100 mg/L; and/or c) 72 h or 96 h ErC_{50} (for algae or other aquatic plants) > 10 to ≤ 100 mg/L; and d) the substance is not rapidly degradable; and/or e) the $\log Kow$ ≥ 4 (unless the BCF < 500); and f) unless the chronic NOECs are > 1 mg/L
4	Poorly soluble substances for which no acute toxicity is recorded at levels up to the water solubility, that are not rapidly degradable and have a $\log Kow \geq 4$, indicating a potential to bio-accumulate are to be classified in this category, unless other scientific evidence shows classification to be unnecessary. Such evidence would include an experimentally determined BCF < 500 , or a chronic toxicity NOECs > 1 mg/L, or evidence of rapid degradation in the environment.



Table 5.17: Screening acute toxicity test results

	Method number	Sample reference number(s) and description
Physical and chemical data		
pH	M 09	6.74
Conductivity (µS/cm)	M 05	42.7
Dissolved oxygen concentration (mg/l)	“Not SANAS Accredited”	5.53
Total residual chlorine (present✓/not present ×)		×
Temperature (°C)		20
Toxicity test results		
15 minute <i>Vibrio fischeri</i> bioluminescent screening test (average % inhibition (-) or stimulation (+))	T 01	-52
30 minute <i>Vibrio fischeri</i> bioluminescent screening test (average % inhibition (-) or stimulation (+))		-27
30 minute <i>Vibrio fischeri</i> bioluminescent test toxicity unit (TUa)		<1
72h <i>Selenastrum capricornutum</i> growth inhibition screening test (% growth inhibition (-) or growth stimulation (+))	T 02	-12
72h <i>Selenastrum capricornutum</i> growth inhibition test toxicity unit (TUa)		<1
24h <i>Daphnia pulex</i> acute toxicity screening test (% mortality)	T 03	10
48h <i>Daphnia pulex</i> acute toxicity screening test (% mortality)		35
48h <i>Daphnia pulex</i> acute toxicity test toxicity unit (TUa)		<1
96h <i>Poecilia reticulata</i> acute toxicity screening test (% mortality)	T 04	0
96h <i>Poecilia reticulata</i> acute toxicity test toxicity unit (TUa)		<1



5.4. Material safety data sheet

SANS 10234 specifies that a safety data sheet (SDS) shall be produced for all substances and mixtures which meet the harmonized criteria for physical, health or environmental hazards under the GHS and for all mixtures which contain substances that meet the criteria for carcinogenic, toxic to reproduction or target organ toxicity in concentrations exceeding the cut-off values/concentration limits specified by the criteria for mixtures. The table is reproduced in this document for ease of reference – please refer to Table 5.18. It can be seen that the health and aquatic hazards are screened using generic concentration limit values of 0.1 % or 1.0 % depending on the hazard.

Table 5.18: Cut-off values / concentration limits for hazard classes

Hazard Class	Cut-off value (concentration limit) %
Acute toxicity	≥1.0
Skin corrosion	≥1.0
Skin irritation	≥1.0
Serious eye damage	≥1.0
Eye irritation	≥1.0
Respiratory sensitisation	≥1.0
Skin sensitisation	≥1.0
Mutagenicity:	≥1.0
Category 1	≥0.1
Category 2:	≥1.0
Carcinogenicity	≥0.1
Reproductive toxicity	≥0.1
Target organ systemic toxicity:	≥1.0
Single exposure	≥1.0
Repeat exposure	≥1.0
Hazardous to the aquatic environment	≥1.0

In order to evaluate the hazards according to the three pathways to health hazards (oral, dermatological, and respiratory), different criteria have to be considered. In terms of the dermatological and respiratory pathways consideration should be given to the total concentrations of the elements in the rock material. However, the solid rock material on the WRDs will not pose a direct health hazard through oral ingestion, and here reference should be made to the leachable concentrations as it is the leach solution that can be ingested orally.

5.4.1. Total concentrations

The total concentrations of the material as determined during the initial total concentration testing are summarised in Table 3.1. The elements and facilities that do not comply with the 1 % guideline set in SANS 10234 for acute toxicity, skin corrosion, skin irritation, serious eye damage, eye irritation, respiratory sensitisation, mutagenicity (category 2), and target organ system toxicity (single and repeat exposure) are summarised in Table 5.19.



In addition to this, the facilities and elements that do not comply with the SANS 10234 guideline for mutagenicity (Category 1), carcinogenicity, and reproductive toxicity of 0.1 % are also included. It should be noted that the facilities and elements listed as not complying with the 1 % guideline value do not comply with the 0.1 % guideline by default.

Table 5.19: Summary of total concentrations compared to SANS 10234 generic guidelines

Facility	Exceed 1 % guideline	Exceed 0.1 % guideline
King WRD	Al – 5.55 %; Fe - >15 %; K – 1.65 %.	Ba – 0.18 %; Ca – 0.1 %; Mg – 0.125 %; Ti – 0.21 %.
Bruce WRD	Al – 6.95 %; Fe - >15 %; K – 2.0 %.	Mg – 0.13 %; Ti – 0.37 %.
King Paste	Al – 1.8 %; Fe - >15 %.	K – 0.4 %.
Bruce BC11	Al – 3.9 %; Fe - >15 %.	K – 0.33 %; Ti – 0.135 %.
Parsons discard	Al – 2.7 %; Fe - >15 %.	K – 0.395 %.

From Table 5.19 it can be seen that all the facilities can be classified as hazardous based on individual element total concentrations.

However, it has to be taken into account that the solid rock material on the WRDs will not pose a direct health hazard through oral ingestion, dermatological processes, or respiratory processes. Rather, it is the element concentrations from leachate emanating from the surface stockpiles following rainfall recharge onto WRDs, or wet deposition on slimes dams, that will be representative of the water quality that has the potential to eventually reach, and impact, the neighbouring groundwater or surface water users.

5.4.2. Leachable concentrations

As mentioned above, it has to be taken into account that the solid rock material will not pose a direct health hazard through oral ingestion, dermatological processes, or respiratory processes. Rather, it is the element concentrations from leachate emanating from the surface stockpiles following rainfall recharge onto WRDs, or wet deposition on slimes dams, that will be representative of the water quality that has the potential to eventually reach, and impact, the neighbouring groundwater or surface water users. Therefore, the leachable concentrations have to be considered when the SANS 10234 classification is made.

Comparing the leach concentrations obtained from leach testing of the rock material (please refer to Table 3.2) to the SANS 10234 generic guidelines of 1.0 % or 0.1 % concentrations summarised in Table 5.18 it can be seen that none of the elements exceed the SANS 10234 guideline limits of 0.1 and 1 % concentration.



Based on the leach test concentrations the material can be classified as being **non-hazardous for health impacts**.

5.4.3. Material safety data sheet (MSDS)

The MSDS can be viewed in Appendix C.



6. Conclusions

6.1. Initial round of testing

6.1.1. Total concentration test results

The test results for the total concentrations (TC) show that hexavalent chromium (King and Parsons waste material); manganese (Parsons waste material) and lead (King and Bruce waste material) exceed the TCT0 guidelines in some of the samples. Barium and arsenic exceed the TCT0 guidelines in all the samples. All the samples comply with the TCT1 guidelines.

It should be noted that all elements that exceed the TCT0 guideline values still comply with the TCT1 guideline values.

6.1.2. Leachable concentration test results

In general the elements comply with the LCT0 guidelines, except nitrate (King and Bruce waste material), barium (King, Bruce and Parsons waste material), manganese (King Paste) and zinc (King waste material).

It should be noted that all elements that exceed the LCT0 guideline values still comply with the LCT1 guideline values.

6.2. Verification round of testing

6.2.1. Total concentration test results

There are some discrepancies in the results from the two rounds of analysis:

- Arsenic concentrations from the verification testing are much lower than the initial round of testing, and do not exceed the TCT0 guideline value of 5.8 mg/L;
- Fluoride concentrations from the verification testing are much higher than the initial round of testing, and exceed the TCT0 guideline value of 100 mg/L;
- Cadmium concentrations from the verification testing are much higher than the initial round of testing, and exceed the TCT0 guideline value of 7.5 mg/L;
- Manganese concentrations from the verification testing are much lower than the initial round of testing, and do not exceed the TCT0 guideline value of 5.8 mg/L

The reason for the discrepancies in results between the two laboratories is not known with certainty, but is most probably associated with the difference methods used by the two laboratories. Factors of variance include acids used, temperatures at which the testes were done, time to completion of tests, and other laboratory management factors.



There are a number of elements that exceed the TCT0 guideline values, including fluoride, barium, cadmium, lead.

6.2.2. Leachable concentration test results

- The barium concentration exceeds the LCT0 guideline value, but not in the same sample. In addition, the boron, lead and selenium concentrations also exceed the LCT0 guideline value.

6.3. Discussion of leach test analysis results

At the Bruce WRD facility the average barium concentration in leachate exceeds the LCT0 guideline values only slightly (by 0.145 mg/L), and it would be reasonable to assume that dilution with groundwater in the underlying and surrounding aquifers will reduce the leachate concentration to below that LCT0 guideline value, assuming that the barium concentration in the natural groundwater complies with the LCT0 guidelines in the first place – no information on this is available.

Facilities where additional studies have to be performed to determine whether dilution of the leachate with groundwater will yield a combined groundwater quality compliant with LCT0 are:

- King WRD;
- King Paste;
- Bruce BC11; and
- Parsons Discard.

These studies would include:

- Determining the natural groundwater quality in the area in terms of barium concentrations;
- Possibly a basic groundwater contaminant model to determine the cumulative impact of leachate from the facilities on the underlying and surrounding aquifers should the natural barium and manganese concentrations in the groundwater be below LCT0 guideline values.

6.4. Waste classification based on TC and LC test analyses

Based on the above, the material from all the different sites is classified as Type 3 Waste following the GN 635 classification system.

This classification is mostly based on the results of the total concentration testing results where there are elements that exceed the TCT0 guidelines for all the samples. As discussed in Section 3.3 the Bruce WRD facility may not be impacted when taking into consideration dilution with natural groundwater based on the leach concentration results.



6.5. Natural groundwater quality

The groundwater in the Khumani area is naturally high in nitrate with concentrations ranging between 30 mg/L and 81 mg/L in the majority of the monitoring boreholes.

The sulphate concentrations in monitoring boreholes BK12 and BK17 are measured at 300 and 279 mg/L respectively. These values exceed the LCT0 guideline value of 250 mg/L.

Manganese and zinc form part of the 4 main elements to be considered when assessing the impact of leachate from the surface facilities towards the aquifers. The measured concentrations from all the samples comply with the LCT0 guideline values. The manganese concentrations are mostly in the order of 0.001 to 0.006 mg/L with BK36 showing a concentration of 0.11 mg/L. Zinc concentrations are consistently below detection limit (<0.005 mg/L).

Natural barium concentrations in the area fall below detection limit (<0.001 mg/L). The borehole at the paste disposal area shows an elevated barium concentration which can be attributable to the nearby paste facility. The barium concentration in this borehole is measured at 0.835 mg/L, which is one order of magnitude less than the source concentration at the paste facility. This indicates the influence of dilution of the source fluids with uncontaminated natural groundwater.

6.6. Comparison of natural groundwater quality to the expected leach quality

Based on the available groundwater quality data and the leach test results little impact is expected on the groundwater quality in the underlying and surrounding aquifers, except:

- All facilities have the potential to increase the aluminium and sodium concentrations due to seepage into the underlying aquifers. The resultant water will still comply with LCT0 guideline values;
- All facilities, except the BC11 facility, can be expected to have an impact on the barium concentrations in the groundwater. The barium concentrations are expected to increase up to 1.7 to 2.3 mg/L over time as the plumes develop and ultimately the barium concentrations will exceed the LCT0 guidelines;
- At the King WRD potassium concentrations could increase. There are no LCT0 guideline values to compare it against;
- The King Paste facility could pose some risk of increasing the manganese concentration in the underlying aquifers up to 1.7 mg/L. This value exceeds the LCT0 guideline value;
- The Bruce BC11 and King WRD facilities could cause an increase in the zinc concentrations in the underlying aquifers. At the King WRD facility the leachate could exceed the LCT0 guideline value slightly (0.085 mg/l vs 0.07 mg/L). At the Bruce BC11 facility the impact could be more prominent, with concentrations increasing to 0.175 mg/L (a factor of 2.5).



6.7. Landfill site recommendation

Following the GN 636 guideline, the material from all the facilities may only be disposed of at a Class C landfill designed in accordance with Section 1(1) and (2) of the GN 636 Norms and Standards, or, subject to Section 3(4) it may be disposed of at a landfill site designed in accordance with the requirements for a GLB+ landfill as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998).

6.8. SANS 10234 classification

6.8.1. Physical hazards

- The rock material stored on site is not considered to be explosive. In addition to this, the water used in the process on site is not explosive;
- The rock material stored on site is not considered to be a flammable gas. In addition to this, the water used in the process on site is a flammable gas;
- The material stored on site is not considered to be flammable. In addition to this, the water used in the process on site is not a flammable aerosol. Therefore, the material does not have to be considered for classification as flammable aerosols;
- Neither the rock material stored on site, nor the water used in the process, is an oxidising gas;
- Neither the rock material stored on site, nor the water used in the process, is a gas under pressure;
- Neither the rock material stored on site, nor the water used in the process, is considered to be flammable liquids;
- Neither the rock material stored on site, nor the water used in the process, are flammable solids;
- Neither the rock material stored on site, nor the water used in the process, is considered to be self-reactive;
- Neither the rock material stored on site, nor the water used in the process, is considered to be pyrophoric;
- As can be deduced from the fact that the material has been stored on site for years and no spontaneous combustion has taken neither the rock material stored on site, nor the water used in the process, is considered to be prone to self-heating and spontaneous combustion;
- Neither the rock material stored on site, nor the water used in the process, is considered to be prone to emit flammable gasses on contact with water;
- Neither the rock material stored on site, nor the water used in the process, is considered to be an oxidising substance;
- Neither the rock material stored on site, nor the water used in the process, is classified as organic peroxides;
- Neither the rock material stored on site, nor the water used in the process is corrosive to metals;



- The various material stored on site do not pose physical hazards as grouped or classed in the SANS 10234 guideline. Neither the rock material, nor the water used in the wash process, poses an explosive, oxidising, flammable or other risk. Therefore, the material is **classified as non-hazardous** in terms of physical hazards.

6.8.2. Health hazards

- The acute toxicity estimate according to the oral route can be calculated for the waste rock and the slimes (paste) material:
 - Waste rock: 0.062; and
 - Slimes: 0.092
- From the above both mixtures are classified as Category 1 (the highest toxicity category) for acute health effects;
- In order to determine the skin corrosion and irritant hazard the 1 % concentration rule is applied, from this aluminium, iron, and potassium have to be include in the assessment. In addition, other chemicals re considered to be an irritant based on literature publications. These include sulphate, nitrate, cyanide, hexavalent chromium, arsenic, bismuth, calcium, cobalt, magnesium, sodium, nickel, selenium, uranium, zinc, and chloride. The calculated sum of concentrations of the elements listed above are summarised below for each of the mixtures:
 - Waste rock: 20.8 %; and
 - Paste (Slimes): 19.8 %.
- From the above results both mixtures are classified as hazardous in terms of skin corrosion or irritation;
- To determine the risk for eye damage and irritation the 1 % concentration rule is again applied. In addition, reference is made to elements that have been identified as a risk based on research. The elements to be included in the assessment are aluminium, iron, potassium, sulphate, nitrate, cyanide, hexavalent chromium, silver, arsenic, bismuth, calcium, cobalt, lithium, magnesium, sodium, nickel, antimony, selenium, vanadium, and chloride. The calculated sum of concentrations of the elements listed above are summarised below for each of the “mixtures”:
 - Waste rock: 4.8 %; and
 - Slimes (paste): 20.2 %.
- From the above results both mixtures are classified as Category 1 hazardous to the eye.
- For each mixture there are individual substances (elements) that are classified as a skin or a respiratory sensitizer and are present at, or above, the concentration limits shown in Table 5.7. These elements can be summarised:
 - Skin & respiratory sensitizers ≥ 0.1 and < 1.0 %:
 - Waste rock: none;
 - Slimes: potassium;
 - Skin & respiratory sensitizers ≥ 1.0 %:
 - Waste rock: iron, potassium; and
 - Slimes: iron.



- From the above both the waste rock and slimes or paste material “mixtures” can be classified as hazardous in terms of respiratory and skin sensitization hazards.
- The following mutagens are identified:
 - Category 1 mutagen (ingredient concentration ≥ 0.1):
 - Waste rock: aluminium, iron, potassium;
 - Slimes (paste): aluminium, iron, potassium;
 - Category 2 mutagen (ingredient concentration ≥ 1.0):
 - Waste rock: None; and
 - Slimes (paste): None.
- Although Category 1 carcinogens are present, none of the mixtures contain known carcinogens at concentrations ranging from 0.1 % and above. Therefore, none of the mixtures are classified as being carcinogenic;
- Both mixtures show the presence of Category 1 reproductive toxicants:
 - Category 1 reproductive toxicants ≥ 0.1 % and < 0.3 %:
 - Waste rock: none;
 - Slimes (paste): none.
 - Category 1 reproductive toxicants ≥ 0.3 %:
 - Waste rock: aluminium; and
 - Slimes (paste): aluminium.
- Both mixtures contain specific target organ – single exposure toxicants:
 - Category 1 (≥ 1.0 % and < 10 %):
 - Waste rock: None;
 - Slimes (paste) material: None
 - Category 1 (≥ 10 %):
 - Waste rock: None;
 - Slimes (paste) material: None.
 - Category 2 (≥ 1.0 % and < 10 %):
 - Waste rock: aluminium (4.8 %), potassium (1.1 %);
 - Slimes (paste) material: aluminium (1.8 %);
 - Category 2 (≥ 10 %):
 - Waste rock: iron (15 %); and
 - Slimes (paste) material: iron (15 %);
- Both mixtures contain specific target organ – repeated exposure toxicants:
 - Category 1 (≥ 1.0 % and < 10 %):
 - Waste rock: None;
 - Slimes material: None
 - Category 1 (≥ 10 %):
 - Waste rock: None;
 - Slimes material: None.
 - Category 2 (≥ 1.0 % and < 10 %):
 - Waste rock: aluminium (4.8 %);
 - Slimes material: aluminium (1.8%);
 - Category 2 (≥ 10 %):
 - Waste rock: iron (15 %); and



-
- Slimes material: iron (15 %).

6.8.3. Hazards to the aquatic environment

Laboratory testing shows that the material is non-hazardous to the aquatic environment from both an acute and a chronic toxicity point of view.

6.8.4. General comment

It should be noted that the hazard classification is influenced by the locality where the material is stored or used. The classification is applicable to the conditions are Black Rock as they are now.

Should the material be used off site, the material be used for some other purpose, or moved to within close range of surface water bodies (for example the calccrete may be sold off-site for use somewhere else in construction where it could be located close to, or within a surface stream) the classification will have to be revisited to ensure it is still applicable.



**APPENDIX A:
LABORATORY ANALYSIS CERTIFICATES
INITIAL ROUND OF TESTING**



SGS

TEST REPORT

CLIENT DETAILS

Contact: **Martiens Prinsloo**
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Project: **(Not specified)**
Order Number: **ARM.15.008-SGS**
Samples: **34**
Sample matrix: **SOIL**

LABORATORY DETAILS

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Laboratory Manager: **Martin Olivier**
SGS Reference: **JB15-06547 R0**
Report Number: **0000009394**
Date Received: **2015/05/12 11:50:52AM**
Date Reported: **2015/06/11 09:32:30AM**

COMMENTS

The document is issued in accordance with SANAS's accreditation requirements.
Accredited for compliance with ISO/IEC 17025. SANAS accredited laboratory T0107.



Analysis of metals, anions and total cyanide was subcontracted.

SIGNATORIES

Greg Ondrejko
Technical Supervisor/Technical Signatory

Martin Olivier
Operations Manager/Technical Signatory



ANALYTICAL REPORT

JB15-06547 R0

Report number 000009394
Client reference: ARM.15.008-SGS

Sample Number	JB15-06547.001	JB15-06547.002	JB15-06547.003	JB15-06547.004	JB15-06547.005
Sample Name	King Waste Rock Dump A Soil	King Waste Rock Dump B Soil	Bruce Waste Dump A Soil	Bruce Waste Dump B Soil	King Paste Soil
Sample Matrix					

Parameter **Units** **LOR**
Soluble Anions in Soil by Ion Chromatography Method: ME-AN-014

Parameter	Units	LOR	JB15-06547.001	JB15-06547.002	JB15-06547.003	JB15-06547.004	JB15-06547.005
Nitrate*	mg/kg	5	171	222	164	220	29
Sulphate*	mg/kg	5	74	84	25	32	56

Fluoride on soils by Ion Selective Electrode Method: ME-AN-021

Parameter	Units	LOR	JB15-06547.001	JB15-06547.002	JB15-06547.003	JB15-06547.004	JB15-06547.005
Fluoride by ISE raw result*	mg/l	0.2	0.68	0.52	0.43	0.37	0.26

Hexavalent Chromium in Soil Method: ME-AN-040

Parameter	Units	LOR	JB15-06547.001	JB15-06547.002	JB15-06547.003	JB15-06547.004	JB15-06547.005
Hexavalent Chromium*	mg/kg	0.4	12	<0.4	<0.4	<0.4	<0.4

Total Petroleum Hydrocarbons Banded on Soils Method: ME-AN-035

Parameter	Units	LOR	JB15-06547.001	JB15-06547.002	JB15-06547.003	JB15-06547.004	JB15-06547.005
TPH Banded C28-40*	mg/kg	40	<40.00	-	<40.00	-	-
TPH Banded C10-C28 Total	mg/kg	142	<142.00	-	<142.00	-	-
TPH Banded C10-C40 Total*	mg/kg	182	<182.00	-	<182.00	-	-

SUB_SGS Booyens Method: SUB

Parameter	Units	LOR	JB15-06547.001	JB15-06547.002	JB15-06547.003	JB15-06547.004	JB15-06547.005
Aluminium*	%	0.01	5.6	5.5	7.1	6.8	1.8
Arsenic*	ppm	1	101	120	50	45	39
Silver*	ppm	0.3	1.3	0.40	0.60	0.50	<0.30
Boron*	ppm	0.2	18	20	22	25	27
Barium*	ppm	1	1585	2013	425	451	693
Dysprosium*	ppm	0.06	7.1	8.0	5.6	6.1	1.6
Erbium*	ppm	0.05	3.6	4.4	3.2	3.3	0.91
Europium*	ppm	0.05	2.2	2.5	2.1	2.3	0.65
Gadolinium*	ppm	0.05	8.0	9.3	7.7	8.1	2.1
Holmium*	ppm	0.05	1.2	1.4	0.97	0.92	0.15
Neodymium*	ppm	0.1	39	49	51	55	14
Praseodymium*	ppm	0.05	10	13	14	15	3.9
Samarium*	ppm	0.1	7.6	8.9	9.1	9.4	2.4
Thulium*	ppm	0.05	0.42	0.55	0.34	0.31	<0.050
Beryllium*	ppm	0.1	1.1	1.3	1.3	1.4	0.40
Bismuth*	ppm	0.04	0.86	0.74	6.4	1.5	0.49
Calcium*	%	0.01	0.10	0.10	0.080	0.070	0.040
Cadmium*	ppm	0.02	0.080	0.040	0.050	0.040	0.040
Cerium*	ppb	0.05	82	103	122	122	43
Cobalt*	ppm	0.1	6.2	7.3	11	11	4.4
Cesium*	ppm	0.05	1.7	1.8	2.3	2.2	0.51
Chromium*	ppm	1	121	78	157	150	81
Gallium*	ppm	0.5	13	13	18	17	4.5
Germanium*	ppm	0.1	2.5	2.7	1.1	0.60	0.20
Copper*	ppm	0.5	<0.50	<0.50	6.9	6.3	<0.50
Iron*	%	0.01	>15	>15	>15	>15	>15
Indium*	ppm	0.02	0.060	0.060	0.070	0.060	0.020
Lanthanum*	ppb	0.1	44	55	65	65	20
Lutetium*	ppm	0.01	0.50	0.62	0.42	0.43	0.15
Potassium*	%	0.01	1.7	1.6	2.1	1.9	0.40
Lithium*	ppm	1	258	223	39	41	27
Hafrnium*	ppm	0.02	3.8	4.9	4.5	4.2	0.82
Magnesium*	%	0.01	0.12	0.13	0.14	0.12	0.030
Mercury*	ppm	0.01	0.31	0.13	0.12	0.13	0.090
Manganese*	ppm	2	484	547	459	500	709
Molybdenum*	ppm	0.05	1.7	1.9	1.8	1.8	2.0
Sodium*	%	0.01	0.050	0.040	0.040	0.040	0.020
Niobium*	ppm	0.1	14	16	17	19	1.8
Nickel*	ppm	0.5	28	26	47	45	35
Phosphorus*	ppm	50	465	539	568	618	372
Lead*	ppm	0.5	33	35	38	37	14
Rubidium*	ppm	0.2	63	61	67	63	13



ANALYTICAL REPORT

JB15-06547 R0

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Sample Number	JB15-06547.001	JB15-06547.002	JB15-06547.003	JB15-06547.004	JB15-06547.005
Sample Name	King Waste Rock Dump A Soil	King Waste Rock Dump B Soil	Bruce Waste Dump A Soil	Bruce Waste Dump B Soil	King Paste Soil
Sample Matrix					

Parameter Units LOR
SUB_SGS Booyens Method: SUB (continued)

Parameter	Units	LOR	JB15-06547.001	JB15-06547.002	JB15-06547.003	JB15-06547.004	JB15-06547.005
Sulphur ^A	%	0.01	0.050	0.060	0.030	0.030	0.030
Antimony ^A	ppm	0.05	7.5	8.9	3.5	2.9	2.4
Scandium ^A	ppm	0.5	9.4	11	14	13	5.1
Selenium ^A	ppm	2	<2.0	<2.0	<2.0	<2.0	<2.0
Tin ^A	ppm	0.3	3.4	3.7	5.2	4.7	0.70
Strontium ^A	ppm	0.5	232	280	410	473	296
Tantalum ^A	ppb	0.05	1.9	1.7	2.2	1.8	0.20
Terbium ^A	ppm	0.05	1.2	1.4	1.0	1.1	0.19
Tellurium ^A	ppm	0.05	1.2	1.5	0.47	0.38	0.17
Thorium ^A	ppm	0.2	10	10	13	13	3.1
Titanium ^A	%	0.01	0.21	0.21	0.35	0.39	0.070
Thallium ^A	ppm	0.02	0.40	0.40	0.30	0.30	<0.020
Uranium ^A	ppm	0.05	1.5	1.5	1.7	1.6	0.65
Vanadium ^A	ppm	2	98	96	142	129	82
Ytterbium ^A	ppm	0.1	2.5	3.1	2.1	2.2	0.70
Yttrium ^A	ppm	0.1	33	41	27	27	8.6
Tungsten ^A	ppm	0.1	2.8	2.1	13	2.9	0.20
Zinc ^A	ppm	1	46	39	28	23	20
Zirconium ^A	ppm	0.5	136	147	164	159	30

SUB_Anions in Soil for SASLP Method: SUB

Parameter	Units	LOR	JB15-06547.001	JB15-06547.002	JB15-06547.003	JB15-06547.004	JB15-06547.005
Chloride ^A	ppm	500	<500	<500	<500	<500	<500

SUB_Total Cyanide in soil Method: SUB

Parameter	Units	LOR	JB15-06547.001	JB15-06547.002	JB15-06547.003	JB15-06547.004	JB15-06547.005
Total Cyanide ^A	mg/kg	0.01	<0.010	0.050	0.040	0.050	<0.010

Sample Number	JB15-06547.006	JB15-06547.007	JB15-06547.008	JB15-06547.009	JB15-06547.010
Sample Name	Bruce BC11 A Soil	Bruce BC11 B Soil	Parsons Discard Dump A Soil	Parsons Discard Dump B Soil	1 Calcrete Soil
Sample Matrix					

Parameter Units LOR
Soluble Anions in Soil by Ion Chromatography Method: ME-AN-014

Parameter	Units	LOR	JB15-06547.006	JB15-06547.007	JB15-06547.008	JB15-06547.009	JB15-06547.010
Nitrate ^A	mg/kg	5	<5	<5	21	21	108
Sulphate ^A	mg/kg	5	<5	<5	82	66	161



ANALYTICAL REPORT

JB15-06547 R0

Report number 000009394
Client reference: ARM.15.008-SGS

Sample Number	JB15-06547.006	JB15-06547.007	JB15-06547.008	JB15-06547.009	JB15-06547.010
Sample Name	Bruce BC11 A	Bruce BC11 B	Parsons Discard	Parsons Discard	1 Calcrete
Sample Matrix	Soil	Soil	Dump A Soil	Dump B Soil	Soil

Parameter **Units** **LOR**
Fluoride on soils by Ion Selective Electrode Method: ME-AN-021

Fluoride by ISE raw result*	mg/l	0.2	0.26	0.27	0.21	<0.20	1.2
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Hexavalent Chromium in Soil Method: ME-AN-040

Hexavalent Chromium*	mg/kg	0.4	2.1	<0.4	2.6	8.7	<0.4
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Total Petroleum Hydrocarbons Banded on Soils Method: ME-AN-035

TPH Banded C28-40*	mg/kg	40	-	-	-	-	-
TPH Banded C10-C26 Total	mg/kg	142	-	-	-	-	-
TPH Banded C10-C40 Total*	mg/kg	182	-	-	-	-	-

SUB_SGS Booyensens Method: SUB

Parameter	Units	JB15-06547.006	JB15-06547.007	JB15-06547.008	JB15-06547.009	JB15-06547.010	
Aluminium*	%	0.01	3.9	3.9	3.8	1.6	1.6
Arsenic*	ppm	1	24	23	26	23	10
Silver*	ppm	0.3	0.30	0.60	0.40	<0.30	0.40
Boron*	ppm	0.2	18	29	21	23	28
Barium*	ppm	1	248	223	218	453	288
Dysprosium*	ppm	0.05	4.0	3.7	1.5	1.5	1.3
Erbium*	ppm	0.05	2.3	2.2	0.94	0.92	0.83
Europium*	ppm	0.05	1.3	1.2	0.61	0.44	0.28
Gadolinium*	ppm	0.05	5.0	4.7	2.2	1.6	1.3
Holmium*	ppm	0.05	0.63	0.59	0.15	0.14	0.12
Neodymium*	ppm	0.1	28	27	15	11	8.9
Praseodymium*	ppm	0.05	7.4	7.0	4.3	3.0	1.9
Samarium*	ppm	0.1	5.6	5.2	2.6	1.8	1.2
Thulium*	ppm	0.05	0.21	0.17	<0.050	<0.050	<0.050
Beryllium*	ppm	0.1	0.70	1.2	0.50	0.50	0.60
Bismuth*	ppm	0.04	0.76	0.81	0.29	0.26	0.19
Calcium*	%	0.01	0.040	0.030	0.030	0.030	>15
Cadmium*	ppm	0.02	0.040	0.050	0.020	0.050	0.10
Ceum*	ppb	0.05	52	59	41	30	18
Cobalt*	ppm	0.1	3.4	3.1	5.1	4.6	12
Cesium*	ppm	0.05	0.48	0.47	0.43	0.34	0.66
Chromium*	ppm	1	135	107	105	34	44
Gallium*	ppm	0.5	8.7	8.5	4.2	3.3	4.3
Germanium*	ppm	0.1	0.80	2.2	0.30	0.40	<0.10
Copper*	ppm	0.5	0.60	<0.50	<0.50	<0.50	17
Iron*	%	0.01	>15	>15	>15	>15	2.5
Indium*	ppm	0.02	0.040	0.040	0.020	<0.020	0.020
Lanthanum*	ppb	0.1	32	31	21	16	9.4
Lutetium*	ppm	0.01	0.34	0.33	0.15	0.15	0.11
Potassium*	%	0.01	0.32	0.34	0.33	0.46	0.25
Lithium*	ppm	1	12	13	13	22	11
Hafnium*	ppm	0.02	1.8	1.7	0.95	0.98	0.55
Magnesium*	%	0.01	0.050	0.040	0.040	0.020	7.0
Mercury*	ppm	0.01	0.17	0.18	0.070	0.080	0.040
Manganese*	ppm	2	220	187	180	1645	>10000
Molybdenum*	ppm	0.05	1.0	1.6	1.3	1.2	0.60
Sodium*	%	0.01	0.020	0.020	0.020	0.030	0.090
Niobium*	ppm	0.1	4.1	4.0	2.0	2.7	1.7
Nickel*	ppm	0.5	24	23	14	12	49
Phosphorus*	ppm	50	455	446	375	311	129
Lead*	ppm	0.5	20	20	16	13	10
Rubidium*	ppm	0.2	11	12	20	13	13
Sulphur*	%	0.01	0.020	0.020	0.020	0.020	0.040
Antimony*	ppm	0.05	2.5	2.3	2.2	2.0	0.12
Scandium*	ppm	0.5	10	9.7	4.3	3.5	4.2
Selenium*	ppm	2	<2.0	<2.0	<2.0	<2.0	<2.0



ANALYTICAL REPORT

JB15-06547 R0

Report number 000009394

Client reference: ARM.15.008-SGS

Sample Number	JB15-06547.006	JB15-06547.007	JB15-06547.008	JB15-06547.009	JB15-06547.010
Sample Name	Bruce BC11 A	Bruce BC11 B	Parsons Discard	Parsons Discard	1 Calcrete
Sample Matrix	Soil	Soil	Dump A Soil	Dump B Soil	Soil

Parameter
SUB_SGS Booyens Method: SUB (continued)

Parameter	Units	LOR	JB15-06547.006	JB15-06547.007	JB15-06547.008	JB15-06547.009	JB15-06547.010
Tin ^A	ppm	0.3	2.1	2.0	0.80	0.50	0.30
Strontium ^A	ppm	0.5	292	294	292	143	155
Tantalum ^A	ppb	0.05	0.02	0.02	0.23	0.32	0.16
Terbium ^A	ppm	0.05	0.65	0.59	0.20	0.13	0.080
Tellurium ^A	ppm	0.05	0.19	0.12	0.23	0.11	0.090
Thorium ^A	ppm	0.2	7.7	7.4	3.3	2.6	1.9
Titanium ^A	%	0.01	0.14	0.13	0.13	0.050	0.080
Thallium ^A	ppm	0.02	<0.020	<0.020	<0.020	<0.020	<0.020
Uranium ^A	ppm	0.05	1.1	1.1	0.30	0.27	0.58
Vanadium ^A	ppm	2	89	87	85	59	49
Ytterbium ^A	ppm	0.1	1.8	1.6	0.70	0.70	0.50
Yttrium ^A	ppm	0.1	21	20	9.1	9.0	7.9
Tungsten ^A	ppm	0.1	0.50	0.30	<0.10	<0.10	<0.10
Zinc ^A	ppm	1	17	17	16	14	140
Zirconium ^A	ppm	0.5	59	58	58	39	24

SUB_Anions in Soil for SASLP Method: SUB

Parameter	Units	LOR	JB15-06547.006	JB15-06547.007	JB15-06547.008	JB15-06547.009	JB15-06547.010
Chloride ^A	ppm	500	<500	<500	<500	<500	<500

SUB_Total Cyanide in soil Method: SUB

Parameter	Units	LOR	JB15-06547.006	JB15-06547.007	JB15-06547.008	JB15-06547.009	JB15-06547.010
Total Cyanide ^A	mg/kg	0.01	0.025	<0.010	0.080	<0.010	0.025



ANALYTICAL REPORT

JB15-06547 R0

Report number 000009394
Client reference: ARM.15.008-SGS

Sample Number	JB15-06547.011	JB15-06547.012	JB15-06547.013	JB15-06547.014	JB15-06547.015
Sample Name	2 Top Soil	5 Pre-Process A	6 Pre-Process B	7 Post-Reprocess Soil	8 BE - Discard A
Sample Matrix	Soil	Soil	Soil	Soil	Soil

Parameter **Units** **LOR**

Soluble Anions in Soil by Ion Chromatography Method: ME-AN-014

Parameter	Units	LOR	JB15-06547.011	JB15-06547.012	JB15-06547.013	JB15-06547.014	JB15-06547.015
Nitrate*	mg/kg	5	50	18	25	16	<5
Sulphate*	mg/kg	5	335	664	257	329	33

Fluoride on soils by Ion Selective Electrode Method: ME-AN-021

Parameter	Units	LOR	JB15-06547.011	JB15-06547.012	JB15-06547.013	JB15-06547.014	JB15-06547.015
Fluoride by ISE raw result*	mg/l	0.2	1.7	0.28	0.87	<0.20	0.26

Hexavalent Chromium in Soil Method: ME-AN-040

Parameter	Units	LOR	JB15-06547.011	JB15-06547.012	JB15-06547.013	JB15-06547.014	JB15-06547.015
Hexavalent Chromium*	mg/kg	0.4	<0.4	55	<0.4	0.9	2.9

Total Petroleum Hydrocarbons Banded on Soils Method: ME-AN-035

Parameter	Units	LOR	JB15-06547.011	JB15-06547.012	JB15-06547.013	JB15-06547.014	JB15-06547.015
TPH Banded C28-40*	mg/kg	40	-	<40.00	-	<40.00	-
TPH Banded C10-C28 Total	mg/kg	142	-	<142.00	-	<142.00	-
TPH Banded C10-C40 Total*	mg/kg	182	-	<182.00	-	<182.00	-

SUB_SGS Booyensens Method: SUB

Parameter	Units	LOR	JB15-06547.011	JB15-06547.012	JB15-06547.013	JB15-06547.014	JB15-06547.015
Aluminium*	%	0.01	8.2	0.85	4.3	0.47	3.5
Arsenic*	ppm	1	9.0	11	15	18	19
Silver*	ppm	0.3	0.40	<0.30	0.40	0.30	<0.30
Boron*	ppm	0.2	12	44	20	>100	23
Barium*	ppm	1	525	337	2211	5057	212
Dysprosium*	ppm	0.06	4.1	1.5	3.4	1.2	2.8
Erbium*	ppm	0.05	2.4	1.1	2.0	0.99	1.7
Europium*	ppm	0.05	1.0	0.36	1.2	1.6	0.72
Gadolinium*	ppm	0.05	4.0	1.4	3.3	1.1	3.0
Holmium*	ppm	0.05	0.64	0.19	0.50	0.18	0.41
Neodymium*	ppm	0.1	21	7.0	16	4.5	16
Praseodymium*	ppm	0.05	5.3	1.8	3.9	0.98	4.6
Samarium*	ppm	0.1	4.0	1.2	3.3	0.80	3.2
Thulium*	ppm	0.05	0.17	<0.050	0.13	<0.050	0.12
Beryllium*	ppm	0.1	1.4	0.60	1.3	1.0	0.60
Bismuth*	ppm	0.04	0.29	0.21	0.32	0.16	0.29
Calcium*	%	0.01	5.6	1.8	1.3	4.6	0.13
Cadmium*	ppm	0.02	0.20	0.31	0.18	0.35	<0.020
Cerium*	ppb	0.05	50	17	37	9.3	44
Cobalt*	ppm	0.1	23	7.5	10	61	5.3
Cesium*	ppm	0.05	2.5	1.2	4.8	0.30	0.35
Chromium*	ppm	1	76	175	118	38	99
Gallium*	ppm	0.5	15	4.9	11	10	8.9
Germanium*	ppm	0.1	<0.10	0.10	0.20	0.60	0.30
Copper*	ppm	0.5	50	24	37	75	<0.50
Iron*	%	0.01	4.7	>15	9.2	12	>15
Indium*	ppm	0.02	0.060	0.030	0.050	<0.020	0.030
Lanthanum*	ppb	0.1	24	9.8	17	6.8	22
Lutetium*	ppm	0.01	0.30	0.14	0.27	0.15	0.26
Potassium*	%	0.01	0.50	0.26	1.6	0.080	0.98
Lithium*	ppm	1	24	6.0	39	15	102
Hafnium*	ppm	0.02	2.2	0.48	1.9	0.090	2.3
Magnesium*	%	0.01	3.8	0.30	0.95	0.89	0.030
Mercury*	ppm	0.01	0.050	0.16	0.14	0.090	0.10
Manganese*	ppm	2	2369	>10000	2894	>10000	1688
Molybdenum*	ppm	0.05	2.9	2.4	1.5	1.4	1.5
Sodium*	%	0.01	0.070	0.020	0.13	0.10	0.030
Niobium*	ppm	0.1	7.1	1.6	4.3	0.60	7.0
Nickel*	ppm	0.5	45	17	29	16	22
Phosphorus*	ppm	50	551	637	1310	314	421
Lead*	ppm	0.5	15	24	30	84	36
Rubidium*	ppm	0.2	36	16	65	3.4	28



ANALYTICAL REPORT

JB15-06547 R0

Report number 000009394

Client reference: ARM.15.008-SGS

Sample Number	JB15-06547.011	JB15-06547.012	JB15-06547.013	JB15-06547.014	JB15-06547.015
Sample Name	2 Top Soil	5 Pre-Process A	6 Pre-Process B	7 Post-Reprocess	8 BE - Discard A
Sample Matrix	Soil	Soil	Soil	Soil	Soil

Parameter

Units LOR

SUB_SGS Booyens Method: SUB (continued)

Parameter	Units	LOR	JB15-06547.011	JB15-06547.012	JB15-06547.013	JB15-06547.014	JB15-06547.015
Sulphur ^A	%	0.01	0.050	0.060	0.080	0.17	0.020
Antimony ^A	ppm	0.05	0.080	0.40	0.45	0.45	1.7
Scandium ^A	ppm	0.5	17	4.0	13	2.3	8.9
Selenium ^A	ppm	2	<2.0	<2.0	<2.0	<2.0	<2.0
Tin ^A	ppm	0.3	1.7	0.50	1.3	<0.30	1.7
Strontium ^A	ppm	0.5	166	97	219	880	339
Tantalum ^A	ppb	0.05	0.71	0.14	0.32	0.080	0.62
Terbium ^A	ppm	0.05	0.54	0.12	0.44	0.060	0.40
Tellurium ^A	ppm	0.05	0.23	0.090	1.7	1.7	0.12
Thorium ^A	ppm	0.2	6.8	1.9	5.5	0.50	7.0
Titanium ^A	%	0.01	0.36	0.040	0.18	0.030	0.090
Thallium ^A	ppm	0.02	0.30	<0.020	0.30	<0.020	0.20
Uranium ^A	ppm	0.05	1.5	1.7	3.4	0.090	1.3
Vanadium ^A	ppm	2	140	50	207	3.0	106
Ytterbium ^A	ppm	0.1	1.5	0.70	1.3	0.60	1.2
Yttrium ^A	ppm	0.1	22	12	19	15	17
Tungsten ^A	ppm	0.1	<0.10	<0.10	<0.10	<0.10	<0.10
Zinc ^A	ppm	1	83	31	100	125	13
Zirconium ^A	ppm	0.5	79	12	64	3.1	85

SUB_Anions in Soil for SASLP Method: SUB

Parameter	Units	LOR	JB15-06547.011	JB15-06547.012	JB15-06547.013	JB15-06547.014	JB15-06547.015
Chloride ^A	ppm	500	<500	<500	<500	<500	<500

SUB_Total Cyanide in soil Method: SUB

Parameter	Units	LOR	JB15-06547.011	JB15-06547.012	JB15-06547.013	JB15-06547.014	JB15-06547.015
Total Cyanide ^A	mg/kg	0.01	0.025	<0.010	<0.010	0.11	<0.010



ANALYTICAL REPORT

JB15-06547 R0

Report number 000009394
Client reference: ARM.15.008-SGS

Sample Number	JB15-06547.016	JB15-06547.017	JB15-06547.018	JB15-06547.019	JB15-06547.020
Sample Name	9 BE - Discard B	10 - BE - Old Slimes Dam A	12 BE - HL A	13 BE - HL B	15 BE - Slimes B
Sample Matrix	Soil	Soil	Soil	Soil	Soil

Parameter **Units** **LOR**
Soluble Anions in Soil by Ion Chromatography Method: ME-AN-014

Parameter	Units	LOR	9 BE - Discard B	10 - BE - Old Slimes Dam A	12 BE - HL A	13 BE - HL B	15 BE - Slimes B
Nitrate*	mg/kg	5	<5	24	9	<5	<5
Sulphate*	mg/kg	5	97	43	38	18	74

Fluoride on soils by Ion Selective Electrode Method: ME-AN-021

Parameter	Units	LOR	9 BE - Discard B	10 - BE - Old Slimes Dam A	12 BE - HL A	13 BE - HL B	15 BE - Slimes B
Fluoride by ISE raw result*	mg/l	0.2	0.31	0.44	0.62	<0.20	<0.20

Hexavalent Chromium in Soil Method: ME-AN-040

Parameter	Units	LOR	9 BE - Discard B	10 - BE - Old Slimes Dam A	12 BE - HL A	13 BE - HL B	15 BE - Slimes B
Hexavalent Chromium*	mg/kg	0.4	0.6	1.7	6.4	4.1	10

Total Petroleum Hydrocarbons Banded on Soils Method: ME-AN-035

Parameter	Units	LOR	9 BE - Discard B	10 - BE - Old Slimes Dam A	12 BE - HL A	13 BE - HL B	15 BE - Slimes B
TPH Banded C28-40*	mg/kg	40	-	-	-	-	-
TPH Banded C10-C28 Total	mg/kg	142	-	-	-	-	-
TPH Banded C10-C40 Total*	mg/kg	182	-	-	-	-	-

SUB_SGS Booyens Method: SUB

Parameter	Units	LOR	9 BE - Discard B	10 - BE - Old Slimes Dam A	12 BE - HL A	13 BE - HL B	15 BE - Slimes B
Aluminium*	%	0.01	2.1	8.2	2.0	0.49	1.0
Arsenic*	ppm	1	19	16	28	13	20
Silver*	ppm	0.3	<0.30	<0.30	<0.30	<0.30	1.1
Boron*	ppm	0.2	24	17	27	20	25
Barium*	ppm	1	511	1034	4214	32	2036
Dysprosium*	ppm	0.06	1.5	3.9	3.6	0.63	1.2
Erbium*	ppm	0.05	0.83	2.4	2.1	0.25	0.68
Europium*	ppm	0.05	0.84	1.2	2.0	0.18	0.81
Gadolinium*	ppm	0.05	2.6	4.2	3.4	0.89	1.5
Holmium*	ppm	0.05	0.13	0.61	0.59	<0.050	0.080
Neodymium*	ppm	0.1	19	27	12	6.0	8.7
Praseodymium*	ppm	0.05	5.2	7.9	2.7	1.4	2.2
Samarium*	ppm	0.1	3.6	4.6	3.1	1.1	1.8
Thulium*	ppm	0.05	<0.050	0.18	0.14	<0.050	<0.050
Beryllium*	ppm	0.1	0.50	2.3	3.7	<0.10	1.1
Bismuth*	ppm	0.04	0.29	0.34	0.25	0.090	0.20
Calcium*	%	0.01	0.15	0.21	2.1	0.12	0.060
Cadmium*	ppm	0.02	0.090	0.030	0.34	0.030	0.030
Cerium*	ppb	0.05	56	82	23	17	22
Cobalt*	ppm	0.1	3.4	24	25	1.3	15
Cesium*	ppm	0.05	0.34	9.6	1.5	0.090	0.34
Chromium*	ppm	1	90	146	37	106	42
Gallium*	ppm	0.5	6.0	23	7.1	1.8	3.8
Germanium*	ppm	0.1	0.40	0.60	0.60	0.30	0.40
Copper*	ppm	0.5	<0.50	25	<0.50	<0.50	<0.50
Iron*	%	0.01	>15	11	>15	>15	>15
Indium*	ppm	0.02	0.020	0.080	0.070	<0.020	0.040
Lanthanum*	ppb	0.1	26	38	10	5.8	11
Lutetium*	ppm	0.01	0.12	0.31	0.25	0.060	0.11
Potassium*	%	0.01	0.48	3.4	0.86	0.020	0.27
Lithium*	ppm	1	25	13	12	2.0	5.0
Hafrnium*	ppm	0.02	0.77	3.9	0.55	0.13	0.39
Magnesium*	%	0.01	0.040	0.39	1.1	0.030	0.030
Mercury*	ppm	0.01	0.060	0.050	0.15	0.060	0.070
Manganese*	ppm	2	4937	3239	>10000	2716	3919
Molybdenum*	ppm	0.05	1.8	0.60	1.6	1.9	1.4
Sodium*	%	0.01	0.090	0.080	0.040	0.010	0.020
Niobium*	ppm	0.1	1.7	5.7	1.8	0.50	1.2
Nickel*	ppm	0.5	17	47	76	4.8	27
Phosphorus*	ppm	50	448	300	179	188	379
Lead*	ppm	0.5	17	6.7	26	3.7	20
Rubidium*	ppm	0.2	17	179	35	0.90	9.6



ANALYTICAL REPORT

JB15-06547 R0

Report number 000009394

Client reference: ARM.15.008-SGS

Sample Number	JB15-06547.016	JB15-06547.017	JB15-06547.018	JB15-06547.019	JB15-06547.020
Sample Name	9 BE - Discard B	10 - BE - Old Slimes Dam A	12 BE - HL A	13 BE - HL B	15 BE - Slimes B
Sample Matrix	Soil	Soil	Soil	Soil	Soil

Parameter

Units LOR

SUB_SGS Booyens Method: SUB (continued)

Parameter	Units	LOR	JB15-06547.016	JB15-06547.017	JB15-06547.018	JB15-06547.019	JB15-06547.020
Sulphur ^A	%	0.01	0.040	<0.010	0.010	<0.010	0.050
Antimony ^A	ppm	0.05	1.8	0.21	2.5	1.7	1.3
Scandium ^A	ppm	0.5	5.9	15	5.6	2.5	4.1
Selenium ^A	ppm	2	<2.0	<2.0	<2.0	<2.0	<2.0
Tin ^A	ppm	0.3	0.50	1.9	0.50	<0.30	0.30
Strontium ^A	ppm	0.5	576	66	173	176	147
Tantalum ^A	ppb	0.05	0.22	1.1	0.21	0.090	0.13
Terbium ^A	ppm	0.05	0.21	0.57	0.48	<0.050	0.10
Tellurium ^A	ppm	0.05	0.20	0.40	3.7	<0.050	0.76
Thorium ^A	ppm	0.2	3.8	14	2.8	1.1	1.9
Titanium ^A	%	0.01	0.070	0.22	0.10	0.020	0.080
Thallium ^A	ppm	0.02	<0.020	0.50	<0.020	<0.020	<0.020
Uranium ^A	ppm	0.05	0.61	1.6	0.89	0.14	0.45
Vanadium ^A	ppm	2	93	110	76	63	88
Ytterbium ^A	ppm	0.1	0.60	1.5	1.3	0.20	0.50
Yttrium ^A	ppm	0.1	8.9	22	27	2.1	8.1
Tungsten ^A	ppm	0.1	27	1.2	<0.10	<0.10	<0.10
Zinc ^A	ppm	1	15	18	43	12	14
Zirconium ^A	ppm	0.5	27	146	21	7.5	15

SUB_Anions in Soil for SASLP Method: SUB

Parameter	Units	LOR	JB15-06547.016	JB15-06547.017	JB15-06547.018	JB15-06547.019	JB15-06547.020
Chloride ^A	ppm	500	<500	<500	<500	<500	<500

SUB_Total Cyanide in soil Method: SUB

Parameter	Units	LOR	JB15-06547.016	JB15-06547.017	JB15-06547.018	JB15-06547.019	JB15-06547.020
Total Cyanide ^A	mg/kg	0.01	0.24	<0.010	0.080	0.080	<0.010



ANALYTICAL REPORT

JB15-06547 R0

Report number 000009394
Client reference: ARM.15.008-SGS

Sample Number	JB15-06547.021	JB15-06547.022	JB15-06547.023	JB15-06547.024	JB15-06547.025
Sample Name	17 BE - BN WRD	18 BE - BN WRD	21 BE - Historic	22 BE - Historic	25 BE - Contam
Sample Matrix	A Soil	B Soil	A Soil	B Soil	1 A Soil

Parameter **Units** **LOR**
Soluble Anions in Soil by Ion Chromatography Method: ME-AN-014

Parameter	Units	LOR	JB15-06547.021	JB15-06547.022	JB15-06547.023	JB15-06547.024	JB15-06547.025
Nitrate*	mg/kg	5	6	57	<5	<5	<5
Sulphate*	mg/kg	5	41	37	10	8	<5

Fluoride on soils by Ion Selective Electrode Method: ME-AN-021

Parameter	Units	LOR	JB15-06547.021	JB15-06547.022	JB15-06547.023	JB15-06547.024	JB15-06547.025
Fluoride by ISE raw result*	mg/l	0.2	0.45	0.40	0.61	0.28	<0.20

Hexavalent Chromium in Soil Method: ME-AN-040

Parameter	Units	LOR	JB15-06547.021	JB15-06547.022	JB15-06547.023	JB15-06547.024	JB15-06547.025
Hexavalent Chromium*	mg/kg	0.4	1.6	3.2	0.8	3.2	3.6

Total Petroleum Hydrocarbons Banded on Soils Method: ME-AN-035

Parameter	Units	LOR	JB15-06547.021	JB15-06547.022	JB15-06547.023	JB15-06547.024	JB15-06547.025
TPH Banded C28-40*	mg/kg	40	-	-	-	-	-
TPH Banded C10-C28 Total	mg/kg	142	-	-	-	-	-
TPH Banded C10-C40 Total*	mg/kg	182	-	-	-	-	-

SUB_SGS Booyens Method: SUB

Parameter	Units	LOR	JB15-06547.021	JB15-06547.022	JB15-06547.023	JB15-06547.024	JB15-06547.025
Aluminium*	%	0.01	2.4	8.6	1.6	3.7	4.5
Arsenic*	ppm	1	15	9.0	28	22	14
Silver*	ppm	0.3	<0.30	0.30	<0.30	<0.30	<0.30
Boron*	ppm	0.2	18	15	34	20	26
Barium*	ppm	1	1718	955	931	1854	250
Dysprosium*	ppm	0.06	2.0	3.6	2.0	2.7	2.9
Erbium*	ppm	0.05	1.2	2.2	1.2	1.5	1.5
Europium*	ppm	0.05	0.90	1.2	0.80	1.1	0.79
Gadolinium*	ppm	0.05	2.1	4.0	2.5	2.9	3.2
Holmium*	ppm	0.05	0.20	0.54	0.25	0.34	0.39
Neodymium*	ppm	0.1	14	27	13	20	17
Praseodymium*	ppm	0.05	3.8	8.0	3.4	5.7	4.5
Samarium*	ppm	0.1	2.3	4.5	2.8	3.3	3.2
Thulium*	ppm	0.05	<0.050	0.16	<0.050	0.060	0.090
Beryllium*	ppm	0.1	0.60	2.3	1.3	1.5	1.4
Bismuth*	ppm	0.04	0.21	0.26	0.33	0.24	0.26
Calcium*	%	0.01	0.14	0.16	0.35	0.080	0.050
Cadmium*	ppm	0.02	0.090	0.040	0.050	0.060	0.050
Cerium*	ppb	0.05	52	88	31	80	52
Cobalt*	ppm	0.1	18	21	13	12	12
Cesium*	ppm	0.05	1.6	9.6	0.55	0.97	0.73
Chromium*	ppm	1	128	117	57	106	76
Gallium*	ppm	0.5	7.8	23	6.2	11	11
Germanium*	ppm	0.1	1.0	0.20	1.4	0.80	0.20
Copper*	ppm	0.5	17	10	<0.50	2.7	<0.50
Iron*	%	0.01	9.4	8.0	>15	>15	>15
Indium*	ppm	0.02	0.030	0.050	0.030	0.050	0.050
Lanthanum*	ppb	0.1	18	51	17	31	22
Lutetium*	ppm	0.01	0.16	0.29	0.17	0.20	0.23
Potassium*	%	0.01	0.81	3.7	0.51	0.32	0.73
Lithium*	ppm	1	6.0	9.0	5.0	12	41
Hafrnium*	ppm	0.02	1.6	4.1	0.84	1.5	1.4
Magnesium*	%	0.01	0.12	0.33	0.22	0.090	0.060
Mercury*	ppm	0.01	0.070	0.060	0.080	0.090	0.11
Manganese*	ppm	2	>10000	941	>10000	>10000	2518
Molybdenum*	ppm	0.05	1.3	0.53	1.8	1.6	0.71
Sodium*	%	0.01	0.030	0.10	0.030	0.030	0.060
Niobium*	ppm	0.1	2.4	5.1	3.8	3.8	3.4
Nickel*	ppm	0.5	27	39	41	23	44
Phosphorus*	ppm	50	251	232	280	522	262
Lead*	ppm	0.5	21	7.2	37	72	27
Rubidium*	ppm	0.2	37	190	17	19	28



ANALYTICAL REPORT

JB15-06547 R0

Report number 000009394

Client reference: ARM.15.008-SGS

Sample Number	JB15-06547.021	JB15-06547.022	JB15-06547.023	JB15-06547.024	JB15-06547.025
Sample Name	17 BE - BN WRD	18 BE - BN WRD	21 BE - Historic	22 BE - Historic	25 BE - Contam
Sample Matrix	A Soil	B Soil	A Soil	B Soil	1 A Soil

Parameter

Units LOR

SUB_SGS Booyens Method: SUB (continued)

Parameter	Units	LOR	JB15-06547.021	JB15-06547.022	JB15-06547.023	JB15-06547.024	JB15-06547.025
Sulphur ^A	%	0.01	0.020	0.020	<0.010	0.010	<0.010
Antimony ^A	ppm	0.05	0.30	0.35	2.7	0.75	0.94
Scandium ^A	ppm	0.5	6.8	16	4.5	11	12
Selenium ^A	ppm	2	<2.0	<2.0	<2.0	<2.0	<2.0
Tin ^A	ppm	0.3	0.50	2.0	0.70	0.90	1.2
Strontium ^A	ppm	0.5	151	100	77	205	195
Tantalum ^A	ppb	0.05	0.37	1.1	0.23	0.45	0.45
Terbium ^A	ppm	0.05	0.21	0.53	0.25	0.38	0.42
Tellurium ^A	ppm	0.05	0.95	0.45	0.30	0.94	0.060
Thorium ^A	ppm	0.2	5.0	16	3.0	6.6	6.9
Titanium ^A	%	0.01	0.090	0.24	0.11	0.18	0.17
Thallium ^A	ppm	0.02	0.40	0.50	0.20	0.30	<0.020
Uranium ^A	ppm	0.05	0.63	1.6	0.93	1.1	0.88
Vanadium ^A	ppm	2	73	113	116	151	93
Ytterbium ^A	ppm	0.1	0.80	1.4	0.80	1.0	1.0
Yttrium ^A	ppm	0.1	10	22	15	15	18
Tungsten ^A	ppm	0.1	<0.10	<0.10	<0.10	<0.10	<0.10
Zinc ^A	ppm	1	10	14	19	15	11
Zirconium ^A	ppm	0.5	69	157	32	53	52

SUB_Anions in Soil for SASLP Method: SUB

Parameter	Units	LOR	JB15-06547.021	JB15-06547.022	JB15-06547.023	JB15-06547.024	JB15-06547.025
Chloride ^A	ppm	500	<500	<500	<500	<500	<500

SUB_Total Cyanide in soil Method: SUB

Parameter	Units	LOR	JB15-06547.021	JB15-06547.022	JB15-06547.023	JB15-06547.024	JB15-06547.025
Total Cyanide ^A	mg/kg	0.01	0.025	0.050	<0.010	<0.010	<0.010



ANALYTICAL REPORT

JB15-06547 R0

Report number 000009394
Client reference: ARM.15.008-SGS

Sample Number	JB15-06547.026	JB15-06547.027	JB15-06547.028	JB15-06547.029	JB15-06547.030
Sample Name	26 BE - Contam	27 BE - BIS	28 BE - TITR	29 BE - West Pit	30 BE - West Pit
Sample Matrix	1 B Soil	Soil	Soil	A Soil	B Soil

Parameter **Units** **LOR**
Soluble Anions in Soil by Ion Chromatography Method: ME-AN-014

Parameter	Units	LOR	JB15-06547.026	JB15-06547.027	JB15-06547.028	JB15-06547.029	JB15-06547.030
Nitrate*	mg/kg	5	<5	<5	<5	20	18
Sulphate*	mg/kg	5	20	<5	21	<5	<5

Fluoride on soils by Ion Selective Electrode Method: ME-AN-021

Parameter	Units	LOR	JB15-06547.026	JB15-06547.027	JB15-06547.028	JB15-06547.029	JB15-06547.030
Fluoride by ISE raw result*	mg/l	0.2	0.32	<0.20	0.39	0.26	0.27

Hexavalent Chromium in Soil Method: ME-AN-040

Parameter	Units	LOR	JB15-06547.026	JB15-06547.027	JB15-06547.028	JB15-06547.029	JB15-06547.030
Hexavalent Chromium*	mg/kg	0.4	17	<0.4	3.8	19	3.0

Total Petroleum Hydrocarbons Banded on Soils Method: ME-AN-035

Parameter	Units	LOR	JB15-06547.026	JB15-06547.027	JB15-06547.028	JB15-06547.029	JB15-06547.030
TPH Banded C28-40*	mg/kg	40	-	-	-	<40.00	-
TPH Banded C10-C28 Total	mg/kg	142	-	-	-	<142.00	-
TPH Banded C10-C40 Total*	mg/kg	182	-	-	-	<182.00	-

SUB_SGS Booyensens Method: SUB

Parameter	Units	LOR	JB15-06547.026	JB15-06547.027	JB15-06547.028	JB15-06547.029	JB15-06547.030
Aluminium*	%	0.01	2.7	0.40	1.9	5.1	7.6
Arsenic*	ppm	1	17	12	16	11	20
Silver*	ppm	0.3	<0.30	<0.30	<0.30	<0.30	0.70
Boron*	ppm	0.2	16	15	15	24	17
Barium*	ppm	1	609	228	1204	265	184
Dysprosium*	ppm	0.06	2.0	0.66	2.1	3.5	2.8
Erbium*	ppm	0.05	1.2	0.38	1.3	2.2	1.9
Europium*	ppm	0.05	0.80	0.080	0.79	0.94	0.64
Gadolinium*	ppm	0.05	2.6	0.44	2.1	3.6	2.7
Holmium*	ppm	0.05	0.27	<0.050	0.25	0.53	0.43
Neodymium*	ppm	0.1	16	1.6	14	21	15
Praseodymium*	ppm	0.05	4.2	0.26	4.1	5.6	4.1
Samarium*	ppm	0.1	3.2	0.40	2.5	4.1	2.9
Thulium*	ppm	0.05	<0.050	<0.050	<0.050	0.16	0.12
Beryllium*	ppm	0.1	1.3	0.50	2.0	1.1	2.0
Bismuth*	ppm	0.04	0.28	0.080	0.21	0.41	0.33
Calcium*	%	0.01	0.050	0.020	0.080	0.040	0.10
Cadmium*	ppm	0.02	0.020	0.040	0.040	0.030	0.040
Cerium*	ppb	0.05	43	3.7	66	51	38
Cobalt*	ppm	0.1	12	4.3	10	13	7.9
Cesium*	ppm	0.05	0.74	0.35	0.75	2.9	2.9
Chromium*	ppm	1	69	60	84	136	216
Gallium*	ppm	0.5	7.4	1.6	5.9	14	18
Germanium*	ppm	0.1	0.50	0.30	0.80	0.30	0.70
Copper*	ppm	0.5	<0.50	<0.50	<0.50	26	91
Iron*	%	0.01	>15	>15	>15	11	>15
Indium*	ppm	0.02	0.050	<0.020	0.030	0.070	0.070
Lanthanum*	ppb	0.1	19	1.6	24	28	21
Lutetium*	ppm	0.01	0.19	0.060	0.17	0.33	0.26
Potassium*	%	0.01	0.74	0.070	0.24	1.4	0.95
Lithium*	ppm	1	22	2.0	9.0	33	43
Hafnium*	ppm	0.02	1.2	0.030	0.63	4.0	3.7
Magnesium*	%	0.01	0.070	0.020	0.11	0.090	0.090
Mercury*	ppm	0.01	0.070	0.070	0.060	0.14	0.090
Manganese*	ppm	2	4485	231	5974	338	591
Molybdenum*	ppm	0.05	1.2	0.97	1.3	1.3	1.5
Sodium*	%	0.01	0.030	0.020	0.030	0.050	0.050
Niobium*	ppm	0.1	2.3	0.50	2.0	4.8	3.2
Nickel*	ppm	0.5	31	21	21	48	56
Phosphorus*	ppm	50	293	95	240	215	451
Lead*	ppm	0.5	24	2.9	29	8.0	9.1
Rubidium*	ppm	0.2	28	3.1	15	56	47



ANALYTICAL REPORT

JB15-06547 R0

Report number: 000009394
Client reference: ARM.15.008-SGS

Sample Number	JB15-06547.026	JB15-06547.027	JB15-06547.028	JB15-06547.029	JB15-06547.030
Sample Name	26 BE - Contam	27 BE - BIS	28 BE - TITR	29 BE - West Pit	30 BE - West Pit
Sample Matrix	1 B Soil	Soil	Soil	A Soil	B Soil

Parameter
SUB_SGS Booyens Method: SUB (continued)

Parameter	Units	LOR	JB15-06547.026	JB15-06547.027	JB15-06547.028	JB15-06547.029	JB15-06547.030
Sulphur ^A	%	0.01	0.020	<0.010	<0.010	<0.010	<0.010
Antimony ^A	ppm	0.05	1.5	1.2	1.5	1.1	1.1
Scandium ^A	ppm	0.5	8.4	1.4	5.2	14	17
Selenium ^A	ppm	2	<2.0	<2.0	<2.0	<2.0	<2.0
Tin ^A	ppm	0.3	0.80	<0.30	0.50	1.8	1.2
Strontium ^A	ppm	0.5	267	15	80	60	50
Tantalum ^A	ppb	0.05	0.27	0.080	0.15	0.79	0.81
Terbium ^A	ppm	0.05	0.28	<0.050	0.25	0.48	0.35
Tellurium ^A	ppm	0.05	0.14	0.080	0.37	0.090	<0.050
Thorium ^A	ppm	0.2	4.9	0.50	3.5	12	9.7
Titanium ^A	%	0.01	0.10	0.010	0.090	0.19	0.18
Thallium ^A	ppm	0.02	<0.020	<0.020	0.30	0.20	<0.020
Uranium ^A	ppm	0.05	1.1	0.18	0.92	2.5	3.7
Vanadium ^A	ppm	2	112	82	145	108	139
Ytterbium ^A	ppm	0.1	0.80	0.30	0.80	1.5	1.3
Yttrium ^A	ppm	0.1	14	4.2	12	22	21
Tungsten ^A	ppm	0.1	<0.10	<0.10	<0.10	<0.10	<0.10
Zinc ^A	ppm	1	15	11	16	7.0	15
Zirconium ^A	ppm	0.5	43	4.1	23	149	145

SUB_Anions in Soil for SASLP Method: SUB

Parameter	Units	LOR	JB15-06547.026	JB15-06547.027	JB15-06547.028	JB15-06547.029	JB15-06547.030
Chloride ^A	ppm	500	<500	<500	<500	<500	<500

SUB_Total Cyanide in soil Method: SUB

Parameter	Units	LOR	JB15-06547.026	JB15-06547.027	JB15-06547.028	JB15-06547.029	JB15-06547.030
Total Cyanide ^A	mg/kg	0.01	0.050	<0.010	0.025	0.010	0.10



ANALYTICAL REPORT

JB15-06547 R0

Report number 000009394
Client reference: ARM.15.008-SGS

Sample Number	JB15-06547.031	JB15-06547.032	JB15-06547.033	JB15-06547.034
Sample Name	31 BE - Village A	32 BE - Village B	33 BE - East Pit A	34 BE - East Pit B
Sample Matrix	Soil	Soil	Soil	Soil

Parameter **Units** **LOR**
Soluble Anions in Soil by Ion Chromatography Method: ME-AN-014

Parameter	Units	LOR	JB15-06547.031	JB15-06547.032	JB15-06547.033	JB15-06547.034
Nitrate*	mg/kg	5	<5	6	10	9
Sulphate*	mg/kg	5	45	30	31	10

Fluoride on soils by Ion Selective Electrode Method: ME-AN-021

Parameter	Units	LOR	JB15-06547.031	JB15-06547.032	JB15-06547.033	JB15-06547.034
Fluoride by ISE raw result*	mg/l	0.2	0.46	0.90	0.21	<0.20

Hexavalent Chromium in Soil Method: ME-AN-040

Parameter	Units	LOR	JB15-06547.031	JB15-06547.032	JB15-06547.033	JB15-06547.034
Hexavalent Chromium*	mg/kg	0.4	18	3.9	4.1	3.7

Total Petroleum Hydrocarbons Banded on Soils Method: ME-AN-035

Parameter	Units	LOR	JB15-06547.031	JB15-06547.032	JB15-06547.033	JB15-06547.034
TPH Banded C28-40*	mg/kg	40	-	-	<40.00	-
TPH Banded C10-C28 Total	mg/kg	142	-	-	<142.00	-
TPH Banded C10-C40 Total*	mg/kg	182	-	-	<182.00	-

SUB_SGS Booyens Method: SUB

Parameter	Units	LOR	JB15-06547.031	JB15-06547.032	JB15-06547.033	JB15-06547.034
Aluminium*	%	0.01	2.1	6.3	2.8	2.1
Arsenic*	ppm	1	15	17	18	15
Silver*	ppm	0.3	<0.30	<0.30	<0.30	0.30
Boron*	ppm	0.2	10	15	26	16
Barium*	ppm	1	299	686	3385	1735
Dysprosium*	ppm	0.06	1.9	3.7	3.5	2.0
Erbium*	ppm	0.05	1.1	2.1	1.9	1.2
Europium*	ppm	0.05	0.35	1.1	1.8	0.95
Gadolinium*	ppm	0.05	1.8	3.9	4.0	2.2
Holmium*	ppm	0.05	0.17	0.54	0.52	0.24
Neodymium*	ppm	0.1	9.1	24	21	13
Praseodymium*	ppm	0.05	2.4	7.0	6.1	3.5
Samarium*	ppm	0.1	1.7	4.2	4.1	2.4
Thulium*	ppm	0.05	<0.050	0.14	0.13	<0.050
Beryllium*	ppm	0.1	0.70	1.9	1.7	1.2
Bismuth*	ppm	0.04	0.16	0.31	0.35	0.20
Calcium*	%	0.01	>15	3.1	0.14	0.090
Cadmium*	ppm	0.02	0.090	0.060	0.070	0.050
Cerium*	ppb	0.05	20	71	76	43
Cobalt*	ppm	0.1	8.6	20	29	17
Cesium*	ppm	0.05	3.2	7.0	1.1	0.99
Chromium*	ppm	1	21	91	100	78
Gallium*	ppm	0.5	5.3	19	10	7.4
Germanium*	ppm	0.1	<0.10	0.20	0.30	0.30
Copper*	ppm	0.5	11	15	53	10
Iron*	%	0.01	1.7	5.8	>15	>15
Indium*	ppm	0.02	0.030	0.050	0.050	0.040
Lanthanum*	ppb	0.1	10	34	28	20
Lutetium*	ppm	0.01	0.16	0.29	0.24	0.15
Potassium*	%	0.01	0.93	2.1	0.55	0.44
Lithium*	ppm	1	6.0	10	20	15
Hafrnium*	ppm	0.02	0.89	3.4	1.4	0.96
Magnesium*	%	0.01	0.47	0.75	0.12	0.080
Mercury*	ppm	0.01	0.040	0.050	0.050	0.050
Manganese*	ppm	2	539	951	>10000	>10000
Molybdenum*	ppm	0.05	0.20	0.33	1.6	1.2
Sodium*	%	0.01	0.060	0.060	0.050	0.060
Niobium*	ppm	0.1	2.2	5.3	2.6	2.4
Nickel*	ppm	0.5	26	35	39	29
Phosphorus*	ppm	50	121	262	282	289
Lead*	ppm	0.5	4.8	14	37	34
Rubidium*	ppm	0.2	54	133	29	26



ANALYTICAL REPORT

JB15-06547 R0

Report number 000009394
Client reference: ARM.15.008-SGS

Sample Number	JB15-06547.031	JB15-06547.032	JB15-06547.033	JB15-06547.034
Sample Name	31 BE - Village A	32 BE - Village B	33 BE - East Pit A	34 BE - East Pit B
Sample Matrix	Soil	Soil	Soil	Soil

Parameter
SUB_SGS Booyens Method: SUB (continued)

Parameter	Units	LOR	JB15-06547.031	JB15-06547.032	JB15-06547.033	JB15-06547.034
Sulphur ^A	%	0.01	0.020	0.020	0.010	<0.010
Antimony ^A	ppm	0.05	<0.050	0.16	1.0	0.82
Scandium ^A	ppm	0.5	5.8	14	10	6.1
Selenium ^A	ppm	2	<2.0	<2.0	<2.0	<2.0
Tin ^A	ppm	0.3	0.50	1.7	0.70	0.50
Strontium ^A	ppm	0.5	54	139	147	134
Tantalum ^A	ppb	0.05	0.14	0.73	0.30	0.25
Terbium ^A	ppm	0.05	0.16	0.50	0.52	0.24
Tellurium ^A	ppm	0.05	0.11	0.28	2.6	0.72
Thorium ^A	ppm	0.2	3.8	13	5.5	3.8
Titanium ^A	%	0.01	0.11	0.17	0.16	0.12
Thallium ^A	ppm	0.02	<0.020	0.40	0.60	0.40
Uranium ^A	ppm	0.05	1.3	1.4	1.3	0.69
Vanadium ^A	ppm	2	38	106	145	93
Ytterbium ^A	ppm	0.1	0.70	1.4	1.1	0.80
Yttrium ^A	ppm	0.1	12	24	21	12
Tungsten ^A	ppm	0.1	<0.10	<0.10	<0.10	<0.10
Zinc ^A	ppm	1	12	11	22	19
Zirconium ^A	ppm	0.5	35	122	48	34

SUB_Anions in Soil for SASLP Method: SUB

Parameter	Units	LOR	JB15-06547.031	JB15-06547.032	JB15-06547.033	JB15-06547.034
Chloride ^A	ppm	500	<500	<500	<500	<500

SUB_Total Cyanide in soil Method: SUB

Parameter	Units	LOR	JB15-06547.031	JB15-06547.032	JB15-06547.033	JB15-06547.034
Total Cyanide ^A	mg/kg	0.01	<0.010	<0.010	0.40	0.38



METHOD SUMMARY

JB15-06547 R0

Report number 0000009394
Client reference: ARM.15.008-SGS

Table with 2 columns: METHOD and METHODOLOGY SUMMARY. Rows include MS_EN_ME-AN-014, MS_EN_ME-AN-035, and MS_EN_ME-AN-040 with their respective descriptions.

Table with 2 columns: FOOTNOTES and descriptions. Includes codes like IS, LNR, QFH, QFL and their meanings. Also contains a warning section and accreditation information.



T0107



SGS

TEST REPORT (Amended)

CLIENT DETAILS		LABORATORY DETAILS	
Contact	Martiens Prinsloo	Laboratory	SGS South Africa (Pty) Limited
Client	Future Flow	Address	259 Kent Avenue Fermdale, 2194
Address	PO BOX 161 Menlyn 0063 Pretoria	Telephone	+27 (0)11 590 3000
Telephone	012 345 1337	Laboratory Manager	Martin Olivier
Facsimile	086 695 3846	SGS Reference	JB15-06548 R1
Email	martiens@ffgpm.co.za	Report Number	0000010190
Project	(Not specified)	Date Received	2015/05/12 12:45:59PM
Order Number	ARM.15.008-SGS	Date Reported	2015/09/22 04:52:19PM
Samples	36		
Sample matrix	SOIL		

COMMENTS
<p>The document is issued in accordance with SANAS's accreditation requirements. Accredited for compliance with ISO/IEC 17025. SANAS accredited laboratory T0107.</p> <p>This report/certificate is a re-issued copy and replaces the originally issued document dated 17/06/2015. The reason for re-issue is the blanks were not included in the original report.</p> <p>Sample(s) leached using TCLP#1 and TCLP#2 as indicated. Results reported on leachate.</p> <p>Analysis of Chloride was subcontracted.</p>



SIGNATORIES	
<p>_____ Greg Ondrejkojic Technical Supervisor/Technical Signatory</p>	<p>_____ Martin Olivier Operations Manager/Technical Signatory</p>



ANALYTICAL REPORT

JB15-06548 R1

Report number 0000010190
Client reference: ARM.15.008-SGS

Sample Number	JB15-06548.001	JB15-06548.002	JB15-06548.003	JB15-06548.004	JB15-06548.005
Sample Name	King Waste Rock Dump A Soil	King Waste Rock Dump B Soil	Bruce Waste Dump A Soil	Bruce Waste Dump B Soil	King Paste Soil
Sample Matrix					

Parameter Units LOR
Australian Standard Leaching Procedure - Acetic Acid Method: AS4439.3

Parameter	Units	LOR	JB15-06548.001	JB15-06548.002	JB15-06548.003	JB15-06548.004	JB15-06548.005
Extraction fluid used*	-	-	TCLP#1	TCLP#1	TCLP#1	TCLP#1	TCLP#1
Weight Sample*	g	-	50.0	50.0	50.0	50.0	50.0
Vol. ml*	ml	-	1000	1000	1000	1000	1000
Final pH*	-	0.1	4.9	4.9	4.9	4.9	4.9

Anions on leachates by Ion Chromatography Method: ME-AN-014

Parameter	Units	LOR	JB15-06548.001	JB15-06548.002	JB15-06548.003	JB15-06548.004	JB15-06548.005
Sulphate	mg/l	0.05	3.9	3.2	0.99	1.1	2.1
Nitrate	mg/l	0.1	11	7.9	4.0	17	1.6

Total Cyanide in leachates Method: ME-AN-031

Parameter	Units	LOR	JB15-06548.001	JB15-06548.002	JB15-06548.003	JB15-06548.004	JB15-06548.005
Total Cyanide	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Hexavalent Chromium by Discrete Analyser on Leachates Method: ME-AN-040

Parameter	Units	LOR	JB15-06548.001	JB15-06548.002	JB15-06548.003	JB15-06548.004	JB15-06548.005
Hexavalent Chromium*	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Fluoride on leachates by Ion Selective Electrode Method: ME-AN-021

Parameter	Units	LOR	JB15-06548.001	JB15-06548.002	JB15-06548.003	JB15-06548.004	JB15-06548.005
Fluoride by ISE	mg/l	0.05	0.10	0.08	0.05	0.05	0.08

ICP-OES Metals on leachates (Dissolved) Method: ME-AN-027 D

Parameter	Units	LOR	JB15-06548.001	JB15-06548.002	JB15-06548.003	JB15-06548.004	JB15-06548.005
Silver	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Aluminium	mg/l	0.02	0.21	0.28	0.31	0.19	0.28
Arsenic	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	mg/l	0.005	0.038	0.045	0.030	0.025	0.025
Barium	mg/l	0.002	1.8	1.7	0.77	0.92	2.2
Beryllium	mg/l	0.0001	0.0022	0.0023	0.0010	0.0006	0.0010
Bismuth	mg/l	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Calcium	mg/l	0.5	24	19	11	21	8.8
Cadmium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	0.020
Copper	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Iron	mg/l	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lanthanum	mg/l	0.2	-	-	-	-	-
Potassium	mg/l	0.2	11	13	7.3	8.3	4.7
Lithium	mg/l	0.005	0.015	0.038	<0.005	<0.005	<0.005
Magnesium	mg/l	0.01	11	7.8	4.1	7.8	2.7
Manganese	mg/l	0.01	0.10	0.19	0.16	0.18	1.7
Molybdenum	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sodium	mg/l	0.5	1190	1170	1170	1130	1130
Nickel	mg/l	0.005	0.005	<0.005	0.006	<0.005	0.007
Phosphorus	mg/l	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulphur*	mg/l	0.07	1.3	1.3	0.42	0.54	0.93
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Selenium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon	mg/l	1	3	3	3	3	2
Tin	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/l	0.001	0.19	0.16	0.096	0.10	0.11
Tellurium	mg/l	0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Thorium*	mg/l	0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Titanium	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Thallium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	mg/l	0.01	0.02	0.02	0.01	0.03	0.02
Vanadium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tungsten	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01



ANALYTICAL REPORT

JB15-06548 R1

Report number 0000010190
Client reference: ARM.15.008-SGS

Sample Number	JB15-06548.006	JB15-06548.007	JB15-06548.008	JB15-06548.009	JB15-06548.010
Sample Name	Bruce BC11 A	Bruce BC11 B	Parsons Discard Dump A	Parsons Discard Dump B	1 Calcrete
Sample Matrix	Soil	Soil	Soil	Soil	Soil

Parameter Units LOR
Australian Standard Leaching Procedure - Acetic Acid Method: AS4439.3

Parameter	Units	LOR	JB15-06548.006	JB15-06548.007	JB15-06548.008	JB15-06548.009	JB15-06548.010
Extraction fluid used*	-	-	TCLP#1	TCLP#1	TCLP#1	TCLP#1	2
Weight Sample*	g	-	50.0	50.0	50.0	50.0	50.0
Vol. ml*	ml	-	1000	1000	1000	1000	1000
Final pH*	-	0.1	4.9	4.9	4.9	4.9	6.4

Anions on leachates by Ion Chromatography Method: ME-AN-014

Parameter	Units	LOR	JB15-06548.006	JB15-06548.007	JB15-06548.008	JB15-06548.009	JB15-06548.010
Sulphate	mg/l	0.05	0.13	0.26	1.2	1.8	8.9
Nitrate	mg/l	0.1	<0.1	<0.1	1.2	0.4	7.3

Total Cyanide in leachates Method: ME-AN-031

Parameter	Units	LOR	JB15-06548.006	JB15-06548.007	JB15-06548.008	JB15-06548.009	JB15-06548.010
Total Cyanide	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Hexavalent Chromium by Discrete Analyser on Leachates Method: ME-AN-040

Parameter	Units	LOR	JB15-06548.006	JB15-06548.007	JB15-06548.008	JB15-06548.009	JB15-06548.010
Hexavalent Chromium*	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Fluoride on leachates by Ion Selective Electrode Method: ME-AN-021

Parameter	Units	LOR	JB15-06548.006	JB15-06548.007	JB15-06548.008	JB15-06548.009	JB15-06548.010
Fluoride by ISE	mg/l	0.05	0.06	0.07	<0.05	<0.05	0.48

ICP-OES Metals on leachates (Dissolved) Method: ME-AN-027 D

Parameter	Units	LOR	JB15-06548.006	JB15-06548.007	JB15-06548.008	JB15-06548.009	JB15-06548.010
Silver	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Aluminium	mg/l	0.02	0.32	0.39	0.35	0.29	<0.02
Arsenic	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	mg/l	0.005	0.020	0.021	0.022	0.024	<0.005
Barium	mg/l	0.002	0.48	0.44	1.2	2.3	0.40
Beryllium	mg/l	0.0001	0.0010	0.0012	0.0008	0.0006	0.0002
Bismuth	mg/l	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Calcium	mg/l	0.5	5.2	7.5	2.1	2.0	1030
Cadmium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	mg/l	0.002	<0.002	<0.002	<0.002	0.002	0.005
Copper	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Iron	mg/l	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lanthanum	mg/l	0.2	-	-	-	-	-
Potassium	mg/l	0.2	3.9	4.2	5.8	4.8	5.3
Lithium	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	0.045
Magnesium	mg/l	0.01	1.9	2.5	0.97	0.68	192
Manganese	mg/l	0.01	0.08	0.09	0.27	0.39	3.3
Molybdenum	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sodium	mg/l	0.5	1150	1120	1110	1110	6.8
Nickel	mg/l	0.005	0.005	0.006	<0.005	<0.005	0.010
Phosphorus	mg/l	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Lead	mg/l	0.01	<0.01	0.01	<0.01	<0.01	<0.01
Sulphur*	mg/l	0.07	0.17	0.18	0.52	0.84	3.4
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Selenium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon	mg/l	1	2	2	<1	<1	7
Tin	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/l	0.001	0.060	0.059	0.048	0.042	1.0
Tellurium	mg/l	0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Thorium*	mg/l	0.04	<0.04	<0.04	<0.04	<0.04	0.06
Titanium	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Thallium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	mg/l	0.01	0.03	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tungsten	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01



ANALYTICAL REPORT

JB15-06548 R1

Report number 0000010190
Client reference: ARM.15.008-SGS

Sample Number	JB15-06548.011	JB15-06548.012	JB15-06548.013	JB15-06548.014	JB15-06548.015
Sample Name	2 Top Soil	5 Pre-Process A	6 Pre-Process B	7 Post-Reprocess	8 BE - Discard A
Sample Matrix	Soil	Soil	Soil	Soil	Soil

Parameter **Units** **LOR**
Australian Standard Leaching Procedure - Acetic Acid Method: AS4439.3

Parameter	Units	LOR	JB15-06548.011	JB15-06548.012	JB15-06548.013	JB15-06548.014	JB15-06548.015
Extraction fluid used*	-	-	2	1	1	1	1
Weight Sample*	g	-	50.0	50.0	50.0	50.0	50.0
Vol. ml*	ml	-	1000	1000	1000	1000	1000
Final pH*	-	0.1	6.3	5.2	4.9	6.5	5.0

Anions on leachates by Ion Chromatography Method: ME-AN-014

Parameter	Units	LOR	JB15-06548.011	JB15-06548.012	JB15-06548.013	JB15-06548.014	JB15-06548.015
Sulphate	mg/l	0.05	19	14	7.8	15	0.36
Nitrate	mg/l	0.1	2.7	1.0	1.0	1.4	<0.1

Total Cyanide in leachates Method: ME-AN-031

Parameter	Units	LOR	JB15-06548.011	JB15-06548.012	JB15-06548.013	JB15-06548.014	JB15-06548.015
Total Cyanide	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Hexavalent Chromium by Discrete Analyser on Leachates Method: ME-AN-040

Parameter	Units	LOR	JB15-06548.011	JB15-06548.012	JB15-06548.013	JB15-06548.014	JB15-06548.015
Hexavalent Chromium*	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Fluoride on leachates by Ion Selective Electrode Method: ME-AN-021

Parameter	Units	LOR	JB15-06548.011	JB15-06548.012	JB15-06548.013	JB15-06548.014	JB15-06548.015
Fluoride by ISE	mg/l	0.05	0.26	0.08	0.13	0.12	0.08

ICP-OES Metals on leachates (Dissolved) Method: ME-AN-027 D

Parameter	Units	LOR	JB15-06548.011	JB15-06548.012	JB15-06548.013	JB15-06548.014	JB15-06548.015
Silver	mg/l	0.002	0.003	0.002	<0.002	0.007	<0.002
Aluminium	mg/l	0.02	<0.02	0.10	0.38	<0.02	0.51
Arsenic	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	mg/l	0.005	0.24	0.056	0.055	0.26	0.024
Barium	mg/l	0.002	0.50	0.59	1.3	1.9	0.41
Beryllium	mg/l	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Bismuth	mg/l	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Calcium	mg/l	0.5	856	200	28	494	84
Cadmium	mg/l	0.001	0.001	<0.001	0.001	<0.001	<0.001
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	0.007	<0.005
Chromium	mg/l	0.002	0.003	0.003	<0.002	0.003	<0.002
Copper	mg/l	0.02	<0.02	<0.02	0.02	<0.02	<0.02
Iron	mg/l	0.05	<0.05	<0.05	0.34	<0.05	<0.05
Lanthanum	mg/l	0.2	-	-	-	-	-
Potassium	mg/l	0.2	16	2.9	7.9	4.1	8.7
Lithium	mg/l	0.005	0.038	<0.005	<0.005	0.006	0.013
Magnesium	mg/l	0.01	278	5.8	15	14	1.4
Manganese	mg/l	0.01	0.81	4.0	5.0	22	0.15
Molybdenum	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sodium	mg/l	0.5	16	920	899	922	1000
Nickel	mg/l	0.005	<0.005	<0.005	0.006	<0.005	<0.005
Phosphorus	mg/l	0.03	0.10	<0.03	<0.03	<0.03	<0.03
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulphur*	mg/l	0.07	5.5	5.3	2.0	5.4	0.29
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Selenium	mg/l	0.01	0.02	<0.01	<0.01	0.02	<0.01
Silicon	mg/l	1	11	2	2	3	1
Tin	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/l	0.001	2.6	0.27	0.52	-	0.098
Tellurium	mg/l	0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Thorium*	mg/l	0.04	<0.04	0.04	0.05	0.20	<0.04
Titanium	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Thallium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tungsten	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01



ANALYTICAL REPORT

JB15-06548 R1

Report number 0000010190

Client reference: ARM.15.008-SGS

Sample Number	JB15-06548.011	JB15-06548.012	JB15-06548.013	JB15-06548.014	JB15-06548.015
Sample Name	2 Top Soil	5 Pre-Process A	6 Pre-Process B	7 Post-Reprocess	8 BE - Discard A
Sample Matrix	Soil	Soil	Soil	Soil	Soil

Parameter **Units** **LOR**
ICP-OES Metals on leachates (Dissolved) Method: ME-AN-027 D (continued)

Parameter	Units	LOR	JB15-06548.011	JB15-06548.012	JB15-06548.013	JB15-06548.014	JB15-06548.015
Yttrium	mg/l	0.01	-	-	-	-	-
Zinc	mg/l	0.01	0.09	0.03	0.10	0.20	0.03
Zirconium*	mg/l	0.16	<0.18	<0.18	<0.18	<0.18	<0.18

Dissolved Hg on Leachates by ICP-MS Method: ME-AN-026

Parameter	Units	LOR	JB15-06548.011	JB15-06548.012	JB15-06548.013	JB15-06548.014	JB15-06548.015
Mercury	µg/l	0.1	<0.10	<0.10	<0.10	<0.10	<0.10

SUB_Chloride on leachates by titration Method: SUB

Parameter	Units	LOR	JB15-06548.011	JB15-06548.012	JB15-06548.013	JB15-06548.014	JB15-06548.015
Chloride^	mg/l	5	<5.0	<5.0	<5.0	<5.0	<5.0

TCLP - Leachate Evaluation Method: ME-AN-022

Parameter	Units	LOR	JB15-06548.011	JB15-06548.012	JB15-06548.013	JB15-06548.014	JB15-06548.015
Evaluation pH	-	0.1	9.1	9.4	8.6	9.7	8.8



ANALYTICAL REPORT

JB15-06548 R1

Report number 0000010190
Client reference: ARM.15.008-SGS

Sample Number	JB15-06548.016	JB15-06548.017	JB15-06548.018	JB15-06548.019	JB15-06548.020
Sample Name	9 BE - Discard B	10 - BE - Old Slimes Dam A	12 BE - HLA	13 BE - HL B	16 BE - Slimes B
Sample Matrix	Soil	Soil	Soil	Soil	Soil

Parameter Units LOR
Australian Standard Leaching Procedure - Acetic Acid Method: AS4439.3

Parameter	Units	LOR	JB15-06548.016	JB15-06548.017	JB15-06548.018	JB15-06548.019	JB15-06548.020
Extraction fluid used*	-	-	1	1	1	1	1
Weight Sample*	g	-	50.0	50.0	50.0	50.0	50.0
Vol. ml*	ml	-	1000	1000	1000	1000	1000
Final pH*	-	0.1	4.9	4.9	6.5	4.9	4.9

Anions on leachates by Ion Chromatography Method: ME-AN-014

Parameter	Units	LOR	JB15-06548.016	JB15-06548.017	JB15-06548.018	JB15-06548.019	JB15-06548.020
Sulphate	mg/l	0.05	1.1	1.2	0.54	0.05	1.9
Nitrate	mg/l	0.1	<0.1	1.7	<0.1	<0.1	<0.1

Total Cyanide in leachates Method: ME-AN-031

Parameter	Units	LOR	JB15-06548.016	JB15-06548.017	JB15-06548.018	JB15-06548.019	JB15-06548.020
Total Cyanide	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Hexavalent Chromium by Discrete Analyser on Leachates Method: ME-AN-040

Parameter	Units	LOR	JB15-06548.016	JB15-06548.017	JB15-06548.018	JB15-06548.019	JB15-06548.020
Hexavalent Chromium*	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Fluoride on leachates by Ion Selective Electrode Method: ME-AN-021

Parameter	Units	LOR	JB15-06548.016	JB15-06548.017	JB15-06548.018	JB15-06548.019	JB15-06548.020
Fluoride by ISE	mg/l	0.05	<0.05	<0.05	0.09	<0.05	0.05

ICP-OES Metals on leachates (Dissolved) Method: ME-AN-027 D

Parameter	Units	LOR	JB15-06548.016	JB15-06548.017	JB15-06548.018	JB15-06548.019	JB15-06548.020
Silver	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Aluminium	mg/l	0.02	0.40	0.04	<0.02	0.11	0.11
Arsenic	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	mg/l	0.005	0.024	0.021	0.019	0.014	0.016
Barium	mg/l	0.002	1.1	0.82	0.014	0.10	2.5
Beryllium	mg/l	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Bismuth	mg/l	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Calcium	mg/l	0.5	45	45	401	<0.5	4.4
Cadmium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	mg/l	0.002	0.002	<0.002	0.002	0.002	0.002
Copper	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Iron	mg/l	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lanthanum	mg/l	0.2	-	-	-	-	-
Potassium	mg/l	0.2	7.2	4.4	11	1.3	2.5
Lithium	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Magnesium	mg/l	0.01	1.4	9.9	77	0.11	1.7
Manganese	mg/l	0.01	0.18	0.07	1.0	0.13	0.19
Molybdenum	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sodium	mg/l	0.5	904	884	910	909	752
Nickel	mg/l	0.005	<0.005	<0.005	0.011	<0.005	<0.005
Phosphorus	mg/l	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulphur*	mg/l	0.07	0.60	0.70	0.44	0.13	0.97
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Selenium	mg/l	0.01	<0.01	<0.01	0.02	<0.01	<0.01
Silicon	mg/l	1	1	3	4	<1	1
Tin	mg/l	0.01	<0.01	<0.01	0.01	<0.01	<0.01
Strontium	mg/l	0.001	0.079	0.096	0.34	0.033	0.076
Tellurium	mg/l	0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Thorium*	mg/l	0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Titanium	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Thallium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tungsten	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01



ANALYTICAL REPORT

JB15-06548 R1

Report number 0000010190
Client reference: ARM.15.008-SGS

Sample Number	JB15-06548.021	JB15-06548.022	JB15-06548.023	JB15-06548.024	JB15-06548.025
Sample Name	17 BE - BN WRD A Soil	18 BE - BN WRD B Soil	21 BE - Historic A Soil	21 BE - Historic B Soil	25 BE - Contam 1A Soil
Sample Matrix					

Parameter Units LOR
Australian Standard Leaching Procedure - Acetic Acid Method: AS4439.3

Parameter	Units	LOR	JB15-06548.021	JB15-06548.022	JB15-06548.023	JB15-06548.024	JB15-06548.025
Extraction fluid used*	-	-	1	1	1	1	1
Weight Sample*	g	-	50.0	50.0	50.0	50.0	50.0
Vol. ml*	ml	-	1000	1000	1000	1000	1000
Final pH*	-	0.1	4.9	4.9	5.0	4.9	4.9

Anions on leachates by Ion Chromatography Method: ME-AN-014

Parameter	Units	LOR	JB15-06548.021	JB15-06548.022	JB15-06548.023	JB15-06548.024	JB15-06548.025
Sulphate	mg/l	0.05	1.3	2.1	0.13	0.48	0.07
Nitrate	mg/l	0.1	<0.1	4.2	<0.1	<0.1	<0.1

Total Cyanide in leachates Method: ME-AN-031

Parameter	Units	LOR	JB15-06548.021	JB15-06548.022	JB15-06548.023	JB15-06548.024	JB15-06548.025
Total Cyanide	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Hexavalent Chromium by Discrete Analyser on Leachates Method: ME-AN-040

Parameter	Units	LOR	JB15-06548.021	JB15-06548.022	JB15-06548.023	JB15-06548.024	JB15-06548.025
Hexavalent Chromium*	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Fluoride on leachates by Ion Selective Electrode Method: ME-AN-021

Parameter	Units	LOR	JB15-06548.021	JB15-06548.022	JB15-06548.023	JB15-06548.024	JB15-06548.025
Fluoride by ISE	mg/l	0.05	0.08	<0.05	<0.05	0.05	<0.05

ICP-OES Metals on leachates (Dissolved) Method: ME-AN-027 D

Parameter	Units	LOR	JB15-06548.021	JB15-06548.022	JB15-06548.023	JB15-06548.024	JB15-06548.025
Silver	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Aluminium	mg/l	0.02	0.15	0.04	0.16	0.15	0.31
Arsenic	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	mg/l	0.005	0.020	0.025	0.022	0.020	0.026
Barium	mg/l	0.002	1.4	1.3	0.12	0.37	0.24
Beryllium	mg/l	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Bismuth	mg/l	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Calcium	mg/l	0.5	5.6	14	35	42	11
Cadmium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	mg/l	0.002	0.003	<0.002	<0.002	0.002	<0.002
Copper	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Iron	mg/l	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lanthanum	mg/l	0.2	-	-	-	-	-
Potassium	mg/l	0.2	4.2	4.4	4.4	6.7	5.0
Lithium	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Magnesium	mg/l	0.01	5.6	11	22	4.9	1.6
Manganese	mg/l	0.01	0.42	0.09	1.7	0.14	0.12
Molybdenum	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sodium	mg/l	0.5	916	849	891	761	925
Nickel	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Phosphorus	mg/l	0.03	<0.03	0.05	<0.03	<0.03	<0.03
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulphur*	mg/l	0.07	0.63	0.99	0.08	0.26	0.10
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Selenium	mg/l	0.01	<0.01	0.01	<0.01	<0.01	<0.01
Silicon	mg/l	1	2	3	1	3	2
Tin	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/l	0.001	0.047	0.091	0.072	0.071	0.044
Tellurium	mg/l	0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Thorium*	mg/l	0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Titanium	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Thallium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tungsten	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01



ANALYTICAL REPORT

JB15-06548 R1

Report number 0000010190
Client reference: ARM.15.008-SGS

Sample Number	JB15-06548.026	JB15-06548.027	JB15-06548.028	JB15-06548.029	JB15-06548.030
Sample Name	26 BE - Contam 1 B Soil	27 BE - BIS Soil	28 BE - TITR Soil	29 BE - West Pit A Soil	30 BE - West Pit B Soil
Sample Matrix					

Parameter Units LOR
Australian Standard Leaching Procedure - Acetic Acid Method: AS4439.3

Parameter	Units	LOR	JB15-06548.026	JB15-06548.027	JB15-06548.028	JB15-06548.029	JB15-06548.030
Extraction fluid used*	-	-	1	1	1	1	1
Weight Sample*	g	-	50.0	50.0	50.0	50.0	50.0
Vol. ml*	ml	-	1000	1000	1000	1000	1000
Final pH*	-	0.1	4.9	4.9	4.9	4.9	4.9

Anions on leachates by Ion Chromatography Method: ME-AN-014

Parameter	Units	LOR	JB15-06548.026	JB15-06548.027	JB15-06548.028	JB15-06548.029	JB15-06548.030
Sulphate	mg/l	0.05	0.67	<0.05	0.58	0.13	0.12
Nitrate	mg/l	0.1	<0.1	<0.1	<0.1	1.1	1.1

Total Cyanide in leachates Method: ME-AN-031

Parameter	Units	LOR	JB15-06548.026	JB15-06548.027	JB15-06548.028	JB15-06548.029	JB15-06548.030
Total Cyanide	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Hexavalent Chromium by Discrete Analyser on Leachates Method: ME-AN-040

Parameter	Units	LOR	JB15-06548.026	JB15-06548.027	JB15-06548.028	JB15-06548.029	JB15-06548.030
Hexavalent Chromium*	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Fluoride on leachates by Ion Selective Electrode Method: ME-AN-021

Parameter	Units	LOR	JB15-06548.026	JB15-06548.027	JB15-06548.028	JB15-06548.029	JB15-06548.030
Fluoride by ISE	mg/l	0.05	<0.05	<0.05	<0.05	<0.05	0.09

ICP-OES Metals on leachates (Dissolved) Method: ME-AN-027 D

Parameter	Units	LOR	JB15-06548.026	JB15-06548.027	JB15-06548.028	JB15-06548.029	JB15-06548.030
Silver	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Aluminium	mg/l	0.02	0.20	0.02	0.07	0.08	0.18
Arsenic	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	mg/l	0.005	0.028	0.018	0.025	0.017	0.022
Barium	mg/l	0.002	0.80	0.14	0.78	0.21	0.20
Beryllium	mg/l	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0008
Bismuth	mg/l	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Calcium	mg/l	0.5	5.9	6.0	23	11	9.7
Cadmium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	0.004
Copper	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Iron	mg/l	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lanthanum	mg/l	0.2	-	-	-	-	-
Potassium	mg/l	0.2	5.4	1.4	4.9	4.4	4.3
Lithium	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Magnesium	mg/l	0.01	2.3	0.55	5.8	3.4	3.4
Manganese	mg/l	0.01	0.18	0.17	0.14	0.04	0.07
Molybdenum	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sodium	mg/l	0.5	870	904	1670	842	900
Nickel	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	0.007
Phosphorus	mg/l	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulphur*	mg/l	0.07	0.36	0.08	0.34	0.09	0.13
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Selenium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon	mg/l	1	2	<1	3	1	2
Tin	mg/l	0.01	<0.01	<0.01	<0.01	0.01	<0.01
Strontium	mg/l	0.001	0.091	0.013	0.089	0.048	0.046
Tellurium	mg/l	0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Thorium*	mg/l	0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Titanium	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Thallium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	0.02
Vanadium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tungsten	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01



ANALYTICAL REPORT

JB15-06548 R1

Report number 0000010190
Client reference: ARM.15.008-SGS

Sample Number	JB15-06548.031	JB15-06548.032	JB15-06548.033	JB15-06548.034	JB15-06548.035
Sample Name	31 BE - Village A	32 BE - Village B	33 BE - East Pit A	34 BE - East Pit B	TCLP#1 Blank
Sample Matrix	Soil	Soil	Soil	Soil	

Parameter **Units** **LOR**
Australian Standard Leaching Procedure - Acetic Acid Method: AS4439.3

Parameter	Units	LOR	JB15-06548.031	JB15-06548.032	JB15-06548.033	JB15-06548.034	JB15-06548.035
Extraction fluid used*	-	-	2	1	1	1	1
Weight Sample*	g	-	50.0	50.0	50.0	50.0	-
Vol. ml*	ml	-	1000	1000	1000	1000	1000
Final pH*	-	0.1	6.4	6.3	4.9	4.9	4.9

Anions on leachates by Ion Chromatography Method: ME-AN-014

Parameter	Units	LOR	JB15-06548.031	JB15-06548.032	JB15-06548.033	JB15-06548.034	JB15-06548.035
Sulphate	mg/l	0.05	6.0	1.2	0.17	0.25	<0.05
Nitrate	mg/l	0.1	<0.1	0.1	0.2	0.3	<0.1

Total Cyanide in leachates Method: ME-AN-031

Parameter	Units	LOR	JB15-06548.031	JB15-06548.032	JB15-06548.033	JB15-06548.034	JB15-06548.035
Total Cyanide	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Hexavalent Chromium by Discrete Analyser on Leachates Method: ME-AN-040

Parameter	Units	LOR	JB15-06548.031	JB15-06548.032	JB15-06548.033	JB15-06548.034	JB15-06548.035
Hexavalent Chromium*	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Fluoride on leachates by Ion Selective Electrode Method: ME-AN-021

Parameter	Units	LOR	JB15-06548.031	JB15-06548.032	JB15-06548.033	JB15-06548.034	JB15-06548.035
Fluoride by ISE	mg/l	0.05	0.58	0.13	<0.05	<0.05	<0.05

ICP-OES Metals on leachates (Dissolved) Method: ME-AN-027 D

Parameter	Units	LOR	JB15-06548.031	JB15-06548.032	JB15-06548.033	JB15-06548.034	JB15-06548.035
Silver	mg/l	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Aluminium	mg/l	0.02	<0.02	<0.02	0.08	0.07	<0.02
Arsenic	mg/l	0.01	0.02	0.01	<0.01	<0.01	<0.01
Boron	mg/l	0.005	0.031	0.017	0.025	0.021	<0.005
Barium	mg/l	0.002	0.58	0.71	1.0	0.53	<0.002
Beryllium	mg/l	0.0001	<0.0001	<0.0001	0.0005	0.0003	<0.0001
Bismuth	mg/l	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Calcium	mg/l	0.5	1250	450	16	16	<0.5
Cadmium	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	mg/l	0.002	<0.002	0.002	<0.002	0.002	<0.002
Copper	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Iron	mg/l	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lanthanum	mg/l	0.2	-	-	-	-	-
Potassium	mg/l	0.2	12	8.6	7.4	6.0	<0.2
Lithium	mg/l	0.005	0.066	<0.005	<0.005	<0.005	<0.005
Magnesium	mg/l	0.01	24	46	3.1	2.3	<0.01
Manganese	mg/l	0.01	0.14	<0.01	0.86	0.70	<0.01
Molybdenum	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sodium	mg/l	0.5	2.0	901	881	907	966
Nickel	mg/l	0.005	<0.005	<0.005	0.008	<0.005	<0.005
Phosphorus	mg/l	0.03	0.12	<0.03	<0.03	<0.03	<0.03
Lead	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulphur*	mg/l	0.07	2.4	0.76	0.26	0.16	<0.07
Antimony	mg/l	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Selenium	mg/l	0.01	0.02	0.01	<0.01	<0.01	<0.01
Silicon	mg/l	1	5	8	3	2	<1
Tin	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/l	0.001	0.51	0.27	0.090	0.057	<0.001
Tellurium	mg/l	0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Thorium*	mg/l	0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Titanium	mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Thallium	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	mg/l	0.01	0.03	0.04	0.02	0.02	<0.01
Vanadium	mg/l	0.001	0.009	<0.001	<0.001	<0.001	0.001
Tungsten	mg/l	0.01	<0.01	<0.01	<0.01	<0.01	<0.01



ANALYTICAL REPORT

JB15-06548 R1

Report number 0000010190

Client reference: ARM.15.008-SGS

Sample Number	JB15-06548.031	JB15-06548.032	JB15-06548.033	JB15-06548.034	JB15-06548.035
Sample Name	31 BE - Village A Soil	32 BE - Village B Soil	33 BE - East Pit A Soil	34 BE - East Pit B Soil	TCLP#1 Blank

Parameter **Units** **LOR**
ICP-OES Metals on leachates (Dissolved) Method: ME-AN-027 D (continued)

Parameter	Units	LOR	JB15-06548.031	JB15-06548.032	JB15-06548.033	JB15-06548.034	JB15-06548.035
Yttrium	mg/l	0.01	-	-	-	-	-
Zinc	mg/l	0.01	0.02	0.01	0.02	0.07	<0.01
Zirconium*	mg/l	0.16	<0.16	<0.16	<0.16	<0.16	<0.16

Dissolved Hg on Leachates by ICP-MS Method: ME-AN-026

Parameter	Units	LOR	JB15-06548.031	JB15-06548.032	JB15-06548.033	JB15-06548.034	JB15-06548.035
Mercury	µg/l	0.1	<0.10	<0.10	<0.10	<0.10	<0.10

SUB_Chloride on leachates by titration Method: SUB

Parameter	Units	LOR	JB15-06548.031	JB15-06548.032	JB15-06548.033	JB15-06548.034	JB15-06548.035
Chloride^	mg/l	5	<5.0	<5.0	<5.0	<5.0	-

TCLP - Leachate Evaluation Method: ME-AN-022

Parameter	Units	LOR	JB15-06548.031	JB15-06548.032	JB15-06548.033	JB15-06548.034	JB15-06548.035
Evaluation pH	-	0.1	9.6	9.4	8.2	7.4	-



SGS

METHOD SUMMARY

JB15-06548 R1

Report number: **0000010190**
Client reference: **ARM.15.008-SGS**

METHOD

METHODOLOGY SUMMARY

MS_EN_AS4439.3	Contaminants of interest in a waste material are leached out of the waste with a selected leaching solution under controlled conditions. The appropriate extraction fluid is determined by the final fate and inherent alkalinity of the waste. The ratio of sample to extraction fluid is 1 to 20 by mass. The concentration of each contaminant of interest is determined in the leachate by appropriate methods after separation from the sample by filtering. The method is based on AS4439.3-1997.
MS_EN_AS4439.3	Extraction Fluid #2: This fluid is made by combining dilute sodium hydroxide solution and glacial acetic acid with water. The pH of this fluid should be 5.0 +/- 0.1. Extraction Fluid #3: This fluid is made by diluting glacial acetic acid with water. The pH of this fluid should be 2.9 +/- 0.1.
MS_EN_ME-AN-014	Inorganic anions (Br, Cl, F, NO ₃ , NO ₂ , SO ₄) are determined on aqueous samples by ion chromatography. The method is based on EPA 300.1 and APHA 4110 B. Br, Cl, F and NO ₂ are not determined on TCLP leachates.
MS_EN_ME-AN-021	Fluoride is measured on an aliquot of aqueous sample using a fluoride ion selective electrode and calibrated meter. The method is based on APHA 4500-F C.
MS_EN_ME-AN-022	The appropriate extraction fluid for the TCLP leach is determined based on the inherent alkalinity of the sample by measuring the pH of a portion of the sample mixed with deionised water.
MS_EN_ME-AN-027	Dissolved metals are determined on a filtered and acidified portion of aqueous sample by inductively coupled plasma optical emission spectrometry (ICP-OES). The method is based on EPA 200.7 and APHA 3120.
MS_EN_ME-AN-031	This method is based on ISO 14403:2002(E) Water Quality – Determination of Total Cyanide and Free Cyanide by Continuous Flow Analysis. It is applicable to the determination of total dissolved cyanide in various types of environmental samples. The matrices applicable to this method are drinking water, surface water, groundwater, mixed industrial and domestic wastewaters and leachates.
MS_EN_ME-AN-040	Hexavalent chromium, when reacted with diphenylcarbide in acid solution, produces a red-violet colour which is measured photometrically at wavelength 540 nm.



JB15-06548 R1

Report number: 0000010190
Client reference: ARM.15.008-SGS

FOOTNOTES

IS Insufficient sample for analysis.
LNR Sample listed, but not received.
^ Performed by outside laboratory.
LOR Limit of Reporting
↑↓ Raised or Lowered Limit of Reporting

QFH QC result is above the upper tolerance
QFL QC result is below the lower tolerance
- The sample was not analysed for this analyte
* Results marked "Not SANAS Accredited" in this report are not included in the SANAS Schedule of Accreditation for this laboratory / certification body / inspection body*.

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Unless otherwise indicated, samples were received in containers fit for purpose

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**APPENDIX B:
LABORATORY ANALYSIS CERTIFICATES
VERIFICATION ROUND OF TESTING**



WATERLAB (PTY) LTD			
 WATERLAB	23B De Havilland Crescent Parkview Techno Park, Masing Naudé Road, Pretoria P.O. Box 283, 0020		Telephone: +2712 – 349 – 1066 Facsimile: +2712 – 349 – 2064 Email: accounts@waterlab.co.za
	CERTIFICATE OF ANALYSES EXTRACTIONS AS 4439.3		
Date received:	2015/10/28	Date completed:	2015/11/30
Project number:	1000	Report number:	55461
		Order number:	ARM
Client name:	Future Flow Groundwater and Project Management Solutions		Contact person:
Address:	P.O. Box 161, Menlyn, 0063		Martiens Prinsloo
Telephone:	0123451337		Email:
			martiens@ffgpm.co.za
		Cell:	0836334949
Sample storage:			
Sample preparation:			
Analyses	Bruce Waste Dump 1	Bruce BC 11	LCTO mg/l
	Sample Number	19459	
TCLP / Borax / Distilled Water	Borax	Borax	
Ratio*	1:20	1:20	
Units	mg/ℓ	mg/ℓ	
As, Arsenic	<0.010	0.016	0.01
B, Boron	7.00	<0.025	0.5
Ba, Barium	<0.025	1.00	0.7
Cd, Cadmium	<0.003	<0.003	0.003
Co, Cobalt	<0.025	<0.025	0.5
Cr _{total} , Chromium Total	<0.025	<0.025	0.1
Cr(VI), Chromium (VI)	<0.010	<0.010	0.05
Cu, Copper	0.110	0.071	2.0
Hg, Mercury	<0.001	<0.001	0.006
Mn, Manganese	<0.025	<0.025	0.5
Mo, Molybdenum	<0.025	<0.025	0.07
Ni, Nickel	<0.025	<0.025	0.07
Pb, Lead	<0.010	0.025	0.01
Sb, Antimony	<0.020	<0.020	0.02
Se, Selenium	<0.010	0.017	0.01
V, Vanadium	<0.025	0.076	0.2
Zn, Zinc	0.038	<0.025	5
Inorganic Anions	mg/ℓ	mg/ℓ	
Total Dissolved Solids*	2880	1248	1000
Chloride as Cl	<2	<2	300
Sulphate as SO ₄	<2	<2	250
Nitrate as N	1.3	<0.1	11
Fluoride as F	0.3	0.2	1.5
Total Cyanide as CN	<0.01	<0.01	0.07
pH	9.4	9.4	
% Solids	---	---	
[s]=subcontracted			
E. Botha			
Geochemistry Project Manager			



WATERLAB (PTY) LTD					
 WATERLAB	238 De Havilland Crescent Perseus Techno Park, Meiring Naudé Road,			Telephone: +2712 – 349 – 1088 Facsimile: +2712 – 349 – 2064 Email: accounts@waterlab.co.za	
	<u>CERTIFICATE OF ANALYSES</u>				
Digestion AS 4439.3					
Date received:	2015/10/28			Date completed:	2015/11/30
Project number:	1000	Report number:	55461	Order number:	ARM
Client name:	Future Flow Groundwater and Project Management Solutions			Contact person:	Martiens Prinsloo
Address:	P.O. Box 161, Menlyn, 0063			Email:	martiens@ffgpm.co.za
Telephone:	0123451337			Cell:	0836334949
Analyses	Bruce Waste Dump 1		Bruce BC 11		TCT0 mg/kg
	Sample Number	19459	19460		
Digestion	Aqua Regia		Aqua Regia		
Dry Mass Used (g)	0.25		0.25		
Volume Used (mℓ)	100		100		
Units	mg/ℓ	mg/kg	mg/ℓ	mg/kg	
As, Arsenic	0.012	4.80	<0.010	<4.00	5.8
B, Boron	0.176	70	0.042	17	150
Ba, Barium	0.994	398	0.565	226	62.5
Cd, Cadmium	0.053	21	0.071	28	7.5
Co, Cobalt	<0.025	<10	<0.025	<10	50
Cr _{Total} , Chromium Total	0.338	135	0.256	102	46000
Cu, Copper	<0.025	<10	<0.025	<10	16
Hg, Mercury	<0.001	<0.400	<0.001	<0.400	0.93
Mn, Manganese	0.090	36	0.210	84	1000
Mo, Molybdenum	<0.025	<10	<0.025	<10	40
Ni, Nickel	0.117	47	0.042	17	91
Pb, Lead	0.072	29	<0.010	<4.00	20
Sb, Antimony	<0.010	<4.00	<0.010	<4.00	10
Se, Selenium	<0.010	<4.00	<0.010	<4.00	10
V, Vanadium	0.226	90	0.117	47	150
Zn, Zinc	0.051	20	0.057	23	240
Inorganic Anions	mg/ℓ	mg/kg	mg/ℓ	mg/kg	
Cr(VI), Chromium (VI) Total [s]	---	<5	---	<5	6.5
Total Fluoride [s] mg/kg	---	274	---	178	100
Total Cyanide as CN mg/kg	---	<0.01	---	<0.01	14
[s] = subcontracted					
UTD = Unable to determine					
<u>E. Botha</u>					
Geochemistry Project Manager					



**APPENDIX C:
LABORATORY ANALYSIS CERTIFICATE:
AQUATIC TOXICITY TESTING**



G2016/43



T0384

7.0 RESULTS

Table 2: 16/339 and 16/340 Toxicity Results

Physical and chemical data	Method number	Sample reference number(s) and description	
		16/339 BRUCE WASTE DUMP A	16/340 5 PRE- PROCESS A
pH	M 09	6.74	8.28
Conductivity (µS/cm)	M 05	42.7	127.3
Dissolved oxygen concentration (mg/l)		5.53	7.23
Total residual chlorine (present✓/not present ×)	"Not SANAS Accredited"	×	×
Temperature (°C)		20	20

Tebogo Gwamanda
Analytical Chemist

Toxicity test results

15 minute <i>Vibrio fischeri</i> bioluminescent screening test (average % inhibition (-) or stimulation (+))	T 01	-52	-14
30 minute <i>Vibrio fischeri</i> bioluminescent screening test (average % inhibition (-) or stimulation (+))		-27	-13
30 minute <i>Vibrio fischeri</i> bioluminescent test toxicity unit (TUa)		<1	<1
72h <i>Selenastrum capricornutum</i> growth inhibition screening test (% growth inhibition (-) or growth stimulation (+))	T 02	-12	+18
72h <i>Selenastrum capricornutum</i> growth inhibition test toxicity unit (TUa)		<1	<1
24h <i>Daphnia pulex</i> acute toxicity screening test (% mortality)	T 03	10	15
48h <i>Daphnia pulex</i> acute toxicity screening test (% mortality)		35	15
48h <i>Daphnia pulex</i> acute toxicity test toxicity unit (TUa)		<1	<1
96h <i>Poecilia reticulata</i> acute toxicity screening test (% mortality)	T 04	0	30
96h <i>Poecilia reticulata</i> acute toxicity test toxicity unit (TUa)		<1	<1



Mahadi Motsumi
(Quality Manager)






**APPENDIX D:
MATERIAL SAFETY DATA SHEET**

MATERIAL SAFETY DATA SHEET

Section 1: Identification of the substance and the supplier	
Product name(s):	Waste rock and slimes (paste) material.
Product identifiers:	Rock material. Mixed red to dark grey competent waste rock, and fine grained, red to dark grey slimes (paste) like material from mining excavations and processing.
Manufacturer: ARM Ferrous Beeshoek Mine 24 Impala Road Chislehurst Sandton 2146	Information telephone number: +27 (0)53 723 8000 Head office telephone number: +27 (0)11 779 1000
Product use:	Waste rock material from mining operations is stockpiled on surface in dedicated waste rock stockpiles. Slimes (paste) material is stockpiled on a dedicated surface slimes dam.
Note:	This MSDS covers a variety of lithologies. The individual composition of hazardous constituents may vary between different lithologies, and also within each lithology.
Section 2: Hazards identification	
GHS classification Physical hazards	The waste rock and slimes (paste) like material do not pose physical hazards as grouped or classed in the SANS 10234 guideline. These hazards include explosives, flammable gasses, flammable aerosols, oxidising gasses, gasses under pressure, flammable liquids, flammable solids, self-reactive substances and mixtures, prophyrical substances, self-heating substances and mixtures, substances and mixtures that on contact with water emit flammable gasses, oxidising substances or mixtures, organic peroxides, and being corrosive to metals. Neither waste rock and slimes (paste) material; nor the water used in the wash process poses an explosive, oxidising, flammable or other risk. Therefore, the material is classified as non-hazardous in terms of physical hazards.
GHS classification Health hazards	The waste rock and slimes/paste like material pose various health hazards: Acute toxicity: Waste rock and slimes/paste material are both classified as Category 1 hazards. Skin corrosion and irritation: both the waste rock and the slimes (paste) material are classified as hazardous. Serious eye damage and eye irritation: Waste rock and

	<p>slimes/paste material are both classified as Category 1 hazards to the eyes.</p> <p>Respiratory and skin sensitisation: Waste rock and slimes (paste) material are both classified as hazardous.</p> <p>Germ cell mutagenicity: Category 1 mutagen: Waste rock and slimes (paste) Category 2 mutagen: None.</p> <p>Carcinogenicity: None of the mixtures are classified as carcinogenic.</p> <p>Reproductive toxicity: Category 1 toxicants (>0.1 and ≤0.3 %): None Category 2 toxicants: (≥0.3 %) Waste rock, slimes (paste)</p> <p>Specific target organ toxicity – single exposure Category 1 (≥ 1.0 % and < 10 %): None. Category 1 (≥ 10 %): None Category 2 (≥ 1.0 % and < 10 %): Waste rock, slimes (paste) material Category 2 (≥ 10 %): Waste rock, slimes (paste).</p> <p>Specific target organ toxicity – repeated exposure Category 1 (≥ 1.0 % and < 10 %): None. Category 1 (≥ 10 %): None. Category 2 (≥ 1.0 % and < 10 %): Waste rock, slimes (paste) material Category 2 (≥ 10 %): Waste rock, slimes (paste)</p>
<p>GHS classification</p>	<p>To follow</p>
<p>Aquatic hazards</p>	
<p>SANS 10234 GHS label elements</p> <p>Health hazards</p>	<p>Acute toxicity: <u>Signal words:</u> Danger  <u>Hazard statement:</u> Fatal if swallowed <u>Precautionary statements:</u> Wash hands thoroughly after handling Do not eat, drink or smoke when using this product IF SWALLOWED: Immediately call a poison centre or doctor Rinse mouth Dispose of material to applicable surface storage facility</p> <p>Skin corrosion and irritation: <u>Signal words:</u> Warning  <u>Hazard statement:</u> Causes skin irritation <u>Precautionary statements:</u> Wash hands thoroughly after handling Wear protective gloves, protective clothing, eye protection</p>

	<p>IF ON SKIN: Wash with plenty of water If skin irritation occurs: Get medical advice/attention Take off contaminated clothing and wash before re-use</p> <p>Serious eye damage and eye irritation: </p> <p><u>Signal words:</u> Danger</p> <p><u>Hazard statement:</u> Causes severe eye damage</p> <p><u>Precautionary statements:</u> Wear protective gloves, protective clothing, eye protection IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing Immediately call a POISON CENTRE or doctor/physician</p> <p>Respiratory and skin sensitisation: </p> <p><u>Signal words:</u> Danger</p> <p><u>Hazard statement:</u> May cause allergy or asthma symptoms or breathing difficulties if inhaled May cause an allergic skin reaction</p> <p><u>Precautionary statements:</u> Do not breathe dust Contaminated work clothing should not be allowed out of the workplace IF INHALED: If breathing is difficult, remove to fresh air and keep at rest in a position comfortable for breathing IF ON SKIN: Wash with plenty of water If experiencing respiratory symptoms: Call a POISON CENTRE or doctor/physician If skin irritation or rash occurs: Get medical advice/attention Wash contaminated clothing before re-use Dispose of material to applicable surface storage facility</p> <p>Germ cell mutagenicity: </p> <p><u>Signal words:</u> Danger</p> <p><u>Hazard statement:</u> May cause genetic defects</p> <p><u>Precautionary statements:</u> Obtain special instructions before use Do not handle until all safety precautions have been read and understood Use personal protective equipment as required If exposed or concerned: Call a POISON CENTRE or doctor/physician Dispose of material to applicable surface storage facility</p> <p>Carcinogenicity: <u>Signal words:</u> None</p>
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	<p><u>Hazard statement:</u> None</p> <p><u>Precautionary statements:</u> None</p> <p>Reproductive toxicity:</p> <p><u>Signal words:</u> Danger</p> <p><u>Hazard statement:</u> May damage fertility or the unborn child</p> <p><u>Precautionary statements:</u></p> <p>Obtain special instructions before use Do not handle until all safety precautions have been read and understood Use personal protective equipment as required If exposed or concerned: Call a POISON CENTRE or doctor/physician Dispose of material to applicable surface storage facility</p> <p>Specific target organ toxicity – single exposure:</p> <p><u>Signal words:</u> Danger</p> <p><u>Hazard statement:</u> Causes damage to organs</p> <p><u>Precautionary statements:</u></p> <p>Do not breathe dust Wash hands thoroughly after handling Do not eat, drink or smoke when using this product IF EXPOSED: Call a POISON CENTRE or doctor/physician Dispose of material to applicable surface storage facility</p> <p>Specific target organ toxicity – repeated exposure:</p> <p><u>Signal words:</u> Danger</p> <p><u>Hazard statement:</u> Causes damage to organs</p> <p><u>Precautionary statements:</u></p> <p>Do not breathe dust Wash hands thoroughly after handling Do not eat, drink or smoke when using this product Get medical advice/attention if you feel unwell Dispose of material to applicable surface storage facility</p>
Section 3: Composition / information on ingredients	
	<p>Waste rock: Is generally a mixture of low grade iron ore lithologies</p> <p>Slimes (paste): Is generally a mixture of low grade iron ore lithologies.</p>
Section 4: First aid measures	
Eye contact:	Immediately flush the contaminated eye(s) with gently flowing water for 20-30 minutes, by the clock, while holding the eyelid(s) open. Check for and remove any contact

	lenses. Neutral saline solution may be used as soon as it is available. If irritation persists transport victim to an emergency care facility.
Product on skin:	Remove contaminated clothing and wash skin with plenty of running water for at least 20-30 minutes. If irritation persists transport victim to an emergency care facility. Wash contaminated clothing before re-use.
Product ingested:	NEVER give anything by mouth if victim is rapidly losing consciousness, or is unconscious or convulsing. Remove dentures if any. Have victim rinse mouth thoroughly with water. DO NOT INDUCE VOMITING. Have victim drink 240 to 300 ml of water. If vomiting occurs naturally, rinse mouth and repeat administration of water. Quickly transport victim to an emergency care facility for attention.
Product inhaled:	Remove victim to fresh air and keep at rest in a position to aid in breathing. If breathing is difficult, oxygen may be beneficial if administered by trained personnel, preferably on a doctor's advice. Immediately transport victim to an emergency care facility.
Notes to physician:	Treat symptomatically. Contact poison treatment specialist immediately if large quantities have been ingested or inhaled.
Protection for first-aiders:	No action shall be taken involving any personal risk or without suitable training. It may be dangerous to the person providing aid.
Section 5: Firefighting measures	
Flashpoint & method:	The waste rock and slimes (paste) material will not burn or support combustion.
Extinguishing media:	Use extinguishing media appropriate to the surrounding fire.
Specific hazards arising from the material:	None.
Special protective equipment and precautions for firefighters:	Firefighters to wear protection appropriate to the surrounding fire including boots, overalls, gloves, face and eye protection, and breathing apparatus.
Section 6: Accidental release measures	
Personal precautions, protective equipment and emergency procedures:	Wear suitable protective clothing, including breathing apparatus and eye protection to protect against contamination of the skin and eyes. Keep unnecessary and untrained personnel from the area. Avoid breathing dust Put on appropriate personal protective equipment.

Environmental precautions:	Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers. Inform the relevant authorities if the product has caused environmental pollution (sewers, waterways, soil and air).
Methods and materials for containment and clean-up	Obtain appropriate machinery and vehicles to collect and transport the waste rock or slimes (paste) material. Transport the material to the appropriate surface stockpile area (e.g. waste rock dump or slimes dam). Ensure all material is collected and the spill area is rehabilitated.
Section 7: Handling and storage	
Precautions for safe handling:	Put on appropriate personal protective equipment. Eating, drinking and smoking should be prohibited in areas where this material is handled and stored. Workers should wash hands and face before eating, drinking and smoking. Remove contaminated clothing and protective equipment before entering eating areas. Do not ingest. Avoid contact with eyes and skin. Avoid breathing dust.
Conditions for safe storage, including any incompatibilities:	Store on appropriate, and designated, surface stockpiles (e.g. waste rock dump or slimes dam); Adhere to storage facility design, including: <ul style="list-style-type: none"> • Maximum height and angle of facility; • Maximum rate of rise of the slimes dam to allow proper drying of the material; • Manage surface water runoff from, and around, the stockpiles, • Keep within demarcated footprint boundaries. Do not walk or drive on the slimes dam, it may not be able to support the weight. Avoid actions that cause dust to become airborne.
Section 8: Exposure controls / personal protection	
Control parameters:	Avoid breathing dust Avoid ingesting water contaminated by leach from the material.
Appropriate engineering controls:	Ensure rehabilitation, including capping and vegetation of disused or closed surface storage facilities where possible. Ensure control of dust through dust suppression where possible. Ensure proper operation of the slimes dam adhering to the engineered design.
Individual protection measures, such as personal protective	<u>Hygiene measures:</u> Wash hands, forearms and face thoroughly after handling material, before eating, smoking

equipment (PPE):	<p>and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the stockpile location.</p> <p><u>Eye/face protection:</u> Safety eyewear complying with an approved standard should be used when a risk assessment indicates this is necessary to avoid exposure to dusts. Recommended: safety glasses with side-shields.</p> <p><u>Body protection:</u> Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.</p> <p><u>Other skin protection:</u> Appropriate footwear and any additional skin protection measures should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product. Recommended: Wear rubber boots or safety shoes.</p> <p><u>Respiratory protection:</u> Use a properly fitted, air-purifying or air-fed respirator complying with an approved standard if a risk assessment indicates this is necessary. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator.</p>
Section 9: Physical and chemical properties	
Appearance:	<p><u>Waste rock:</u> Mixed red to dark grey competent rock material.</p> <p><u>Slimes (paste) material:</u> finer sized crushed or sorted grained, red to dark grey rock material from mining processing.</p>
Odour:	<p>Waste rock: None</p> <p>Slimes (paste): None.</p>
pH:	<p>Waste rock: 5 - 7</p> <p>Slimes (paste): 5 - 7.</p>
Melting point / freeze point:	Not available.
Final boiling point and boiling range:	Not available.
Flash point:	Not available.
Evaporation rate:	Not available.
Flammability (solid, gas):	Not available.
Upper/lower flammability or	Not available.

explosive points:	
Vapour pressure:	Not available.
Vapour density:	Not available.
Relative density:	Not available.
Solubility:	Not available.
Partition coefficient: n-octanol/water:	Not available.
Auto-ignition temperature:	Not available.
Decomposition temperature:	Not available.
Viscosity:	Not available.
Section 10: Stability and reactivity	
Reactivity:	Waste rock: Non-reactive Slimes (paste): Non-reactive.
Chemical stability:	Waste rock: Stable Slimes (paste): Stable.
Possibility of hazardous reactions:	Waste rock: None Slimes (paste): None.
Conditions to avoid:	Waste rock: None Slimes (paste): None.
Incompatible materials:	Waste rock: None Slimes (paste): None.
Hazardous decomposition materials:	Waste rock: None Slimes (paste): None.
Section 11: Toxicological information	
Likely routes of exposure:	Inhalation Skin/eye exposure
Symptoms related to the physical, chemical and toxicological characteristics	Inhalation: <ul style="list-style-type: none"> • May cause allergy or asthma symptoms or breathing difficulties if inhaled Skin/eye exposure: <ul style="list-style-type: none"> • May cause severe eye damage • May cause skin irritation
Delayed and immediate effects, as well as chronic effects	No specific information is available.
Numerical measures of toxicity:	Please refer to the SANS 10234 classification guidelines as presented in Section 2 of this MSDS for the range of dose, concentration or conditions that may cause adverse health effects.
Interactive effects:	No information available.
Section 12: Ecological information:	
Toxicity:	Not available yet
Persistence and degradability:	The rock material will take many decades to degrade.

	Therefore, it is recommended that it is removed mechanically and deposited on an appropriate storage facility on site (waste rock dump slimes dam etc.).
Bio-accumulative potential:	No information available.
Mobility in soil:	Leach from the waste rock and slimes (paste) material can enter the soil and there migrate further together with the groundwater.
Section 13: Disposal considerations	
Disposal considerations:	<p>Store on appropriate, and designated, surface stockpiles (e.g. waste rock dump or slimes dam);</p> <p>Adhere to storage facility design, including:</p> <ul style="list-style-type: none"> • Maximum height and angle of facility; • Maximum rate of rise of the slimes dam to allow proper drying of the material; • Manage surface water runoff from, and around, the stockpiles, • Keep within demarcated footprint boundaries. <p>Do not walk or drive on the slimes dam, it may not be able to support the weight.</p> <p>Avoid actions that cause dust to become airborne.</p>
Section 14: Transport information	
UN number (SANS 10228 & 10229-1):	<u>Waste rock</u> : Not listed in SANS 10228; <u>Slimes (paste)</u> : Not listed in SANS 10228.
UN proper shipping name:	<u>Waste rock</u> : Not listed in SANS 10228; <u>Slimes (paste)</u> : Not listed in SANS 10228.
Transport hazard classes:	<u>Waste rock</u> : Not listed in SANS 10228; <u>Slimes (paste)</u> : Not listed in SANS 10228.
Packing group:	Not applicable.
Environmental hazards:	Please contact the environmental officer to discuss environmental hazards.
Section 15: Regulatory information	
Safety, health, environmental regulations:	Hazardous Substances Act 15 of 1973 and Regulations; Occupational Health and Safety Act 85 of 1993.