SAMANCOR CHROME – MIDDELBURG FERROCHROME

# Geochemical Analysis and Waste Classification of the CDR Slimes (Middelburg Ferrochrome)

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## Delh. 2020.001-17

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# 1. Introduction

Delta H (Delta-H Water System Modelling PTY Ltd) was requested by Samancor Chrome to conduct a geochemical study and waste classification according to SANS10234, GNR 635 and 636 to identify barrier requirements as per National Norms and Standards for the CDR Slimes dam at Middelburg Ferrochrome. The Samancor Middelburg Ferrochrome (MFC) facility was established in 1964 to produce Low Carbon Ferrochrome for use in the production of steel. During the production time, a process known as Chrome Direct Reduction (CDR) was employed, whereby chrome ore is brought into contact with finely divided coal at high temperature. Dust is formed a by-product from the CDR process, which is captured with water sprays producing a slimes material of high moisture content. In the 1990's, MFC disposed of this CDR dust, known as CDR slimes, at a constructed disposal area (approximately 4000 $m^2$) located to the west of the MFC production facility. In 2015, MFC stopped manufacturing Low Carbon Ferrochrome.

Since 2011, Samancor Middelburg Ferrochrome (MFC) has been endeavouring to obtain regulatory authorisation for the closure of the CDR. As part of the closure process, three sampling campaigns were run to characterise the CDR Slimes material and for classification of the material in accordance with the procedures prescribed in terms of the National Environmental Management: Waste Act (NEM:WA) (Act No. 59 of 2008). A summary of the previous sampling campaigns is provided in the review report by Delta H (2019). However, these preceding assessments indicated that the geochemical characteristics of the CDR Slimes material are heterogeneous and vary both horizontally and vertically throughout the disposal site. This has resulted in unsuccessful attempts to obtain authorisation of the CDR closure thus far.

In this regard, a subsequent geochemical study was conducted by Delta H to broaden the geochemical data set of the CDR Slimes, establish the potential leachate quality, and make more informed decisions on the barrier requirements for the CDR closure. The scope of work for the geochemical characterisation of the CDR Slimes is defined in the RFQ 4500861662 and included the following:

1. Selection and collection of representative sample material
    a. Nine (9) representative samples of the CDR Slimes were retrieved by Delta H
2. Static testing of collected material samples comprising of
    a. Acid-Base Accounting (ABA) including sulphur speciation,
    b. NAG tests,
    c. Hazard classification according to SANS 10234 Globally Harmonized System of Classification and Labelling Chemicals (GHS) (i.e. to determine if a material is hazardous based on the nature of its intrinsic physical, health and environmental hazardous properties based on 16-point Safety Data Sheet (SDS),
    d. Waste classification according to Government Notices R. 634, 634 and 636 (i.e. determination of leachable and total concentrations using Australian Standard Leach Procedure and aqua regia digestion, respectively).
3. Report including review and interpretation of static test results, hazard, and waste classification according to SANS 10234, GN R. 635 and 636.

Analysis of ABA, sulphur speciation, NAG tests and leach tests for the waste classification were conducted by SANAS accredited Waterlab (Pty) Ltd. Interwaste (Pty) Ltd laboratory was appointed to conduct the hazardous waste classification according to SANS 10234. The geochemical characterization is based on the geochemical data including the evaluation of the Acid Rock Drainage (ARD) provided by Waterlab (Pty) Ltd, determination of potential hazardous characteristics of the CDR Slimes samples by Interwaste (Pty) Ltd, as well as a formal waste classification in accordance to the NEMWA – Norms and Standards as specified in the Government Notices R. 634, 635 and 636 (Government Gazette No. 36784, 23/08/2013) pertaining to the National Environmental Management: Waste Act (Act No. 59 of 2008) by the Department of Environmental Affairs. The current technical memo summarises the results of these analyses.

## 2. Core Sampling

Window sampling was employed whereby nine (9) samples were collected from different layers of five geotechnical boreholes to characterise the heterogenous CDR Slimes material. Images of the recovered core for each borehole are provided in Appendix A. The boreholes were drilled with a push rig and retrieved in Shelby tubes (1 m tube length). The core was removed from the Shelby tubes and split into half. One half of each selected core sample was bagged, sealed, and tagged and submitted to Waterlab (Pty) Ltd. for geochemical analyses including the following:

- ABA, NAG, Sulphur speciation and paste pH;
- Distilled water extraction (leach tests with 1:4 solid to liquid ratio) with 15 metals, Hg, F, Cr(VI), TDS, Cl, $SO_4$ and $NO_3$;
- Distilled water extraction (leach tests with 1:20 solid to liquid ratio) with 15 metals, Hg, F, Cr(VI), TDS, Cl, $SO_4$ and $NO_3$;
- Aqua regia digestion with total concentrations for all inorganic cations including 15 metals, Hg, F, Cr(VI), Cl, F, $NO_3$, $SO_4$ and CN;
- X-Ray Diffraction (XRD); and
- Total organic and inorganic carbon content.

The other half of each core sample (bagged, sealed and tagged) was submitted to Interwaste (Pty) Ltd. for moisture content, particle size distribution and determination of organic components (PAHs, VOC, sVOC, TPH), organic contaminant screening and hazardous waste classification in terms of SANS 10234 as well as safety data sheet (SDS) compilation. A summary description of the nine core samples is given in Table 2-1 and borehole locations are indicated in Figure 2-1.

**Table 2-1: Summary description of core samples.**

| BH ID | Latitude | Longitude | Drill Depth (mbgl) | Sample Depth (mbgl) | Sample ID | Sample Description |
|---|---|---|---|---|---|---|
| MF01 | -25.81045 | 29.48731 | 2.8 | 0-1 | MF1 0-1m | Light grey filter cake |
| | | | | 1-2 | MF1 1-2m | Black filter cake |
| MF02 | -25.80970 | 29.48710 | 5 | 0.5-1 | MF2 0.5-1m | Black filter cake |
| | | | | 2-2.5 | MF2 2-2.5m | Light grey filter cake |
| | | | | 3-4 | MF2 3-4m | Contact zone of filter cake and weathered bed rock |
| MF03 | -25.81115 | 29.48734 | 2.3 | 0.5-1.5 | MF3 0.5-1.5m | Composite of grey and black interlayered filter cake |
| MF04 | -25.81022 | 29.48667 | 1.8 | 0.5-1.5 | MF4 0.5-1.5m | Composite of grey and black interlayered filter cake |
| MF05 | -25.80933 | 29.48630 | 3 | 0.2-0.8 | MF5 0.2-0.8m | Black and grey interlayered filter cake |
| | | | | 1-2 | MF5 1-2m | Grey filter cake |


**Figure 2-1: Overview map indicating sample locations and disposal areas.**

Window sampling showed the presence of grey and black interlayered very fine grained to powdery filter cake. Typically, the ferrochrome fine dust is grey, while the black layers represent the coarse dust (Ma and Garbers-Craig, 2006). According to Ma and Garbers-Craig (2006), the fine grey dust mostly consists of agglomerated particles comprising oxide, metallic and carbon-based phases, while the coarse black dust mainly consists of oxide and carbon-based particles that are irregular in shape. The alternating grey and black layers varied in thickness from a few mm to several decimetre (Figure 2-2). The layering was inconsistent between the different profiles. A detailed log for each geotechnical borehole is provided in Appendix B.

**Figure 2-2: Interlayered CDR Slimes material containing fine (grey) and coarse (black) ferrochrome dust.**

# 3. Geochemical Classification Methodology

## 3.1. Geochemical Test Work

The geochemical test work was carried out by Waterlab (Pty) Ltd and Interwaste (Pty) Ltd, SANAS (South African National Accreditation System) accredited laboratories and included the following:

- Acid-Base Accounting (ABA), Net Acid Generation (NAG), Sulphur (S)-speciation and Paste pH.
- Determination of total concentrations on solids using Aqua regia digestion with analysis for all cations including 15 metals, Hg, F and CrVI.
- Determination of leachable concentrations using distilled water extraction (for waste to be disposed of with non-putrescible waste) at a liquid-to-solid ratio of 1:20 with analysis for 15 metals, Hg, F, CrVI, TDS, Cl, SO4, $NO_3$ to enable a formal waste classification.
- Determination of leachable concentrations using distilled water extraction at a liquid-to-solid ratio of 1:4 to facilitate a more realistic estimation of source terms for the solute transport model (NB: The waste classification requires a liquid-to-solid ratio of 1:20, which accounts for dilution in the aquifer but is unrealistic for a transport model source term derivation).
- XRD mineralogy.
- Determination of organic components (PAHs, VOC, sVOC, TPH), organic contaminant screening and hazardous waste classification in terms of SANS 10234 as well as safety data sheet (SDS) compilation (Interwaste).

## 3.2. Acid Rock Drainage Potential

Acid rock drainage is a process whereby contaminants (especially metals and sulphate) are released from solid to liquid phase under acidic pH conditions due to the oxidation of sulphide minerals in the presence of oxygen (or other oxidants like ferric iron or manganese) and water, potentially accelerated by bacteria. Heat may be generated in the process. The term acid rock drainage is also used to refer to saline and neutral mine drainage, which are characterised by neutral to alkaline pH conditions and more moderate metal and sulphate contents.

The laboratory tests to determine the potential of rock samples to produce Acid Rock Drainage (ARD) are generally grouped into two categories: static and kinetic tests. The static tests are relatively simple, inexpensive and rapid, whereas kinetic tests may take several months. Kinetic tests are typically carried out if the results of the static tests are inconclusive or kinetic reaction rates (of acid production and neutralisation) are required for geochemical models.

The current test work reported upon here comprises of static tests.

### *3.2.1. Acid-Base Accounting (ABA)*

Acid-base accounting (ABA) by Sobek et al. (1978) is a screening procedure whereby the acid-neutralising potential (assets) and acid-generating potential (liabilities) of rock samples are determined and the difference (net neutralising potential, equity) is calculated. It is a static procedure and provides no information on the rate with which acid generation or neutralisation will proceed. Reaction rates are usually determined by kinetic weathering or leaching tests. It must be noted that acid-neutralising (or buffer) reaction rates of most minerals (apart from the carbonates) are typically slower than the sulphide oxidation rates in the rocks.

ABA tests calculate the acid potential (AP) of a sample due to the theoretical oxidation of the total sulphur content of the sample to sulphuric acid. As the AP is usually expressed in kg $CaCO_3$ per tonne of rock, the conversion factor is 31.25 kg $CaCO_3$/tonne:

$$AP = \frac{\text{Sulphur content (\%)} * \ 1000\text{kg}}{100} * \frac{molecular\ weight\ of\ CaCO_3}{atomic\ weight\ of\ sulphur}$$

$$= sulphur\ content\ (\%) * 31.25 kg\ CaCO_3\ per\ tonne$$

The total sulphur content of a sample is hereby commonly determined by LECO. The AP can be converted into the Maximum Potential Acidity (MPA, expressed as kg $H_2SO_4$/tonne), which is commonly used in Australia by simply multiplying the AP with 0.98.

The neutralisation potential (NP) of a sample, mostly provided by carbonates hydroxides and silicates, is determined according to Sobek et al. (1978) by digestion of hydrochloric acid. The NP is expressed in kg $CaCO_3$ per tonne of rock but can be converted into the Acid Neutralising Capacity (ANC, expressed as kg $H_2SO_4$/tonne), used in Australia by simply multiplying the NP with 0.98.

It must be noted that this theoretical and widely used neutralisation potential does not necessarily represent the real neutralisation potential that would occur in the field as it is site-specific to environmental conditions, mineralogy, kinetic reactions and dissolution rates (Morin and Hutt 2001). Two key indicators are used to assess the risk of acid drainage:

1. The Net Neutralisation Potential (NNP) is calculated by subtracting the Acid Potential (AP) from the Neutralising Potential (NP):

$$NNP = NP - AP,$$

with negative NNP values indicating the potential to generate acidity and therefore a predicted net acid drainage water quality from the rock. Positive values indicate acid-neutralising potential or a predicted net alkaline drainage water quality from a rock sample, though some authorities (Canada) request NNP values larger than 20 before non-acid generation can be assumed.

2. The Neutralisation Potential Ratio (NPR) is calculated by dividing NP by the AP:

$$NPR = NP / AP,$$

with the following assessment criteria for a sample:

- NPR larger than 2 generally indicates non-acid generation (NAG), i.e. neutral or alkaline leachate, but in case of preferential exposure or reactivity of sulphides NPR larger than 4 is needed for complete acid neutralisation (Price et al., 1997).
- NPR between 1 and 2 is considered inconclusive or uncertain regarding acid generation.
- NPR below 1 indicates potentially acid generating (PAG) material.

### *3.2.2. Paste pH*

As part of the ABA procedure according to Sobek et al. (1978), the paste pH of a mixture of the pulverized rock sample and distilled water (pH typically 5.3) is determined. The measured pH value indicates whether a sample was at the time of analysis acidic (paste pH<5), near neutral (5<paste pH<10) or alkaline (paste pH>10). Acidic paste pH values indicate a non-reactive or absent neutralisation potential.

### *3.2.3. Sulphur speciation*

ABA assumes conservatively that all sulphur in the sample will react to form sulphuric acid, while in fact some of the sulphur may be present in non-acid producing sulphates (e.g. gypsum, barite), organic or elemental sulphur. If a significant part of the total sulphur occurs as sulphate sulphur instead of sulphide sulphur, the overall risk of acid generation is reduced. Furthermore, acid generation of samples with sulphide sulphur content below 0.3 % is considered short term (Price and Errington 1995, Soregaroli and Lawrence 1998) due to limited sulphur supply. The Sulphide Acid Potential (SAP) of a sample is then calculated according to:

$$SAP = Sulphide\ sulphur\ content\ (\%) * 31.25\ kg\ CaCO_3\ per\ tonne$$

Following the determination of the SAP, the Sulphide Net Neutralising Potential (NNP-$S^{2-}$) and the Sulphide Neutralising Potential Ratio (NPR-$S^{2-}$) can be calculated to assess the acid generation risk under consideration of the sulphur speciation.

In general, the use of total sulphur for the determination of the maximum potential acidity is considered more conservative (Brady 1990), but is obviously overly conservative for oxidised ore bodies or materials.

### *3.2.4. Carbonate neutralisation potential*

ABA assumes that the rate of mineral dissolution providing the Neutralisation Potential NP (carbonates hydroxides and silicates) is higher or equal to the rate of acid generation, which can realistically only be assumed for carbonate minerals like calcite or dolomite.

Furthermore, the equilibrium pH ranges at which hydroxides and silicates buffer (once the carbonate minerals are depleted) are typically lower than 6 (e.g. gibbsite < pH 4.3, ferrihydrite < pH 3.5) and therefore insufficient to maintain a neutral mine drainage.

The Carbonate Neutralisation Potential ($CO_3$-NP), based on the inorganic carbon content (IC) of a sample as an indicator of the presence of carbonate minerals (including iron and manganese carbonates) alone, is given by:

$$CO_3\text{-NP (kg } CaCO_3\text{/tonne)} = IC\ (\%) * 83.3$$

The following interpretations can be derived from a comparison of the two neutralisation potentials (Morin and Hutt 2001):

- $CO_3$-NP = NP: Neutralisation potential provided by reactive carbonate minerals.
- $CO_3$-NP > NP: Not all carbonate minerals are rapidly reactive (e.g. significant concentration of iron and manganese carbonates) or not all carbon is carbonate.
- $CO_3$-NP < NP: Non-carbonate minerals are major contributor to the neutralisation potential.

### *3.2.5. Net Acid Generation (NAG) test*

Net acid generation tests directly determine the acid generating potential of sulphide minerals in a rock sample by oxidation with hydrogen peroxide ($H_2O_2$). Acid generation and acid neutralization reactions occur simultaneously, and the test provides therefore a net result of the amount of acid generated.

After complete oxidation of the sample, the final NAG pH is used as a screening criterion for the acid generation potential:

- NAG pH below 3.5 indicates a high risk of acid generation,
- NAG pH value larger than 5.5 indicates no risk of acid generation, and
- NAG pH value between 3.5 and 5.5 indicates a low risk of acid generation.

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

### 3.3. LEACH TESTING AND WASTE CLASSIFICATION

Leach tests are commonly used as a preliminary screening process to identify potential constituents of concern based on a comparison against relevant water quality and effluent standards or other specified limits. In the context of this study, the total and leachable concentrations will be used to classify the mine residues in accordance to the NEMWA – Norms and Standards as specified in the Government Notices R. 63, 635 and 636 (Government Gazette No. 36784, 23/08/2013) pertaining to the National Environmental Management: Waste Act (Act No. 59 of 2008) by the Department of Environmental Affairs. According to the Government Notices, the leachable concentrations are determined using the Australian Standard Leaching Procedure (AS 4439.3-1997, bottle leaching procedure) and the total concentrations using aqua regia digestion. The applicable leachable or total concentration thresholds used by the authorities to classify the waste into several categories are given in Table 3-1.

**Table 3-1: Waste type classification by total and leachable concentration thresholds (TCT and LCT) for landfill disposal.**

| Total concentration threshold | Link between TCT and LCT | Leachable concentration threshold | Waste Type | Landfill design |
|---|---|---|---|---|
| < TCT0 | and | < LCT0 | Type 4 | Class D |
| < TCT1 | and | < LCT1 | Type 3 | Class C |
| < TCT1 | and | < LCT2 | Type 2 | Class B |
| < TCT2 | or | < LCT3 | Type 1 | Class A |
| > TCT2 | or | > LCT3 | Type 0 | Not allowed |

### 3.4. X-RAY DIFFRACTION (XRD) ANALYSIS

The sample material was prepared for XRD analysis with the aid of a back-loading preparation method. Diffractograms were obtained using a Malvern Panalytical Aeris diffractometer with PIXcel detector and fixed slits with Fe filtered Co-Kα radiation. The phases were identified using X'Pert Highscore plus software. For the quantitative determination of amorphous content, the material was scanned after addition of 20 % Si and micronizing using a McCrone micronizing mill. The relative phase amounts (weight %) were estimated by the Rietveld method.

# 4. Geochemical Test Results

## 4.1. Intra-Laboratory Quality Control

The analyses for sample MF5 1-2m (sulphur speciation, NAG pH, paste pH, AP and NP) was run in duplicate for internal quality control purposes by the laboratory and are highlighted in Table 4-1. To assess the data quality, the Relative Percentage Difference (RPD) of the analysis was calculated as follows:

$$RPD = \frac{|a-b|}{average(a,b)} * 100\%$$

The following criterions were used to assess the RPD values:

- RPD < 1% Excellent
- RPD < 2.5% Good
- RPD < 5% Average
- RPD > 5% Poor

The internal quality control showed an excellent (RPD < 1%) reproducibility of the following parameter:

- Total sulphur
- pH 4.5 NAG (kg $H_2SO_4$/t) and pH 7 NAG (kg $H_2SO_4$/t)
- Past pH
- Neutralisation Potential (NP)
- Net Neutralising Potential (NNP)

A good (RPD < 2.5%) reproducibility is recognised for:

- NAG pH 4.5 and NAG pH 7
- Neutralisation Potential Ratio (NPR)

An average (RPD < 5%) reproducibility is recognised for:

- Acid potential (AP)

A poor (RDP > 5%) reproducibility is recognised for:

- Sulphate sulphur
- Sulphide sulphur

While the observed poor reproducibility of the sulphide sulphur and sulphate sulphur content is obviously of concern, the actual differences between the two sulphide sulphur and sulphate sulphur analyses are minute (0.11 vs. 0.10 % and 0.01 vs. 0.02 %, respectively) and do not change the classification of this sample. The data are therefore considered acceptable for the purpose of the acid rock drainage assessment. No ionic charge balances were determined for the leach test analysis due to missing major elements (predominantly cations) in the leach test results, as they are not required for the waste classification process.

## 4.2. Acid Rock Drainage Potential

The ABA, sulphur speciation and calculated SAP, NNP and NPR values for the different CDR Slimes samples are summarised in Table 4-1 while the original laboratory certificates are provided in Appendix C.

**Table 4-1: ABA, NAG, S-Speciation results and Carbon content for the CDR Slimes samples and calculated NP, NNP and NPR values (duplicate sample results highlighted in grey).**

| | Sample ID | MF1 0-1m | MF1 1-2m | MF2 0.5-1m | MF2 2-2.5m | MF2 3-4m | MF3 0.5-1.5m | MF4 0.5-1.5m | MF5 0.2-0.8m | MF5 1-2m | MF5 1-2m (duplicate) | RPD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lab ID | 96716 | 96717 | 96718 | 96719 | 96720 | 96721 | 96722 | 96723 | 96724 | 96724 D | 96724 D |
| SULPHUR | Total Sulphur (%) | 0.04 | 0.84 | 1.65 | 0.97 | 0.05 | 0.63 | 1.18 | 0.80 | 0.12 | 0.12 | 0.0% |
| | Sulphate Sulphur as S (%) | 0.04 | 0.63 | 1.57 | 0.89 | 0.04 | 0.58 | 1.15 | 0.74 | 0.11 | 0.10 | 9.5% |
| | Sulphide Sulphur (%) | <0.01 | 0.22 | 0.08 | 0.08 | 0.01 | 0.05 | 0.03 | 0.07 | 0.01 | 0.02 | 66.7% |
| CARBON | Total Carbon (%) | 1.59 | 49.20 | 25.90 | 2.46 | 0.67 | 1.96 | 4.06 | 18.40 | 1.17 | | |
| | Organic Carbon (%) | 1.40 | 47.80 | 24.60 | 2.19 | 0.44 | 1.86 | 3.25 | 18.40 | 0.92 | | |
| | Inorganic Carbon (%) | 0.19 | 1.40 | 1.30 | 0.27 | 0.23 | 0.10 | 0.81 | 0.00 | 0.25 | | |
| | $CO_3$-NP ($CaCO_3$/t) | 15.83 | 116.62 | 108.29 | 22.49 | 19.16 | 8.33 | 67.47 | 0.00 | 20.83 | | |
| NAG | NAG pH 4.5 | 8.20 | 4.10 | 8.70 | 8.60 | 7.10 | 8.20 | 8.60 | 8.30 | 8.10 | 8.20 | 1.2% |
| | pH 4.5 NAG (kg $H_2SO_4$/t) | <0.01 | 0.59 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.0% |
| | NAG pH 7 | 8.20 | 4.50 | 8.70 | 8.60 | 7.10 | 8.20 | 8.60 | 8.30 | 8.10 | 8.20 | 1.2% |
| | pH 7 NAG (kg $H_2SO_4$/t) | <0.01 | 18.62 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.0% |
| ACID BASE ACCOUNTING | Paste pH | 8.3 | 5.8 | 9.7 | 8.9 | 7.4 | 8.6 | 9.3 | 8.9 | 8.6 | 8.6 | 0.0% |
| | Acid Potential (AP) (kg/t) | 1.27 | 26.00 | 52.00 | 30.00 | 1.53 | 20.00 | 37.00 | 25.00 | 3.64 | 3.74 | 2.7% |
| | $S^{2-}$Acid Potential (SAP) (kg/t) | <0.31 | 6.88 | 2.50 | 2.50 | 0.31 | 1.56 | 0.94 | 2.19 | 0.31 | 0.63 | |
| | Neut Potential (NP) | 27.00 | 5.20 | 162.00 | 44.00 | 12.00 | 51.00 | 102.00 | 119.00 | 31.00 | 31.00 | 0.0% |
| | Net Neut Potential (NNP) | 25.00 | -21.00 | 111.00 | 14.00 | 10.00 | 31.00 | 65.00 | 94.00 | 27.00 | 27.00 | 0.0% |
| | Neut Potential Ratio (NPR) | 21.00 | 0.20 | 3.15 | 1.46 | 7.75 | 2.57 | 2.76 | 4.72 | 8.44 | 8.28 | 1.9% |
| | NNP-$S^{2-}$ | <26.69 | -1.68 | 159.50 | 41.50 | 11.69 | 49.44 | 101.06 | 116.81 | 30.69 | 30.38 | |
| | NPR-$S^{2-}$ | <87.10 | 0.76 | 64.80 | 17.60 | 38.40 | 32.64 | 108.80 | 54.40 | 99.20 | 49.60 | |
| | NPR-$CO_3$ | 12.46 | 4.49 | 2.08 | 0.75 | 12.52 | 0.42 | 1.82 | 0.00 | 5.72 | 0.00 | |
| | NPR-$CO_3$-$S^{2-}$ | <51.05 | 16.96 | 43.32 | 9.00 | 61.31 | 5.33 | 71.97 | 0.00 | 66.64 | 0.00 | |

### 4.2.1. *Paste pH results*

The paste pH range of most tested samples was circum-neutral (pH 7.4 to 9.7, Table 4-1) at the time of analysis, suggesting that most samples contain readily available alkalinity to buffer any acidity that may be released upon deposition or generally comprise low readily available acidity. Only sample MF1 1-2m had a slightly acidic pH of 5.8, indicating that this sample has potential to release readily available acidity during storage.

### 4.2.2. *ABA results*

The total sulphur content in the CDR Slimes samples ranged from 0.04 to 1.65% of which the acid generating sulphide sulphur content was generally low (≤0.08%) (Table 4-1). Only sample MF1 1-2m contained one order of magnitude higher sulphide sulphur content of 0.22%. The Neutralisation Potentials (NP) of samples MF1 0-1m, MF2 3-4m, MF5 0.2-0.8m and MF5 1-2m (and duplicate) exceeded the Acid Potentials (AP), resulting in positive Net Neutralisation Potentials (NNP). This together with NPR ratios larger than four (required for complete acid neutralisation), classifies these samples as non-acid generating (Figure 4-1). Although the NP exceeded the AP in samples MF2 0.5-1m, MF2 2-2.5m, MF3 0.5-1.5m and MF4 0.5-1.5m, these samples are classified as inconclusive and potentially acid generating if preferentially exposed due to the NPR being less than four. Sample MF1 1-2m is flagged as "long-term" acid generating based on the total sulphur content, low NPR ratio and AP exceeding the low NP leading to a negative NNP (Table 4-1, Figure 4-1).

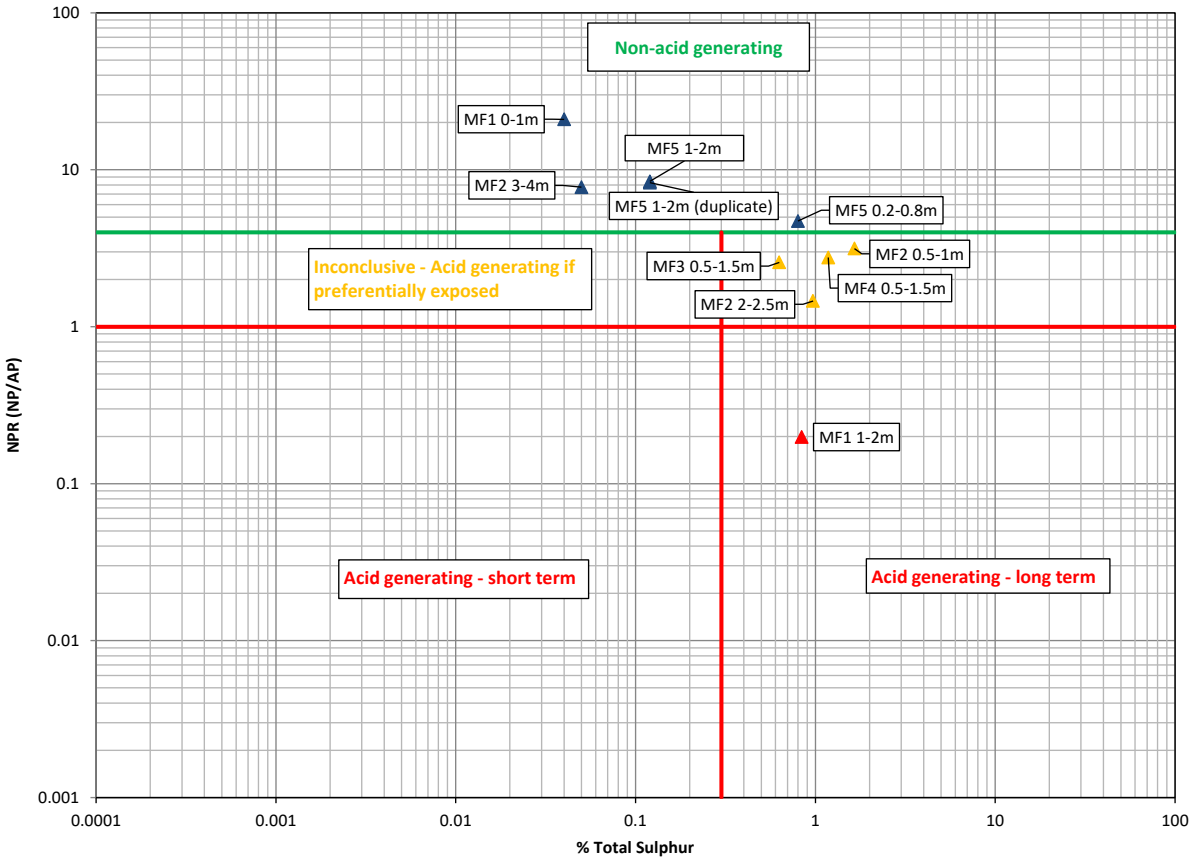



**Figure 4-1: Neutralising potential ratio versus total sulphur content.**

### 4.2.3. *ABA results under consideration of sulphur speciation*

The sulphur speciation results showed that in all the tested samples, 75% in sample MF1 1-2m to 99% in sample MF1 0-1m of total sulphur content occurs as non-acid generating sulphate sulphur. As stated earlier, the ABA methodology assumes conservatively that all sulphur in the sample will react to form sulphuric acid; while a significant part of the total sulphur may occur as non-acid producing sulphate sulphur, reducing potentially the overall risk of acid generation further. A plot of the sulphur species and total sulphur contents of the samples is given in Figure 4-2. While a strong correlation between total and sulphate sulphur contents ($R^2$ = 99%) is recognised for the tested samples, only a poor correlation between the total and sulphide sulphur content ($R^2$ = 23%) is evident. Since the regression line indicates a poor correlation for sulphide sulphur, it should not be used to estimate the sulphide sulphur content of the samples. However, the analysis showed that most of the total sulphur content of the samples occurs as non-acid generating sulphate sulphur.

$$Sulphide\ sulphur\ (\%) = 0.06 * Total\ sulphur\ (\%) + 0.02$$

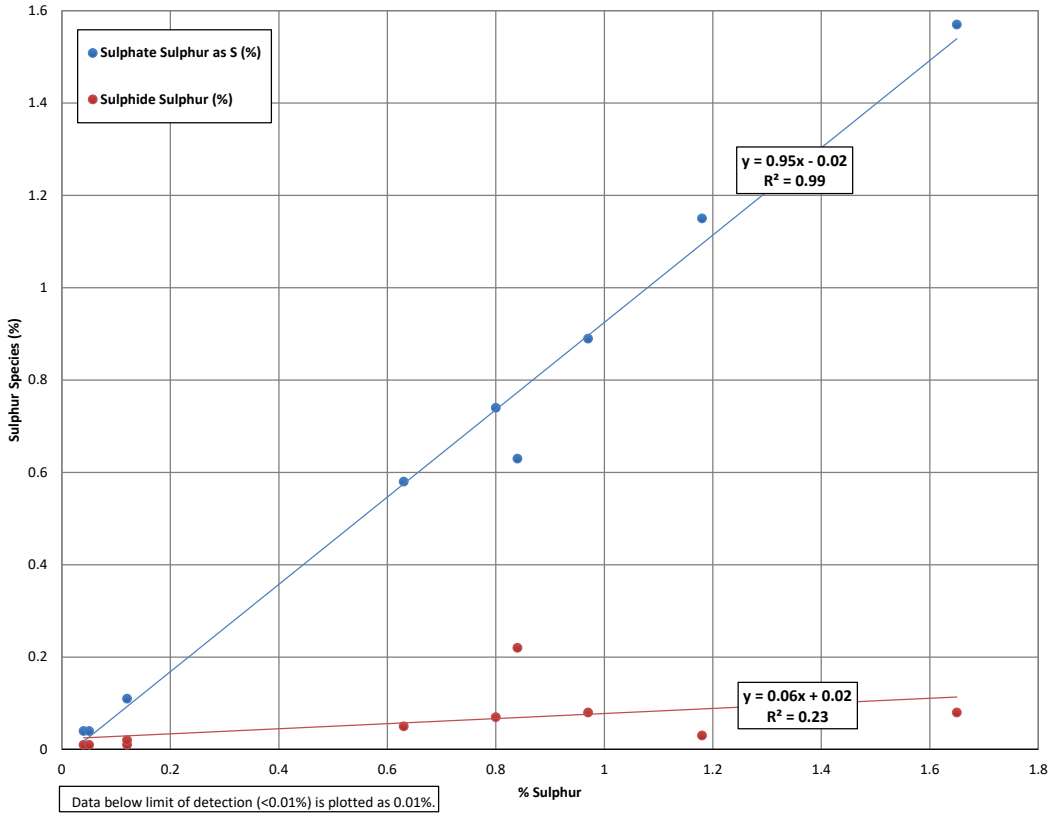



**Figure 4-2: Sulphur species versus total sulphur content.**

Therefore, considering the sulphur speciation, all samples except for sample MF1 1-2m are now re-classified as non-acid generating. Sample MF1 1-2m is categorised as "short-term" acid generating due to its low sulphide neutralising potential ratio (NPR-$S^{2-}$, calculated using the sulphide acid potential (SAP) versus the sulphide sulphur instead of the total sulphur content) and the sample containing approximately 25% of its total sulphur as acid-generating sulphide sulphur (Figure 4-3).

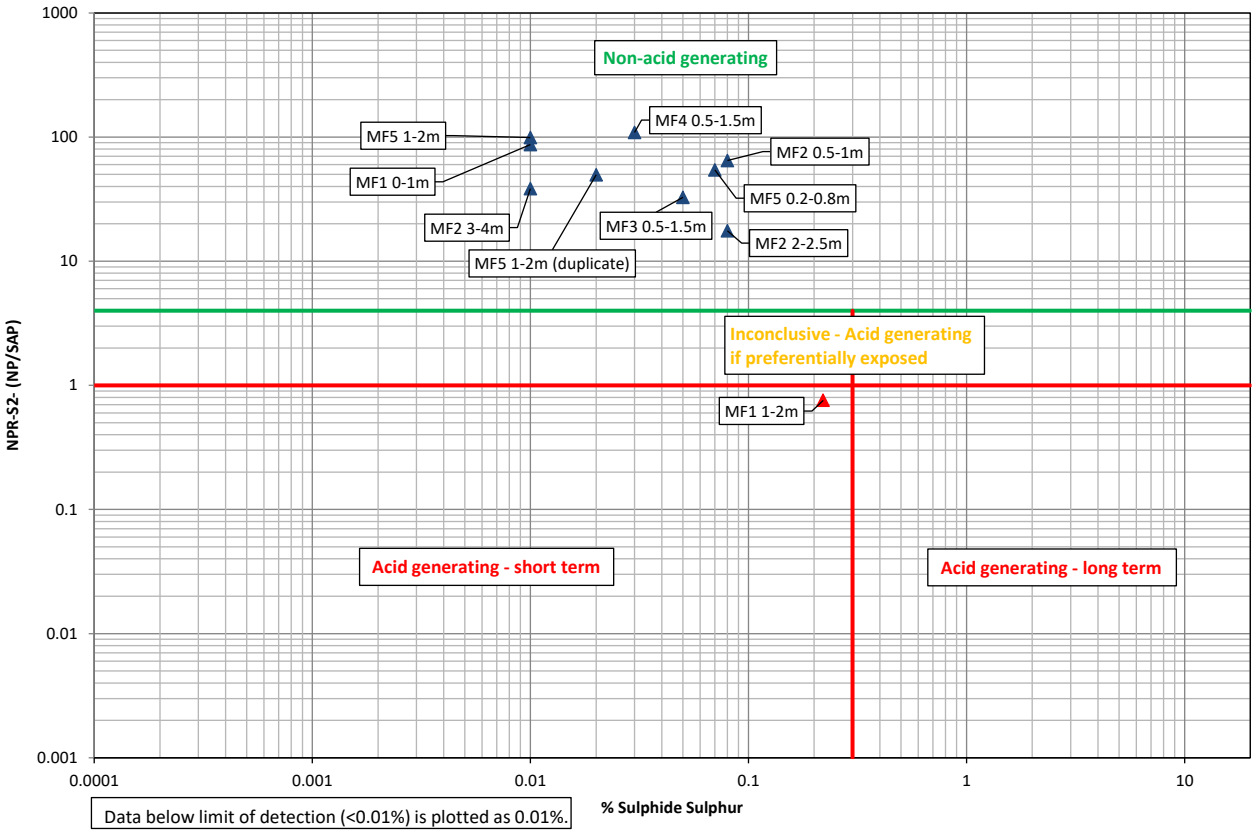



**Figure 4-3: Sulphide neutralising potential ratio versus sulphide sulphur content.**

### *4.2.4. ABA results under consideration of carbonate speciation*

Total carbon concentrations varied widely in the nine CDR Slimes samples, ranging from 0.67% to 49.2%, while inorganic carbon contents ranged from 0% to 1.4% (Table 4-1). The inorganic carbon content is potentially significant from an acid neutralisation perspective as it gives rise to calculated carbonate neutralisation potential ($CO_3$-NP, see chapter 3.2.4) which varied between 0 kg $CaCO_3$/t in sample MF5 0.2-0.8m and 116.62 kg $CaCO_3$/t in sample MF1 1-2m.

A poor to no correlation was observed for most samples between the $CO_3$-NP and the traditional NP (after Sobek et al. 1978) in Figure 4-4, suggesting that the available neutralisation potential is generally not provided by reactive carbonate minerals. Most samples had higher NP values than calculated $CO_3$-NP values ($CO_3$-NP values up to 116.62 kg $CaCO_3$/tonne, while NP values are up to 162 kg $CaCO_3$/tonne), suggesting that mostly non-carbonate minerals contribute to the neutralisation potential. For sample MF1 1-2m, the $CO_3$-NP value was substantially larger than the NP value and for sample MF2 3-4m slighter larger, indicating that most carbonate minerals in the sample are not rapidly reactive or not all carbon is carbonate.

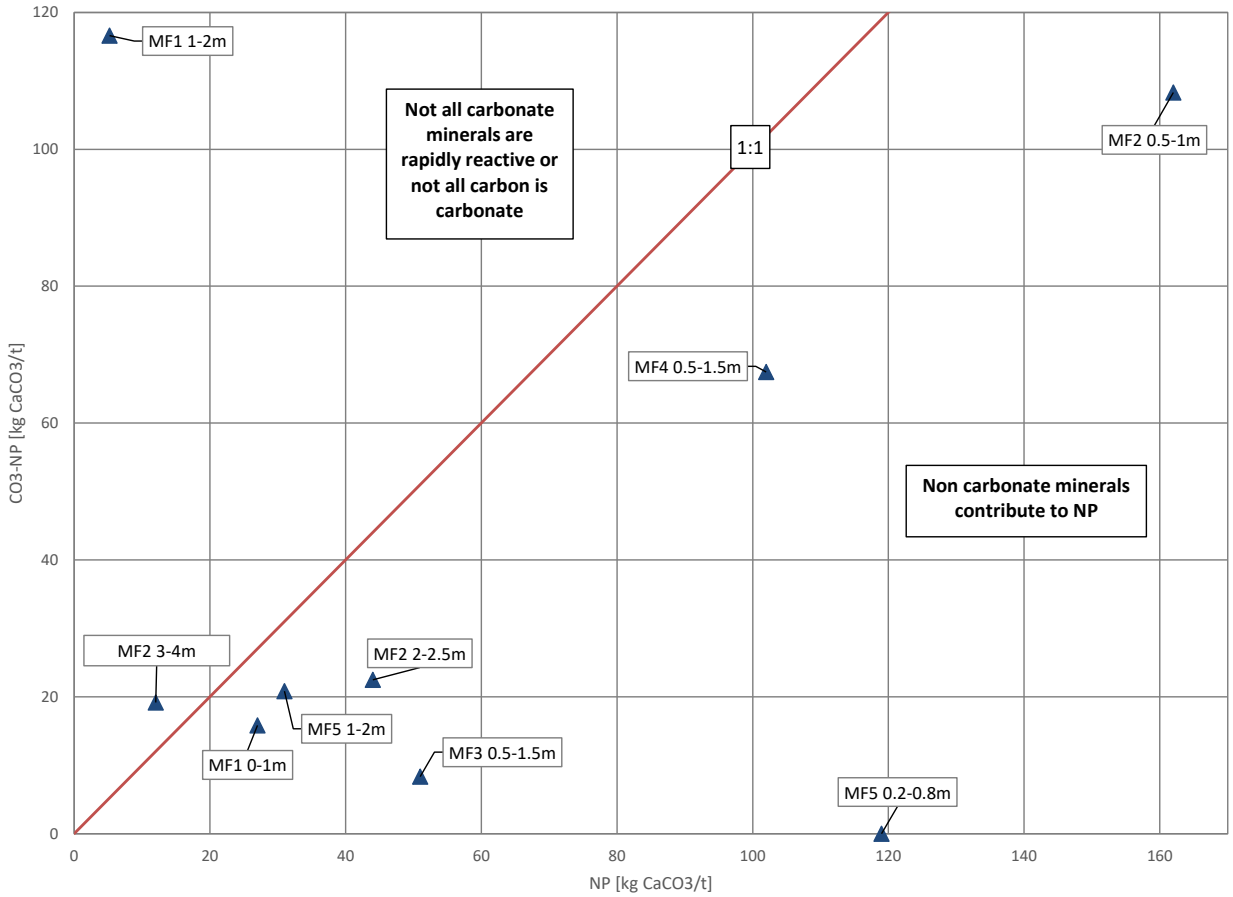



**Figure 4-4: Carbonate neutralisation potential versus (Sobek) neutralisation potential.**

A classification of the samples based on the Neutralising Potential Ratio calculated from the $CO_3$-NP (NPR- $CO_3$) and the sulphide acid potential versus the sulphide sulphur content is given in Figure 4-5. Based on the calculated $CO_3$-NPR values, samples MF1 0-1m, MF2 3-4m and MF5 1-2m are classified as non-acid generating, samples MF4 0.5-1.5m and MF2 0.5-1m as inconclusive, and samples MF2 2-2.5m and MF3 0.5-1.5m are now classified as “short-term” acid generating. It should be noted that sample MF5 0.2-0.8m cannot be classified according to the $CO_3$-NPR as its value is equal to zero.

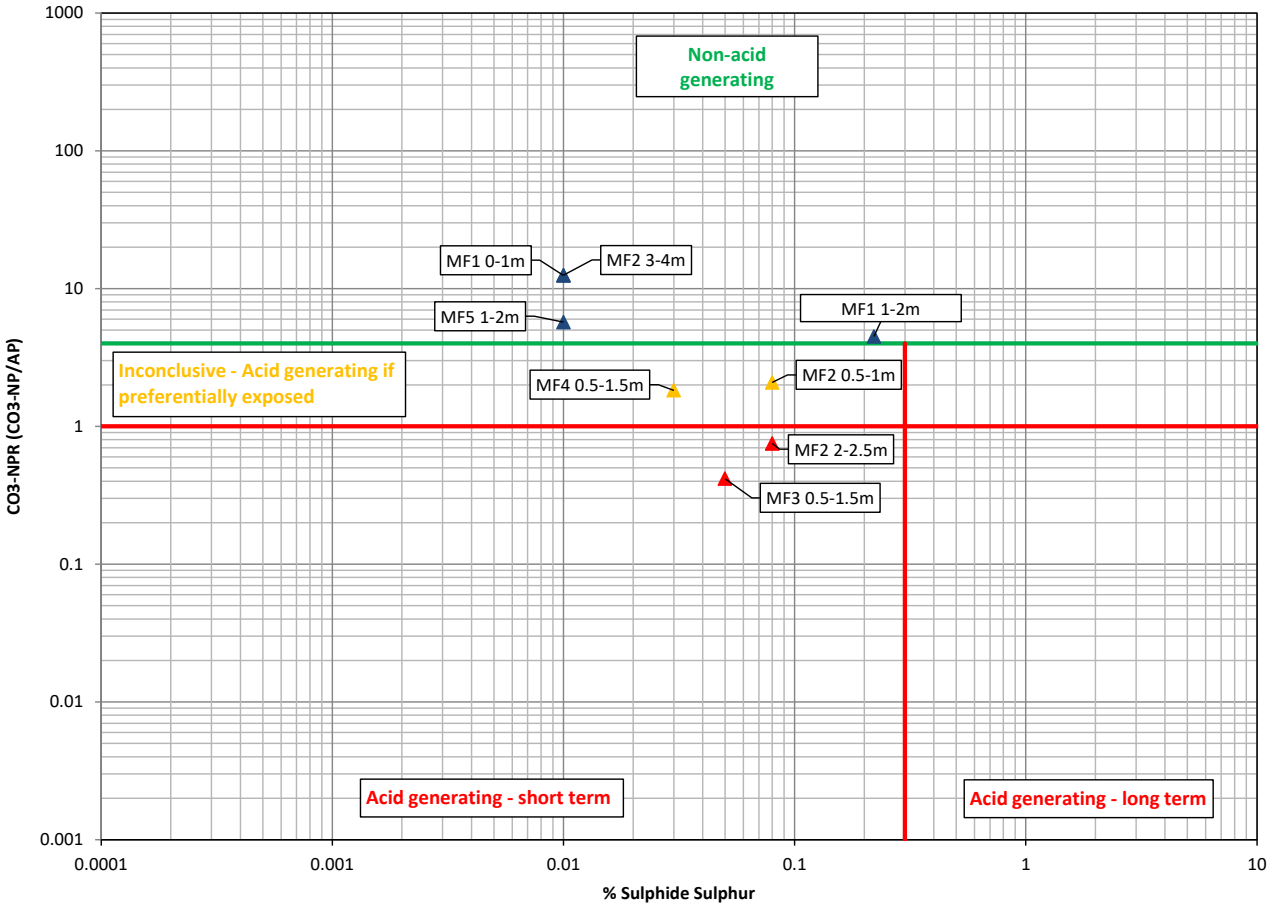



**Figure 4-5: Carbonate neutralisation potential versus sulphide sulphur (%).**

### *4.2.5. NAG test results*

The NAG pH is the result of oxidation of sulphide minerals in the samples by hydrogen peroxide ($H_2O_2$). The NAG test would also be expected to oxidise iron/manganese carbonate minerals (like siderite) in the samples and release the residual acidity associated with these minerals if present. Samples with a NAG pH value less than 3.5 are considered to indicate potentially acid generating (PAG) material, while samples with a NAG pH larger than 5.5 are considered to indicate non-acid generating (NAG) material, with intermediate values between 3.5 and 5.5 indicating a low risk of acid generation.

The combined evaluation of the NAG pH and NPR values (Figure 4-6), with a lower NPR screening criteria for samples with NAG pH values larger 5.5, suggests that samples MF1 0-1m, MF2 3-4m, MF5 0.2-0.8m and MF5 1-2m are non-acid generating. Samples MF2 0.5-1m, MF2 2-2.5m, MF3 0.5-1.5m and MF4 0.5-1.5m have a low risk of acid generation ("uncertain"), while sample MF1 1-2m is classified as acid generating due to its low NAG pH value of 4.5. These screening criteria provide the same classification results as seen in the NPR vs. total sulphur classification in section 4.2.2, Figure 4-1.

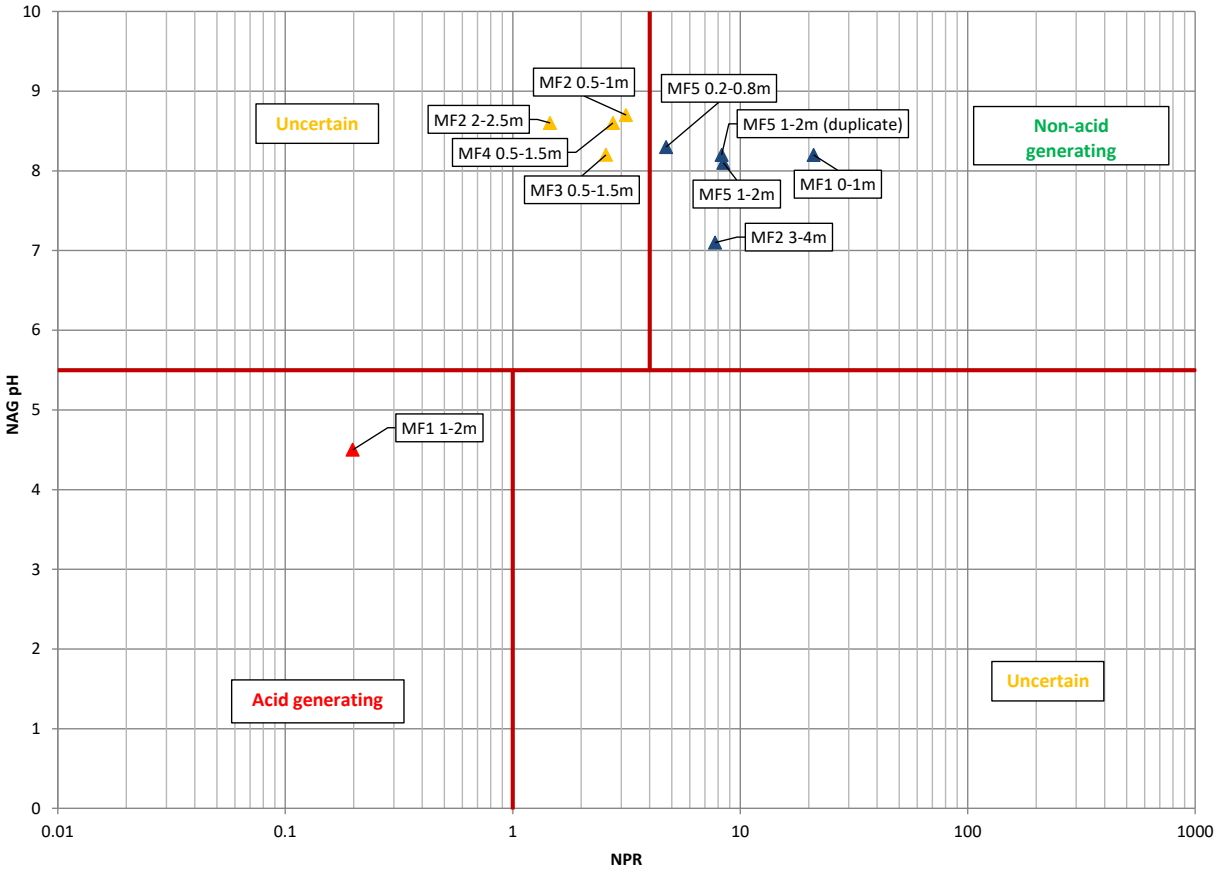



**Figure 4-6: NAG pH versus neutralisation potential ratio.**

### *4.2.6. NAG test results under consideration of sulphur speciation*

If the sulphur speciation is considered in the assessment of the NAG test results by using the sulphide neutralising potential ratio (NPR-$S^{2-}$, calculated using the sulphide acid potential, SAP) instead of the NPR ratio, sample MF1 1-2m is classified as acid-generating, whereas all other samples are categorised as non-acid generating as shown in Figure 4-7. This screening method provides the same results as shown for the sulphide neutralising potential ratio versus the sulphide sulphur content in section 4.2.3, Figure 4-3.

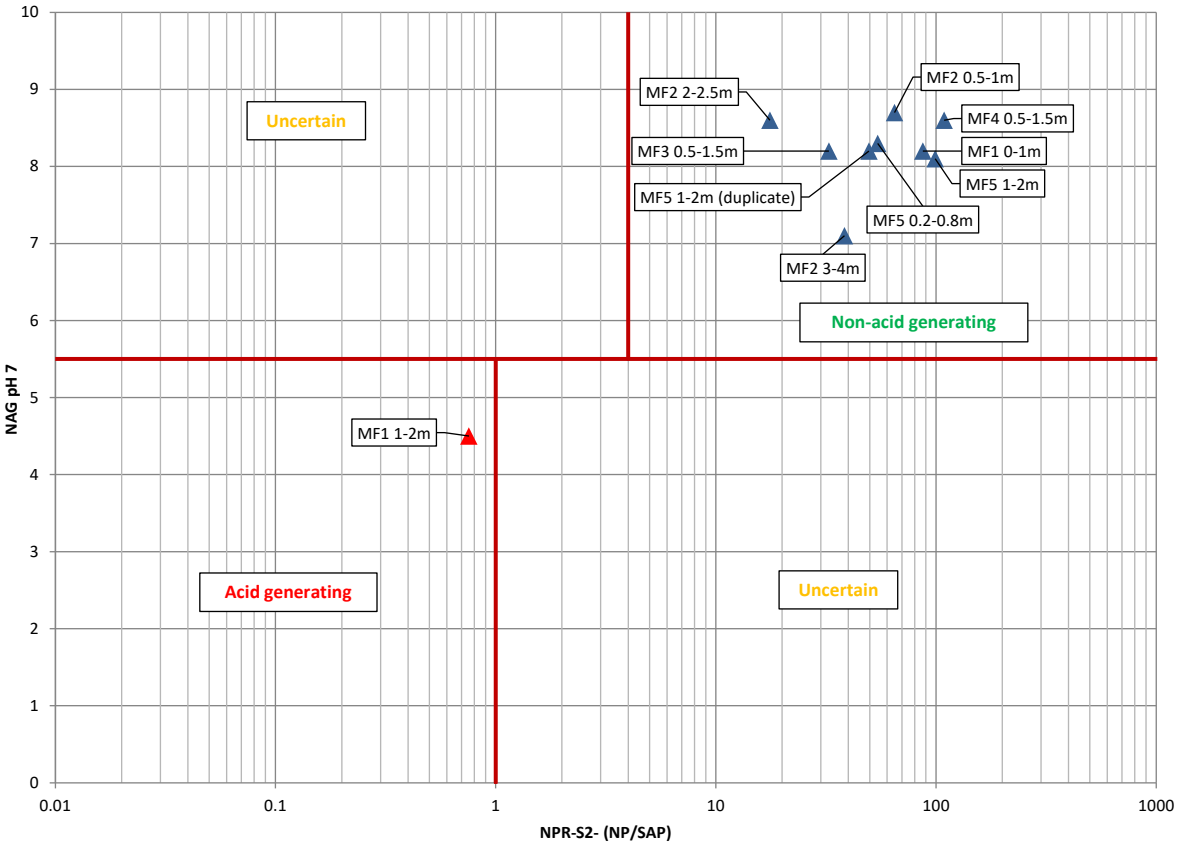



**Figure 4-7: NAG pH versus sulphide neutralisation potential ratio (NPR-S2).**

### *4.2.7. Summary of ARD test results*

Samples MF1 0-1m, MF2 3-4m, MF5 0.2-0.8m and MF5 1-2m were consistently classified as non-acid generating for all ABA and NAG test results. Sample MF1 1-2m was mainly classified as acid-generating, except for when considering the carbonate neutralisation potential ratio vs. the sulphide sulphur content, which categorised the sample as non-acid generating. This is due to the carbonate NPR being sufficiently higher than the acid-generating sulphide sulphur content in the sample.

However, the ABA and NAG test results for all other CDR slimes samples appear contradictory as they shift between acid generating, inconclusive and non-acid generating. This is primarily due to their relatively limited sulphide sulphur contents and subsequently calculated acid potentials, as well as the differentiation between readily available carbonate neutralisation potential versus non-carbonate minerals mostly contributing to the neutralisation potential.

Based on a combined evaluation of all test results the following classifications are given:

- Sample MF1 1-2m is classified as potentially acid generating due to its negative (sulphide) net neutralisation potential.
- Samples MF1 0-1m, MF2 3-4m, MF5 0.2-0.8m and MF5 1-2m are classified as non-acid generating based on positive net neutralisation potentials and low content of acid generating sulphide sulphur.
- Samples MF2 0.5-1m, MF4 0.5-1.5, MF2 2-2.5 and MF3 0.5-1.5m are classified as inconclusive (or uncertain) and potentially acid generating if preferentially exposed to the atmosphere. If acid generating, this should be short term, i.e. decades and not centuries due to its low sulphide sulphur content.

### 4.3. MINERALOGICAL ANALYSIS

To gain a better understanding of their mineralogical make-up, the samples underwent XRD analysis. The relative phase amounts or mineral groups were determined in weight-% and are provided in Table 4-2. The presented mineral names in Table 4-2 may not reflect the actual compositions of minerals identified, but rather the mineral group. To quantify the amorphous phase identified in the CDR Slimes samples, 20% of Si was added to the samples. Thereafter, the samples were micronized using a McCrone micronizing mill before being scanned. It should be noted that the amorphous content may carry an error of ±15 weight %. The amorphous content is likely presenting organic carbon and/or a glassy phase formed during the chrome direct reduction (CDR) process, whereby chrome ore is brought into contact with finely divided coal at high temperatures. During the CDR process, dust is captured as a by-product via water sprays representing the CDR slimes samples which are mostly composed of an amorphous phase (Table 4-2).

The key features of the mineralogical analysis are as follows:

- The mineral composition of almost all samples (except for sample MF2 3-4m) is dominated (78 to 92 weight %) by an amorphous phase likely presenting organic carbon and/or a glassy phase from the CDR process.
- The remaining minor and trace elements comprise chromite, calcite, quartz, mullite, bassanite, magnetite and iron which vary in weight % within two orders of magnitude.
- Sample MF2 3-4m differs in composition as it comprises the contact zone between the CRD Slimes material and underlying weathered bedrock composed of interlayered sandstone, mudstone, and shale. Major mineral phases are amorphous (49 weight %) and quartz (43 weight %), minor minerals are kaolinite and hematite and traces were detected of dolomite and plagioclase.

**Table 4-2: Major mineral composition of the CDR Slimes samples (XRD Analysis) (weight %).**

| Compound Name | Ideal Chemical Formula | MF1 0-1m | MF1 1-2m | MF2 0.5-1m | MF2 2-2.5m | MF2 3-4m | MF3 0.5-1.5m | MF4 0.5-1.5m | MF5 0.2-0.8m | MF5 1-2m |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 96716 | 96717 | 96718 | 96719 | 96720 | 96721 | 96722 | 96723 | 96724 |
| **Quartz** | $SiO_2$ | 5 | 3.46 | 2.21 | 3.07 | 42.71 | 2.58 | 2.09 | 3.15 | 10.94 |
| **Mullite** | $3Al_2O_3\ 2SiO_2$ | 1.06 | 7.74 | 4.4 | 0 | | 0 | 0.06 | 8.65 | 1.21 |
| **Bassanite** | $2(CaSO_4)\ H_2O$ | 0.06 | 1.27 | 0.57 | 2.17 | | 0.37 | 0.18 | 0.05 | 0.16 |
| **Magnetite** | $Fe_3O_4$ | 0.03 | 1.02 | 0.01 | 0.04 | | 0 | 0 | 0.36 | 0.04 |
| **Iron** | Fe | 0.05 | 0 | 0.99 | 0.01 | | 0.68 | 0.82 | 0.14 | 0.04 |
| **Chromite** | $Fe^{2+}Cr_2O_4$ | 2.25 | 4.77 | 9.18 | 2.1 | | 13.64 | 14.6 | 8.68 | 1.81 |
| **Calcite** | $CaCO_3$ | 0.64 | 2.15 | 0.95 | 0.51 | | 0.55 | 2.27 | 0.62 | 0.52 |
| **Amorphous** | | 90.9 | 79.58 | 81.7 | 92.09 | 48.8 | 82.18 | 79.96 | 78.35 | 85.28 |
| **Dolomite** | $Ca,Mg\ (CO_3)_2$ | | | | | 0.86 | | | | |
| **Hematite** | $Fe_2O_3$ | | | | | 1.46 | | | | |
| **Kaolinite** | $Al_2Si_2O_5(OH)_4$ | | | | | 5.34 | | | | |
| **Plagioclase** | $(Na,Ca)(Si,Al)_4O_8$ | | | | | 0.83 | | | | |

## 4.4. LEACHATE CHEMISTRY AND WASTE CLASSIFICATION

### *4.4.1. GN. R. 635 and 636*

Total and leachable concentrations of the nine CDR Slimes samples were analysed by Waterlab (Pty) Ltd., South Africa to determine the leachate quality, identify constituents of concern and classify the material according to waste type and landfill design required upon disposal. The total and leachable concentrations (liquid to solid ratio 1:20) along with the applicable thresholds used for the classification of the samples are presented in Table 4-3, Table 4-4 and Table 4-5 and, respectively. It is important to note that according to the Government Notices R. 634, 635 and 636 (Government Gazette No. 36784, 23/08/2013), the exceedance of a threshold value for **any element** or chemical substance determines the overall waste classification for each sample (Table 4-7).

All samples exceeded TCT0 thresholds for total concentrations (aqua regia) as indicated in Table 4-3.

- **Ba** and **Pb** are constituents of concern in all analysed samples.

Further exceedances of the **TCT0** threshold include:

- **Co** and **V** for samples MF1 1-2m, MF2 0.5-1m, MF2 3-4m, MF3 0.5-1.5m, MF4 0.5-1.5m, and MF5 0.2-0.8m.
- **Cu** and **Mn** for samples MF2 0.5-1m, MF2 3-4m, MF3 0.5-1.5m, MF4 0.5-1.5m, and MF5 0.2-0.8m.
- **$Cr_{total}$** (46000 mg/kg) for samples MF2 0.5-1m, MF3 0.5-1.5m, and MF4 0.5-1.5.
- Exceedances for **Ni** (91 mg/kg) were found in samples Mf1 0-1m, MF1 1-2m, MF2 0.5-1m, MF3 0.5-1.5m, MF4 0.5-1.5m, MF5 0.2-0.8m and MF5 1-2m.
- TCT0 threshold for **Zn** (240 mg/kg) was exceeded in all samples except MF2 3-4m.
- The **Cr(VI)** (6.5 mg/kg) threshold was exceeded in samples MF1 1-2m, MF2 2-2.5m, MF3 0.5-1.5m, MF4 0.5-1.5 and MF5 1-2m.
- The threshold for **F** (100 mg/kg) was exceeded in samples MF1 1-2m, MF2 2-2.5m, MF5 0.2-0.8m and MF5 1-2m.

The following exceedances are noted for the distilled water leachable concentrations (1:20 ratio) in Table 4-5:

- The LCT0 threshold was exceeded for **$Cr_{total}$** (0.1 mg/l) in samples MF1 0-1m, MF1 1-2m, MF3 0.5-1.5m, MF4 0.5-1.5m, MF5 0.2-0.8m and MF5 1-2m.
- The LCT0 threshold was exceeded for **Cr (VI)** (0.05 mg/l) in samples MF1 0-1m, MF1 1-2m, MF2 2-2.5m, MF5 0.2-0.8m and MF5 1-2m.
- Sample MF3 0.5-1.5m slightly exceeded the **LCT2** threshold for **Cr (VI)** (5 mg/l).
- The LCT0 threshold for **TDS** (1000 mg/l) was exceeded in sample MF2 2-2.5m.
- The LCT0 threshold for **$SO_4$** (250 mg/l) was exceeded in samples MF1 1-2m, MF2 0.5-1m, and MF2 2-2.5m.
- The LCT0 threshold for **F** (1.5 mg/l) was exceeded in samples MF2 3-4m, MF4 0.5-1.5m and MF5 0.2-0.8m.

Table 4-6 provides additional information on the leachate quality based on a distilled water leachate 1:4 (solid to liquid) ratio. While not applicable for the waste classification, the distilled water (1:4 ratio) leachable concentrations were conducted as the results emulate more realistic liquid to solid ratios without dilution. Expectedly, the 1:4 ratio leachable concentrations are significantly higher than the 1:20 ratio concentrations. The results are utilised for comparison purposes only, and do not form any part of the formal waste classification. Exceedances were noted for the following thresholds and parameters:

- The LCT0 threshold for B was exceeded in samples MF2 2-2.5m and MF5 0.2-0.8m.
- The LCT0 thresholds for both $Cr_{total}$ and Cr(VI) were exceeded in samples MF1 1-2m, MF2 2-2.5m, MF5 0.2-0.8m and MF5 1-2m.
- The LCT1 thresholds for both $Cr_{total}$ and Cr(VI) were exceeded in sample MF1 0-1m.
- The LCT2 thresholds for both $Cr_{total}$ and Cr(VI) were exceeded in sample MF3 0.5-1.5.

- Hg exceeded the LCT0 threshold in samples MF2 0.5-1m and MF4 0.5-1.5m.
- Mo exceeded the LCT0 threshold in samples MF2 0.5-1m, MF2 2-2.5m, MF4 0.5-1.5m and MF5 0.2-0.8m.
- Sb exceeded the LCT0 threshold in sample MF4 0.5-1.5m.
- Zn exceeded the LCT0 threshold in sample MF1 1-2m.
- The LCT0 threshold for TDS was exceeded in samples MF1 1-2m, MF2 0.5-1m, MF2 2-2.5m, MF3 0.5-1.5m and MF4 0.5-1.5m.
- The LCT0 threshold for $SO_4$ was exceeded in all samples excluding samples MF1 0-1m and MF2 3-4m.
- F exceeded the LCT0 threshold in all samples except for sample MF2 2-2.5m

Based on the prescribed analysis of total concentrations and the distilled water leachate (1:20 solid to liquid ratio only) concentrations, the following classification is given:

The general exceedance of the total concentration thresholds TCT0 for barium and lead in all samples (i.e. TCT0 < TC <TCT1, as well as the other exceedances) along with all leachable concentrations below their LCT1 thresholds (i.e. LC < LCT1) for $Cr_{total}$, Cr(VI), TDS, SO4 and F classifies all samples, except for sample MF3 0.5-1.5m, formally as Type 3 Waste (Table 4-7). This waste type theoretically requires a Class C landfill design unless a risk assessment by a qualified person suggests otherwise. Only sample MF3 0.5-1.5m exceeded the LCT2 threshold for Cr(VI), classifying the sample as Type 1 Waste, requiring a Class A landfill design.

The geochemical assessment of five CDR Slimes profiles sampled from the disposal area confirmed both the vertical and horizontal heterogeneity of the material observed in previous studies. This leads to variations in the classification of the waste type. Although the majority of the samples was classified as Type 3 Waste, some sections of the CDR Slimes disposal area exceeded the LCT2 threshold for Cr(VI), which however cannot be referenced to a particular horizon throughout the dump. Due to the heterogeneous composition of the CDR Slimes material, the CDR Slimes storage facility therefore needs to be handled according to the worst-case sample result until conclusively screened (classified) during excavation.

Table 4-3: Totals (aqua regia digestion) concentrations for the nine CDR Slimes samples (exceedances highlighted).

| Total | MF1 0-1m | MF1 1-2m | MF2 0.5-1m | MF2 2-2.5m | MF2 3-4m | MF3 0.5-1.5m | MF4 0.5-1.5m | MF5 0.2-0.8m | MF5 1-2m | Threshold | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Number** | **96716** | **96717** | **96718** | **96719** | **96720** | **96721** | **96722** | **96723** | **96724** | **TCT0** | **TCT1** | **TCT2** |
| **Units** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** |
| As, Arsenic | <0.400 | 0.800 | 1 | <0.400 | 0.400 | 0.400 | 0.400 | 2.40 | 0.800 | 5.80 | 500.00 | 2,000 |
| B, Boron | <10 | 36 | 68 | 58 | 13 | 32 | 38 | 103 | 35 | 150 | 15,000 | 6,000 |
| Ba, Barium | 118.0 | 226.0 | 218.0 | 95.6 | 324.8 | 72.8 | 102.0 | 399.6 | 121.2 | 62.5 | 6,250 | 25,000 |
| Cd, Cadmium | <0.400 | <0.400 | <0.400 | <0.400 | <0.400 | <0.400 | <0.400 | <0.400 | <0.400 | 7.5 | 260 | 1,040 |
| Co, Cobalt | 18 | 54.4 | 127.6 | <10 | 59.2 | 125.6 | 176.8 | 104 | 32 | 50 | 5,000 | 20,000 |
| $Cr_{Total,}$ Chromium Total | 12000 | 24000 | 78,800 | 9200 | 294 | 71,200 | 89,600 | 40000 | 9200 | 46,000 | 800,000 | N/A |
| Cu, Copper | <4.00 | 11 | 70 | <4.00 | 94 | 31 | 77 | 45 | <4.00 | 16 | 19,500 | 78,000 |
| Hg, Mercury | <0.400 | <0.400 | <0.400 | <0.400 | <0.400 | <0.400 | <0.400 | <0.400 | <0.400 | 0.93 | 160.00 | 640 |
| Mn, Manganese | 856 | 287 | 4,000 | 844 | 1,436 | 4,400 | 4,800 | 1,640 | 884 | 1,000 | 25,000 | 100,000 |
| Mo, Molybdenum | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 | 40 | 1,000 | 4,000 |
| Ni, Nickel | 129.2 | 176 | 536 | 72 | 45 | 564 | 740 | 460 | 132.8 | 91 | 10,600 | 42,400 |
| Pb, Lead | 57.6 | 176.8 | 154 | 53.6 | 38.8 | 195.2 | 190 | 226.4 | 70.4 | 20 | 1,900 | 7,600 |
| Sb, Antimony | <0.400 | <0.400 | <0.400 | <0.400 | <0.400 | <0.400 | <0.400 | <0.400 | <0.400 | 10 | 75 | 300 |
| Se, Selenium | <0.400 | 0.400 | <0.400 | <0.400 | <0.400 | 0.400 | <0.400 | <0.400 | <0.400 | 10 | 50 | 200 |
| V, Vanadium | <10 | 180.8 | 336 | <10 | 293.6 | 247.6 | 309.2 | 258.4 | 22 | 150 | 2,680 | 10,720 |
| Zn, Zinc | 2868 | 6400 | 12800 | 2040 | 114 | 11200 | 12800 | 15200 | 2852 | 240 | 160,000 | 640,000 |
| ***Inorganic Anions*** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** |
| Chloride as Cl | 562.40 | <20 | 1431.00 | 40.55 | 94.16 | 116.00 | 871.40 | 244.00 | 68.22 | | | |
| Sulphate as SO4 | 24161 | 16813 | 25848 | 475 | 1051 | 8539 | 7087 | 4724 | 2888 | | | |
| Nitrate as N | 13.29 | 155.80 | 22.46 | 5.80 | 19.50 | 62.47 | 21.55 | 89.75 | 11.82 | | | |
| Total Fluoride [s] mg/kg | 19.91 | 106.6 | 31.05 | 105.6 | 46.37 | 48.56 | 44.86 | 100.7 | 185.8 | 100 | 10,000 | 40,000 |
| Cr(VI), Chromium (VI) Total [s] | <2 | 9.2 | <2 | 22.4 | <2 | 186.8 | 104.4 | 4.40 | 12.8 | 6.5 | 500.00 | 2,000 |
| Total Cyanide as CN | 9.6 | 2.2 | 13 | <0.5 | <0.5 | 1.2 | 4.6 | 2.7 | <0.5 | 14 | 10,500 | 42,000 |

**Table 4-4: Total concentrations (aqua regia) for all cations (in mg/l) of the CDR Slimes samples.**

| Sample ID | MF1 0-1m | MF1 1-2m | MF2 0.5-1m | MF2 2-2.5m | MF2 3-4m | MF3 0.5-1.5m | MF4 0.5-1.5m | MF5 0.2-0.8m | MF5 1-2m |
|---|---|---|---|---|---|---|---|---|---|
| **Lab ID** | **96716** | **96717** | **96718** | **96719** | **96720** | **96721** | **96722** | **96723** | **96724** |
| Ag | 0.003 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Al | 18 | 112 | 83 | 21 | 157 | 44 | 61 | 162 | 33 |
| Be | 0.003 | 0.015 | 0.011 | 0.005 | 0.005 | 0.006 | 0.007 | 0.030 | 0.005 |
| Bi | 0.004 | 0.011 | 0.012 | 0.002 | 0.001 | 0.007 | 0.012 | 0.017 | 0.003 |
| Ca | 26 | 30 | 56 | 61 | 12 | 25 | 48 | 51 | 26 |
| Ce | 0.007 | 0.010 | 0.013 | 0.008 | 0.041 | 0.003 | 0.006 | 0.048 | 0.017 |
| Cs | 0.004 | <0.001 | 0.002 | 0.005 | 0.001 | 0.003 | 0.003 | 0.002 | 0.003 |
| Dy | 0.001 | 0.007 | 0.008 | 0.001 | 0.011 | 0.002 | 0.003 | 0.017 | 0.002 |
| Er | 0.001 | 0.005 | 0.005 | 0.001 | 0.006 | 0.001 | 0.002 | 0.011 | 0.001 |
| Eu | <0.001 | 0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.001 | <0.001 |
| Fe | 57 | 92 | 213 | 42 | 244 | 21 | 280 | 152 | 109 |
| Ga | 0.075 | 0.072 | 0.277 | 0.042 | 0.032 | 0.263 | 0.306 | 0.199 | 0.064 |
| Gd | 0.001 | 0.004 | 0.003 | 0.001 | 0.004 | 0.001 | 0.001 | 0.010 | 0.002 |
| Ge | 0.005 | 0.010 | 0.013 | 0.003 | 0.001 | 0.010 | 0.013 | 0.020 | 0.004 |
| Hf | 0.034 | 0.029 | 0.011 | <0.001 | 0.030 | 0.001 | 0.003 | 0.033 | 0.002 |
| Ho | <0.001 | 0.002 | 0.002 | <0.001 | 0.002 | <0.001 | 0.001 | 0.004 | 0.001 |
| K | 18 | 4.1 | 32 | 19 | 11 | 23 | 25 | 8.0 | 19 |
| La | 0.002 | 0.003 | 0.006 | 0.003 | 0.008 | 0.001 | 0.002 | 0.021 | 0.003 |
| Li | 0.054 | 0.075 | 0.088 | 0.071 | 0.084 | 0.103 | 0.089 | 0.136 | 0.078 |
| Lu | <0.001 | 0.001 | 0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.001 | <0.001 |
| Mg | 28 | 25 | 135 | 41 | 12 | 133 | 160 | 128 | 36 |
| Mn | 2.30 | 0.830 | 10 | 2.26 | 4.13 | 12 | 13 | 4.38 | 2.39 |
| Na | 2 | 2 | 28 | 6 | 4 | 9 | 14 | 4 | 3 |
| Nb | <0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Nd | 0.002 | 0.006 | 0.006 | 0.003 | 0.010 | 0.001 | 0.002 | 0.021 | 0.003 |
| Os | 0.001 | 0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 |
| P | 1.50 | 0.875 | 1.56 | 1.60 | 1.65 | 1.89 | 1.87 | 2.67 | 1.69 |
| Pd | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Pr | <0.001 | 0.001 | 0.001 | 0.001 | 0.002 | <0.001 | <0.001 | 0.005 | 0.001 |
| Pt | <0.001 | 0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Rb | 0.020 | <0.001 | 0.036 | 0.018 | 0.015 | 0.025 | 0.029 | 0.010 | 0.022 |
| Sc | 0.006 | 0.027 | 0.022 | 0.055 | 0.042 | 0.006 | 0.009 | 0.037 | 0.006 |
| Si | 944 | 182 | 163 | 841 | 670 | 581 | 352 | 284 | 876 |
| Sm | 0.001 | 0.003 | 0.002 | 0.001 | 0.003 | <0.001 | 0.001 | 0.006 | 0.001 |
| Sn | 0.005 | 0.007 | 0.003 | 0.004 | <0.001 | 0.003 | 0.003 | 0.008 | 0.003 |
| Sr | 0.056 | 0.061 | 0.084 | 0.063 | 0.021 | 0.031 | 0.052 | 0.125 | 0.043 |
| Tb | <0.001 | 0.001 | 0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.002 | <0.001 |

| Sample ID | MF1 0-1m | MF1 1-2m | MF2 0.5-1m | MF2 2-2.5m | MF2 3-4m | MF3 0.5-1.5m | MF4 0.5-1.5m | MF5 0.2-0.8m | MF5 1-2m |
|---|---|---|---|---|---|---|---|---|---|
| **Lab ID** | **96716** | **96717** | **96718** | **96719** | **96720** | **96721** | **96722** | **96723** | **96724** |
| Th | 0.006 | 0.020 | 0.015 | 0.003 | 0.022 | 0.003 | 0.005 | 0.042 | 0.007 |
| Ti | 0.688 | 9.28 | 5.42 | 0.679 | 23 | 1.78 | 2.75 | 10 | 1.93 |
| Tl | 0.003 | 0.003 | 0.011 | 0.003 | 0.001 | 0.009 | 0.012 | 0.012 | 0.003 |
| Tm | <0.001 | 0.001 | 0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.001 | <0.001 |
| U | 0.001 | 0.013 | 0.008 | 0.001 | 0.007 | 0.002 | 0.004 | 0.022 | 0.004 |
| W | 0.089 | 0.109 | 0.107 | 0.072 | 0.117 | 0.035 | 0.035 | 0.033 | 0.179 |
| Y | 0.001 | 0.007 | 0.006 | 0.001 | 0.006 | 0.001 | 0.002 | 0.015 | 0.002 |
| Yb | 0.002 | 0.005 | 0.005 | 0.002 | 0.006 | 0.002 | 0.003 | 0.010 | 0.002 |
| Zr | <0.001 | 0.082 | 0.006 | <0.001 | 0.047 | <0.001 | <0.001 | 0.064 | <0.001 |

| **In all samples <0.001 mg/l** |
|---|
| Au |
| In |
| Ir |
| Rh |
| Ru |
| Ta |
| Te |

**Table 4-5: Leachate (distilled water 1:20 ratio) test concentrations for the samples (exceedances highlighted).**

| Leachable 1:20 | MF1 0-1m | MF1 1-2m | MF2 0.5-1m | MF2 2-2.5m | MF2 3-4m | MF3 0.5-1.5m | MF4 0.5-1.5m | MF5 0.2-0.8m | MF5 1-2m | Threshold | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Number** | **96716** | **96717** | **96718** | **96719** | **96720** | **96721** | **96722** | **96723** | **96724** | **LCT0** | **LCT1** | **LCT2** | **LCT3** |
| **Units** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** |
| As, Arsenic | 0.003 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | 0.003 | 0.001 | 0.002 | 0.01 | 0.5 | 1 | 4 |
| B, Boron | 0.070 | 0.075 | 0.129 | 0.233 | 0.149 | 0.158 | 0.152 | 0.188 | 0.106 | 0.5 | 25 | 50 | 200 |
| Ba, Barium | <0.025 | 0.032 | 0.051 | <0.025 | 0.063 | <0.025 | <0.025 | 0.067 | <0.025 | 0.7 | 35 | 70 | 280 |
| Cd, Cadmium | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.003 | 0.15 | 0.3 | 1.2 |
| Co, Cobalt | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.5 | 25 | 50 | 200 |
| $Cr_{Total,}$ Chromium Total | 1.63 | 0.176 | <0.025 | 0.065 | <0.025 | 4.93 | 0.176 | 0.126 | 0.216 | 0.1 | 5 | 10 | 40 |
| Cr(VI), Chromium (VI) | 1.61 | 0.157 | <0.010 | 0.055 | <0.010 | 5.1 | <0.010 | 0.116 | 0.178 | 0.05 | 2.5 | 5 | 20 |
| Cu, Copper | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | 2.0 | 100 | 200 | 800 |
| Hg, Mercury | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.006 | 0.3 | 0.6 | 2.4 |
| Mn, Manganese | <0.025 | 0.041 | <0.025 | <0.025 | 0.066 | <0.025 | 0.062 | <0.025 | <0.025 | 0.5 | 25 | 50 | 200 |
| Mo, Molybdenum | <0.025 | <0.025 | 0.068 | <0.025 | <0.025 | <0.025 | 0.030 | <0.025 | <0.025 | 0.07 | 3.5 | 7 | 28 |
| Ni, Nickel | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.07 | 3.5 | 7 | 28 |
| Pb, Lead | 0.001 | <0.001 | 0.001 | <0.001 | 0.001 | 0.001 | 0.006 | <0.001 | <0.001 | 0.01 | 0.5 | 1 | 4 |
| Sb, Antimony | 0.001 | <0.001 | 0.004 | 0.003 | <0.001 | 0.001 | 0.014 | 0.001 | 0.001 | 0.02 | 1.0 | 2 | 8 |
| Se, Selenium | 0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | 0.002 | <0.001 | <0.001 | 0.01 | 0.5 | 1 | 4 |
| V, Vanadium | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.2 | 10 | 20 | 80 |
| Zn, Zinc | 0.026 | 1.03 | <0.025 | <0.025 | <0.025 | 0.067 | 0.253 | <0.025 | <0.025 | 5.0 | 250 | 500 | 2000 |
| ***Inorganic Anions*** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** |
| Total Dissolved Solids* | 72 | 922 | 854 | 1,796 | 104 | 354 | 384 | 210 | 146 | 1,000 | 12,500 | 25,000 | 100,000 |
| Chloride as Cl | <2 | <2 | 20 | 13 | 6 | 4 | 15 | <2 | <2 | 300 | 15,000 | 30,000 | 120,000 |
| Sulphate as SO4 | 9 | 640 | 548 | 1195 | 38 | 177 | 113 | 95 | 70 | 250 | 12,500 | 25,000 | 100,000 |
| Nitrate as N | 0.2 | 0.3 | <0.1 | 0.1 | <0.1 | 1.2 | <0.1 | <0.1 | 0.1 | 11 | 550 | 1100 | 4400 |
| Fluoride as F | 1.0 | 0.6 | 1.5 | 0.4 | 1.6 | 1.0 | 1.6 | 3 | 1.3 | 1.5 | 75 | 150 | 600 |
| Paste pH | 8.3 | 5.8 | 9.7 | 9.8 | 7.4 | 8.6 | 9.3 | 8.9 | 8.6 | | | | |
| Moisture % | 47.3 | 45.7 | 38.3 | 55.6 | 15.8 | 46.6 | 31.9 | 42.6 | 57.3 | | | | |

**Table 4-6: Leachate (distilled water 1:4 ratio) test concentrations for the samples (exceedances highlighted).**

| Leachable 1:4 | MF1 0-1m | MF1 1-2m | MF2 0.5-1m | MF2 2-2.5m | MF2 3-4m | MF3 0.5-1.5m | MF4 0.5-1.5m | MF5 0.2-0.8m | MF5 1-2m | Threshold | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Number** | **96716** | **96717** | **96718** | **96719** | **96720** | **96721** | **96722** | **96723** | **96724** | **LCT0** | **LCT1** | **LCT2** | **LCT3** |
| **Units** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** |
| As, Arsenic | 0.002 | <0.001 | <0.001 | 0.002 | 0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.01 | 0.5 | 1 | 4 |
| B, Boron | 0.193 | 0.454 | 0.319 | 0.767 | 0.215 | 0.268 | 0.334 | 0.743 | 0.407 | 0.5 | 25 | 50 | 200 |
| Ba, Barium | <0.025 | <0.025 | 0.039 | 0.033 | 0.036 | <0.025 | <0.025 | 0.034 | 0.029 | 0.7 | 35 | 70 | 280 |
| Cd, Cadmium | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.010 | 0.15 | 0.3 | 1.2 |
| Co, Cobalt | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.5 | 25 | 50 | 200 |
| $Cr_{Total,}$ Chromium Total | 7.17 | 0.366 | <0.025 | 0.121 | <0.025 | 24 | 0.078 | 0.164 | 0.559 | 0.1 | 5 | 10 | 40 |
| Cr(VI), Chromium (VI) | 2.80 | 0.372 | <0.010 | 0.101 | <0.010 | 16.3 | <0.010 | 0.169 | 1.490 | 0.05 | 2.5 | 5 | 20 |
| Cu, Copper | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | 2.0 | 100 | 200 | 800 |
| Hg, Mercury | <0.001 | <0.001 | 0.030 | 0.005 | 0.004 | <0.001 | 0.021 | <0.001 | <0.001 | 0.006 | 0.3 | 0.6 | 2.4 |
| Mn, Manganese | <0.025 | 0.291 | <0.025 | <0.025 | 0.034 | <0.025 | <0.025 | <0.025 | <0.025 | 0.5 | 25 | 50 | 200 |
| Mo, Molybdenum | <0.025 | <0.025 | 0.414 | 0.099 | 0.036 | <0.025 | 0.127 | 0.085 | 0.038 | 0.07 | 3.5 | 7 | 28 |
| Ni, Nickel | <0.025 | 0.044 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.07 | 3.5 | 7 | 28 |
| Pb, Lead | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.01 | 0.5 | 1 | 4 |
| Sb, Antimony | 0.003 | <0.001 | 0.006 | 0.014 | <0.001 | 0.002 | 0.025 | <0.001 | 0.002 | 0.02 | 1.0 | 2 | 8 |
| Se, Selenium | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.01 | 0.5 | 1 | 4 |
| V, Vanadium | <0.025 | <0.025 | <0.025 | 0.048 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.2 | 10 | 20 | 80 |
| Zn, Zinc | <0.025 | 10.0 | <0.025 | <0.025 | <0.025 | 0.041 | 0.033 | <0.025 | <0.025 | 5.0 | 250 | 500 | 2000 |
| ***Inorganic Anions*** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** |
| Total Dissolved Solids | 225* | 2408 | 4342 | 2430 | 414 | 1501* | 1118 | 902 | 574* | 1,000 | 12,500 | 25,000 | 100,000 |
| Chloride as Cl | 2 | <2 | 125 | 55 | 14 | 14 | 36 | 4 | 5 | 300 | 15,000 | 30,000 | 120,000 |
| Sulphate as SO4 | 47 | 1411 | 2667 | 1389 | 133 | 897 | 460 | 365 | 262 | 250 | 12,500 | 25,000 | 100,000 |
| Nitrate as N | 0.2 | 2.2 | <0.1 | 0.3 | 0.3 | 2.3 | 0.1 | 0.1 | 0.4 | 11 | 550 | 1100 | 4400 |
| Fluoride as F | 3.3 | 4.0 | 4.2 | 1.0 | 3.2 | 2.1 | 4.9 | 5.0 | 2.4 | 1.5 | 75 | 150 | 600 |

**Table 4-7: Summary table of waste classification results for the CDR Slimes samples.**

| Sample | TCT | LCT | Waste Type | Landfill design |
|---|---|---|---|---|
| **MF1 0-1m** | <TCT1 | <LTC1 | **Type 3** | **Class C** |
| **MF1 1-2m** | <TCT1 | <LTC1 | **Type 3** | **Class C** |
| **MF2 0.5-1m** | <TCT1 | <LTC1 | **Type 3** | **Class C** |
| **MF2 2-2.5m** | <TCT1 | <LTC1 | **Type 3** | **Class C** |
| **MF2 3-4m** | <TCT1 | <LTC1 | **Type 3** | **Class C** |
| **MF3 0.5-1.5m** | <TCT1 | < LCT3 | **Type 1** | **Class A** |
| **MF4 0.5-1.5m** | <TCT1 | <LTC1 | **Type 3** | **Class C** |
| **MF5 0.2-0.8m** | <TCT1 | <LTC1 | **Type 3** | **Class C** |
| **MF5 1-2m** | <TCT1 | <LTC1 | **Type 3** | **Class C** |

### *4.4.2. SANS 10234 Hazardous waste classification*

A hazardous waste classification according to SANS 10234 was conducted on the nine CDR slimes (including one bedrock) samples by Interwaste in August 2020. The SANS 10234 classification is based on total and leachable metals and metalloids as listed in GN.R. 635, inorganic anions (Cl, F, $NO_3$, $SO_4$ and CN), organics as listed in GN.R. 635 and other detectable organic substances as well as crystalline content, pH and particle size distribution. All laboratory certificates are provided in Appendix C. It should be noted that the classification is based on the worst-case sample scenario since all samples were derived from the same waste generation process. A definition of all hazard classes and categories as well as a detailed waste classification is provided in the SANS 10234 classification report by Interwaste (2020) attached in Appendix D.

Results obtained from the organic analyses showed that no hazardous organic constituents were present in the samples. However, based on the inorganic CDR slimes components, the waste is classified as hazardous to human health. According to SANS 10234, hazardous waste is defined as any waste that contains organic or inorganic elements or compounds that may, owing to the inherent physical, chemical or toxicological characteristics of that waste, have a detrimental impact on health and the environment (Interwaste, 2020). The hazardous components identified in the CDR slimes material can be summarised as follows:

- Quartz
  - Carcinogenicity: Category 1A
  - Specific Target Organ Toxicity (STOT): Single exposure Category 3, repeat exposure Category 1
- Silicon Dioxide
  - STOT: Repeat exposure Category 1
- Iron oxide
  - Skin corrosion / irritation: category 2
  - Eye damage / irritation: category 2
  - STOT: Single exposure category 3

According to the SANS 10234 classification (Interwaste, 2020), the CDR slimes material was categorised as hazardous waste based on the following hazard classes and statements:

- Hazard classes and categories hazard classes and categories:
  - Skin irritation → Category 2,
  - Eye irritation → Category 2A,
  - Carcinogenicity → Category 1B,
  - Specific target organ toxicity → single exposure → Category 3, and
  - Specific target organ toxicity → repeated exposure → Category 1.
- Hazard statements:
  - H315: causes skin irritation,
  - H319: Causes severe eye irritation,

- H335: May cause respiratory irritation,
- H350: May cause cancer, and
- H372: Causes damage to organs through prolonged or repeated exposure.

Due to the identified hazards to human health, a safety data sheet (SDS) is required for the CDS slimes disposal facility as per “Waste Classification and Management Regulations 2013 (GNR634)”. A safety data sheet was compiled by Interwaste (2020) for the handling of the CDR Slimes material and is provided in Appendix D.

# 5. Discussion and Conclusion

A geochemical assessment of five CDR Slimes profiles sampled from the disposal area confirmed both vertical and horizontal heterogeneity of the material observed in previous studies (Delta H, 2019). Window sampling showed the presence of grey and black interlayered very fine grained to powdery filter cake representing ferrochrome fine and coarse dust, respectively. The alternating grey and black layers vary in thickness from a few mm to several decimetres. The layering is inconsistent between the different profiles. The mineralogical composition of the eight CDR Slimes samples (excluding one bedrock sample) was similar with small fluctuations in minor and trace minerals. Although the identified constituents of concern ($Cr_{total}$, Cr(VI), $SO_4$, F, Ba, Co, Cu, Mn, Ni, Pb, V, Zn and TDS) exceeded the TCT0 threshold in most samples, fluctuations in Cr(VI) leachable concentrations were observed ranging from less than the detection limit (<0.01 mg/l) to just over 5 mg/l, exceeding the LCT2 threshold. According to Ma and Garbers-Craig (2006), such variations in chemical composition of the ferrochrome dust and crystalline phases is expected and depends on the furnace type and heat, steel grade, composition of raw material used as well as operational parameters.

ABA results also showed variations in the acid generation potential for the different CDR Slimes samples. Sample MF1 1-2m is clearly classified as potentially acid generating due to its negative (sulphide) net neutralisation potential while samples MF1 0-1m, MF2 3-4m, MF5 0.2-0.8m and MF5 1-2m are classified as non-acid generating based on positive net neutralisation potentials and low contents of acid generating sulphide sulphur. Samples MF2 0.5-1m, MF4 0.5-1.5, MF2 2-2.5 and MF3 0.5-1.5m are classified as inconclusive (or uncertain) and potentially acid generating (short-term) if preferentially exposed to the atmosphere due to low sulphide sulphur contents.

Chemical variations of the filter cake, particularly for Cr(VI), lead to different waste type classifications of the CDR Slimes disposal site. Although most samples were classified as Type 3 Waste, requiring a Class C landfill design, one sample exceeded the Cr(VI) LCT2 threshold leading to a Type 1 Waste category, requiring a Class A landfill design. CDR dust is known to contain high levels of Cr(VI), which is both toxic and carcinogenic. Since the results cannot be referenced to a particular horizon within the CDR Slimes dam, the material can be further classified spatially during excavation.

A waste classification according to SANS 10234 regulations indicated that the CDR Slimes material is hazardous to human health. Hazardous components identified included quartz (carcinogenic, respiratory), silicon dioxide (respiratory) and iron dioxide (skin corrosion, eye damage, organ damage) alongside a small particle size (0.9 µm to 2090 µm). The hazard statements are summarised as follows and require a safety data sheet (provided in Appendix D) to enable safe handling procedures when in contact with the CDR Slimes material:

- H315: causes skin irritation,
- H319: Causes severe eye irritation,
- H335: May cause respiratory irritation,
- H350: May cause cancer, and
- H372: Causes damage to organs through prolonged or repeated exposure.

## 5.1. Comparison with previous assessments

This waste classification of samples collected in June 2020 confirms the findings summarised in the review-report (Delta H, 2019), which contains analytical results of three different sampling campaigns A (EnviroSim, 2019), B (Golder, 2019) and C (EnviroSim, 2019). When all geochemical results were considered individually, one CDR Slimes composite sample (campaign A, A1-comp sample) also exceeded the LCT2 threshold for Cr(VI). However, total concentrations of antinomy were below the detection limit in the current study, other than found in the CDR Slimes sample from campaign B (Golder, 2019; Delta H, 2019). As indicated during sample campaign C by Knight Piésold (EnviroSim, 2019), Cr(VI), F and $SO_4$ are regarded as potential leachable contaminants of concern, which was also found during this assessment. However, sample campaign C additionally indicated that the leaching potential of Mn, Ni, Pb, Sb and Zn was elevated within the different sampled profiles (EnviroSim, 2019). These metals were not found to be elevated in the 1:20 ratio leachate in this study.

Furthermore, similar TCT0 exceedances were observed for sample campaign C (EnviroSim, 2019; Delta H, 2019), except that additional exceedances were noticed for $Cr_{total}$ and F, but no exceedance for As during this assessment. Although the CDR Slimes material is derived from the same CDR processing facility, four analytical assessments indicated that the CDR Slimes material is heterogenous in composition, both vertically and horizontally due to variations in steel grade, composition of raw material used as well as operational parameters.

### 5.2. RECOMMENDATIONS

A review of previously conducted geochemical studies together with results obtained during this geochemical assessment indicated that most samples were classified as Type 3 waste. However, one composite sample from sampling campaign A (EnviroSim, 2019) and one profile sample of this sampling campaign was classified as Type 1 waste based on the Cr(VI) concentration. Since no distinct layering could be associated with elevated Cr and Cr(VI) concentrations, there exist opportunity to classify the CDR slimes spatially during excavation of the material. It is recommended to:

- Distinguish the CDR slimes dam into waste Class C and Class A areas, based on a sampling grid using initially only total Cr as a criteria to flag areas of concern.
- A waste classification of the flagged areas should follow thereafter to confirm the classification. All Class A areas should then be excavated and disposed of at a licensed disposal facility. The remaining Class C areas material will be excavated and transported to existing plant (process) operations.
- Material should be excavated up to the (pre-deposition) host rock/soil.
    - Initiate soil sampling after removal of the CDR slimes material to assess potential secondary sources and apply a risk-based approach to advice on future remediation (if required).
    - The soil sampling results will be used to inform the further classification of the material and additional excavation specifications.

## 6. References


Delta H, 2019. *Samancor Middelburg Ferrochrome-Review of Chrome Direct Reduction Slimes Waste Classification*. Report number. Delh.2019.014-13

ENVASS. 2012. Samancor 30CDR Slimes dam Hydrogeological Investigation. GEO Pollution Technologies, Gauteng. 53pp.

EnviroSim Consulting, 2019. *Waste Classification and Site Risk Characterisation of the MFC CDR Slimes Disposal Area*. Report number KPC-02-2018-B.

Golder Associates Africa (Pty) Ltd. 2011. Middelburg Ferrochrome, A Division Of Samancor Chrome LTD: Delineation of Groundwater Pollution Plumes and Predictions of Plume Migration – Rev1. 115pp.

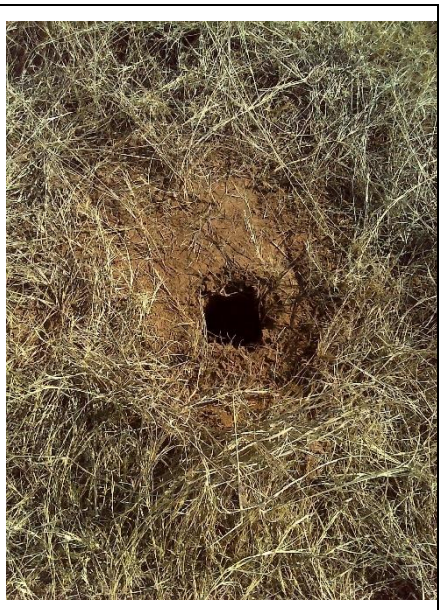
Golder Associates Africa (Pty) Ltd., 2019. *Samancor Chrome-Middelburg Ferrochrome: Classification and assessment of Chrome Direct Reductant Slimes*. Report number 19125329-327644-1.

Interwaste, 2020. *Classification of Samancor Chrome, Chrome Direct Reduction (CDR) Slimes Stockpiles in terms of SANS 10234.*

Ma, G. and Garbers-Craig, A.M. 2006. A review on the characteristics, formation mechanisms and treatment processes of Cr(VI)-containing pyrometallurgical wastes. *Journal of the Southern African Institute of Mining and Metallurgy,* 106: 753-763.

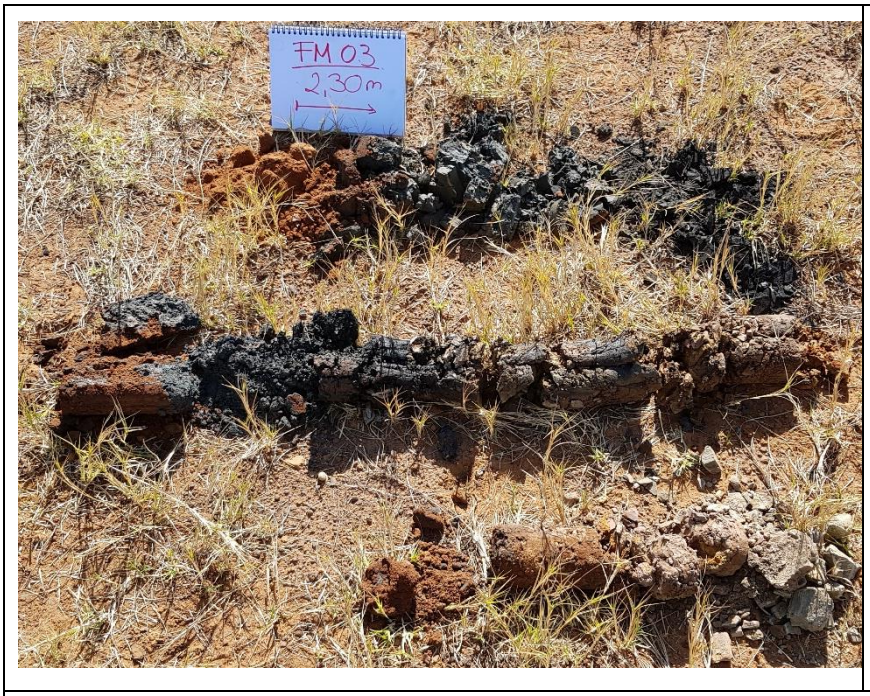
## Appendix A (geo-sites)

* Note that borehole labels displayed in the images were accidentally transposed to FM instead of MF.

Core log of borehole MF01 with a depth of 2.8 m.


Core log of borehole MF02 with a depth of 5 m.




Core log of borehole MF03 with a depth of 2.3 m.


Core log of borehole MF04 with a depth of 1.8 m.


Core log of borehole MF05 with a depth of 3 m.

## Appendix B (Core logs)

**Appendix Table 1: Core logs obtained via push rig window sampling of the CDR Slimes; lithologies are denoted as FC=filter cake, mudst=mudstone and sst=sandstone.**

| MF01 | | | MF02 | | |
|---|---|---|---|---|---|
| **Depth top (mbgl)** | **Depth bottom (mbgl)** | **Description** | **Depth top (mbgl)** | **Depth bottom (mbgl)** | **Description** |
| 0.00 | 0.15 | brown top soil | 0.00 | 0.10 | brown top soil |
| 0.15 | 0.20 | dry, powdery black FC | 0.10 | 0.80 | interlayered dark-grey/black FC |
| 0.20 | 1.00 | dark grey, moist, clayey FC | 0.80 | 1.00 | moist black, powdery FC |
| 1.00 | 1.20 | grey/black fine interlayered FC, moist | 1.00 | 1.20 | dark grey, clayey FC |
| 1.20 | 1.40 | black FC | 1.20 | 1.80 | dark grey to black FC |
| 1.40 | 1.80 | grey and black interlayered FC | 1.80 | 2.00 | Grey, clayey FC |
| 1.80 | 2.20 | black FC, less moist | 2.00 | 2.90 | moist grey FC with black layers |
| 2.20 | 2.80 | weathered, clayey red-brown shale | 2.90 | 3.00 | moist, black FC |
| 2.80 | 3.00 | brown-orange weathered bedrock | 3.00 | 5.00 | interlayered weathered shale/mudst/sst |
| **MF03** | | | **MF04** | | |
| **Depth top (mbgl)** | **Depth bottom (mbgl)** | **Description** | **Depth top (mbgl)** | **Depth bottom (mbgl)** | **Description** |
| 0.00 | 0.15 | reddish brown top soil | 0.00 | 0.10 | red-brown top soil |
| 0.15 | 0.90 | interlayered grey and dark grey, clayey FC | 0.10 | 0.80 | interlayered grey/dark grey, clayey FC |
| 0.90 | 1.00 | black FC | 0.80 | 1.00 | black FC |
| 1.00 | 1.15 | grey FC with thin, light-grey layers | 1.00 | 1.40 | interlayered dark-grey/grey/black FC |
| 1.15 | 1.50 | black FC | 1.40 | 1.60 | weathered bedrock grey-brown with nodules (rhyolite?) |
| 1.50 | 2.30 | weathered sst/mudst/shale | 1.60 | 1.80 | weathered orange-brown shale/sst |

| MF03 | | |
|---|---|---|
| **Depth top (mbgl)** | **Depth bottom (mbgl)** | **Description** |
| 0.00 | 0.20 | reddish brown top soil |
| 0.20 | 0.40 | interlayered grey and black FC |
| 0.40 | 0.70 | black, powdery FC |
| 0.70 | 0.90 | grey FC |
| 0.90 | 1.00 | black FC |
| 1.00 | 1.80 | grey, clayey FC |
| 1.80 | 2.00 | light grey FC |
| 2.00 | 3.00 | weathered, clayey bedrock (interlayered sst/ mudst/shale) |

## Appendix C (Laboratory certificates)

| Sample Id | Sample number | Sn | Sn | Sr | Sr | Ta | Ta |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF1 0-1m | 96716 | 0.005 | 2.00 | 0.056 | 22 | <0.001 | <0.400 |
| MF1 1-2m | 96717 | 0.007 | 2.80 | 0.061 | 24 | <0.001 | <0.400 |
| MF2 0.5-1m | 96718 | 0.003 | 1.20 | 0.084 | 34 | <0.001 | <0.400 |
| MF2 2-2.5m | 96719 | 0.004 | 1.60 | 0.063 | 25 | <0.001 | <0.400 |
| MF2 3-4m | 96720 | <0.001 | <0.400 | 0.021 | 8.40 | <0.001 | <0.400 |
| MF3 0.5-1.5m | 96721 | 0.003 | 1.20 | 0.031 | 12 | <0.001 | <0.400 |
| MF4 0.5-1.5m | 96722 | 0.003 | 1.20 | 0.052 | 21 | <0.001 | <0.400 |
| MF5 0.2-0.8m | 96723 | 0.008 | 3.20 | 0.125 | 50 | <0.001 | <0.400 |
| MF5 1-2m | 96724 | 0.003 | 1.20 | 0.043 | 17 | <0.001 | <0.400 |

| Sample Id | Sample number | Tb | Tb | Te | Te | Th | Th |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF1 0-1m | 96716 | <0.001 | <0.400 | <0.001 | <0.400 | 0.006 | 2.40 |
| MF1 1-2m | 96717 | 0.001 | 0.400 | <0.001 | <0.400 | 0.020 | 8.00 |
| MF2 0.5-1m | 96718 | 0.001 | 0.400 | <0.001 | <0.400 | 0.015 | 6.00 |
| MF2 2-2.5m | 96719 | <0.001 | <0.400 | <0.001 | <0.400 | 0.003 | 1.20 |
| MF2 3-4m | 96720 | 0.001 | 0.400 | <0.001 | <0.400 | 0.022 | 8.80 |
| MF3 0.5-1.5m | 96721 | <0.001 | <0.400 | <0.001 | <0.400 | 0.003 | 1.20 |
| MF4 0.5-1.5m | 96722 | <0.001 | <0.400 | <0.001 | <0.400 | 0.005 | 2.00 |
| MF5 0.2-0.8m | 96723 | 0.002 | 0.800 | <0.001 | <0.400 | 0.042 | 17 |
| MF5 1-2m | 96724 | <0.001 | <0.400 | <0.001 | <0.400 | 0.007 | 2.80 |

| Sample Id | Sample number | Ti | Ti | Tl | Tl | Tm | Tm |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF1 0-1m | 96716 | 0.688 | 275 | 0.003 | 1.20 | <0.001 | <0.400 |
| MF1 1-2m | 96717 | 9.28 | 3712 | 0.003 | 1.20 | 0.001 | 0.400 |
| MF2 0.5-1m | 96718 | 5.42 | 2168 | 0.011 | 4.40 | 0.001 | 0.400 |
| MF2 2-2.5m | 96719 | 0.679 | 272 | 0.003 | 1.20 | <0.001 | <0.400 |
| MF2 3-4m | 96720 | 23 | 9396 | 0.001 | 0.400 | 0.001 | 0.400 |
| MF3 0.5-1.5m | 96721 | 1.78 | 712 | 0.009 | 3.60 | <0.001 | <0.400 |
| MF4 0.5-1.5m | 96722 | 2.75 | 1100 | 0.012 | 4.80 | <0.001 | <0.400 |
| MF5 0.2-0.8m | 96723 | 10 | 4002 | 0.012 | 4.80 | 0.001 | 0.400 |
| MF5 1-2m | 96724 | 1.93 | 772 | 0.003 | 1.20 | <0.001 | <0.400 |

| Sample Id | Sample number | U | U | W | W | Y | Y |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF1 0-1m | 96716 | 0.001 | 0.400 | 0.089 | 36 | 0.001 | 0.400 |
| MF1 1-2m | 96717 | 0.013 | 5.20 | 0.109 | 44 | 0.007 | 2.80 |
| MF2 0.5-1m | 96718 | 0.008 | 3.20 | 0.107 | 43 | 0.006 | 2.40 |
| MF2 2-2.5m | 96719 | 0.001 | 0.400 | 0.072 | 29 | 0.001 | 0.400 |
| MF2 3-4m | 96720 | 0.007 | 2.80 | 0.117 | 47 | 0.006 | 2.40 |
| MF3 0.5-1.5m | 96721 | 0.002 | 0.800 | 0.035 | 14 | 0.001 | 0.400 |
| MF4 0.5-1.5m | 96722 | 0.004 | 1.60 | 0.035 | 14 | 0.002 | 0.800 |
| MF5 0.2-0.8m | 96723 | 0.022 | 8.80 | 0.033 | 13 | 0.015 | 6.00 |
| MF5 1-2m | 96724 | 0.004 | 1.60 | 0.179 | 72 | 0.002 | 0.800 |

| Sample Id | Sample number | Yb | Yb | Zr | Zr |
|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.001 | <0.400 |
| MF1 0-1m | 96716 | 0.002 | 0.800 | <0.001 | <0.400 |
| MF1 1-2m | 96717 | 0.005 | 2.00 | 0.082 | 33 |
| MF2 0.5-1m | 96718 | 0.005 | 2.00 | 0.006 | 2.40 |
| MF2 2-2.5m | 96719 | 0.002 | 0.800 | <0.001 | <0.400 |
| MF2 3-4m | 96720 | 0.006 | 2.40 | 0.047 | 19 |
| MF3 0.5-1.5m | 96721 | 0.002 | 0.800 | <0.001 | <0.400 |
| MF4 0.5-1.5m | 96722 | 0.003 | 1.20 | <0.001 | <0.400 |
| MF5 0.2-0.8m | 96723 | 0.010 | 4.00 | 0.064 | 26 |
| MF5 1-2m | 96724 | 0.002 | 0.800 | <0.001 | <0.400 |

**[*] Elements analysed on the ICP-OES Instrument**

| Sample Id | Sample number | Ir | Ir | K* | K* | La | La |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.5 | <200 | <0.001 | <0.400 |
| MF1 0-1m | 96716 | <0.001 | <0.400 | 18 | 7200 | 0.002 | 0.800 |
| MF1 1-2m | 96717 | <0.001 | <0.400 | 4.1 | 1654 | 0.003 | 1.20 |
| MF2 0.5-1m | 96718 | <0.001 | <0.400 | 32 | 12800 | 0.006 | 2.40 |
| MF2 2-2.5m | 96719 | <0.001 | <0.400 | 19 | 7600 | 0.003 | 1.20 |
| MF2 3-4m | 96720 | <0.001 | <0.400 | 11 | 4400 | 0.008 | 3.20 |
| MF3 0.5-1.5m | 96721 | <0.001 | <0.400 | 23 | 9200 | 0.001 | 0.400 |
| MF4 0.5-1.5m | 96722 | <0.001 | <0.400 | 25 | 10000 | 0.002 | 0.800 |
| MF5 0.2-0.8m | 96723 | <0.001 | <0.400 | 8.0 | 3198 | 0.021 | 8.40 |
| MF5 1-2m | 96724 | <0.001 | <0.400 | 19 | 7600 | 0.003 | 1.20 |

| Sample Id | Sample number | Li | Li | Lu | Lu | Mg* | Mg* |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.001 | <0.400 | <1 | <400 |
| MF1 0-1m | 96716 | 0.054 | 22 | <0.001 | <0.400 | 28 | 11200 |
| MF1 1-2m | 96717 | 0.075 | 30 | 0.001 | 0.400 | 25 | 10000 |
| MF2 0.5-1m | 96718 | 0.088 | 35 | 0.001 | 0.400 | 135 | 54000 |
| MF2 2-2.5m | 96719 | 0.071 | 28 | <0.001 | <0.400 | 41 | 16400 |
| MF2 3-4m | 96720 | 0.084 | 34 | 0.001 | 0.400 | 12 | 4800 |
| MF3 0.5-1.5m | 96721 | 0.103 | 41 | <0.001 | <0.400 | 133 | 53200 |
| MF4 0.5-1.5m | 96722 | 0.089 | 36 | <0.001 | <0.400 | 160 | 64000 |
| MF5 0.2-0.8m | 96723 | 0.136 | 54 | 0.001 | 0.400 | 128 | 51200 |
| MF5 1-2m | 96724 | 0.078 | 31 | <0.001 | <0.400 | 36 | 14400 |

| Sample Id | Sample number | Mn* | Mn* | Na* | Na* | Nb | Nb |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.025 | <10 | <0.025 | <10 | <0.001 | <0.400 |
| MF1 0-1m | 96716 | 2.30 | 919 | 2 | 800 | <0.001 | <0.400 |
| MF1 1-2m | 96717 | 0.830 | 332 | 2 | 800 | 0.002 | 0.800 |
| MF2 0.5-1m | 96718 | 10 | 4059 | 28 | 11200 | <0.001 | <0.400 |
| MF2 2-2.5m | 96719 | 2.26 | 904 | 6 | 2400 | <0.001 | <0.400 |
| MF2 3-4m | 96720 | 4.13 | 1653 | 4 | 1600 | <0.001 | <0.400 |
| MF3 0.5-1.5m | 96721 | 12 | 4894 | 9 | 3600 | <0.001 | <0.400 |
| MF4 0.5-1.5m | 96722 | 13 | 5193 | 14 | 5600 | <0.001 | <0.400 |
| MF5 0.2-0.8m | 96723 | 4.38 | 1751 | 4 | 1600 | <0.001 | <0.400 |
| MF5 1-2m | 96724 | 2.39 | 957 | 3 | 1200 | <0.001 | <0.400 |

| Sample Id | Sample number | Nd | Nd | Os | Os | P | P |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF1 0-1m | 96716 | 0.002 | 0.800 | 0.001 | 0.400 | 1.50 | 599 |
| MF1 1-2m | 96717 | 0.006 | 2.40 | 0.001 | 0.400 | 0.875 | 350 |
| MF2 0.5-1m | 96718 | 0.006 | 2.40 | 0.001 | 0.400 | 1.56 | 622 |
| MF2 2-2.5m | 96719 | 0.003 | 1.20 | <0.001 | <0.400 | 1.60 | 641 |
| MF2 3-4m | 96720 | 0.010 | 4.00 | <0.001 | <0.400 | 1.65 | 659 |
| MF3 0.5-1.5m | 96721 | 0.001 | 0.400 | <0.001 | <0.400 | 1.89 | 756 |
| MF4 0.5-1.5m | 96722 | 0.002 | 0.800 | <0.001 | <0.400 | 1.87 | 748 |
| MF5 0.2-0.8m | 96723 | 0.021 | 8.40 | 0.001 | 0.400 | 2.67 | 1067 |
| MF5 1-2m | 96724 | 0.003 | 1.20 | <0.001 | <0.400 | 1.69 | 676 |

| Sample Id | Sample number | Pd | Pd | Pr | Pr | Pt | Pt |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF1 0-1m | 96716 | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF1 1-2m | 96717 | 0.001 | 0.400 | 0.001 | 0.400 | 0.001 | 0.400 |
| MF2 0.5-1m | 96718 | <0.001 | <0.400 | 0.001 | 0.400 | 0.001 | 0.400 |
| MF2 2-2.5m | 96719 | <0.001 | <0.400 | 0.001 | 0.400 | <0.001 | <0.400 |
| MF2 3-4m | 96720 | <0.001 | <0.400 | 0.002 | 0.800 | <0.001 | <0.400 |
| MF3 0.5-1.5m | 96721 | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF4 0.5-1.5m | 96722 | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF5 0.2-0.8m | 96723 | <0.001 | <0.400 | 0.005 | 2.00 | <0.001 | <0.400 |
| MF5 1-2m | 96724 | <0.001 | <0.400 | 0.001 | 0.400 | <0.001 | <0.400 |

| Sample Id | Sample number | Rb | Rb | Rh | Rh | Ru | Ru |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF1 0-1m | 96716 | 0.020 | 8.00 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF1 1-2m | 96717 | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF2 0.5-1m | 96718 | 0.036 | 14.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF2 2-2.5m | 96719 | 0.018 | 7.200 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF2 3-4m | 96720 | 0.015 | 6.000 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF3 0.5-1.5m | 96721 | 0.025 | 10.000 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF4 0.5-1.5m | 96722 | 0.029 | 11.600 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF5 0.2-0.8m | 96723 | 0.010 | 4.000 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF5 1-2m | 96724 | 0.022 | 8.800 | <0.001 | <0.400 | <0.001 | <0.400 |

| Sample Id | Sample number | Sc | Sc | Si* | Si* | Sm | Sm |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.2 | <80 | <0.001 | <0.400 |
| MF1 0-1m | 96716 | 0.006 | 2.40 | 944 | 377600 | 0.001 | 0.400 |
| MF1 1-2m | 96717 | 0.027 | 11 | 182 | 72800 | 0.003 | 1.20 |
| MF2 0.5-1m | 96718 | 0.022 | 8.80 | 163 | 65200 | 0.002 | 0.800 |
| MF2 2-2.5m | 96719 | 0.055 | 22 | 841 | 336400 | 0.001 | 0.400 |
| MF2 3-4m | 96720 | 0.042 | 17 | 670 | 268000 | 0.003 | 1.20 |
| MF3 0.5-1.5m | 96721 | 0.006 | 2.40 | 581 | 232400 | <0.001 | <0.400 |
| MF4 0.5-1.5m | 96722 | 0.009 | 3.60 | 352 | 140800 | 0.001 | 0.400 |
| MF5 0.2-0.8m | 96723 | 0.037 | 15 | 284 | 113600 | 0.006 | 2.40 |
| MF5 1-2m | 96724 | 0.006 | 2.40 | 876 | 350400 | 0.001 | 0.400 |

# WATERLAB (PTY) LTD

## CERTIFICATE OF ANALYSES

## ICP QUANTITATIVE ANALYSIS

**Date received:** 2020/06/11
**Project number:** 1000

**Date Completed:** 2020/07/21
**Report number:** 92197a


**Client name:** Delta H
**Adress:** PO Box 11465, Silver Lakes, 0054

**Contact person:** Dr Martin Holland
**Contact person:** T. Rossouw
**Email:** martin@delta-h.co.za
**Email:** theo@delta-h.co.za
**Cell:** 082 497 9088
**Cell:** 072 365 4613


| Extract | Sample Dry Mass | Volume | Mass (g/l) | Factor |
|---|---|---|---|---|
| HNO3 : HF | 0.25 | 100 | 2.5 | 400 |

| Sample Id | Sample number | Ag | Ag | Al* | Al* | Au | Au |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.100 | <40 | <0.001 | <0.400 |
| MF1 0-1m | 96716 | 0.003 | 1.20 | 18 | 7200 | <0.001 | <0.400 |
| MF1 1-2m | 96717 | <0.001 | <0.400 | 112 | 44800 | <0.001 | <0.400 |
| MF2 0.5-1m | 96718 | <0.001 | <0.400 | 83 | 33200 | <0.001 | <0.400 |
| MF2 2-2.5m | 96719 | <0.001 | <0.400 | 21 | 8400 | <0.001 | <0.400 |
| MF2 3-4m | 96720 | <0.001 | <0.400 | 157 | 62800 | <0.001 | <0.400 |
| MF3 0.5-1.5m | 96721 | <0.001 | <0.400 | 44 | 17600 | <0.001 | <0.400 |
| MF4 0.5-1.5m | 96722 | <0.001 | <0.400 | 61 | 24400 | <0.001 | <0.400 |
| MF5 0.2-0.8m | 96723 | <0.001 | <0.400 | 162 | 64800 | <0.001 | <0.400 |
| MF5 1-2m | 96724 | <0.001 | <0.400 | 33 | 13200 | <0.001 | <0.400 |

| Sample Id | Sample number | Be | Be | Bi | Bi | Ca* | Ca* |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.001 | <0.400 | <1 | <400 |
| MF1 0-1m | 96716 | 0.003 | 1.20 | 0.004 | 1.60 | 26 | 10400 |
| MF1 1-2m | 96717 | 0.015 | 6.00 | 0.011 | 4.40 | 30 | 12000 |
| MF2 0.5-1m | 96718 | 0.011 | 4.40 | 0.012 | 4.80 | 56 | 22400 |
| MF2 2-2.5m | 96719 | 0.005 | 2.00 | 0.002 | 0.800 | 61 | 24400 |
| MF2 3-4m | 96720 | 0.005 | 2.00 | 0.001 | 0.400 | 12 | 4800 |
| MF3 0.5-1.5m | 96721 | 0.006 | 2.40 | 0.007 | 2.80 | 25 | 10000 |
| MF4 0.5-1.5m | 96722 | 0.007 | 2.80 | 0.012 | 4.80 | 48 | 19200 |
| MF5 0.2-0.8m | 96723 | 0.030 | 12 | 0.017 | 6.80 | 51 | 20400 |
| MF5 1-2m | 96724 | 0.005 | 2.00 | 0.003 | 1.20 | 26 | 10400 |

| Sample Id | Sample number | Ce | Ce | Cs | Cs | Dy | Dy |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF1 0-1m | 96716 | 0.007 | 2.80 | 0.004 | 1.60 | 0.001 | 0.400 |
| MF1 1-2m | 96717 | 0.010 | 4.00 | <0.001 | <0.400 | 0.007 | 2.80 |
| MF2 0.5-1m | 96718 | 0.013 | 5.20 | 0.002 | 0.800 | 0.008 | 3.20 |
| MF2 2-2.5m | 96719 | 0.008 | 3.20 | 0.005 | 2.00 | 0.001 | 0.400 |
| MF2 3-4m | 96720 | 0.041 | 16 | 0.001 | 0.400 | 0.011 | 4.40 |
| MF3 0.5-1.5m | 96721 | 0.003 | 1.20 | 0.003 | 1.20 | 0.002 | 0.800 |
| MF4 0.5-1.5m | 96722 | 0.006 | 2.40 | 0.003 | 1.20 | 0.003 | 1.20 |
| MF5 0.2-0.8m | 96723 | 0.048 | 19 | 0.002 | 0.800 | 0.017 | 6.80 |
| MF5 1-2m | 96724 | 0.017 | 6.80 | 0.003 | 1.20 | 0.002 | 0.800 |

| Sample Id | Sample number | Er | Er | Eu | Eu | Fe* | Fe* |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.001 | <0.400 | <0.025 | <10 |
| MF1 0-1m | 96716 | 0.001 | 0.400 | <0.001 | <0.400 | 57 | 22800 |
| MF1 1-2m | 96717 | 0.005 | 2.00 | 0.001 | 0.400 | 92 | 36800 |
| MF2 0.5-1m | 96718 | 0.005 | 2.00 | <0.001 | <0.400 | 213 | 85200 |
| MF2 2-2.5m | 96719 | 0.001 | 0.400 | <0.001 | <0.400 | 42 | 16800 |
| MF2 3-4m | 96720 | 0.006 | 2.40 | 0.001 | 0.400 | 244 | 97600 |
| MF3 0.5-1.5m | 96721 | 0.001 | 0.400 | <0.001 | <0.400 | 21 | 8400 |
| MF4 0.5-1.5m | 96722 | 0.002 | 0.800 | <0.001 | <0.400 | 280 | 112000 |
| MF5 0.2-0.8m | 96723 | 0.011 | 4.40 | 0.001 | 0.400 | 152 | 60800 |
| MF5 1-2m | 96724 | 0.001 | 0.400 | <0.001 | <0.400 | 109 | 43600 |

| Sample Id | Sample number | Ga | Ga | Gd | Gd | Ge | Ge |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF1 0-1m | 96716 | 0.075 | 30 | 0.001 | 0.40 | 0.005 | 2.00 |
| MF1 1-2m | 96717 | 0.072 | 29 | 0.004 | 1.60 | 0.010 | 4.00 |
| MF2 0.5-1m | 96718 | 0.277 | 111 | 0.003 | 1.20 | 0.013 | 5.20 |
| MF2 2-2.5m | 96719 | 0.042 | 17 | 0.001 | 0.400 | 0.003 | 1.20 |
| MF2 3-4m | 96720 | 0.032 | 13 | 0.004 | 1.60 | 0.001 | 0.400 |
| MF3 0.5-1.5m | 96721 | 0.263 | 105 | 0.001 | 0.400 | 0.010 | 4.00 |
| MF4 0.5-1.5m | 96722 | 0.306 | 122 | 0.001 | 0.400 | 0.013 | 5.20 |
| MF5 0.2-0.8m | 96723 | 0.199 | 80 | 0.010 | 4.00 | 0.020 | 8.00 |
| MF5 1-2m | 96724 | 0.064 | 26 | 0.002 | 0.800 | 0.004 | 1.60 |

| Sample Id | Sample number | Hf | Hf | Ho | Ho | In | In |
|---|---|---|---|---|---|---|---|
| | | mg/l | mg/kg | mg/l | mg/kg | mg/l | mg/kg |
| Det Limit | | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF1 0-1m | 96716 | 0.034 | 14 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF1 1-2m | 96717 | 0.029 | 12 | 0.002 | 0.800 | <0.001 | <0.400 |
| MF2 0.5-1m | 96718 | 0.011 | 4.40 | 0.002 | 0.800 | <0.001 | <0.400 |
| MF2 2-2.5m | 96719 | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF2 3-4m | 96720 | 0.030 | 12 | 0.002 | 0.800 | <0.001 | <0.400 |
| MF3 0.5-1.5m | 96721 | 0.001 | 0.400 | <0.001 | <0.400 | <0.001 | <0.400 |
| MF4 0.5-1.5m | 96722 | 0.003 | 1.20 | 0.001 | 0.400 | <0.001 | <0.400 |
| MF5 0.2-0.8m | 96723 | 0.033 | 13 | 0.004 | 1.60 | <0.001 | <0.400 |
| MF5 1-2m | 96724 | 0.002 | 0.800 | 0.001 | 0.400 | <0.001 | <0.400 |

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## CERTIFICATE OF ANALYSES

**Digestion AS 4439.3**

| | | | |
|---|---|---|---|
| **Date received:** | **2020/06/11** | **Date completed:** | **2020/07/06** |
| **Project number:** | **1000** | **Report number:** **92197** | **Order number:** | **Delh.2020.001-17(v2) Middelburg Ferrochrome** |

| | | | |
|---|---|---|---|
| **Client name:** | **Delta H** | **Contact person:** | **Dr Martin Holland** |
| **Address:** | **PO Box 11465, Silver Lakes, 0054** | **Contact person:** | **T. Rossouw** |
| **Telephone:** | **---** | **Email:** | **martin@delta-h.co.za** |
| | | **Email:** | **theo@delta-h.co.za** |
| | | **Cell:** | **082 497 9088** |
| | | **Cell:** | **072 365 4613** |

| Analyses | MF1 0-1m | | MF1 1-2m | | MF2 0.5-1m | | MF2 2-2.5m | | MF2 3-4m | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Number** | 96716 | | 96717 | | 96718 | | 96719 | | 96720 | | | | |
| **Digestion** | HNO3 : HF | | HNO3 : HF | | HNO3 : HF | | HNO3 : HF | | HNO3 : HF | | | | |
| **Dry Mass Used (g)** | 0.25 | | 0.25 | | 0.25 | | 0.25 | | 0.25 | | | | |
| **Volume Used (mℓ)** | 100 | | 100 | | 100 | | 100 | | 100 | | | | |
| **Units** | mg/ℓ | mg/kg | mg/ℓ | mg/kg | mg/ℓ | mg/kg | mg/ℓ | mg/kg | mg/ℓ | mg/kg | TCT0 mg/kg | TCT1 mg/kg | TCT2 mg/kg |
| As, Arsenic | <0.001 | <0.400 | 0.002 | 0.800 | 0.003 | 1 | <0.001 | <0.400 | 0.001 | 0.400 | 5.8 | 500 | 2000 |
| B, Boron | <0.025 | <10 | 0.089 | 36 | 0.171 | 68 | 0.146 | 58 | 0.033 | 13 | 150 | 15000 | 6000 |
| Ba, Barium | 0.295 | 118 | 0.565 | 226 | 0.545 | 218 | 0.239 | 96 | 0.812 | 325 | 62.5 | 6250 | 25000 |
| Cd, Cadmium | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | 7.5 | 260 | 1040 |
| Co, Cobalt | 0.045 | 18 | 0.136 | 54 | 0.319 | 128 | <0.025 | <10 | 0.148 | 59 | 50 | 5000 | 20000 |
| $Cr_{Total}$, Chromium Total | 30 | 12000 | 60 | 24000 | 197 | 78800 | 23 | 9200 | 0.736 | 294 | 46000 | 800000 | N/A |
| Cu, Copper | <0.010 | <4.00 | 0.027 | 11 | 0.176 | 70 | <0.010 | <4.00 | 0.235 | 94 | 16 | 19500 | 78000 |
| Hg, Mercury | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | 0.93 | 160 | 640 |
| Mn, Manganese | 2.14 | 856 | 0.72 | 287 | 10.00 | 4000 | 2.11 | 844 | 3.59 | 1436 | 1000 | 25000 | 100000 |
| Mo, Molybdenum | <0.025 | <10 | <0.025 | <10 | <0.025 | <10 | <0.025 | <10 | <0.025 | <10 | 40 | 1000 | 4000 |
| Ni, Nickel | 0.323 | 129 | 0.440 | 176 | 1.340 | 536 | 0.181 | 72 | 0.112 | 45 | 91 | 10600 | 42400 |
| Pb, Lead | 0.144 | 58 | 0.442 | 177 | 0.385 | 154 | 0.134 | 54 | 0.097 | 39 | 20 | 1900 | 7600 |
| Sb, Antimony | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | 10 | 75 | 300 |
| Se, Selenium | <0.001 | <0.400 | 0.001 | 0.400 | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | 10 | 50 | 200 |
| V, Vanadium | <0.025 | <10 | 0.452 | 181 | 0.840 | 336 | <0.025 | <10 | 0.734 | 294 | 150 | 2680 | 10720 |
| Zn, Zinc | 7.17 | 2868 | 16 | 6400 | 32 | 12800 | 5.10 | 2040 | 0.286 | 114 | 240 | 160000 | 640000 |
| ***Inorganic Anions*** | **mg/ℓ** | **mg/kg** | **mg/ℓ** | **mg/kg** | **mg/ℓ** | **mg/kg** | **mg/ℓ** | **mg/kg** | **mg/ℓ** | **mg/kg** | | | |
| Chloride as Cl [o] | --- | 562.40 | --- | <20 | --- | 1431.00 | --- | 40.55 | --- | 94.16 | | | |
| Sulphate as $SO_4$ [o] | --- | 24161.00 | --- | 16813.00 | --- | 25848.00 | --- | 475.10 | --- | 1051.00 | | | |
| Nitrate as N [o] | --- | 13.29 | --- | 155.80 | --- | 22.46 | --- | 5.80 | --- | 19.50 | | | |
| Total Fluoride [o] | --- | 19.91 | --- | 106.60 | --- | 31.05 | --- | 105.60 | --- | 46.37 | 100 | 10000 | 40000 |
| Cr(VI), Chromium (VI) Total [o] | --- | <2 | --- | 9.20 | --- | <2 | --- | 22.40 | --- | <2 | 6.5 | 500 | 2000 |
| Total Cyanide as CN [o] | --- | 9.6 | --- | 2.2 | --- | 13 | --- | <0.5 | --- | <0.5 | 14 | 10500 | 42000 |

| Analyses | MF3 0.5-1.5m | | MF4 0.5-1.5m | | MF5 0.2-0.8m | | MF5 1-2m | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Number** | 96721 | | 96722 | | 96723 | | 96724 | | | | |
| **Digestion** | HNO3 : HF | | HNO3 : HF | | HNO3 : HF | | HNO3 : HF | | | | |
| **Dry Mass Used (g)** | 0.25 | | 0.25 | | 0.25 | | 0.25 | | | | |
| **Volume Used (mℓ)** | 100 | | 100 | | 100 | | 100 | | | | |
| **Units** | mg/ℓ | mg/kg | mg/ℓ | mg/kg | mg/ℓ | mg/kg | mg/ℓ | mg/kg | TCT0 mg/kg | TCT1 mg/kg | TCT2 mg/kg |
| As, Arsenic | 0.001 | 0.400 | 0.001 | 0.400 | 0.006 | 2.40 | 0.002 | 0.800 | 5.8 | 500 | 2000 |
| B, Boron | 0.080 | 32 | 0.096 | 38 | 0.258 | 103 | 0.088 | 35 | 150 | 15000 | 6000 |
| Ba, Barium | 0.182 | 73 | 0.255 | 102 | 0.999 | 400 | 0.303 | 121 | 62.5 | 6250 | 25000 |
| Cd, Cadmium | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | 7.5 | 260 | 1040 |
| Co, Cobalt | 0.314 | 126 | 0.442 | 177 | 0.260 | 104 | 0.080 | 32 | 50 | 5000 | 20000 |
| $Cr_{Total}$, Chromium Total | 178 | 71200 | 224 | 89600 | 100 | 40000 | 23 | 9200 | 46000 | 800000 | N/A |
| Cu, Copper | 0.078 | 31 | 0.192 | 77 | 0.113 | 45 | <0.010 | <4.00 | 16 | 19500 | 78000 |
| Hg, Mercury | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | 0.93 | 160 | 640 |
| Mn, Manganese | 11 | 4400 | 12 | 4800 | 4.10 | 1640 | 2.21 | 884 | 1000 | 25000 | 100000 |
| Mo, Molybdenum | <0.025 | <10 | <0.025 | <10 | <0.025 | <10 | <0.025 | <10 | 40 | 1000 | 4000 |
| Ni, Nickel | 1.41 | 564 | 1.85 | 740 | 1.150 | 460 | 0.332 | 133 | 91 | 10600 | 42400 |
| Pb, Lead | 0.488 | 195 | 0.475 | 190 | 0.566 | 226 | 0.176 | 70 | 20 | 1900 | 7600 |
| Sb, Antimony | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | 10 | 75 | 300 |
| Se, Selenium | 0.001 | 0.400 | <0.001 | <0.400 | <0.001 | <0.400 | <0.001 | <0.400 | 10 | 50 | 200 |
| V, Vanadium | 0.619 | 248 | 0.773 | 309 | 0.646 | 258 | 0.055 | 22 | 150 | 2680 | 10720 |
| Zn, Zinc | 28 | 11200 | 32 | 12800 | 38 | 15200 | 7.13 | 2852 | 240 | 160000 | 640000 |
| ***Inorganic Anions*** | **mg/ℓ** | **mg/kg** | **mg/ℓ** | **mg/kg** | **mg/ℓ** | **mg/kg** | **mg/ℓ** | **mg/kg** | | | |
| Chloride as Cl [o] | --- | 116.00 | --- | 871.40 | --- | 244.00 | --- | 68.22 | | | |
| Sulphate as $SO_4$ [o] | --- | 8539.00 | --- | 7087.00 | --- | 4724.00 | --- | 2888.00 | | | |
| Nitrate as N [o] | --- | 62.47 | --- | 21.55 | --- | 89.75 | --- | 11.82 | | | |
| Total Fluoride [o] | --- | 48.56 | --- | 44.86 | --- | 100.70 | --- | 185.80 | 100 | 10000 | 40000 |
| Cr(VI), Chromium (VI) Total [o] | --- | 186.80 | --- | 104.40 | --- | 4.40 | --- | 12.80 | 6.5 | 500 | 2000 |
| Total Cyanide as CN [o] | --- | 1.2 | --- | 4.6 | --- | 2.7 | --- | <0.5 | 14 | 10500 | 42000 |

[o] = Outsourced

S. Laubscher
Assistant Geochemistry Project Manager

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## CERTIFICATE OF ANALYSES
**EXTRACTIONS AS 4439.3**

| | | | |
|---|---|---|---|
| **Date received:** | **2020/06/11** | **Date completed:** | **2020/07/06** |
| **Project number:** | **1000** | **Report number: 92197** | **Order number:** | **Delh.2020.001-17(v2) Middelburg Ferrochrome** |

| | | | |
|---|---|---|---|
| **Client name:** | **Delta H** | **Contact person:** | **Dr Martin Holland** |
| **Address:** | **PO Box 11465, Silver Lakes, 0054** | **Contact person:** | **T. Rossouw** |
| **Telephone:** | **---** | **Email:** | **martin@delta-h.co.za** |
| | | **Email:** | **theo@delta-h.co.za** |
| | | **Cell:** | **082 497 9088** |
| | | **Cell:** | **072 365 4613** |

| Analyses | MF1 0-1m | MF1 1-2m | MF2 0.5-1m | MF2 2-2.5m | MF2 3-4m | MF3 0.5-1.5m | MF4 0.5-1.5m | MF5 0.2-0.8m | MF5 1-2m | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Number** | **96716** | **96717** | **96718** | **96719** | **96720** | **96721** | **96722** | **96723** | **96724** | | | | |
| **TCLP / Borax / Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | | | | |
| **Ratio*** | **1:20** | **1:20** | **1:20** | **1:20** | **1:20** | **1:20** | **1:20** | **1:20** | **1:20** | | | | |
| **Units** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **LCT0 mg/l** | **LCT1 mg/l** | **LCT2 mg/l** | **LCT3 mg/l** |
| As, Arsenic | 0.003 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | 0.003 | 0.001 | 0.002 | 0.01 | 0.5 | 1 | 4 |
| B, Boron | 0.070 | 0.075 | 0.129 | 0.233 | 0.149 | 0.158 | 0.152 | 0.188 | 0.106 | 0.5 | 25 | 50 | 200 |
| Ba, Barium | <0.025 | 0.032 | 0.051 | <0.025 | 0.063 | <0.025 | <0.025 | 0.067 | <0.025 | 0.7 | 35 | 70 | 280 |
| Cd, Cadmium | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.003 | 0.15 | 0.3 | 1.2 |
| Co, Cobalt | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.5 | 25 | 50 | 200 |
| $Cr_{Total}$, Chromium Total | 1.63 | 0.176 | <0.025 | 0.065 | <0.025 | 4.93 | 0.176 | 0.126 | 0.216 | 0.1 | 5 | 10 | 40 |
| Cr(VI), Chromium (VI) | 1.61 | 0.157 | <0.010 | 0.055 | <0.010 | 5.10 | <0.010 | 0.116 | 0.178 | 0.05 | 2.5 | 5 | 20 |
| Cu, Copper | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | 2.0 | 100 | 200 | 800 |
| Hg, Mercury | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.006 | 0.3 | 0.6 | 2.4 |
| Mn, Manganese | <0.025 | 0.041 | <0.025 | <0.025 | 0.066 | <0.025 | 0.062 | <0.025 | <0.025 | 0.5 | 25 | 50 | 200 |
| Mo, Molybdenum | <0.025 | <0.025 | 0.068 | <0.025 | <0.025 | <0.025 | 0.030 | <0.025 | <0.025 | 0.07 | 3.5 | 7 | 28 |
| Ni, Nickel | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.07 | 3.5 | 7 | 28 |
| Pb, Lead | 0.001 | <0.001 | 0.001 | <0.001 | 0.001 | 0.001 | 0.006 | <0.001 | <0.001 | 0.01 | 0.5 | 1 | 4 |
| Sb, Antimony | 0.001 | <0.001 | 0.004 | 0.003 | <0.001 | 0.001 | 0.014 | 0.001 | 0.001 | 0.02 | 1.0 | 2 | 8 |
| Se, Selenium | 0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | 0.002 | <0.001 | <0.001 | 0.01 | 0.5 | 1 | 4 |
| V, Vanadium | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.2 | 10 | 20 | 80 |
| Zn, Zinc | 0.026 | 1.03 | <0.025 | <0.025 | <0.025 | 0.067 | 0.253 | <0.025 | <0.025 | 5.0 | 250 | 500 | 2000 |
| ***Inorganic Anions*** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | | | | |
| Total Dissolved Solids* | 72 | 922 | 854 | 1796 | 104 | 354 | 384 | 210 | 146 | 1000 | 12 500 | 25 000 | 100 000 |
| Chloride as Cl | <2 | <2 | 20 | 13 | 6 | 4 | 15 | <2 | <2 | 300 | 15 000 | 30 000 | 120 000 |
| Sulphate as SO4 | 9 | 640 | 548 | 1195 | 38 | 177 | 113 | 95 | 70 | 250 | 12 500 | 25 000 | 100 000 |
| Nitrate as N | 0.2 | 0.3 | <0.1 | 0.1 | <0.1 | 1.2 | <0.1 | <0.1 | 0.1 | 11 | 550 | 1100 | 4400 |
| Fluoride as F | 1.0 | 0.6 | 1.5 | 0.4 | 1.6 | 1.0 | 1.6 | 3.0 | 1.3 | 1.5 | 75 | 150 | 600 |
| Paste pH | 8.3 | 5.8 | 9.7 | 9.8 | 7.4 | 8.6 | 9.3 | 8.9 | 8.6 | | | | |
| Moisture % | 47.3 | 45.7 | 38.3 | 55.6 | 15.8 | 46.6 | 31.9 | 42.6 | 57.3 | | | | |
| Acid Base Accounting | See attached report 92197 ABA | | | | | | | | | | | | |
| Net Acid Generation | See attached report 92197 NAG | | | | | | | | | | | | |
| Sulphur Speciation | See attached report 92197 SS | | | | | | | | | | | | |
| X-ray Diffraction [o] | See attached report 92197 XRD | | | | | | | | | | | | |
| Total Organic & Inorganic Carbon [o] | See attached report 92197 TOC | | | | | | | | | | | | |

| Analyses | MF1 0-1m | MF1 1-2m | MF2 0.5-1m | MF2 2-2.5m | MF2 3-4m | MF3 0.5-1.5m | MF4 0.5-1.5m | MF5 0.2-0.8m | MF5 1-2m | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Number** | **96716** | **96717** | **96718** | **96719** | **96720** | **96721** | **96722** | **96723** | **96724** | | | | |
| **TCLP / Borax / Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | | | | |
| **Ratio*** | **1:4** | **1:4** | **1:4** | **1:4** | **1:4** | **1:4** | **1:4** | **1:4** | **1:4** | | | | |
| **Units** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **LCT0 mg/l** | **LCT1 mg/l** | **LCT2 mg/l** | **LCT3 mg/l** |
| As, Arsenic | 0.002 | <0.001 | <0.001 | 0.002 | 0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.01 | 0.5 | 1 | 4 |
| B, Boron | 0.193 | 0.454 | 0.319 | 0.767 | 0.215 | 0.268 | 0.334 | 0.743 | 0.407 | 0.5 | 25 | 50 | 200 |
| Ba, Barium | <0.025 | <0.025 | 0.039 | 0.033 | 0.036 | <0.025 | <0.025 | 0.034 | 0.029 | 0.7 | 35 | 70 | 280 |
| Cd, Cadmium | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.003 | 0.15 | 0.3 | 1.2 |
| Co, Cobalt | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.5 | 25 | 50 | 200 |
| $Cr_{Total}$, Chromium Total | 7.17 | 0.366 | <0.025 | 0.121 | <0.025 | 24 | 0.078 | 0.164 | 0.559 | 0.1 | 5 | 10 | 40 |
| Cr(VI), Chromium (VI) | 2.80 | 0.372 | <0.010 | 0.101 | <0.010 | 16.3 | <0.010 | 0.169 | 1.49 | 0.05 | 2.5 | 5 | 20 |
| Cu, Copper | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | 2.0 | 100 | 200 | 800 |
| Hg, Mercury | <0.001 | <0.001 | 0.030 | 0.005 | 0.004 | <0.001 | 0.021 | <0.001 | <0.001 | 0.006 | 0.3 | 0.6 | 2.4 |
| Mn, Manganese | <0.025 | 0.291 | <0.025 | <0.025 | 0.034 | <0.025 | <0.025 | <0.025 | <0.025 | 0.5 | 25 | 50 | 200 |
| Mo, Molybdenum | <0.025 | <0.025 | 0.414 | 0.099 | 0.036 | <0.025 | 0.127 | 0.085 | 0.038 | 0.07 | 3.5 | 7 | 28 |
| Ni, Nickel | <0.025 | 0.044 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.07 | 3.5 | 7 | 28 |
| Pb, Lead | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.01 | 0.5 | 1 | 4 |
| Sb, Antimony | 0.003 | <0.001 | 0.006 | 0.014 | <0.001 | 0.002 | 0.025 | <0.001 | 0.002 | 0.02 | 1.0 | 2 | 8 |
| Se, Selenium | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.01 | 0.5 | 1 | 4 |
| V, Vanadium | <0.025 | <0.025 | <0.025 | 0.048 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.2 | 10 | 20 | 80 |
| Zn, Zinc | <0.025 | 10 | <0.025 | <0.025 | <0.025 | 0.041 | 0.033 | <0.025 | <0.025 | 5.0 | 250 | 500 | 2000 |
| ***Inorganic Anions*** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | | | | |
| Total Dissolved Solids | 225* | 2408 | 4342 | 2430 | 414 | 1501* | 1118 | 902 | 574* | 1000 | 12 500 | 25 000 | 100 000 |
| Chloride as Cl | 2 | <2 | 125 | 55 | 14 | 14 | 36 | 4 | 5 | 300 | 15 000 | 30 000 | 120 000 |
| Sulphate as SO4 | 47 | 1411 | 2667 | 1389 | 133 | 897 | 460 | 365 | 262 | 250 | 12 500 | 25 000 | 100 000 |
| Nitrate as N | 0.2 | 2.2 | <0.1 | 0.3 | 0.3 | 2.3 | 0.1 | 0.1 | 0.4 | 11 | 550 | 1100 | 4400 |
| Fluoride as F | 3.3 | 4.0 | 4.2 | 1.0 | 3.2 | 2.1 | 4.9 | 5.0 | 2.4 | 1.5 | 75 | 150 | 600 |

[o] = Outsourced
[*] = Taken from Electrical Conductivity

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## CERTIFICATE OF ANALYSES
**EXTRACTIONS AS 4439.3**

| | | | |
|---|---|---|---|
| **Date received:** | **2020/06/11** | **Date completed:** | **2020/07/06** |
| **Project number:** | **1000** | **Report number: 92197** | **Order number:** | **Delh.2020.001-17(v2) Middelburg Ferrochrome** |

| | | | |
|---|---|---|---|
| **Client name:** | **Delta H** | **Contact person:** | **Dr Martin Holland** |
| **Address:** | **PO Box 11465, Silver Lakes, 0054** | **Contact person:** | **T. Rossouw** |
| **Telephone:** | **---** | **Email:** | **martin@delta-h.co.za** |
| | | **Email:** | **theo@delta-h.co.za** |
| | | **Cell:** | **082 497 9088** |
| | | **Cell:** | **072 365 4613** |

| Analyses | MF1 0-1m | MF1 1-2m | MF2 0.5-1m | MF2 2-2.5m | MF2 3-4m | MF3 0.5-1.5m | MF4 0.5-1.5m | MF5 0.2-0.8m | MF5 1-2m | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Number** | **96716** | **96717** | **96718** | **96719** | **96720** | **96721** | **96722** | **96723** | **96724** | | | | |
| **TCLP / Borax / Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | | | | |
| **Ratio*** | **1:20** | **1:20** | **1:20** | **1:20** | **1:20** | **1:20** | **1:20** | **1:20** | **1:20** | | | | |
| **Units** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **LCT0 mg/l** | **LCT1 mg/l** | **LCT2 mg/l** | **LCT3 mg/l** |
| As, Arsenic | 0.003 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | 0.003 | 0.001 | 0.002 | 0.01 | 0.5 | 1 | 4 |
| B, Boron | 0.070 | 0.075 | 0.129 | 0.233 | 0.149 | 0.158 | 0.152 | 0.188 | 0.106 | 0.5 | 25 | 50 | 200 |
| Ba, Barium | <0.025 | 0.032 | 0.051 | <0.025 | 0.063 | <0.025 | <0.025 | 0.067 | <0.025 | 0.7 | 35 | 70 | 280 |
| Cd, Cadmium | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.003 | 0.15 | 0.3 | 1.2 |
| Co, Cobalt | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.5 | 25 | 50 | 200 |
| $Cr_{Total}$, Chromium Total | 1.63 | 0.176 | <0.025 | 0.065 | <0.025 | 4.93 | 0.176 | 0.126 | 0.216 | 0.1 | 5 | 10 | 40 |
| Cr(VI), Chromium (VI) | 1.61 | 0.157 | <0.010 | 0.055 | <0.010 | 5.10 | <0.010 | 0.116 | 0.178 | 0.05 | 2.5 | 5 | 20 |
| Cu, Copper | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | 2.0 | 100 | 200 | 800 |
| Hg, Mercury | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.006 | 0.3 | 0.6 | 2.4 |
| Mn, Manganese | <0.025 | 0.041 | <0.025 | <0.025 | 0.066 | <0.025 | 0.062 | <0.025 | <0.025 | 0.5 | 25 | 50 | 200 |
| Mo, Molybdenum | <0.025 | <0.025 | 0.068 | <0.025 | <0.025 | <0.025 | 0.030 | <0.025 | <0.025 | 0.07 | 3.5 | 7 | 28 |
| Ni, Nickel | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.07 | 3.5 | 7 | 28 |
| Pb, Lead | 0.001 | <0.001 | 0.001 | <0.001 | 0.001 | 0.001 | 0.006 | <0.001 | <0.001 | 0.01 | 0.5 | 1 | 4 |
| Sb, Antimony | 0.001 | <0.001 | 0.004 | 0.003 | <0.001 | 0.001 | 0.014 | 0.001 | 0.001 | 0.02 | 1.0 | 2 | 8 |
| Se, Selenium | 0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | 0.002 | <0.001 | <0.001 | 0.01 | 0.5 | 1 | 4 |
| V, Vanadium | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.2 | 10 | 20 | 80 |
| Zn, Zinc | 0.026 | 1.03 | <0.025 | <0.025 | <0.025 | 0.067 | 0.253 | <0.025 | <0.025 | 5.0 | 250 | 500 | 2000 |
| ***Inorganic Anions*** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | | | | |
| Total Dissolved Solids* | 72 | 922 | 854 | 1796 | 104 | 354 | 384 | 210 | 146 | 1000 | 12 500 | 25 000 | 100 000 |
| Chloride as Cl | <2 | <2 | 20 | 13 | 6 | 4 | 15 | <2 | <2 | 300 | 15 000 | 30 000 | 120 000 |
| Sulphate as SO4 | 9 | 640 | 548 | 1195 | 38 | 177 | 113 | 95 | 70 | 250 | 12 500 | 25 000 | 100 000 |
| Nitrate as N | 0.2 | 0.3 | <0.1 | 0.1 | <0.1 | 1.2 | <0.1 | <0.1 | 0.1 | 11 | 550 | 1100 | 4400 |
| Fluoride as F | 1.0 | 0.6 | 1.5 | 0.4 | 1.6 | 1.0 | 1.6 | 3.0 | 1.3 | 1.5 | 75 | 150 | 600 |
| Paste pH | 8.3 | 5.8 | 9.7 | 9.8 | 7.4 | 8.6 | 9.3 | 8.9 | 8.6 | | | | |
| Moisture % | 47.3 | 45.7 | 38.3 | 55.6 | 15.8 | 46.6 | 31.9 | 42.6 | 57.3 | | | | |
| Acid Base Accounting | See attached report 92197 ABA | | | | | | | | | | | | |
| Net Acid Generation | See attached report 92197 NAG | | | | | | | | | | | | |
| Sulphur Speciation | See attached report 92197 SS | | | | | | | | | | | | |
| X-ray Diffraction [o] | See attached report 92197 XRD | | | | | | | | | | | | |
| Total Organic & Inorganic Carbon [o] | See attached report 92197 TOC | | | | | | | | | | | | |

| Analyses | MF1 0-1m | MF1 1-2m | MF2 0.5-1m | MF2 2-2.5m | MF2 3-4m | MF3 0.5-1.5m | MF4 0.5-1.5m | MF5 0.2-0.8m | MF5 1-2m | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Number** | **96716** | **96717** | **96718** | **96719** | **96720** | **96721** | **96722** | **96723** | **96724** | | | | |
| **TCLP / Borax / Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | **Distilled Water** | | | | |
| **Ratio*** | **1:4** | **1:4** | **1:4** | **1:4** | **1:4** | **1:4** | **1:4** | **1:4** | **1:4** | | | | |
| **Units** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **LCT0 mg/l** | **LCT1 mg/l** | **LCT2 mg/l** | **LCT3 mg/l** |
| As, Arsenic | 0.002 | <0.001 | <0.001 | 0.002 | 0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.01 | 0.5 | 1 | 4 |
| B, Boron | 0.193 | 0.454 | 0.319 | 0.767 | 0.215 | 0.268 | 0.334 | 0.743 | 0.407 | 0.5 | 25 | 50 | 200 |
| Ba, Barium | <0.025 | <0.025 | 0.039 | 0.033 | 0.036 | <0.025 | <0.025 | 0.034 | 0.029 | 0.7 | 35 | 70 | 280 |
| Cd, Cadmium | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.003 | 0.15 | 0.3 | 1.2 |
| Co, Cobalt | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.5 | 25 | 50 | 200 |
| $Cr_{Total}$, Chromium Total | 7.17 | 0.366 | <0.025 | 0.121 | <0.025 | 24 | 0.078 | 0.164 | 0.559 | 0.1 | 5 | 10 | 40 |
| Cr(VI), Chromium (VI) | 2.80 | 0.372 | <0.010 | 0.101 | <0.010 | 16.3 | <0.010 | 0.169 | 1.49 | 0.05 | 2.5 | 5 | 20 |
| Cu, Copper | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | 2.0 | 100 | 200 | 800 |
| Hg, Mercury | <0.001 | <0.001 | 0.030 | 0.005 | 0.004 | <0.001 | 0.021 | <0.001 | <0.001 | 0.006 | 0.3 | 0.6 | 2.4 |
| Mn, Manganese | <0.025 | 0.291 | <0.025 | <0.025 | 0.034 | <0.025 | <0.025 | <0.025 | <0.025 | 0.5 | 25 | 50 | 200 |
| Mo, Molybdenum | <0.025 | <0.025 | 0.414 | 0.099 | 0.036 | <0.025 | 0.127 | 0.085 | 0.038 | 0.07 | 3.5 | 7 | 28 |
| Ni, Nickel | <0.025 | 0.044 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.07 | 3.5 | 7 | 28 |
| Pb, Lead | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.01 | 0.5 | 1 | 4 |
| Sb, Antimony | 0.003 | <0.001 | 0.006 | 0.014 | <0.001 | 0.002 | 0.025 | <0.001 | 0.002 | 0.02 | 1.0 | 2 | 8 |
| Se, Selenium | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.01 | 0.5 | 1 | 4 |
| V, Vanadium | <0.025 | <0.025 | <0.025 | 0.048 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | 0.2 | 10 | 20 | 80 |
| Zn, Zinc | <0.025 | 10 | <0.025 | <0.025 | <0.025 | 0.041 | 0.033 | <0.025 | <0.025 | 5.0 | 250 | 500 | 2000 |
| ***Inorganic Anions*** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | **mg/ℓ** | | | | |
| Total Dissolved Solids | 225* | 2408 | 4342 | 2430 | 414 | 1501* | 1118 | 902 | 574* | 1000 | 12 500 | 25 000 | 100 000 |
| Chloride as Cl | 2 | <2 | 125 | 55 | 14 | 14 | 36 | 4 | 5 | 300 | 15 000 | 30 000 | 120 000 |
| Sulphate as SO4 | 47 | 1411 | 2667 | 1389 | 133 | 897 | 460 | 365 | 262 | 250 | 12 500 | 25 000 | 100 000 |
| Nitrate as N | 0.2 | 2.2 | <0.1 | 0.3 | 0.3 | 2.3 | 0.1 | 0.1 | 0.4 | 11 | 550 | 1100 | 4400 |
| Fluoride as F | 3.3 | 4.0 | 4.2 | 1.0 | 3.2 | 2.1 | 4.9 | 5.0 | 2.4 | 1.5 | 75 | 150 | 600 |

[o] = Outsourced
[*] = Taken from Electrical Conductivity

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Assistant Geochemistry Project Manager

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## CERTIFICATE OF ANALYSES
### X-RAY DIFFRACTION

**Date received: 2020-06-11**
**Project number: 1000**
**Report number: 92197**
**Date completed: 2020-07-02**
**Order number: Delh.2020.001-17(v2) - Middelburg Ferrochrome**

**Client name: Delta H**
**Address: PO Box 11465, Silver Lakes, 0054**

**Contact person: Dr Martin Holland**
**Contact person: T. Rossouw**
**Email: martin@delta-h.co.za**
**Email: theo@delta-h.co.za**
**Cell: 082 497 9088**
**Cell: 072 365 4613**

**Composition (%) [o]**

| MF1 0-1m | | MF1 1-2m | | MF2 0.5-1m | |
|---|---|---|---|---|---|
| 96716 | | 96717 | | 96718 | |
| **Mineral** | Amount ( weight % ) | **Mineral** | Amount ( weight % ) | **Mineral** | Amount ( weight % ) |
| **Quartz** | 5 | **Quartz** | 3.46 | **Quartz** | 2.21 |
| **Mullite** | 1.06 | **Mullite** | 7.74 | **Mullite** | 4.4 |
| **Bassanite** | 0.06 | **Bassanite** | 1.27 | **Bassanite** | 0.57 |
| **Magnetite** | 0.03 | **Magnetite** | 1.02 | **Magnetite** | 0.01 |
| **Iron** | 0.05 | **Iron** | 0 | **Iron** | 0.99 |
| **Chromite** | 2.25 | **Chromite** | 4.77 | **Chromite** | 9.18 |
| **Calcite** | 0.64 | **Calcite** | 2.15 | **Calcite** | 0.95 |
| **Amorphous** | 90.9 | **Amorphous** | 79.58 | **Amorphous** | 81.7 |

**Composition (%) [o]**

| MF2 2-2.5m | | MF2 3-4m | | MF3 0.5-1.5m | |
|---|---|---|---|---|---|
| 96719 | | 96720 | | 96721 | |
| **Mineral** | Amount ( weight % ) | **Mineral** | Amount ( weight % ) | **Mineral** | Amount ( weight % ) |
| **Quartz** | 3.07 | **Quartz** | 42.71 | **Quartz** | 2.58 |
| **Mullite** | 0 | **Dolomite** | 0.86 | **Mullite** | 0 |
| **Bassanite** | 2.17 | **Hematite** | 1.46 | **Bassanite** | 0.37 |
| **Magnetite** | 0.04 | **Kaolinite** | 5.34 | **Magnetite** | 0 |
| **Iron** | 0.01 | **Plagioclase** | 0.83 | **Iron** | 0.68 |
| **Chromite** | 2.1 | **Amorphous** | 48.8 | **Chromite** | 13.64 |
| **Calcite** | 0.51 | --- | --- | **Calcite** | 0.55 |
| **Amorphous** | 92.09 | --- | --- | **Amorphous** | 82.18 |

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## CERTIFICATE OF ANALYSES
## X-RAY DIFFRACTION

**Date received: 2020-06-11**
**Project number: 1000**
**Report number: 92197**
**Date completed: 2020-07-02**
**Order number: Delh.2020.001-17(v2) - Middelburg Ferrochrome**

**Client name: Delta H**
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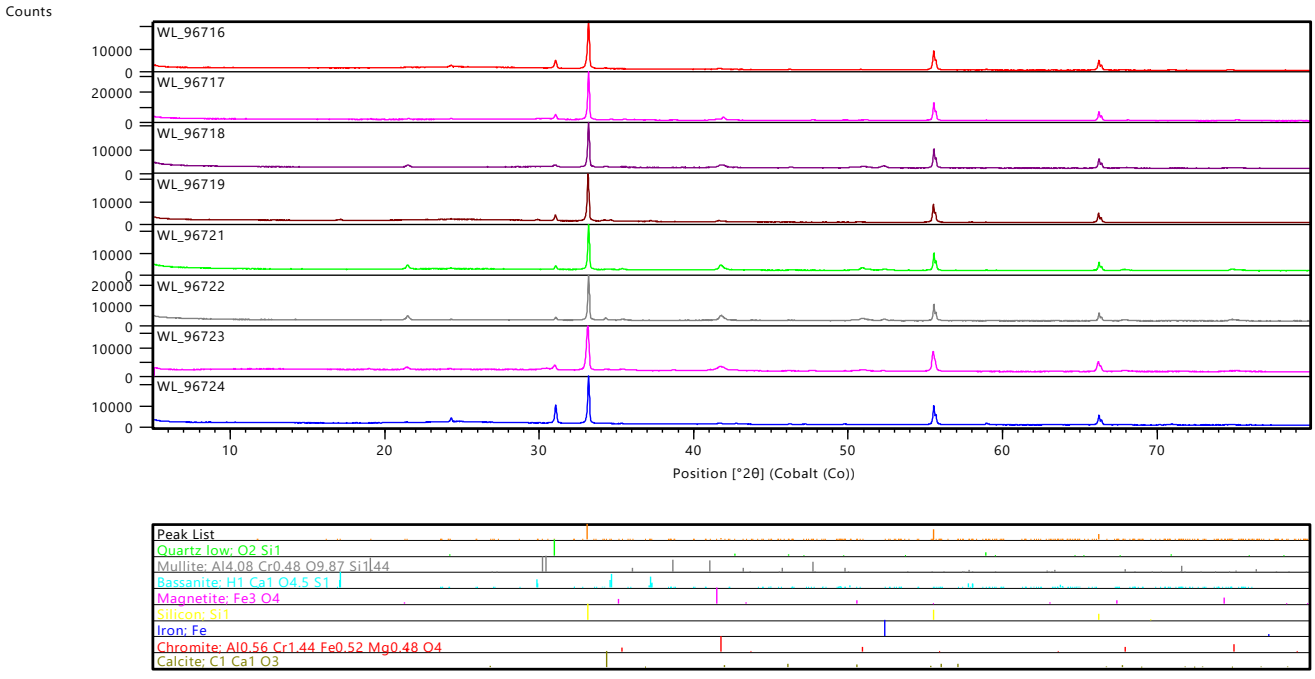
**Contact person: Dr Martin Holland**
**Contact person: T. Rossouw**
**Email: martin@delta-h.co.za**
**Email: theo@delta-h.co.za**
**Cell: 082 497 9088**
**Cell: 072 365 4613**

**Composition (%) [o]**

| MF4 0.5-1.5m | | MF5 0.2-0.8m | | MF5 1-2m | |
|---|---|---|---|---|---|
| 96722 | | 96723 | | 96724 | |
| **Mineral** | Amount ( weight % ) | **Mineral** | Amount ( weight % ) | **Mineral** | Amount ( weight % ) |
| **Quartz** | 2.09 | **Quartz** | 3.15 | **Quartz** | 10.94 |
| **Mullite** | 0.06 | **Mullite** | 8.65 | **Mullite** | 1.21 |
| **Bassanite** | 0.18 | **Bassanite** | 0.05 | **Bassanite** | 0.16 |
| **Magnetite** | 0 | **Magnetite** | 0.36 | **Magnetite** | 0.04 |
| **Iron** | 0.82 | **Iron** | 0.14 | **Iron** | 0.04 |
| **Chromite** | 14.6 | **Chromite** | 8.68 | **Chromite** | 1.81 |
| **Calcite** | 2.27 | **Calcite** | 0.62 | **Calcite** | 0.52 |
| **Amorphous** | 79.96 | **Amorphous** | 78.35 | **Amorphous** | 85.28 |

**[o] = Outsourced**

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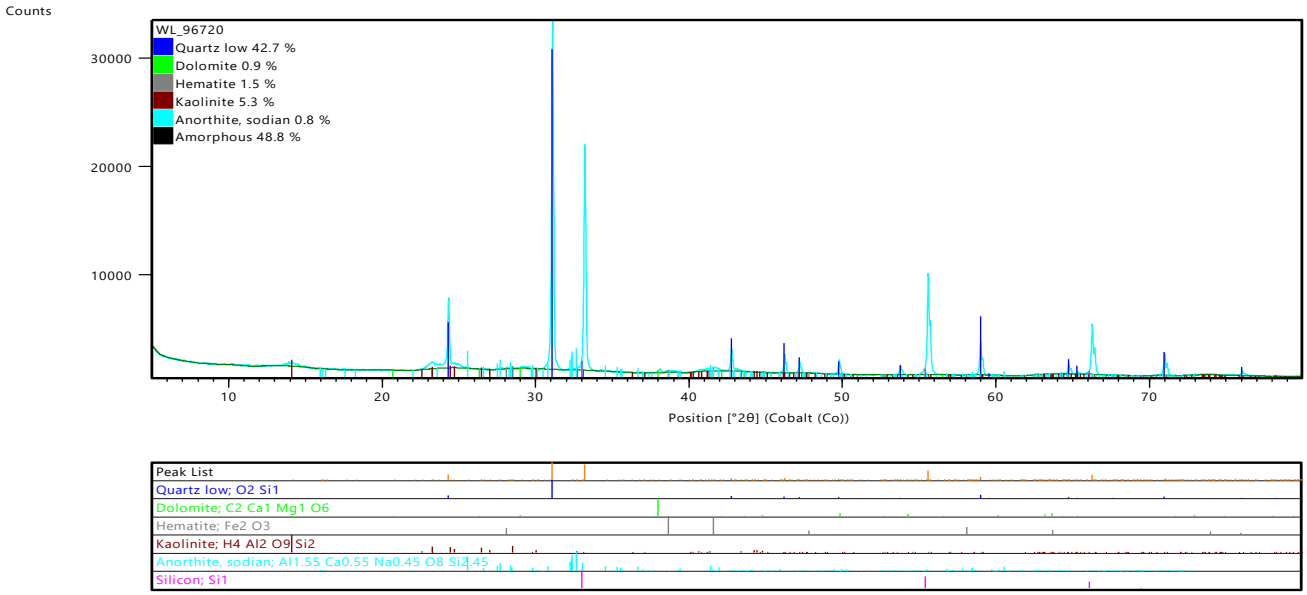


**Note:**

The material was scanned after addition of 20 % Si for quantitative determination of amorphous content and micronizing using a McCrone micronizing mill. The material was prepared for XRD analysis using a back loading preparation method. Diffractograms were obtained using a Malvern Panalytical Aeris diffractometer with PIXcel detector and fixed slits with Fe filtered Co-Kα radiation. The phases were identified using X'Pert Highscore plus software.
The relative phase amounts (weight %) were estimated by the Rietveld method.

**Comment:**

- In case the results do not correspond to results of other analytical techniques, please let me know for further fine tuning of XRD results.
- Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group.
- Due to preferred orientation and crystallite size effects, results may not be as accurate as shown.
- Traces of additional phases may be present.
- Determination of amorphous content can carry an error of +- 15 weight per cent.
- The amorphous component may represent organic carbon or a glassy phase forming part of a slag.

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## X-RAY DIFFRACTION

**Date received: 2020-06-11**
**Project number: 1000**
**Report number: 92197**
**Date completed: 2020-07-02**
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**Email: theo@delta-h.co.za**
**Cell: 082 497 9088**
**Cell: 072 365 4613**

**Ideal Mineral compositions:**

| Compound Name | Chemical Formula |
|---|---|
| **Quartz** | SiO2 |
| **Kaolinite** | Al2 Si2 O5 (OH)4 |
| **Mullite** | 3Al2O3 2SiO2 |
| **Plagioclase** | (Na,Ca)(Si,Al)4O8 |
| **Bassanite** | $2(Ca)2(SO_4)•(H_2O)$ |
| **Calcite** | CaCO3 |
| **Dolomite** | Ca Mg (C O3)2 |
| **Hematite** | Fe2O3 |
| **Chromite** | Fe++Cr2O4 |
| **Iron** | Fe |
| **Magnetite** | Fe3O4 |

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## CERTIFICATE OF ANALYSES

### SULPHUR SPECIATION

Methods from: Prediction Manual For Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1

**Date received: 2020-06-11**
**Project number: 1000**
**Report number: 92197**
**Date completed: 2020-07-07**
**Order number: Delh.2020.001-17(v2) - Middelburg Ferrochrome**

**Client name: Delta H**
**Address: PO Box 11465, Silver Lakes, 0054**

**Contact person: Dr Martin Holland**
**Contact person: T. Rossouw**
**Email: martin@delta-h.co.za**
**Email: theo@delta-h.co.za**
**Cell: 082 497 9088**
**Cell: 072 365 4613**

| Sulphur Speciation* | Sample Identification | | | | |
|---|---|---|---|---|---|
| | MF1 0-1m | MF1 1-2m | MF2 0.5-1m | MF2 2-2.5m | MF2 3-4m |
| **Sample Number** | **96716** | **96717** | **96718** | **96719** | **96720** |
| **Total Sulphur (%) (ELTRA)** | 0.04 | 0.84 | 1.65 | 0.97 | 0.05 |
| **Sulphate Sulphur as S** (%) | 0.04 | 0.63 | 1.57 | 0.89 | 0.04 |
| **Sulphide Sulphur** (%) | <0.01 | 0.22 | 0.08 | 0.08 | 0.01 |

| Sulphur Speciation* | Sample Identification | | | | |
|---|---|---|---|---|---|
| | MF3 0.5-1.5m | MF4 0.5-1.5m | MF5 0.2-0.8m | MF5 1-2m | MF5 1-2m |
| **Sample Number** | **96721** | **96722** | **96723** | **96724** | **96724 D** |
| **Total Sulphur (%) (ELTRA)** | 0.63 | 1.18 | 0.80 | 0.12 | 0.12 |
| **Sulphate Sulphur as S** (%) | 0.58 | 1.15 | 0.74 | 0.11 | 0.10 |
| **Sulphide Sulphur** (%) | 0.05 | 0.03 | 0.07 | 0.01 | 0.02 |

Notes:

- Samples analysed with Pyrolysis at 550°C as per Prediction Manual For Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1. Multiply Sulphate Sulphur to calculate SO4 % by 2.996. Please see the method for interferences.
- Organic Sulphur is not taken into account and may be included in the results.
- Please let me know if results do not correspond to other data.

S. Laubscher

Assistant Geochemistry Project Manager

# WATERLAB (PTY) LTD

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## CERTIFICATE OF ANALYSES
### Organic / Inorganic Carbon

**Date received: 2020-06-11**
**Project number: 1000**
**Report number: 92197**
**Date completed: 2020-07-02**
**Order number: Delh.2020.001-17(v2) - Middelburg Ferrochrome**

**Client name: Delta H**
**Address: PO Box 11465, Silver Lakes, 0054**

**Contact person: Dr Martin Holland**
**Contact person: T. Rossouw**
**Email: martin@delta-h.co.za**
**Email: theo@delta-h.co.za**
**Cell: 082 497 9088**
**Cell: 072 365 4613**

| Analysis | Sample Identification | | | | |
|---|---|---|---|---|---|
| | MF1 0-1m | MF1 1-2m | MF2 0.5-1m | MF2 2-2.5m | MF2 3-4m |
| **Sample Number** | **96716** | **96717** | **96718** | **96719** | **96720** |
| **Total Carbon (%) (LECO)[o]** | 1.59 | 49.2 | 25.9 | 2.46 | 0.67 |
| **Organic Carbon (%) (LECO) [o]** | 1.40 | 47.8 | 24.6 | 2.19 | 0.44 |
| **Inorganic Carbon (%) (LECO) [o]** | 0.19 | 1.40 | 1.30 | 0.27 | 0.23 |

| Analysis | Sample Identification | | | |
|---|---|---|---|---|
| | MF3 0.5-1.5m | MF4 0.5-1.5m | MF5 0.2-0.8m | MF5 1-2m |
| **Sample Number** | **96721** | **96722** | **96723** | **96724** |
| **Total Carbon (%) (LECO)[o]** | 1.96 | 4.06 | 18.4 | 1.17 |
| **Organic Carbon (%) (LECO) [o]** | 1.86 | 3.25 | 18.4 | 0.92 |
| **Inorganic Carbon (%) (LECO) [o]** | 0.10 | 0.81 | 0 | 0.25 |

**[o] = Outsourced**

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Assistant Geochemistry Project Manager

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## CERTIFICATE OF ANALYSES
## ACID – BASE ACCOUNTING
## EPA-600 MODIFIED SOBEK METHOD

**Date received: 2020-06-11**
**Project number: 1000**
**Report number: 92197**
**Date completed: 2020-07-07**
**Order number: Delh.2020.001-17(v2) - Middelburg Ferrochrome**

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**Email: theo@delta-h.co.za**
**Cell: 082 497 9088 / 072 365 4613**

| Acid – Base Accounting Modified Sobek (EPA-600) | Sample Identification | | | | |
|---|---|---|---|---|---|
| | MF1 0-1m | MF1 1-2m | MF2 0.5-1m | MF2 2-2.5m | MF2 3-4m |
| **Sample Number** | **96716** | **96717** | **96718** | **96719** | **96720** |
| **Paste pH** | 8.3 | 5.8 | 9.7 | 8.9 | 7.4 |
| **Total Sulphur (%) (LECO)** | 0.04 | 0.84 | 1.65 | 0.97 | 0.05 |
| **Acid Potential (AP) (kg/t)** | 1.27 | 26 | 52 | 30 | 1.53 |
| **Neutralization Potential (NP)** | 27 | 5.20 | 162 | 44 | 12 |
| **Nett Neutralization Potential (NNP)** | 25 | -21 | 111 | 14 | 10 |
| **Neutralising Potential Ratio (NPR) (NP : AP)** | 21 | 0.198 | 3.15 | 1.46 | 7.75 |
| **Rock Type** | III | I | II | II | III |

| Acid – Base Accounting Modified Sobek (EPA-600) | Sample Identification | | | | |
|---|---|---|---|---|---|
| | MF3 0.5-1.5m | MF4 0.5-1.5m | MF5 0.2-0.8m | MF5 1-2m | MF5 1-2m |
| **Sample Number** | **96721** | **96722** | **96723** | **96724** | **96724 D** |
| **Paste pH** | 8.6 | 9.3 | 8.9 | 8.6 | 8.6 |
| **Total Sulphur (%) (LECO)** | 0.63 | 1.18 | 0.80 | 0.12 | 0.12 |
| **Acid Potential (AP) (kg/t)** | 20 | 37 | 25 | 3.64 | 3.74 |
| **Neutralization Potential (NP)** | 51 | 102 | 119 | 31 | 31 |
| **Nett Neutralization Potential (NNP)** | 31 | 65 | 94 | 27 | 27 |
| **Neutralising Potential Ratio (NPR) (NP : AP)** | 2.57 | 2.76 | 4.72 | 8.44 | 8.28 |
| **Rock Type** | II | II | II | III | III |

*** Negative NP values are obtained when the volume of NaOH (0.1N) titrated (pH: 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 – 2.5 Any negative NP values are corrected to 0.00.**
Please refer to Appendix **(p.2)** for a Terminology of terms and guidelines for rock classification

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## APPENDIX: TERMINOLOGY AND ROCK CLASSIFICATION

### TERMINOLOGY (SYNONYMS)

- Acid Potential (AP) ; *Synonyms*: Maximum Potential Acidity (MPA)
  **Method**: Total S(%) (Leco Analyzer) x 31.25
- Neutralization Potential (NP) ; *Synonyms:* Gross Neutralization Potential (GNP) ; *Syn*: Acid Neutralization Capacity (ANC) (The capacity of a sample to consume acid)
  **Method**: Fizz Test ; Acid-Base Titration (Sobek & Modified Sobek (Lawrence) Methods)
- Nett Neutralization Potential (NNP) ; *Synonyms:* Nett Acid Production Potential (NAPP)
  **Calculation:** NNP = NP – AP ; NAPP = ANC – MPA
- Neutralising Potential Ratio (NPR)
  **Calculation:** NPR = NP : AP

### CLASSIFICATION ACCORDING TO NETT NEUTRALISING POTENTIAL (NNP)

If NNP (NP – AP) < 0, the sample has the potential to generate acid
If NNP (NP – AP) > 0, the sample has the potential to neutralise acid produced

Any sample with NNP < 20 is potentiall acid-generating, and any sample with NNP > -20 might not generate acid (Usher *et al*., 2003)

### ROCK CLASSIFICATION

| | | |
|---|---|---|
| **TYPE I** | Potentially Acid Forming | Total S(%) > 0.25% and NP:AP ratio 1:1 or less |
| **TYPE II** | Intermediate | Total S(%) > 0.25% and NP:AP ratio 1:3 or less |
| **TYPE III** | Non-Acid Forming | Total S(%) < 0.25% and NP:AP ratio 1:3 or greater |

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### CLASSIFICATION ACCORDING TO NEUTRALISING POTENTIAL RATIO (NPR)

Guidelines for screening criteria based on ABA (Price *et al*., 1997; Usher *et al*., 2003)

| Potential for ARD | Initial NPR Screening Criteria | Comments |
|---|---|---|
| **Likely** | **< 1:1** | Likely AMD generating |
| **Possibly** | **1:1 – 2:1** | Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides |
| **Low** | **2:1 – 4:1** | Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficiently reactive NP |
| **None** | **>4:1** | No further AMD testing required unless materials are to be used as a source of alkalinity |

### CLASSIFICATION ACCORDING TO SULPHUR CONTENT (%S) AND NEUTRALISING POTENTIAL RATIO (NPR)

For sustainable long-term acid generation, at least 0.3% Sulphide-S is needed. Values below this can yield acidity but it is likely to be only of short-term significance. From these facts, and using the NPR values, a number of rules can be derived:

1) Samples with less than 0.3% Sulphide-S are regarded as having insufficient oxidisable Sulphide-S to sustain acid generation.
2) NPR ratios of >4:1 are considered to have enough neutralising capacity.
3) NPR ratios of 3:1 to 1:1 are consider inconclusive.
4) NPR ratios below 1:1 with Sulphide-S above 3% are potentially acid-generating. (Soregaroli & Lawrence, 1998 ; Usher *et al*., 2003)

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## CERTIFICATE OF ANALYSES
## NET ACID GENERATION

**Date received: 2020-06-11**
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**Date completed: 2020-07-02**
**Order number: Delh.2020.001-17(v2) - Middelburg Ferrochrome**

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| Net Acid Generation | Sample Identification: pH 4.5 | | | | |
|---|---|---|---|---|---|
| | MF1 0-1m | MF1 1-2m | MF2 0.5-1m | MF2 2-2.5m | MF2 3-4m |
| **Sample Number** | **96716** | **96717** | **96718** | **96719** | **96720** |
| **NAG pH: ($H_2O_2$)** | 8.2 | 4.1 | 8.7 | 8.6 | 7.1 |
| **NAG (kg $H_2SO_4$ / t)** | <0.01 | 0.59 | <0.01 | <0.01 | <0.01 |

| Net Acid Generation | Sample Identification: pH 4.5 | | | | |
|---|---|---|---|---|---|
| | MF3 0.5-1.5m | MF4 0.5-1.5m | MF5 0.2-0.8m | MF5 1-2m | MF5 1-2m |
| **Sample Number** | **96721** | **96722** | **96723** | **96724** | **96724 D** |
| **NAG pH: ($H_2O_2$)** | 8.2 | 8.6 | 8.3 | 8.1 | 8.2 |
| **NAG (kg $H_2SO_4$ / t)** | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

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| Net Acid Generation | Sample Identification: pH 7 | | | | |
|---|---|---|---|---|---|
| | MF1 0-1m | MF1 1-2m | MF2 0.5-1m | MF2 2-2.5m | MF2 3-4m |
| **Sample Number** | **96716** | **96717** | **96718** | **96719** | **96720** |
| **NAG pH: ($H_2O_2$)** | 8.2 | 4.5 | 8.7 | 8.6 | 7.1 |
| **NAG (kg $H_2SO_4$ / t)** | <0.01 | 18.62 | <0.01 | <0.01 | <0.01 |

| Net Acid Generation | Sample Identification: pH 7 | | | | |
|---|---|---|---|---|---|
| | MF3 0.5-1.5m | MF4 0.5-1.5m | MF5 0.2-0.8m | MF5 1-2m | MF5 1-2m |
| **Sample Number** | **96721** | **96722** | **96723** | **96724** | **96724 D** |
| **NAG pH: ($H_2O_2$)** | 8.2 | 8.6 | 8.3 | 8.1 | 8.2 |
| **NAG (kg $H_2SO_4$ / t)** | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

Notes:

- Samples analysed with Single Addition NAG test as per Prediction Manual For Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1.
- Please let me know if results do not correspond to other data.

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## Appendix D (Interwaste SANS 10234 Classification Report)

- Samancor Middelburg Ferrochrome-Review of Chrome Direct Reduction Slimes Waste Classification Report
- SANS 10234 Safety data sheet (SDS) for CDR slimes stockpile (Interwaste, 2020)

# SAMANCOR CHROME

# Samancor Chrome, Chrome Direct Reduction Slimes Stockpile - SANS 10234 Classification Report

**Prepared on behalf of:**
Samancor Chrome
Middelburg
South Africa

**Email:** Corne.pretorius@samancorcr.com

**Prepared by:**
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Email: info@interwaste.co.za

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# EXECUTIVE SUMMARY:

| Summary of SANS 10234 Classification – Chrome Direct Reduction Slimes Stockpile | |
|---|---|
| Hazard Classes & Categories Hazard Classes & Categories | Skin Irritation – Category 2<br>Eye Irritation – Category 2A<br>Carcinogenicity – Category 1B<br>Specific Target Organ Toxicity – Single Exposure – Category 3<br>Specific Target Organ Toxicity – Repeated Exposure – Category 1 |
| GHS Pictogram |   |
| Signal Word | **Danger** |
| Hazard Statements | H315: Causes skin irritation<br>H319: Causes sev ere eye irritation<br>H335: May cause respiratory irritation<br>H350: May cause cancer<br>H372: Causes damage to organs through prolonged or repeated exposure |

| Waste Profile and classification | | |
|---|---|---|
| **Item** | **Description** | **Classified / Included** |
| **General Waste** | A waste that does not pose an immediate hazard or threat to health or to the environment, and includes domestic, building and demolition waste, business waste and inert waste. | × |
| **Hazardous Waste** | Means any waste that contains organic or inorganic elements or compounds that may, owing to the inherent physical, chemical or toxicological characteristics of that waste, have a detrimental impact on health and the environment. | ✓ |
| **Safety Data Sheet** | Preparation of a Safety Data Sheet (SDS). A SDS is required for all hazardous wastes (excluding Health Care Risk Waste (HCRW) in terms of Regulation 5(1) of GN. R. 634 of 2013. | ✓ |

| | | |
|---|---|---|
| **SANS 10234 Classification** | Classification as hazardous or non-hazardous in accordance with SANS 10234 (Regulation 4(2) of GN 634 of 2013). This is not a requirement where a waste can categorically be defined under Annexure 1 to GN. R. 634 of 2013. | ✓ |

DISCLAIMER: The information in this Waste Classification Report and associated Safety Data Sheet (SDS), where relevant, has been developed on the basis of the information available to Interwaste at the time of submission, and provides Interwaste's best reasonable and professional assessment of the intrinsic hazards posed by the subject waste streams. INTERWASTE MAKES NO WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE OR COURSE OF MANAGEMENT OR USAGE OF TRADE. It remains the waste generator's responsibility for determining whether their waste is fit for a particular purpose and suitable for user's/waste manager's method of use, management or application. Given the variety of factors that can affect the management, transport, storage and handling of the waste, some of which are uniquely within the generator's knowledge and control, it is essential that the generator evaluate the subject Report and SDS to determine whether they are fit for the particular purpose and suitable for third party user's / manager's method of use or application. Interwaste cannot be held liable for changes in the waste's constituents caused by a change in process, or raw material input into the process. The make up of waste is, by its very nature, variable. The manner in which the waste is to be handled may vary depending on its constituents.

## DEFINITIONS:

**Dermal corrosion:** See skin corrosion.

**Dermal irritation:** See skin irritation.

**Eye irritation:** The production of changes in the eye following the application of test substance to the anterior surface of the eye, which are fully reversible within 21 days of application.

**Flash point:** The lowest temperature (corrected to a standard pressure of 101.3 kPa) at which the application of an ignition source causes the vapours of a liquid to ignite under specified test conditions.

**Hazard statement:** A statement assigned to a hazard class and category that describes the nature of the hazards of a hazardous product, including, where appropriate, the degree of hazard.

**Hazard category**: The division of criteria within each hazard class, e.g. oral acute toxicity includes five hazard categories and flammable liquids includes four hazard categories. These categories compare hazard severity within a hazard class and should not be taken as a comparison of hazard categories more generally; Hazard class means the nature of the physical, health or environmental hazard, e.g. flammable solid, carcinogen, oral acute toxicity.

**Label means:** An appropriate group of written, printed or graphic information elements concerning a hazardous product, selected as relevant to the target sector(s) that is affixed to, printed on, or attached to the immediate container of a hazardous product, or to the outside packaging of a hazardous product.

**Mixture:** A mixture or a solution composed of two or more substances in which they do not react.

**Mutagen:** An agent giving rise to an increased occurrence of mutations in populations of cells and /or organisms.

**Pictogram:** A graphical composition that may include a symbol plus other graphic elements, such as a border, background pattern or colour that is intended to convey specific information.

**Precautionary Statements:** phrase or pictogram (or both) that describes recommended measures that should be taken into account to minimize or prevent adverse effects resulting from exposure to a hazardous product, or improper storage or handling of a hazardous product.

**Regulations:** The Waste Classification and Management Regulations under the NEM:WA.

**Serious eye damage:** The production of tissue damage in the eye, or serious physical decay of vision, following application of a test substance to the

| | |
|---|---|
| | anterior surface of the eye, which is not fully reversible within 21 days of application. |
| **Signal word:** | A word used to indicate the relative level of severity of hazard and alert the reader to a potential hazard on the label. The GHS uses "Danger" and "Warning" as signal words. |
| **Skin corrosion:** | The production of irreversible damage to the skin following the application of a test substance for up to 4 hours. |
| **Skin irritation:** | The production of reversible damage to the skin following the application of a test substance for up to 4 hours. |
| **Substance:** | Chemical elements and their compounds in the natural state or obtained by any production process, including any additive necessary to preserve the stability of the product and any impurities deriving from the process used, but excluding any solvent which may be separated without affecting the stability of the substance or changing its composition. |
| **Symbol:** | A graphical element intended to succinctly convey information. |

## ABBREVIATIONS:

| | |
|---|---|
| **CDC:** | Centres for Disease Control & Prevention |
| **DEA:** | Department of Environmental Affairs |
| **GHS:** | Globally Harmonized System of Classification and Labelling of Chemicals. |
| **IARC:** | International Agency for Research on Cancer |
| **MSDS:** | Material Safety Data Sheet |
| **NEM:WA:** | National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008)[NEM:WA] |
| **NEM:WAA:** | National Environmental Management: Waste Amendment Act, 2014 (Act No. 26 of 2014)[NEM:WAA] |
| **SANS:** | South African National Standard |
| **SDS**: | Safety Data Sheet |
| **STOT**: | Specific Target Organ Toxicity |
| **USEPA**: | United States Environmental Protection Agency |

# 1. BACKGROUND AND INTRODUCTION

Samancor Chrome, commissioned Interwaste (Pty) Ltd. (hereinafter referred to as 'Interwaste') to classify their Chrome Direct Reduction Slimes Stockpile, in terms of SANS 10234 (Globally Harmonised System of Classification and Labelling of Chemicals, GHS). The above mentioned material falls within the ambit of the definition of 'waste' provided for in the National Environmental Management: Waste Amendment Act, 2014 (Act 26 of 2014)[NEM:WAA], and thus need to be managed in accordance with the relevant provisions of the Act, as well as any relevant Regulations promulgated thereunder.

Interwaste has adopted a hierarchical approach toward classifying the subject waste stream. The approach is intended to inform the classification of the subject waste stream according to SANS 10234 in an efficient, cost effective and orderly manner, without compromising on the quality of the classification or the need to adhere to applicable legal requirements. Key to this approach is to use available laboratory analysis on the subject waste stream in conjunction with existing hazard information on the waste as a whole, or key ingredients/components thereof, thereby avoiding the need for potentially costly 'duplicate' testing and the unnecessary use of test animals.

Regulation 4 (2) of the Department of Environmental Affairs' (DEA) *Waste Classification and Management Regulations* (GN. R. 634 of 23 August 2013), hereinafter referred to as 'the Regulations', have been used as the legal trigger toward the requisite classification of this waste stream. Accordingly, in terms of Regulation 4 (2), Interwaste has classified the waste according to the relevant provisions of SANS 10234 (Globally Harmonised System of Classification and Labelling of Chemicals, GHS).

## 1.1 WASTE GENERATION PROCESS OVERVIEW

The subject waste stream is generated as a by-product during the production of low carbon ferrochrome, whereby chrome ore is brought into contact with finely divided coal at high temperature. The resultant slimes are the dust produced in this process which is captured via water sprays, and stored in the slimes dam.

## 1.2 OVERVIEW OF SANS 10234, GHS

The SANS 10234, GHS, standard covers the harmonized criteria for the classification of hazardous substances and mixtures, including waste, for their safe transport, storage and handling, according to their intrinsic health, environmental and physical hazards. It gives the harmonized communication elements for labelling and Safety Data Sheets (SDS). The standard accordingly provides detail on classification criteria (including tests methods,

for physical hazard classes, often with reference to SANS 10228), labelling, hazard identification symbols (pictograms), packaging and the minimum information required for a Safety Data Sheet (SDS).

The promulgation of the National Waste Classification and Management Regulations under the National Environmental Management: Waste Act, 2008 (Act 59 of 2008)[NEM:WA] has significantly altered the regulatory environment in South Africa in respect of the classification of waste; where until now the comprehensive classification of waste has not been a clear legal requirement.

Importantly, the classification of a waste has little bearing on the disposal or management requirements thereof, but is used primarily to inform

i) appropriate handling and storage of hazardous waste, as well as
ii) the development of an associated Safety Data Sheet (SDS) for the waste in terms of SANS10234, as is required in terms of Regulation 5 (1).

The classification of the waste, in terms of SANS 10234, does not necessarily inform the disposal requirements thereof, but may be used to a degree to inform the potential applicability of landfill restrictions imposed under section 5 (1) of the Standard for the Disposal of Waste to Landfill, GN. R. 635 of 23 August 2013.

## 2. SAMPLING AND ANALYSIS

| Sampler | Date | Method |
|---|---|---|
| Interwaste Representative | 12/06/2020 | 9 samples of the CDR Slimes Stockpile was delivered to the Interwaste's Waste Analytical Laboratory in Germiston, for subsequent analysis. |

| Laboratory Analysis—Elemental (XRF) | | | |
|---|---|---|---|
| **Compositional characterisation** | **Laboratory** | **Total Concentration** | **Leachable Concentration** |
| • Metals and metalloids, as listed in GN. R. 635<br>• Other detectable metals | Waterlab (Provided by client): Report number: 92197a | ✓<br>✓ | ✓<br>N/A |
| Inorganic anions, as listed in GN.R. 635: ($Cl$, $F$, $NO_3$, $SO_4$, $CN$) | Waterlab (Provided by client): Report number: 92197a | ✓ | x |
| • Organics, as listed in GN.R. 635<br>• Other detectable organic substances | Interwaste Laboratory | ✓<br>✓ | N/A<br>N/A |

| Laboratory Analysis – Crystalline phases (XRD) | Laboratory | Total Concentration |
|---|---|---|
| • Crystalline content (all detectable crystalline compounds)<br>• Particle size distribution (PSD) | Waterlab Report number: 92197 | ✓<br>✓ |
| **Physical and chemical properties** | **Laboratory** | **Range** |
| • pH<br>• Flash point | Interwaste Laboratory | ✓<br>X |

N/A = not applicable

Raw data from the laboratory analysis are attached hereto in Annexure B

## 2.1 RESULTS AND DISCUSSION

All analytical results received were converted to a percentage by mass basis, in order to assess the contaminant concentrations against the prescribed cut-off values / concentration limits (Table 1 & Table 2) to be applied for human health and environmental hazard classes as per SANS 10234.

Table 1: SANS10234 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 | Category 1 | ≥ 0.1% |
| | Category 2 | ≥ 1.0% |
| Carcinogenicity | | ≥ 0.1% |
| Reproductive toxicity | | ≥ 0.1% |
| Target organ systemic toxicity | Single exposure | ≥ 1.0% |
| | Repeat exposure | ≥ 1.0% |
| Hazardous to the aquatic environment | | ≥ 1.0% |

The application of the cut-off values, as per Table 1, shows thirteen (13) contaminants in the waste to be considered potentially relevant to the classification thereof in terms of SANS 10234; with reasons for 'relevance' indicated where applicable.

| Table 2: Chrome Direct Reduction Slimes Stockpile ingredients ≥ 0.1% by mass – Relevant ingredient determination | | | |
|---|---|---|---|
| **Compound Form** | **Concentration (%)** | **Relevant to classification** | **Reason** |
| Quartz ($SiO_2$)[A] | 2.09 – 42.71 | ✓ | >1.0% |
| Mullite ($3Al_2O_32SiO_2$)[A] | 0.06 – 8.65 | ✓ | >1.0% |
| Bassanite ($2(Ca)2(SO_4).(H_2O)$[A] | 0.16 – 2.17 | ✓ | >1.0% |
| Magnetite ($Fe_3O_4$)[A] | 0.36 – 1.02 | ✓ | >0.1% but <1.0% and not C, M, or R* |
| Iron (Fe)[A] | 0.05 – 0.99 | X | >0.1% but <1.0% and not C, M, or R* |
| Chromite ($Fe_2CrO_4$)[A] | 2.10 – 14.60 | ✓ | >1.0% |
| Calcite ($CaCO_3$)[A] | 0.52 – 2.27 | ✓ | >1.0% |
| Dolomite ($CaMg(CO_3)_2$)[A] | 0 – 0.86 | X | >0.1% but <1.0% and not C, M, or R* |
| Hematite ($Fe_2O_3$)[A] | 0 – 1.46 | ✓ | >1.0% |
| Kaolinite ($Al_2Si_2O_5(OH)_4$)[A] | 0 – 5.34 | ✓ | >1.0% |
| Plagioclase ($(Na,Ca)(Si,Al)_4O_8$)[A] | 0 – 0.83 | X | >0.1% but <1.0% and not C, M, or R* |
| Aluminium Oxide ($Al_2O_3$)[B] | 0 – 5.76 | ✓ | >1.0% |
| Silicon Dioxide ($SiO_2$)[B] | 8.61 – 31.59 | ✓ | >1.0% |
| Phosphorous Pentoxide ($P_2O_5$)[B] | 0.16 – 0.49 | X | >0.1% but <1.0% and not C, M, or R* |
| Calcium Carbonate ($CaCO_3$)[B] | 0 – 1.55 | ✓ | >1.0% |
| Manganese Oxide ($MnO_2$)[B] | 0.14 – 0.82 | X | >0.1% but <1.0% and not C, M, or R* |
| Iron Oxide ($Fe_2O_3$)[B] | 0.83 – 14.97 | ✓ | >1.0% |
| Sodium Sulphate ($NaSO_4$)[B] | 0.49 – 6.92 | ✓ | >1.0% |

* C = Carcinogenic, M = Mutagenic or R = Reproductive Toxin (with cut-off values of 0.1% relevant to these hazard classes, as opposed to 1% for all remaining human health and aquatic hazard classes)

[A] Crystalline form as per XRD analysis.

[B] Chemical form assumed based on literature, or associated elemental concentrations in the waste.

| Table 3: Chrome Direct Reduction Slimes Stockpile – Relevant ingredient hazard data | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ingredient** | | **Quartz** | **Mullite** | **Bassanite** | **Magnetite** | **Chromite** |
| Chemical composition by weight % | | 2.09 – 42.71 | 0.06 – 8.65 | 0.16 – 2.17 | 0.36 – 1.02 | 2.10 – 14.60 |
| CAS Number | | 14808-60-7 | 1302-93-8 | 7778-18-9 | 1317-61-9 | 1308-31-2 |
| Human health hazards | | | | | | |
| Acute Toxicity | Oral | | | | | |
| | Inhalation | | | | | |
| | Dermal | | | | | |
| Skin corrosion / irritation | | | | | | |
| Eye damage / irritation | | | | | | |
| Mutagenicity | | | | | | |
| Carcinogenicity | | Category 1A | | | | |
| Reproductive toxicity | | | | | | |
| Specific Target Organ Toxicity (STOT) | Single Exposure | Category 3 (Resp)* | | | | |
| | Repeat Exposure | Category 1 | | | | |
| Aspiration Hazard | | | | | | |
| Skin/respiratory sensitisation | | | | | | |
| Aquatic hazards | | | | | | |
| Acute | | | | | | |
| Chronic | | | | | | |

| Table 4: Chrome Direct Reduction Slimes Stockpile – Relevant ingredient hazard data….continued | | | | | | |
|---|---|---|---|---|---|---|
| **Ingredient** | | **Calcite** | **Hematite** | **Kaolinite** | **Aluminium Oxide** | **Silicon Dioxide** |
| Chemical composition by weight % | | 0.52 – 2.27 | 0 – 1.46 | 0 – 5.34 | 0 – 5.76 | 8.61 – 31.59 |
| CAS Number | | 471-34-1 | 1317-60-8 | 7778-18-9 | 1317-61-9 | 14808-60-7 |
| Human health hazards | | | | | | |
| Acute Toxicity | Oral | | | | | |
| | Inhalation | | | | | |
| | Dermal | | | | | |
| Skin corrosion / irritation | | | | | | |
| Eye damage / irritation | | | | | | |
| Mutagenicity | | | | | | |
| Carcinogenicity | | | | | | |
| Reproductive toxicity | | | | | | |
| Specific Target Organ Toxicity (STOT) | Single Exposure | | | | | |
| | Repeat Exposure | | | | | Category 1 |
| Aspiration Hazard | | | | | | |
| Skin/respiratory sensitisation | | | | | | |
| Aquatic hazards | | | | | | |
| Acute | | | | | | |
| Chronic | | | | | | |

| Table 5: Chrome Direct Reduction Slimes Stockpile – Relevant ingredient hazard data….continued | | | | |
|---|---|---|---|---|
| **Ingredient** | | **Calcium Carbonate** | **Iron Oxide** | **Sodium Sulphate** |
| Chemical composition by weight % | | 0 – 1.55 | 0.83 – 14.97 | 0.49 – 6.92 |
| CAS Number | | 471-34-1 | 1309-37-1 | 7757-82-6 |
| Human health hazards | | | | |
| Acute Toxicity | Oral | | | |
| | Inhalation | | | |
| | Dermal | | | |
| Skin corrosion / irritation | | | Category 2 | |
| Eye damage / irritation | | | Category 2 | |
| Mutagenicity | | | | |
| Carcinogenicity | | | | |
| Reproductive toxicity | | | | |
| Specific Target Organ Toxicity (STOT) | Single Exposure | | Category 3 (Resp)* | |
| | Repeat Exposure | | | |
| Aspiration Hazard | | | | |
| Skin/respiratory sensitisation | | | | |
| Aquatic hazards | | | | |
| Acute | | | | |
| Chronic | | | | |

# 3. SANS 10234 CLASSIFICATION – 'INGREDIENT' HAZARD DATA

SANS 10234 makes a general allowance for the use of existing hazard data on classified 'ingredients' in a mixture toward the classification of that mixture. This is primarily aimed at avoiding unnecessary testing in the laboratory on the mixture (i.e. the waste in this instance) as a whole, particularly as it pertains to animal testing in respect of human health and environmental hazard groups. This process (in general terms) relies on knowing the intrinsic hazards or hazardous properties of the ingredients in a mixture, in combination with knowledge of the contribution thereof (by mass) to the overall mixture / waste.

The following phased approach was adopted by Interwaste toward classifying the subject waste stream, so that the outcomes are scientifically correct and the output thereof defensible:

1. Waste generator discussions and review of the process(es) generating the waste, as well as any existing/relevant SDS's;
2. Laboratory analysis, focused on relevant contaminants of concern;
3. Literature review / assimilation of hazard data and existing GHS classifications on the waste / mixture as a whole, or similar waste streams; where… "*test data already generated for the classification of a chemical under existing systems shall be accepted when classifying a waste under the harmonised system, thereby avoiding duplicate testing and the unnecessary use of test animals*" (SANS 10234);
4. A) Application of bridging principles prescribed under SANS 10234 towards hazard class classification, given the lack of availability of existing hazard information on similar waste streams (Annexure A has reference);

   B) Application of additivity principles under the GHS where bridging principles inadequate towards hazard class classification; given that no hazard data is available on the waste/mixture as a whole, but where there is sufficient existing hazard data on the ingredients/constituents of the waste to allow for such.

To this end, the available knowledge on the ingredient composition for the subject waste stream has been used to source available hazard data for each of the relevant ingredients. The term 'relevant ingredients' is used to describe those ingredients in the waste that were measured at a concentration of >0.1% (by mass); where Table 2 refers.

## SANS 10234 (GHS) Detailed Waste Classification

| | |
|---|---|
| **Waste appearance** | Grey to black clay and slimes. |

**Classification Summary**

**Skin Irritation (Category 2), Eye Irritation (Category 2), Carcinogenicity (Category 1B), Specific Target Organ Toxicity – Single Exposure (Category 3), and Specific Target Organ Toxicity – Repeated Exposure (Category 1).**

**Assumptions and limitations**

- The measured metal substances were assumed to be present in oxide form as found in literature for waste similar to the subject waste stream.
- Hazard information for substances is sourced from:
  - Analytical results
  - Hazardous relevant ingredients, SDS (where relevant).
  - Supplement to SANS 10234:2008 Edition 1.
  - European Chemicals Agency, Classification & Labelling Inventory Database.
  - US Centre for Disease Control (CDC).
- The mixture has a pH of 7.3 – 9.6

| Hazard Class | Hazard Category | Classification Criteria | Assessed Concentration wt.% | Waste Hazard Category |
|---|---|---|---|---|
| **Physical Hazards** | | | | |
| **Explosives** | Division 1.1 – 1.6 | According to the results of the tests in Part I of the UN Manual of tests and criteria | No substance identified | |
| **Flammable Gases** | 1 | Gases and gas mixtures that, at 20$^0$C and a standard pressure of 101.3 kPa:<br>a) Are ignitable when in a mixture of 13% or less by volume in air, or<br>b) Have a flammable range with air of at least 12 percentage points regardless of the lower flammable limit | No substance identified | |
| | 2 | Gases or gas mixtures, other than those of category 1, which, at 20$^0$C and a standard pressure of 101.3 kPa, have a flammable range while mixed in air | No substance identified | |
| **Flammable Aerosols** | 1 - 2 | On the basis of its components, of its chemical heat of combustion and, if applicable, of the results of the foam test, for foam aerosols, and of the ignition distance test and enclosed space test, for spray aerosols (see Part III, section 31 of the UN Manual of tests and criteria) | No substance identified | |
| **Oxidizing Gases** | 1 | Any gas that may, generally by providing oxygen, cause or contribute to the combustion of other material more than air does | No substance identified | |
| **Gases Under Pressure** | Compressed Gas | A gas that, when packaged under pressure, is entirely gaseous at -50$^0$C, including all gases with a critical temperature ≤ -50$^0$C | No substance identified | |

| Hazard Class | Hazard Category | Classification Criteria | Assessed Concentration wt.% | Waste Hazard Category |
|---|---|---|---|---|
| | Liquefied Gas | A gas that, when packaged under pressure, is partially liquid at temperatures above -50$^0$C<br><br>A distinction is made between:<br><br>a) High pressure liquefied gas, a gas with a critical temperature between -50$^0$C and +65$^0$C, and<br>b) Low pressure liquefied gas, a gas with a critical temperature above +65$^0$C | No substance identified | |
| | Refrigerated Liquefied Gas | A gas that, when packaged, is made partially liquid because of its low temperature | No substance identified | |
| | Dissolved Gas | A gas that, when packaged under pressure, is dissolved in a liquid phase solvent | No substance identified | |
| **Flammable Liquids** | 1 | Flash point < 23$^0$C and initial boiling point ≤ 35$^0$C | No substance identified | |
| | 2 | Flash point < 23$^0$C and initial boiling point > 35$^0$C | No substance identified | |
| | 3 | Flash point < 23$^0$C and ≤ 60$^0$C | No substance identified | |
| | 4 | Flash point > 60$^0$C and ≤ 93$^0$C | No substance identified | |
| **Flammable Solids** | 1 | a) substance and mixtures other than metal powders<br><br>The wetted zone does not stop the fire and the burning time is < 45s, or the burning rate is > 2,2mm/s<br><br>b) The burning time is ≤ 5 min | No substance identified | |
| | 2 | a) substance and mixtures other than metal powders<br><br>The wetted zone does not stop the fire for at least 4 minutes and the burning time is < 45s, or the burning rate is > 2,2mm/s<br><br>b) The burning time is > 5 min and ≤ 10min | No substance identified | |

| Hazard Class | Hazard Category | Classification Criteria | Assessed Concentration wt.% | Waste Hazard Category |
|---|---|---|---|---|
| **Self-Reactive Substances** | Type A | According to the results of the tests in Part II, section 20.4.2 of the UN Manual of tests and criteria | No substance identified | |
| | Type B | According to the results of the tests in Part II, section 20.4.2 of the UN Manual of tests and criteria | No substance identified | |
| | Types C and D | According to the results of the tests in Part II, section 20.4.2 of the UN Manual of tests and criteria | No substance identified | |
| | Types E and F | According to the results of the tests in Part II, section 20.4.2 of the UN Manual of tests and criteria | No substance identified | |
| | Type G | According to the results of the tests in Part II, section 20.4.2 of the UN Manual of tests and criteria | No substance identified | |
| **Pyrophoric Liquids** | 1 | The liquid ignites 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 | No substance identified | |
| **Pyrophoric Solids** | 1 | The solid ignites within 5 min of coming into contact with air | No substance identified | |
| **Self-Heating Substances** | 1 | A positive result is obtained in a test using a cubical container of sides 25 mm at $140^0$C | No substance identified | |
| | 2 | a) A positive result is obtained in a test using a cubical container of sides 100 mm at $140^0$C and a negative result is obtained in a test using a cubical container of sides 25 mm at $140^0$C and the substance is to be packed in the packages with a volume of more than 3 $m^3$, or<br>b) A positive result is obtained in a test using a cubical container of sides 100 mm at 1400C and a negative result is obtained in a test using a cubical container of sides 25 mm at $140^0$C, a positive result is obtained in a test using a cubical container of sides 100mm at $120^0$C and the substance is to be packed in packages with a volume of more than 450litres, or<br>c) A positive result is obtained | No substance identified | |

| Hazard Class | Hazard Category | Classification Criteria | Assessed Concentration wt.% | Waste Hazard Category |
|---|---|---|---|---|
| | | in a test using a cubical container of sides 100 mm at $140^0$C and a negative result is obtained in a test using a cubical container of sides 25 mm at $140^0$C and a positive result is obtained in a test using a cubical container of sides 100 mm at $100^0$C | | |
| **Substances that, on contact with water, emit flammable gases** | 1 | Any substance that reacts vigorously with water at ambient temperatures and demonstrates a tendency for the gas produced to ignite spontaneously, or that reacts readily with water at ambient temperatures such that the rate of evolution of flammable gas is equal to or greater than 10L/kg of substance over any 1min | No substance identified | |
| | 2 | Any substance that reacts vigorously with water at ambient temperatures and demonstrates a tendency for the gas produced to ignite spontaneously, or that reacts readily with water at ambient temperatures such that the rate of evolution of flammable gas is equal to or greater than 10L/kg of substance over any 1min | No substance identified | |
| | 3 | Any substance that reacts slowly with water at ambient temperatures such that the rate of evolution of flammable gas is equal to or greater than 1L/kg of substance per hour, and that does not meet the criteria for the categories 1 and 2 | No substance identified | |
| **Oxidizing Liquids** | 1 | Any substance that, in the 1 : 1 mixture, by mass, of substance and cellulose tested, spontaneously ignites, or the mean pressure rise time of a 1 : 1 mixture, by mass of 50% perchloric acid and cellulose | No substance identified | |
| | 2 | Any substance that, in the 1 : 1 mixture, by mass, of substance and cellulose tested, exhibits a mean pressure rise time less than or to the mean pressure rise time of a 1 : 1 mixture, by mass, of 40% aqueous sodium chlorate solution and cellulose, and the criteria for category 1 are not met | No substance identified | |
| | 3 | Any substance that, in the 1 : 1 mixture by mass, of substance and cellulose tested, exhibits a mean pressure rise time less than or equal to the mean pressure rise time of a 1 : 1 mixture, by mass, of 65% aqueous nitric acid and cellulose, and the | No substance identified | |

| Hazard Class | Hazard Category | Classification Criteria | Assessed Concentration wt.% | Waste Hazard Category |
|---|---|---|---|---|
| | | criteria for categories 1 and 2 are not met | | |
| **Oxidizing Solids** | 1 | Any substance that, in the 4 : 1 or 1: 1 sample-to-cellulose ratio, by mass, exhibits a mean burning time less than the mean burning time of a 3 : 2 mixture, by mass, of potassium bromate and cellulose | No substance identified | |
| | 2 | Any substance that, in the 4 : 1 or 1: 1 sample-to-cellulose ratio, by mass, exhibits a mean burning time equal to or less than the mean burning time of a 2 : 3 mixture, by mass, of potassium bromate and cellulose and the criteria for category 1 are not met | No substance identified | |
| | 3 | Any substance that, in the 4 : 1 or 1: 1 sample-to-cellulose ratio, by mass, exhibits a mean burning time equal to or less than the mean burning time of a 3 : 7 mixture, by mass, of potassium bromate and cellulose and the criteria for categories 1 and 2 are not met | No substance identified | |
| **Organic Peroxides** | Type A | According to the results of test series A to H in the Part II, Section 20.4.3 of the UN manual of tests and criteria | No substance identified | |
| | Type B | According to the results of test series A to H in the Part II, Section 20.4.3 of the UN manual of tests and criteria | No substance identified | |
| | Type C and D | According to the results of test series A to H in the Part II, Section 20.4.3 of the UN manual of tests and criteria | No substance identified | |
| | Type E and F | According to the results of test series A to H in the Part II, Section 20.4.3 of the UN manual of tests and criteria | No substance identified | |
| | Type G | According to the results of test series A to H in the Part II, Section 20.4.3 of the UN manual of tests and criteria | No substance identified | |
| **Corrosive to Metals** | 1 | Corrosion rate on steel or aluminium surfaces exceeding 6,25mm/year at $55^0$C | No substance identified | |
| **Health Hazards** | | | | |
| **Acute toxicity** | 1, 2, 3, 4 & 5 | If a mixture acute toxicity estimate (ATE) is within a specified range specific to routes of exposure. | No substance identified | |
| **Skin Corrosion/ Irritation** | 1 | If an individual substance ≥ 5% and is classified under category 1, or if a mixture pH ≥ 11.5 or ≤ 2, or if an individual substance ≥ 1% has pH ≥ 11.5 or ≤ 2, or if an individual | No substance identified | |

| Hazard Class | Hazard Category | Classification Criteria | Assessed Concentration wt.% | Waste Hazard Category |
|---|---|---|---|---|
| | | substance ≥ 1% for which additivity does not apply is corrosive (category 1). | | |
| | 2 | If an individual substance ≥ 1% but ≤ 5% and is classified under category 1, or if an individual substance ≥ 10% and is classified under category 2, or if (10 × skin category 1) +skin category 2 ≥ 10%, or if an individual substance ≥ 3% for which additivity does not apply and is classified skin irritant category 2. | Iron Oxide (Category 2), at 0.83 – 14.97% | Skin Irritation (Category 2) |
| | 3 | If an individual substance < 10% but ≥ 1% and is classified under category 2, or if an individual substance ≥ 10% and is classified under category 3, or if (10 × skin category 1) +skin category 2 < 10% but ≥ 1%, or if (10 × skin category 1 + skin category 2 + skin category 3) ≥ 10% | No substance identified | |
| **Serious Eye Damage/Eye irritation** | 1 | If an individual substance ≥ 3% and is classified skin/eye category 1, or if a mixture pH ≥ 11.5 or ≤ 2, or if (skin category 1 + eye category 1) ≥ 3%, or if an individual substance ≥ 1% has pH ≥ 11.5 or ≤ 2, or if an individual substance ≥ 1% for which additivity does not apply is corrosive (category 1).. | No substance identified | |
| | 2 | If an individual substance ≥ 1% but < 3% and is classified skin/eye category 1, or if an individual substance ≥ 10% and is classified under category 2A, or if (10 × eye category 1 +eye category 2A) ≥ 10%, or if (skin category 1 + eye category 1) ≥ 1% but < 3%, or if an individual substance ≥ 3% for which additivity does not apply and is classified skin/eye irritant category 2, or if (10 × eye category 1 + 10 × skin category 1 + eye category 2A/2B) ≥ 10%. | Iron Oxide (Category 2), at 0.83 – 14.97% | Eye Irritation (Category 2) |
| **Respiratory sensitization and skin sensitization** | Skin sensitization Category 1 | If an individual substance ≥ 0.1% and is classified skin sensitization category 1 | No substance identified | |
| | Respiratory sensitization Category 1 | If an individual solid or liquid or gaseous substance ≥ 0.1% and is classified respiratory sensitization category 1 | No substance identified | |
| **Germ Cell Mutagenicity** | 1 | If an individual substance ≥ 0.1% and is classified under category 1 | No substance identified | |
| | 2 | If an individual substance ≥ 0.1% and is classified under category 2 | No substance identified | |
| **Carcinogenicity** | 1A | If an individual substance ≥ 0.1% and is classified category 1 carcinogen | No substance identified | |

| Hazard Class | Hazard Category | Classification Criteria | Assessed Concentration wt.% | Waste Hazard Category |
|---|---|---|---|---|
| | | (known) | | |
| | 1B | If an individual substance ≥ 0.1% and is classified category 1 carcinogen (presumed) | Quartz (Category 1A), at 2.09 – 42.71% | Carcinogenicity (Category 1B) |
| | 2 | If an individual substance ≥ 0.1% and is classified category 2 carcinogen. | No substance identified | |
| **Reproductive Toxicity** | 1A | If an individual substance ≥ 0.1% and is classified reproductive toxicant category 1 (known). | No substance identified | |
| | 1B | If an individual substance ≥ 0.1% and is classified reproductive toxicant category 1 (presumed). | No substance identified | |
| | 2 | If an individual substance ≥ 0.1% and is classified reproductive toxicant category 2. | No substance identified | |
| | Category for effects on, or via lactation | If an individual substance ≥ 0.1% and is classified reproductive toxicant for effects on, or via lactation. | No substance identified | |
| **Specific Target Organ Toxicity – Single Exposure** | 1 | If an individual substance ≥ 1% and is classified STOT – single exposure category 1. | No substance identified | |
| | 2 | If an individual substance ≥ 1% and is classified STOT – single exposure category 2. | No substance identified | |
| | 3 | If an individual substance ≥ 20% and is classified STOT – single exposure category 3. | Quartz (Category 3), at 2.09 – 42.71% | Specific Target Organ Toxicity – Single Exposure (Category 3) |
| **Specific Target Organ Toxicity – Repeated Exposure** | 1 | If an individual substance ≥ 1% and is classified STOT – repeated exposure category 1. | Quartz (Category 1A), at 2.09 – 42.71%, and Silicon Dioxide (Category 1), at 8.61 – 31.59% | Specific Target Organ Toxicity – Repeated Exposure (Category 1) |
| | 2 | If an individual substance ≥ 1% and is classified STOT – Repeated exposure category 2 | No substance identified | |
| **Aspiration Hazards** | 1 | If an individual substance ≥ 10% and is classified as aspiration toxicant category 1 and has a kinematic viscosity ≤ 20.5 $mm^2/s$, at 40 °C | No substance identified | |
| | 2 | If an individual substance ≥ 10% and is classified as aspiration toxicant category 2 and has a kinematic viscosity ≤ 14 $mm^2/s$, at 40 °C | No substance identified | |
| **Hazards to the Aquatic Environment** | | | | |
| **Acute Aquatic Toxicity** | 1 | If (Multiplication factor as determined in the GHS × Acute 1) > 25%. | No substance identified | |
| | 2 | If (Multiplication factor as determined in the GHS × 10 × Acute 1 + Acute 2) > 25%. | No substance identified | |

| Hazard Class | Hazard Category | Classification Criteria | Assessed Concentration wt.% | Waste Hazard Category |
|---|---|---|---|---|
| | 3 | If (Multiplication factor as determined in the GHS × 100 × Acute 1 + 10 × Acute 2 + Acute 3) > 25%. | No substance identified | |
| Chronic Aquatic Toxicity | 1 | If (Multiplication factor as determined in the GHS × Chronic 1) > 25%. | No substance identified | |
| | 2 | If (Multiplication factor as determined in the GHS × 10 × Chronic 1 + Chronic 2) > 25%. | No substance identified | |
| | 3 | If (Multiplication factor as determined in the GHS × 100 × | No substance identified | |
| | 4 | If (Chronic 1 + Chronic 2 + Chronic 3 + Chronic 4) > 25% | No substance identified | |

# 4. DISCUSSION

The Chrome Direct Reduction Slimes Stockpile classifies as hazardous. The intrinsic hazards posed by the Chrome Direct Reduction Slimes Stockpile relates predominantly to Skin Irritation – Category 2, Eye Irritation – Category 2A, Carcinogenicity – Category 1B, Specific Target Organ Toxicity – Single Exposure – Category 3, and Specific Target Organ Toxicity – Repeated Exposure – Category 1 respectively.

As per the 'Waste Classification and Management Regulations, 2013 (GNR634)', a safety data sheet (SDS) is required for the Chrome Direct Reduction Slimes Stockpile.

# ANNEXURE A: GHS CLASSIFICATION CRITERIA

## Skin Corrosion/irritation

| SANS10234, Table 26 – Cut-off values/concentration limits of the ingredients of a mixture classified as skin category 1, 2 or 3 that trigger classification of the mixture as hazardous to skin | | | |
|---|---|---|---|
| Sum of ingredients classified as: | Cut-off values/concentration limits of the ingredients that trigger the classification of a mixture % | | |
| | 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 |

## Serious Eye Damage/Eye Irritation

| SANS 10234 Table 30 – Cut-off values/concentration limits of the ingredients of a mixture classified as category 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 the 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 |

## Carcinogenicity

| SANS10234, Table 39 - Cut-off values/concentration limits of ingredients classified as carcinogens that trigger classification of a mixture. | | |
|---|---|---|
| Ingredient classified as: | Cut-off values/concentration limits of the ingredients that trigger the classification of a mixture<br>% | |
| | Category 1 carcinogen | Category 2 carcinogen |
| Category 1 carcinogen | ≥ 0.1% | |
| Category 2 carcinogen | - | ≥ 0.1% |
| | | ≥ 1.0% |

## Reproductive Toxicity—Fertility

| SANS10234, Table 42 – Cut-off values/concentration limits of the ingredients of a mixture classified as reproductive toxicants that trigger classification of the mixture | | | |
|---|---|---|---|
| Sum of ingredients classified as: | Cut-off values/concentration limits of the ingredients that trigger the classification of a mixture<br>% | | |
| | Category 1 | Category 2 | Additional category for effects on, or via lactation |
| Category 1 reproductive toxicant | ≥0.1 | | |
| Category 2 reproductive toxicant | | ≥0.1 | |
| Additional category for effects on, or via lactation | | | ≥0.1 |

## Germ Cell Mutagenicity

| SANS 12034, Table 36 - Cut-off values/concentration limits of ingredients of a mixture that trigger classification as germ cell mutagens | | |
|---|---|---|
| Hazard category of the ingredient(s) | Cut-off values/concentration limits of the ingredients that trigger the classification of a mixture<br>% | |
| | Category 1 | Category 2 |
| Category 1 | ≥ 0.1% | |
| Category 2 | | ≥ 1% |

## Specific Target Organ Toxicity (STOT)—Single Exposure

| SANS 12034, Table 46 - Cut-off values/concentration limits of ingredients of a mixture that trigger classification as a specific target organ toxicant – single exposures | | |
|---|---|---|
| Hazard category of the ingredient(s) | Cut-off values/concentration limits of the ingredients that trigger the classification of a mixture % | |
| | Category 1 | Category 2 |
| Category 1 | ≥ 1% | |
| Category 2 | | ≥ 1% |

## Specific Target Organ Toxicity (STOT)—Repeated Exposure

| SANS 12034, Table 51 - Cut-off values/concentration limits of ingredients of a mixture that trigger classification as a specific target organ toxicant – repeated exposures | | |
|---|---|---|
| Hazard category of the ingredient(s) | Cut-off values/concentration limits of the ingredients that trigger the classification of a mixture % | |
| | Category 1 | Category 2 |
| Category 1 | ≥ 1% | |
| Category 2 | | ≥ 1% |

## Hazards to the Aquatic Environment

| SANS 10234, Table 58 – Classification of Mixtures for Acute Hazards to the Aquatic Environment, based on the summation of classified components | |
|---|---|
| Sum of the components/ingredients classified as: | Acute hazard category of the mixture |
| Acute 1 X M >25% | 1 |
| (M X 10 X Acute 1) + Acute 2 >25% | 2 |
| (M X 100 X Acute 1) + (10 X Acute 2) + Acute 3 >25% | 3 |

* LC50 KMnO4 ≥ 0.1 ≤ 1.0 mg/l; therefore M = 1

| SANS 10234, Table 59 – Classification of Mixtures for Chronic Hazards to the Aquatic Environment, based on the summation of classified components | | |
|---|---|---|
| Sum of the components/ingredients classified as: | | Chronic hazard category of the mixture |
| Chronic 1 X M | >25% | 1 |
| (M X 10 X Chronic 1) + Chronic 2 | >25% | 2 |
| (M X 100 X Chronic 1) + (10 X Chronic 2) + Chronic 3 | >25% | 3 |
| | | |
| Chronic 1 + Chronic 2 + Chronic 3 + Chronic 4 | >25% | 4 |

# ANNEXURE B: LABORATORY RESULTS

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## Sample Identification Number: IW2020-0469

| Laboratory Analysis Report for Landfill Assessment | | | |
|---|---|---|---|
| **Requested By:** | Keelan Chetty | **Waste Name:** | MF5 1-2M Slime Stockpile Chrome Direct Reduction |
| **Generator:** | Samancor Chrome | **Received Date:** | 12/06/2020 |
| **Lab Reference:** | IW2020-0469 | **Analysis Date:** | 03/07/2020 |
| **No. of Samples:** | 1 | **Report Date:** | 28/07/2020 |
| **Sample Description:** | Greyish brown clay | | |

Table 1: Miscellaneous tests for sample: IW2020-0469 *

| Parameter Tested | Unit | IW2020-0469 |
|---|---|---|
| **Sample Moisture Content** | % (w/w) | 48.36 |
| **Conductivity** [A] | uS/cm | 172.1 |
| **Initial Sample pH** [A] | pH Units | 9.27 |
| **Sample pH after HCl Addition** | pH Units | NT |
| **Leach Solution Applied** | Solution Type | Water |
| **Final Leach Solution pH** | pH Units | NT |
| **Physical State** | NA | Solid |
| **Water Miscibility** | NA | Immiscible |
| **Calorific Value** | MJ/kg | NT |
| **Additional Information** | NA | Low Odour |

* UTD = Unable to determine; NT = Not tested; A = SANAS accredited method; Where not specified, the methods are not accredited; Conductivity and pH measured by electronic conductivity and pH meter at ~22C (10% H2O extracts of solids). Moisture by mass loss on heating at ~103C for 30 mins.

Table 2: GC-MS total and leachable organics for sample: IW2020-0469 *

| Contaminant Name | Detection Limit (mg/kg) | Concentration (mg/kg) | Theoretical Max. Leach Concentration (mg/L) |
|---|---|---|---|
| **Nonane** | 2.000 | BDL | BDL |
| **Decane** | 2.000 | BDL | BDL |
| **Dodecane** | 2.000 | BDL | BDL |
| **Tetradecane** | 2.000 | BDL | BDL |
| **Hexadecane** | 2.000 | BDL | BDL |
| **Octadecane** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **Nonadecane** | 2.000 | BDL | BDL |
| **Eicosane** | 2.000 | BDL | BDL |
| **Docosane** | 2.000 | BDL | BDL |
| **Tetracosane** | 2.000 | BDL | BDL |
| **Hexacosane** | 2.000 | BDL | BDL |
| **Octacosane** | 2.000 | BDL | BDL |
| **Hentriacontane** | 2.000 | BDL | BDL |
| **n-Hexane** | 0.002 | BDL | BDL |
| **Heptane** | 0.002 | BDL | BDL |
| **Octane** | 0.002 | BDL | BDL |
| **Nonane2** | 0.002 | BDL | BDL |
| **Decane3** | 0.002 | BDL | BDL |
| **1,2-Dichloroethylene** [A] | 0.002 | BDL | BDL |
| **Chloroform** [A] | 0.002 | BDL | BDL |
| **1,1,1-Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,2-Dichloroethane** [A] | 0.002 | BDL | BDL |
| **1,1-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Benzene** [A] | 0.002 | BDL | BDL |
| **Carbon Tetrachloride** [A] | 0.002 | BDL | BDL |
| **Trichloroethylene** [A] | 0.002 | BDL | BDL |
| **Bromodichloromethane** [A] | 0.002 | BDL | BDL |
| **cis-1,3-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Toluene** [A] | 0.002 | BDL | BDL |
| **1,1,2 Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,3-Dichloropropane** [A] | 0.002 | BDL | BDL |
| **Dibromochloromethane** [A] | 0.002 | BDL | BDL |
| **1.2 Dibromoethane** [A] | 0.002 | BDL | BDL |
| **Tetrachloroethylene** [A] | 0.002 | BDL | BDL |
| **Chlorobenzene** [A] | 0.002 | BDL | BDL |
| **1,1,1,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |
| **Ethylbenzene** [A] | 0.002 | BDL | BDL |
| **o-Xylene** [A] | 0.002 | BDL | BDL |
| **Styrene** [A] | 0.002 | BDL | BDL |
| **1,1,2,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |

| | | | |
|---|---|---|---|
| **1,2,3-Trichloropropane** [A] | 0.002 | BDL | BDL |
| **Bromobenzene** [A] | 0.002 | BDL | BDL |
| **Propylbenzene** [A] | 0.002 | BDL | BDL |
| **4-Chlorotoluene** [A] | 0.002 | BDL | BDL |
| **1,2,3-Trimethylbenzene** [A] | 0.002 | BDL | BDL |
| **tert-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,4-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **sec-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,2-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **n-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **Hexachloroethane** [A] | 0.002 | BDL | BDL |
| **1,2 Dibromo-3-chloropropane** [A] | 0.002 | BDL | BDL |
| **1,3,5-Trichlorobenzene** [A] | 0.002 | BDL | BDL |
| **Naphthalene** [A] | 0.002 | BDL | BDL |
| **Hexachlorobutadiene** [A] | 0.002 | BDL | BDL |
| **Phenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethyl) ether** | 2.000 | BDL | BDL |
| **2-Chlorophenol** | 2.000 | BDL | BDL |
| **1,4-Dichlorobenzene** | 2.000 | BDL | BDL |
| **1,2-Dichlorobenzene** | 2.000 | BDL | BDL |
| **2-Methylphenol (o-Cresol)** | 2.000 | BDL | BDL |
| **Bis(2-chloro-1-methylethyl) ether** | 2.000 | BDL | BDL |
| **4-Methylphenol (p-Cresol)** | 2.000 | BDL | BDL |
| **Hexachloroethane** | 2.000 | BDL | BDL |
| **Nitrobenzene** | 2.000 | BDL | BDL |
| **Isophorone** | 2.000 | BDL | BDL |
| **2-Nitrophenol** | 2.000 | BDL | BDL |
| **2,4-Dimethylphenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethoxy) methane** | 2.000 | BDL | BDL |
| **2,4-Dichlorophenol** | 2.000 | BDL | BDL |
| **1,3,5-Trichlorobenzene** | 2.000 | BDL | BDL |
| **Naphthalene** | 2.000 | BDL | BDL |
| **p-Chloroaniline** | 2.000 | BDL | BDL |
| **4-Chloro-3-methylphenol** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **2-Methylnaphthalene** | 2.000 | BDL | BDL |
| **Hexachlorocyclopentadiene** | 2.000 | BDL | BDL |
| **2,4,6-Trichlorophenol** | 2.000 | BDL | BDL |
| **2,4,5-Trichlorophenol** | 2.000 | BDL | BDL |
| **1-Chloronaphthalene** | 2.000 | BDL | BDL |
| **Diphenyl ether** | 2.000 | BDL | BDL |
| **2-Nitroaniline** | 2.000 | BDL | BDL |
| **Dimethyl phthalate** | 2.000 | BDL | BDL |
| **2-methyl-1,3-dinitro-Benzene** | 2.000 | BDL | BDL |
| **Acenaphthylene** | 2.000 | BDL | BDL |
| **Acenaphthene** | 2.000 | BDL | BDL |
| **Dibenzofuran** | 2.000 | BDL | BDL |
| **1-Methyl-2,4-dinitrobenzene** | 2.000 | BDL | BDL |
| **Diethylphthalate** | 2.000 | BDL | BDL |
| **1-chloro-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **dimethyl-Cyanamide** | 2.000 | BDL | BDL |
| **Fluorene** | 2.000 | BDL | BDL |
| **3-Methyl-2-phenylpyridine** | 2.000 | BDL | BDL |
| **Azobenzene** | 2.000 | BDL | BDL |
| **1-Bromo-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **Hexachlorobenzene** | 2.000 | BDL | BDL |
| **Pentachlorophenol** | 2.000 | BDL | BDL |
| **Phenanthrene** | 2.000 | BDL | BDL |
| **5H-Indeno[1,2-b]pyridine** | 2.000 | BDL | BDL |
| **Dibutyl phthalate** | 2.000 | BDL | BDL |
| **Fluoranthene** | 2.000 | 4.070 | 0.204 |
| **Benzyl butyl phthalate** | 2.000 | BDL | BDL |
| **Triphenylene** | 2.000 | BDL | BDL |
| **Benz[a]anthracene** | 2.000 | BDL | BDL |
| **Bis(2-ethylhexyl) phthalate** | 2.000 | BDL | BDL |
| **Di-n-octyl phthalate** | 2.000 | BDL | BDL |
| **Benzo[b]fluoranthene** | 2.000 | BDL | BDL |
| **Indenol[1,2,3-cd]pyrene** | 2.000 | BDL | BDL |
| **Benzo[b]triphenylene** | 2.000 | BDL | BDL |
| **Benzo[ghi]perylene** | 2.000 | BDL | BDL |

* UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit; A = SANAS accredited method; Where not specified, the methods are not accredited; All elements measured by GC-MS analysis

Table 3: Landfill assessment for: IW2020-0469 *

| Contaminant Name | Total (mg/kg) | Leachable (mg/L) | Waste Type |
|---|---|---|---|
| **Inorganic Anions** | | | |
| **TDS** | 1118.65 | 55.9325 | Type 4 |
| **Organic Compounds** | | | |
| **Benzene** | BDL | BDL | Type 3 |
| **Benzo(a)pyrene** | NT | NT | UTD |
| **Carbon tetrachloride** | BDL | BDL | Type 3 |
| **Chlorobenzene** | BDL | BDL | Type 3 |
| **Chloroform** | BDL | BDL | Type 3 |
| **2-Chlorophenol** | BDL | BDL | Type 3 |
| **Di (2 ethylhexyl) phthalate** | BDL | BDL | Type 3 |
| **1,2-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,4-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,2-Dichloroethane** | BDL | BDL | Type 3 |
| **1,1-Dichloroethylene** | NT | NT | UTD |
| **1,2-Dichloroethylene** | NT | NT | UTD |
| **Dichloromethane** | NT | NT | UTD |
| **2,4-Dichlorophenol** | BDL | BDL | Type 3 |
| **2,4-Dinitrotoluene** | NT | NT | UTD |
| **Ethylbenzene** | BDL | BDL | Type 3 |
| **Formaldehyde** | NT | NT | UTD |
| **Hexachlorobutadiene** | BDL | BDL | Type 3 |
| **Methyl ethyl ketone** | NT | NT | UTD |
| **MTBE (Methyl t-butyl ether)** | NT | NT | UTD |
| **Nitrobenzene** | BDL | BDL | Type 3 |
| **PAHs (total)** | 4.000 | N/A | Type 3 |
| **Petroleum H/Cs, C6 to C9** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C10 to C36** | BDL | N/A | Type 3 |
| **Phenols (total, non-halogenated)** | BDL | BDL | Type 3 |
| **Polychlorinated biphenyls** | NT | NT | UTD |
| **Styrene** | BDL | BDL | Type 3 |
| **1,1,1-Tetrachloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Tetrachloroethane** | BDL | BDL | Type 3 |
| **Tetrachloroethylene** | NT | NT | UTD |
| **Toluene** | BDL | BDL | Type 3 |

| | | | |
|---|---|---|---|
| **Trichlorobenzenes (Total)** | BDL | BDL | Type 3 |
| **1,1,1-Trichloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Trichloroethane** | BDL | BDL | Type 3 |
| **Trichlorophenol** | NT | NT | UTD |
| **2,4,6-Trichlorophenol** | BDL | BDL | Type 3 |
| **Vinyl Chloride** | NT | NT | UTD |
| **Xylene** | BDL | BDL | Type 3 |

*UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit;

**Determining the landfill site class for disposal:**

The assigned waste type determines the class of landfill site where a particular waste stream may be disposed. A waste type of one (Type 1) is assigned to waste that presents the most risk to the environment when disposed of at a landfill site and therefore requires disposal at a site with stringent engineering controls corresponding to a so called "Class A" site. Type four (Type 4) waste presents a low risk to the environment when disposed of to a landfill site and therefore may be disposed of at a less stringently engineered, "Class D" site. Type zero waste (Type 0) may not be disposed of to any landfill site in South Africa without prior treatment. The *National Waste Classification and Management Regulations* detail specific requirements surrounding the classification and assessment of waste for disposal to landfill (See references). Note that a GHS (SANS10234) compliant classification and safety data sheet is required before a final waste management decision should be taken and should be read in conjunction with this assessment.

**Standard Operational Procedure:**

Identification of analysis methods:

IW-S-1: Determination of Metals in Liquids and solids using ICP-OES Optima 8300; IW-S-2: Determination of the VOC content of liquid and solids using GC6850, MS5976C; IW-S-3: pH Measurement; IW-S-4: EC Measurement; IW-S-5: Calibration and measurement of samples using Supercal Modular calorimeter; IW-S-6: Toxicity characteristic leaching procedure – TCLP; IW-S-7: Field Protable X-ray Flourecence FTXRF; AS 4439.1-1999: Wastes, sediments and contaminated soils - Preparation of leachates - Preliminary assessment; AS 4439.3-1997: Wastes, sediments and contaminated soils - Preparation of leachates - Bottle leaching procedures.

**Scope of Accreditation:**

| Materials/Products Tested | Types of Tests | Standard Specifications, Equipment/Techniques Used |
|---|---|---|
| 1- Waste (Solid, sludge and liquid) | Quantification of metals by ICP-OES following ASLP, reagent water (Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Rb, P, Pb, Sb, Se, Sn, Sr, Ti, Tl, U, V, Zn) | IW-M-01 - Based on method 6010C |
| 2- Solids & Liquids | Determination of VOC; BTEX by GC/MS Headspace | IW-M-02 - Based on method EPA 8260B; EPA 5030B(Liquid) and EPA 5035 (solid) |
| 3- Potable water & leachates | pH at 25 $^{o}$C | IW-M-03 |
| 4- Potable water & leachates | Electrical Conductivity at 25$^{o}$C | IW-M-04 |

**Disclaimer:**

*Analysis results relate only to the samples submitted. The laboratory has no control over the sampling protocol, the representivity of the samples and the manner in which the samples were collected, transported, stored, preserved or otherwise handled outside of the laboratory facility and therefore takes no responsibility whatsoever for these activities. Third parties using INTERWASTE results can verify the results by contacting the laboratory. INTERWASTE are not liable or responsible for the customer use and/or interpretation of test results. This certificate cannot be reproduced without the written consent of INTERWASTE laboratory.*

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**References**

1.) Government Notice R.365, National Environmental Management: Waste Act (59/2008): National norms and standards for the assessment of waste for landfill disposal, Gazette No. 36

Signed by: Dr. Cheila Canario
Signed at: 2020-07-28 14:55:18 +02:00
Reason: Witnessing Dr. Cheila Canario

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# Sample Identification Number: IW2020-0468

| Laboratory Analysis Report for Landfill Assessment | | | |
|---|---|---|---|
| **Requested By:** | Keelan Chetty | **Waste Name:** | MF2 0.5-1M Slime Stockpile Chrome Direct Reduction |
| **Generator:** | Samancor Chrome | **Received Date:** | 12/06/2020 |
| **Lab Reference:** | IW2020-0468 | **Analysis Date:** | 03/07/2020 |
| **No. of Samples:** | 1 | **Report Date:** | 28/07/2020 |
| **Sample Description:** | Dark grey dry slime | | |

Table 1: Miscellaneous tests for sample: IW2020-0468 *

| Parameter Tested | Unit | IW2020-0468 |
|---|---|---|
| **Sample Moisture Content** | % (w/w) | 35.78 |
| **Conductivity** [A] | uS/cm | 2230 |
| **Initial Sample pH** [A] | pH Units | 8.92 |
| **Sample pH after HCl Addition** | pH Units | NT |
| **Leach Solution Applied** | Solution Type | Water |
| **Final Leach Solution pH** | pH Units | NT |
| **Physical State** | NA | Solid |
| **Water Miscibility** | NA | Immiscible |
| **Calorific Value** | MJ/kg | NT |
| **Additional Information** | NA | Low Odour |

* UTD = Unable to determine; NT = Not tested; A = SANAS accredited method; Where not specified, the methods are not accredited; Conductivity and pH measured by electronic conductivity and pH meter at ~22C (10% H2O extracts of solids). Moisture by mass loss on heating at ~103C for 30 mins.

Table 2: GC-MS total and leachable organics for sample: IW2020-0468 *

| Contaminant Name | Detection Limit (mg/kg) | Concentration (mg/kg) | Theoretical Max. Leach Concentration (mg/L) |
|---|---|---|---|
| **Nonane** | 2.000 | BDL | BDL |
| **Decane** | 2.000 | BDL | BDL |
| **Dodecane** | 2.000 | BDL | BDL |
| **Tetradecane** | 2.000 | BDL | BDL |
| **Hexadecane** | 2.000 | BDL | BDL |
| **Octadecane** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **Nonadecane** | 2.000 | BDL | BDL |
| **Eicosane** | 2.000 | BDL | BDL |
| **Docosane** | 2.000 | BDL | BDL |
| **Tetracosane** | 2.000 | BDL | BDL |
| **Hexacosane** | 2.000 | BDL | BDL |
| **Octacosane** | 2.000 | BDL | BDL |
| **Hentriacontane** | 2.000 | BDL | BDL |
| **n-Hexane** | 0.002 | BDL | BDL |
| **Heptane** | 0.002 | BDL | BDL |
| **Octane** | 0.002 | BDL | BDL |
| **Nonane2** | 0.002 | BDL | BDL |
| **Decane3** | 0.002 | BDL | BDL |
| **1,2-Dichloroethylene** [A] | 0.002 | BDL | BDL |
| **Chloroform** [A] | 0.002 | BDL | BDL |
| **1,1,1-Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,2-Dichloroethane** [A] | 0.002 | BDL | BDL |
| **1,1-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Benzene** [A] | 0.002 | BDL | BDL |
| **Carbon Tetrachloride** [A] | 0.002 | BDL | BDL |
| **Trichloroethylene** [A] | 0.002 | BDL | BDL |
| **Bromodichloromethane** [A] | 0.002 | BDL | BDL |
| **cis-1,3-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Toluene** [A] | 0.002 | BDL | BDL |
| **1,1,2 Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,3-Dichloropropane** [A] | 0.002 | BDL | BDL |
| **Dibromochloromethane** [A] | 0.002 | BDL | BDL |
| **1.2 Dibromoethane** [A] | 0.002 | BDL | BDL |
| **Tetrachloroethylene** [A] | 0.002 | BDL | BDL |
| **Chlorobenzene** [A] | 0.002 | BDL | BDL |
| **1,1,1,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |
| **Ethylbenzene** [A] | 0.002 | BDL | BDL |
| **o-Xylene** [A] | 0.002 | BDL | BDL |
| **Styrene** [A] | 0.002 | BDL | BDL |
| **1,1,2,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |

| | | | |
|---|---|---|---|
| **1,2,3-Trichloropropane** [A] | 0.002 | BDL | BDL |
| **Bromobenzene** [A] | 0.002 | BDL | BDL |
| **Propylbenzene** [A] | 0.002 | BDL | BDL |
| **4-Chlorotoluene** [A] | 0.002 | BDL | BDL |
| **1,2,3-Trimethylbenzene** [A] | 0.002 | BDL | BDL |
| **tert-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,4-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **sec-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,2-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **n-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **Hexachloroethane** [A] | 0.002 | BDL | BDL |
| **1,2 Dibromo-3-chloropropane** [A] | 0.002 | BDL | BDL |
| **1,3,5-Trichlorobenzene** [A] | 0.002 | BDL | BDL |
| **Naphthalene** [A] | 0.002 | BDL | BDL |
| **Hexachlorobutadiene** [A] | 0.002 | BDL | BDL |
| **Phenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethyl) ether** | 2.000 | BDL | BDL |
| **2-Chlorophenol** | 2.000 | BDL | BDL |
| **1,4-Dichlorobenzene** | 2.000 | BDL | BDL |
| **1,2-Dichlorobenzene** | 2.000 | BDL | BDL |
| **2-Methylphenol (o-Cresol)** | 2.000 | BDL | BDL |
| **Bis(2-chloro-1-methylethyl) ether** | 2.000 | BDL | BDL |
| **4-Methylphenol (p-Cresol)** | 2.000 | BDL | BDL |
| **Hexachloroethane** | 2.000 | BDL | BDL |
| **Nitrobenzene** | 2.000 | BDL | BDL |
| **Isophorone** | 2.000 | BDL | BDL |
| **2-Nitrophenol** | 2.000 | BDL | BDL |
| **2,4-Dimethylphenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethoxy) methane** | 2.000 | BDL | BDL |
| **2,4-Dichlorophenol** | 2.000 | BDL | BDL |
| **1,3,5-Trichlorobenzene** | 2.000 | BDL | BDL |
| **Naphthalene** | 2.000 | BDL | BDL |
| **p-Chloroaniline** | 2.000 | BDL | BDL |
| **4-Chloro-3-methylphenol** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **2-Methylnaphthalene** | 2.000 | BDL | BDL |
| **Hexachlorocyclopentadiene** | 2.000 | BDL | BDL |
| **2,4,6-Trichlorophenol** | 2.000 | BDL | BDL |
| **2,4,5-Trichlorophenol** | 2.000 | BDL | BDL |
| **1-Chloronaphthalene** | 2.000 | BDL | BDL |
| **Diphenyl ether** | 2.000 | BDL | BDL |
| **2-Nitroaniline** | 2.000 | BDL | BDL |
| **Dimethyl phthalate** | 2.000 | BDL | BDL |
| **2-methyl-1,3-dinitro-Benzene** | 2.000 | BDL | BDL |
| **Acenaphthylene** | 2.000 | BDL | BDL |
| **Acenaphthene** | 2.000 | BDL | BDL |
| **Dibenzofuran** | 2.000 | BDL | BDL |
| **1-Methyl-2,4-dinitrobenzene** | 2.000 | BDL | BDL |
| **Diethylphthalate** | 2.000 | BDL | BDL |
| **1-chloro-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **dimethyl-Cyanamide** | 2.000 | BDL | BDL |
| **Fluorene** | 2.000 | BDL | BDL |
| **3-Methyl-2-phenylpyridine** | 2.000 | BDL | BDL |
| **Azobenzene** | 2.000 | BDL | BDL |
| **1-Bromo-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **Hexachlorobenzene** | 2.000 | BDL | BDL |
| **Pentachlorophenol** | 2.000 | BDL | BDL |
| **Phenanthrene** | 2.000 | BDL | BDL |
| **5H-Indeno[1,2-b]pyridine** | 2.000 | BDL | BDL |
| **Dibutyl phthalate** | 2.000 | BDL | BDL |
| **Fluoranthene** | 2.000 | BDL | BDL |
| **Benzyl butyl phthalate** | 2.000 | BDL | BDL |
| **Triphenylene** | 2.000 | BDL | BDL |
| **Benz[a]anthracene** | 2.000 | BDL | BDL |
| **Bis(2-ethylhexyl) phthalate** | 2.000 | BDL | BDL |
| **Di-n-octyl phthalate** | 2.000 | BDL | BDL |
| **Benzo[b]fluoranthene** | 2.000 | BDL | BDL |
| **Indenol[1,2,3-cd]pyrene** | 2.000 | BDL | BDL |
| **Benzo[b]triphenylene** | 2.000 | BDL | BDL |
| **Benzo[ghi]perylene** | 2.000 | BDL | BDL |

* UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit; A = SANAS accredited method; Where not specified, the methods are not accredited; All elements measured by GC-MS analysis

Table 3: Landfill assessment for: IW2020-0468 *

| Contaminant Name | Total (mg/kg) | Leachable (mg/L) | Waste Type |
|---|---|---|---|
| **Inorganic Anions** | | | |
| **TDS** | 14495 | 724.75 | Type 4 |
| **Organic Compounds** | | | |
| **Benzene** | BDL | BDL | Type 3 |
| **Benzo(a)pyrene** | NT | NT | UTD |
| **Carbon tetrachloride** | BDL | BDL | Type 3 |
| **Chlorobenzene** | BDL | BDL | Type 3 |
| **Chloroform** | BDL | BDL | Type 3 |
| **2-Chlorophenol** | BDL | BDL | Type 3 |
| **Di (2 ethylhexyl) phthalate** | BDL | BDL | Type 3 |
| **1,2-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,4-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,2-Dichloroethane** | BDL | BDL | Type 3 |
| **1,1-Dichloroethylene** | NT | NT | UTD |
| **1,2-Dichloroethylene** | NT | NT | UTD |
| **Dichloromethane** | NT | NT | UTD |
| **2,4-Dichlorophenol** | BDL | BDL | Type 3 |
| **2,4-Dinitrotoluene** | NT | NT | UTD |
| **Ethylbenzene** | BDL | BDL | Type 3 |
| **Formaldehyde** | NT | NT | UTD |
| **Hexachlorobutadiene** | BDL | BDL | Type 3 |
| **Methyl ethyl ketone** | NT | NT | UTD |
| **MTBE (Methyl t-butyl ether)** | NT | NT | UTD |
| **Nitrobenzene** | BDL | BDL | Type 3 |
| **PAHs (total)** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C6 to C9** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C10 to C36** | BDL | N/A | Type 3 |
| **Phenols (total, non-halogenated)** | BDL | BDL | Type 3 |
| **Polychlorinated biphenyls** | NT | NT | UTD |
| **Styrene** | BDL | BDL | Type 3 |
| **1,1,1-Tetrachloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Tetrachloroethane** | BDL | BDL | Type 3 |
| **Tetrachloroethylene** | NT | NT | UTD |
| **Toluene** | BDL | BDL | Type 3 |

| | | | |
|---|---|---|---|
| **Trichlorobenzenes (Total)** | BDL | BDL | Type 3 |
| **1,1,1-Trichloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Trichloroethane** | BDL | BDL | Type 3 |
| **Trichlorophenol** | NT | NT | UTD |
| **2,4,6-Trichlorophenol** | BDL | BDL | Type 3 |
| **Vinyl Chloride** | NT | NT | UTD |
| **Xylene** | BDL | BDL | Type 3 |

*UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit;

**Determining the landfill site class for disposal:**

The assigned waste type determines the class of landfill site where a particular waste stream may be disposed. A waste type of one (Type 1) is assigned to waste that presents the most risk to the environment when disposed of at a landfill site and therefore requires disposal at a site with stringent engineering controls corresponding to a so called "Class A" site. Type four (Type 4) waste presents a low risk to the environment when disposed of to a landfill site and therefore may be disposed of at a less stringently engineered, "Class D" site. Type zero waste (Type 0) may not be disposed of to any landfill site in South Africa without prior treatment. The *National Waste Classification and Management Regulations* detail specific requirements surrounding the classification and assessment of waste for disposal to landfill (See references). Note that a GHS (SANS10234) compliant classification and safety data sheet is required before a final waste management decision should be taken and should be read in conjunction with this assessment.

**Standard Operational Procedure:**

Identification of analysis methods:

IW-S-1: Determination of Metals in Liquids and solids using ICP-OES Optima 8300; IW-S-2: Determination of the VOC content of liquid and solids using GC6850, MS5976C; IW-S-3: pH Measurement; IW-S-4: EC Measurement; IW-S-5: Calibration and measurement of samples using Supercal Modular calorimeter; IW-S-6: Toxicity characteristic leaching procedure – TCLP; IW-S-7: Field Protable X-ray Flourecence FTXRF; AS 4439.1-1999: Wastes, sediments and contaminated soils - Preparation of leachates - Preliminary assessment; AS 4439.3-1997: Wastes, sediments and contaminated soils - Preparation of leachates - Bottle leaching procedures.

**Scope of Accreditation:**

| Materials/Products Tested | Types of Tests | Standard Specifications, Equipment/Techniques Used |
|---|---|---|
| 1- Waste (Solid, sludge and liquid) | Quantification of metals by ICP-OES following ASLP, reagent water (Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Rb, P, Pb, Sb, Se, Sn, Sr, Ti, Tl, U, V, Zn) | IW-M-01 - Based on method 6010C |
| 2- Solids & Liquids | Determination of VOC; BTEX by GC/MS Headspace | IW-M-02 - Based on method EPA 8260B; EPA 5030B(Liquid) and EPA 5035 (solid) |
| 3- Potable water & leachates | pH at 25 $^{o}$C | IW-M-03 |
| 4- Potable water & leachates | Electrical Conductivity at 25$^{o}$C | IW-M-04 |

**Disclaimer:**

*Analysis results relate only to the samples submitted. The laboratory has no control over the sampling protocol, the representivity of the samples and the manner in which the samples were collected, transported, stored, preserved or otherwise handled outside of the laboratory facility and therefore takes no responsibility whatsoever for these activities. Third parties using INTERWASTE results can verify the results by contacting the laboratory. INTERWASTE are not liable or responsible for the customer use and/or interpretation of test results. This certificate cannot be reproduced without the written consent of INTERWASTE laboratory.*

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**References**

1.) Government Notice R.365, National Environmental Management: Waste Act (59/2008): National norms and standards for the assessment of waste for landfill disposal, Gazette No. 36

Signed by: Dr. Cheila Canario
Signed at: 2020-07-28 14:53:07 +02:00
Reason: Witnessing Dr. Cheila Canario

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# Sample Identification Number: IW2020-0467

| Laboratory Analysis Report for Landfill Assessment | | | |
|---|---|---|---|
| **Requested By:** | Keelan Chetty | **Waste Name:** | MF3 0.5-1.5M Slime Stockpile Chrome Direct Reduction |
| **Generator:** | Samancor Chrome | **Received Date:** | 12/06/2020 |
| **Lab Reference:** | IW2020-0467 | **Analysis Date:** | 03/07/2020 |
| **No. of Samples:** | 1 | **Report Date:** | 28/07/2020 |
| **Sample Description:** | Dark Grey coarse sample | | |

Table 1: Miscellaneous tests for sample: IW2020-0467 *

| Parameter Tested | Unit | IW2020-0467 |
|---|---|---|
| **Sample Moisture Content** | % (w/w) | 34.74 |
| **Conductivity** [A] | uS/cm | 298 |
| **Initial Sample pH** [A] | pH Units | 9.12 |
| **Sample pH after HCl Addition** | pH Units | NT |
| **Leach Solution Applied** | Solution Type | Water |
| **Final Leach Solution pH** | pH Units | NT |
| **Physical State** | NA | Solid |
| **Water Miscibility** | NA | Immiscible |
| **Calorific Value** | MJ/kg | NT |
| **Additional Information** | NA | Low Odour |

* UTD = Unable to determine; NT = Not tested; A = SANAS accredited method; Where not specified, the methods are not accredited; Conductivity and pH measured by electronic conductivity and pH meter at ~22C (10% H2O extracts of solids). Moisture by mass loss on heating at ~103C for 30 mins.

Table 2: GC-MS total and leachable organics for sample: IW2020-0467 *

| Contaminant Name | Detection Limit (mg/kg) | Concentration (mg/kg) | Theoretical Max. Leach Concentration (mg/L) |
|---|---|---|---|
| **Nonane** | 2.000 | BDL | BDL |
| **Decane** | 2.000 | BDL | BDL |
| **Dodecane** | 2.000 | BDL | BDL |
| **Tetradecane** | 2.000 | BDL | BDL |
| **Hexadecane** | 2.000 | BDL | BDL |
| **Octadecane** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **Nonadecane** | 2.000 | BDL | BDL |
| **Eicosane** | 2.000 | BDL | BDL |
| **Docosane** | 2.000 | BDL | BDL |
| **Tetracosane** | 2.000 | BDL | BDL |
| **Hexacosane** | 2.000 | BDL | BDL |
| **Octacosane** | 2.000 | BDL | BDL |
| **Hentriacontane** | 2.000 | BDL | BDL |
| **n-Hexane** | 0.002 | BDL | BDL |
| **Heptane** | 0.002 | BDL | BDL |
| **Octane** | 0.002 | BDL | BDL |
| **Nonane2** | 0.002 | BDL | BDL |
| **Decane3** | 0.002 | BDL | BDL |
| **1,2-Dichloroethylene** [A] | 0.002 | BDL | BDL |
| **Chloroform** [A] | 0.002 | BDL | BDL |
| **1,1,1-Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,2-Dichloroethane** [A] | 0.002 | BDL | BDL |
| **1,1-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Benzene** [A] | 0.002 | BDL | BDL |
| **Carbon Tetrachloride** [A] | 0.002 | BDL | BDL |
| **Trichloroethylene** [A] | 0.002 | BDL | BDL |
| **Bromodichloromethane** [A] | 0.002 | BDL | BDL |
| **cis-1,3-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Toluene** [A] | 0.002 | BDL | BDL |
| **1,1,2 Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,3-Dichloropropane** [A] | 0.002 | BDL | BDL |
| **Dibromochloromethane** [A] | 0.002 | BDL | BDL |
| **1.2 Dibromoethane** [A] | 0.002 | BDL | BDL |
| **Tetrachloroethylene** [A] | 0.002 | BDL | BDL |
| **Chlorobenzene** [A] | 0.002 | BDL | BDL |
| **1,1,1,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |
| **Ethylbenzene** [A] | 0.002 | BDL | BDL |
| **o-Xylene** [A] | 0.002 | BDL | BDL |
| **Styrene** [A] | 0.002 | BDL | BDL |
| **1,1,2,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |

| | | | |
|---|---|---|---|
| **1,2,3-Trichloropropane** [A] | 0.002 | BDL | BDL |
| **Bromobenzene** [A] | 0.002 | BDL | BDL |
| **Propylbenzene** [A] | 0.002 | BDL | BDL |
| **4-Chlorotoluene** [A] | 0.002 | BDL | BDL |
| **1,2,3-Trimethylbenzene** [A] | 0.002 | BDL | BDL |
| **tert-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,4-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **sec-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,2-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **n-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **Hexachloroethane** [A] | 0.002 | BDL | BDL |
| **1,2 Dibromo-3-chloropropane** [A] | 0.002 | BDL | BDL |
| **1,3,5-Trichlorobenzene** [A] | 0.002 | BDL | BDL |
| **Naphthalene** [A] | 0.002 | BDL | BDL |
| **Hexachlorobutadiene** [A] | 0.002 | BDL | BDL |
| **Phenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethyl) ether** | 2.000 | BDL | BDL |
| **2-Chlorophenol** | 2.000 | BDL | BDL |
| **1,4-Dichlorobenzene** | 2.000 | BDL | BDL |
| **1,2-Dichlorobenzene** | 2.000 | BDL | BDL |
| **2-Methylphenol (o-Cresol)** | 2.000 | BDL | BDL |
| **Bis(2-chloro-1-methylethyl) ether** | 2.000 | BDL | BDL |
| **4-Methylphenol (p-Cresol)** | 2.000 | BDL | BDL |
| **Hexachloroethane** | 2.000 | BDL | BDL |
| **Nitrobenzene** | 2.000 | BDL | BDL |
| **Isophorone** | 2.000 | BDL | BDL |
| **2-Nitrophenol** | 2.000 | BDL | BDL |
| **2,4-Dimethylphenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethoxy) methane** | 2.000 | BDL | BDL |
| **2,4-Dichlorophenol** | 2.000 | BDL | BDL |
| **1,3,5-Trichlorobenzene** | 2.000 | BDL | BDL |
| **Naphthalene** | 2.000 | BDL | BDL |
| **p-Chloroaniline** | 2.000 | BDL | BDL |
| **4-Chloro-3-methylphenol** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **2-Methylnaphthalene** | 2.000 | BDL | BDL |
| **Hexachlorocyclopentadiene** | 2.000 | BDL | BDL |
| **2,4,6-Trichlorophenol** | 2.000 | BDL | BDL |
| **2,4,5-Trichlorophenol** | 2.000 | BDL | BDL |
| **1-Chloronaphthalene** | 2.000 | BDL | BDL |
| **Diphenyl ether** | 2.000 | BDL | BDL |
| **2-Nitroaniline** | 2.000 | BDL | BDL |
| **Dimethyl phthalate** | 2.000 | BDL | BDL |
| **2-methyl-1,3-dinitro-Benzene** | 2.000 | BDL | BDL |
| **Acenaphthylene** | 2.000 | BDL | BDL |
| **Acenaphthene** | 2.000 | BDL | BDL |
| **Dibenzofuran** | 2.000 | BDL | BDL |
| **1-Methyl-2,4-dinitrobenzene** | 2.000 | BDL | BDL |
| **Diethylphthalate** | 2.000 | BDL | BDL |
| **1-chloro-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **dimethyl-Cyanamide** | 2.000 | BDL | BDL |
| **Fluorene** | 2.000 | BDL | BDL |
| **3-Methyl-2-phenylpyridine** | 2.000 | BDL | BDL |
| **Azobenzene** | 2.000 | BDL | BDL |
| **1-Bromo-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **Hexachlorobenzene** | 2.000 | BDL | BDL |
| **Pentachlorophenol** | 2.000 | BDL | BDL |
| **Phenanthrene** | 2.000 | BDL | BDL |
| **5H-Indeno[1,2-b]pyridine** | 2.000 | BDL | BDL |
| **Dibutyl phthalate** | 2.000 | BDL | BDL |
| **Fluoranthene** | 2.000 | BDL | BDL |
| **Benzyl butyl phthalate** | 2.000 | BDL | BDL |
| **Triphenylene** | 2.000 | BDL | BDL |
| **Benz[a]anthracene** | 2.000 | BDL | BDL |
| **Bis(2-ethylhexyl) phthalate** | 2.000 | BDL | BDL |
| **Di-n-octyl phthalate** | 2.000 | BDL | BDL |
| **Benzo[b]fluoranthene** | 2.000 | BDL | BDL |
| **Indenol[1,2,3-cd]pyrene** | 2.000 | BDL | BDL |
| **Benzo[b]triphenylene** | 2.000 | BDL | BDL |
| **Benzo[ghi]perylene** | 2.000 | BDL | BDL |

* UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit; A = SANAS accredited method; Where not specified, the methods are not accredited; All elements measured by GC-MS analysis

Table 3: Landfill assessment for: IW2020-0467 *

| Contaminant Name | Total (mg/kg) | Leachable (mg/L) | Waste Type |
|---|---|---|---|
| **Inorganic Anions** | | | |
| **TDS** | 1937 | 96.85 | Type 4 |
| **Organic Compounds** | | | |
| **Benzene** | BDL | BDL | Type 3 |
| **Benzo(a)pyrene** | NT | NT | UTD |
| **Carbon tetrachloride** | BDL | BDL | Type 3 |
| **Chlorobenzene** | BDL | BDL | Type 3 |
| **Chloroform** | BDL | BDL | Type 3 |
| **2-Chlorophenol** | BDL | BDL | Type 3 |
| **Di (2 ethylhexyl) phthalate** | BDL | BDL | Type 3 |
| **1,2-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,4-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,2-Dichloroethane** | BDL | BDL | Type 3 |
| **1,1-Dichloroethylene** | NT | NT | UTD |
| **1,2-Dichloroethylene** | NT | NT | UTD |
| **Dichloromethane** | NT | NT | UTD |
| **2,4-Dichlorophenol** | BDL | BDL | Type 3 |
| **2,4-Dinitrotoluene** | NT | NT | UTD |
| **Ethylbenzene** | BDL | BDL | Type 3 |
| **Formaldehyde** | NT | NT | UTD |
| **Hexachlorobutadiene** | BDL | BDL | Type 3 |
| **Methyl ethyl ketone** | NT | NT | UTD |
| **MTBE (Methyl t-butyl ether)** | NT | NT | UTD |
| **Nitrobenzene** | BDL | BDL | Type 3 |
| **PAHs (total)** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C6 to C9** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C10 to C36** | BDL | N/A | Type 3 |
| **Phenols (total, non-halogenated)** | BDL | BDL | Type 3 |
| **Polychlorinated biphenyls** | NT | NT | UTD |
| **Styrene** | BDL | BDL | Type 3 |
| **1,1,1-Tetrachloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Tetrachloroethane** | BDL | BDL | Type 3 |
| **Tetrachloroethylene** | NT | NT | UTD |
| **Toluene** | BDL | BDL | Type 3 |

| | | | |
|---|---|---|---|
| **Trichlorobenzenes (Total)** | BDL | BDL | Type 3 |
| **1,1,1-Trichloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Trichloroethane** | BDL | BDL | Type 3 |
| **Trichlorophenol** | NT | NT | UTD |
| **2,4,6-Trichlorophenol** | BDL | BDL | Type 3 |
| **Vinyl Chloride** | NT | NT | UTD |
| **Xylene** | BDL | BDL | Type 3 |

*UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit;

**Determining the landfill site class for disposal:**

The assigned waste type determines the class of landfill site where a particular waste stream may be disposed. A waste type of one (Type 1) is assigned to waste that presents the most risk to the environment when disposed of at a landfill site and therefore requires disposal at a site with stringent engineering controls corresponding to a so called "Class A" site. Type four (Type 4) waste presents a low risk to the environment when disposed of to a landfill site and therefore may be disposed of at a less stringently engineered, "Class D" site. Type zero waste (Type 0) may not be disposed of to any landfill site in South Africa without prior treatment. The *National Waste Classification and Management Regulations* detail specific requirements surrounding the classification and assessment of waste for disposal to landfill (See references). Note that a GHS (SANS10234) compliant classification and safety data sheet is required before a final waste management decision should be taken and should be read in conjunction with this assessment.

**Standard Operational Procedure:**

Identification of analysis methods:

IW-S-1: Determination of Metals in Liquids and solids using ICP-OES Optima 8300; IW-S-2: Determination of the VOC content of liquid and solids using GC6850, MS5976C; IW-S-3: pH Measurement; IW-S-4: EC Measurement; IW-S-5: Calibration and measurement of samples using Supercal Modular calorimeter; IW-S-6: Toxicity characteristic leaching procedure – TCLP; IW-S-7: Field Protable X-ray Flourecence FTXRF; AS 4439.1-1999: Wastes, sediments and contaminated soils - Preparation of leachates - Preliminary assessment; AS 4439.3-1997: Wastes, sediments and contaminated soils - Preparation of leachates - Bottle leaching procedures.

**Scope of Accreditation:**

| Materials/Products Tested | Types of Tests | Standard Specifications, Equipment/Techniques Used |
|---|---|---|
| 1- Waste (Solid, sludge and liquid) | Quantification of metals by ICP-OES following ASLP, reagent water (Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Rb, P, Pb, Sb, Se, Sn, Sr, Ti, Tl, U, V, Zn) | IW-M-01 - Based on method 6010C |
| 2- Solids & Liquids | Determination of VOC; BTEX by GC/MS Headspace | IW-M-02 - Based on method EPA 8260B; EPA 5030B(Liquid) and EPA 5035 (solid) |
| 3- Potable water & leachates | pH at 25 $^{o}$C | IW-M-03 |
| 4- Potable water & leachates | Electrical Conductivity at 25$^{o}$C | IW-M-04 |

**Disclaimer:**

*Analysis results relate only to the samples submitted. The laboratory has no control over the sampling protocol, the representivity of the samples and the manner in which the samples were collected, transported, stored, preserved or otherwise handled outside of the laboratory facility and therefore takes no responsibility whatsoever for these activities. Third parties using INTERWASTE results can verify the results by contacting the laboratory. INTERWASTE are not liable or responsible for the customer use and/or interpretation of test results. This certificate cannot be reproduced without the written consent of INTERWASTE laboratory.*

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**References**

1.) Government Notice R.365, National Environmental Management: Waste Act (59/2008): National norms and standards for the assessment of waste for landfill disposal, Gazette No. 36

Signed by: Dr. Cheila Canario
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## Sample Identification Number: IW2020-0466

| Laboratory Analysis Report for Landfill Assessment | | | |
|---|---|---|---|
| **Requested By:** | Keelan Chetty | **Waste Name:** | MF1 0-1M Slime Stockpile Chrome Direct Reduction |
| **Generator:** | Samancor Chrome | **Received Date:** | 12/06/2020 |
| **Lab Reference:** | IW2020-0466 | **Analysis Date:** | 03/07/2020 |
| **No. of Samples:** | 1 | **Report Date:** | 28/07/2020 |
| **Sample Description:** | Black Slime | | |

Table 1: Miscellaneous tests for sample: IW2020-0466 *

| Parameter Tested | Unit | IW2020-0466 |
|---|---|---|
| **Sample Moisture Content** | % (w/w) | 33.56 |
| **Conductivity** [A] | uS/cm | 117.2 |
| **Initial Sample pH** [A] | pH Units | 9.23 |
| **Sample pH after HCl Addition** | pH Units | NT |
| **Leach Solution Applied** | Solution Type | Water |
| **Final Leach Solution pH** | pH Units | NT |
| **Physical State** | NA | Solid |
| **Water Miscibility** | NA | Immiscible |
| **Calorific Value** | MJ/kg | NT |
| **Additional Information** | NA | Low Odour |

* UTD = Unable to determine; NT = Not tested; A = SANAS accredited method; Where not specified, the methods are not accredited; Conductivity and pH measured by electronic conductivity and pH meter at ~22C (10% H2O extracts of solids). Moisture by mass loss on heating at ~103C for 30 mins.

Table 2: GC-MS total and leachable organics for sample: IW2020-0466 *

| Contaminant Name | Detection Limit (mg/kg) | Concentration (mg/kg) | Theoretical Max. Leach Concentration (mg/L) |
|---|---|---|---|
| **Nonane** | 2.000 | BDL | BDL |
| **Decane** | 2.000 | BDL | BDL |
| **Dodecane** | 2.000 | BDL | BDL |
| **Tetradecane** | 2.000 | BDL | BDL |
| **Hexadecane** | 2.000 | BDL | BDL |
| **Octadecane** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **Nonadecane** | 2.000 | BDL | BDL |
| **Eicosane** | 2.000 | BDL | BDL |
| **Docosane** | 2.000 | BDL | BDL |
| **Tetracosane** | 2.000 | BDL | BDL |
| **Hexacosane** | 2.000 | BDL | BDL |
| **Octacosane** | 2.000 | BDL | BDL |
| **Hentriacontane** | 2.000 | BDL | BDL |
| **n-Hexane** | 0.002 | BDL | BDL |
| **Heptane** | 0.002 | BDL | BDL |
| **Octane** | 0.002 | BDL | BDL |
| **Nonane2** | 0.002 | BDL | BDL |
| **Decane3** | 0.002 | BDL | BDL |
| **1,2-Dichloroethylene** [A] | 0.002 | BDL | BDL |
| **Chloroform** [A] | 0.002 | BDL | BDL |
| **1,1,1-Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,2-Dichloroethane** [A] | 0.002 | BDL | BDL |
| **1,1-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Benzene** [A] | 0.002 | BDL | BDL |
| **Carbon Tetrachloride** [A] | 0.002 | BDL | BDL |
| **Trichloroethylene** [A] | 0.002 | BDL | BDL |
| **Bromodichloromethane** [A] | 0.002 | BDL | BDL |
| **cis-1,3-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Toluene** [A] | 0.002 | BDL | BDL |
| **1,1,2  Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,3-Dichloropropane** [A] | 0.002 | BDL | BDL |
| **Dibromochloromethane** [A] | 0.002 | BDL | BDL |
| **1.2 Dibromoethane** [A] | 0.002 | BDL | BDL |
| **Tetrachloroethylene** [A] | 0.002 | BDL | BDL |
| **Chlorobenzene** [A] | 0.002 | BDL | BDL |
| **1,1,1,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |
| **Ethylbenzene** [A] | 0.002 | BDL | BDL |
| **o-Xylene** [A] | 0.002 | BDL | BDL |
| **Styrene** [A] | 0.002 | BDL | BDL |
| **1,1,2,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |

| | | | |
|---|---|---|---|
| **1,2,3-Trichloropropane** [A] | 0.002 | BDL | BDL |
| **Bromobenzene** [A] | 0.002 | BDL | BDL |
| **Propylbenzene** [A] | 0.002 | BDL | BDL |
| **4-Chlorotoluene** [A] | 0.002 | BDL | BDL |
| **1,2,3-Trimethylbenzene** [A] | 0.002 | BDL | BDL |
| **tert-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,4-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **sec-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,2-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **n-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **Hexachloroethane** [A] | 0.002 | BDL | BDL |
| **1,2 Dibromo-3-chloropropane** [A] | 0.002 | BDL | BDL |
| **1,3,5-Trichlorobenzene** [A] | 0.002 | BDL | BDL |
| **Naphthalene** [A] | 0.002 | BDL | BDL |
| **Hexachlorobutadiene** [A] | 0.002 | BDL | BDL |
| **Phenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethyl) ether** | 2.000 | BDL | BDL |
| **2-Chlorophenol** | 2.000 | BDL | BDL |
| **1,4-Dichlorobenzene** | 2.000 | BDL | BDL |
| **1,2-Dichlorobenzene** | 2.000 | BDL | BDL |
| **2-Methylphenol (o-Cresol)** | 2.000 | BDL | BDL |
| **Bis(2-chloro-1-methylethyl) ether** | 2.000 | BDL | BDL |
| **4-Methylphenol (p-Cresol)** | 2.000 | BDL | BDL |
| **Hexachloroethane** | 2.000 | BDL | BDL |
| **Nitrobenzene** | 2.000 | BDL | BDL |
| **Isophorone** | 2.000 | BDL | BDL |
| **2-Nitrophenol** | 2.000 | BDL | BDL |
| **2,4-Dimethylphenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethoxy) methane** | 2.000 | BDL | BDL |
| **2,4-Dichlorophenol** | 2.000 | BDL | BDL |
| **1,3,5-Trichlorobenzene** | 2.000 | BDL | BDL |
| **Naphthalene** | 2.000 | BDL | BDL |
| **p-Chloroaniline** | 2.000 | BDL | BDL |
| **4-Chloro-3-methylphenol** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **2-Methylnaphthalene** | 2.000 | BDL | BDL |
| **Hexachlorocyclopentadiene** | 2.000 | BDL | BDL |
| **2,4,6-Trichlorophenol** | 2.000 | BDL | BDL |
| **2,4,5-Trichlorophenol** | 2.000 | BDL | BDL |
| **1-Chloronaphthalene** | 2.000 | BDL | BDL |
| **Diphenyl ether** | 2.000 | BDL | BDL |
| **2-Nitroaniline** | 2.000 | BDL | BDL |
| **Dimethyl phthalate** | 2.000 | BDL | BDL |
| **2-methyl-1,3-dinitro-Benzene** | 2.000 | BDL | BDL |
| **Acenaphthylene** | 2.000 | BDL | BDL |
| **Acenaphthene** | 2.000 | BDL | BDL |
| **Dibenzofuran** | 2.000 | BDL | BDL |
| **1-Methyl-2,4-dinitrobenzene** | 2.000 | BDL | BDL |
| **Diethylphthalate** | 2.000 | BDL | BDL |
| **1-chloro-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **dimethyl-Cyanamide** | 2.000 | BDL | BDL |
| **Fluorene** | 2.000 | BDL | BDL |
| **3-Methyl-2-phenylpyridine** | 2.000 | BDL | BDL |
| **Azobenzene** | 2.000 | BDL | BDL |
| **1-Bromo-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **Hexachlorobenzene** | 2.000 | BDL | BDL |
| **Pentachlorophenol** | 2.000 | BDL | BDL |
| **Phenanthrene** | 2.000 | BDL | BDL |
| **5H-Indeno[1,2-b]pyridine** | 2.000 | BDL | BDL |
| **Dibutyl phthalate** | 2.000 | BDL | BDL |
| **Fluoranthene** | 2.000 | BDL | BDL |
| **Benzyl butyl phthalate** | 2.000 | BDL | BDL |
| **Triphenylene** | 2.000 | BDL | BDL |
| **Benz[a]anthracene** | 2.000 | BDL | BDL |
| **Bis(2-ethylhexyl) phthalate** | 2.000 | BDL | BDL |
| **Di-n-octyl phthalate** | 2.000 | BDL | BDL |
| **Benzo[b]fluoranthene** | 2.000 | BDL | BDL |
| **Indenol[1,2,3-cd]pyrene** | 2.000 | BDL | BDL |
| **Benzo[b]triphenylene** | 2.000 | BDL | BDL |
| **Benzo[ghi]perylene** | 2.000 | BDL | BDL |

* UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit; A = SANAS accredited method; Where not specified, the methods are not accredited; All elements measured by GC-MS analysis

Table 3: Landfill assessment for: IW2020-0466 *

| Contaminant Name | Total (mg/kg) | Leachable (mg/L) | Waste Type |
|---|---|---|---|
| **Inorganic Anions** | | | |
| **TDS** | 761.8 | 38.09 | Type 4 |
| **Organic Compounds** | | | |
| **Benzene** | BDL | BDL | Type 3 |
| **Benzo(a)pyrene** | NT | NT | UTD |
| **Carbon tetrachloride** | BDL | BDL | Type 3 |
| **Chlorobenzene** | BDL | BDL | Type 3 |
| **Chloroform** | BDL | BDL | Type 3 |
| **2-Chlorophenol** | BDL | BDL | Type 3 |
| **Di (2 ethylhexyl) phthalate** | BDL | BDL | Type 3 |
| **1,2-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,4-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,2-Dichloroethane** | BDL | BDL | Type 3 |
| **1,1-Dichloroethylene** | NT | NT | UTD |
| **1,2-Dichloroethylene** | NT | NT | UTD |
| **Dichloromethane** | NT | NT | UTD |
| **2,4-Dichlorophenol** | BDL | BDL | Type 3 |
| **2,4-Dinitrotoluene** | NT | NT | UTD |
| **Ethylbenzene** | BDL | BDL | Type 3 |
| **Formaldehyde** | NT | NT | UTD |
| **Hexachlorobutadiene** | BDL | BDL | Type 3 |
| **Methyl ethyl ketone** | NT | NT | UTD |
| **MTBE (Methyl t-butyl ether)** | NT | NT | UTD |
| **Nitrobenzene** | BDL | BDL | Type 3 |
| **PAHs (total)** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C6 to C9** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C10 to C36** | BDL | N/A | Type 3 |
| **Phenols (total, non-halogenated)** | BDL | BDL | Type 3 |
| **Polychlorinated biphenyls** | NT | NT | UTD |
| **Styrene** | BDL | BDL | Type 3 |
| **1,1,1-Tetrachloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Tetrachloroethane** | BDL | BDL | Type 3 |
| **Tetrachloroethylene** | NT | NT | UTD |
| **Toluene** | BDL | BDL | Type 3 |

| | | | |
|---|---|---|---|
| **Trichlorobenzenes (Total)** | BDL | BDL | Type 3 |
| **1,1,1-Trichloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Trichloroethane** | BDL | BDL | Type 3 |
| **Trichlorophenol** | NT | NT | UTD |
| **2,4,6-Trichlorophenol** | BDL | BDL | Type 3 |
| **Vinyl Chloride** | NT | NT | UTD |
| **Xylene** | BDL | BDL | Type 3 |

*UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit;

**Determining the landfill site class for disposal:**

The assigned waste type determines the class of landfill site where a particular waste stream may be disposed. A waste type of one (Type 1) is assigned to waste that presents the most risk to the environment when disposed of at a landfill site and therefore requires disposal at a site with stringent engineering controls corresponding to a so called "Class A" site. Type four (Type 4) waste presents a low risk to the environment when disposed of to a landfill site and therefore may be disposed of at a less stringently engineered, "Class D" site. Type zero waste (Type 0) may not be disposed of to any landfill site in South Africa without prior treatment. The *National Waste Classification and Management Regulations* detail specific requirements surrounding the classification and assessment of waste for disposal to landfill (See references). Note that a GHS (SANS10234) compliant classification and safety data sheet is required before a final waste management decision should be taken and should be read in conjunction with this assessment.

**Standard Operational Procedure:**

Identification of analysis methods:

IW-S-1: Determination of Metals in Liquids and solids using ICP-OES Optima 8300; IW-S-2: Determination of the VOC content of liquid and solids using GC6850, MS5976C; IW-S-3: pH Measurement; IW-S-4: EC Measurement; IW-S-5: Calibration and measurement of samples using Supercal Modular calorimeter; IW-S-6: Toxicity characteristic leaching procedure – TCLP; IW-S-7: Field Protable X-ray Flourecence FTXRF; AS 4439.1-1999: Wastes, sediments and contaminated soils - Preparation of leachates - Preliminary assessment; AS 4439.3-1997: Wastes, sediments and contaminated soils - Preparation of leachates - Bottle leaching procedures.

**Scope of Accreditation:**

| Materials/Products Tested | Types of Tests | Standard Specifications, Equipment/Techniques Used |
|---|---|---|
| 1- Waste (Solid, sludge and liquid) | Quantification of metals by ICP-OES following ASLP, reagent water (Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Rb, P, Pb, Sb, Se, Sn, Sr, Ti, Tl, U, V, Zn) | IW-M-01 - Based on method 6010C |
| 2- Solids & Liquids | Determination of VOC; BTEX by GC/MS Headspace | IW-M-02 - Based on method EPA 8260B; EPA 5030B(Liquid) and EPA 5035 (solid) |
| 3- Potable water & leachates | pH at 25 $^{o}$C | IW-M-03 |
| 4- Potable water & leachates | Electrical Conductivity at 25$^{o}$C | IW-M-04 |

**Disclaimer:**

*Analysis results relate only to the samples submitted. The laboratory has no control over the sampling protocol, the representivity of the samples and the manner in which the samples were collected, transported, stored, preserved or otherwise handled outside of the laboratory facility and therefore takes no responsibility whatsoever for these activities. Third parties using INTERWASTE results can verify the results by contacting the laboratory. INTERWASTE are not liable or responsible for the customer use and/or interpretation of test results. This certificate cannot be reproduced without the written consent of INTERWASTE laboratory.*

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**References**

1.) Government Notice R.365, National Environmental Management: Waste Act (59/2008): National norms and standards for the assessment of waste for landfill disposal, Gazette No. 36

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# Sample Identification Number: IW2020-0465

| Laboratory Analysis Report for Landfill Assessment | | | |
|---|---|---|---|
| **Requested By:** | Keelan Chetty | **Waste Name:** | MF2 2-2.5M Slime Stockpile Chrome Direct Reduction |
| **Generator:** | Samancor Chrome | **Received Date:** | 12/06/2020 |
| **Lab Reference:** | IW2020-0465 | **Analysis Date:** | 03/07/2020 |
| **No. of Samples:** | 1 | **Report Date:** | 28/07/2020 |
| **Sample Description:** | Grey semi wet solid | | |

Table 1: Miscellaneous tests for sample: IW2020-0465 *

| Parameter Tested | Unit | IW2020-0465 |
|---|---|---|
| **Sample Moisture Content** | % (w/w) | 34.68 |
| **Conductivity** [A] | uS/cm | 1068 |
| **Initial Sample pH** [A] | pH Units | 8.8 |
| **Sample pH after HCl Addition** | pH Units | NT |
| **Leach Solution Applied** | Solution Type | Water |
| **Final Leach Solution pH** | pH Units | NT |
| **Physical State** | NA | Solid |
| **Water Miscibility** | NA | Immiscible |
| **Calorific Value** | MJ/kg | NT |
| **Additional Information** | NA | Low Odour |

* UTD = Unable to determine; NT = Not tested; A = SANAS accredited method; Where not specified, the methods are not accredited; Conductivity and pH measured by electronic conductivity and pH meter at ~22C (10% H2O extracts of solids). Moisture by mass loss on heating at ~103C for 30 mins.

Table 2: GC-MS total and leachable organics for sample: IW2020-0465 *

| Contaminant Name | Detection Limit (mg/kg) | Concentration (mg/kg) | Theoretical Max. Leach Concentration (mg/L) |
|---|---|---|---|
| **Nonane** | 2.000 | BDL | BDL |
| **Decane** | 2.000 | BDL | BDL |
| **Dodecane** | 2.000 | BDL | BDL |
| **Tetradecane** | 2.000 | BDL | BDL |
| **Hexadecane** | 2.000 | BDL | BDL |
| **Octadecane** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **Nonadecane** | 2.000 | BDL | BDL |
| **Eicosane** | 2.000 | BDL | BDL |
| **Docosane** | 2.000 | BDL | BDL |
| **Tetracosane** | 2.000 | BDL | BDL |
| **Hexacosane** | 2.000 | BDL | BDL |
| **Octacosane** | 2.000 | BDL | BDL |
| **Hentriacontane** | 2.000 | BDL | BDL |
| **n-Hexane** | 0.002 | BDL | BDL |
| **Heptane** | 0.002 | BDL | BDL |
| **Octane** | 0.002 | BDL | BDL |
| **Nonane2** | 0.002 | BDL | BDL |
| **Decane3** | 0.002 | BDL | BDL |
| **1,2-Dichloroethylene** [A] | 0.002 | BDL | BDL |
| **Chloroform** [A] | 0.002 | BDL | BDL |
| **1,1,1-Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,2-Dichloroethane** [A] | 0.002 | BDL | BDL |
| **1,1-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Benzene** [A] | 0.002 | BDL | BDL |
| **Carbon Tetrachloride** [A] | 0.002 | BDL | BDL |
| **Trichloroethylene** [A] | 0.002 | BDL | BDL |
| **Bromodichloromethane** [A] | 0.002 | BDL | BDL |
| **cis-1,3-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Toluene** [A] | 0.002 | BDL | BDL |
| **1,1,2 Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,3-Dichloropropane** [A] | 0.002 | BDL | BDL |
| **Dibromochloromethane** [A] | 0.002 | BDL | BDL |
| **1.2 Dibromoethane** [A] | 0.002 | BDL | BDL |
| **Tetrachloroethylene** [A] | 0.002 | BDL | BDL |
| **Chlorobenzene** [A] | 0.002 | BDL | BDL |
| **1,1,1,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |
| **Ethylbenzene** [A] | 0.002 | BDL | BDL |
| **o-Xylene** [A] | 0.002 | BDL | BDL |
| **Styrene** [A] | 0.002 | BDL | BDL |
| **1,1,2,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |

| | | | |
|---|---|---|---|
| **1,2,3-Trichloropropane** [A] | 0.002 | BDL | BDL |
| **Bromobenzene** [A] | 0.002 | BDL | BDL |
| **Propylbenzene** [A] | 0.002 | BDL | BDL |
| **4-Chlorotoluene** [A] | 0.002 | BDL | BDL |
| **1,2,3-Trimethylbenzene** [A] | 0.002 | BDL | BDL |
| **tert-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,4-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **sec-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,2-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **n-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **Hexachloroethane** [A] | 0.002 | BDL | BDL |
| **1,2 Dibromo-3-chloropropane** [A] | 0.002 | BDL | BDL |
| **1,3,5-Trichlorobenzene** [A] | 0.002 | BDL | BDL |
| **Naphthalene** [A] | 0.002 | BDL | BDL |
| **Hexachlorobutadiene** [A] | 0.002 | BDL | BDL |
| **Phenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethyl) ether** | 2.000 | BDL | BDL |
| **2-Chlorophenol** | 2.000 | BDL | BDL |
| **1,4-Dichlorobenzene** | 2.000 | BDL | BDL |
| **1,2-Dichlorobenzene** | 2.000 | BDL | BDL |
| **2-Methylphenol (o-Cresol)** | 2.000 | BDL | BDL |
| **Bis(2-chloro-1-methylethyl) ether** | 2.000 | BDL | BDL |
| **4-Methylphenol (p-Cresol)** | 2.000 | BDL | BDL |
| **Hexachloroethane** | 2.000 | BDL | BDL |
| **Nitrobenzene** | 2.000 | BDL | BDL |
| **Isophorone** | 2.000 | BDL | BDL |
| **2-Nitrophenol** | 2.000 | BDL | BDL |
| **2,4-Dimethylphenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethoxy) methane** | 2.000 | BDL | BDL |
| **2,4-Dichlorophenol** | 2.000 | BDL | BDL |
| **1,3,5-Trichlorobenzene** | 2.000 | BDL | BDL |
| **Naphthalene** | 2.000 | BDL | BDL |
| **p-Chloroaniline** | 2.000 | BDL | BDL |
| **4-Chloro-3-methylphenol** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **2-Methylnaphthalene** | 2.000 | BDL | BDL |
| **Hexachlorocyclopentadiene** | 2.000 | BDL | BDL |
| **2,4,6-Trichlorophenol** | 2.000 | BDL | BDL |
| **2,4,5-Trichlorophenol** | 2.000 | BDL | BDL |
| **1-Chloronaphthalene** | 2.000 | BDL | BDL |
| **Diphenyl ether** | 2.000 | BDL | BDL |
| **2-Nitroaniline** | 2.000 | BDL | BDL |
| **Dimethyl phthalate** | 2.000 | BDL | BDL |
| **2-methyl-1,3-dinitro-Benzene** | 2.000 | BDL | BDL |
| **Acenaphthylene** | 2.000 | BDL | BDL |
| **Acenaphthene** | 2.000 | BDL | BDL |
| **Dibenzofuran** | 2.000 | BDL | BDL |
| **1-Methyl-2,4-dinitrobenzene** | 2.000 | BDL | BDL |
| **Diethylphthalate** | 2.000 | BDL | BDL |
| **1-chloro-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **dimethyl-Cyanamide** | 2.000 | BDL | BDL |
| **Fluorene** | 2.000 | BDL | BDL |
| **3-Methyl-2-phenylpyridine** | 2.000 | BDL | BDL |
| **Azobenzene** | 2.000 | BDL | BDL |
| **1-Bromo-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **Hexachlorobenzene** | 2.000 | BDL | BDL |
| **Pentachlorophenol** | 2.000 | BDL | BDL |
| **Phenanthrene** | 2.000 | BDL | BDL |
| **5H-Indeno[1,2-b]pyridine** | 2.000 | BDL | BDL |
| **Dibutyl phthalate** | 2.000 | BDL | BDL |
| **Fluoranthene** | 2.000 | BDL | BDL |
| **Benzyl butyl phthalate** | 2.000 | BDL | BDL |
| **Triphenylene** | 2.000 | BDL | BDL |
| **Benz[a]anthracene** | 2.000 | BDL | BDL |
| **Bis(2-ethylhexyl) phthalate** | 2.000 | BDL | BDL |
| **Di-n-octyl phthalate** | 2.000 | BDL | BDL |
| **Benzo[b]fluoranthene** | 2.000 | BDL | BDL |
| **Indenol[1,2,3-cd]pyrene** | 2.000 | BDL | BDL |
| **Benzo[b]triphenylene** | 2.000 | BDL | BDL |
| **Benzo[ghi]perylene** | 2.000 | BDL | BDL |

* UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit; A = SANAS accredited method; Where not specified, the methods are not accredited; All elements measured by GC-MS analysis

Table 3: Landfill assessment for: IW2020-0465 *

| Contaminant Name | Total (mg/kg) | Leachable (mg/L) | Waste Type |
|---|---|---|---|
| **Inorganic Anions** | | | |
| **TDS** | 6942 | 347.1 | Type 4 |
| **Organic Compounds** | | | |
| **Benzene** | BDL | BDL | Type 3 |
| **Benzo(a)pyrene** | NT | NT | UTD |
| **Carbon tetrachloride** | BDL | BDL | Type 3 |
| **Chlorobenzene** | BDL | BDL | Type 3 |
| **Chloroform** | BDL | BDL | Type 3 |
| **2-Chlorophenol** | BDL | BDL | Type 3 |
| **Di (2 ethylhexyl) phthalate** | BDL | BDL | Type 3 |
| **1,2-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,4-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,2-Dichloroethane** | BDL | BDL | Type 3 |
| **1,1-Dichloroethylene** | NT | NT | UTD |
| **1,2-Dichloroethylene** | NT | NT | UTD |
| **Dichloromethane** | NT | NT | UTD |
| **2,4-Dichlorophenol** | BDL | BDL | Type 3 |
| **2,4-Dinitrotoluene** | NT | NT | UTD |
| **Ethylbenzene** | BDL | BDL | Type 3 |
| **Formaldehyde** | NT | NT | UTD |
| **Hexachlorobutadiene** | BDL | BDL | Type 3 |
| **Methyl ethyl ketone** | NT | NT | UTD |
| **MTBE (Methyl t-butyl ether)** | NT | NT | UTD |
| **Nitrobenzene** | BDL | BDL | Type 3 |
| **PAHs (total)** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C6 to C9** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C10 to C36** | BDL | N/A | Type 3 |
| **Phenols (total, non-halogenated)** | BDL | BDL | Type 3 |
| **Polychlorinated biphenyls** | NT | NT | UTD |
| **Styrene** | BDL | BDL | Type 3 |
| **1,1,1-Tetrachloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Tetrachloroethane** | BDL | BDL | Type 3 |
| **Tetrachloroethylene** | NT | NT | UTD |
| **Toluene** | BDL | BDL | Type 3 |

| | | | |
|---|---|---|---|
| **Trichlorobenzenes (Total)** | BDL | BDL | Type 3 |
| **1,1,1-Trichloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Trichloroethane** | BDL | BDL | Type 3 |
| **Trichlorophenol** | NT | NT | UTD |
| **2,4,6-Trichlorophenol** | BDL | BDL | Type 3 |
| **Vinyl Chloride** | NT | NT | UTD |
| **Xylene** | BDL | BDL | Type 3 |

*UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit;

**Determining the landfill site class for disposal:**

The assigned waste type determines the class of landfill site where a particular waste stream may be disposed. A waste type of one (Type 1) is assigned to waste that presents the most risk to the environment when disposed of at a landfill site and therefore requires disposal at a site with stringent engineering controls corresponding to a so called "Class A" site. Type four (Type 4) waste presents a low risk to the environment when disposed of to a landfill site and therefore may be disposed of at a less stringently engineered, "Class D" site. Type zero waste (Type 0) may not be disposed of to any landfill site in South Africa without prior treatment. The *National Waste Classification and Management Regulations* detail specific requirements surrounding the classification and assessment of waste for disposal to landfill (See references). Note that a GHS (SANS10234) compliant classification and safety data sheet is required before a final waste management decision should be taken and should be read in conjunction with this assessment.

**Standard Operational Procedure:**

Identification of analysis methods:

IW-S-1: Determination of Metals in Liquids and solids using ICP-OES Optima 8300; IW-S-2: Determination of the VOC content of liquid and solids using GC6850, MS5976C; IW-S-3: pH Measurement; IW-S-4: EC Measurement; IW-S-5: Calibration and measurement of samples using Supercal Modular calorimeter; IW-S-6: Toxicity characteristic leaching procedure – TCLP; IW-S-7: Field Protable X-ray Flourecence FTXRF; AS 4439.1-1999: Wastes, sediments and contaminated soils - Preparation of leachates - Preliminary assessment; AS 4439.3-1997: Wastes, sediments and contaminated soils - Preparation of leachates - Bottle leaching procedures.

**Scope of Accreditation:**

| Materials/Products Tested | Types of Tests | Standard Specifications, Equipment/Techniques Used |
|---|---|---|
| 1- Waste (Solid, sludge and liquid) | Quantification of metals by ICP-OES following ASLP, reagent water (Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Rb, P, Pb, Sb, Se, Sn, Sr, Ti, Tl, U, V, Zn) | IW-M-01 - Based on method 6010C |
| 2- Solids & Liquids | Determination of VOC; BTEX by GC/MS Headspace | IW-M-02 - Based on method EPA 8260B; EPA 5030B(Liquid) and EPA 5035 (solid) |
| 3- Potable water & leachates | pH at 25 $^{o}$C | IW-M-03 |
| 4- Potable water & leachates | Electrical Conductivity at 25$^{o}$C | IW-M-04 |

**Disclaimer:**

*Analysis results relate only to the samples submitted. The laboratory has no control over the sampling protocol, the representivity of the samples and the manner in which the samples were collected, transported, stored, preserved or otherwise handled outside of the laboratory facility and therefore takes no responsibility whatsoever for these activities. Third parties using INTERWASTE results can verify the results by contacting the laboratory. INTERWASTE are not liable or responsible for the customer use and/or interpretation of test results. This certificate cannot be reproduced without the written consent of INTERWASTE laboratory.*

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**References**

1.) Government Notice R.365, National Environmental Management: Waste Act (59/2008): National norms and standards for the assessment of waste for landfill disposal, Gazette No. 36

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## Sample Identification Number: IW2020-0464

| Laboratory Analysis Report for Landfill Assessment | | | |
|---|---|---|---|
| **Requested By:** | Keelan Chetty | **Waste Name:** | MF4 0.5-1.5M Slime Stockpile Chrome Direct Reduction |
| **Generator:** | Samancor Chrome | **Received Date:** | 12/06/2020 |
| **Lab Reference:** | IW2020-0464 | **Analysis Date:** | 03/07/2020 |
| **No. of Samples:** | 1 | **Report Date:** | 28/07/2020 |
| **Sample Description:** | Grey Gravel Slime | | |

Table 1: Miscellaneous tests for sample: IW2020-0464 *

| Parameter Tested | Unit | IW2020-0464 |
|---|---|---|
| **Sample Moisture Content** | % (w/w) | 39.26 |
| **Conductivity** [A] | uS/cm | 1144 |
| **Initial Sample pH** [A] | pH Units | 9.54 |
| **Sample pH after HCl Addition** | pH Units | NT |
| **Leach Solution Applied** | Solution Type | Water |
| **Final Leach Solution pH** | pH Units | NT |
| **Physical State** | NA | Solid |
| **Water Miscibility** | NA | Immiscible |
| **Calorific Value** | MJ/kg | NT |
| **Additional Information** | NA | Low Odour |

* UTD = Unable to determine; NT = Not tested; A = SANAS accredited method; Where not specified, the methods are not accredited; Conductivity and pH measured by electronic conductivity and pH meter at ~22C (10% H2O extracts of solids). Moisture by mass loss on heating at ~103C for 30 mins.

Table 2: GC-MS total and leachable organics for sample: IW2020-0464 *

| Contaminant Name | Detection Limit (mg/kg) | Concentration (mg/kg) | Theoretical Max. Leach Concentration (mg/L) |
|---|---|---|---|
| **Nonane** | 2.000 | BDL | BDL |
| **Decane** | 2.000 | BDL | BDL |
| **Dodecane** | 2.000 | BDL | BDL |
| **Tetradecane** | 2.000 | BDL | BDL |
| **Hexadecane** | 2.000 | BDL | BDL |
| **Octadecane** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **Nonadecane** | 2.000 | BDL | BDL |
| **Eicosane** | 2.000 | BDL | BDL |
| **Docosane** | 2.000 | BDL | BDL |
| **Tetracosane** | 2.000 | BDL | BDL |
| **Hexacosane** | 2.000 | BDL | BDL |
| **Octacosane** | 2.000 | BDL | BDL |
| **Hentriacontane** | 2.000 | BDL | BDL |
| **n-Hexane** | 0.002 | BDL | BDL |
| **Heptane** | 0.002 | BDL | BDL |
| **Octane** | 0.002 | BDL | BDL |
| **Nonane2** | 0.002 | BDL | BDL |
| **Decane3** | 0.002 | BDL | BDL |
| **1,2-Dichloroethylene** [A] | 0.002 | BDL | BDL |
| **Chloroform** [A] | 0.002 | BDL | BDL |
| **1,1,1-Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,2-Dichloroethane** [A] | 0.002 | BDL | BDL |
| **1,1-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Benzene** [A] | 0.002 | BDL | BDL |
| **Carbon Tetrachloride** [A] | 0.002 | BDL | BDL |
| **Trichloroethylene** [A] | 0.002 | BDL | BDL |
| **Bromodichloromethane** [A] | 0.002 | BDL | BDL |
| **cis-1,3-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Toluene** [A] | 0.002 | BDL | BDL |
| **1,1,2 Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,3-Dichloropropane** [A] | 0.002 | BDL | BDL |
| **Dibromochloromethane** [A] | 0.002 | BDL | BDL |
| **1.2 Dibromoethane** [A] | 0.002 | BDL | BDL |
| **Tetrachloroethylene** [A] | 0.002 | BDL | BDL |
| **Chlorobenzene** [A] | 0.002 | BDL | BDL |
| **1,1,1,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |
| **Ethylbenzene** [A] | 0.002 | BDL | BDL |
| **o-Xylene** [A] | 0.002 | BDL | BDL |
| **Styrene** [A] | 0.002 | BDL | BDL |
| **1,1,2,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |

| | | | |
|---|---|---|---|
| **1,2,3-Trichloropropane** [A] | 0.002 | BDL | BDL |
| **Bromobenzene** [A] | 0.002 | BDL | BDL |
| **Propylbenzene** [A] | 0.002 | BDL | BDL |
| **4-Chlorotoluene** [A] | 0.002 | BDL | BDL |
| **1,2,3-Trimethylbenzene** [A] | 0.002 | BDL | BDL |
| **tert-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,4-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **sec-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,2-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **n-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **Hexachloroethane** [A] | 0.002 | BDL | BDL |
| **1,2 Dibromo-3-chloropropane** [A] | 0.002 | BDL | BDL |
| **1,3,5-Trichlorobenzene** [A] | 0.002 | BDL | BDL |
| **Naphthalene** [A] | 0.002 | BDL | BDL |
| **Hexachlorobutadiene** [A] | 0.002 | BDL | BDL |
| **Phenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethyl) ether** | 2.000 | BDL | BDL |
| **2-Chlorophenol** | 2.000 | BDL | BDL |
| **1,4-Dichlorobenzene** | 2.000 | BDL | BDL |
| **1,2-Dichlorobenzene** | 2.000 | BDL | BDL |
| **2-Methylphenol (o-Cresol)** | 2.000 | BDL | BDL |
| **Bis(2-chloro-1-methylethyl) ether** | 2.000 | BDL | BDL |
| **4-Methylphenol (p-Cresol)** | 2.000 | BDL | BDL |
| **Hexachloroethane** | 2.000 | BDL | BDL |
| **Nitrobenzene** | 2.000 | BDL | BDL |
| **Isophorone** | 2.000 | BDL | BDL |
| **2-Nitrophenol** | 2.000 | BDL | BDL |
| **2,4-Dimethylphenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethoxy) methane** | 2.000 | BDL | BDL |
| **2,4-Dichlorophenol** | 2.000 | BDL | BDL |
| **1,3,5-Trichlorobenzene** | 2.000 | BDL | BDL |
| **Naphthalene** | 2.000 | BDL | BDL |
| **p-Chloroaniline** | 2.000 | BDL | BDL |
| **4-Chloro-3-methylphenol** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **2-Methylnaphthalene** | 2.000 | BDL | BDL |
| **Hexachlorocyclopentadiene** | 2.000 | BDL | BDL |
| **2,4,6-Trichlorophenol** | 2.000 | BDL | BDL |
| **2,4,5-Trichlorophenol** | 2.000 | BDL | BDL |
| **1-Chloronaphthalene** | 2.000 | BDL | BDL |
| **Diphenyl ether** | 2.000 | BDL | BDL |
| **2-Nitroaniline** | 2.000 | BDL | BDL |
| **Dimethyl phthalate** | 2.000 | BDL | BDL |
| **2-methyl-1,3-dinitro-Benzene** | 2.000 | BDL | BDL |
| **Acenaphthylene** | 2.000 | BDL | BDL |
| **Acenaphthene** | 2.000 | BDL | BDL |
| **Dibenzofuran** | 2.000 | BDL | BDL |
| **1-Methyl-2,4-dinitrobenzene** | 2.000 | BDL | BDL |
| **Diethylphthalate** | 2.000 | BDL | BDL |
| **1-chloro-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **dimethyl-Cyanamide** | 2.000 | BDL | BDL |
| **Fluorene** | 2.000 | BDL | BDL |
| **3-Methyl-2-phenylpyridine** | 2.000 | BDL | BDL |
| **Azobenzene** | 2.000 | BDL | BDL |
| **1-Bromo-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **Hexachlorobenzene** | 2.000 | BDL | BDL |
| **Pentachlorophenol** | 2.000 | BDL | BDL |
| **Phenanthrene** | 2.000 | BDL | BDL |
| **5H-Indeno[1,2-b]pyridine** | 2.000 | BDL | BDL |
| **Dibutyl phthalate** | 2.000 | BDL | BDL |
| **Fluoranthene** | 2.000 | BDL | BDL |
| **Benzyl butyl phthalate** | 2.000 | BDL | BDL |
| **Triphenylene** | 2.000 | BDL | BDL |
| **Benz[a]anthracene** | 2.000 | BDL | BDL |
| **Bis(2-ethylhexyl) phthalate** | 2.000 | BDL | BDL |
| **Di-n-octyl phthalate** | 2.000 | BDL | BDL |
| **Benzo[b]fluoranthene** | 2.000 | BDL | BDL |
| **Indenol[1,2,3-cd]pyrene** | 2.000 | BDL | BDL |
| **Benzo[b]triphenylene** | 2.000 | BDL | BDL |
| **Benzo[ghi]perylene** | 2.000 | BDL | BDL |

* UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit; A = SANAS accredited method; Where not specified, the methods are not accredited; All elements measured by GC-MS analysis

Table 3: Landfill assessment for: IW2020-0464 *

| Contaminant Name | Total (mg/kg) | Leachable (mg/L) | Waste Type |
|---|---|---|---|
| **Inorganic Anions** | | | |
| **TDS** | 7436 | 371.8 | Type 4 |
| **Organic Compounds** | | | |
| **Benzene** | BDL | BDL | Type 3 |
| **Benzo(a)pyrene** | NT | NT | UTD |
| **Carbon tetrachloride** | BDL | BDL | Type 3 |
| **Chlorobenzene** | BDL | BDL | Type 3 |
| **Chloroform** | BDL | BDL | Type 3 |
| **2-Chlorophenol** | BDL | BDL | Type 3 |
| **Di (2 ethylhexyl) phthalate** | BDL | BDL | Type 3 |
| **1,2-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,4-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,2-Dichloroethane** | BDL | BDL | Type 3 |
| **1,1-Dichloroethylene** | NT | NT | UTD |
| **1,2-Dichloroethylene** | NT | NT | UTD |
| **Dichloromethane** | NT | NT | UTD |
| **2,4-Dichlorophenol** | BDL | BDL | Type 3 |
| **2,4-Dinitrotoluene** | NT | NT | UTD |
| **Ethylbenzene** | BDL | BDL | Type 3 |
| **Formaldehyde** | NT | NT | UTD |
| **Hexachlorobutadiene** | BDL | BDL | Type 3 |
| **Methyl ethyl ketone** | NT | NT | UTD |
| **MTBE (Methyl t-butyl ether)** | NT | NT | UTD |
| **Nitrobenzene** | BDL | BDL | Type 3 |
| **PAHs (total)** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C6 to C9** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C10 to C36** | BDL | N/A | Type 3 |
| **Phenols (total, non-halogenated)** | BDL | BDL | Type 3 |
| **Polychlorinated biphenyls** | NT | NT | UTD |
| **Styrene** | BDL | BDL | Type 3 |
| **1,1,1-Tetrachloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Tetrachloroethane** | BDL | BDL | Type 3 |
| **Tetrachloroethylene** | NT | NT | UTD |
| **Toluene** | BDL | BDL | Type 3 |

| | | | |
|---|---|---|---|
| **Trichlorobenzenes (Total)** | BDL | BDL | Type 3 |
| **1,1,1-Trichloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Trichloroethane** | BDL | BDL | Type 3 |
| **Trichlorophenol** | NT | NT | UTD |
| **2,4,6-Trichlorophenol** | BDL | BDL | Type 3 |
| **Vinyl Chloride** | NT | NT | UTD |
| **Xylene** | BDL | BDL | Type 3 |

*UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit;

**Determining the landfill site class for disposal:**

The assigned waste type determines the class of landfill site where a particular waste stream may be disposed. A waste type of one (Type 1) is assigned to waste that presents the most risk to the environment when disposed of at a landfill site and therefore requires disposal at a site with stringent engineering controls corresponding to a so called "Class A" site. Type four (Type 4) waste presents a low risk to the environment when disposed of to a landfill site and therefore may be disposed of at a less stringently engineered, "Class D" site. Type zero waste (Type 0) may not be disposed of to any landfill site in South Africa without prior treatment. The *National Waste Classification and Management Regulations* detail specific requirements surrounding the classification and assessment of waste for disposal to landfill (See references). Note that a GHS (SANS10234) compliant classification and safety data sheet is required before a final waste management decision should be taken and should be read in conjunction with this assessment.

**Standard Operational Procedure:**

Identification of analysis methods:

IW-S-1: Determination of Metals in Liquids and solids using ICP-OES Optima 8300; IW-S-2: Determination of the VOC content of liquid and solids using GC6850, MS5976C; IW-S-3: pH Measurement; IW-S-4: EC Measurement; IW-S-5: Calibration and measurement of samples using Supercal Modular calorimeter; IW-S-6: Toxicity characteristic leaching procedure – TCLP; IW-S-7: Field Protable X-ray Flourecence FTXRF; AS 4439.1-1999: Wastes, sediments and contaminated soils - Preparation of leachates - Preliminary assessment; AS 4439.3-1997: Wastes, sediments and contaminated soils - Preparation of leachates - Bottle leaching procedures.

**Scope of Accreditation:**

| Materials/Products Tested | Types of Tests | Standard Specifications, Equipment/Techniques Used |
|---|---|---|
| 1- Waste (Solid, sludge and liquid) | Quantification of metals by ICP-OES following ASLP, reagent water (Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Rb, P, Pb, Sb, Se, Sn, Sr, Ti, Tl, U, V, Zn) | IW-M-01 - Based on method 6010C |
| 2- Solids & Liquids | Determination of VOC; BTEX by GC/MS Headspace | IW-M-02 - Based on method EPA 8260B; EPA 5030B(Liquid) and EPA 5035 (solid) |
| 3- Potable water & leachates | pH at 25 $^{o}$C | IW-M-03 |
| 4- Potable water & leachates | Electrical Conductivity at 25$^{o}$C | IW-M-04 |

**Disclaimer:**

*Analysis results relate only to the samples submitted. The laboratory has no control over the sampling protocol, the representivity of the samples and the manner in which the samples were collected, transported, stored, preserved or otherwise handled outside of the laboratory facility and therefore takes no responsibility whatsoever for these activities. Third parties using INTERWASTE results can verify the results by contacting the laboratory. INTERWASTE are not liable or responsible for the customer use and/or interpretation of test results. This certificate cannot be reproduced without the written consent of INTERWASTE laboratory.*

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**References**

1.) Government Notice R.365, National Environmental Management: Waste Act (59/2008): National norms and standards for the assessment of waste for landfill disposal, Gazette No. 36

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## Sample Identification Number: IW2020-0463

| Laboratory Analysis Report for Landfill Assessment | | | |
|---|---|---|---|
| **Requested By:** | Keelan Chetty | **Waste Name:** | MF1 1-2M Slime Stockpile Chrome Direct Reduction |
| **Generator:** | Samancor Chrome | **Received Date:** | 12/06/2020 |
| **Lab Reference:** | IW2020-0463 | **Analysis Date:** | 03/07/2020 |
| **No. of Samples:** | 1 | **Report Date:** | 28/07/2020 |
| **Sample Description:** | Black Solid Slime | | |

Table 1: Miscellaneous tests for sample: IW2020-0463 *

| Parameter Tested | Unit | IW2020-0463 |
|---|---|---|
| **Sample Moisture Content** | % (w/w) | 33.17 |
| **Conductivity** [A] | uS/cm | 491 |
| **Initial Sample pH** [A] | pH Units | 7.34 |
| **Sample pH after HCl Addition** | pH Units | NT |
| **Leach Solution Applied** | Solution Type | Water |
| **Final Leach Solution pH** | pH Units | NT |
| **Physical State** | NA | Solid |
| **Water Miscibility** | NA | Immiscible |
| **Calorific Value** | MJ/kg | NT |
| **Additional Information** | NA | Low Odour |

* UTD = Unable to determine; NT = Not tested; A = SANAS accredited method; Where not specified, the methods are not accredited; Conductivity and pH measured by electronic conductivity and pH meter at ~22C (10% H2O extracts of solids). Moisture by mass loss on heating at ~103C for 30 mins.

Table 2: GC-MS total and leachable organics for sample: IW2020-0463 *

| Contaminant Name | Detection Limit (mg/kg) | Concentration (mg/kg) | Theoretical Max. Leach Concentration (mg/L) |
|---|---|---|---|
| **Nonane** | 2.000 | BDL | BDL |
| **Decane** | 2.000 | BDL | BDL |
| **Dodecane** | 2.000 | BDL | BDL |
| **Tetradecane** | 2.000 | BDL | BDL |
| **Hexadecane** | 2.000 | BDL | BDL |
| **Octadecane** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **Nonadecane** | 2.000 | BDL | BDL |
| **Eicosane** | 2.000 | BDL | BDL |
| **Docosane** | 2.000 | BDL | BDL |
| **Tetracosane** | 2.000 | BDL | BDL |
| **Hexacosane** | 2.000 | BDL | BDL |
| **Octacosane** | 2.000 | BDL | BDL |
| **Hentriacontane** | 2.000 | BDL | BDL |
| **n-Hexane** | 0.002 | BDL | BDL |
| **Heptane** | 0.002 | BDL | BDL |
| **Octane** | 0.002 | BDL | BDL |
| **Nonane2** | 0.002 | BDL | BDL |
| **Decane3** | 0.002 | BDL | BDL |
| **1,2-Dichloroethylene** [A] | 0.002 | BDL | BDL |
| **Chloroform** [A] | 0.002 | BDL | BDL |
| **1,1,1-Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,2-Dichloroethane** [A] | 0.002 | BDL | BDL |
| **1,1-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Benzene** [A] | 0.002 | BDL | BDL |
| **Carbon Tetrachloride** [A] | 0.002 | BDL | BDL |
| **Trichloroethylene** [A] | 0.002 | BDL | BDL |
| **Bromodichloromethane** [A] | 0.002 | BDL | BDL |
| **cis-1,3-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Toluene** [A] | 0.002 | BDL | BDL |
| **1,1,2 Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,3-Dichloropropane** [A] | 0.002 | BDL | BDL |
| **Dibromochloromethane** [A] | 0.002 | BDL | BDL |
| **1.2 Dibromoethane** [A] | 0.002 | BDL | BDL |
| **Tetrachloroethylene** [A] | 0.002 | BDL | BDL |
| **Chlorobenzene** [A] | 0.002 | BDL | BDL |
| **1,1,1,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |
| **Ethylbenzene** [A] | 0.002 | BDL | BDL |
| **o-Xylene** [A] | 0.002 | BDL | BDL |
| **Styrene** [A] | 0.002 | BDL | BDL |
| **1,1,2,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |

| | | | |
|---|---|---|---|
| **1,2,3-Trichloropropane** [A] | 0.002 | BDL | BDL |
| **Bromobenzene** [A] | 0.002 | BDL | BDL |
| **Propylbenzene** [A] | 0.002 | BDL | BDL |
| **4-Chlorotoluene** [A] | 0.002 | BDL | BDL |
| **1,2,3-Trimethylbenzene** [A] | 0.002 | BDL | BDL |
| **tert-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,4-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **sec-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,2-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **n-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **Hexachloroethane** [A] | 0.002 | BDL | BDL |
| **1,2 Dibromo-3-chloropropane** [A] | 0.002 | BDL | BDL |
| **1,3,5-Trichlorobenzene** [A] | 0.002 | BDL | BDL |
| **Naphthalene** [A] | 0.002 | BDL | BDL |
| **Hexachlorobutadiene** [A] | 0.002 | BDL | BDL |
| **Phenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethyl) ether** | 2.000 | BDL | BDL |
| **2-Chlorophenol** | 2.000 | BDL | BDL |
| **1,4-Dichlorobenzene** | 2.000 | BDL | BDL |
| **1,2-Dichlorobenzene** | 2.000 | BDL | BDL |
| **2-Methylphenol (o-Cresol)** | 2.000 | BDL | BDL |
| **Bis(2-chloro-1-methylethyl) ether** | 2.000 | BDL | BDL |
| **4-Methylphenol (p-Cresol)** | 2.000 | BDL | BDL |
| **Hexachloroethane** | 2.000 | BDL | BDL |
| **Nitrobenzene** | 2.000 | BDL | BDL |
| **Isophorone** | 2.000 | BDL | BDL |
| **2-Nitrophenol** | 2.000 | BDL | BDL |
| **2,4-Dimethylphenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethoxy) methane** | 2.000 | BDL | BDL |
| **2,4-Dichlorophenol** | 2.000 | BDL | BDL |
| **1,3,5-Trichlorobenzene** | 2.000 | BDL | BDL |
| **Naphthalene** | 2.000 | BDL | BDL |
| **p-Chloroaniline** | 2.000 | BDL | BDL |
| **4-Chloro-3-methylphenol** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **2-Methylnaphthalene** | 2.000 | BDL | BDL |
| **Hexachlorocyclopentadiene** | 2.000 | BDL | BDL |
| **2,4,6-Trichlorophenol** | 2.000 | BDL | BDL |
| **2,4,5-Trichlorophenol** | 2.000 | BDL | BDL |
| **1-Chloronaphthalene** | 2.000 | BDL | BDL |
| **Diphenyl ether** | 2.000 | BDL | BDL |
| **2-Nitroaniline** | 2.000 | BDL | BDL |
| **Dimethyl phthalate** | 2.000 | BDL | BDL |
| **2-methyl-1,3-dinitro-Benzene** | 2.000 | BDL | BDL |
| **Acenaphthylene** | 2.000 | BDL | BDL |
| **Acenaphthene** | 2.000 | BDL | BDL |
| **Dibenzofuran** | 2.000 | BDL | BDL |
| **1-Methyl-2,4-dinitrobenzene** | 2.000 | BDL | BDL |
| **Diethylphthalate** | 2.000 | BDL | BDL |
| **1-chloro-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **dimethyl-Cyanamide** | 2.000 | BDL | BDL |
| **Fluorene** | 2.000 | BDL | BDL |
| **3-Methyl-2-phenylpyridine** | 2.000 | BDL | BDL |
| **Azobenzene** | 2.000 | BDL | BDL |
| **1-Bromo-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **Hexachlorobenzene** | 2.000 | BDL | BDL |
| **Pentachlorophenol** | 2.000 | BDL | BDL |
| **Phenanthrene** | 2.000 | BDL | BDL |
| **5H-Indeno[1,2-b]pyridine** | 2.000 | BDL | BDL |
| **Dibutyl phthalate** | 2.000 | BDL | BDL |
| **Fluoranthene** | 2.000 | BDL | BDL |
| **Benzyl butyl phthalate** | 2.000 | BDL | BDL |
| **Triphenylene** | 2.000 | BDL | BDL |
| **Benz[a]anthracene** | 2.000 | BDL | BDL |
| **Bis(2-ethylhexyl) phthalate** | 2.000 | BDL | BDL |
| **Di-n-octyl phthalate** | 2.000 | BDL | BDL |
| **Benzo[b]fluoranthene** | 2.000 | BDL | BDL |
| **Indenol[1,2,3-cd]pyrene** | 2.000 | BDL | BDL |
| **Benzo[b]triphenylene** | 2.000 | BDL | BDL |
| **Benzo[ghi]perylene** | 2.000 | BDL | BDL |

* UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit; A = SANAS accredited method; Where not specified, the methods are not accredited; All elements measured by GC-MS analysis

Table 3: Landfill assessment for: IW2020-0463 *

| Contaminant Name | Total (mg/kg) | Leachable (mg/L) | Waste Type |
|---|---|---|---|
| **Inorganic Anions** | | | |
| **TDS** | 3191.5 | 159.575 | Type 4 |
| **Organic Compounds** | | | |
| **Benzene** | BDL | BDL | Type 3 |
| **Benzo(a)pyrene** | NT | NT | UTD |
| **Carbon tetrachloride** | BDL | BDL | Type 3 |
| **Chlorobenzene** | BDL | BDL | Type 3 |
| **Chloroform** | BDL | BDL | Type 3 |
| **2-Chlorophenol** | BDL | BDL | Type 3 |
| **Di (2 ethylhexyl) phthalate** | BDL | BDL | Type 3 |
| **1,2-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,4-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,2-Dichloroethane** | BDL | BDL | Type 3 |
| **1,1-Dichloroethylene** | NT | NT | UTD |
| **1,2-Dichloroethylene** | NT | NT | UTD |
| **Dichloromethane** | NT | NT | UTD |
| **2,4-Dichlorophenol** | BDL | BDL | Type 3 |
| **2,4-Dinitrotoluene** | NT | NT | UTD |
| **Ethylbenzene** | BDL | BDL | Type 3 |
| **Formaldehyde** | NT | NT | UTD |
| **Hexachlorobutadiene** | BDL | BDL | Type 3 |
| **Methyl ethyl ketone** | NT | NT | UTD |
| **MTBE (Methyl t-butyl ether)** | NT | NT | UTD |
| **Nitrobenzene** | BDL | BDL | Type 3 |
| **PAHs (total)** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C6 to C9** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C10 to C36** | BDL | N/A | Type 3 |
| **Phenols (total, non-halogenated)** | BDL | BDL | Type 3 |
| **Polychlorinated biphenyls** | NT | NT | UTD |
| **Styrene** | BDL | BDL | Type 3 |
| **1,1,1-Tetrachloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Tetrachloroethane** | BDL | BDL | Type 3 |
| **Tetrachloroethylene** | NT | NT | UTD |
| **Toluene** | BDL | BDL | Type 3 |

| | | | |
|---|---|---|---|
| **Trichlorobenzenes (Total)** | BDL | BDL | Type 3 |
| **1,1,1-Trichloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Trichloroethane** | BDL | BDL | Type 3 |
| **Trichlorophenol** | NT | NT | UTD |
| **2,4,6-Trichlorophenol** | BDL | BDL | Type 3 |
| **Vinyl Chloride** | NT | NT | UTD |
| **Xylene** | BDL | BDL | Type 3 |

*UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit;

**Determining the landfill site class for disposal:**

The assigned waste type determines the class of landfill site where a particular waste stream may be disposed. A waste type of one (Type 1) is assigned to waste that presents the most risk to the environment when disposed of at a landfill site and therefore requires disposal at a site with stringent engineering controls corresponding to a so called "Class A" site. Type four (Type 4) waste presents a low risk to the environment when disposed of to a landfill site and therefore may be disposed of at a less stringently engineered, "Class D" site. Type zero waste (Type 0) may not be disposed of to any landfill site in South Africa without prior treatment. The *National Waste Classification and Management Regulations* detail specific requirements surrounding the classification and assessment of waste for disposal to landfill (See references). Note that a GHS (SANS10234) compliant classification and safety data sheet is required before a final waste management decision should be taken and should be read in conjunction with this assessment.

**Standard Operational Procedure:**

Identification of analysis methods:

IW-S-1: Determination of Metals in Liquids and solids using ICP-OES Optima 8300; IW-S-2: Determination of the VOC content of liquid and solids using GC6850, MS5976C; IW-S-3: pH Measurement; IW-S-4: EC Measurement; IW-S-5: Calibration and measurement of samples using Supercal Modular calorimeter; IW-S-6: Toxicity characteristic leaching procedure – TCLP; IW-S-7: Field Protable X-ray Flourecence FTXRF; AS 4439.1-1999: Wastes, sediments and contaminated soils - Preparation of leachates - Preliminary assessment; AS 4439.3-1997: Wastes, sediments and contaminated soils - Preparation of leachates - Bottle leaching procedures.

**Scope of Accreditation:**

| Materials/Products Tested | Types of Tests | Standard Specifications, Equipment/Techniques Used |
|---|---|---|
| 1- Waste (Solid, sludge and liquid) | Quantification of metals by ICP-OES following ASLP, reagent water (Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Rb, P, Pb, Sb, Se, Sn, Sr, Ti, Tl, U, V, Zn) | IW-M-01 - Based on method 6010C |
| 2- Solids & Liquids | Determination of VOC; BTEX by GC/MS Headspace | IW-M-02 - Based on method EPA 8260B; EPA 5030B(Liquid) and EPA 5035 (solid) |
| 3- Potable water & leachates | pH at 25 $^{o}$C | IW-M-03 |
| 4- Potable water & leachates | Electrical Conductivity at 25$^{o}$C | IW-M-04 |

**Disclaimer:**

*Analysis results relate only to the samples submitted. The laboratory has no control over the sampling protocol, the representivity of the samples and the manner in which the samples were collected, transported, stored, preserved or otherwise handled outside of the laboratory facility and therefore takes no responsibility whatsoever for these activities. Third parties using INTERWASTE results can verify the results by contacting the laboratory. INTERWASTE are not liable or responsible for the customer use and/or interpretation of test results. This certificate cannot be reproduced without the written consent of INTERWASTE laboratory.*

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**References**

1.) Government Notice R.365, National Environmental Management: Waste Act (59/2008): National norms and standards for the assessment of waste for landfill disposal, Gazette No. 36

Signed by: Dr. Cheila Canario
Signed at: 2020-07-28 14:51:34 +02:00
Reason: Witnessing Dr. Cheila Canario

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## Sample Identification Number: IW2020-0462

| Laboratory Analysis Report for Landfill Assessment | | | |
|---|---|---|---|
| **Requested By:** | Keelan Chetty | **Waste Name:** | MF2 3-4M Slime Stockpile Chrome Direct Reduction |
| **Generator:** | Samancor Chrome | **Received Date:** | 12/06/2020 |
| **Lab Reference:** | IW2020-0462 | **Analysis Date:** | 03/07/2020 |
| **No. of Samples:** | 1 | **Report Date:** | 28/07/2020 |
| **Sample Description:** | Dry Brown Slime | | |

Table 1: Miscellaneous tests for sample: IW2020-0462 *

| Parameter Tested | Unit | IW2020-0462 |
|---|---|---|
| **Sample Moisture Content** | % (w/w) | 3.85 |
| **Conductivity** [A] | uS/cm | 273 |
| **Initial Sample pH** [A] | pH Units | 9.17 |
| **Sample pH after HCl Addition** | pH Units | NT |
| **Leach Solution Applied** | Solution Type | Water |
| **Final Leach Solution pH** | pH Units | NT |
| **Physical State** | NA | Solid |
| **Water Miscibility** | NA | Immiscible |
| **Calorific Value** | MJ/kg | NT |
| **Additional Information** | NA | Low Odour |

* UTD = Unable to determine; NT = Not tested; A = SANAS accredited method; Where not specified, the methods are not accredited; Conductivity and pH measured by electronic conductivity and pH meter at ~22C (10% H2O extracts of solids). Moisture by mass loss on heating at ~103C for 30 mins.

Table 2: GC-MS total and leachable organics for sample: IW2020-0462 *

| Contaminant Name | Detection Limit (mg/kg) | Concentration (mg/kg) | Theoretical Max. Leach Concentration (mg/L) |
|---|---|---|---|
| **Nonane** | 2.000 | BDL | BDL |
| **Decane** | 2.000 | BDL | BDL |
| **Dodecane** | 2.000 | BDL | BDL |
| **Tetradecane** | 2.000 | BDL | BDL |
| **Hexadecane** | 2.000 | BDL | BDL |
| **Octadecane** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **Nonadecane** | 2.000 | BDL | BDL |
| **Eicosane** | 2.000 | BDL | BDL |
| **Docosane** | 2.000 | BDL | BDL |
| **Tetracosane** | 2.000 | BDL | BDL |
| **Hexacosane** | 2.000 | BDL | BDL |
| **Octacosane** | 2.000 | BDL | BDL |
| **Hentriacontane** | 2.000 | BDL | BDL |
| **n-Hexane** | 0.002 | BDL | BDL |
| **Heptane** | 0.002 | BDL | BDL |
| **Octane** | 0.002 | BDL | BDL |
| **Nonane2** | 0.002 | BDL | BDL |
| **Decane3** | 0.002 | BDL | BDL |
| **1,2-Dichloroethylene** [A] | 0.002 | BDL | BDL |
| **Chloroform** [A] | 0.002 | BDL | BDL |
| **1,1,1-Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,2-Dichloroethane** [A] | 0.002 | BDL | BDL |
| **1,1-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Benzene** [A] | 0.002 | BDL | BDL |
| **Carbon Tetrachloride** [A] | 0.002 | BDL | BDL |
| **Trichloroethylene** [A] | 0.002 | BDL | BDL |
| **Bromodichloromethane** [A] | 0.002 | BDL | BDL |
| **cis-1,3-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Toluene** [A] | 0.002 | BDL | BDL |
| **1,1,2  Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,3-Dichloropropane** [A] | 0.002 | BDL | BDL |
| **Dibromochloromethane** [A] | 0.002 | BDL | BDL |
| **1.2 Dibromoethane** [A] | 0.002 | BDL | BDL |
| **Tetrachloroethylene** [A] | 0.002 | BDL | BDL |
| **Chlorobenzene** [A] | 0.002 | BDL | BDL |
| **1,1,1,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |
| **Ethylbenzene** [A] | 0.002 | BDL | BDL |
| **o-Xylene** [A] | 0.002 | BDL | BDL |
| **Styrene** [A] | 0.002 | BDL | BDL |
| **1,1,2,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |

| | | | |
|---|---|---|---|
| **1,2,3-Trichloropropane** [A] | 0.002 | BDL | BDL |
| **Bromobenzene** [A] | 0.002 | BDL | BDL |
| **Propylbenzene** [A] | 0.002 | BDL | BDL |
| **4-Chlorotoluene** [A] | 0.002 | BDL | BDL |
| **1,2,3-Trimethylbenzene** [A] | 0.002 | BDL | BDL |
| **tert-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,4-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **sec-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,2-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **n-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **Hexachloroethane** [A] | 0.002 | BDL | BDL |
| **1,2 Dibromo-3-chloropropane** [A] | 0.002 | BDL | BDL |
| **1,3,5-Trichlorobenzene** [A] | 0.002 | BDL | BDL |
| **Naphthalene** [A] | 0.002 | BDL | BDL |
| **Hexachlorobutadiene** [A] | 0.002 | BDL | BDL |
| **Phenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethyl) ether** | 2.000 | BDL | BDL |
| **2-Chlorophenol** | 2.000 | BDL | BDL |
| **1,4-Dichlorobenzene** | 2.000 | BDL | BDL |
| **1,2-Dichlorobenzene** | 2.000 | BDL | BDL |
| **2-Methylphenol (o-Cresol)** | 2.000 | BDL | BDL |
| **Bis(2-chloro-1-methylethyl) ether** | 2.000 | BDL | BDL |
| **4-Methylphenol (p-Cresol)** | 2.000 | BDL | BDL |
| **Hexachloroethane** | 2.000 | BDL | BDL |
| **Nitrobenzene** | 2.000 | BDL | BDL |
| **Isophorone** | 2.000 | BDL | BDL |
| **2-Nitrophenol** | 2.000 | BDL | BDL |
| **2,4-Dimethylphenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethoxy) methane** | 2.000 | BDL | BDL |
| **2,4-Dichlorophenol** | 2.000 | BDL | BDL |
| **1,3,5-Trichlorobenzene** | 2.000 | BDL | BDL |
| **Naphthalene** | 2.000 | BDL | BDL |
| **p-Chloroaniline** | 2.000 | BDL | BDL |
| **4-Chloro-3-methylphenol** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **2-Methylnaphthalene** | 2.000 | BDL | BDL |
| **Hexachlorocyclopentadiene** | 2.000 | BDL | BDL |
| **2,4,6-Trichlorophenol** | 2.000 | BDL | BDL |
| **2,4,5-Trichlorophenol** | 2.000 | BDL | BDL |
| **1-Chloronaphthalene** | 2.000 | BDL | BDL |
| **Diphenyl ether** | 2.000 | BDL | BDL |
| **2-Nitroaniline** | 2.000 | BDL | BDL |
| **Dimethyl phthalate** | 2.000 | BDL | BDL |
| **2-methyl-1,3-dinitro-Benzene** | 2.000 | BDL | BDL |
| **Acenaphthylene** | 2.000 | BDL | BDL |
| **Acenaphthene** | 2.000 | BDL | BDL |
| **Dibenzofuran** | 2.000 | BDL | BDL |
| **1-Methyl-2,4-dinitrobenzene** | 2.000 | BDL | BDL |
| **Diethylphthalate** | 2.000 | BDL | BDL |
| **1-chloro-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **dimethyl-Cyanamide** | 2.000 | BDL | BDL |
| **Fluorene** | 2.000 | BDL | BDL |
| **3-Methyl-2-phenylpyridine** | 2.000 | BDL | BDL |
| **Azobenzene** | 2.000 | BDL | BDL |
| **1-Bromo-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **Hexachlorobenzene** | 2.000 | BDL | BDL |
| **Pentachlorophenol** | 2.000 | BDL | BDL |
| **Phenanthrene** | 2.000 | BDL | BDL |
| **5H-Indeno[1,2-b]pyridine** | 2.000 | BDL | BDL |
| **Dibutyl phthalate** | 2.000 | BDL | BDL |
| **Fluoranthene** | 2.000 | BDL | BDL |
| **Benzyl butyl phthalate** | 2.000 | BDL | BDL |
| **Triphenylene** | 2.000 | BDL | BDL |
| **Benz[a]anthracene** | 2.000 | BDL | BDL |
| **Bis(2-ethylhexyl) phthalate** | 2.000 | BDL | BDL |
| **Di-n-octyl phthalate** | 2.000 | BDL | BDL |
| **Benzo[b]fluoranthene** | 2.000 | BDL | BDL |
| **Indenol[1,2,3-cd]pyrene** | 2.000 | BDL | BDL |
| **Benzo[b]triphenylene** | 2.000 | BDL | BDL |
| **Benzo[ghi]perylene** | 2.000 | BDL | BDL |

* UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit; A = SANAS accredited method; Where not specified, the methods are not accredited; All elements measured by GC-MS analysis

Table 3: Landfill assessment for: IW2020-0462 *

| Contaminant Name | Total (mg/kg) | Leachable (mg/L) | Waste Type |
|---|---|---|---|
| **Inorganic Anions** | | | |
| **TDS** | 1774.5 | 88.725 | Type 4 |
| **Organic Compounds** | | | |
| **Benzene** | BDL | BDL | Type 3 |
| **Benzo(a)pyrene** | NT | NT | UTD |
| **Carbon tetrachloride** | BDL | BDL | Type 3 |
| **Chlorobenzene** | BDL | BDL | Type 3 |
| **Chloroform** | BDL | BDL | Type 3 |
| **2-Chlorophenol** | BDL | BDL | Type 3 |
| **Di (2 ethylhexyl) phthalate** | BDL | BDL | Type 3 |
| **1,2-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,4-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,2-Dichloroethane** | BDL | BDL | Type 3 |
| **1,1-Dichloroethylene** | NT | NT | UTD |
| **1,2-Dichloroethylene** | NT | NT | UTD |
| **Dichloromethane** | NT | NT | UTD |
| **2,4-Dichlorophenol** | BDL | BDL | Type 3 |
| **2,4-Dinitrotoluene** | NT | NT | UTD |
| **Ethylbenzene** | BDL | BDL | Type 3 |
| **Formaldehyde** | NT | NT | UTD |
| **Hexachlorobutadiene** | BDL | BDL | Type 3 |
| **Methyl ethyl ketone** | NT | NT | UTD |
| **MTBE (Methyl t-butyl ether)** | NT | NT | UTD |
| **Nitrobenzene** | BDL | BDL | Type 3 |
| **PAHs (total)** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C6 to C9** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C10 to C36** | BDL | N/A | Type 3 |
| **Phenols (total, non-halogenated)** | BDL | BDL | Type 3 |
| **Polychlorinated biphenyls** | NT | NT | UTD |
| **Styrene** | BDL | BDL | Type 3 |
| **1,1,1-Tetrachloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Tetrachloroethane** | BDL | BDL | Type 3 |
| **Tetrachloroethylene** | NT | NT | UTD |
| **Toluene** | BDL | BDL | Type 3 |

| | | | |
|---|---|---|---|
| **Trichlorobenzenes (Total)** | BDL | BDL | Type 3 |
| **1,1,1-Trichloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Trichloroethane** | BDL | BDL | Type 3 |
| **Trichlorophenol** | NT | NT | UTD |
| **2,4,6-Trichlorophenol** | BDL | BDL | Type 3 |
| **Vinyl Chloride** | NT | NT | UTD |
| **Xylene** | BDL | BDL | Type 3 |

*UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit;

**Determining the landfill site class for disposal:**

The assigned waste type determines the class of landfill site where a particular waste stream may be disposed. A waste type of one (Type 1) is assigned to waste that presents the most risk to the environment when disposed of at a landfill site and therefore requires disposal at a site with stringent engineering controls corresponding to a so called "Class A" site. Type four (Type 4) waste presents a low risk to the environment when disposed of to a landfill site and therefore may be disposed of at a less stringently engineered, "Class D" site. Type zero waste (Type 0) may not be disposed of to any landfill site in South Africa without prior treatment. The *National Waste Classification and Management Regulations* detail specific requirements surrounding the classification and assessment of waste for disposal to landfill (See references). Note that a GHS (SANS10234) compliant classification and safety data sheet is required before a final waste management decision should be taken and should be read in conjunction with this assessment.

**Standard Operational Procedure:**

Identification of analysis methods:

IW-S-1: Determination of Metals in Liquids and solids using ICP-OES Optima 8300; IW-S-2: Determination of the VOC content of liquid and solids using GC6850, MS5976C; IW-S-3: pH Measurement; IW-S-4: EC Measurement; IW-S-5: Calibration and measurement of samples using Supercal Modular calorimeter; IW-S-6: Toxicity characteristic leaching procedure – TCLP; IW-S-7: Field Protable X-ray Flourecence FTXRF; AS 4439.1-1999: Wastes, sediments and contaminated soils - Preparation of leachates - Preliminary assessment; AS 4439.3-1997: Wastes, sediments and contaminated soils - Preparation of leachates - Bottle leaching procedures.

**Scope of Accreditation:**

| Materials/Products Tested | Types of Tests | Standard Specifications, Equipment/Techniques Used |
|---|---|---|
| 1- Waste (Solid, sludge and liquid) | Quantification of metals by ICP-OES following ASLP, reagent water (Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Rb, P, Pb, Sb, Se, Sn, Sr, Ti, Tl, U, V, Zn) | IW-M-01 - Based on method 6010C |
| 2- Solids & Liquids | Determination of VOC; BTEX by GC/MS Headspace | IW-M-02 - Based on method EPA 8260B; EPA 5030B(Liquid) and EPA 5035 (solid) |
| 3- Potable water & leachates | pH at 25 $^{o}$C | IW-M-03 |
| 4- Potable water & leachates | Electrical Conductivity at 25$^{o}$C | IW-M-04 |

**Disclaimer:**

*Analysis results relate only to the samples submitted. The laboratory has no control over the sampling protocol, the representivity of the samples and the manner in which the samples were collected, transported, stored, preserved or otherwise handled outside of the laboratory facility and therefore takes no responsibility whatsoever for these activities. Third parties using INTERWASTE results can verify the results by contacting the laboratory. INTERWASTE are not liable or responsible for the customer use and/or interpretation of test results. This certificate cannot be reproduced without the written consent of INTERWASTE laboratory.*

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**References**

1.) Government Notice R.365, National Environmental Management: Waste Act (59/2008): National norms and standards for the assessment of waste for landfill disposal, Gazette No. 36

Signed by: Dr. Cheila Canario
Signed at: 2020-07-28 14:51:17 +02:00
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# Sample Identification Number: IW2020-0461

| Laboratory Analysis Report for Landfill Assessment | | | |
|---|---|---|---|
| **Requested By:** | Keelan Chetty | **Waste Name:** | MF5 0.2-0.8M Slime Stockpile Chrome Direct Reduction |
| **Generator:** | Samancor Chrome | **Received Date:** | 12/06/2020 |
| **Lab Reference:** | IW2020-0461 | **Analysis Date:** | 03/07/2020 |
| **No. of Samples:** | 1 | **Report Date:** | 28/07/2020 |
| **Sample Description:** | Black & Grey Clay | | |

Table 1: Miscellaneous tests for sample: IW2020-0461 *

| Parameter Tested | Unit | IW2020-0461 |
|---|---|---|
| **Sample Moisture Content** | % (w/w) | 51.01 |
| **Conductivity** [A] | uS/cm | 588 |
| **Initial Sample pH** [A] | pH Units | 9.15 |
| **Sample pH after HCl Addition** | pH Units | NT |
| **Leach Solution Applied** | Solution Type | Water |
| **Final Leach Solution pH** | pH Units | NT |
| **Physical State** | NA | Solid |
| **Water Miscibility** | NA | Immiscible |
| **Calorific Value** | MJ/kg | NT |
| **Additional Information** | NA | Low Odour |

* UTD = Unable to determine; NT = Not tested; A = SANAS accredited method; Where not specified, the methods are not accredited; Conductivity and pH measured by electronic conductivity and pH meter at ~22C (10% H2O extracts of solids). Moisture by mass loss on heating at ~103C for 30 mins.

Table 2: GC-MS total and leachable organics for sample: IW2020-0461 *

| Contaminant Name | Detection Limit (mg/kg) | Concentration (mg/kg) | Theoretical Max. Leach Concentration (mg/L) |
|---|---|---|---|
| **Nonane** | 2.000 | BDL | BDL |
| **Decane** | 2.000 | BDL | BDL |
| **Dodecane** | 2.000 | BDL | BDL |
| **Tetradecane** | 2.000 | BDL | BDL |
| **Hexadecane** | 2.000 | BDL | BDL |
| **Octadecane** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **Nonadecane** | 2.000 | BDL | BDL |
| **Eicosane** | 2.000 | BDL | BDL |
| **Docosane** | 2.000 | BDL | BDL |
| **Tetracosane** | 2.000 | BDL | BDL |
| **Hexacosane** | 2.000 | BDL | BDL |
| **Octacosane** | 2.000 | BDL | BDL |
| **Hentriacontane** | 2.000 | BDL | BDL |
| **n-Hexane** | 0.002 | BDL | BDL |
| **Heptane** | 0.002 | BDL | BDL |
| **Octane** | 0.002 | BDL | BDL |
| **Nonane2** | 0.002 | BDL | BDL |
| **Decane3** | 0.002 | BDL | BDL |
| **1,2-Dichloroethylene** [A] | 0.002 | BDL | BDL |
| **Chloroform** [A] | 0.002 | BDL | BDL |
| **1,1,1-Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,2-Dichloroethane** [A] | 0.002 | BDL | BDL |
| **1,1-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Benzene** [A] | 0.002 | BDL | BDL |
| **Carbon Tetrachloride** [A] | 0.002 | BDL | BDL |
| **Trichloroethylene** [A] | 0.002 | BDL | BDL |
| **Bromodichloromethane** [A] | 0.002 | BDL | BDL |
| **cis-1,3-Dichloropropene** [A] | 0.002 | BDL | BDL |
| **Toluene** [A] | 0.002 | BDL | BDL |
| **1,1,2 Trichloroethane** [A] | 0.002 | BDL | BDL |
| **1,3-Dichloropropane** [A] | 0.002 | BDL | BDL |
| **Dibromochloromethane** [A] | 0.002 | BDL | BDL |
| **1.2 Dibromoethane** [A] | 0.002 | BDL | BDL |
| **Tetrachloroethylene** [A] | 0.002 | BDL | BDL |
| **Chlorobenzene** [A] | 0.002 | BDL | BDL |
| **1,1,1,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |
| **Ethylbenzene** [A] | 0.002 | BDL | BDL |
| **o-Xylene** [A] | 0.002 | BDL | BDL |
| **Styrene** [A] | 0.002 | BDL | BDL |
| **1,1,2,2-Tetrachloroethane** [A] | 0.002 | BDL | BDL |

| | | | |
|---|---|---|---|
| **1,2,3-Trichloropropane** [A] | 0.002 | BDL | BDL |
| **Bromobenzene** [A] | 0.002 | BDL | BDL |
| **Propylbenzene** [A] | 0.002 | BDL | BDL |
| **4-Chlorotoluene** [A] | 0.002 | BDL | BDL |
| **1,2,3-Trimethylbenzene** [A] | 0.002 | BDL | BDL |
| **tert-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,4-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **sec-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **1,2-Dichlorobenzene** [A] | 0.002 | BDL | BDL |
| **n-Butylbenzene** [A] | 0.002 | BDL | BDL |
| **Hexachloroethane** [A] | 0.002 | BDL | BDL |
| **1,2 Dibromo-3-chloropropane** [A] | 0.002 | BDL | BDL |
| **1,3,5-Trichlorobenzene** [A] | 0.002 | BDL | BDL |
| **Naphthalene** [A] | 0.002 | BDL | BDL |
| **Hexachlorobutadiene** [A] | 0.002 | BDL | BDL |
| **Phenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethyl) ether** | 2.000 | BDL | BDL |
| **2-Chlorophenol** | 2.000 | BDL | BDL |
| **1,4-Dichlorobenzene** | 2.000 | BDL | BDL |
| **1,2-Dichlorobenzene** | 2.000 | BDL | BDL |
| **2-Methylphenol (o-Cresol)** | 2.000 | BDL | BDL |
| **Bis(2-chloro-1-methylethyl) ether** | 2.000 | BDL | BDL |
| **4-Methylphenol (p-Cresol)** | 2.000 | BDL | BDL |
| **Hexachloroethane** | 2.000 | BDL | BDL |
| **Nitrobenzene** | 2.000 | BDL | BDL |
| **Isophorone** | 2.000 | BDL | BDL |
| **2-Nitrophenol** | 2.000 | BDL | BDL |
| **2,4-Dimethylphenol** | 2.000 | BDL | BDL |
| **Bis(2-chloroethoxy) methane** | 2.000 | BDL | BDL |
| **2,4-Dichlorophenol** | 2.000 | BDL | BDL |
| **1,3,5-Trichlorobenzene** | 2.000 | BDL | BDL |
| **Naphthalene** | 2.000 | BDL | BDL |
| **p-Chloroaniline** | 2.000 | BDL | BDL |
| **4-Chloro-3-methylphenol** | 2.000 | BDL | BDL |

| | | | |
|---|---|---|---|
| **2-Methylnaphthalene** | 2.000 | BDL | BDL |
| **Hexachlorocyclopentadiene** | 2.000 | BDL | BDL |
| **2,4,6-Trichlorophenol** | 2.000 | BDL | BDL |
| **2,4,5-Trichlorophenol** | 2.000 | BDL | BDL |
| **1-Chloronaphthalene** | 2.000 | BDL | BDL |
| **Diphenyl ether** | 2.000 | BDL | BDL |
| **2-Nitroaniline** | 2.000 | BDL | BDL |
| **Dimethyl phthalate** | 2.000 | BDL | BDL |
| **2-methyl-1,3-dinitro-Benzene** | 2.000 | BDL | BDL |
| **Acenaphthylene** | 2.000 | BDL | BDL |
| **Acenaphthene** | 2.000 | BDL | BDL |
| **Dibenzofuran** | 2.000 | BDL | BDL |
| **1-Methyl-2,4-dinitrobenzene** | 2.000 | BDL | BDL |
| **Diethylphthalate** | 2.000 | BDL | BDL |
| **1-chloro-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **dimethyl-Cyanamide** | 2.000 | BDL | BDL |
| **Fluorene** | 2.000 | BDL | BDL |
| **3-Methyl-2-phenylpyridine** | 2.000 | BDL | BDL |
| **Azobenzene** | 2.000 | BDL | BDL |
| **1-Bromo-4-phenoxybenzene** | 2.000 | BDL | BDL |
| **Hexachlorobenzene** | 2.000 | BDL | BDL |
| **Pentachlorophenol** | 2.000 | BDL | BDL |
| **Phenanthrene** | 2.000 | BDL | BDL |
| **5H-Indeno[1,2-b]pyridine** | 2.000 | BDL | BDL |
| **Dibutyl phthalate** | 2.000 | BDL | BDL |
| **Fluoranthene** | 2.000 | BDL | BDL |
| **Benzyl butyl phthalate** | 2.000 | BDL | BDL |
| **Triphenylene** | 2.000 | BDL | BDL |
| **Benz[a]anthracene** | 2.000 | BDL | BDL |
| **Bis(2-ethylhexyl) phthalate** | 2.000 | BDL | BDL |
| **Di-n-octyl phthalate** | 2.000 | BDL | BDL |
| **Benzo[b]fluoranthene** | 2.000 | BDL | BDL |
| **Indenol[1,2,3-cd]pyrene** | 2.000 | BDL | BDL |
| **Benzo[b]triphenylene** | 2.000 | BDL | BDL |
| **Benzo[ghi]perylene** | 2.000 | BDL | BDL |

* UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit; A = SANAS accredited method; Where not specified, the methods are not accredited; All elements measured by GC-MS analysis

Table 3: Landfill assessment for: IW2020-0461 *

| Contaminant Name | Total (mg/kg) | Leachable (mg/L) | Waste Type |
|---|---|---|---|
| **Inorganic Anions** | | | |
| **TDS** | 3822 | 191.1 | Type 4 |
| **Organic Compounds** | | | |
| **Benzene** | BDL | BDL | Type 3 |
| **Benzo(a)pyrene** | NT | NT | UTD |
| **Carbon tetrachloride** | BDL | BDL | Type 3 |
| **Chlorobenzene** | BDL | BDL | Type 3 |
| **Chloroform** | BDL | BDL | Type 3 |
| **2-Chlorophenol** | BDL | BDL | Type 3 |
| **Di (2 ethylhexyl) phthalate** | BDL | BDL | Type 3 |
| **1,2-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,4-Dichlorobenzene** | BDL | BDL | Type 3 |
| **1,2-Dichloroethane** | BDL | BDL | Type 3 |
| **1,1-Dichloroethylene** | NT | NT | UTD |
| **1,2-Dichloroethylene** | NT | NT | UTD |
| **Dichloromethane** | NT | NT | UTD |
| **2,4-Dichlorophenol** | BDL | BDL | Type 3 |
| **2,4-Dinitrotoluene** | NT | NT | UTD |
| **Ethylbenzene** | BDL | BDL | Type 3 |
| **Formaldehyde** | NT | NT | UTD |
| **Hexachlorobutadiene** | BDL | BDL | Type 3 |
| **Methyl ethyl ketone** | NT | NT | UTD |
| **MTBE (Methyl t-butyl ether)** | NT | NT | UTD |
| **Nitrobenzene** | BDL | BDL | Type 3 |
| **PAHs (total)** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C6 to C9** | BDL | N/A | Type 3 |
| **Petroleum H/Cs, C10 to C36** | BDL | N/A | Type 3 |
| **Phenols (total, non-halogenated)** | BDL | BDL | Type 3 |
| **Polychlorinated biphenyls** | NT | NT | UTD |
| **Styrene** | BDL | BDL | Type 3 |
| **1,1,1-Tetrachloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Tetrachloroethane** | BDL | BDL | Type 3 |
| **Tetrachloroethylene** | NT | NT | UTD |
| **Toluene** | BDL | BDL | Type 3 |

| | | | |
|---|---|---|---|
| **Trichlorobenzenes (Total)** | BDL | BDL | Type 3 |
| **1,1,1-Trichloroethane** | BDL | BDL | Type 3 |
| **1,1,2-Trichloroethane** | BDL | BDL | Type 3 |
| **Trichlorophenol** | NT | NT | UTD |
| **2,4,6-Trichlorophenol** | BDL | BDL | Type 3 |
| **Vinyl Chloride** | NT | NT | UTD |
| **Xylene** | BDL | BDL | Type 3 |

*UTD = Unable to determine; NT = Not tested; BDL = Element below indicated detection limit;

**Determining the landfill site class for disposal:**

The assigned waste type determines the class of landfill site where a particular waste stream may be disposed. A waste type of one (Type 1) is assigned to waste that presents the most risk to the environment when disposed of at a landfill site and therefore requires disposal at a site with stringent engineering controls corresponding to a so called "Class A" site. Type four (Type 4) waste presents a low risk to the environment when disposed of to a landfill site and therefore may be disposed of at a less stringently engineered, "Class D" site. Type zero waste (Type 0) may not be disposed of to any landfill site in South Africa without prior treatment. The *National Waste Classification and Management Regulations* detail specific requirements surrounding the classification and assessment of waste for disposal to landfill (See references). Note that a GHS (SANS10234) compliant classification and safety data sheet is required before a final waste management decision should be taken and should be read in conjunction with this assessment.

**Standard Operational Procedure:**

Identification of analysis methods:

IW-S-1: Determination of Metals in Liquids and solids using ICP-OES Optima 8300; IW-S-2: Determination of the VOC content of liquid and solids using GC6850, MS5976C; IW-S-3: pH Measurement; IW-S-4: EC Measurement; IW-S-5: Calibration and measurement of samples using Supercal Modular calorimeter; IW-S-6: Toxicity characteristic leaching procedure – TCLP; IW-S-7: Field Protable X-ray Flourecence FTXRF; AS 4439.1-1999: Wastes, sediments and contaminated soils - Preparation of leachates - Preliminary assessment; AS 4439.3-1997: Wastes, sediments and contaminated soils - Preparation of leachates - Bottle leaching procedures.

**Scope of Accreditation:**

| Materials/Products Tested | Types of Tests | Standard Specifications, Equipment/Techniques Used |
|---|---|---|
| 1- Waste (Solid, sludge and liquid) | Quantification of metals by ICP-OES following ASLP, reagent water (Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Rb, P, Pb, Sb, Se, Sn, Sr, Ti, Tl, U, V, Zn) | IW-M-01 - Based on method 6010C |
| 2- Solids & Liquids | Determination of VOC; BTEX by GC/MS Headspace | IW-M-02 - Based on method EPA 8260B; EPA 5030B(Liquid) and EPA 5035 (solid) |
| 3- Potable water & leachates | pH at 25 $^{o}$C | IW-M-03 |
| 4- Potable water & leachates | Electrical Conductivity at 25$^{o}$C | IW-M-04 |

**Disclaimer:**

*Analysis results relate only to the samples submitted. The laboratory has no control over the sampling protocol, the representivity of the samples and the manner in which the samples were collected, transported, stored, preserved or otherwise handled outside of the laboratory facility and therefore takes no responsibility whatsoever for these activities. Third parties using INTERWASTE results can verify the results by contacting the laboratory. INTERWASTE are not liable or responsible for the customer use and/or interpretation of test results. This certificate cannot be reproduced without the written consent of INTERWASTE laboratory.*

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**References**

1.) Government Notice R.365, National Environmental Management: Waste Act (59/2008): National norms and standards for the assessment of waste for landfill disposal, Gazette No. 36

Signed by: Dr. Cheila Canario
Signed at: 2020-07-28 14:51:01 +02:00
Reason: Witnessing Dr. Cheila Canario

# ANNEXURE C: GENERATOR SANS 10234 SAFETY DATA SHEET (SDS) FOR CHROME DIRECT REDUCTION SLIMES STOCKPILE

SANS10234 Safety Data Sheet

# Samancor Chrome

Chrome Direct Reduction (CDR) Slimes Stockpile

| Section1: Product & Generator Identification | | | |
|---|---|---|---|
| Waste Type | Chrome Direct Reduction (CDR) Slimes Stockpile | Synonym(s) | - |
| Waste Generator | Samancor Chrome Middelburg Ferrochrome | Mail: Corne.pretorius@samancorcr.com | |
| | | Emergency Contact Person | Corne Pretorius |
| | | Emergency No. | **+27 (0)** |
| Waste Origin | The subject waste stream is generated as a by-product during the production of low carbon ferrochrome, whereby chrome ore is brought into contact with finely divided coal at high temperature. The resultant slimes are the dust produced in this process which is captured via water sprays, and stored in the slimes dam. | | |

| Section 2: Hazards Identification | | |
|---|---|---|
| Physical | Health | Environmental |
| - | Skin Irritation (Category 2)<br>Eye Irritation (Category 2)<br>Carcinogenicity (Category 1B)<br>Specific Target Organ Toxicity – Single Exposure (Category 3)<br>Specific Target Organ Toxicity – Repeated Exposure (Category 1) | - |
| GHS Hazard Symbol(s) | | |
|   | | |
| Signal Word | **Danger** | |
| Hazard Statement(s) | H315: Causes skin irritation<br>H319: Causes severe eye irritation<br>H335: May cause respiratory irritation<br>H350: May cause cancer<br>H372: Causes damage to organs through prolonged or repeated exposure | |
| Precautionary Statement(s) | P201: Obtain special instructions before use<br>P202: Do not handle until all safety precautions have been read and understood<br>P260: Do not breathe dust<br>P264: Wash exposed parts of body thoroughly after handling<br>P270: Do not eat or drink when near this waste stream<br>P271: Use only outdoors or in well ventilated area<br>P280: Wear protective gloves / protective clothing / eye protection / face protection<br>P281: Use personal protective equipment as required<br>P314: Get medical advice/attention if you feel unwell<br>P362: Take off contaminated clothing and wash before re-use<br>P302+P352: IF ON SKIN: Wash with plenty of soap and water | |

| | |
|---|---|
| | P304+P340: IF INHALED: Remove to fresh air and keep at rest in a position comfortable for breathing<br>P308+P313: If exposed or concerned: Call a POISON CENTRE or doctor/physician<br>P332+P313: If skin irritation occurs: Get medical advice/attention<br>P337+P313: If eye irritation persists: Get medical advice/attention<br>P305+P351+P338: IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing<br>P405: Store locked up<br>P403+P233: Store in a well-ventilated place and keep container tightly closed<br>P501:Dispose of waste stream in line with local legislation |

**Section 3: Composition / Information on Ingredients**

| Common Chemical Name | Synonym(s) | CAS# | Concentration (%/weight) |
|---|---|---|---|
| Quartz | | 14808-60-7 | 2.09 – 42.71 |
| Mullite | | 1302-93-8 | 0.06 – 8.65 |
| Bassanite | | 7778-18-9 | 0.16 – 2.17 |
| Magnetite | | 1317-61-9 | 0.36 – 1.02 |
| Iron | | 7439-89-6 | 0.05 – 0.99 |
| Chromite | | 1308-31-2 | 2.10 – 14.60 |
| Calcite | | 471-34-1 | 0.52 – 2.27 |
| Dolomite | | 16389-88-1 | 0 – 0.86 |
| Hematite | | 1317-60-8 | 0 – 1.46 |
| Kaolinite | | 1318-74-7 | 0 – 5.34 |
| Plagioclase | | - | 0 – 0.83 |
| Aluminium Oxide | | 1344-28-1 | 0 – 5.76 |
| Silicon Dioxide | | 14808-60-7 | 8.61 – 31.59 |
| Phosphorous Pentoxide | | 1314-56-3 | 0.16 – 0.49 |
| Calcium Carbonate | | 471-34-1 | 0 – 1.55 |
| Manganese Oxide | | 1313-13-9 | 0.14 – 0.82 |
| Iron Oxide | | 1309-37-1 | 0.83 – 14.97 |
| Sodium Sulphate | | 7757-82-6 | 0.49 – 6.92 |

The Chrome Direct Reduction Slimes Stockpile consists of the above mentioned ingredients, which may be present within their indicated concentrations in this waste stream.

**Section 4: First Aid Measures**

| | |
|---|---|
| General advice | When consulting a physician. Show this safety data sheet to the doctor in attendance. |
| Contact with Skin | Take off contaminated clothing and shoes immediately. Wash off with plenty of soap and water. Obtain medical advice if irritation persists or later develops. |
| Contact with Eyes | Check for and remove contact lenses. Hold eyelids open and rinse thoroughly with plenty of water for at least 15 minutes. Obtain medical advice. |
| Inhalation | If irritation develops or persist, call for medical assistance. |
| Ingestion | Never give anything by mouth to an unconscious person. Rinse mouth with water. DO NOT induce vomiting. |
| PPE for First Aid Responders | Wear protective clothing, gloves, and eye protection. |

**Section 5: Fire-fighting Measures**

| | |
|---|---|
| Extinguishing Media | Use extinguishing medium suitable to the surrounding environment. |

| | |
|---|---|
| Potential Products of Combustion | Not determined. |
| Protective equipment / precautions for fire-fighters | Wear self-contained breathing apparatus for firefighting as necessary. |

**Section 6: Accidental Release Measures**

| | | |
|---|---|---|
| Personal Precautions / PPE | Response and clean-up crews must be properly trained. | |
| Environmental Precautions | Prevent further leakage or leakage if safe to do so. Do not let product enter drains. Discharge into the environment if permitted. | |
| Clean-up Method / Materials & Containment | SMALL SPILL | LARGE SPILL |
| | As per large spill → | Collect spilled waste manually, and place into appropriate receptacle, noting that any materials used during the clean-up reflects the same hazards as the Chrome Direct Reduction Slimes Stockpile. |
| Materials/containers NOT to be Used for Clean-up | None identified. | |

**Section 7: Handling and Storage**

| | |
|---|---|
| Precautions for Safe Handling | Handle in accordance with good industrial hygiene and safety practice. The personal protection and controls identified in Section 8 of the SDS should be used as appropriate. |
| Precautions for Safe Storage | Apply relevant license conditions and or National Waste Storage Standards, as relevant. |
| Compatibility Issues | Not determined. |

**Section 8: Exposure Controls / Personal Protection**

| | Component | Source | Limit (mg/m$^3$ unless otherwise stated) |
|---|---|---|---|
| Exposure Limits | Quartz | OSHA (Dust) | 0.1 (TWA) |
| | Calcium Carbonate | OSHA (Dust) | 15 (PEL) |
| | Sodium Sulphate | DNEL (Dust) | 4 (TWA) |

| | | |
|---|---|---|
| Engineering Controls | Clean up contaminated areas | |
| Personal Protective Equipment | Eye Protection | Safety glasses or goggles. |
| | Skin Protection | Gloves and clothing covering body as determined by a risk assessment. |
| | Respiratory Protection | Suitable respiratory equipment to be selected under guidance by the relevant occupational health and safety authority. |

**Section 9: Physical and Chemical Properties**

| **Appearance** | | **Physical Characteristics (continued)** | |
|---|---|---|---|
| **Physical state** | Solid | **Initial boiling point** | Not determined |
| **Colour** | Grey to black | **Flash point** | Not determined |
| **Odour** | | **Auto ignition temperature** | Not determined |
| **Odour** | Not determined | **Decomposition temperature** | Not determined |
| **Odour threshold** | Not determined | **Solubility** | Not determined |
| **Physical Characteristics** | | **Partition coefficient: n-octanol/water** | Not determined |
| **pH** | 7.3 – 9.6 | **Viscosity** | Not determined |

| | | | |
|---|---|---|---|
| **Melting point** | Not determined | **% volatile(s)** | Not determined |
| **Flammability** | Not determined | **Evaporation rate** | Not determined |

**Section 10: Stability and Reactivity**

| | |
|---|---|
| Chemical stability | Stable under normal conditions. |
| Possibility of Hazardous Reactions | Not subject to polymerisation under normal conditions. |
| Hazardous Decomposition Products | Not determined. |
| Incompatible Substances / Materials | Not determined. |
| Conditions to Avoid | Incompatible materials. |

**Section 11: Toxicological Information**

| | | |
|---|---|---|
| Likely Routes of Exposure | | Dermal, inhalation, and eye contact |
| Acute Symptoms and Effects | Skin/eye Contact | May cause serious skin and eye irritation. |
| | Inhalation | Not determined. |
| | Ingestion / Oral exposure | Not determined. |

| Constituent / Ingredient Toxicity | $LD_{50}$ | | $LC_{50}$ |
|---|---|---|---|
| | Oral | Dermal | Inhalation (Vapours) |
| Chrome Direct Reduction Slimes Stockpile | > 5 000mg/kg | > 5 000mg/kg | > 20.0 mg/l |

| | |
|---|---|
| Specific Target Organ Toxicity | May cause respiratory irritation following single exposure. Causes damage to organs through prolonged or repeated exposure. |
| Germ Cell Mutagenicity | - |
| Carcinogenicity | May cause cancer. |
| Reproductive toxicity | - |
| Irritancy | - |
| Sensitization | - |

**Section 12: Ecological Information**

| Constituent Ecotoxicity | $LC_{50}$ | $EC_{50}$ |
|---|---|---|
| Chrome Direct Reduction Slimes Stockpile | > 100 mg/L | > 100 mg/L |

| | |
|---|---|
| Persistence and Degradability | Not determined. |
| Bioaccumulation Potential | Not determined. |
| Mobility in Soil | Not determined. |
| Other Adverse Effects | Not determined. |

**Section 13: Disposal Considerations**

As assessed in terms of the South African National Standard for the Assessment of Waste for Landfill Disposal (GN R 635 of 23 August 2013).

| | |
|---|---|
| Potential Landfill Prohibition / Restrictions | As assessed under GN R 635 of August 2013. |
| Treatment Prior to Disposal | Not determined. |

| **Section 14: Transport Information** | | | |
|---|---|---|---|
| Waste Classification | Not classified as a dangerous good for transport | Labelling Required | *Not required under SANS 10228 |
| UN number | - | | |
| Shipping Name | - | | |
| Packing Group | - | | |
| SANS10228 / Transport Hazard Class(es) | - | | |
| Marine Pollutant | - | | |
| Special Instruction(s) | - | | |

| **Section 15: Regulatory Information** | |
|---|---|
| Safety, Health and Environmental Legislation / Standards / Guideline | Comments / Applicability |
| National Environmental Management Act, 1998 (Act 107 of 1998)[NEMA] | Principles, aims and objectives from environmental management in South Africa. |
| National Environmental Management: Waste Act, 2008 (Act 59 of 2008)[NEM:WA] | Principles, aims and objectives for sound waste management practices in South Africa. Provides for, *inter alia*, the definition of 'waste' |
| National Waste Classification and Management Regulations (GN R 634 of 23 August 2013) | Covers the requirements for waste management, classification and assessment for disposal to landfill of waste in South Africa. |
| National Standard for the Assessment of Waste for Disposal to Landfill (GN R 635 of 23 August 2013) | Covers the requirements for the assessment of waste for disposal to landfill; where disposal is relevant. |
| National Standard for the Disposal of Waste to Landfill (GN R 636 of 23 August 2013) | Covers the requirements (incl. prohibitions) for the disposal of waste to landfill; where disposal is relevant. |
| SANS 10228 (The identification and classification of dangerous goods for transport) | Standard cover the identification of dangerous goods that are capable of posing significant risk to health and safety or to property and the environment; where such is linked to transport requirements for the transport of such goods. |
| SANS 10232 (Transport of Dangerous Goods – Emergency Information Systems) | Covers the requirements for emergency information systems, placards and emergency information documents relevant to incidents involving dangerous goods. |
| SANS 10234 (Globally Harmonised System of Classification and Labelling of Chemicals) | Covers the classification of hazardous substances, 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. |
| National Water Act, 1998 (Act 36 of 1998)[NWA] | Promotes the protection of water resources in the National interest. |
| Occupational Health and Safety Act, 1993 (Act 85 | Provides for the health and safety of persons at work. |

| | |
|---|---|
| of 1993)[OHSA], as amended | |

**Section 16: Other Information**

| Physical Hazards | | Health Hazards | | Environmental Hazards | |
|---|---|---|---|---|---|
| Explosives | X | Acute Toxicity: Oral | X | Acute Toxicity – Acute | X |
| Flammable Gases | X | Acute Toxicity: Skin | X | Acute Toxicity – Chronic | X |
| Flammable Aerosols | X | Acute Toxicity: Inhalation | X | | |
| Oxidizing Gases | X | Skin Corrosion/Irritation | ✓ | | |
| Gases Under Pressure | X | Serious Eye Damage/Eye Irritation | ✓ | | |
| Flammable Liquids | X | Respiratory Sensitization | X | | |
| Flammable Solids | X | Skin Sensitization | X | | |
| Self-Reactive Substances | X | Germ Cell Mutagenicity | X | | |
| Pyrophoric Liquids | X | Carcinogenicity | ✓ | | |
| Pyrophoric Solids | X | Toxic To Reproduction | X | | |
| Self-Heating Substances | X | Specific Target Organ Toxicity – Single Exposure | ✓ | | |
| Substances That, On Contact With Water, Emit Flammable Gases | X | Specific Target Organ Toxicity – Repeated Exposure | ✓ | | |
| Oxidizing Liquids | X | Aspiration Hazard | X | | |
| Oxidizing Solids | X | | | | |
| Organic Peroxides | X | | | | |
| Corrosive To Metals | X | | | | |

| KEY | |
|---|---|
| Applicable | ✓ |
| Not applicable | X |

# Particle size distribution

# Micron Scientific (PTY)LTD

| Measurement Details | |
|---|---|
| **Sample Name** | Average of 'IW2020-0461 - screened' |
| **SDS** | 6368 |
| **SOP File Name** | Default + 60us.msop |

| Measurement Details | |
|---|---|
| **Measurement Date Time** | 2020/07/09 09:33:39 |
| **Analysis Date Time** | 2020/07/09 09:33:39 |
| **Original Record Number** | 54 |

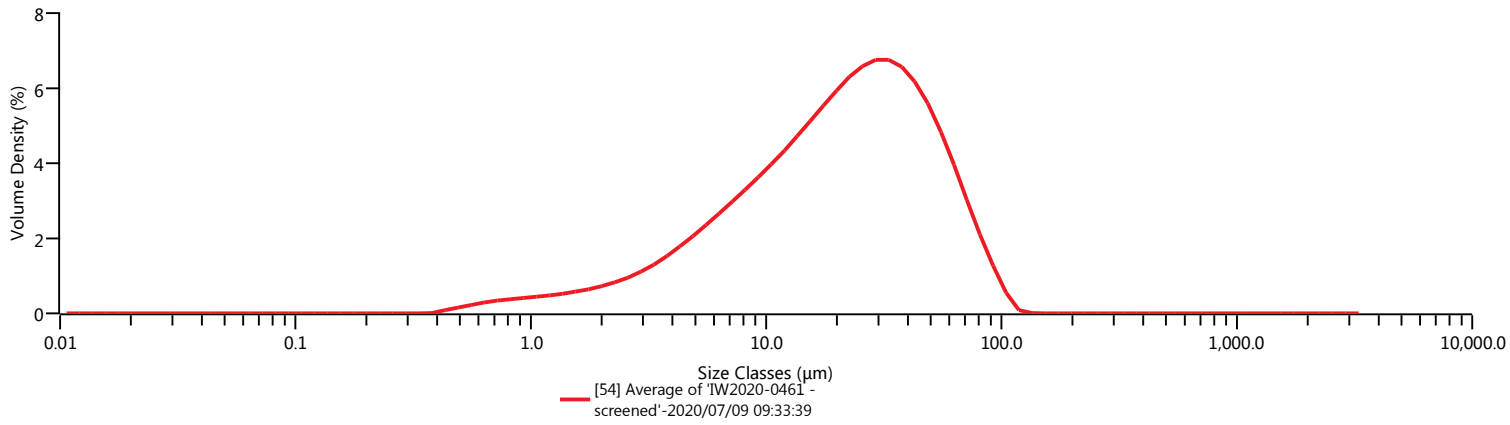
| Analysis | |
|---|---|
| **Particle Name** | Default 1.0 |
| **Dispersant Name** | Water |
| **Particle Absorption Index** | 1.000 |
| **Weighted Residual** | 0.63 % |
| **Analysis Model** | General Purpose |

| Analysis | |
|---|---|
| **Particle Refractive Index** | 1.520 |
| **Dispersant Refractive Index** | 1.330 |
| **Laser Obscuration** | 11.95 % |
| **Scattering Model** | Mie |
| **Analysis Sensitivity** | Normal |

| Result | |
|---|---|
| **Concentration** | 0.0134 % |
| **Uniformity** | 0.763 |
| **Specific Surface Area** | 643.9 $m^2/kg$ |
| **D [3,2]** | 8.87 µm |
| **D [4,3]** | 26.7 µm |

| Result | |
|---|---|
| **Span** | 2.461 |
| **Result Units** | Volume |
| **Dv (10)** | 4.35 µm |
| **Dv (50)** | 21.5 µm |
| **Dv (90)** | 57.2 µm |

Frequency (compatible)




Result

| Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0100 | 0.00 | 0.0995 | 0.00 | 0.991 | 1.57 | 9.86 | 24.76 | 98.1 | 99.52 | 976 | 100.00 |
| 0.0114 | 0.00 | 0.113 | 0.00 | 1.13 | 1.94 | 11.2 | 28.07 | 111 | 99.96 | 1110 | 100.00 |
| 0.0129 | 0.00 | 0.128 | 0.00 | 1.28 | 2.33 | 12.7 | 31.69 | 127 | 100.00 | 1260 | 100.00 |
| 0.0147 | 0.00 | 0.146 | 0.00 | 1.45 | 2.77 | 14.5 | 35.62 | 144 | 100.00 | 1430 | 100.00 |
| 0.0167 | 0.00 | 0.166 | 0.00 | 1.65 | 3.25 | 16.4 | 39.90 | 163 | 100.00 | 1630 | 100.00 |
| 0.0189 | 0.00 | 0.188 | 0.00 | 1.88 | 3.78 | 18.7 | 44.52 | 186 | 100.00 | 1850 | 100.00 |
| 0.0215 | 0.00 | 0.214 | 0.00 | 2.13 | 4.38 | 21.2 | 49.47 | 211 | 100.00 | 2100 | 100.00 |
| 0.0244 | 0.00 | 0.243 | 0.00 | 2.42 | 5.07 | 24.1 | 54.74 | 240 | 100.00 | 2390 | 100.00 |
| 0.0278 | 0.00 | 0.276 | 0.00 | 2.75 | 5.86 | 27.4 | 60.24 | 272 | 100.00 | 2710 | 100.00 |
| 0.0315 | 0.00 | 0.314 | 0.00 | 3.12 | 6.78 | 31.1 | 65.88 | 310 | 100.00 | 3080 | 100.00 |
| 0.0358 | 0.00 | 0.357 | 0.00 | 3.55 | 7.86 | 35.3 | 71.53 | 352 | 100.00 | 3500 | 100.00 |
| 0.0407 | 0.00 | 0.405 | 0.00 | 4.03 | 9.13 | 40.1 | 77.03 | 400 | 100.00 | | |
| 0.0463 | 0.00 | 0.460 | 0.07 | 4.58 | 10.62 | 45.6 | 82.19 | 454 | 100.00 | | |
| 0.0526 | 0.00 | 0.523 | 0.20 | 5.21 | 12.33 | 51.8 | 86.87 | 516 | 100.00 | | |
| 0.0597 | 0.00 | 0.594 | 0.39 | 5.92 | 14.29 | 58.9 | 90.91 | 586 | 100.00 | | |
| 0.0679 | 0.00 | 0.675 | 0.63 | 6.72 | 16.51 | 66.9 | 94.21 | 666 | 100.00 | | |
| 0.0771 | 0.00 | 0.767 | 0.91 | 7.64 | 18.99 | 76.0 | 96.73 | 756 | 100.00 | | |
| 0.0876 | 0.00 | 0.872 | 1.23 | 8.68 | 21.73 | 86.4 | 98.47 | 859 | 100.00 | | |

# Particle size distribution

# Micron Scientific (PTY)LTD

| Measurement Details | |
|---|---|
| **Sample Name** | Average of 'IW2020-0462 - screened' |
| **SDS** | 6369 |
| **SOP File Name** | Default + 60us.msop |

| Measurement Details | |
|---|---|
| **Measurement Date Time** | 2020/07/09 09:52:26 |
| **Analysis Date Time** | 2020/07/09 09:52:26 |
| **Original Record Number** | 58 |

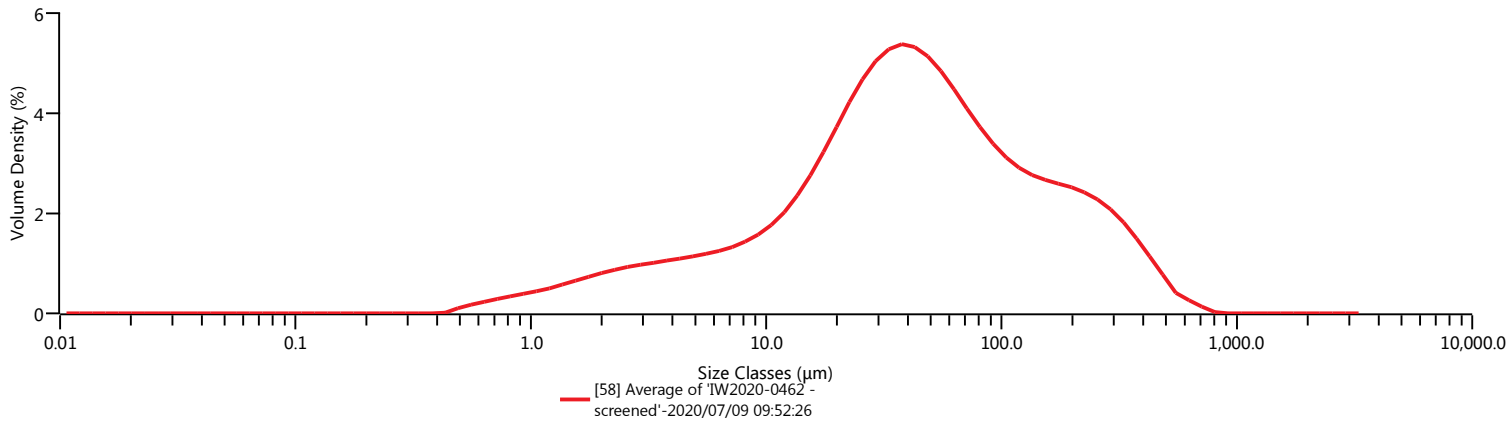
| Analysis | |
|---|---|
| **Particle Name** | Default 1.0 |
| **Dispersant Name** | Water |
| **Particle Absorption Index** | 1.000 |
| **Weighted Residual** | 0.34 % |
| **Analysis Model** | General Purpose |

| Analysis | |
|---|---|
| **Particle Refractive Index** | 1.520 |
| **Dispersant Refractive Index** | 1.330 |
| **Laser Obscuration** | 5.58 % |
| **Scattering Model** | Mie |
| **Analysis Sensitivity** | Normal |

| Result | |
|---|---|
| **Concentration** | 0.0079 % |
| **Uniformity** | 1.536 |
| **Specific Surface Area** | 490.8 $m^2/kg$ |
| **D [3,2]** | 11.6 µm |
| **D [4,3]** | 80.5 µm |

| Result | |
|---|---|
| **Span** | 5.314 |
| **Result Units** | Volume |
| **Dv (10)** | 5.03 µm |
| **Dv (50)** | 40.6 µm |
| **Dv (90)** | 221 µm |

Frequency (compatible)




Result

| Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0100 | 0.00 | 0.0995 | 0.00 | 0.991 | 1.27 | 9.86 | 15.88 | 98.1 | 75.49 | 976 | 100.00 |
| 0.0114 | 0.00 | 0.113 | 0.00 | 1.13 | 1.64 | 11.2 | 17.35 | 111 | 78.09 | 1110 | 100.00 |
| 0.0129 | 0.00 | 0.128 | 0.00 | 1.28 | 2.06 | 12.7 | 19.03 | 127 | 80.51 | 1260 | 100.00 |
| 0.0147 | 0.00 | 0.146 | 0.00 | 1.45 | 2.53 | 14.5 | 20.99 | 144 | 82.81 | 1430 | 100.00 |
| 0.0167 | 0.00 | 0.166 | 0.00 | 1.65 | 3.08 | 16.4 | 23.29 | 163 | 85.03 | 1630 | 100.00 |
| 0.0189 | 0.00 | 0.188 | 0.00 | 1.88 | 3.69 | 18.7 | 25.98 | 186 | 87.19 | 1850 | 100.00 |
| 0.0215 | 0.00 | 0.214 | 0.00 | 2.13 | 4.36 | 21.2 | 29.08 | 211 | 89.30 | 2100 | 100.00 |
| 0.0244 | 0.00 | 0.243 | 0.00 | 2.42 | 5.09 | 24.1 | 32.61 | 240 | 91.32 | 2390 | 100.00 |
| 0.0278 | 0.00 | 0.276 | 0.00 | 2.75 | 5.86 | 27.4 | 36.51 | 272 | 93.22 | 2710 | 100.00 |
| 0.0315 | 0.00 | 0.314 | 0.00 | 3.12 | 6.67 | 31.1 | 40.72 | 310 | 94.96 | 3080 | 100.00 |
| 0.0358 | 0.00 | 0.357 | 0.00 | 3.55 | 7.51 | 35.3 | 45.14 | 352 | 96.49 | 3500 | 100.00 |
| 0.0407 | 0.00 | 0.405 | 0.00 | 4.03 | 8.39 | 40.1 | 49.63 | 400 | 97.74 | | |
| 0.0463 | 0.00 | 0.460 | 0.00 | 4.58 | 9.30 | 45.6 | 54.08 | 454 | 98.69 | | |
| 0.0526 | 0.00 | 0.523 | 0.09 | 5.21 | 10.25 | 51.8 | 58.37 | 516 | 99.33 | | |
| 0.0597 | 0.00 | 0.594 | 0.23 | 5.92 | 11.24 | 58.9 | 62.42 | 586 | 99.66 | | |
| 0.0679 | 0.00 | 0.675 | 0.43 | 6.72 | 12.28 | 66.9 | 66.15 | 666 | 99.88 | | |
| 0.0771 | 0.00 | 0.767 | 0.67 | 7.64 | 13.39 | 76.0 | 69.57 | 756 | 99.99 | | |
| 0.0876 | 0.00 | 0.872 | 0.95 | 8.68 | 14.58 | 86.4 | 72.67 | 859 | 100.00 | | |

# Particle size distribution

# Micron Scientific (PTY)LTD

| Measurement Details | |
|---|---|
| **Sample Name** | Average of 'IW2020-0463 - screened' |
| **SDS** | 6370 |
| **SOP File Name** | Default + 60us.msop |

| Measurement Details | |
|---|---|
| **Measurement Date Time** | 2020/07/09 10:01:56 |
| **Analysis Date Time** | 2020/07/09 10:01:56 |
| **Original Record Number** | 62 |

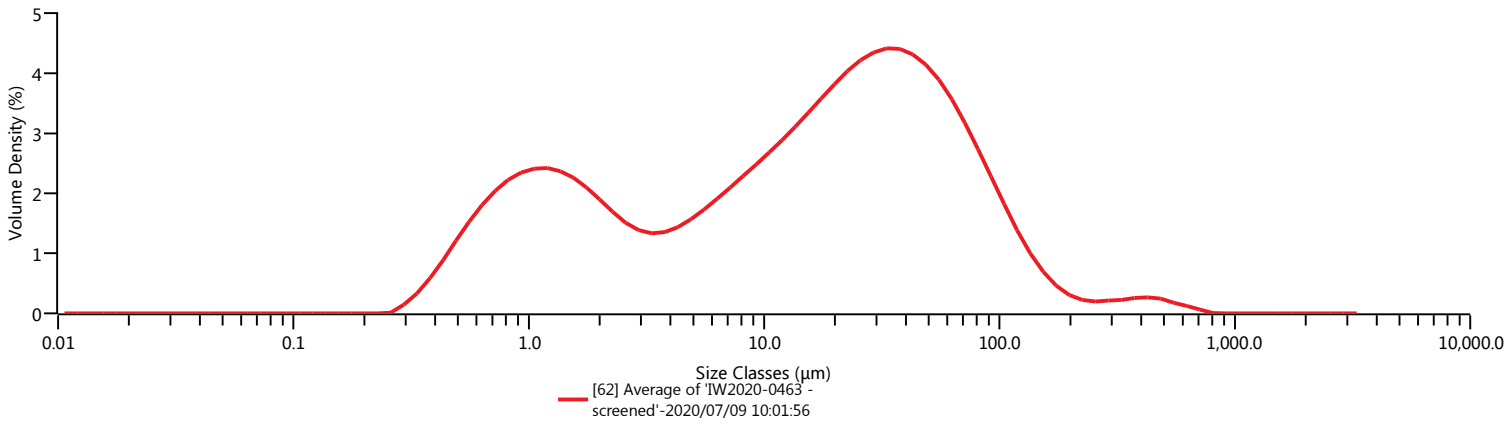
| Analysis | |
|---|---|
| **Particle Name** | Default 1.0 |
| **Dispersant Name** | Water |
| **Particle Absorption Index** | 1.000 |
| **Weighted Residual** | 0.39 % |
| **Analysis Model** | General Purpose |

| Analysis | |
|---|---|
| **Particle Refractive Index** | 1.520 |
| **Dispersant Refractive Index** | 1.330 |
| **Laser Obscuration** | 15.24 % |
| **Scattering Model** | Mie |
| **Analysis Sensitivity** | Normal |

| Result | |
|---|---|
| **Concentration** | 0.0060 % |
| **Uniformity** | 1.716 |
| **Specific Surface Area** | 1813 $m^2/kg$ |
| **D [3,2]** | 3.15 µm |
| **D [4,3]** | 34.0 µm |

| Result | |
|---|---|
| **Span** | 4.606 |
| **Result Units** | Volume |
| **Dv (10)** | 0.932 µm |
| **Dv (50)** | 16.8 µm |
| **Dv (90)** | 78.3 µm |

Frequency (compatible)




Result

| Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0100 | 0.00 | 0.0995 | 0.00 | 0.991 | 10.93 | 9.86 | 39.46 | 98.1 | 93.65 | 976 | 100.00 |
| 0.0114 | 0.00 | 0.113 | 0.00 | 1.13 | 12.94 | 11.2 | 41.69 | 111 | 95.17 | 1110 | 100.00 |
| 0.0129 | 0.00 | 0.128 | 0.00 | 1.28 | 14.96 | 12.7 | 44.10 | 127 | 96.32 | 1260 | 100.00 |
| 0.0147 | 0.00 | 0.146 | 0.00 | 1.45 | 16.94 | 14.5 | 46.69 | 144 | 97.15 | 1430 | 100.00 |
| 0.0167 | 0.00 | 0.166 | 0.00 | 1.65 | 18.83 | 16.4 | 49.48 | 163 | 97.72 | 1630 | 100.00 |
| 0.0189 | 0.00 | 0.188 | 0.00 | 1.88 | 20.58 | 18.7 | 52.47 | 186 | 98.10 | 1850 | 100.00 |
| 0.0215 | 0.00 | 0.214 | 0.00 | 2.13 | 22.16 | 21.2 | 55.66 | 211 | 98.35 | 2100 | 100.00 |
| 0.0244 | 0.00 | 0.243 | 0.00 | 2.42 | 23.57 | 24.1 | 59.02 | 240 | 98.53 | 2390 | 100.00 |
| 0.0278 | 0.00 | 0.276 | 0.00 | 2.75 | 24.82 | 27.4 | 62.54 | 272 | 98.69 | 2710 | 100.00 |
| 0.0315 | 0.00 | 0.314 | 0.12 | 3.12 | 25.97 | 31.1 | 66.17 | 310 | 98.87 | 3080 | 100.00 |
| 0.0358 | 0.00 | 0.357 | 0.39 | 3.55 | 27.08 | 35.3 | 69.85 | 352 | 99.05 | 3500 | 100.00 |
| 0.0407 | 0.00 | 0.405 | 0.88 | 4.03 | 28.21 | 40.1 | 73.53 | 400 | 99.27 | | |
| 0.0463 | 0.00 | 0.460 | 1.61 | 4.58 | 29.40 | 45.6 | 77.14 | 454 | 99.49 | | |
| 0.0526 | 0.00 | 0.523 | 2.62 | 5.21 | 30.70 | 51.8 | 80.60 | 516 | 99.70 | | |
| 0.0597 | 0.00 | 0.594 | 3.90 | 5.92 | 32.14 | 58.9 | 83.85 | 586 | 99.85 | | |
| 0.0679 | 0.00 | 0.675 | 5.40 | 6.72 | 33.73 | 66.9 | 86.82 | 666 | 99.95 | | |
| 0.0771 | 0.00 | 0.767 | 7.11 | 7.64 | 35.48 | 76.0 | 89.47 | 756 | 100.00 | | |
| 0.0876 | 0.00 | 0.872 | 8.97 | 8.68 | 37.39 | 86.4 | 91.75 | 859 | 100.00 | | |

# Particle size distribution

# Micron Scientific (PTY)LTD

| Measurement Details | |
|---|---|
| **Sample Name** | Average of 'IW2020-0464 - screened' |
| **SDS** | 6371 |
| **SOP File Name** | Default + 60us.msop |

| Measurement Details | |
|---|---|
| **Measurement Date Time** | 2020/07/09 10:11:16 |
| **Analysis Date Time** | 2020/07/09 10:11:16 |
| **Original Record Number** | 66 |

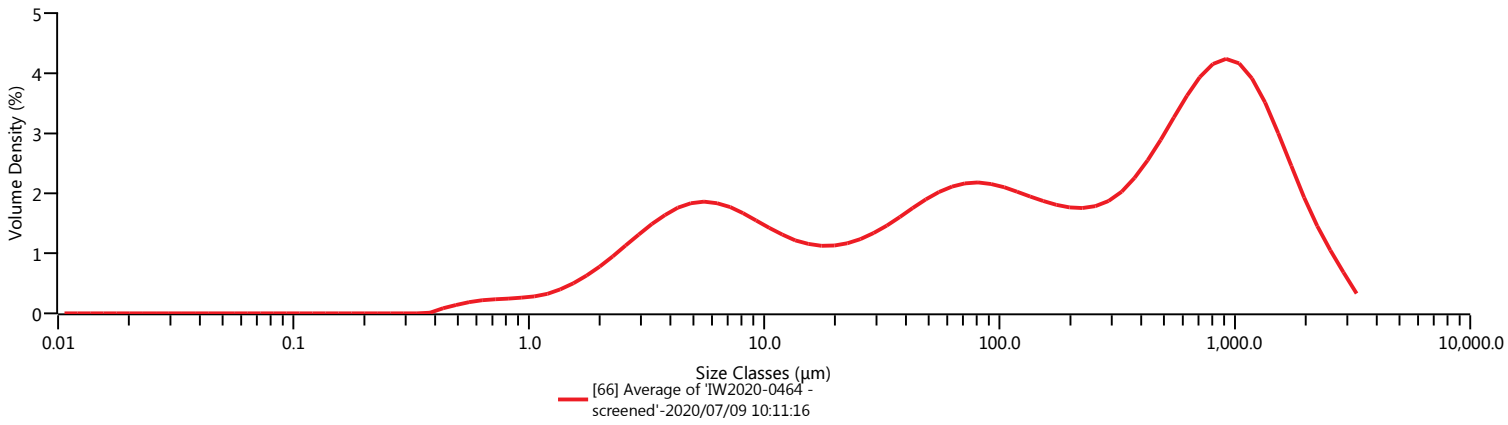
| Analysis | |
|---|---|
| **Particle Name** | Default 1.0 |
| **Dispersant Name** | Water |
| **Particle Absorption Index** | 1.000 |
| **Weighted Residual** | 0.33 % |
| **Analysis Model** | General Purpose |

| Analysis | |
|---|---|
| **Particle Refractive Index** | 1.520 |
| **Dispersant Refractive Index** | 1.330 |
| **Laser Obscuration** | 8.15 % |
| **Scattering Model** | Mie |
| **Analysis Sensitivity** | Normal |

| Result | |
|---|---|
| **Concentration** | 0.0130 % |
| **Uniformity** | 2.612 |
| **Specific Surface Area** | 446.0 $m^2/kg$ |
| **D [3,2]** | 12.8 µm |
| **D [4,3]** | 482 µm |

| Result | |
|---|---|
| **Span** | 8.115 |
| **Result Units** | Volume |
| **Dv (10)** | 4.40 µm |
| **Dv (50)** | 169 µm |
| **Dv (90)** | 1380 µm |

Frequency (compatible)




Result

| Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0100 | 0.00 | 0.0995 | 0.00 | 0.991 | 1.15 | 9.86 | 19.26 | 98.1 | 42.98 | 976 | 81.23 |
| 0.0114 | 0.00 | 0.113 | 0.00 | 1.13 | 1.38 | 11.2 | 20.44 | 111 | 44.73 | 1110 | 84.71 |
| 0.0129 | 0.00 | 0.128 | 0.00 | 1.28 | 1.66 | 12.7 | 21.54 | 127 | 46.42 | 1260 | 87.99 |
| 0.0147 | 0.00 | 0.146 | 0.00 | 1.45 | 1.99 | 14.5 | 22.55 | 144 | 48.05 | 1430 | 90.92 |
| 0.0167 | 0.00 | 0.166 | 0.00 | 1.65 | 2.40 | 16.4 | 23.51 | 163 | 49.61 | 1630 | 93.43 |
| 0.0189 | 0.00 | 0.188 | 0.00 | 1.88 | 2.92 | 18.7 | 24.45 | 186 | 51.11 | 1850 | 95.48 |
| 0.0215 | 0.00 | 0.214 | 0.00 | 2.13 | 3.57 | 21.2 | 25.39 | 211 | 52.58 | 2100 | 97.08 |
| 0.0244 | 0.00 | 0.243 | 0.00 | 2.42 | 4.36 | 24.1 | 26.36 | 240 | 54.04 | 2390 | 98.29 |
| 0.0278 | 0.00 | 0.276 | 0.00 | 2.75 | 5.30 | 27.4 | 27.39 | 272 | 55.53 | 2710 | 99.16 |
| 0.0315 | 0.00 | 0.314 | 0.00 | 3.12 | 6.40 | 31.1 | 28.51 | 310 | 57.08 | 3080 | 99.73 |
| 0.0358 | 0.00 | 0.357 | 0.00 | 3.55 | 7.64 | 35.3 | 29.72 | 352 | 58.77 | 3500 | 100.00 |
| 0.0407 | 0.00 | 0.405 | 0.00 | 4.03 | 9.01 | 40.1 | 31.06 | 400 | 60.64 | | |
| 0.0463 | 0.00 | 0.460 | 0.08 | 4.58 | 10.47 | 45.6 | 32.52 | 454 | 62.76 | | |
| 0.0526 | 0.00 | 0.523 | 0.19 | 5.21 | 12.01 | 51.8 | 34.10 | 516 | 65.17 | | |
| 0.0597 | 0.00 | 0.594 | 0.35 | 5.92 | 13.56 | 58.9 | 35.79 | 586 | 67.89 | | |
| 0.0679 | 0.00 | 0.675 | 0.53 | 6.72 | 15.10 | 66.9 | 37.56 | 666 | 70.92 | | |
| 0.0771 | 0.00 | 0.767 | 0.73 | 7.64 | 16.57 | 76.0 | 39.37 | 756 | 74.21 | | |
| 0.0876 | 0.00 | 0.872 | 0.94 | 8.68 | 17.97 | 86.4 | 41.18 | 859 | 77.68 | | |

# Particle size distribution

# Micron Scientific (PTY)LTD

| Measurement Details | |
|---|---|
| **Sample Name** | Average of 'IW2020-0465 - screened' |
| **SDS** | 6372 |
| **SOP File Name** | Default + 60us.msop |

| Measurement Details | |
|---|---|
| **Measurement Date Time** | 2020/07/09 10:23:00 |
| **Analysis Date Time** | 2020/07/09 10:23:00 |
| **Original Record Number** | 70 |

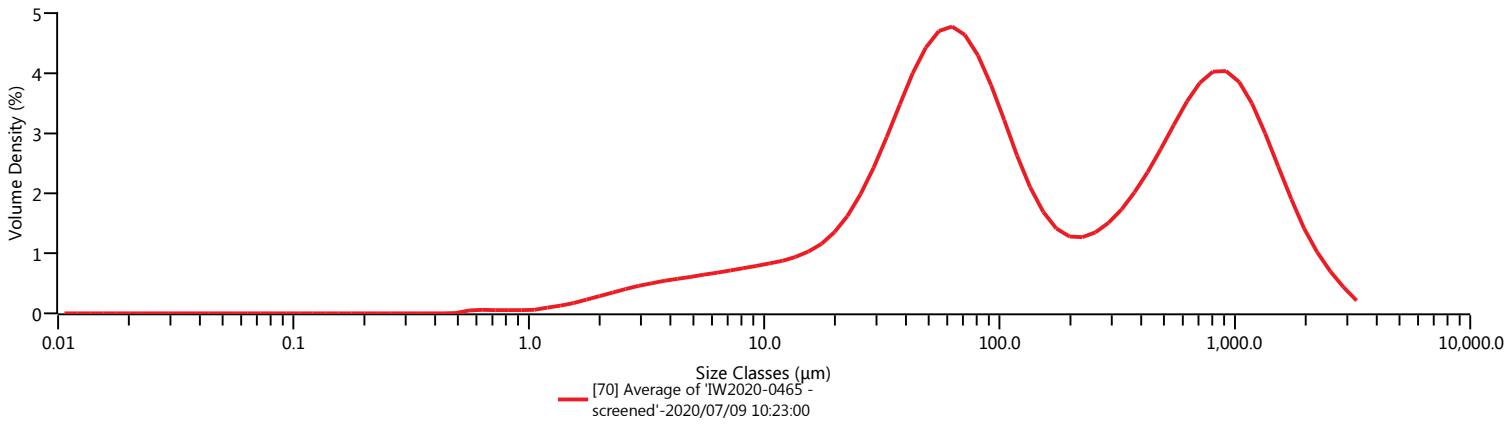
| Analysis | |
|---|---|
| **Particle Name** | Default 1.0 |
| **Dispersant Name** | Water |
| **Particle Absorption Index** | 1.000 |
| **Weighted Residual** | 0.31 % |
| **Analysis Model** | General Purpose |

| Analysis | |
|---|---|
| **Particle Refractive Index** | 1.520 |
| **Dispersant Refractive Index** | 1.330 |
| **Laser Obscuration** | 6.88 % |
| **Scattering Model** | Mie |
| **Analysis Sensitivity** | Normal |

| Result | |
|---|---|
| **Concentration** | 0.0262 % |
| **Uniformity** | 3.486 |
| **Specific Surface Area** | 191.9 $m^2/kg$ |
| **D [3,2]** | 29.8 µm |
| **D [4,3]** | 421 µm |

| Result | |
|---|---|
| **Span** | 11.174 |
| **Result Units** | Volume |
| **Dv (10)** | 16.5 µm |
| **Dv (50)** | 108 µm |
| **Dv (90)** | 1220 µm |

Frequency (compatible)




Result

| Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0100 | 0.00 | 0.0995 | 0.00 | 0.991 | 0.23 | 9.86 | 6.89 | 98.1 | 48.02 | 976 | 84.58 |
| 0.0114 | 0.00 | 0.113 | 0.00 | 1.13 | 0.27 | 11.2 | 7.58 | 111 | 50.71 | 1110 | 87.81 |
| 0.0129 | 0.00 | 0.128 | 0.00 | 1.28 | 0.35 | 12.7 | 8.31 | 127 | 52.90 | 1260 | 90.73 |
| 0.0147 | 0.00 | 0.146 | 0.00 | 1.45 | 0.46 | 14.5 | 9.09 | 144 | 54.64 | 1430 | 93.24 |
| 0.0167 | 0.00 | 0.166 | 0.00 | 1.65 | 0.60 | 16.4 | 9.95 | 163 | 56.04 | 1630 | 95.28 |
| 0.0189 | 0.00 | 0.188 | 0.00 | 1.88 | 0.79 | 18.7 | 10.91 | 186 | 57.21 | 1850 | 96.86 |
| 0.0215 | 0.00 | 0.214 | 0.00 | 2.13 | 1.03 | 21.2 | 12.03 | 211 | 58.27 | 2100 | 98.04 |
| 0.0244 | 0.00 | 0.243 | 0.00 | 2.42 | 1.32 | 24.1 | 13.38 | 240 | 59.32 | 2390 | 98.88 |
| 0.0278 | 0.00 | 0.276 | 0.00 | 2.75 | 1.66 | 27.4 | 15.02 | 272 | 60.44 | 2710 | 99.46 |
| 0.0315 | 0.00 | 0.314 | 0.00 | 3.12 | 2.05 | 31.1 | 17.04 | 310 | 61.69 | 3080 | 99.82 |
| 0.0358 | 0.00 | 0.357 | 0.00 | 3.55 | 2.46 | 35.3 | 19.49 | 352 | 63.13 | 3500 | 100.00 |
| 0.0407 | 0.00 | 0.405 | 0.00 | 4.03 | 2.92 | 40.1 | 22.40 | 400 | 64.81 | | |
| 0.0463 | 0.00 | 0.460 | 0.00 | 4.58 | 3.40 | 45.6 | 25.74 | 454 | 66.77 | | |
| 0.0526 | 0.00 | 0.523 | 0.00 | 5.21 | 3.91 | 51.8 | 29.44 | 516 | 69.05 | | |
| 0.0597 | 0.00 | 0.594 | 0.04 | 5.92 | 4.44 | 58.9 | 33.37 | 586 | 71.67 | | |
| 0.0679 | 0.00 | 0.675 | 0.09 | 6.72 | 5.01 | 66.9 | 37.37 | 666 | 74.61 | | |
| 0.0771 | 0.00 | 0.767 | 0.14 | 7.64 | 5.60 | 76.0 | 41.25 | 756 | 77.83 | | |
| 0.0876 | 0.00 | 0.872 | 0.18 | 8.68 | 6.23 | 86.4 | 44.85 | 859 | 81.20 | | |

# Particle size distribution

# Micron Scientific (PTY)LTD

| Measurement Details | |
|---|---|
| **Sample Name** | Average of 'IW2020-0466 - screened' |
| **SDS** | 6373 |
| **SOP File Name** | Default + 60us.msop |

| Measurement Details | |
|---|---|
| **Measurement Date Time** | 2020/07/09 10:31:38 |
| **Analysis Date Time** | 2020/07/09 10:31:38 |
| **Original Record Number** | 74 |

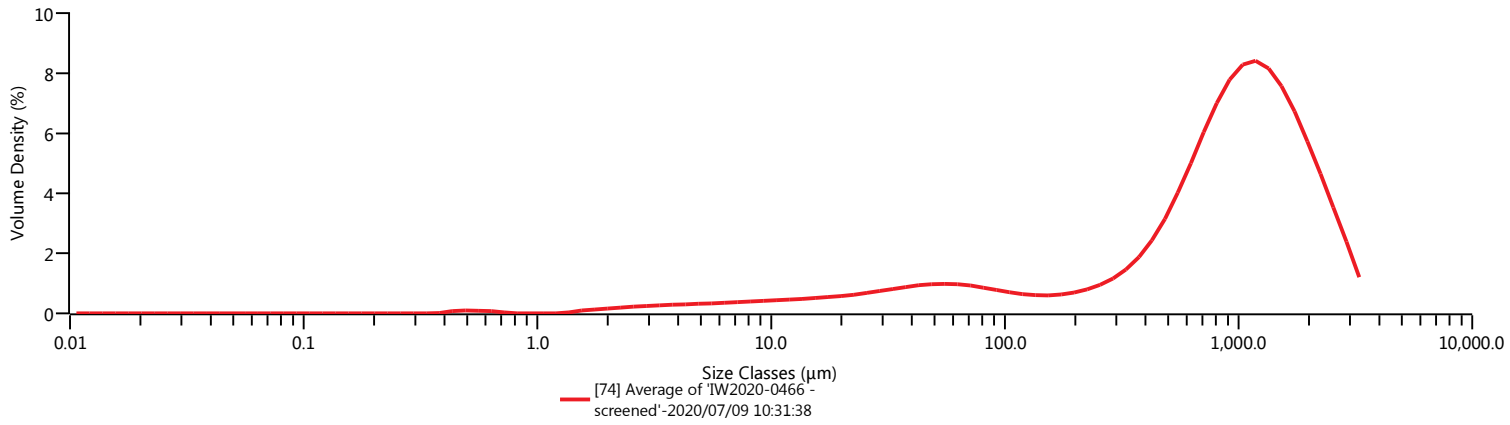
| Analysis | |
|---|---|
| **Particle Name** | Default 1.0 |
| **Dispersant Name** | Water |
| **Particle Absorption Index** | 1.000 |
| **Weighted Residual** | 0.80 % |
| **Analysis Model** | General Purpose |

| Analysis | |
|---|---|
| **Particle Refractive Index** | 1.520 |
| **Dispersant Refractive Index** | 1.330 |
| **Laser Obscuration** | 8.80 % |
| **Scattering Model** | Mie |
| **Analysis Sensitivity** | Normal |

| Result | |
|---|---|
| **Concentration** | 0.0567 % |
| **Uniformity** | 0.650 |
| **Specific Surface Area** | 111.0 $m^2/kg$ |
| **D [3,2]** | 51.5 µm |
| **D [4,3]** | 1020 µm |

| Result | |
|---|---|
| **Span** | 2.206 |
| **Result Units** | Volume |
| **Dv (10)** | 44.6 µm |
| **Dv (50)** | 927 µm |
| **Dv (90)** | 2090 µm |

Frequency (compatible)




Result

| Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0100 | 0.00 | 0.0995 | 0.00 | 0.991 | 0.31 | 9.86 | 3.74 | 98.1 | 14.71 | 976 | 52.63 |
| 0.0114 | 0.00 | 0.113 | 0.00 | 1.13 | 0.31 | 11.2 | 4.10 | 111 | 15.29 | 1110 | 59.56 |
| 0.0129 | 0.00 | 0.128 | 0.00 | 1.28 | 0.31 | 12.7 | 4.48 | 127 | 15.82 | 1260 | 66.61 |
| 0.0147 | 0.00 | 0.146 | 0.00 | 1.45 | 0.33 | 14.5 | 4.89 | 144 | 16.33 | 1430 | 73.44 |
| 0.0167 | 0.00 | 0.166 | 0.00 | 1.65 | 0.41 | 16.4 | 5.31 | 163 | 16.82 | 1630 | 79.77 |
| 0.0189 | 0.00 | 0.188 | 0.00 | 1.88 | 0.52 | 18.7 | 5.76 | 186 | 17.35 | 1850 | 85.39 |
| 0.0215 | 0.00 | 0.214 | 0.00 | 2.13 | 0.66 | 21.2 | 6.24 | 211 | 17.92 | 2100 | 90.17 |
| 0.0244 | 0.00 | 0.243 | 0.00 | 2.42 | 0.82 | 24.1 | 6.76 | 240 | 18.58 | 2390 | 94.05 |
| 0.0278 | 0.00 | 0.276 | 0.00 | 2.75 | 1.00 | 27.4 | 7.33 | 272 | 19.37 | 2710 | 97.00 |
| 0.0315 | 0.00 | 0.314 | 0.00 | 3.12 | 1.21 | 31.1 | 7.94 | 310 | 20.33 | 3080 | 98.99 |
| 0.0358 | 0.00 | 0.357 | 0.00 | 3.55 | 1.43 | 35.3 | 8.62 | 352 | 21.54 | 3500 | 100.00 |
| 0.0407 | 0.00 | 0.405 | 0.00 | 4.03 | 1.66 | 40.1 | 9.35 | 400 | 23.09 | | |
| 0.0463 | 0.00 | 0.460 | 0.07 | 4.58 | 1.91 | 45.6 | 10.13 | 454 | 25.10 | | |
| 0.0526 | 0.00 | 0.523 | 0.15 | 5.21 | 2.18 | 51.8 | 10.95 | 516 | 27.72 | | |
| 0.0597 | 0.00 | 0.594 | 0.22 | 5.92 | 2.46 | 58.9 | 11.77 | 586 | 31.06 | | |
| 0.0679 | 0.00 | 0.675 | 0.29 | 6.72 | 2.75 | 66.9 | 12.58 | 666 | 35.23 | | |
| 0.0771 | 0.00 | 0.767 | 0.31 | 7.64 | 3.07 | 76.0 | 13.35 | 756 | 40.26 | | |
| 0.0876 | 0.00 | 0.872 | 0.31 | 8.68 | 3.39 | 86.4 | 14.06 | 859 | 46.11 | | |

# Particle size distribution

# Micron Scientific (PTY)LTD

| Measurement Details | |
|---|---|
| **Sample Name** | Average of 'IW2020-0467 - screened' |
| **SDS** | 6374 |
| **SOP File Name** | Default + 60us.msop |

| Measurement Details | |
|---|---|
| **Measurement Date Time** | 2020/07/09 10:39:22 |
| **Analysis Date Time** | 2020/07/09 10:39:22 |
| **Original Record Number** | 78 |

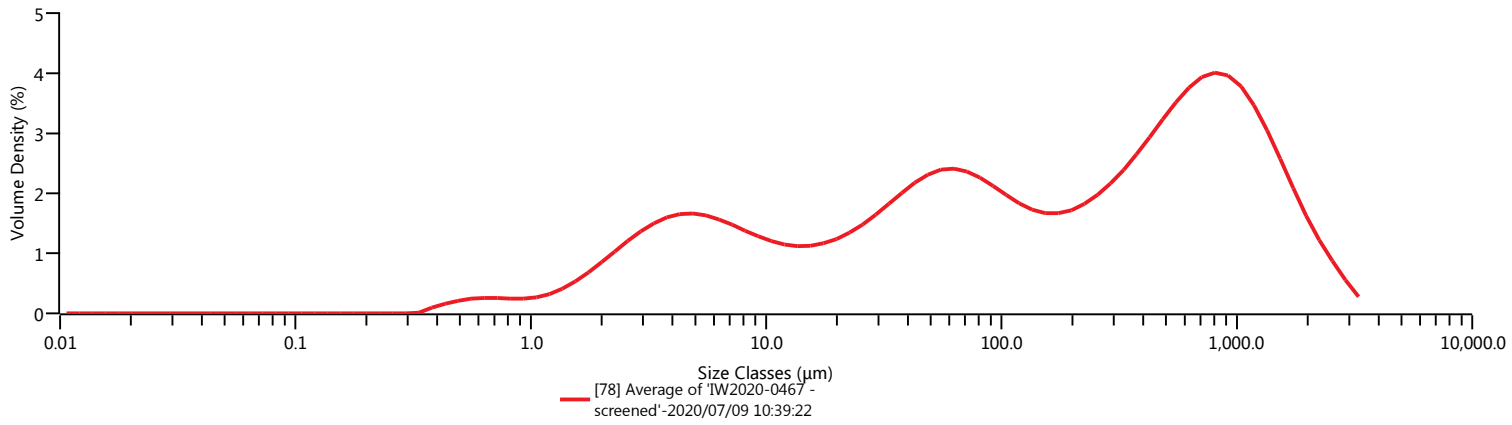
| Analysis | |
|---|---|
| **Particle Name** | Default 1.0 |
| **Dispersant Name** | Water |
| **Particle Absorption Index** | 1.000 |
| **Weighted Residual** | 0.27 % |
| **Analysis Model** | General Purpose |

| Analysis | |
|---|---|
| **Particle Refractive Index** | 1.520 |
| **Dispersant Refractive Index** | 1.330 |
| **Laser Obscuration** | 12.90 % |
| **Scattering Model** | Mie |
| **Analysis Sensitivity** | Normal |

| Result | |
|---|---|
| **Concentration** | 0.0195 % |
| **Uniformity** | 2.631 |
| **Specific Surface Area** | 479.2 $m^2/kg$ |
| **D [3,2]** | 11.9 µm |
| **D [4,3]** | 446 µm |

| Result | |
|---|---|
| **Span** | 8.198 |
| **Result Units** | Volume |
| **Dv (10)** | 4.19 µm |
| **Dv (50)** | 155 µm |
| **Dv (90)** | 1270 µm |

Frequency (compatible)




Result

| Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0100 | 0.00 | 0.0995 | 0.00 | 0.991 | 1.43 | 9.86 | 18.47 | 98.1 | 44.59 | 976 | 83.72 |
| 0.0114 | 0.00 | 0.113 | 0.00 | 1.13 | 1.66 | 11.2 | 19.47 | 111 | 46.24 | 1110 | 86.88 |
| 0.0129 | 0.00 | 0.128 | 0.00 | 1.28 | 1.92 | 12.7 | 20.43 | 127 | 47.76 | 1260 | 89.78 |
| 0.0147 | 0.00 | 0.146 | 0.00 | 1.45 | 2.26 | 14.5 | 21.36 | 144 | 49.20 | 1430 | 92.33 |
| 0.0167 | 0.00 | 0.166 | 0.00 | 1.65 | 2.71 | 16.4 | 22.30 | 163 | 50.58 | 1630 | 94.48 |
| 0.0189 | 0.00 | 0.188 | 0.00 | 1.88 | 3.27 | 18.7 | 23.27 | 186 | 51.97 | 1850 | 96.22 |
| 0.0215 | 0.00 | 0.214 | 0.00 | 2.13 | 3.99 | 21.2 | 24.29 | 211 | 53.40 | 2100 | 97.57 |
| 0.0244 | 0.00 | 0.243 | 0.00 | 2.42 | 4.85 | 24.1 | 25.41 | 240 | 54.92 | 2390 | 98.59 |
| 0.0278 | 0.00 | 0.276 | 0.00 | 2.75 | 5.85 | 27.4 | 26.64 | 272 | 56.56 | 2710 | 99.31 |
| 0.0315 | 0.00 | 0.314 | 0.00 | 3.12 | 6.99 | 31.1 | 28.01 | 310 | 58.36 | 3080 | 99.77 |
| 0.0358 | 0.00 | 0.357 | 0.00 | 3.55 | 8.25 | 35.3 | 29.53 | 352 | 60.35 | 3500 | 100.00 |
| 0.0407 | 0.00 | 0.405 | 0.08 | 4.03 | 9.58 | 40.1 | 31.20 | 400 | 62.56 | | |
| 0.0463 | 0.00 | 0.460 | 0.22 | 4.58 | 10.96 | 45.6 | 33.02 | 454 | 65.01 | | |
| 0.0526 | 0.00 | 0.523 | 0.39 | 5.21 | 12.35 | 51.8 | 34.95 | 516 | 67.70 | | |
| 0.0597 | 0.00 | 0.594 | 0.60 | 5.92 | 13.71 | 58.9 | 36.95 | 586 | 70.63 | | |
| 0.0679 | 0.00 | 0.675 | 0.81 | 6.72 | 15.02 | 66.9 | 38.96 | 666 | 73.77 | | |
| 0.0771 | 0.00 | 0.767 | 1.02 | 7.64 | 16.25 | 76.0 | 40.93 | 756 | 77.06 | | |
| 0.0876 | 0.00 | 0.872 | 1.23 | 8.68 | 17.40 | 86.4 | 42.82 | 859 | 80.41 | | |

# Particle size distribution

# Micron Scientific (PTY)LTD

| Measurement Details | |
|---|---|
| **Sample Name** | Average of 'IW2020-0468 - screened' |
| **SDS** | 6375 |
| **SOP File Name** | Default + 60us.msop |

| Measurement Details | |
|---|---|
| **Measurement Date Time** | 2020/07/09 10:46:44 |
| **Analysis Date Time** | 2020/07/09 10:46:44 |
| **Original Record Number** | 82 |

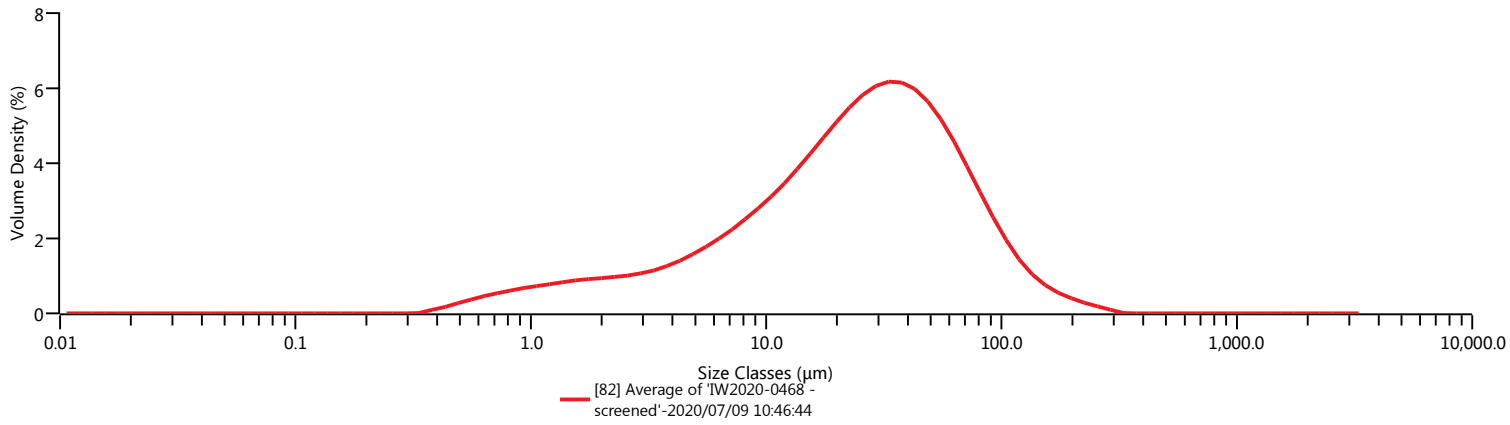
| Analysis | |
|---|---|
| **Particle Name** | Default 1.0 |
| **Dispersant Name** | Water |
| **Particle Absorption Index** | 1.000 |
| **Weighted Residual** | 0.40 % |
| **Analysis Model** | General Purpose |

| Analysis | |
|---|---|
| **Particle Refractive Index** | 1.520 |
| **Dispersant Refractive Index** | 1.330 |
| **Laser Obscuration** | 11.32 % |
| **Scattering Model** | Mie |
| **Analysis Sensitivity** | Normal |

| Result | |
|---|---|
| **Concentration** | 0.0108 % |
| **Uniformity** | 0.945 |
| **Specific Surface Area** | 745.8 $m^2/kg$ |
| **D [3,2]** | 7.66 µm |
| **D [4,3]** | 35.1 µm |

| Result | |
|---|---|
| **Span** | 2.934 |
| **Result Units** | Volume |
| **Dv (10)** | 3.38 µm |
| **Dv (50)** | 25.2 µm |
| **Dv (90)** | 77.3 µm |

Frequency (compatible)




Result

| Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0100 | 0.00 | 0.0995 | 0.00 | 0.991 | 2.65 | 9.86 | 23.31 | 98.1 | 94.46 | 976 | 100.00 |
| 0.0114 | 0.00 | 0.113 | 0.00 | 1.13 | 3.26 | 11.2 | 25.91 | 111 | 96.08 | 1110 | 100.00 |
| 0.0129 | 0.00 | 0.128 | 0.00 | 1.28 | 3.91 | 12.7 | 28.79 | 127 | 97.27 | 1260 | 100.00 |
| 0.0147 | 0.00 | 0.146 | 0.00 | 1.45 | 4.60 | 14.5 | 32.00 | 144 | 98.13 | 1430 | 100.00 |
| 0.0167 | 0.00 | 0.166 | 0.00 | 1.65 | 5.34 | 16.4 | 35.55 | 163 | 98.75 | 1630 | 100.00 |
| 0.0189 | 0.00 | 0.188 | 0.00 | 1.88 | 6.10 | 18.7 | 39.45 | 186 | 99.20 | 1850 | 100.00 |
| 0.0215 | 0.00 | 0.214 | 0.00 | 2.13 | 6.88 | 21.2 | 43.70 | 211 | 99.53 | 2100 | 100.00 |
| 0.0244 | 0.00 | 0.243 | 0.00 | 2.42 | 7.69 | 24.1 | 48.28 | 240 | 99.77 | 2390 | 100.00 |
| 0.0278 | 0.00 | 0.276 | 0.00 | 2.75 | 8.53 | 27.4 | 53.14 | 272 | 99.92 | 2710 | 100.00 |
| 0.0315 | 0.00 | 0.314 | 0.00 | 3.12 | 9.41 | 31.1 | 58.20 | 310 | 100.00 | 3080 | 100.00 |
| 0.0358 | 0.00 | 0.357 | 0.00 | 3.55 | 10.37 | 35.3 | 63.36 | 352 | 100.00 | 3500 | 100.00 |
| 0.0407 | 0.00 | 0.405 | 0.08 | 4.03 | 11.41 | 40.1 | 68.50 | 400 | 100.00 | | |
| 0.0463 | 0.00 | 0.460 | 0.22 | 4.58 | 12.58 | 45.6 | 73.49 | 454 | 100.00 | | |
| 0.0526 | 0.00 | 0.523 | 0.45 | 5.21 | 13.89 | 51.8 | 78.21 | 516 | 100.00 | | |
| 0.0597 | 0.00 | 0.594 | 0.75 | 5.92 | 15.37 | 58.9 | 82.53 | 586 | 100.00 | | |
| 0.0679 | 0.00 | 0.675 | 1.14 | 6.72 | 17.03 | 66.9 | 86.36 | 666 | 100.00 | | |
| 0.0771 | 0.00 | 0.767 | 1.59 | 7.64 | 18.90 | 76.0 | 89.64 | 756 | 100.00 | | |
| 0.0876 | 0.00 | 0.872 | 2.10 | 8.68 | 20.99 | 86.4 | 92.33 | 859 | 100.00 | | |

# Particle size distribution

# Micron Scientific (PTY)LTD

| Measurement Details | |
|---|---|
| **Sample Name** | Average of 'IW2020-0469 - screened' |
| **SDS** | 6376 |
| **SOP File Name** | Default + 60us.msop |

| Measurement Details | |
|---|---|
| **Measurement Date Time** | 2020/07/09 10:54:14 |
| **Analysis Date Time** | 2020/07/09 10:54:14 |
| **Original Record Number** | 86 |

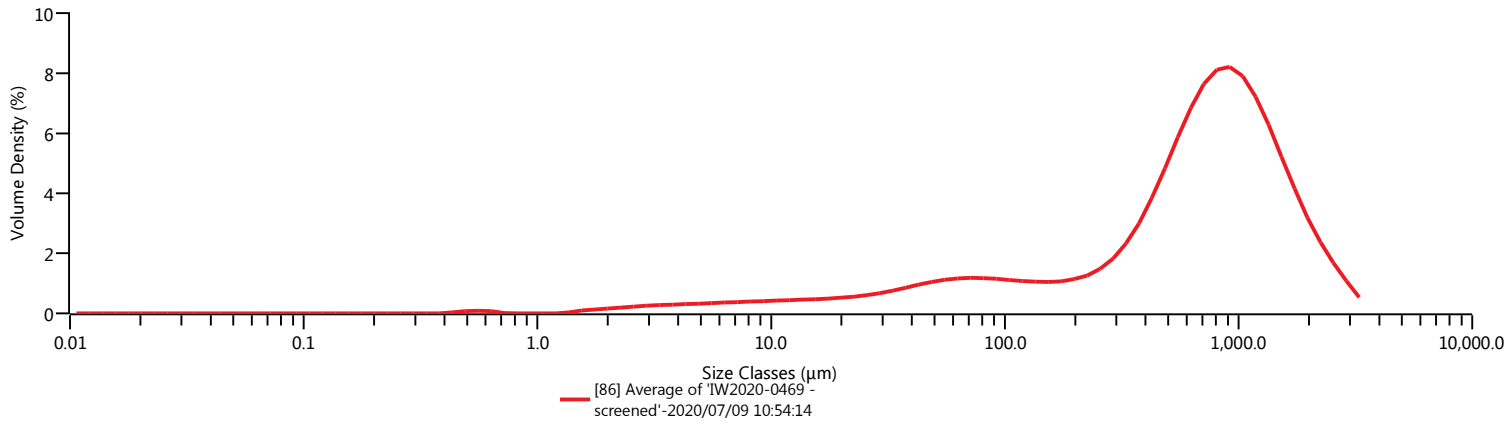
| Analysis | |
|---|---|
| **Particle Name** | Default 1.0 |
| **Dispersant Name** | Water |
| **Particle Absorption Index** | 1.000 |
| **Weighted Residual** | 0.59 % |
| **Analysis Model** | General Purpose |

| Analysis | |
|---|---|
| **Particle Refractive Index** | 1.520 |
| **Dispersant Refractive Index** | 1.330 |
| **Laser Obscuration** | 9.40 % |
| **Scattering Model** | Mie |
| **Analysis Sensitivity** | Normal |

| Result | |
|---|---|
| **Concentration** | 0.0660 % |
| **Uniformity** | 0.696 |
| **Specific Surface Area** | 103.0 $m^2/kg$ |
| **D [3,2]** | 55.5 µm |
| **D [4,3]** | 808 µm |

| Result | |
|---|---|
| **Span** | 2.299 |
| **Result Units** | Volume |
| **Dv (10)** | 47.6 µm |
| **Dv (50)** | 709 µm |
| **Dv (90)** | 1680 µm |

Frequency (compatible)




Result

| Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under | Size (µm) | % Volume Under |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0100 | 0.00 | 0.0995 | 0.00 | 0.991 | 0.22 | 9.86 | 3.70 | 98.1 | 15.42 | 976 | 66.94 |
| 0.0114 | 0.00 | 0.113 | 0.00 | 1.13 | 0.22 | 11.2 | 4.05 | 111 | 16.35 | 1110 | 73.55 |
| 0.0129 | 0.00 | 0.128 | 0.00 | 1.28 | 0.22 | 12.7 | 4.42 | 127 | 17.25 | 1260 | 79.59 |
| 0.0147 | 0.00 | 0.146 | 0.00 | 1.45 | 0.24 | 14.5 | 4.80 | 144 | 18.12 | 1430 | 84.84 |
| 0.0167 | 0.00 | 0.166 | 0.00 | 1.65 | 0.32 | 16.4 | 5.19 | 163 | 18.99 | 1630 | 89.19 |
| 0.0189 | 0.00 | 0.188 | 0.00 | 1.88 | 0.43 | 18.7 | 5.60 | 186 | 19.89 | 1850 | 92.64 |
| 0.0215 | 0.00 | 0.214 | 0.00 | 2.13 | 0.56 | 21.2 | 6.04 | 211 | 20.83 | 2100 | 95.30 |
| 0.0244 | 0.00 | 0.243 | 0.00 | 2.42 | 0.72 | 24.1 | 6.50 | 240 | 21.88 | 2390 | 97.26 |
| 0.0278 | 0.00 | 0.276 | 0.00 | 2.75 | 0.91 | 27.4 | 7.00 | 272 | 23.10 | 2710 | 98.66 |
| 0.0315 | 0.00 | 0.314 | 0.00 | 3.12 | 1.13 | 31.1 | 7.57 | 310 | 24.61 | 3080 | 99.56 |
| 0.0358 | 0.00 | 0.357 | 0.00 | 3.55 | 1.36 | 35.3 | 8.20 | 352 | 26.53 | 3500 | 100.00 |
| 0.0407 | 0.00 | 0.405 | 0.00 | 4.03 | 1.60 | 40.1 | 8.92 | 400 | 29.02 | | |
| 0.0463 | 0.00 | 0.460 | 0.02 | 4.58 | 1.86 | 45.6 | 9.71 | 454 | 32.22 | | |
| 0.0526 | 0.00 | 0.523 | 0.09 | 5.21 | 2.13 | 51.8 | 10.59 | 516 | 36.25 | | |
| 0.0597 | 0.00 | 0.594 | 0.16 | 5.92 | 2.41 | 58.9 | 11.52 | 586 | 41.15 | | |
| 0.0679 | 0.00 | 0.675 | 0.22 | 6.72 | 2.71 | 66.9 | 12.50 | 666 | 46.87 | | |
| 0.0771 | 0.00 | 0.767 | 0.22 | 7.64 | 3.03 | 76.0 | 13.48 | 756 | 53.26 | | |
| 0.0876 | 0.00 | 0.872 | 0.22 | 8.68 | 3.35 | 86.4 | 14.47 | 859 | 60.06 | | |