EXM ADVISORY SERVICES

KUMBA IRON GRADE C WASTE ASSESSMENT
FINAL REPORT

Report No.: JW099/17/G227- Rev 2

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Jones & Wagener
Engineering & Environmental Consultants

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CONTENTS PAGE

APPENDIXES

LIST OF TABLES

LIST OF FIGURES

Acronyms and abbreviations used in this document:

ABA	Acid Base Accounting
ASLP	Australian Standard Leaching Procedure
DEA	Department of Environmental Affairs
DWS	Department of Water and Sanitation
DWAF	Department of Water Affairs and Forestry
FAD	Fine Ash Dam
GN	Government Notice
GNR	Government Notice Regulation
ℓ	Litre
LC	Leach concentration in mg/ℓ
LCT	Leach concentration threshold in mg/ℓ
mg/kg	Milligram per kilogram
mg/ℓ	Milligram per litre
mm	millimetres
NEM:WA	National Environmental Management: Waste Act, Act 59 of 2008, as amended
NWA	National Water Act, Act 39 of 1998, as amended
TC	Total concentration in mg/kg
TCT	Total concentration threshold in mg/kg
TDS	Total dissolved solids
TSF	Tailings storage facility
µS/cm	Micro Siemens per centimetre

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1. INTRODUCTION

1.1 Background

The existing DMS plant at Sishen Iron Ore Company's Sishen Mine is to be upgraded to process C-Grade ore. Application is being made for the processing of C-grade material currently stockpiled on site. The DMS plant should be licensed as a waste management facility as a residue (waste) will be recovered at the upgraded plant.

In addition, disposal of the additional waste streams will need to be disposed of at facilities authorised in terms of the National Environmental Management: Waste Act, Act 59 of 2008, as amended (NEM:WA) and the National Water Act, Act 36 of 1998, as amended (NWA).

The C-Grade will be milled and processed in the still to be upgraded DMS plant. The plant currently processes A-Grade material and two (2) waste streams are generated. One of the waste streams is a wet tailings material, which is disposed of on a four (4) compartment tailings disposal facility. The JIG plant, on the other hand, processes B-Grade ore of which the tailings material is wet deposited in the open valleys between the four (4) compartment tailings disposal facility. Water from the tailings facility is returned to the DMS and JIG plant for re-use.

The DMS and JIG plants also generates coarse, medium and fine discard material, which are co-disposed of on a discard dump via a conveyor system.

The DMS plant will be upgraded to an Ultra High Dense Media Separation (UHDMS) process that will allow for the future processing of both A-grade and C-grade material to produce a saleable iron ore product. The plant will continue to produce both tailings and plant discard to be disposed at the at existing authorised waste management facilities at Sishen Mine.

For waste management licensing purposes and for potential engineering requirements, the various waste streams, including the C-Grade needs to be assessed for disposal purposes in terms of the Department of Environmental Affairs (DEA's) GNR 635 regulations known as the *"National Norms and Standards for the Assessment of Waste for Landfill Disposal"* (DEA, 2013a).

Jones & Wagener (J&W) as therefore appointed to undertake an assessment of the various waste streams to be generated due to the processing of C-grade material.

Trial runs with the C-Grade material were done in the JIG and DMS plants. Samples of the C-Grade Run of Mine Material (RoM), tailings and discard from the JIG plant were obtained for this waste assessment, as well as a tailings sample of the material assessed in the DMS plant.

1.2 Objectives

The objective of the project was to assess the new C-Grade waste streams in terms of the DEA's *"National Norms and Standards for the Assessment of Waste for Landfill Disposal"* (DEA, 2013a). This is required in order to apply for a waste management licence for the processing of C-grade material source from residue stockpiles. Since the tailings and discard are planned to be disposed at existing facilities it is important that the material be assessed in order to determine if the waste does not pose any additional risk to the environment when compared to that which is already disposed at such facilities. The assessment will also be required should there be a need for amendments to the Water Use License (WUL) or any new WULs, and may be required for design purposes. This will only be necessary if the existing waste management facilities not be suitable to manage the environmental risks associated with the processing of C-grade material.

The existing waste streams have already been assessed in a separate project (Exigo[3], 2014).

2. SAMPLE COLLECTION AND ANALYSIS

2.1 Samples

In order to assess each of the various waste streams to be generated due to the processing of C-grade material samples were obtained from processing trials undertaken using the existing processing plants. The following samples were collected and analysed, including:

1. **C-Grade ROM (tested at JIG Plant)**
2. **C-Grade Tailings 1 (tested at JIG Plant)**
3. **C-Grade Discard (tested at JIG Plant)**; and
4. **C-Grade Tailings 2 (tested at the DMS modular plant)**

2.2 Analyses Conducted

The collected samples were submitted to Waterlab, a SANAS accredited laboratory, where the following tests and analyses were conducted:

- The water fractions of the tailings samples were analysed for metals and anions as per GNR 635, excluding cyanide;
- The solid fractions of the tailings, C-Grade ROM and C-Grade Discard Material were subjected to a distilled water leach and the leach solutions were then analysed for the metals and anions listed in GNR 635, excluding cyanide, to determine the leachable concentrations (LCs) of the metals and anions of concern.
- The solid fractions were also subjected to an aqua regia digestion and the digestion solutions then analysed for the metals and anion listed in GNR 635, excluding cyanide, to determine the total concentrations (TCs) of the metals and anions of concern.
- Paste pH's of all solid phases were determined, as well as the water fractions in each sample; and
- The XRD of the C-Grade ROM sample was determined

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

The LCs of the metals and anions were determined using the Australian Standard Leaching Procedure (AS 4439.1, 4439.2 and 4439.3) as prescribed in GNR 635.

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

3. MINERALOGY

3.1 XRD Analysis – C-Grade ROM

Table 3-1 contains a summary of the mineralogy of the C-Grade ROM sample. As can be seen from the table, the major mineral in the C-Grade ROM sample is hematite (Fe_2O_3) followed by quartz (SiO2) (both members of the oxide mineral group). Minor amounts of the phyllosilicate minerals kaolinite and muscovite, together with the silicate mineral talc, make up the remainder of the sample.

Table 3-1: XRD Analysis of the C-Grade ROM

Composition (%) [s]	
C-Grade ROM	
Mineral	Amount (weight %)
Hematite	72.03
Quartz	23.16
Kaolinite	2.72
Muscovite	1.8
Talc	0.30

3.2 Alloway Crustal Abundance Ratios

Table 3-2 below indicates the total concentrations (TCs) of various metals in the C-Grade ROM sample. Also indicated in the table are the Alloway Crustal Abundance concentrations of the particular elements, which is simply an indication of the average abundance of an element in the earth's crust (Alloway et al, 1995). By calculating the ratio of the trace element concentrations to the average composition of the earth's crust (Crustal Abundances) an indication can be obtained whether the concentration of a particular element is raised above the average for the earth or enriched above the average due to some process.

The comparison to the average Crustal Abundance is geochemically accepted as a means of highlighting elements, which may possibly be enriched in the various lithologies. Although enrichment does not necessarily indicate that the element is likely to be an environmental risk, it does, however, indicate where attention should be focussed when assessing metal mobility/solubility.

Based on the results obtained (**Table 3-2**), the C-Grade ROM sample has concentrations of antimony, arsenic, cadmium and iron which are elevated above the average Alloway Crustal Abundance of the earth's crust.

Table 3-2: Total Concentrations and Alloway Abundance Ratios

SAMPLE DESCRIPTION			
	Alloway Crustal Abundance	C-Grade ROM	
Element	mg/kg or %	mg/kg or %	Ratio
Antimony (Sb)	**2.2**	18.80	**8.5**
Arsenic (As)	**1.5**	12	**7.7**
Barium (Ba)	**425**	331	0.78
Cadmium (Cd)	**0.1**	18.0	**180**
Cobalt (Co)	**20**	<10	Not Calculated
Chromium (Cr)	**100**	52	0.52
Copper (Cu)	**50**	<4.0	Not Calculated
Iron (Fe)	**3.2%**	14.5%	**4.5**
Lead (Pb)	**14**	12	0.83
Mercury (Hg)	**0.05**	<0.40	Not Calculated
Manganese (Mn)	**950**	170	0.18
Molybdenum (Mo)	**1.5**	<10	Not Calculated
Nickel (Ni)	**80**	18	0.23
Selenium (Se)	**0.05**	<4.0	Not Calculated
Vanadium (V)	**160**	<10	Not Calculated
Zinc (Zn)	**75**	11	0.15

Although certain of the metals listed in **Table 3-2** have concentrations which exceed the Alloway Crustal Abundance values, it should be noted that the C-Grade ROM, resultant tailings and discard are unlikely to be subjected to chemical processes that would mobilise metals and anions. I.e., the residues associated with the Kumba mine are generally resistant to chemical weathering and thus have very slow reaction rates (Exigo[3], 2014). It may therefore be considered that the wastes (tailings and discard) generated from the C-Grade ROM processing will not have a significant impact on the water environment due to the metals and anions generally being immobile.

4. WASTE ASSESSMENT

4.1 Waste Assessment Overview and Procedure

The DEA's waste assessment system, which replaced the Department of Water Affairs and Forestry's Minimum Requirements waste classification system on 23 August 2013, focuses on the long term storage (in excess of 90 days) and disposal of waste on land or waste disposal facilities. The system is based on the Australian State of Victoria's waste classification system for disposal, which uses the Australian Standard Leaching Procedure (ASLP) to determine the leachable concentrations (LCs) of pollutants in a particular waste (DEA, 2013a).

A number of leach solutions can be used to determine the LCs. For waste to be disposed of with putrescible organic matter, an acetic acid leach solution is used. This leach solution is very similar to the US EPA TCLP leach solution used in the now outdated Minimum Requirements, except that the pH is 5.0, instead of pH 4.93. In cases where a waste has an alkaline pH, and following an acid neutralisation capacity test, a pH 2.9 leach solution must be used.

In cases where non-organic waste is to be co-disposed with other non-organic wastes, a basic 0.10 M sodium tetraborate decahydrate (borax) solution of pH 9.2 ± 0.10 should be used in addition to the acetic acid leach (DEA, 2013a). The objective of the sodium tetraborate test is to identify contaminants that are leached above the various leachable concentration thresholds (LCTs) trigger values at an alkaline pH.

For non-putrescible inorganic waste, such as the tailings, to be disposed of without any other wastes (mono- disposal scenario), reagent water (distilled water) is used as a leach agent.

In addition to the above, the total concentrations (TCs) of the constituents of concern need to be determined and compared to specified total concentration threshold (TCT) values (DEA, 2013a).

The number of potentially hazardous substances in the new assessment system has been significantly reduced from that listed in the old Minimum Requirements of 1998 and brought in line with the potentially hazardous substances being used in other parts of the world to classify waste for disposal purposes. However, if a generator is aware of a hazardous substance other than those listed by the DEA, they are obliged to indicate and analyse for this.

Once the analytical results are known, the waste is assessed in line with the following approach:

- Wastes with any element or chemical substance concentration above the LCT3 or TCT2 values (LC >LCT3 or TC>TCT2) are Type 0 Wastes. Type 0 wastes (extremely hazardous waste), require treatment/stabilisation before disposal;
- Wastes with any element or chemical substance concentration above the LCT2 but below LCT3 values, or above the TCT1 but below TCT2 values (LCT2<LC ≤ LCT3 or TCT1<TC ≤ TCT2), are Type 1 Wastes (highly hazardous waste, which must be disposed of on a Class A landfill constructed with the most conservative double composite barrier system);
- Wastes with any element or chemical substance concentration above the LCT1 but below the LCT2 values and all concentrations below the TCT1 values (LCT1 < LC ≤ LCT2 and TC ≤ TCT1) are Type 2 Wastes (moderate hazardous waste, which must be disposed of on a Class B landfill);
- Wastes with any element or chemical substance concentration above the LCT0 but below LCT1 values and all concentrations below the TCT1 values (LCT0 < LC ≤ LCT1 and TC ≤ TCT1) are Type 3 Wastes (low hazardous waste, which must be disposed of on a Class C landfill);
- Wastes with all elements and chemical substance concentration levels for metal ions and inorganic anions below the LCT0 and TCT0 values (LC ≤ LCT0 and TC ≤ TCT0), as well as below the limits for organics and pesticides as in **Table 4-1**, are Type 4 Wastes (near inert wastes, which must be disposed of on sites with some base preparation, but no formal barrier system);

Table 4-1: Organic limits for wastes to be classified as Type 4 wastes.

Chemical Substances in Waste	Total Concentration (mg/kg)
Organic constituents	
Total organic carbon (TOC)	30 000 (3%)
Benzene, toluene, ethyl benzene and xylenes (BTEX)	6.0
Polychlorinated Biphenyls (PCBs)	1.0
Mineral Oil (C10 to C40)	500
Pesticides	
Aldrin + Dieldrin	0.050
DDT + DDD + DDE	0.050
2,4-D	0.050
Chlordane	0.050
Heptachlor	0.050

- Wastes with all element or chemical substance leachable concentration levels for metal ions and inorganic anions below or equal to the LCT0 limits are considered to be Type 3 wastes, irrespective of the TCs of elements or chemical substances in the waste, provided that:
  - All chemical substance concentration levels are below the total concentration limits for organics and pesticides as listed in **Table 4-1**,;
  - The inherent physical and chemical character of the waste is stable and will not change over time; and,
  - The waste is disposed of to landfill without any other waste.
- Wastes with the TC of an element or chemical substance above the TCT2 limit, and where the concentration cannot be reduced to below the TCT2 limit, but the LC for the particular element or chemical substance is below the LCT3 limit, the waste is considered to be Type 1 Waste.

4.2 Tailings and tailings water fractions

In order to assess the C-Grade Tailings 1 sample, the percentage contributions of the concentrations of the constituents in the liquid fractions and the leach concentrations were calculated based on the percentage liquids to solids – see **Table 4-2**.

Table 4-2: Weighted concentrations based on tailings water and distilled water leach results on solid tailings fraction

KUMBA IRON ORE DMS PLANT UPGRADE: C-Grade Tailings 1							
Percentage solids	**65.00%**						
	Solid Phase: Distilled Water Leach			**Water Phase**			**Leach Concentration**
Element/Compound	**mg/ℓ**	**Contribution Factor**	**Corrected concentration in mg/ℓ**	**mg/ℓ**	**Contribution Factor**	**Corrected concentration in mg/ℓ**	**mg/ℓ**
As, Arsenic	0.0050	0.6500	0.00325	0.0050	0.3500	0.00500	<0.010
B, Boron	0.010	0.6500	0.00813	0.308	0.3500	0.1078	0.116
Ba, Barium	0.288	0.6500	0.18720	0.039	0.3500	0.0137	0.201
Cd, Cadmium	0.0020	0.6500	0.00098	0.0015	0.3500	0.0015	<0.003
Co, Cobalt	0.010	0.6500	0.00813	0.0125	0.3500	0.0125	<0.025
Cr, Chromium - total	0.013	0.6500	0.00813	0.0125	0.3500	0.0125	<0.025
Cr VI, Chromium VI	0.0050	0.6500	0.00325	0.005	0.3500	0.00500	<0.010
Cu, Copper	0.013	0.6500	0.00813	0.005	0.3500	0.00500	<0.025
Fe, Iron	0.26	0.6500	0.17095	0.0125	0.3500	0.0125	0.183
Hg, Mercury	0.0010	0.6500	0.00033	0.0005	0.3500	0.0005	<0.001
Mn, Manganese	0.030	0.6500	0.01950	0.053	0.3500	0.0186	0.038
Mo, Molydenum	0.010	0.6500	0.00813	0.013	0.3500	0.0125	<0.025
Ni, Nickel	0.013	0.6500	0.00813	0.0125	0.3500	0.0125	<0.025
Pb, Lead	0.0050	0.6500	0.00325	0.0050	0.3500	0.00500	<0.010
Sb, Antimony	0.0050	0.6500	0.00325	0.010	0.3500	0.0010	<0.020
Se, Selenium	0.0050	0.6500	0.00325	0.0050	0.3500	0.00500	<0.010
V, Vanadium	0.013	0.6500	0.00813	0.0125	0.3500	0.0125	<0.025
Zn, Zinc	0.013	0.6500	0.00813	0.0125	0.3500	0.0125	<0.025
TDS, Total dissolved solids	30	0.6500	19.50000	854	0.3500	298.9	318
Cl, Chloride	2.0	0.6500	1.30000	69	0.3500	24.2	25
SO_4, Sulphate	6.0	0.6500	3.90000	187	0.3500	65.5	69
NO_3, Nitrate	0.50	0.6500	0.32500	49	0.3500	17.2	17
F, Fluoride	0.40	0.6500	0.26000	0.60	0.3500	0.21	0.470
Note: In order to calculate the % contribution of each phase, values less than (<) the limit of detection were divided by 2							

4.3 Results Assessment

The results of the De-ionised Water Leach and Total Concentration analysis of the C-Grade ROM, C-Grade Tailings 1, C-Grade Discard material and the C-Grade Tailings 2 samples are shown in **Table 4-3, Table 4-5, Table 4-6** and **Table 4-7**.

The results of the water fractions from the C-Grade Tailings 1 and C-Grade Tailings 2 are included in **Table 4-8**.

4.3.1 C-Grade ROM

- In terms of the LCs, none of the constituents exceed the Leach Concentration Threshold 0 (LCT0) values, which classifies it as a Type 4 (inert) waste. The LCT0 values are derived from the SANS 241 drinking water standards;
- In terms of the TCs, however, the concentrations of arsenic, barium, cadmium, antimony and fluoride exceed their respective Total Concentration Threshold 0 (TCT0) values. Based on the *National Norms and Standards for the Assessment of Waste for landfill Disposal,* the C-Grade ROM sample is therefore assessed as a Type 3 (low hazardous waste) which must be disposed of on a Class C landfill.
- The paste pH of the C-Grade ROM was 7.8, which indicates a slightly alkaline material.

4.3.2 C-Grade Tailings 1 (Solid and Water fraction combined)

- Based on the distilled water leach and the water fraction results of the C-Grade Tailings 1 sample, it is evident that nitrate concentration exceeds the LCT0 value, therefore in terms of the LC results, the C-Grade Tailings 1 is assessed as a Type 3 waste.
- In terms of the TCs, arsenic, boron, barium, cadmium, copper and fluoride were found to exceed their respective TCT0 values, and therefore, based on the *National Norms and Standards for the Assessment of Waste for landfill Disposal,* the C-Grade Tailings 1 sample is assessed as a Type 3 (low hazardous waste) which must be disposed of on a Class C landfill.

4.3.3 C-Grade Tailings 1 (Solid fraction)

- In terms of the LCs for the solid fraction of the C-Grade Tailings 1, none of the constituents exceed the Leach Concentration Threshold 0 (LCT0) values, which classifies it as a Type 4 (inert) waste. The LCT0 values are derived from the SANS 241 drinking water standards;
- In terms of the TCs, arsenic, boron, barium, cadmium, copper and fluoride were found to exceed their respective TCT0 values, and therefore, based on the *National Norms and Standards for the Assessment of Waste for landfill Disposal,* the C-Grade Tailings 1 sample is assessed as a Type 3 (low hazardous waste) which must be disposed of on a Class C landfill.
- The paste pH of the C-Grade Tailings 1 was 8.3, which indicates an alkaline material.

4.3.4 C-Grade Discard Material

- In terms of the LCs, none of the constituents exceed the Leach Concentration Threshold 0 (LCT0) values, therefore a Type 4 waste;

- In terms of the TCs, however, the concentrations of barium, cadmium and fluoride were found to exceed their respective TCT0 values, and therefore, based on the *National Norms and Standards for the Assessment of Waste for landfill Disposal,* the C-Grade Discard sample is assessed as a Type 3 (low hazardous waste) which must be disposed of on a Class C landfill.
- The paste pH of the C-Grade Discard material was 7.6, which indicates a slightly alkaline material.

4.3.5 C-Grade Tailings 2 (Solid Fraction)

- In terms of the LCs, the iron was detected at a concentration exceeding the LCT0 value of 2.0 mg/ℓ (which is based on the SANS 241 Drinking Water Standard), therefore a Type 3 waste;
- In terms of the TCs, the concentrations of arsenic, barium, manganese and fluoride were found to exceed their respective TCT0 value. Therefore, based on the *National Norms and Standards for the Assessment of Waste for landfill Disposal,* the C-Grade Tailings 2 sample is assessed as a Type 3 waste which must be disposed of on a Class C landfill.
- The paste pH of the C-Grade Tailings 2 was 8.7, which indicates an alkaline material.

4.3.6 Water Fractions (C-Grade Tailings 1 and C-Grade Tailings 2)

When assessing only the water fractions of the C-Grade Tailings 1 and C-Grade Tailings 2 samples, the water is assessed as a Type 3 waste – see **Table 4-8**. In the water fractions, it is noted that only the concentrations of nitrate exceed the LCT0 concentrations. The concentrations of all other constituents within the water fraction of the two (2) tailings samples were all below the respective LCT0 values.

The water fractions also had pH values of 8.1 (C-Grade Tailings 1) and 7.9 (C-Grade Tailings 2), which indicates a slightly alkaline water. At these pH values, certain metals tend to be less mobile, i.e. dissolved.

Table 4-3: De-ionised Water Leach test and Total Concentration Result: C-Grade ROM versus LCTs and TCTs

Elements & Chemical Substances	Kumba Iron Ore: C-Grade ROM LC in mg/ℓ	Kumba Iron Ore: C-Grade ROM TC in mg/kg	Limit of Report for LC (mg/ℓ)	Type 4 Waste	LCT0 (mg/ℓ)	TCT0 (mg/kg)	Type 3 Waste	LCT1 (mg/ℓ)	TCT1 (mg/kg)	Type 2 Waste	LCT2 (mg/ℓ)	TCT1 (mg/kg)	Type 1 Waste	LCT3 (mg/ℓ)	TCT2 (mg/kg)	Type 0 Waste
As	<0.010	12	0.010		0.010	5.8		0.50	500		1.00	500		4.0	2 000	
B	<0.025	35	0.025		0.50	150		25	15 000		50	15 000		200	60 000	
Ba	0.47	331	0.025		0.70	62.5		35	6 250		70	6 250		280	25 000	
Cd	<0.0030	18	0.0030		0.0030	7.5		0.15	260		0.30	260		1.2	1 040	
Co	<0.025	<10	0.025		0.50	50		25	5 000		50	5 000		200	20 000	
Cr (total)	<0.025	52	0.025		0.10	46 000		5.0	800 000		10	800 000		40		
Cr(VI)	<0.010	<5.0	0.010		0.050	6.5		2.5	500		5.0	500		20	2 000	
Cu	<0.025	<4.0	0.025		2.0	16		100	19 500		200	19 500		800	78 000	
Fe	0.19	145 200	0.025		2.0			100			200			800		
Hg	<0.0010	<0.40	0.0010		0.0060	0.93		0.30	160		0.60	160		2.4	640	
Mn	<0.025	170	0.025		0.50	1 000		25	25 000		50	25 000		200	100 000	
Mo	<0.025	<10	0.025		0.070	40		3.5	1 000		7.0	1 000		28	4 000	
Ni	<0.025	18	0.025		0.070	91		3.5	10 600		7.0	10 600		28	42 400	
Pb	<0.010	12	0.010		0.010	20		0.50	1 900		1.0	1 900		4.0	7 600	
Sb	<0.010	19	0.020		0.020	10		1.0	75		2.0	75		8.0	300	
Se	<0.010	<4.0	0.010		0.010	10		0.50	50		1.0	50		4.0	200	
V	<0.025	<10	0.025		0.20	150		10	2 680		20	2 680		80	10 720	
Zn	0.095	11	0.025		5.0	240		250	160 000		500	160 000		2000	640 000	
Inorganic Anions																
TDS	<10		10		1 000			12 500			25 000			100 000		
Chloride	<2.0		5.0		300			15 000			30 000			120 000		
Sulfate as SO_4	2.0		3.0		250			12 500			25 000			25 000		
NO_3 as N	0.40		0.20		11			550			1 100			4 400		
Fluoride	<0.20	100	0.20		1.5	100		75	10 000		150	10 000		600	40 000	
Cyanide			0.050		0.070	14		3.5	10 500		7.0	10 500		28	42 000	

Dark grey	Not applicable
Yellow	Not analysed
Pink	LC > LCT3 or TC > TCT2: Type 0 Wastes
Purple	LCT2< LC ≤ LCT3 or TCT1 < TC ≤ TCT2 : Type 1 Wastes
Orange	LCT1< LC ≤ LCT2 and TC ≤ TCT1: Type 2 Wastes
Blue	LCT0 < LC ≤ LCT1 and TC ≤ TCT1: Type 3 Wastes
White	LC ≤ LCT0 and TC ≤ TCT0: Type 4 wastes

Table 4-4: De-ionised Water Leach and Tailings Water + Total Concentration Results: C-Grade Tailings 1 versus LCTs and TCTs

Elements & Chemical Substances	Kumba Iron Ore: C-Grade Tailings 1 Solid + Water Fraction				LCT0 (mg/ℓ)	TCT0 (mg/kg)		LCT1 (mg/ℓ)	TCT1 (mg/kg)		LCT2 (mg/ℓ)	TCT1 (mg/kg)		LCT3 (mg/ℓ)	TCT2 (mg/kg)	
	LC in mg/ℓ	TC in mg/kg	Limit of Report for LC (mg/ℓ)													
As	<0.010	21	0.010		0.010	5.8		0.50	500		1.00	500		4.0	2 000	
B	0.12	170	0.025		0.50	150		25	15 000		50	15 000		200	60 000	
Ba	0.20	1 544	0.025		0.70	62.5		35	6 250		70	6 250		280	25 000	
Cd	<0.0030	18	0.0030		0.0030	7.5		0.15	260		0.30	260		1.2	1 040	
Co	<0.025	<10	0.025		0.50	50		25	5 000		50	5 000		200	20 000	
Cr (total)	<0.025	146	0.025		0.10	46 000		5.0	800 000		10	800 000		40		
Cr(VI)	<0.010	<5.0	0.010		0.050	6.5		2.5	500		5.0	500		20	2 000	
Cu	<0.025	39	0.025		2.0	16		100	19 500		200	19 500		800	78 000	
Fe	0.18	134 400	0.025		2.0			100			200			800		
Hg	<0.0010	<0.40	0.0010		0.0060	0.93		0.30	160		0.60	160		2.4	640	
Mn	0.038	386	0.025		0.50	1 000		25	25 000		50	25 000		200	100 000	
Mo	<0.025	<10	0.025	Type 4 Waste	0.070	40	Type 3 Waste	3.5	1 000	Type 2 Waste	7.0	1 000	Type 1 Waste	28	4 000	Type 0 Waste
Ni	<0.025	37	0.025		0.070	91		3.5	10 600		7.0	10 600		28	42 400	
Pb	<0.010	15	0.010		0.010	20		0.50	1 900		1.0	1 900		4.0	7 600	
Sb	<0.020	9.6	0.020		0.020	10		1.0	75		2.0	75		8.0	300	
Se	<0.010	<4.0	0.010		0.010	10		0.50	50		1.0	50		4.0	200	
V	<0.025	21	0.025		0.20	150		10	2 680		20	2 680		80	10 720	
Zn	<0.025	22	0.025		5.0	240		250	160 000		500	160 000		2000	640 000	
Inorganic Anions																
TDS	318		10		1 000			12 500			25 000			100 000		
Chloride	25		5.0		300			15 000			30 000			120 000		
Sulfate as SO_4	69		3.0		250			12 500			25 000			25 000		
NO_3 as N	17		0.20		11			550			1 100			4 400		
Fluoride	0.47	213	0.20		1.5	100		75	10 000		150	10 000		600	40 000	
Cyanide			0.050		0.070	14		3.5	10 500		7.0	10 500		28	42 000	

Dark grey	Not applicable
Yellow	Not analysed
Pink	LC > LCT3 or TC > TCT2: Type 0 Wastes
Purple	LCT2< LC ≤ LCT3 or TCT1 < TC ≤ TCT2 : Type 1 Wastes
Orange	LCT1< LC ≤ LCT2 and TC ≤ TCT1: Type 2 Wastes
Blue	LCT0 < LC ≤ LCT1 and TC ≤ TCT1: Type 3 Wastes
White	LC ≤ LCT0 and TC ≤ TCT0: Type 4 wastes

Table 4-5: De-ionised Water Leach and Total Concentration Results: C-Grade Tailings 1 versus LCTs and TCTs

Elements & Chemical Substances	Kumba Iron Ore: C-Grade Tailings 1 Solid Fraction			Type 4 Waste	LCT0	TCT0	Type 3 Waste	LCT1	TCT1	Type 2 Waste	LCT2	TCT1	Type 1 Waste	LCT3	TCT2	Type 0 Waste
	LC in mg/ℓ	TC in mg/kg	Limit of Report for LC (mg/ℓ)		(mg/ℓ)	(mg/kg)		(mg/ℓ)	(mg/kg)		(mg/ℓ)	(mg/kg)		(mg/ℓ)	(mg/kg)	
As	<0.010	21	0.010		0.010	5.8		0.50	500		1.00	500		4.0	2 000	
B	<0.025	170	0.025		0.50	150		25	15 000		50	15 000		200	60 000	
Ba	0.29	1 544	0.025		0.70	62.5		35	6 250		70	6 250		280	25 000	
Cd	<0.0030	18	0.0030		0.0030	7.5		0.15	260		0.30	260		1.2	1 040	
Co	<0.025	<10	0.025		0.50	50		25	5 000		50	5 000		200	20 000	
Cr (total)	<0.025	146	0.025		0.10	46 000		5.0	800 000		10	800 000		40		
Cr(VI)	<0.010	<5.0	0.010		0.050	6.5		2.5	500		5.0	500		20	2 000	
Cu	<0.025	39	0.025		2.0	16		100	19 500		200	19 500		800	78 000	
Fe	0.26	134 400	0.025		2.0			100			200			800		
Hg	<0.0010	<0.40	0.0010		0.0060	0.93		0.30	160		0.60	160		2.4	640	
Mn	0.030	386	0.025		0.50	1 000		25	25 000		50	25 000		200	100 000	
Mo	<0.025	<10	0.025		0.070	40		3.5	1 000		7.0	1 000		28	4 000	
Ni	<0.025	37	0.025		0.070	91		3.5	10 600		7.0	10 600		28	42 400	
Pb	<0.010	15	0.010		0.010	20		0.50	1 900		1.0	1 900		4.0	7 600	
Sb	<0.010	9.6	0.020		0.020	10		1.0	75		2.0	75		8.0	300	
Se	<0.010	<4.0	0.010		0.010	10		0.50	50		1.0	50		4.0	200	
V	<0.025	21	0.025		0.20	150		10	2 680		20	2 680		80	10 720	
Zn	<0.025	22	0.025		5.0	240		250	160 000		500	160 000		2000	640 000	
Inorganic Anions																
TDS	30		10		1 000			12 500			25 000			100 000		
Chloride	2.0		5.0		300			15 000			30 000			120 000		
Sulfate as SO_4	6.0		3.0		250			12 500			25 000			25 000		
NO_3 as N	0.50		0.20		11			550			1 100			4 400		
Fluoride	0.40	213	0.20		1.5	100		75	10 000		150	10 000		600	40 000	
Cyanide			0.050		0.070	14		3.5	10 500		7.0	10 500		28	42 000	

(grey)	Not applicable
(yellow)	Not analysed
(red)	LC > LCT3 or TC > TCT2: Type 0 Wastes
(purple)	LCT2< LC ≤ LCT3 or TCT1 < TC ≤ TCT2 : Type 1 Wastes
(orange)	LCT1< LC ≤ LCT2 and TC ≤ TCT1: Type 2 Wastes
(blue)	LCT0 < LC ≤ LCT1 and TC ≤ TCT1: Type 3 Wastes
(white)	LC ≤ LCT0 and TC ≤ TCT0: Type 4 wastes

Table 4-6: De-ionised Water Leach test and Total Concentration Result: C-Grade Discard Material versus LCT and TCT

Elements & Chemical Substances	Kumba Iron Ore: C-Grade Discard Material				LCT0	TCT0		LCT1	TCT1		LCT2	TCT1		LCT3	TCT2	
	LC in mg/ℓ	TC in mg/kg	Limit of Report for LC (mg/ℓ)	Type 4 Waste	(mg/ℓ)	(mg/kg)	Type 3 Waste	(mg/ℓ)	(mg/kg)	Type 2 Waste	(mg/ℓ)	(mg/kg)	Type 1 Waste	(mg/ℓ)	(mg/kg)	Type 0 Waste
As	<0.010	<4.0	0.010		0.010	5.8		0.50	500		1.00	500		4.0	2 000	
B	<0.025	123	0.025		0.50	150		25	15 000		50	15 000		200	60 000	
Ba	0.26	588	0.025		0.70	62.5		35	6 250		70	6 250		280	25 000	
Cd	<0.0030	16.4	0.0030		0.0030	7.5		0.15	260		0.30	260		1.2	1 040	
Co	<0.025	<10	0.025		0.50	50		25	5 000		50	5 000		200	20 000	
Cr (total)	<0.025	128	0.025		0.10	46 000		5.0	800 000		10	800 000		40		
Cr(VI)	<0.010	<5.0	0.010		0.050	6.5		2.5	500		5.0	500		20	2 000	
Cu	<0.025	<4.0	0.025		2.0	16		100	19 500		200	19 500		800	78 000	
Fe	0.077	105 600	0.025		2.0			100			200			800		
Hg	<0.0010	<0.40	0.0010		0.0060	0.93		0.30	160		0.60	160		2.4	640	
Mn	<0.025	520	0.025		0.50	1 000		25	25 000		50	25 000		200	100 000	
Mo	<0.025	<10	0.025		0.070	40		3.5	1 000		7.0	1 000		28	4 000	
Ni	<0.025	30	0.025		0.070	91		3.5	10 600		7.0	10 600		28	42 400	
Pb	<0.010	14	0.010		0.010	20		0.50	1 900		1.0	1 900		4.0	7 600	
Sb	<0.010	<8.0	0.020		0.020	10		1.0	75		2.0	75		8.0	300	
Se	<0.010	<4.0	0.010		0.010	10		0.50	50		1.0	50		4.0	200	
V	<0.025	16	0.025		0.20	150		10	2 680		20	2 680		80	10 720	
Zn	<0.025	16	0.025		5.0	240		250	160 000		500	160 000		2000	640 000	
Inorganic Anions																
TDS	<10		10		1 000			12 500			25 000			100 000		
Chloride	<2.0		5.0		300			15 000			30 000			120 000		
Sulfate as SO_4	3.0		3.0		250			12 500			25 000			25 000		
NO_3 as N	0.10		0.20		11			550			1 100			4 400		
Fluoride	<0.20	127	0.20		1.5	100		75	10 000		150	10 000		600	40 000	
Cyanide			0.050		0.070	14		3.5	10 500		7.0	10 500		28	42 000	

Grey	Not applicable
Yellow	Not analysed
Pink	LC > LCT3 or TC > TCT2: Type 0 Wastes
Purple	LCT2< LC ≤ LCT3 or TCT1 < TC ≤ TCT2 : Type 1 Wastes
Orange	LCT1< LC ≤ LCT2 and TC ≤ TCT1: Type 2 Wastes
Blue	LCT0 < LC ≤ LCT1 and TC ≤ TCT1: Type 3 Wastes
White	LC ≤ LCT0 and TC ≤ TCT0: Type 4 wastes

Table 4-7: De-ionised Water Leach test and Total Concentration Result: C-Grade Tailings 2 Solid Fraction versus LCT and TCT

Elements & Chemical Substances	Kumba Iron Ore: C-Grade Tailings 2 Solid Fraction				LCT0 (mg/ℓ)	TCT0 (mg/kg)		LCT1 (mg/ℓ)	TCT1 (mg/kg)		LCT2 (mg/ℓ)	TCT1 (mg/kg)		LCT3 (mg/ℓ)	TCT2 (mg/kg)	
	LC in mg/ℓ	TC in mg/kg	Limit of Report for LC (mg/ℓ)													
As	<0.010	14	0.010		0.010	5.8		0.50	500		1.00	500		4.0	2 000	
B	0.16	139	0.025		0.50	150		25	15 000		50	15 000		200	60 000	
Ba	0.34	1 240	0.025		0.70	62.5		35	6 250		70	6 250		280	25 000	
Cd	<0.0030	<1.2	0.0030		0.0030	7.5		0.15	260		0.30	260		1.2	1 040	
Co	<0.025	14	0.025		0.50	50		25	5 000		50	5 000		200	20 000	
Cr (total)	<0.025	92	0.025		0.10	46 000		5.0	800 000		10	800 000		40		
Cr(VI)	<0.010	<5.0	0.010		0.050	6.5		2.5	500		5.0	500		20	2 000	
Cu	<0.010	<4.0	<0.010		2.0	16		100	19 500		200	19 500		800	78 000	
Fe	3.7	125 200	0.025		2.0			100			200			800		
Hg	<0.0010	<0.40	0.0010		0.0060	0.93		0.30	160		0.60	160		2.4	640	
Mn	0.037	1 012	0.025		0.50	1 000		25	25 000		50	25 000		200	100 000	
Mo	<0.025	<10	0.025	Type 4 Waste	0.070	40	Type 3 Waste	3.5	1 000	Type 2 Waste	7.0	1 000	Type 1 Waste	28	4 000	Type 0 Waste
Ni	<0.025	40	0.025		0.070	91		3.5	10 600		7.0	10 600		28	42 400	
Pb	<0.010	5.6	0.010		0.010	20		0.50	1 900		1.0	1 900		4.0	7 600	
Sb	<0.020	8.8	0.020		0.020	10		1.0	75		2.0	75		8.0	300	
Se	<0.010	<4.0	0.010		0.010	10		0.50	50		1.0	50		4.0	200	
V	<0.025	14	0.025		0.20	150		10	2 680		20	2 680		80	10 720	
Zn	0.068	10	0.025		5.0	240		250	160 000		500	160 000		2000	640 000	
Inorganic Anions																
TDS	72		10		1 000			12 500			25 000			100 000		
Chloride	4.0		5.0		300			15 000			30 000			120 000		
Sulfate as SO_4	8.0		3.0		250			12 500			25 000			25 000		
NO_3 as N	0.50		0.20		11			550			1 100			4 400		
Fluoride	0.20	658	0.20		1.5	100		75	10 000		150	10 000		600	40 000	
Cyanide		<0.010	0.050		0.070	14		3.5	10 500		7.0	10 500		28	42 000	

Dark grey	Not applicable
Yellow	Not analysed
Pink	LC > LCT3 or TC > TCT2: Type 0 Wastes
Purple	LCT2< LC ≤ LCT3 or TCT1 < TC ≤ TCT2 : Type 1 Wastes
Orange	LCT1< LC ≤ LCT2 and TC ≤ TCT1: Type 2 Wastes
Blue	LCT0 < LC ≤ LCT1 and TC ≤ TCT1: Type 3 Wastes
White	LC ≤ LCT0 and TC ≤ TCT0: Type 4 wastes

Table 4-8: C-Grade Tailings 1 and C-Grade Tailings 2 water concentrations versus LCs

Elements & Chemical Substances	Kumba Iron Ore: C-Grade Tailings 1 and C-Grade Tailings 2 Water Fractions				LCT0	TCT0		LCT1	TCT1		LCT2	TCT1		LCT3	TCT2	
	C-Grade Tailings 1 Water in mg/ℓ	C-Grade Tailings 2 Water in mg/ℓ	Limit of Report for LC (mg/ℓ)		(mg/ℓ)	(mg/kg)		(mg/ℓ)	(mg/kg)		(mg/ℓ)	(mg/kg)		(mg/ℓ)	(mg/kg)	
				Type 4 Waste			Type 3 Waste			Type 2 Waste			Type 1 Waste			Type 0 Waste
As	<0.010	<0.010	0.010		0.010			0.50			1.00			4.0		
B	0.31	0.20	0.025		0.50			25			50			200		
Ba	0.039	0.059	0.025		0.70			35			70			280		
Cd	<0.0030	<0.0030	0.0030		0.0030			0.15			0.30			1.2		
Co	<0.025	<0.025	0.025		0.50			25			50			200		
Cr (total)	<0.025	<0.025	0.025		0.10			5.0			10			40		
Cr(VI)	<0.010	<0.010	0.010		0.050			2.5			5.0			20		
Cu	<0.010	<0.010	0.025		2.0			100			200			800		
Fe	<0.025	0.029	0.025		2.0			100			200			800		
Hg	<0.0010	0.0030	0.0010		0.0060			0.30			0.60			2.4		
Mn	0.053	0.026	0.025		0.50			25			50			200		
Mo	<0.025	0.044	0.025		0.070			3.5			7.0			28		
Ni	<0.025	<0.025	0.025		0.070			3.5			7.0			28		
Pb	<0.010	<0.010	0.010		0.010			0.50			1.0			4.0		
Sb	<0.020	<0.020	0.020		0.020			1.0			2.0			8.0		
Se	<0.010	<0.010	0.010		0.010			0.50			1.0			4.0		
V	<0.025	<0.025	0.025		0.20			10			20			80		
Zn	<0.025	<0.025	0.025		5.0			250			500			2000		
Inorganic Anions																
TDS	854	624	10		1 000			12 500			25 000			100 000		
Chloride	69	65	5.0		300			15 000			30 000			120 000		
Sulfate as SO_4	187	205	3.0		250			12 500			25 000			25 000		
NO_3 as N	49	35	0.20		11			550			1 100			4 400		
Fluoride	0.60	1.1	0.20		1.5			75			150			600		
Cyanide			0.050		0.070			3.5			7.0			28		

Dark grey	Not applicable
Yellow	Not analysed
Pink	LC > LCT3 or TC > TCT2: Type 0 Wastes
Purple	LCT2< LC ≤ LCT3 or TCT1 < TC ≤ TCT2 : Type 1 Wastes
Orange	LCT1< LC ≤ LCT2 and TC ≤ TCT1: Type 2 Wastes
Blue	LCT0 < LC ≤ LCT1 and TC ≤ TCT1: Type 3 Wastes
White	LC ≤ LCT0 and TC ≤ TCT0: Type 4 wastes

5. DISCUSSIONS AND CONCLUSIONS

The XRD analysis undertaken on the C-Grade ROM sample indicated that the major mineral in the C-Grade ROM sample is hematite (Fe_2O_3) followed by quartz (SiO_2) (both members of the oxide mineral group). Minor amounts of the phyllosilicate minerals, kaolinite and muscovite, together with the silicate mineral talc, make up the remainder of the sample.

In terms of the heavy metal content of the C-Grade ROM sample, concentrations of antimony, arsenic, cadmium and iron are elevated above the average Alloway Crustal Abundance concentrations and have the potential to pose an environmental risk. However, the distilled water leach tests indicate that none of these metals leach at concentrations above their respective LCT0 values when considering the leach test results only (**Table 4-3**), i.e. the C-Grade ROM sample is, in terms of leachables, assessed as a Type 4 (inert waste).

In terms of the DEA's National Norms and Standards (DEA, 2013a), the wet C-Grade Tailings 1 samples were dewatered, where after the water fraction was analysed for the chemical constituents as listed in the Norms and Standards. The samples were all subjected to distilled water leaches and the leach solutions were analysed for the chemical constituents as listed in the Norms and Standards. The solid fractions were also subjected to a TC analysis. As it is highly unlikely that the samples will contain any of the listed organic constituents of concern, the water fractions and leach and digestive solutions were not analysed for organics. The water fraction was analysed for the metals and anions as listed in the National Norms and Standards.

In order to assess the wet C-Grade Tailings 1 sample, in line with the rules of the National Norms and Standards, the percentage contributions of the concentrations of the chemical constituents in the liquid fraction (tailings water) and the solid fraction leach concentrations were calculated based on the percentage liquids to solids in each of the two samples. The resultant concentrations were then used in this assessment. In terms of leachable concentrations, the C-Grade Tailings 1 (including the liquid water fraction contribution) is assessed as a Type 3 waste due to the elevated nitrate concentration. In terms of total concentrations (TCs), the C-Grade Tailings 1 is also assessed as a Type 3 waste. When only the leach results (LCs) are considered, the C-Grade Tailings 1 is assessed as a Type 4 waste, i.e., it is clear that the C-Grade Tailings 1 water, which contains elevated concentrations of nitrate, causes the tailings to be assessed as a Type 3 waste.

In terms of leachables, the C-Grade Discard material is assessed as a Type 4, inert waste, while based on total concentrations, the Discard Material is a Type 3 waste.

In terms of leachables and total concentrations, the C-Grade Tailings 2 is assessed as a Type 3 waste. It is pointed out that the larger portion of the wet fraction of this tailings was decanted prior to J&W receiving the tailings sample, therefore the contribution to the leachable concentration by the water fraction could not be calculated.

The two water fractions of the tailings samples were also assessed as separate wastes. The water fractions are assessed as Type 3 wastes, therefore storage facilities for the tailings water, such as return water dams, must also be constructed with systems complying with the performance requirements of a Class C landfill. It should be noted that the tailings water is the potential pollution threat to the environment, i.e., the carrier of pollutants.

The results of the waste assessment exercise are summarised in **Table 5-1** below. It is clear from the results that the various wastes, based on their TCs are Type 3 wastes. However, based on the LCs, the C-Grade ROM, C-Grade Tailings 1 and C-Grade Discard are Type 4 wastes. The C-Grade Tailings 2 will also classify as a Type 4 waste if the LC of iron is ignored. Based on this and the fact that, although the C-Grade ROM, C-Grade tailings and C-Grade discard material contain elevated total concentrations of metals, which result in them being assessed as Type 3 wastes, it is unlikely that these wastes will be subject to chemical processes that would mobilise metals and anions, i.e., residues associated with the Kumba mine are generally resistant to chemical weathering and thus have very slow reaction rates (Exigo[3], 2014). It is therefore considered that the discard and tailings itself will not have a significant impact on the water environment and should rather be classified as a Type 4 waste.

Motivation for classifying the discard as a Type 4 waste is further supplemented by the fact that geochemical analyses of the discard material, conducted by Exigo[3] in 2014, classified the reside stockpile as a Type 4 (inert waste).

The default barrier system for a Type 3 waste is shown in **Figure 5-1** below. Class C barrier systems consist of a single composite barrier. Based on the work conducted by Exigo[3] and J&W, therefore, the existing C-Grade ROM stockpile is assessed as a Type 4 (inert waste) and disposal could be allowed on a disposal facility with a Class D base preparation layer – see **Figure 5-2.**

The tailings water fractions on the other hand, have elevated nitrate concentrations and the groundwater in the vicinity of the tailings disposal facility appears to have been impacted by nitrate. Measures must therefore be put in place to reduce the impacts from the tailings and the tailings return water dams, i.e., the dams should be provided by barrier systems complaint with the performance criteria of a Class C barrier.

With regards to the tailings facility and its return water dam, the DWS has recently circulated a letter stating that use can be made of source – pathway – receptor modelling to motivate for an alternative (less stringent barrier system) for mine residues and deposits (DWS, 2016).

Table 5-1: Summary of Waste Assessment Results

Waste	LC Results	TC Results	Overall Result
C-Grade ROM	Type 4	Type 3	Type 3
C-Grade Tailings 1 (including water fraction contribution)	Type 3	Type 3	Type 3
C-Grade Tailings 1: Solid fraction only	Type 4	Type 3	Type 3
C-Grade Tailings 1: Water fraction only	Type 3	N/A	Type 3
C-Grade Discard Material	Type 4	Type 3	Type 3
C-Grade Tailings 2: Solid fraction only	Type 3	Type 3	Type 3
C-Grade Tailings 2: Water fraction only	Type 3	N/A	Type 3

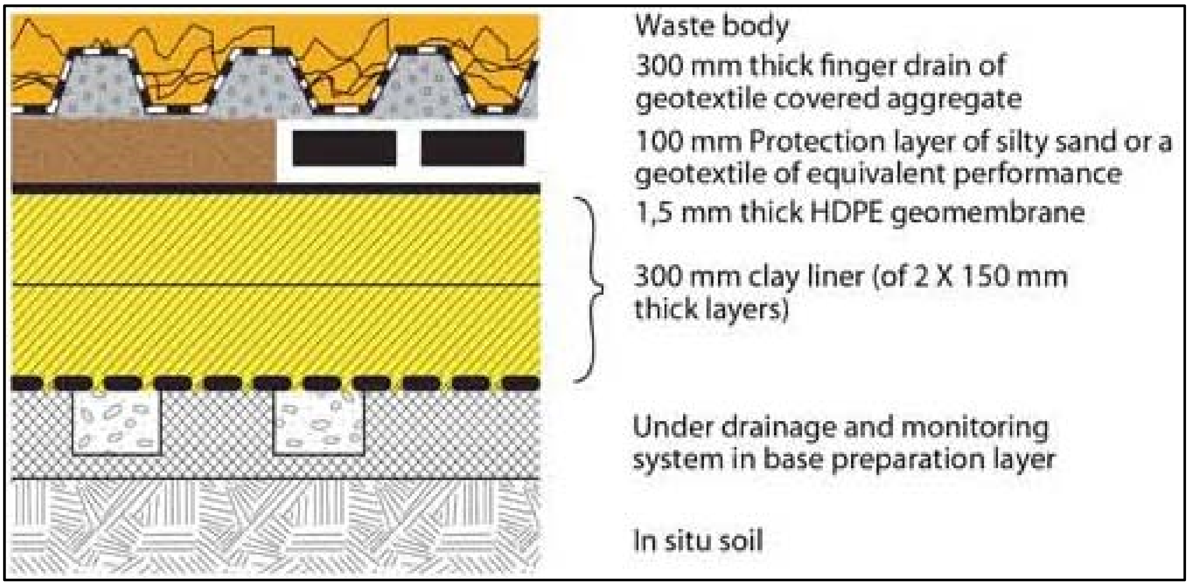

Figure 5-1: Class C landfill barrier system (DEA, 2013b)

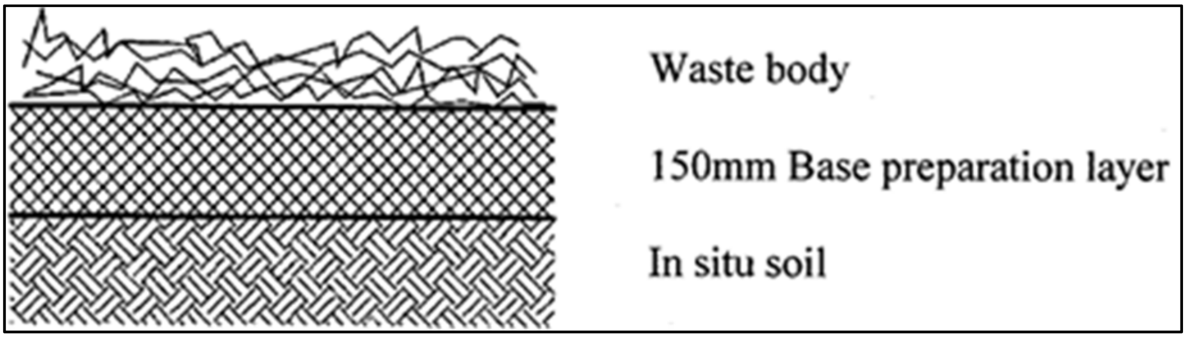

Figure 5-2: Class D base preparation layer (DEA, 2013b)

6. RECOMMENDATIONS

Based on the results obtained from this study and the conclusions drawn, the following recommendations are made:

- The C-Grade ROM material as well as the various C-Grade waste streams being generated by the processing of C-grade material should be considered a Type 4 (inert waste) and may be disposed of on a dump with barrier systems of which the performance complies with that of a Class D landfill.
- All associated water management infrastructure should be provided with barrier systems of which the performance complies with that of a Class C barrier system.
- Alternatively, source-pathway-receptor modelling can be conducted to demonstrate that an alternative, less conservative barrier system, will protect the receiving environment against the impacts of the tailings and tailings water; and
- All designs must be approved by the DWS.

7. REFERENCES

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Cameron Turner
Geohydrologist
for Jones & Wagener

Marius van Zyl
Technical Director

12 September 2017
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APPENDIX A

WATERLAB: ANALYTICAL CERTIFICATES

WATERLAB (PTY) LTD

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CERTIFICATE OF ANALYSES
X-RAY DIFFRACTION

Date received: 2017-04-11
Project number: 132
Report number: 66275
Date completed: 2017-05-09
Order number: PR17-05873

Client name: Jones & Wagener
Address: PO Box 1434, Rivonia, 2128
Telephone: 011 519 0200
Facsimile: 011 519 0201
Contact person: Marius van Zyl
Email: vanzyl@jaws.co.za
Cell: 082 880 1250

Composition (%) [s]	
JIG ROM	
2624	
Mineral	Amount (weight %)
Hematite	72.03
Quartz	23.16
Kaolinite	2.72
Muscovite	1.8
Talc	0.30

[s] Results obtained from sub-contracted laboratory

Note:

The material was prepared for XRD analysis using a backloading preparation method
It was analysed with a PANalytical Empyrean 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 using the Rietveld method.

Comment:

- In case the results do not correspond to results of other analytical techniques, please let me know for further fine tuning of XRD results.
- Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group.
- Due to preferred orientation and crystallite size effects, results may not be as accurate as shown in the table.
- Traces of additional phases may be present.
- Amorphous phases, which may be present, were not taken into consideration during quantification.

Ideal Mineral Composition

Hematite	Fe2O3
Kaolinite	Al2 Si2 O5 (OH)4
Muscovite	K Al2 ((OH)2 Al Si3 O10)
Talc	Mg3Si4O10(OH)2
Quartz	SiO2

E. Botha
Geochemistry Project manager

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CERTIFICATE OF ANALYSES
EXTRACTIONS AS 4439.3

Date received:	**2017/04/11**		**Date completed:**	**2017/05/09**
Project number:	**132**	**Report number: 66275**	**Order number:**	**PR17-05873**
Client name:	**Jones & Wagener**		**Contact person:**	**Marius van Zyl**
Address:	**PO Box 1434, Rivonia, 2128**		**Email:**	**vanzyl@jaws.co.za**
Telephone:	**0115190200**		**Cell:**	**082 880 1250**

Analyses	JIG ROM	JIG Slimes	Plant Discard Materials				
Sample Number	2624	2625	2626				
TCLP / Borax / Distilled Water	Distilled Water	Distilled Water	Distilled Water				
Ratio*	1:20	1:20	1:20				
Units	mg/ℓ	mg/ℓ	mg/ℓ	LCT0 mg/l	LCT1 mg/l	LCT2 mg/l	LCT3 mg/l
As, Arsenic	<0.010	<0.010	<0.010	0.01	0.5	1	4
B, Boron	<0.025	<0.025	<0.025	0.5	25	50	200
Ba, Barium	0.468	0.288	0.258	0.7	35	70	280
Cd, Cadmium	<0.003	<0.003	<0.003	0.003	0.15	0.3	1.2
Co, Cobalt	<0.025	<0.025	<0.025	0.5	25	50	200
$Cr_{Total,}$ Chromium Total	<0.025	<0.025	<0.025	0.1	5	10	40
Cr(VI), Chromium (VI)	<0.010	<0.010	<0.010	0.05	2.5	5	20
Cu, Copper	<0.025	<0.025	<0.025	2.0	100	200	800
Fe, Iron	0.192	0.263	0.077				
Hg, Mercury	<0.001	<0.001	<0.001	0.006	0.3	0.6	2.4
Mn, Manganese	<0.025	0.030	<0.025	0.5	25	50	200
Mo, Molybdenum	<0.025	<0.025	<0.025	0.07	3.5	7	28
Ni, Nickel	<0.025	<0.025	<0.025	0.07	3.5	7	28
Pb, Lead	<0.010	<0.010	<0.010	0.01	0.5	1	4
Sb, Antimony	<0.010	<0.010	<0.010	0.02	1.0	2	8
Se, Selenium	<0.010	<0.010	<0.010	0.01	0.5	1	4
V, Vanadium	<0.025	<0.025	<0.025	0.2	10	20	80
Zn, Zinc	0.095	<0.025	<0.025	5.0	250	500	2000
Inorganic Anions	mg/ℓ	mg/ℓ	mg/ℓ				
Total Dissolved Solids*	<10	30	<10	1000	12 500	25 000	100 000
Chloride as Cl	<2	2	<2	300	15 000	30 000	120 000
Sulphate as SO4	2	6	3	250	12 500	25 000	100 000
Nitrate as N	0.4	0.5	0.1	11	550	1100	4400
Fluoride as F	<0.2	0.4	<0.2	1.5	75	150	600
pH	6.8	7.3	6.8				
Paste pH	7.8	8.3	7.6				
Moisture %	---	18	---				
% Solids	---	65	---				
X-ray Diffraction [s]	See attached Report 66275	---	---				

[s]=subcontracted

***Please note:**
1. The samples were used as received.
2. A moisture content were determined for wet or moist samples.
3. In cases where the sample were a slurry, a solid to liquid ratio were done (reported). Moisture content were determined after filtration
4. The results are reported as received. The moisture content were not taken into account.

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CERTIFICATE OF ANALYSES

Digestion AS 4439.3

Date received:	**2017/04/11**			**Date completed:**	**2017/05/19**
Project number:	**132**	**Report number:**	**66275A**	**Order number:**	**PR17-05873**

Client name:	**Jones & Wagener**	**Contact person:**	**Marius van Zyl**
Address:	**PO Box 1434, Rivonia, 2128**	**Email:**	**vanzyl@jaws.co.za**
Telephone:	**0115190200**	**Cell:**	**082 880 1250**

Analyses	JIG ROM		JIG Slimes		Plant Discard Materials				
Sample Number	2624		2625		2626				
Digestion	HNO3 : HF		HNO3 : HF		HNO3 : HF				
Dry Mass Used (g)	**0.25**		**0.25**		**0.25**				
Volume Used (mℓ)	**100**		**100**		**100**				
Units	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**TCT0 mg/kg**	**TCT1 mg/kg**	**TCT2 mg/kg**
As, Arsenic	0.029	12	0.052	21	<0.010	<4.00	5.8	500	2000
B, Boron	0.088	35	0.424	170	0.307	123	150	15000	6000
Ba, Barium	0.828	331	3.86	1544	1.47	588	62.5	6250	25000
Cd, Cadmium	0.045	18	0.044	18	0.041	16	7.5	260	1040
Co, Cobalt	<0.025	<10	<0.025	<10	<0.025	<10	50	5000	20000
$Cr_{Total,}$ Chromium Total	0.129	52	0.364	146	0.319	128	46000	800000	N/A
Cu, Copper	<0.010	<4.00	0.097	39	<0.010	<4.00	16	19500	78000
Fe, Iron	363	145200	336	134400	264	105600			
Hg, Mercury	<0.001	<0.400	<0.001	<0.400	<0.001	<0.400	0.93	160	640
Mn, Manganese	0.426	170	0.966	386	1.30	520	1000	25000	100000
Mo, Molybdenum	<0.025	<10	<0.025	<10	<0.025	<10	40	1000	4000
Ni, Nickel	0.045	18	0.093	37	0.076	30	91	10600	42400
Pb, Lead	0.029	12	0.037	15	0.034	14	20	1900	7600
Sb, Antimony	0.047	19	0.024	9.60	<0.020	<8.00	10	75	300
Se, Selenium	<0.010	<4.00	<0.010	<4.00	<0.010	<4.00	10	50	200
V, Vanadium	<0.025	<10	0.052	21	0.039	16	150	2680	10720
Zn, Zinc	0.028	11	0.054	22	0.039	16	240	160000	640000
Inorganic Anions	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**			
Cr(VI), Chromium (VI) Total [s]	---	<5	---	<5	---	<5	6.5	500	2000
Total Fluoride [s] mg/kg	---	100	---	213	---	127	100	10000	40000

[s] = subcontracted

UTD = Unable to determine

E. Botha

Geochemistry Project Manager

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CERTIFICATE OF ANALYSES
EXTRACTIONS AS 4439.3

Date received:	2017/05/05			**Date completed:**	2017/05/30
Project number:	132	**Report number:**	66729a	**Order number:**	PR17-05873

Client name:	Jones & Wagener	**Contact person:**	Marius van Zyl
Address:	PO Box 1434, Rivonia, 2128	**Email:**	vanzyl@jaws.co.za
Telephone:	0115190200	**Cell:**	082 880 1250

Analyses	C Grade Tailings (Kumba sample)				
Sample Number	4134				
TCLP / Borax / Distilled Water	Distilled Water				
Ratio*	1:20				
Units	**mg/ℓ**	**LCT0 mg/l**	**LCT1 mg/l**	**LCT2 mg/l**	**LCT3 mg/l**
As, Arsenic	<0.010	0.01	0.5	1	4
B, Boron	0.163	0.5	25	50	200
Ba, Barium	0.339	0.7	35	70	280
Cd, Cadmium	<0.003	0.003	0.15	0.3	1.2
Co, Cobalt	<0.025	0.5	25	50	200
Cr_{Total}, Chromium Total	<0.025	0.1	5	10	40
Cr(VI), Chromium (VI)	<0.010	0.05	2.5	5	20
Cu, Copper	<0.010	2.0	100	200	800
Fe, Iron	3.67				
Hg, Mercury	<0.001	0.006	0.3	0.6	2.4
Mn, Manganese	0.037	0.5	25	50	200
Mo, Molybdenum	<0.025	0.07	3.5	7	28
Ni, Nickel	<0.025	0.07	3.5	7	28
Pb, Lead	<0.010	0.01	0.5	1	4
Sb, Antimony	<0.020	0.02	1.0	2	8
Se, Selenium	<0.010	0.01	0.5	1	4
V, Vanadium	<0.025	0.2	10	20	80
Zn, Zinc	0.068	5.0	250	500	2000
Inorganic Anions	**mg/ℓ**				
Total Dissolved Solids*	72	1000	12 500	25 000	100 000
Chloride as Cl	4	300	15 000	30 000	120 000
Sulphate as SO4	8	250	12 500	25 000	100 000
Nitrate as N	0.5	11	550	1100	4400
Fluoride as F	0.2	1.5	75	150	600
pH	7.2				
Paste pH	8.7				
Moisture %	39				

[s]=subcontracted

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CERTIFICATE OF ANALYSES

Digestion AS 4439.3

Date received:	2017/05/05			**Date completed:**	2017/05/30
Project number:	132	**Report number:**	66729a	**Order number:**	PR17-05873

Client name:	**Jones & Wagener**	**Contact person:**	**Marius van Zyl**
Address:	**PO Box 1434, Rivonia, 2128**	**Email:**	**vanzyl@jaws.co.za**
Telephone:	**0115190200**	**Cell:**	**082 880 1250**

Analyses	C Grade Tailings (Kumba sample)				
Sample Number	4134		TCT0 mg/kg	TCT1 mg/kg	TCT2 mg/kg
Digestion	HNO3 : HF				
Dry Mass Used (g)	0.25				
Volume Used (mℓ)	100				
Units	mg/ℓ	mg/kg			
As, Arsenic	0.034	14	5.8	500	2000
B, Boron	0.347	139	150	15000	6000
Ba, Barium	3.10	1240	62.5	6250	25000
Cd, Cadmium	<0.003	<1.20	7.5	260	1040
Co, Cobalt	0.036	14	50	5000	20000
Cr_{Total}, Chromium Total	0.230	92	46000	800000	N/A
Cu, Copper	<0.010	<4.00	16	19500	78000
Fe, Iron	313	125200			
Hg, Mercury	<0.001	<0.400	0.93	160	640
Mn, Manganese	2.53	1012	1000	25000	100000
Mo, Molybdenum	<0.025	<10	40	1000	4000
Ni, Nickel	0.101	40	91	10600	42400
Pb, Lead	0.014	5.60	20	1900	7600
Sb, Antimony	0.022	8.80	10	75	300
Se, Selenium	<0.010	<4.00	10	50	200
V, Vanadium	0.034	14	150	2680	10720
Zn, Zinc	0.026	10	240	160000	640000
Inorganic Anions	mg/ℓ	mg/kg			
Cr(VI), Chromium (VI) Total [s]	---	<5	6.5	500	2000
Total Fluoride [s] mg/kg	---	658	100	10000	40000
Total Cyanide as CN mg/kg	---	<0.01	14	10500	42000

[s] = subcontracted

UTD = Unable to determine

E. Botha

Geochemistry Project Manager

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T0391

AMENDED CERTIFICATE OF ANALYSES
GENERAL WATER QUALITY PARAMETERS

Date received: 2017-04-24 **Date completed:** 2017-05-22

Project number: 132 **Report number:** 66539-A **Order number:**

Client name: Jones & Wagener Engineering & Environmental Consultant: **Contact person:** Mr. M. van Zyl

Address: 59 Bevan Road, PO BOX 1434, Rivonia, Johannesburg 2128 **e-mail:** vanzyl@jaws.co.za

Telephone: 0115190200 **Facsimile:** **Mobile:**

Analyses in mg/ℓ (Unless specified otherwise)		**Method Identification**	**Sample Identification: G227 Kumba** JIG Slimes
Sample Number			003435
Date\Time Sampled			N/A
pH - Value @ 25 ºC	N	WLAB065	8.1
Total Dissolved Solids @ 180°C	N	WLAB003	854
Chloride as Cl	A	WLAB046	69
Sulphate as SO4	A	WLAB046	187
Fluoride as F	A	WLAB014	0.6
Nitrate as N	A	WLAB046	49
Antimony as Sb (Dissolved)	N	WLAB015	<0.020
Arsenic as As (Dissolved)	N	WLAB015	<0.010
Barium as Ba (Dissolved)	N	WLAB015	0.039
Boron as B (Dissolved)	N	WLAB015	0.308
Cadmium as Cd (Dissolved)	A	WLAB015	<0.003
Hexavalent Chromium as Cr	N	WLAB032	<0.010
Total Chromium as Cr (Dissolved)	A	WLAB015	<0.025
Cobalt as Co (Dissolved)	A	WLAB015	<0.025
Copper as Cu (Dissolved)	A	WLAB015	<0.010
Iron as Fe (Dissolved)	A	WLAB015	<0.025
Lead as Pb (Dissolved)	A	WLAB015	<0.010
Manganese as Mn (Dissolved)	A	WLAB015	0.053
Mercury as Hg (Dissolved)	N	WLAB050	<0.001
Molybdenum as Mo (Dissolved)	N	WLAB015	<0.025
Nickel as Ni (Dissolved)	A	WLAB015	<0.025
Selenium as Se (Dissolved)	N	WLAB015	<0.010
Vanadium as V (Dissolved)	N	WLAB015	<0.025
Zinc as Zn (Dissolved)	A	WLAB015	<0.025

E. Nkabinde - Technical Signatory

This Certificate, **66539-A,** replaces the previous Certificate of Analysis **66539**

A = Accredited N = Not Accredited S = Subcontracted

Tests marked "Not SANAS Accredited" in this report are not included in the SANAS Schedule of Accreditation for this Laboratory.

Results marked "Subcontracted Test" in this report are not included in the SANAS Schedule of accreditation for this Laboratory.

The information contained in this report is relevant only to the sample/samples supplied to **WATERLAB (Pty) Ltd**. Details of sampling conducted by Waterlab (PTY) Ltd, according to WLAB/Sampling Plan and Procedures/SOP, are available on request.

WATERLAB

WATERLAB (Pty) Ltd

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sanas Testing Laboratory
T0391

AMENDED CERTIFICATE OF ANALYSES

GENERAL WATER QUALITY PARAMETERS

Date received: 2017-05-05 **Date completed:** 2017-05-22

Project number: 132 **Report number:** 66730-A **Order number:**

Client name: Jones & Wagener Engineering & Environmental Consultant: **Contact person:** Mr. M. van Zyl

Address: 59 Bevan Road, PO BOX 1434, Rivonia, Johannesburg 2128 **e-mail:** vanzyl@jaws.co.za

Telephone: 0115190200 **Facsimile:** **Mobile:**

Analyses in mg/ℓ (Unless specified otherwise)		**Method Identification**	**Sample Identification: Kumba** Tailings Sample
Sample Number			004135
Date\Time Sampled			N/A
pH - Value @ 25 °C	N	WLAB065	7.9
Total Dissolved Solids @ 180°C	N	WLAB003	624
Chloride as Cl	A	WLAB046	65
Sulphate as SO4	A	WLAB046	205
Fluoride as F	A	WLAB014	1.1
Nitrate as N	A	WLAB046	35
Antimony as Sb (Dissolved)	N	WLAB015	<0.020
Arsenic as As (Dissolved)	N	WLAB015	<0.010
Barium as Ba (Dissolved)	N	WLAB015	0.059
Boron as B (Dissolved)	N	WLAB015	0.201
Cadmium as Cd (Dissolved)	A	WLAB015	<0.003
Hexavalent Chromium as Cr	N	WLAB032	<0.010
Total Chromium as Cr (Dissolved)	A	WLAB015	<0.025
Cobalt as Co (Dissolved)	A	WLAB015	<0.025
Copper as Cu (Dissolved)	A	WLAB015	<0.010
Iron as Fe (Dissolved)	A	WLAB015	0.029
Lead as Pb (Dissolved)	A	WLAB015	<0.010
Manganese as Mn (Dissolved)	A	WLAB015	0.026
Mercury as Hg (Dissolved)	N	WLAB050	0.003
Molybdenum as Mo (Dissolved)	N	WLAB015	0.044
Nickel as Ni (Dissolved)	A	WLAB015	<0.025
Selenium as Se (Dissolved)	N	WLAB015	<0.010
Vanadium as V (Dissolved)	N	WLAB015	<0.025
Zinc as Zn (Dissolved)	A	WLAB015	<0.025

E. Nkabinde - Technical Signatory

This Certificate, **66730-A,** replaces the previous Certificate of Analysis **66730**

A = Accredited N = Not Accredited S = Subcontracted

Tests marked "Not SANAS Accredited" in this report are not included in the SANAS Schedule of Accreditation for this Laboratory.

Results marked "Subcontracted Test" in this report are not included in the SANAS Schedule of accreditation for this Laboratory.

The information contained in this report is relevant only to the sample/samples supplied to **WATERLAB (Pty) Ltd**. Details of sampling conducted by Waterlab (PTY) Ltd, according to WLAB/Sampling Plan and Procedures/SOP, are available on request.