LIDWALA CONSULTING ENGINEERS (PTY) LTD

TUTUKA POWER STATION
EXPANSION OF ASH DISPOSAL FACILITY

ASH ASSESSMENT REPORT

Report No.: JW123/13/D880 – Rev 01

December 2014

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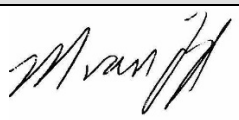
Prepared	Tech Director	Marius van Zyl	December 2014	
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SYNOPSIS

Lidwala Consulting Engineers (Lidwala) was appointed by Eskom to identify, investigate and licence a new ash disposal facility for the Tutuka Power Station. The existing ash disposal facility may also be extended. The Tutuka Power Station employs a dry ash disposal method.

Lidwala appointed Jones & Wagener Engineering and Environmental Consultants (J&W) to assess the coal derived ash from the Power Station in terms of the provisions of the National Environmental Management: Waste Act, Act 59 of 2008, as amended.

Assessment of the ash is required for two purposes:

- To correctly assess the new ash disposal facility for licensing purposes, and
- To develop an appropriate barrier design for the facility based on the outcome of the assessment of the ash in order to protect the water environment.

The assessment of the ash is not the only aspect that may determine the eventual barrier (liner) design of the new ash disposal facility. Site specific conditions, such as the vulnerability of the ground and surface water resources, will also play an important role in the design of the barrier system.

The objectives of this project were to assess the ash in terms of:

- The DEA's waste assessment regulations published for on 23 August 2013 in terms of the provisions of the National Environmental Management: Waste Act, Act 59 of 2008.
- The Regulations promulgated in terms of Section 36 of the National Nuclear Regulator Act, Act 47 of 1999, (NNRA) to establish whether or not the ash disposal facility also have to be licensed in terms of the provisions of the NNRA.

The following tests were carried out on a Tutuka ash sample:

- South African Acid Rain Leach Procedure (ARLP) extract of the Tutuka ash sample and analysis of the inorganic and organic constituents. This was required to classify the ash in terms of the current Minimum Requirements waste classification procedure.
- Total extraction (aqua regia digestion) analysis of the ash sample, including both inorganic and organic constituents. The total extraction analysis is required for the draft waste classification system.
- Australian de-ionised water leach of the dry ash and analysis of the leach solution. This was required to classify the waste in terms of the DEA's draft waste classification regulations for disposal purposes. The de-ionised leach analysis is required in cases where waste types are mono-disposed.
- Radioactivity analysis for gross alpha/beta-activity and for selected radionuclides in the uranium and thorium decay series.
- XRD analysis.

In terms of the DEA's waste assessment regulations, the ash is assessed as a Type 3 waste (low risk waste), which requires disposal on a landfill of which the performance of the barrier system complies with that of a Class C landfill. The outcome of the assessment was the result of the leachable concentrations of boron and chromium VI, and the total concentrations of barium and copper in the ash.

From a radioactivity perspective, it was found that the ash is below the limit set for material to be considered as radioactive. Assuming very conservative human exposure conditions (e.g. exposure in excess of 2 000 hours per annum) the potential radiological impacts to members of the public is below the regulatory criteria for the radiological protection of members of the public. The assumed conditions did not consider the possibility for members of the public residing on top of the ash disposal facility for extended periods of time, in which case additional exposure conditions would need to be considered.

Based on the findings of this study, it is recommended that:

- The extended Tutuka Power Station ash disposal facility should be licenced as a Class C landfill,
- The barrier system should comply with the performance requirements of a Class C landfill, and
- Human settlements are not to be allowed on top of the ash disposal facilities either during operation or after closure.

M van Zyl

Acronyms and abbreviations:

Acronym / abbreviations	Definition
ASLP	Australian Standard Leaching Procedure
B^-	Landfills constructed without a leachate detection and collection layer
BA	Basic Assessment
DEA	Department of Environmental Affairs
Bq/gram	Becquerel per gram
DI	Deionised
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EIA	Environmental Impact Assessment
LC	Leach concentration in mg/ℓ
LCT	Leach concentration threshold in mg/ℓ
LC_{50}	The concentration at which 50% of test organisms will die after a certain exposure time to a chemical compound or element
m^3	Cubic metres
M	molar
mg/kg	milligram per kilogram
mg/ℓ	milligram per litre
µm	micrometre
TC	Total concentration in mg/kg
TCT	Total concentration threshold in mg/kg
TCLP	Toxic Characteristic Leach Procedure
TDS	Total Dissolved Salts
<	Smaller than
>	Greater than

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1. INTRODUCTION

1.1 Background

Lidwala Consulting Engineers (Pty) Ltd (Lidwala) was appointed by Eskom to identify, investigate and license a long term ash disposal facility (or an expansion of the existing system) for the existing Tutuka Power Station located close to Standerton in Mpumalanga, South Africa.

It is envisaged that the total area to be covered by the ash disposal facility will be in the order of 2 500 hectares. In order to achieve this, the expansion footprint will be in the order of 759 hectares.

The Tutuka Power Station employs a dry ash disposal method, i.e., the ash has a 20 % moisture content.

Lidwala appointed Jones & Wagener (J&W) to conduct a waste classification and assessment of the ash.

Classification and assessment of the ash is required for two purposes:

- To correctly classify the ash disposal facility for licensing and environmental authorisation purposes, and
- To assist in the development of an appropriate barrier or liner design system for the facility.

For the classification and assessment, a composite sample of the dry ash disposed of onto the current ash disposal facility was used.

1.2 Objectives

The objectives of this project were to classify and assess the ash in terms of:

- The Department of Water Affairs and Forestry's (the DWAF's) "Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste", Second Edition (DWAF, 1998a) (Minimum Requirements) and the Department of Environmental Affairs letter dated June 2009. Based on the classification, a monthly ash disposal rate was also calculated. The Minimum Requirements is the

current official waste classification system, but will be replaced once the draft waste classification regulations are promulgated.

- The Department of Environmental Affairs' (DEA's) draft waste assessment regulations published for comment in August 2012 in terms of the provisions of the National Environmental Management: Waste Act, Act 59 of 2008 (DEA, 2012a). The ash was assessed in terms of the draft system, as the ash disposal facility may only be constructed when the new assessment system is in place, and Mr K. Legge of the Department of Water Affairs indicated that the new landfill barrier system must be implemented once the new classification system is in place (K. Legge, 2011).
- Regulations promulgated in terms of Section 36 of the National Nuclear Regulator Act, Act 47 of 1999, (NNRA) to establish whether or not the ash disposal facility also have to be licensed in terms of the provisions of the NNRA as a radioactive waste.

The ash was originally also classified in terms of the Department of Water Affairs' "Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste", but this classification methodology became obsolete with the promulgation of the "National norms and standards for the assessment of waste for landfill disposal" on 23 August 2013. This report is therefore an update of the earlier waste classification report compiled by J&W in July 2013 (JW123/13/D880 – Rev 00).

2. METHODOLOGY

2.1 Phase 1: Sample Collection and Analysis

2.1.1 Samples Collected

Tutuka Power Station collected three representative composite samples of ash over a 10 day sampling period. One sample was collected in a glass bottle and the other two samples were collected in clean plastic bottles. The sample collected in the glass bottle was used for the organic analyses, while the ones collected in the plastic bottles were used for the inorganic and radio activity analyses respectively.

J&W received the unmarked samples on 26 April 2013 and the samples were delivered to the Waterlab and NECSA laboratories on 29 April 2013.

2.1.2 Tests Conducted

In order to classify and assess the ash for disposal purposes, the following tests were carried out on the samples obtained:

- Total extraction (aqua regia digestion) analysis of the ash sample, including both inorganic and organic constituents. This was required to classify the waste in terms of the DEA's draft waste classification regulations for disposal purposes. These results are also applicable to the now promulgated waste assessment system.
- South African Acid Rain Leach Procedure (ARLP) extract of the ash sample and analysis of the inorganic and organic constituents. This was required to classify the ash in terms of the current Minimum Requirements waste classification procedure, but the results are not required for the DEA's waste assessment procedure promulgated in August 2013.
- Australian de-ionised (DI) water leach of the dry ash and analysis of the leach solution. This was required to classify the waste in terms of the DEA's draft waste classification

regulations for disposal purposes. The results were also used for the now promulgated waste assessment system, which is the subject of this revised report.

- Radiological analysis by NECSA for gross alpha/beta-activity and for selected radionuclides in the uranium and thorium decay series.
- XRD analysis of the ash.

The laboratory certificates are included in **Appendices A** and **B,** including those that were applicable to the Minimum Requirements waste classification system.

2.2 Phase 2: Interpretation of Laboratory Results

J&W assessed the ash in this revised report in terms of the National Norms and Standards. The ash was not classified in terms of SANS 10234. This particular project focused on the assessment of the power station ash for disposal purposes.

3. WASTE ASSESSMENT FOR LANDFILL DISPOSAL (DEA, 2013A)

The new waste assessment system, which replaced the Department of Water Affairs and Forestry's (DWAF's) Minimum Requirements 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 assessment 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 (DEA, 2013a).

A number of leach solutions can be used. 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 a high pH, and following an acid neutralisation capacity test, a pH 2.9 leach solution must be used.

In cases where non-organic waste, such as the coal derived ash is 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 a high pH.

For non-putrescible inorganic waste to be disposed of without any other wastes (mono-disposal scenario), reagent water (distilled water) is used as a leach agent. The distilled water leach was also used for the Tutuka Power Station ash as the waste is mono-disposed.

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 classification 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, which must be disposed of on a Class A landfill constructed with the most conservative 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, 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, 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 2-1**, are Type 4 Wastes (near inert wastes, which must be disposed of on sites with some base preparation, but no formal barrier system):

Table 2-1: 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 waste, irrespective of the total concentration 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 in the **Table 2-1**;
  - 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 wastes.

- 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. TUTUKA ASH ASSESSMENT

Based on the analytical results obtained from the distilled water leach and total concentration analyses performed on the ash, the Tutuka Power Station ash sample is assessed as a Type 3 waste requiring disposal on a waste disposal facility with a Class C barrier system provided there are no site specific risks that require a more conservative barrier system – see **Table 4-1** and **Figure 4-1**.

The Type 3 waste assessment was the result of the LC value of boron (B) and chromium VI concentrations exceeding their respective LCT0 values, and the TCs of barium (Ba) and copper (Cu) exceeding their respective TCT0 concentration values – see **Table 4-1**.

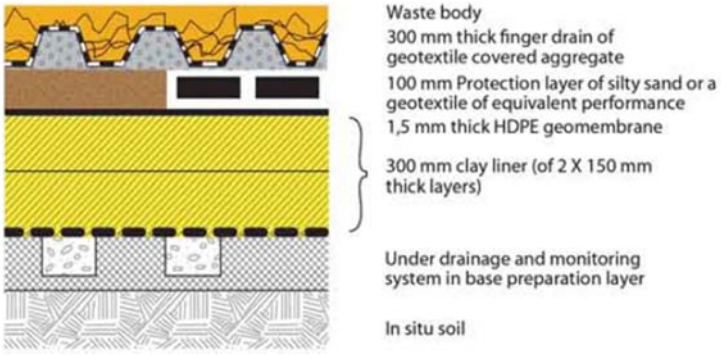

Figure 4-1: Class C landfill barrier system (DEA, 2013b)

Table 4-1: Distilled Water (LC) and Total Concentration (TC) results of Tutuka Power Station Ash Sample compared with the LCT and TCT values

Elements & Chemical Substances	Tutuka Power Station Ash				LCT0	TCT0		LCT1	TCT1		LCT2	TCT1		LCT3	TCT2	
	Distilled Water leach concentration (LC) (mg/ℓ)	Total concentration (TC) (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)	
Metal Ions																
As	<0.010	<2.00	0.010		0.01	5.8		0.50	500		1.0	500		4.0	2 000	
B	2.10	<5.00	0.025		0.5	150		25	15 000		50	15 000		200	60 000	
Ba	0.119	373	0.025		0.7	62.5		35	6 250		70	6 250		280	25 000	
Cd	<0.005	6.4	0.005		0.003	7.5		0.15	260		0.3	260		1.2	1 040	
Co	<0.025	15	0.025		0.5	50		25	5 000		50	5 000		200	20 000	
Cr (total)	0.280	77	0.025		0.10	46 000		5	800 000		10	800 000		40		
Cr(VI)	0.280	2.1	0.010		0.05	6.5		2.5	500		5	500		20	2 000	
Cu	<0.025	17	0.025		2.0	16		100	19 500		200	19 500		800	78 000	
Hg	<0.001	<0.200	0.001		0.006	0.93		0.3	160		0.6	160		2.4	640	
Mn	<0.025	315	0.025		0.5	1 000		25	25 000		50	25 000		200	100 000	
Mo	0.102	<5.00	0.025		0.07	40		3.5	1 000		7	1 000		28	4 000	
Ni	<0.025	40	0.025		0.07	91		3.5	10 600		7	10 600		28	42 400	
Pb	<0.020	<4.00	0.020		0.01	20		0.5	1 900		1	1 900		4	7 600	
Sb	<0.010	<2.00	0.010		0.02	10		1.0	75		2	75		8	300	
Se	0.011	<4.00	0.020		0.01	10		0.5	50		1	50		4	200	
V	0.106	71	0.025		0.2	150		10	2 680		20	2 680		80	10 720	
Zn	<0.025	42	0.025		5.0	240		250	160 000		500	160 000		2000	640 000	
Inorganic Anions																
TDS	328		10		1 000			12 500			25 000			100 000		
Chloride	9		5		300			15 000			30 000			120 000		
Sulphate as SO_4	153		5		250			12 500			25 000			100 000		
NO_3 as N	<0.20		0.2		11			550			1 100			4 400		
Fluoride	0.30	91	0.01		1.5	100		75	10 000		150	10 000		600	40 000	
Cyanide	<0.05	<1.00	0.05		0.07	14		3.5	10 500		7.0	10 500		28	42 000	
Organics																
Benzene	<0.002	40	0.002					0.01	10		0.02	10		0.08	40	
Benzo(a)pyrene	<0.0001	<2	0.0001					0.035	1.7		0.070	1.7		0.28	6.8	
Carbon tetrachloride	<0.005	<100	0.005					0.20	4		0.40	4		1.6	16	
Chlorobenzene	<0.002	<40	0.002					5.0	8 800		10	8 800		40	35 200	
Chloroform	<0.005	<100	0.005					15	700		30	700		120	2 800	
2-Chlorophenol	<0.002	<40	0.002					15	2 100		30	2 100		120	8 400	
Di (2-ethylhexyl) phthalate	<0.010	<200	0.010					0.50	40		1	40		4	160	
1,2-Dichlorobenzene	<0.002	<40	0.002					5	31 900		10	31 900		40	127 600	
1,4-Dichlorobenzene	<0.002	<40	0.002					15	18 400		30	18 400		120	73 600	
1,2-Dichloroethane	<0.002	<40	0.002					1.5	3.7		3	3.7		12	14.8	
1,1-Dichloroethylene (1,1-Dichloroethene)	<0.010	<200	0.010					0.35	150		0.7	150		2.8	600	
1,2-Dichloroethylene	<0.010	<200	0.010					2.5	3 750		5.0	3 750		20	15 000	
Dichloromethane	<0.020	<400	0.020					0.25	16		0.5	16		2	64	
2,4-Dichlorophenol	<0.002	<40	0.002					10	800		20	800		80	3 200	
				Type 4 Waste			Type 3 Waste			Type 2 Waste			Type 1 Waste			Type 0 Waste

Elements & Chemical Substances	Tutuka Power Station Ash			LCT0 (mg/ℓ)	TCT0 (mg/kg)	LCT1 (mg/ℓ)	TCT1 (mg/kg)	LCT2 (mg/ℓ)	TCT1 (mg/kg)	LCT3 (mg/ℓ)	TCT2 (mg/kg)
	Distilled Water leach concentration (LC) (mg/ℓ)	Total concentration (TC) (mg/kg)	Limit of Report for LC (mg/ℓ)								
Metal Ions											
2,4-Dinitrotoluene	<0.001	<20	0.001			0.065	5.2	0.13	5.2	0.52	20.8
Ethyl benzene	<0.002	<40	0.002			3.5	540	7	540	28	2 160
Formaldehyde	<0.050	<200	0.050			25	2 000	50	2 000	200	8 000
Hexachlorobutadiene	<0.002	<40	0.002			0.03	2.8	0.06	2.8	0.24	5.4
Methyl ethyl ketone (butanone)	<0.001	<1	0.001			100	8 000	200	8 000	800	32 000
MTBE (Methyl t-butyl ether)	<0.005	<100	0.005			2.5	1 435	5.0	1 435	20	5 740
Nitrobenzene	<0.001	<20	0.001			1	45	2	45	8	180
PAHs (total)	<0.002	<40	0.002				50		50		200
Petroleum hydrocarbons (C6 to C9)	<0.025	<0.50	0.025				650		650		2 240
Petroleum hydrocarbons (C10 to C36)	<0.010	<0.20	0.010				10 000		10 000		40 000
Phenols (Total non-halogenated)	<0.020	<400	0.020			7	560	14	560	56	2 240
Polychlorinated biphynels (PCBs)	<0.005	<200	0.005			0.025	12	0.050	12	0.20	48
Styrene	<0.005	<100	0.005			1.0	120	2	120	8	480
1,1,1,2-Tretrachloroethane	<0.010	<200	0.010			5	400	10	400	40	1 600
1,1,2,2-Tretrachloroethane	<0.010	<200	0.010			0.65	5.0	1.3	5.0	5.3	20
Tetrachloroethylene	<0.010	<200	0.010			0.25	200	0.50	200	2	800
Toluene	<0.010	<200	0.010			35	1 150	70	1 150	280	4 600
Trichlorobenzenes (Total)	<0.010	<40	0.010			3.5	3 300	7.0	3 300	28	13 200
1,1,1-Trichloroethane	<0.005	<100	0.005			15	1 200	30	1 200	120	4 800
1,1,2-Trichloroethane	<0.005	<100	0.005			0.6	48	1	48	4	192
Trichloroethylene	<0.010	<200	0.010			0.25	11 600	2	11 600	8	46 400
2,4,6-Trichlorophenol	<0.002	<40	0.002			10	1 770	20	1 770	80	7 080
Vinyl chloride	<0.001	<1	0.001			0.015	1.5	0.03	1.5	0.12	6.0
Xylenes (total)	<0.005	<100	0.005			25	890	50	890	200	3.560
Pesticides											
Aldrin + Dieldrin	<0.001	<2	0.001		0.05	0.015	0.05	0.03	1.2	0.03	4.8
DDT + DDD + DDE	<0.001	<2	0.001		0.05	1	0.05	2	50	2	200
2.4-D	<0.001	<2	0.001		0.05	1.5	0.05	3	120	3	480
Chlordane	<0.001	<2	0.001		0.05	0.05	0.05	0.1	4	0.1	16
Heptachlor	<0.001	<2	0.001		0.05	0.015	0.05	0.03	1.2	0.03	4.8

	Not applicable
	Not analysed
	LC > LCT3 or TC > TCT2: Type 0 Wastes
	LCT2 < LC ≤ LCT3 or TCT1 < TC ≤ TCT2 : Type 1 Wastes
	LCT1 < LC ≤ LCT2 and TC ≤ TCT1: Type 2 Wastes
	LCT0 < LV ≤ LCT1 and TC ≤ TCT1: Type 3 Wastes
	LC ≤ LCT0 and TC ≤ TCT0: Type 4 wastes
(1)	Waterlab indicated that due to analytical noise, it is possible that the total chromium could be less than chromium VI. They have repeated the analysis.

5. RADIOACTIVITY OF THE ASH

It was agreed that radioactivity analyses of the ash will be conducted and therefore an ash sample was analysed at NECSA for radioactivity.

The potassium-40, gross alpha and gross beta results are presented in **Table 5-1**. The results for each nuclide analysed for are attached as **Appendix B**.

The results indicate that the ash is excluded from regulatory control. None of the individual nuclides and their progeny analysed for had activities above 0.50 Bq/gram, while the total radioactivity of the ash was significantly below 1000 Bq/gram, which would trigger regulatory control. The radioactivity of potassium-40 was also well below the 50 Bq/gram regulatory control value.

In terms of the potential impact on public health, J&W sub-contracted Dr J J van Blerk of Aquisim Consulting to conduct a first order assessment based on the results obtained. Dr Van Blerk's report is attached as **Appendix C** and is summarised below.

For the assessment conducted by Aquisim, the following assumptions were made, namely:

- Members of the public are exposed to the material for a period of 2 000 hours per annum (7.6 hours per day for 260 days per annum - equal to the period normally used for worker radiological safety assessments, such as tailings dam operators).
- During this exposure period, an adult member of the public inhales 1 850 m^3 of air (or 0.93 m^3/hour, which is the average breathing rate for and adult during sleeping, sitting, and for light and heavy exercise). For this study it was assumed that the respirable dust load is 1 x 10^{-4} grams/m^3.

For these assumed conditions, the inhalation dose to adult members of the public will be in the order of 6.8 µSv/annum for the sample analysed, while the external gamma radiation for an adult member of the public (2 000 hours on top of the facility) would be in the order of 140 µSv/annum, which is well below the legal dose constraint applicable to the public of 1 000 µSv/annum.

The external gamma radiation dose will decrease linearly with a decrease in exposure period, while the exposure with distance away from the facility will decrease exponentially (i.e., at a small distance away from the facility, the dose will decrease to insignificant levels).

Based on the assessment conducted, Dr Van Blerk concluded that:

- The material is below the limit set for material to be considered as radioactive,
- Assuming very conservative conditions, the potential radiological impact is below the regulatory criteria for the radiological protection of members of the public.

Dr Van Blerk did not consider a scenario where members of the public constructed dwellings on top of the ash disposal facilities, which is unlikely as the ash disposal facility will not be open for the public. Nevertheless, it is recommended that human settlements must not be allowed on the ash disposal facilities during operation and after closure of the disposal facility.

Table 5-1: Summary of radiological results

Radioactivity in Bq/gram(1)	Tutuka Ash	Exclusion Level
^{40}K (Potassium-40)	0.248	50 (2)
Gross alpha	2.440	_
Gross beta	0.983	_
Total radioactivity (alpha + beta)	**3.423**	**1000**

1: The values in the NECSA report are reported as Bq/kg and were converted to Bg/gram to be in line with the values as stipulated in the legislation (Dept of Minerals and Energy, 2006).

2: For material to be used in the building industry the potassium 40 level must not exceed 10 Bq/gram.

6. DISCUSSION AND CONCLUSIONS

In terms of the DEA's waste assessment for disposal system, the Tutuka Power Station ash is classified as a Type 3 waste, which requires disposal on a landfill of which the performance complies with that of a Class C barrier system. This assessment was the result of the leachable concentrations of boron and the chromium VI exceeding their respective LTC0s and the total concentrations of barium and copper in the ash exceeding their TCT0s.

From a radioactivity perspective, it was found that the ash is below the limit set for material to be considered as radioactive. Assuming very conservative human exposure conditions (e.g. exposure in excess of 2 000 hours per annum) the potential radiological impact to members of the public is below the regulatory criteria for the radiological protection of members of the public. The assumed conditions did not consider the possibility for members of the public residing on top of the ash disposal facility for extended periods of time, in which case additional exposure conditions would need to be considered (e.g. radon exhalation and the subsequent built-up of radon inside a house) (Aquasim, 2013).

7. RECOMMENDATIONS

Based on the findings of this study, it is recommended that:

- The extended Tutuka Power Station ash disposal facility should be licenced as a Class C landfill,
- The barrier system should comply with the performance requirements of a Class C landfill, and
- Human settlements are not to be allowed on top of the ash disposal facilities either during operation or after closure.

8. REFERENCES

a) Department of Environmental Affairs, 2013a. *National Environmental Management: Waste Act (Act 59 of 2008). National norms and standard for the assessment of waste for landfill disposal.* R635 of 23 August 2013, Government Gazette No. 36784, Government Printer, Pretoria.

b) Department of Environmental Affairs, 2013b. *National Environmental Management: Waste Act (Act 59 of 2008). National norms and standards for disposal of waste to landfill*. Notice 636 of 23 August 2012, Government Gazette No. 36784, Government Printer, Pretoria.

c) Department of Minerals and Energy, 2006. *Regulations in terms of Section 36, read with Section 47 of the National Nuclear Regulator Act, 1999 (Act no 47 of 1999) on safety standards and regulatory practices*. Notice R 388, Government Gazette 28755. Government Printer, Pretoria.

d) SABS Standards Division, 2008. *South African National Standard: Globally Harmonized System of Classification and Labelling of Chemicals (GHS)*. SABS, Pretoria.

Marius van Zyl

Leigh-Ann Potter

John Glendinning
Project Director
for Jones & Wagener

8 December 2014

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Appendix A

WATERLAB LABORATORY CERTIFICATES

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CERTIFICATE OF ANALYSES
TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2013-04-30 **Date completed: 2013-05-31**
Project number: 132 **Report number: 39728** **Order number: D880/MvZ/21921**

Client name: JONES & WAGENER CONSULTING CIVIL ENGINEERS **Contact person: Mr. M. van Zyl**
Address: P.O. Box 1434 Rivonia 2128 **Email: vanzyl@jaws.co.za**
Telephone: 011 - 519 - 0200 **Facsimile: 011 - 519 - 0201** **Cell: 082 880 1250**

Analyses	Sample Identification :	
	Tutuka Power Station Ash	
Sample number	4827	
TCLP / Acid Rain / Distilled Water / H_2O_2	Acid Rain	
Dry Mass Used (g)	50	
Volume Used (mℓ)	1000	
Units	mg/ℓ	mg/kg
Fluoride as F	0.3	6.0
Hexavalent Chromium as Cr^{6+}	0.483	9.66
Mercury as Hg	<0.001	<0.020
Total Cyanide as CN	<0.05	<1.00
ICP-OES Quant	See attached report 39728 ICP AR	
ZHE Organic Analyses	See attached report 39728 ZHE Organics AR	

Please note: The blank was subtracted from all leach results.

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

CERTIFICATE OF ANALYSES

ICP-OES - QUANT

Date received:	30/04/2013	**Date Completed:**	27/05/2013
Project number:	132	**Report number:**	39728

Client name:	Jones & Wagener Consulting Civil Engineers	**Contact person:**	Mr. M. van Zyl
Adress:	P.O. Box 1434, Rivonia, 2128	**Email:**	vanzyl@jaws.co.za
Telephone:	011 - 519 - 0200	**Facsimile:**	011 - 519 - 0201

Extract	Sample Dry Mass	Volume	Mass (g/l)	Factor
Acid Rain	50	1000	50	20

Sample Id	Sample number	Al	Al	As	As
		mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.100	<2.00	<0.010	<0.200
Tutuka Power Station Ash	4827	0.138	2.76	0.125	2.50

Sample Id	Sample number	Ba	Ba	Cd	Cd	Co	Co
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.005	<0.100	<0.025	<0.500
Tutuka Power Station Ash	4827	0.259	5.18	<0.005	<0.100	<0.025	<0.500

Sample Id	Sample number	Cr	Cr	Cu	Cu	Fe	Fe
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.025	<0.500	<0.025	<0.500
Tutuka Power Station Ash	4827	0.483	9.66	<0.025	<0.500	<0.025	<0.500

Sample Id	Sample number	Mn	Mn
		mg/l	mg/kg
Det Limit		<0.025	<0.500
Tutuka Power Station Ash	4827	0.283	5.66

Sample Id	Sample number	Pb	Pb	Sb	Sb
		mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.020	<0.400	<0.010	<0.200
Tutuka Power Station Ash	4827	<0.020	<0.400	<0.010	<0.200

Sample Id	Sample number	Se	Se	Sr	Sr	Tl	Tl
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.020	<0.400	<0.025	<0.500	<0.025	<0.500
Tutuka Power Station Ash	4827	0.038	0.760	4.78	96	<0.025	<0.500

Sample Id	Sample number	V	V	Zn	Zn
		mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.025	<0.500
Tutuka Power Station Ash	4827	0.487	9.74	<0.025	<0.500

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CERTIFICATE OF ANALYSES

ORGANIC ANALYSES PARAMETERS [s] – Acid Rain

Date received: : 2013-04-30 **Date completed: 2013-05-31**

Project number: 132 **Report number: 39728** **Order number: D880/MvZ/21921**

Client name: JONES & WAGENER CONSULTING CIVIL ENGINEERS **Contact person: Marius van Zyl**

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Telephone: 011 - 519 - 0200 **Facsimile: 011 - 519 - 0201** **Mobile: 082 880 1250**

Organic Analyses: Volatile Organic Compound - Acid Rain		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X1**	
Benzene	**ug/l**	<2
Carbon Tetrachloride	**ug/l**	<5
Chloroform	**ug/l**	<5
1,4-Dichlorobenzene	**ug/l**	<2
1,2-Dichloroethane	**ug/l**	<2
Ethylbenzene	**ug/l**	<2
Hexachlorobutadiene	**ug/l**	<2
Isopropylbenzene	**ug/l**	<2
Naphthalene	**ug/l**	<2
1,1,2-Trichloroethane	**ug/l**	<5
Xylenes total	**ug/l**	<5
1,2,3 Trichlorobenzene	**ug/l**	<2
Tetrachloroethylene	**ug/l**	<10

Organic Analyses: Semi Volatile Organic Compound - Acid Rain		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X1**	
Benzo(a)pyrene	**ug/l**	<0.1
Hexachlorobenzene	**ug/l**	<1

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CERTIFICATE OF ANALYSES

ORGANIC ANALYSES PARAMETERS [s] – Acid Rain

Date received: : 2013-04-30 **Date completed: 2013-05-31**

Project number: 132 **Report number: 39728** **Order number: D880/MvZ/21921**

Client name: JONES & WAGENER CONSULTING CIVIL ENGINEERS **Contact person: Marius van Zyl**

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Organic Analyses: Phenols - Acid Rain		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X1**	
Cresols	**ug/l**	<2
2,4,5-Trichlorophenol	**ug/l**	<2
Phenol	**ug/l**	<2

[s] = Analyses performed by a Sub-contracted Laboratory

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

CERTIFICATE OF ANALYSES

ICP-OES - QUANT

Date received:	**30/04/2013**	**Date Completed:**	**27/05/2013**
Project number:	**132**	**Report number:**	**39728**

Client name:	**Jones & Wagener Consulting Civil Engineers**	**Contact person:**	**Mr. M. van Zyl**
Adress:	**P.O. Box 1434, Rivonia, 2128**	**Email:**	**vanzyl@jaws.co.za**
Telephone:	**011 - 519 - 0200**	**Facsimile:**	**011 - 519 - 0201**

Extract	Sample Dry Mass	Volume	Mass (g/l)	Factor
Distilled Water	50	1000	50	20

Sample Id	Sample number	As	As	B	B	Ba	Ba
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.200	<0.025	<0.500	<0.025	<0.500
Tutuka Power Station Ash	4827	<0.010	<0.200	2.10	42	0.119	2.38

Sample Id	Sample number	Cd	Cd	Co	Co	Cr	Cr
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.005	<0.100	<0.025	<0.500	<0.025	<0.500
Tutuka Power Station Ash	4827	<0.005	<0.100	<0.025	<0.500	0.280	5.60

Sample Id	Sample number	Cu	Cu	Mn	Mn	Mo	Mo
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.025	<0.500	<0.025	<0.500
Tutuka Power Station Ash	4827	<0.025	<0.500	<0.025	<0.500	0.102	2.04

Sample Id	Sample number	Ni	Ni	Pb	Pb	Sb	Sb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.500	<0.020	<0.400	<0.010	<0.200
Tutuka Power Station Ash	4827	<0.025	<0.500	<0.020	<0.400	<0.010	<0.200

Sample Id	Sample number	Se	Se	V	V	Zn	Zn
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.200	<0.025	<0.500	<0.025	<0.500
Tutuka Power Station Ash	4827	0.011	0.220	0.106	2.12	<0.025	<0.500

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ORGANIC ANALYSES PARAMETERS [s] – Distilled Water

Date received: : 2013-04-30 **Date completed: 2013-05-31**

Project number: 132 **Report number: 39728** **Order number: D880/MvZ/21921**

Client name: JONES & WAGENER CONSULTING CIVIL ENGINEERS **Contact person: Marius van Zyl**

Address: P.O. Box 1434 Rivonia 2128 **e-mail: vanzyl@jaws.co.za**

Telephone: 011 - 519 - 0200 **Facsimile: 011 - 519 - 0201** **Mobile: 082 880 1250**

Organic Analyses: Volatile Organic Compound - Distilled Water		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X1**	
Benzene	**ug/l**	<2
Carbon Tetrachloride	**ug/l**	<5
Chlorobenzene	**ug/l**	<2
Chloroform	**ug/l**	<5
1,2-Dichlorobenzene	**ug/l**	<2
1,4-Dichlorobenzene	**ug/l**	<2
1,2-Dichloroethane	**ug/l**	<2
Ethylbenzene	**ug/l**	<2
Hexachlorobutadiene	**ug/l**	<2
Isopropylbenzene	**ug/l**	<2
MTBE	**ug/l**	<5
Naphthalene	**ug/l**	<2
Styrene	**ug/l**	<5
1,1,1,2-Tetrachloroethane	**ug/l**	<10
1,1,2,2-Tetrachloroethane	**ug/l**	<10
Toluene	**ug/l**	<10
1,1,1-Trichloroethane	**ug/l**	<5
1,1,2-Trichloroethane	**ug/l**	<5
Xylenes total	**ug/l**	<5
1,2,4 Trichlorobenzene	**ug/l**	<2
1,2,3 Trichlorobenzene	**ug/l**	<2
Dichloromethane	**ug/l**	<20
1,1-Dichloroethylene	**ug/l**	<10
1,2-Dichloroethylene	**ug/l**	<10
Tetrachloroethylene	**ug/l**	<10
Trichloroethylene	**ug/l**	<10

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ORGANIC ANALYSES PARAMETERS [s] – Distilled Water

Date received: : 2013-04-30 **Date completed: 2013-05-31**

Project number: 132 **Report number: 39728** **Order number: D880/MvZ/21921**

Client name: JONES & WAGENER CONSULTING CIVIL ENGINEERS **Contact person: Marius van Zyl**

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Organic Analyses: Polars - Distilled Water		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X1**	
2-Butanone	**mg/l**	<1
Vinyl Chloride	**mg/l**	<1

Organic Analyses: Formaldehyde Distilled Water		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X1**	
Formaldehyde	**ug/l**	<50

Organic Analyses: Semi Volatile Organic Compound - Distilled Water		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X1**	
Benzo(a)pyrene	**ug/l**	<0.1
Di (2 ethylhexyl) Phthalate	**ug/l**	<10
Hexachlorobenzene	**ug/l**	<1
Nitrobenzene	**ug/l**	<1
2,4 Dinitrotoluene	**ug/l**	<1
Hexachloroethane	**ug/l**	<1
Total PAH's	**ug/l**	<2

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ORGANIC ANALYSES PARAMETERS [s] – Distilled Water

Date received: : 2013-04-30 **Date completed: 2013-05-31**

Project number: 132 **Report number: 39728** **Order number: D880/MvZ/21921**

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Telephone: 011 - 519 - 0200 **Facsimile: 011 - 519 - 0201** **Mobile: 082 880 1250**

Organic Analyses: Phenols - Distilled Water		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X1**	
Cresols	**ug/l**	<2
2-Chlorophenol	**ug/l**	<2
2,4-Dichlorophenol	**ug/l**	<2
Pentachlorophenol	**ug/l**	<2
2,4,5-Trichlorophenol	**ug/l**	<2
2,4,6-Trichlorophenol	**ug/l**	<2
Phenols (total,non-halogenated)	**ug/l**	<20

Organic Analyses: Pesticides - Distilled Water		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X1**	
Adrin	**ug/l**	<0.1
Dieldrin	**ug/l**	<0.1
DDT	**ug/l**	<0.1
DDE	**ug/l**	<0.1
DDD	**ug/l**	<0.1
Heptachlor	**ug/l**	<0.1
Chlordane	**ug/l**	<0.1
2,4 Dichlorophenoxyacetic Acid	**ug/l**	<0.1

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CERTIFICATE OF ANALYSES

ORGANIC ANALYSES PARAMETERS [s] – Distilled Water

Date received: : 2013-04-30 **Date completed: 2013-05-31**

Project number: 132 **Report number: 39728** **Order number: D880/MvZ/21921**

Client name: JONES & WAGENER CONSULTING CIVIL ENGINEERS **Contact person: Marius van Zyl**

Address: P.O. Box 1434 Rivonia 2128 **e-mail: vanzyl@jaws.co.za**

Telephone: 011 - 519 - 0200 **Facsimile: 011 - 519 - 0201** **Mobile: 082 880 1250**

Organic Analyses: PCB - Distilled Water		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X1**	
Ballsmitters Totals	**ug/l**	<5

Organic Analyses: TPH - Distilled Water		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X1**	
Petroleum H/Cs,C6-C9	**ug/l**	<25
Petroleum H/Cs,C10 to C36	**ug/l**	<10

[s] = Analyses performed by a Sub-contracted Laboratory

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CERTIFICATE OF ANALYSES
TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2013-04-30 | **Date completed: 2013-05-27**
Project number: 132 | **Report number: 39728** | **Order number: D880/MvZ/21921**

Client name: JONES & WAGENER CONSULTING CIVIL ENGINEERS | **Contact person: Mr. M. van Zyl**
Address: P.O. Box 1434 Rivonia 2128 | **Email: vanzyl@jaws.co.za**
Telephone: 011 - 519 - 0200 | **Facsimile: 011 - 519 - 0201** | **Cell: 082 880 1250**

Analyses	Sample Identification : Tutuka Power Station Ash	
Sample number	**4827**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**Distilled Water**	
Dry Mass Used (g)	**50**	
Volume Used (mℓ)	**1000**	
Paste pH	11.0	
Units	**mg/ℓ**	**mg/kg**
Total Dissolved Solids at 180°C	328	6 560
Chloride as Cl	9	180
Sulphate as SO_4	153	3 060
Nitrate as N	<0.2	<4.0
Fluoride as F	0.3	6.0
Total Cyanide as CN	<0.05	<1.00
Mercury as Hg	<0.001	<0.020
Hexavalent Chromium as Cr^{6+}	0.280	5.60
ICP-OES Quant (See list attached)	See attached report 39728 ICP DW	
X-Ray Diffraction	See attached report 39728 XRD	
ZHE Organic Analyses	See attached report 39728 ZHE Organics DW	

Sample number	**4827**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**Aqua Regia**	
Dry Mass Used (g)	**0.25**	
Volume Used (mℓ)	**50**	
Units	**mg/ℓ**	**mg/kg**
Mercury as Hg	<0.001	<0.200
Total Hexavalent Chromium as Cr^{6+}	-------	2.1
Total Fluoride as F [s] (Solid) ppm	91	
Total CN on solid mg/kg	<0.01	
ICP-OES Quant	See attached report 39728 ICP AQR	
Total Organics [s] (solid)	See attached report 39728 Total Organics	

[s]= Results obtained from subcontracted laboratory

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Geochemistry Project Manager

WATERLAB (PTY) LTD

CERTIFICATE OF ANALYSES

ICP-OES - SCAN

Date received:	**30/04/2013**	**Date Completed:**	**05/06/2013**
Project number:	**132**	**Report number:**	**39728**

Client name:	**Jones & Wagener Consulting Civil Engineers**	**Contact person:**	**Mr. M. van Zyl**
Adress:	**P.O. Box 1434, Rivonia, 2128**	**Email:**	**vanzyl@jaws.co.za**
Telephone:	**011 - 519 - 0200**	**Facsimile:**	**011 - 519 - 0201**

Extract	Sample Dry Mass	Volume	Mass (g/l)	Factor
Aqua Regia	0.5	100	5	200

Sample Id	Sample number	As	As	B	B	Ba	Ba
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<2.00	<0.025	<5.00	<0.025	<5.00
Tutuka Power Station Ash	4827	<0.010	<2.00	<0.025	<5.00	1.87	373

Sample Id	Sample number	Cd	Cd	Co	Co	Cr	Cr
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.005	<1.00	<0.025	<5.00	<0.025	<5.00
Tutuka Power Station Ash	4827	0.032	6.40	0.076	15	0.387	77

Sample Id	Sample number	Cu	Cu	Mn	Mn	Mo	Mo
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<5.00	<0.025	<5.00	<0.025	<5.00
Tutuka Power Station Ash	4827	0.087	17	1.58	315	<0.025	<5.00

Sample Id	Sample number	Ni	Ni	Pb	Pb	Sb	Sb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<5.00	<0.020	<4.00	<0.010	<2.00
Tutuka Power Station Ash	4827	0.198	40	<0.020	<4.00	<0.010	<2.00

Sample Id	Sample number	Se	Se	V	V	Zn	Zn
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.020	<4.00	<0.025	<5.00	<0.025	<5.00
Tutuka Power Station Ash	4827	<0.020	<4.00	0.353	71	0.210	42

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CERTIFICATE OF ANALYSES

ORGANIC ANALYSES PARAMETERS [s] – Total Organics

Date received: : 2013-04-30 **Date completed: 2013-05-31**

Project number: 132 **Report number: 39728** **Order number: D880/MvZ/21921**

Client name: JONES & WAGENER CONSULTING CIVIL ENGINEERS **Contact person: Marius van Zyl**

Address: P.O. Box 1434 Rivonia 2128 **e-mail: vanzyl@jaws.co.za**

Telephone: 011 - 519 - 0200 **Facsimile: 011 - 519 - 0201** **Mobile: 082 880 1250**

Organic Analyses: Volatile Organic Compound - Total Organics		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X20**	
Benzene	**ug/kg**	<40
Carbon Tetrachloride	**ug/kg**	<100
Chlorobenzene	**ug/kg**	<40
Chloroform	**ug/kg**	<100
1,2-Dichlorobenzene	**ug/kg**	<40
1,4-Dichlorobenzene	**ug/kg**	<40
1,2-Dichloroethane	**ug/kg**	<40
Ethylbenzene	**ug/kg**	<40
Hexachlorobutadiene	**ug/kg**	<40
Isopropylbenzene	**ug/kg**	<40
MTBE	**ug/kg**	<100
Naphthalene	**ug/kg**	<40
Styrene	**ug/kg**	<100
1,1,1,2-Tetrachloroethane	**ug/kg**	<200
1,1,2,2-Tetrachloroethane	**ug/kg**	<200
Toluene	**ug/kg**	<200
1,1,1-Trichloroethane	**ug/kg**	<100
1,1,2-Trichloroethane	**ug/kg**	<100
Xylenes total	**ug/kg**	<100
1,2,4 Trichlorobenzene	**ug/kg**	<40
1,2,3 Trichlorobenzene	**ug/kg**	<40
Dichloromethane	**ug/kg**	<400
1,1-Dichloroethylene	**ug/kg**	<200
1,2-Dichloroethylene	**ug/kg**	<200
Tetrachloroethylene	**ug/kg**	<200
Trichloroethylene	**ug/kg**	<200

E. Botha
Geochemistry Project Manager

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CERTIFICATE OF ANALYSES

ORGANIC ANALYSES PARAMETERS [s] – Total Organics

Date received: : 2013-04-30 **Date completed: 2013-05-31**

Project number: 132 **Report number: 39728** **Order number: D880/MvZ/21921**

Client name: JONES & WAGENER CONSULTING CIVIL ENGINEERS **Contact person: Marius van Zyl**

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Organic Analyses: Polars - Total Organics		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**x1**	
2-Butanone	**mg/kg**	<1
Vinyl Chloride	**mg/kg**	<1

Organic Analyses: Formaldehyde Total Organics		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X40**	
Formaldehyde	**ug/kg**	<200

Organic Analyses: Semi Volatile Organic Compound - Total Organics		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X20**	
Benzo(a)pyrene	**ug/kg**	<2
Di (2 ethylhexyl) Phthalate	**ug/kg**	<200
Hexachlorobenzene	**ug/kg**	<20
Nitrobenzene	**ug/kg**	<20
2,4 Dinitrotoluene	**ug/kg**	<20
Hexachloroethane	**ug/kg**	<20
Total PAH's	**ug/kg**	<40

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ORGANIC ANALYSES PARAMETERS [s] – Total Organics

Date received: : 2013-04-30 **Date completed: 2013-05-31**

Project number: 132 **Report number: 39728** **Order number: D880/MvZ/21921**

Client name: JONES & WAGENER CONSULTING CIVIL ENGINEERS **Contact person: Marius van Zyl**

Address: P.O. Box 1434 Rivonia 2128 **e-mail: vanzyl@jaws.co.za**

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Organic Analyses: Phenols - Total Organics		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X20**	
Cresols	**ug/kg**	<40
2-Chlorophenol	**ug/kg**	<40
2,4-Dichlorophenol	**ug/kg**	<40
Pentachlorophenol	**ug/kg**	<40
2,4,5-Trichlorophenol	**ug/kg**	<40
2,4,6-Trichlorophenol	**ug/kg**	<40
Phenols (total,non-halogenated)	**ug/kg**	<400

Organic Analyses: Pesticides - Total Organics		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X20**	
Adrin	**ug/l**	<2
Dieldrin	**ug/l**	<2
DDT	**ug/l**	<2
DDE	**ug/l**	<2
DDD	**ug/l**	<2
Heptachlor	**ug/l**	<2
Chlordane	**ug/l**	<2
2,4 Dichlorophenoxyacetic Acid	**ug/l**	<2

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ORGANIC ANALYSES PARAMETERS [s] – Total Organics

Date received: : 2013-04-30 **Date completed: 2013-05-31**

Project number: 132 **Report number: 39728** **Order number: D880/MvZ/21921**

Client name: JONES & WAGENER CONSULTING CIVIL ENGINEERS **Contact person: Marius van Zyl**

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Organic Analyses: PCB - Total Organics		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X20**	
Ballsmitters Totals	**ug/kg**	<100

Organic Analyses: TPH - Total Organics		
Analyses in ug/l (Unless specified otherwise)		**Sample Identification :**
		Tutuka Power Station Ash
Sample Number		**4827**
Dilution	**X20**	
Petroleum H/Cs,C6-C9	**mg/kg**	<0.5
Petroleum H/Cs,C10 to C36	**mg/kg**	<0.2

[s] = Analyses performed by a Sub-contracted Laboratory

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CERTIFICATE OF ANALYSES
X-RAY DIFFRACTION

Date received: 2013-04-30 **Date completed: 2013-05-25**
Project number: 132 **Report number:** **Order number: D880/MvZ/21921**

Client name: JONES & WAGENER CONSULTING CIVIL ENGINEERS **Contact person: Mr. M. van Zyl**
Address: P.O. Box 1434 Rivonia 2128 **Email: vanzyl@jaws.co.za**
Telephone: 011 - 519 - 0200 **Facsimile: 011 - 519 - 0201** **Cell: 082 880 1250**

Composition (%) [s]		
Tutuka Power Station Ash		
4827		
Mineral	Amount (weight %)	Error
Amorphous	46.94	1.29
Calcite	3.11	0.39
Hematite	0.94	0.23
Magnetite	1.89	0.2
Mullite	29.69	1.02
Quartz	17.44	0.63

[s] Results obtained from sub-contracted laboratory

Note:

The material submitted was scanned after addition of 20 % Si for quantitative determination of amorphous content and micronizing in a McCrone micronizing mill.
It was analysed with a PANalytical Empyrean diffractometer with PIXcel detector and fixed slits with Fe filtered Co-Kαradiation. The phases were identified using X'Pert Highscore plus software.

The relative phase amounts (weight %) were estimated using the Rietveld method.
Errors are on the 3 sigma level in the column to the right of the amount (in weight per cent).

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.
- Errors reported for phases occurring in minor amounts are sometimes larger than that of the quantity reported, indicating the possible absence of those phases.
- Due to preferred orientation effects results may not be as accurate as shown in the table.

Ideal Mineral Composition

Calcite CaCO3
Hematite Fe2O3
Magnetite Fe3O4
Mullite 3Al2O3 2SiO2
Quartz SiO2

Appendix B

RADIOACTIVITY ANALYSIS REPORT

RadioAnalysis
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necsa
We're in your world

Contact: ***Mr M van Zyl***
Company: ***Jones & Wagener***
Address: ***P O Box 1434***
Rivonia
2128

Date: ***27 June 2013***
Report number: ***RA-14297-01***
Pages: ***3***
Your reference: ***D880MVL21918***

Analysis Report

Radioactivity analysis of solids

Compiled by: ***D Kotze***

Checked by: ***J Smit***

1. SERVICE

Analysis solid samples for gross alpha/beta-activity and for selected radionuclides in the uranium and thorium decay series.

Number of samples recieved: 1

The samples were received on: 30 April 2013

2. SAMPLE PREPARATION AND ANALYSIS

Method	Description	Completed	Assayer	Verified by
WIN-114	**Dry sample, mill to homogenise**	09/05/2013	E Mothlabane	J Smit
WIN-138	**Gross alpha/beta analysis**	24/06/2013	S May	E Nhlapo
WIN-167	**U and Th by neutron activation analysis**	25/06/2013	A Sathekga	M Raven
WIN-101	^{226}Ra, ^{228}Ra, ^{228}Th, ^{40}K by gamma analysis	13/06/2013	N Seaga	M Raven
WIN-158	**^{210}Pb by low energy gamma analysis**	20/06/2013	N Seaga	M Raven

Results indicated in **bold in this report were obtained from methods that are not included in the SANAS Schedule of Accreditation fo this laboratory*

3. RESULTS

3.1 Results are attached as an appendix to this report.

3.2 Results report are related only to sample portions tested.

3.3 The method for gross alpha/beta-activity is intended to merely be a screening technique and gives only a first order estimate of total activities. Errors associated with unavoidable differences between particle energies of the calibration standards and samples, are not accounted for in the reported uncertainty which is mainly based on counting statistics. The reported uncertainty may therefore be an underestimation of the true uncertainty.

4. QUALITY ASSURANCE

4.1 RadioAnalysis is a SANAS accredited laboratory (Testing Laboratory T0111) based on ISO/IEC Standard 17025. All analytical methods are documented in the RadioAnalysis Quality System.

4.2 Results in this report were obtained from one or more individual test reports produced by accredited or non-accredit methods.

- Test reports containing results obtained from methods included in the SANAS Schedule of Accreditation, are verified and signed by SANAS Technical Signatories for those methods.
- Test reports containing results obtained from methods not included in the SANAS Schedule of Accreditation, are verified and signed by qualified competent analysts for those methods.
- The individual test reports are available upon request

4.3 The compiler is the Technical Expert for all the methods.

4.4 The compiled report is checked by a person other than the compiler for accuracy of data transcription.

4.5 The RadioAnalysis Laboratory keeps the original signed hard copy of this report on record for three years.

APPENDIX 1: ANALYTICAL RESULTS

Activity concentrations of nuclides

Unit: Bq/kg

Field code	Tutuka Power		
Lab code	RA-14297X001		
Nuclide	Value	Unc.	MDA
^{238}U	114	8	14
^{234}U	115	8	14
^{226}Ra	122	8	16
^{210}Pb	125	32	100
^{235}U	5.25	0.38	0.63
^{232}Th	138	6	3.2
^{228}Ra	120	11	25
^{228}Th	151	18	39
^{40}K	248	34	84
Gross alpha	2440	180	310
Gross beta	983	21	33

*Results indicated in **bold** in this report were obtained from methods that are not included in the SANAS Schedule of Accreditation fo this laboratory*

Notes:

1. If a measured value (**Value** column) was recorded, it is reported regardless if the value is less than the minimum detectable activity concentration (**MDA** column) or even if the value is negative. In the case where a value could not be obtained, a less than MDA ("< MDA") will be indicated.
2. The reported uncertainty (**Unc.** column) is quoted at 1 sigma (or coverage factor k = 1). The uncertainty is calculated mainly from counting statistics and it is not the standard deviation obtained from replicate measurements. No uncertainty value is reported of a less than MDA ("< MDA") is indicated in the **Value** column.
3. The minimum detectable activity concentration (**MDA** column) is calculated with a 95% confidence level.
4. A values is reported with 3 significant digits if it is greater than the MDA value and the associated uncertainty will be reported the same precision. If a value is less than the MDA, the value and its associated uncertainty are reported with 2 significant digits regardless their respective magnitudes. A MDA value is always reported with 2 significant digits.

Appendix C

AQUISIM REPORT

Technical Memorandum

AquiSim Consulting (Pty) Ltd

P O Box 51777, Wierda Park, 0149, South Africa

Telephone: + (27) (0)12 654-0212
Facsimile: + (27) (0)866 89-6006
E-mail: aquisim@netactive.co.za

To:	Marius van Zyl	**Date:**	15 July 2013
cc:		**Project No:**	ASC-1037C
From:	Japie van Blerk	**File No:**	01
RE:	**INTERPRETATION OF FULL SPECTRUM RADIOLOGICAL ANALYSIS: TUTUKA POWER STATION**		

National Legislation

Materials and residues that contain naturally occurring radionuclides (i.e., radionuclides associated with the U-238, Th-232 and U-235 decay series) are generally referred to as Naturally Occurring Radioactive Material (NORM).

The legal limit in South Africa for material to be classified as radioactive is 0.5 $Bq.g^{-1}$ (nuclide specific). The protection of human health and the environment from adverse effects associated with exposure to ionizing radiation is regulated in terms of the National Nuclear Regulator Act (NNRA) (Act 47 of 1999) and the Nuclear Energy Act (NEA) (Act No. 46 of 1999).

The NNRA established the National Nuclear Regulator (NNR) as the statutory body responsible for regulating the nuclear industry, as well as NORM associated with the mining and mineral processing industry. Due to the presence of naturally occurring radionuclides, NORM has the potential to impact negatively on the health of humans that are exposed to these material.

In terms of its mandate, the NNR must publish requirements, guidelines, and standards for the protection of persons, property, and the environment against exposure to ionizing radiation that are consistent with international requirements and guidelines. Regulation No. 388 (dated 28 April 2006) defines regulations regarding safety standards and regulatory practices promulgated by the NNR. This means that material containing natural occurring radionuclides can only be regarded as radioactive if any of the radionuclides in the 238, U-234, U-235, and Th-232 decay series is above the exemption level of 0.5 $Bq.g^{-1}$.

The regulatory protection criteria defined in Regulation No. 388 for the protection of members of the public is consistent with international guidelines provided by the IAEA and ICRP. In terms of Regulation No. 388 the following limits apply:

- The annual effective dose limits for members of the public from all authorised actions is 1 mSv.
- No action may be authorised which would give rise to any member of the public receiving a radiation dose from all authorised actions exceeding 1 mSv in a year.

Consistent with international guidelines, the regulation makes provision for the application of a dose constraint for authorised actions to ensure optimisation of radiation protection. The following is stated (Section 4.5.2):

> Where applicable in terms of the prior safety assessment, the optimisation of protection must be subject to dose constraints specific to the authorised action, which must not exceed values that can cause the relevant dose limits to be exceeded and which ensure as far as practicable that doses are restricted by application of the ALARA principle on a source-specific basis rather than by dose limits (Section 4.5.2.1).
>
> For members of the public, the dose constraint applicable to the average member of the critical group within the exposure population is 0.25 mSv per year specific to the authorised action unless otherwise agreed by the Regulator on a case-by case basis, taking into account the dose limit specified for exposure of members of the public from all sources (Section 4.5.2.2).

Full Spectrum RadioAnalytical Results

Full spectrum results of an ash samples analysed at the Necsa RadioAnalytical Laboratories (Sanas Accredited) are available and listed in Table 1. From the results it is clear that all nuclides are below the exemption criteria of 0.5 $Bq.g^{-1}$ (or 500 $Bq.kg^{-1}$). This means that the material is not considered as radioactive material *per se*.

Table 1 Summary of the Necsa full spectrum radiological analysis (RA-14297, dated 27 June 2013) of an ash sample from the Tutuka Power Station.

Nuclide	Tutuka Power Station (RA-14297X001)		
	Value	Uncertainty	MDA
	$Bq.kg^{-1}$		
U-238	1.14E+02	8.00E+00	1.40E+01
U-234	1.15E+02	8.00E+00	1.40E+01
Ra-226	1.22E+02	8.00E+00	1.60E+01
Pb-210	1.25E+02	3.20E+01	1.00E+02
U-235	5.25E+00	3.80E-01	6.30E-01
Th-232	1.38E+02	6.00E+00	3.20E+00
Ra-228	1.20E+02	1.10E+01	2.50E+01
Th-228	1.51E+02	1.80E+01	3.90E+01
K-40	2.48E+02	3.40E+01	8.40E+01
Gross α	2.44E+03	1.80E+02	3.10E+02
Gross β	9.83E+02	2.10E+01	3.30E+01

Radiological Impact to Members of the Public

In order to assess the potential radiological impact to members of the public, information in terms of how these people interact with the material is needed (e.g. period exposed to the material, inhalation of dust particles containing the material, inadvertent ingestion of the material, etc.). This information is not available at present.

As an alternative, conservative assumption can be made regarding some of these parameters, to estimate the potential radiological impact under the assumed conditions. For this purpose, the following assumptions are made:

- Members of the public are exposed to the material for a period of 2000 hours per annum (equal to the period normally used for worker radiological safety assessments, such as tailings dam operators).
- During this exposure period, an adult member of the public inhale 1860 m^3 of air (or 0.93 $m^3.h^{-1}$, which is the average breathing rate during sleeping, sitting, light and heavy exercise). For this purpose it is assume that the inhalable dust load is 1E-04 $g.m^{-3}$.

For these assumed conditions, the inhalation dose to an adult members of the public will be in the order of 5.3 $\mu Sv.a^{-1}$ for the sample, while the external gamma radiation (normally referred to as ground shine) for an adult member of the public (2000 hour exposure period) would be in the order of 140 $\mu Sv.a^{-1}$. The external gamma radiation dose will decrease linearly with a decrease in exposure period, while the exposure with distance away from the facility will decrease exponentially (i.e., a small distance away from the facility, the dose will decrease to insignificant levels).

Conclusion

The material is below the limit set for material to be considered as radioactive. Assuming very conservative conditions (e.g. exposure for a period of 2000 hours per annum) the potential radiological impact to members of the public is below the regulatory criteria for the radiological protection of members of the public. It should be noted, however, that the assumed conditions does not consider the possibility for members of the public residing on top of the facility for extended periods of time, in which case additional exposure conditions would need to be considered (e.g. radon exhalation and the subsequent built-up of radon inside a house). It is not known whether such conditions is a possibility or realistic in this case.

Please do not hesitate to contact me if something is unclear.

Best Regards

JJ van Blerk (Sent electronically)
DIRECTOR: AquiSim Consulting (Pty) Ltd.