19 November 2018 HPRM D18/24372



Chief Executive Officer Department of Water and Environmental Regulation Locked Bag 33 **CLOISTERS SQUARE WA 6850** 

**Dear Chief Executive Officer** 

#### TRIAL NOTIFICATION: SOUTHERN PORTS (L5099/1974/14) – BULK SPODUMENE PRODUCTS FROM SHED 4 TO BERTH 3 SHIPLOADER

In accordance with Condition 2 of Environmental Licence L5099/1974/14 for the Southern Ports (SP), please consider this correspondence as formal Trial Notification relating to the export shipments of Mineral Resources Limited (MRL) Spodumene products from its Mt Marion operation using bulk loading methods...

Four products are produced at the Mt Marion operation; vary between 4-6% lithium and a coarse and fine product.

The Trial will commence 30 days from the date and time that this notification is sent to DWER. The trial will include monthly shipments, with an average of 34,000 tonnes per ship (with a maximum of 65,000 tonnes per ship). The Trial will continue for up to 12 months and will include the export of up to 500,000 dry metric tonnes of Spodumene.

Based on SP loading controls, monitoring commitments and product quality as detailed in Attachment 1, the potential risk to both human health and ecosystem as a consequence of the proposed Trial is considered low. The proposed handling strategy has been determined based on the hazards identified in the product quality testing. Further, SP's current monitoring program, as required under our existing licence will support this Trial. Both SP and MRL are committed to continual improvement and the Trial outcomes will be assessed and reported, with a view to subsequent licence amendment application.

All four Spodumene products proposed for the Trial are compliant with the criteria listed under Condition 5 of Environmental Licence L5099/1974/14, summary below.

ESPERANCE ALBANY BUNBURY PO Box 175 PO Box 4 PO Box 35 Albany, WA 6331 Bunbury, WA 6231 Esperance, WA 6450 West Perth, WA 6872 T: +61 8 9892 9000 T: +61 8 9729 6500 T: +61 8 9072 3333 T: +61 8 9235 8000 ABN: 30 044 341 250

PERTH PO Box 1049

E: enquiries@southernports.com.au

	Laboratory Testing results					
Licence L5099/1974/14	6% Fine	6% Coarse	6% 50:50 Coarse:Fine	4% Coarse		
(a) Contain asbestos in concentrations equal to or greater than 0.01% w/w for non-friable asbestos or 0.01% w/w for fibrous asbestos;	0.002 %	less than 0.001 %	0.001 %	less than 0.001 %		
(b) Contain respirable silica equal to or greater than 1% w/w;	0.179 wt%	0.001 wt%	0.055 wt%	0.002 wt%		
(c) Exceed the radiation transport limit of 10 Bq/g for Uranium-238 and Thorium232 combined;		0.04 Bq/g		0.05 Bq/g		
(d) Exceed Rubidium-87 concentrations of 30 Bq/g; or		0.59 Bq/g		1.23 Bq/g		
(e) Are a waste or waste-derived by product (except Clean fill).	No	No	No	No		

In support of this Notification and for your information, please find additional information in Attachment 1 (Trial Notification Matrix) and the associated NATA accredited laboratory testing and consultant reports in the remaining Attachments.

We look forward to your response, and should you require further information, please don't hesitate to contact Alex Leonard (SP Environmental Manager) on 9072 3388 or 0429 073 546.

Sincerely,

Alan Byers Interim Chief Executive Officer **Southern Ports** Albany - Bunbury - Esperance

Cc: Danielle Eyre (DWER), Kim Dennison (MRL), David Swain (MRL)

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## Attachment 1 – DWER Trial Notification Matrix

Minimum Trial notification information to be provided to DWER (DRAFT for final stakeholder comment)

Trial shipment notification: Summary of Health and Environmental risks associated bulk loading of four spodumene products through the Port of Esperance

Description of proposed Trial	<ul> <li>Mt Marion Lithium Project currently produces the following Spodumene export bulk products, collectively these will be referred to as the "products" throughout this Notification.</li> <li>6% Lithium Fine ("6% fine")</li> <li>6% Lithium 50:50 Coarse: Fine ( "6% 50:50")</li> <li>6% Lithium 50:50 Coarse: Fine ( "6% 50:50")</li> <li>4% Lithium Coarse ("4% coarse")</li> </ul>
	All four products are sourced from the same mine areas at Mt Marion and are physically and chemically treated in the same facilities however removed from the process at different stages. The products have been physically processed to reduce the particle size through a crushing plant. The products are then treated through a multi stage wet beneficiation process to remove unwanted components.
	Products will be loaded into road trains directly from the beneficiation plant stockpile by a wheel loader. Road trains will transport the product to the Port of Esperance utilising the Coolgardie-Esperance Highway (approximately a 4 hours transport time). The product will be unloaded into Shed 4 after a concrete floor has been laid to provide a sealed floor and prevent contamination. Front end loaders will outload into the enclosed circuit to the Berth 3 shiploader.
	The Trial will commence 30 days from the date and time that this notification is sent to DWER with the first shipment due in January 2019. The Trial will be ongoing over the next 12 months with a total of 500,000 dry metric tonnes expected to be exported over this period. Shipments are expected every 27-28 days with some months receiving two ships. Shipments will average 34,000 tonnes but can reach at a maximum 65,000 tonnes. Trial and monitoring results will be utilised to support a formal Licence Amendment.
Human health hazards associated with the Trial material	None of the products present significant human health hazards and are all suitable for assessment by the "Self-assessment decision-making flow chart" for trial shipment notification since all products: <ul> <li>Are not a waste or a waste-derived product;</li> </ul>
	Have respirable silica <1% (Attachments 10 to 13);
	<ul> <li>Asbestos fibres are &lt;0.01% (Attachments 14 to 17); and</li> </ul>
	<ul> <li>Radioactivity is &lt;10 Bq/g (U238/Th232) and &lt;30 Bq/g (Rb87) (Attachment 18 and 19).</li> </ul>
Environmental hazards associated with the Trial material	All four products present minimal environmental hazards since:     • All four products do not pose any significant bioavailability risks to the marine environment based on the deionised water leachate results for metals (Attachment 20). The
	results were compared to the following risk criteria: ANZECC-ARMCANZ (2000) trigger values for marine water for all four products indicating risks are acceptable to the surrounding marine environment. The
	stormwater discharge points into the berth pockets of the inner harbour constitute a highly modified environment (90% Level of protection Applicable) and initial dilution of at least ten fold is considered.
	Note that there is no pathway of leachates to drinking water as the handling areas are sealed and the underlying aquifer is brackish and not used for human
	<ul> <li>All four under the main case nows seaward).</li> <li>All four products will be wet separated at the mine and will arrive at the Port storage shed above their DEM (Attachments 2 to 5) and moisture will be maintained above the DEM prior to loading.</li> </ul>
	<ul> <li>All four products have mice (muscovite) &lt;5% (Attachments 6 to 9) and these levels will be kept at &lt;5%.</li> </ul>
	<ul> <li>Three products had less than 3% of their particulates &lt;10 μm (Attachments 10 to 13), but one product the 6% fines had 4.8% of its particulates less than 10 μm (Δthachment 10).</li> </ul>
	The product is odourless; and
	• The operations will present no more noise than the usual operations that include truck movements to Shed 5 (next to shed 4) and the operation of iron ore circuit.
Key human health and environmental risks associated with handling the trial material	<ul> <li>No relevant environmental risk criteria applicable for airborne lithium or lithium concentrations in fresh or marine waters.</li> </ul>

Minimum Trial notification information	to be provided to DWER (DRAFT for final stakeholder comment)
Description of all sensitive receptors, including location and distance from source of hazard	<ul> <li>Unloading of the spodumene in Shed 4 constitutes the prescribed activity closest to the residential receptors and this is &gt;500m from the nearest residential receptor at premises not owned by the Port. Shed 4 is not likely to constitute any significant emissions as any unloading or loading of product in the shed will be conducted under fully enclosed conditions. Note that: <ul> <li>The DWER Noise Branch excludes premises from their assessments if they are owned by the Port. Noise is the key emission affecting residents.</li> <li>Dust risks have shown to be acceptable from PM10 monitoring on the Ports boundary in data reported to DWER;</li> <li>The Berth 3 shiploader is the only likely source of dust and is located over 700m from any residential receptor including those owned by the Port.</li> </ul> </li> </ul>
Description of receptor pathways	<ul> <li>Stormwater run-off from sealed surfaces on Berth 3 could mobilise dust to the marine environment. However, the area drains landward to an underground sump that will be inspected on a monthly basis and emptied of solids as required.</li> <li>No discharge to groundwater as all handling surfaces are sealed;</li> <li>Main dust source is from the berth 3 shiploader and wind could carry dust to the marine environment or the residential receptors. These emissions will be acceptable and below relevant criteria based on product quality and loading controls.</li> </ul>
Description of appropriate handling methods and controls on hazard source for mitigating (and/or minimising) risks to receptors – as determined by self-assessment framework provided by DWER	<ul> <li>Using the "Self-assessment decision-making flow chart" for trial shipment notification:</li> <li>Three of the four products: 6% coarse product; 6% 50-50 product and the 4% coarse product are all considered to be suitable for handling method number 1;</li> <li>The 6% fine product is suitable for handling method number 2.</li> <li>The risks of the trial are negligible since the proposed loading represents handling method number 3, well in excess of the minimum loading requirements for these products. The loading controls for storage and loading represents handling method number 3, well in excess of the minimum loading requirements for these products.</li> <li>An enclosed shed and an enclosed conveyor circuit;</li> <li>A shiploader that can be lowered into the hold with misting sprays on the loader;</li> <li>As per licence condition 22, the moisture of the spodumene to be kept above the DEM before and during shiploading; and</li> <li>As per condition 24 of licence for iron ore, if dust is visibly escaping the hold, misting sprays on shiploader to be operated.</li> </ul>
Description of proposed monitoring for Trial period	<ul> <li>Monitoring to be conducted as per existing licence conditions:</li> <li>Condition 21: Table 4 for ongoing spodumene product quality;</li> <li>Condition 23: Monitoring as required to ensure moisture of the spodumene stockpile to be kept above the DEM before and during shiploading;</li> <li>Condition 22: Boundary PM10 dust monitoring for Lithium at sites 1-5;</li> <li>Condition 27: Ensure any reportable event for PM10 is reported as required;</li> <li>Condition 32: Relating to monitoring of lithium in stormwater and washwaters; and</li> <li>Condition 33: Relating to monitoring of lithium in stormwater and washwaters; and</li> <li>Condition 33: Relating to monitoring results will occur as required by Condition 6 and include any incidents/complaints or non-material procedural changes. Five reports will be submitted over the 12 month period, the first report being due 30 days after the first shipment, the remaining to be provided at 4, 7, 10 and the end of the trial period.</li> <li>An application for a formal licence amendment will be submitted at least three months before the cessation of the trial period.</li> </ul>
Description of proposed contingency measures/management actions in the event of unexpected / unplanned incident resulting from Trial	<ul> <li>In the unlikely event that dust is an issue, dust management triggers used for iron ore on Berth 3 will also apply to spodumene:</li> <li>If visible dust is observed escaping the hatch dust mitigation measures will be implemented including activating the misting sprays on the shiploader; and</li> <li>Loading will be shut down if dust is visible from the Port beach.</li> <li>In the unlikely event that noise is identified as an issue by the real time noise loggers or complaints are received, the Conditions of the Regulation 17 Approval will apply requiring reporting, investigation and remedial action.</li> </ul>

Attachment 2 - Dust Extinction Moisture (DEM) for the 6% fine product



11 October 2018

Rain Lewis Metallurgical Surpervisor Nagrom the Mineral Processor 49 Owen Road, Kelmscott WA 6111 E: rain@nagrom.com.au D: +61 8 9399 3934

Delivered by email: <u>rain@nagrom.com.au</u>

#### RE: Dust Extinction Moisture test results on MM SC6 20180904

Dear Rain:

Our report follows, providing dust extinction moisture test results for the MM SC6 20180904 spodumene material received. This report completes the work we have been contracted for as provided in your PO NAG05996.

Please feel free to contact me should you have any questions.

Kind regards,

Corin Holmes Operations Manager Australia Perth, Western Australia cholmes@jenike.com

cc:

John W. Carson, Ph.D., President, Tyngsboro, Massachusetts; jwcarson@jenike.com



### Dust Extinction Moisture Test Results on MM SC6 20180904

Nagrom the Mineral Processor

Report No: 71193-2

11 October 2018 ©2018

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**Report author** Dewi Octavia, Project Engineer, Perth, Western Australia; <u>doctavia@jenike.com</u>

Report reviewer Corin P. Holmes MSc Eng, Operations Manager Australia, Perth, Western Australia; <u>cholmes@jenike.com</u>

#### We value your feedback. Please send your comments to ceo@jenike.com

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#### **1 INTRODUCTION**

Nagrom is interested in understanding the dusting behavior of a spodumene material labelled as "MM SC6 20180904". As such, they contracted Jenike & Johanson Pty Ltd (J&J) to determine the dust extinction moisture (DEM) content of the material. The DEM content is that at which a material is deemed to emit no dust as determined based on Australian Standard AS 4156.6-2000.

The following provides the results of the test work.

#### 2 FLOW PROPERTIES TEST RESULTS

A spodumene sample labelled MM SC6 20180904 was received for DEM. The *as received* moisture content<sup>1</sup> was determined, and the test results are summarized in the table below.

Table 1: Summary of MM Sc6 Enviro Comp results				
As received moisture 17.0%				
DEM %	4.4%			

#### **Dust Extinction Moisture Test**

A dust extinction moisture (DEM) test was performed for the MM SC6 20180904 spodumene material to investigate the effects of moisture content on dust generation. The results of the test indicate that the material has a DEM value of 4.4%. Full results of the test work are provided in the Appendix.

#### **3** TEST REPORT TABLES, PLOTS, AND APPENDIX

Detailed tables and plots of the test results are shown in the pages that follow.

<sup>&</sup>lt;sup>1</sup> Moisture values were determined by drying small samples at 107°C in a forced convection oven, until no change in moisture content is observed. The loss in weight of each sample, divided by its original weight before drying, is denoted as the *moisture*.



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#### Disclaimer

The information contained in this Flow Properties Test Report contains test results only and does not take into account the specific design requirements, needs, and circumstances of any particular storage, handling, and conveying application. The information enclosed must not be used for design purposes without consultation with an appropriately skilled and qualified bulk material handling professional, taking into account specific design requirements, circumstances, and risks.

All Calculated Design Parameters in this report represent limiting conditions for flow.



# Part II Test Results



## **Bulk Material 1**

# MM SC6 20180904



### Dust extinction moisture

#### MM SC6 20180904

The dust extinction moisture is 4.36%

Table 1.1: Dust Extinction Moisture

Initial Moisture $\%$	Final Dust Number
0.20	1752
1.73	88
2.47	33
5.17	19
17.35	0

Figure 1.1: Dust extinction moisture curve





# Part III Appendix



#### Dust extinction moisture

The dust extinction moisture test is used to investigate the effects of moisture content on dust generation. This test is conducted using a rotating drum, based on Australian standard AS 4156.6 - 2000.

The test determines a dust number (mass of dust collected/original mass of sample multiplied by 100,000) for various moisture contents. The dust numbers are plotted on a log-log scale against their respective moisture contents to produce a dust/moisture curve.

The standard identifies the dust extinction moisture as the moisture at which a dust number of 10 is attained on the dust/moisture curve. Although the standard was originally developed for higher rank coals, it has been successfully used for years on many coals and other bulk materials. The curve, along with field experience and dust emission goals, can be used in selecting a moisture content limit(s) to suit your application(s), and establishing operating and monitoring practices that may be required.

The standard calls for removal of particles greater than 6.3 mm. The particle size used is reported, which may or may not meet this requirement.

The AS 4156.6 - 2000 standard states the reproducibility of the test to be 10% (relative), and errors in total moisture measurements to be  $\pm 0.2\%$  and in dust number  $\pm 6\%$ .

Attachment 3 - Dust Extinction Moisture (DEM) for the 6% coarse product



14 November 2018

Rain Lewis Metallurgical Surpervisor Nagrom the Mineral Processor 49 Owen Road, Kelmscott WA 6111 E: rain@nagrom.com.au D: +61 8 9399 3934

Delivered by email: <u>rain@nagrom.com.au</u>

#### RE: Dust Extinction Moisture test results on Spodumene MM SC4 and MM SC6

Dear Rain:

Our report follows, providing dust extinction moisture test results for the Spodumene MM SC4 and MM SC6 materials received. This report completes the work we have been contracted for as provided in your PO NAG05996.

Please feel free to contact me should you have any questions.

Kind regards,

Dewi Octavia Project Engineer Perth, Western Australia doctavia@jenike.com

cc:

John W. Carson, Ph.D., President, Tyngsboro, Massachusetts; jwcarson@jenike.com



### **Dust Extinction Moisture Test Results on Spodumene MM SC4 and MM SC6**

Nagrom

Report No: 71193-3

14 November 2018

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**Report author** Dewi Octavia, Project Engineer, Perth, Western Australia; <u>doctavia@jenike.com</u>

Report reviewer Corin P. Holmes MSc Eng, Operations Manager Australia, Perth, Western Australia; <u>cholmes@jenike.com</u>

#### We value your feedback. Please send your comments to ceo@jenike.com

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#### **1 INTRODUCTION**

Nagrom has contracted Jenike & Johanson Pty Ltd (J&J) to perform dust extinction moisture (DEM) tests on Spodumene MM SC4 and MM SC6 materials. The DEM content is that at which a material is deemed to emit no dust as determined based on Australian Standard AS 4156.6-2000.

The following provides the results of the test work.

#### 2 FLOW PROPERTIES TEST RESULTS

Two spodumene samples labelled MM SC4 and MM SC6 were received for DEM testing. The *as received* moisture content, maximum moisture content<sup>1</sup> before free draining occurs, and particle size distribution were determined for each material. The test results are summarized in the table below.

Table 1: Summary of Spodumene MM SC4 and MM SC6 test results				
	Weight of sample provided	23.5 kg		
	As received moisture	2.7%		
MM SC4	Maximum moisture content (before free draining occurs)	17.6%		
	DEM	1.3%		
	Weight percentage greater than 6.3mm	0.1%		
	Weight of sample provided	30.6 kg		
	As received moisture	1.6%		
MM SC6	Maximum moisture content (before free draining occurs)	7.5%		
	DEM	1.0%		
	Weight percentage greater than 6.3mm	0.1%		

Photos of the samples can be found in the Appendix section.

#### Particle size analysis

A particle size distribution (PSD) was determined for both spodumene materials, using a dry sieving method (Ro-Tap, with tapping, 5 minutes total time). The materials were air dried prior to sieving. Plots showing the PSD are provided in the Appendix section. The calculated P10, P50, and P90 sizes<sup>2</sup> are given in the following table.

Table 2: Particle size distribution test results summary				
MaterialP10 [mm]P50 [mm]P90 [m				
MM SC4	0.49	1.27	4.40	
MM SC6	0.98	2.41	5.16	

<sup>1</sup> Moisture values were determined by drying small samples at 107°C in a forced convection oven, until no change in moisture content is observed. The loss in weight of each sample, divided by its original weight before drying, is denoted as the *moisture*.

<sup>2</sup> The terms P10, P50, and P90 refer to the particle sizes at which 10%, 50%, and 90% of the sample is smaller, respectively. The value for P50 is also referred to as the mass median diameter.



#### **Dust Extinction Moisture Test**

A dust extinction moisture (DEM) test was performed for each of the spodumene materials, MM SC4 and MM SC6, to investigate the effects of moisture content on dust generation. The results of the test indicate that the MM SC4 and MM SC6 materials have a DEM value of 1.3% and 1.0%, respectively. Full results of the test work are provided in the Appendix.

The table below provides a detailed summary of data generated during the course of the test work.

	Table 3: DEM results, MM SC4					
Moisture Tested [%]	Sample pre-weight [g]	Filter bag weight [g]	Filter bag + dust post-weight [g]	Dust number	DEM	
0.2	2500	37.625	46.450	353		
0.4	2500	40.305	45.527	209		
0.8	2500	39.492	39.668	7	1.20/	
1.3	2500	38.593	38.636	2	1.3%	
1.4	2500	37.550	37.678	5		
2.5	2500	38.638	38.683	2		

Table 4: DEM results, MM SC6					
Moisture Tested [%]	Sample pre-weight [g]	Filter bag weight [g]	Filter bag + dust post-weight [g]	Dust number	DEM
0.2	2500	38.307	43.343	201	·
0.4	2500	38.956	42.624	147	1.0%
0.6	2500	36.964	39.924	118	
0.8	2500	37.816	37.966	6	
1.3	2500	38.069	38.109	2	
1.4	2500	37.900	38.002	4	

#### **3** TEST REPORT TABLES, PLOTS, AND APPENDIX

Detailed tables and plots of the test results are shown in the pages that follow.



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#### Disclaimer

The information contained in this Flow Properties Test Report contains test results only and does not take into account the specific design requirements, needs, and circumstances of any particular storage, handling, and conveying application. The information enclosed must not be used for design purposes without consultation with an appropriately skilled and qualified bulk material handling professional, taking into account specific design requirements, circumstances, and risks.

All Calculated Design Parameters in this report represent limiting conditions for flow.



# Part II Test Results



## **Bulk Material 1**

# $\mathbf{MM} \ \mathbf{SC4}$



Bulk material 1 MM SC4 Moisture content As  $\operatorname{Rec'd}$ Particle size -6.3 mm

Proj $\#71193\mathrm{C}$ - ID#16766





### Particle Size Distribution

#### Particle Size Distribution By Sieving

Table 1.1: Reference via Ro-Tap w/ tapper			
Sieve $name$	Size	Retained	%
ISO 8.0 mm	8 mm	0.00	
ISO $6.30 \text{ mm}$	$6.3 \ mm$	0.11	
ISO $3.35 \text{ mm}$	$3.35\ mm$	15.39	
ISO $1.70 \text{ mm}$	$1.7 \ mm$	19.06	
ISO 850 µm	$850 \ \mu m$	30.62	
ISO 425 $\mu m$	$425 \ \mu m$	29.58	
ISO 212 µm	$212 \ \mu m$	4.49	
ISO 150 µm	$150 \ \mu m$	0.25	
PAN	$0 \ \mu m$	0.49	
	Total	100.00	
Sie	ving Yield	99.96	
Initial 7	Total Mass	833.2	gm

Particle	Size
$p_{10}$	493 $\mu m$
$p_{20}$	$637 \ \mu m$
$p_{50}$	$1.27 \ mm$
$p_{80}$	2.96 mm
$p_{90}$	$4.404\ mm$

#### Figure 1.2: Particle size distribution, by mass





Bulk material 1MM SC4Moisture contentAs Rec'dParticle size-6.3 mm

### Dust extinction moisture

#### MM SC4

The dust extinction moisture is 1.27%

 Table 1.2: Dust Extinction Moisture

Initial Moisture $\%$	Final Dust Number
0.21	353
0.44	209
0.82	7
1.43	5
2.54	2
1.29	2

Figure 1.3: Dust extinction moisture curve





## **Bulk Material 2**

# $\mathbf{MM} \ \mathbf{SC6}$



Bulk material 2MM SC6Moisture contentAs Rec'dParticle size-6.3 mm

Proj #71193C - ID #16767



Figure 2.1: MM SC6



### Particle Size Distribution

#### Particle Size Distribution By Sieving

Sieve	name	Size	Retained	%
ISO 8	.0 mm	8 mm	0.00	
ISO $6.$	30  mm	$6.3 \ mm$	0.14	
ISO 3.	$35 \mathrm{~mm}$	$3.35\ mm$	25.60	
ISO $1$ .	$70 \mathrm{mm}$	$1.7 \ mm$	42.68	
ISO 8	$50 \ \mu m$	$850 \ \mu m$	25.43	
ISO $4$	$25 \ \mu m$	$425 \ \mu m$	5.54	
ISO $2$	$12 \ \mu m$	$212 \ \mu m$	0.34	
ISO 1	$50 \ \mu m$	$150 \ \mu m$	0.08	
PA	AN	$0 \ \mu m$	0.18	
		Total	100.00	
Sieving Yield			99.98	
	Initial T	otal Mass	1.03	kg

$1able 2.1.$ Herefelle via $10^{-1}ab w/ tabbe$	Table 2.1:	Reference v	via Ro-Tap	w/ tapper
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Particle	Size
$p_{10}$	979 $\mu m$
$p_{20}$	$1.31 \ mm$
$p_{50}$	$2.41 \ mm$
$p_{80}$	$4.012\ mm$
$p_{90}$	$5.164\ mm$

Figure 2.2: Particle size distribution, by mass



Particle Size (mm)



Bulk material 2MM SC6Moisture contentAs Rec'dParticle size-6.3 mm

### Dust extinction moisture

#### MM SC6

The dust extinction moisture is 0.98%

 Table 2.2: Dust Extinction Moisture

Initial Moisture $\%$	Final Dust Number
0.19	201
0.35	147
0.58	118
0.81	6
1.45	4
1.27	2

Figure 2.3: Dust extinction moisture curve





# Part III Appendix



### Particle Size Distribution

#### Sieving

The particle size distribution was determined using a dry sieving method. Depending on the equipment used, shaking, tapping and/or vibration was used to promote flow through the sieves. This can result in dispersing weak agglomerates and/or breaking weak particles. Materials with significant cohesive strength and/or adhesion to surfaces may not screen well, particularly at finer screen sizes.

Particle size results are dependent on the method, and methods that use different physical principles would be expected to give different results. With all methods, particle shape is an influencing factor that is not well captured by the results alone. A single particle, being a three-dimensional object, has multiple dimensions, and this can only be represented by a single value in the case of a perfect sphere.

The results are given as the percentage retained on a given sieve as well as a cumulative distribution. The terms  $p_{10}$ ,  $p_{50}$ , and  $p_{90}$  refer to the particle sizes at which 10%, 50%, and 90% of the sample is smaller, respectively. This assumes that there is sufficient data on either side of each value to provide proper interpolation; otherwise the values are not given. The sieving yield is the initial mass of material, less the sum of the retained masses after sieving, all divided by the initial mass, expressed as a percentage.

The opening sizes are nominal and are specified in ASTM standard E-11 or ISO 3310, as noted.



#### Dust extinction moisture

The dust extinction moisture test is used to investigate the effects of moisture content on dust generation. This test is conducted using a rotating drum, based on Australian standard AS 4156.6 - 2000.

The test determines a dust number (mass of dust collected/original mass of sample multiplied by 100,000) for various moisture contents. The dust numbers are plotted on a log scale against their respective moisture contents on a linear scale to produce a dust/moisture curve.

The standard identifies the dust extinction moisture as the moisture at which a dust number of 10 is attained on the dust/moisture curve. Although the standard was originally developed for higher rank coals, it has been successfully used for years on many coals and other bulk materials. The curve, along with field experience and dust emission goals, can be used in selecting a moisture content limit(s) to suit your application(s), and establishing operating and monitoring practices that may be required.

The standard calls for removal of particles greater than 6.3 mm. The particle size used is reported, which may or may not meet this requirement.

The AS 4156.6 - 2000 standard states the reproducibility of the test to be 10% (relative), and errors in total moisture measurements to be  $\pm 0.2\%$  and in dust number  $\pm 6\%$ .

Attachment 4 - Dust Extinction Moisture (DEM) for the 6% 50-50 product



25 September 2018

Rain Lewis Metallurgical Surpervisor Nagrom the Mineral Processor 49 Owen Road, Kelmscott WA 6111 E: rain@nagrom.com.au D: +61 8 9399 3934

Delivered by email: rain@nagrom.com.au

#### **RE: Dust Extinction Moisture test results on MM Sc6 Enviro Comp**

Dear Rain:

Our report follows, providing dust extinction moisture test results for the MM Sc6 Enviro Comp spodumene material received. This report completes the work we have been contracted for as provided in your PO NAG05996.

Please feel free to contact me should you have any questions.

Kind regards,

Corin Holmes Operations Manager Australia Perth, Western Australia cholmes@jenike.com

cc:

John W. Carson, Ph.D., President, Tyngsboro, Massachusetts; jwcarson@jenike.com


## Dust Extinction Moisture Test Results on MM Sc6 Enviro Comp

Nagrom the Mineral Processor

Report No: 71193-1 Revision 1

25 September 2018

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#### **Report author**

Dewi Octavia, Project Engineer, Perth, Western Australia; doctavia@jenike.com

#### **Report reviewer**

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Document Control			
Date	Revision details		
25/9/2018	Report 71193-1 - Initial release		
25/9/2018	Report 71193-1 Revision 1 – Updated sample name		

#### We value your feedback. Please send your comments to ceo@jenike.com

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#### **1 INTRODUCTION**

Nagrom is interested in understanding the dusting behavior of MM Sc6 Enviro Comp. As such, they contracted Jenike & Johanson Pty Ltd (J&J) to determine the dust extinction moisture (DEM) content of the material. The DEM content is that at which a material is deemed to emit no dust as determined based on Australian Standard AS 4156.6-2000.

The following provides the results of the test work.

#### 2 FLOW PROPERTIES TEST RESULTS

A spodumene sample labelled MM Sc6 Enviro Comp was received for DEM. The *as received* moisture content<sup>1</sup> was determined, and the test results are summarized in the table below.

Table 1: Summary of MM Sc6 Enviro Comp results			
As received moisture	11.7%		
DEM %	3.3%		

#### **Dust Extinction Moisture Test**

A dust extinction moisture (DEM) test was performed for the spodumene material to investigate the effects of moisture content on dust generation. The results of the test indicate that the material has a DEM value of 3.3%. Full results of the test work are provided in the Appendix.

<sup>&</sup>lt;sup>1</sup> Moisture values were determined by drying small samples at 107°C in a forced convection oven, until no change in moisture content is observed. The loss in weight of each sample, divided by its original weight before drying, is denoted as the *moisture*.



APPENDIX



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## Disclaimer

The information contained in this Flow Properties Test Report contains test results only and does not take into account the specific design requirements, needs, and circumstances of any particular storage, handling, and conveying application. The information enclosed must not be used for design purposes without consultation with an appropriately skilled and qualified bulk material handling professional, taking into account specific design requirements, circumstances, and risks.

All Calculated Design Parameters in this report represent limiting conditions for flow.



# Part II Test Results



## **Bulk Material 1**

## MM Sc6 Enviro Comp



Bulk material 1MM Sc6 Enviro CompMoisture contentAs Rec'dParticle sizeAs Rec'dProj #71193 - ID #16664







### Dust extinction moisture

### MM Sc6 Enviro Comp

The dust extinction moisture is 3.27%

Table 1.1: Dust Extinction Moisture

Initial Moisture $\%$	Final Dust Number
0.17	1916
0.56	1357
1.50	87
11.70	1
5.50	1

Figure 1.2: Dust extinction moisture curve





# Part III Appendix



### Dust extinction moisture

The dust extinction moisture test is used to investigate the effects of moisture content on dust generation. This test is conducted using a rotating drum, based on Australian standard AS 4156.6 - 2000.

The test determines a dust number (mass of dust collected/original mass of sample multiplied by 100,000) for various moisture contents. The dust numbers are plotted on a log-log scale against their respective moisture contents to produce a dust/moisture curve.

The standard identifies the dust extinction moisture as the moisture at which a dust number of 10 is attained on the dust/moisture curve. Although the standard was originally developed for higher rank coals, it has been successfully used for years on many coals and other bulk materials. The curve, along with field experience and dust emission goals, can be used in selecting a moisture content limit(s) to suit your application(s), and establishing operating and monitoring practices that may be required.

The standard calls for removal of particles greater than 6.3 mm. The particle size used is reported, which may or may not meet this requirement.

The AS 4156.6 - 2000 standard states the reproducibility of the test to be 10% (relative), and errors in total moisture measurements to be  $\pm 0.2\%$  and in dust number  $\pm 6\%$ .

Attachment 5 - Dust Extinction Moisture (DEM) for the 4% coarse product



14 November 2018

Rain Lewis Metallurgical Surpervisor Nagrom the Mineral Processor 49 Owen Road, Kelmscott WA 6111 E: rain@nagrom.com.au D: +61 8 9399 3934

Delivered by email: <u>rain@nagrom.com.au</u>

#### RE: Dust Extinction Moisture test results on Spodumene MM SC4 and MM SC6

Dear Rain:

Our report follows, providing dust extinction moisture test results for the Spodumene MM SC4 and MM SC6 materials received. This report completes the work we have been contracted for as provided in your PO NAG05996.

Please feel free to contact me should you have any questions.

Kind regards,

Dewi Octavia Project Engineer Perth, Western Australia doctavia@jenike.com

cc:

John W. Carson, Ph.D., President, Tyngsboro, Massachusetts; jwcarson@jenike.com



## **Dust Extinction Moisture Test Results on Spodumene MM SC4 and MM SC6**

Nagrom

Report No: 71193-3

14 November 2018

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**Report author** Dewi Octavia, Project Engineer, Perth, Western Australia; <u>doctavia@jenike.com</u>

Report reviewer Corin P. Holmes MSc Eng, Operations Manager Australia, Perth, Western Australia; <u>cholmes@jenike.com</u>

#### We value your feedback. Please send your comments to ceo@jenike.com

#### Table of contents:

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### **1 INTRODUCTION**

Nagrom has contracted Jenike & Johanson Pty Ltd (J&J) to perform dust extinction moisture (DEM) tests on Spodumene MM SC4 and MM SC6 materials. The DEM content is that at which a material is deemed to emit no dust as determined based on Australian Standard AS 4156.6-2000.

The following provides the results of the test work.

#### 2 FLOW PROPERTIES TEST RESULTS

Two spodumene samples labelled MM SC4 and MM SC6 were received for DEM testing. The *as received* moisture content, maximum moisture content<sup>1</sup> before free draining occurs, and particle size distribution were determined for each material. The test results are summarized in the table below.

Table 1: Sum	nary of Spodumene MM SC4 and MM S	C6 test results
	Weight of sample provided	23.5 kg
	As received moisture	2.7%
MM SC4	Maximum moisture content (before free draining occurs)	17.6%
	DEM	1.3%
	Weight percentage greater than 6.3mm	0.1%
	Weight of sample provided	30.6 kg
	As received moisture	1.6%
MM SC6	Maximum moisture content (before free draining occurs)	7.5%
	DEM	1.0%
	Weight percentage greater than 6.3mm	0.1%

Photos of the samples can be found in the Appendix section.

#### Particle size analysis

A particle size distribution (PSD) was determined for both spodumene materials, using a dry sieving method (Ro-Tap, with tapping, 5 minutes total time). The materials were air dried prior to sieving. Plots showing the PSD are provided in the Appendix section. The calculated P10, P50, and P90 sizes<sup>2</sup> are given in the following table.

Table 2: Particle size distribution test results summary					
Material	P10 [mm]	P50 [mm]	P90 [mm]		
MM SC4	0.49	1.27	4.40		
MM SC6	0.98	2.41	5.16		

<sup>1</sup> Moisture values were determined by drying small samples at 107°C in a forced convection oven, until no change in moisture content is observed. The loss in weight of each sample, divided by its original weight before drying, is denoted as the *moisture*.

<sup>2</sup> The terms P10, P50, and P90 refer to the particle sizes at which 10%, 50%, and 90% of the sample is smaller, respectively. The value for P50 is also referred to as the mass median diameter.



#### **Dust Extinction Moisture Test**

A dust extinction moisture (DEM) test was performed for each of the spodumene materials, MM SC4 and MM SC6, to investigate the effects of moisture content on dust generation. The results of the test indicate that the MM SC4 and MM SC6 materials have a DEM value of 1.3% and 1.0%, respectively. Full results of the test work are provided in the Appendix.

The table below provides a detailed summary of data generated during the course of the test work.

	Table 3: DEM results, MM SC4					
Moisture Tested [%]	Sample pre-weight [g]	Filter bag weight [g]	Filter bag + dust post-weight [g]	Dust number	DEM	
0.2	2500	37.625	46.450	353		
0.4	2500	40.305	45.527	209		
0.8	2500	39.492	39.668	7	1 20/	
1.3	2500	38.593	38.636	2	1.3%	
1.4	2500	37.550	37.678	5		
2.5	2500	38.638	38.683	2		

Table 4: DEM results, MM SC6					
Moisture Tested [%]	Sample pre-weight [g]	Filter bag weight [g]	Filter bag + dust post-weight [g]	Dust number	DEM
0.2	2500	38.307	43.343	201	· · · · · · · · · · · · · · · · · · ·
0.4	2500	38.956	42.624	147	
0.6	2500	36.964	39.924	118	1.00/
0.8	2500	37.816	37.966	6	1.0%
1.3	2500	38.069	38.109	2	
1.4	2500	37.900	38.002	4	

### **3** TEST REPORT TABLES, PLOTS, AND APPENDIX

Detailed tables and plots of the test results are shown in the pages that follow.



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#### Disclaimer

The information contained in this Flow Properties Test Report contains test results only and does not take into account the specific design requirements, needs, and circumstances of any particular storage, handling, and conveying application. The information enclosed must not be used for design purposes without consultation with an appropriately skilled and qualified bulk material handling professional, taking into account specific design requirements, circumstances, and risks.

All Calculated Design Parameters in this report represent limiting conditions for flow.



# Part II Test Results



## **Bulk Material 1**

## $\mathbf{MM} \ \mathbf{SC4}$



Bulk material 1 MM SC4 Moisture content As  $\operatorname{Rec'd}$ Particle size -6.3 mm

Proj $\#71193\mathrm{C}$ - ID#16766





### Particle Size Distribution

### Particle Size Distribution By Sieving

Table 1.1: Reference via Ro-Tap w/ tapper				
Sieve $name$	Size	Retained	%	
ISO 8.0 mm	8 mm	0.00		
ISO $6.30 \text{ mm}$	$6.3 \ mm$	0.11		
ISO $3.35 \text{ mm}$	$3.35\ mm$	15.39		
ISO $1.70 \text{ mm}$	$1.7 \ mm$	19.06		
ISO 850 µm	$850 \ \mu m$	30.62		
ISO 425 $\mu m$	$425 \ \mu m$	29.58		
ISO 212 µm	$212 \ \mu m$	4.49		
ISO 150 µm	$150 \ \mu m$	0.25		
PAN	$0 \ \mu m$	0.49		
	Total	100.00		
Sie	ving Yield	99.96		
Initial 7	Total Mass	833.2	gm	

Particle	Size
$p_{10}$	493 $\mu m$
$p_{20}$	$637 \ \mu m$
$p_{50}$	$1.27 \ mm$
$p_{80}$	2.96 mm
$p_{90}$	$4.404\ mm$

#### Figure 1.2: Particle size distribution, by mass





Bulk material 1MM SC4Moisture contentAs Rec'dParticle size-6.3 mm

## Dust extinction moisture

#### MM SC4

The dust extinction moisture is 1.27%

 Table 1.2: Dust Extinction Moisture

Initial Moisture $\%$	Final Dust Number
0.21	353
0.44	209
0.82	7
1.43	5
2.54	2
1.29	2

Figure 1.3: Dust extinction moisture curve





## **Bulk Material 2**

## $\mathbf{MM} \ \mathbf{SC6}$



Bulk material 2MM SC6Moisture contentAs Rec'dParticle size-6.3 mm

Proj #71193C - ID #16767



Figure 2.1: MM SC6



### Particle Size Distribution

### Particle Size Distribution By Sieving

Sieve	name	Size	Retained	%
ISO 8	.0 mm	8 mm	0.00	
ISO $6.$	30  mm	$6.3 \ mm$	0.14	
ISO 3.	$35 \mathrm{~mm}$	$3.35\ mm$	25.60	
ISO $1$ .	$70 \mathrm{mm}$	$1.7 \ mm$	42.68	
ISO 8	$50 \ \mu m$	$850 \ \mu m$	25.43	
ISO $4$	$25 \ \mu m$	$425 \ \mu m$	5.54	
ISO $2$	$12 \ \mu m$	$212 \ \mu m$	0.34	
ISO 1	$50 \ \mu m$	$150 \ \mu m$	0.08	
PA	AN	$0 \ \mu m$	0.18	
		Total	100.00	
	Siev	ving Yield	99.98	
	Initial T	otal Mass	1.03	kg
				-

Table 2.1:	Reference	via	Ro-Tap	w/	tapper
------------	-----------	-----	--------	----	--------

Particle	Size
$p_{10}$	979 $\mu m$
$p_{20}$	$1.31 \ mm$
$p_{50}$	$2.41 \ mm$
$p_{80}$	$4.012\ mm$
$p_{90}$	$5.164\ mm$

Figure 2.2: Particle size distribution, by mass





Bulk material 2MM SC6Moisture contentAs Rec'dParticle size-6.3 mm

## Dust extinction moisture

#### MM SC6

The dust extinction moisture is 0.98%

 Table 2.2: Dust Extinction Moisture

Initial Moisture $\%$	Final Dust Number
0.19	201
0.35	147
0.58	118
0.81	6
1.45	4
1.27	2

Figure 2.3: Dust extinction moisture curve





# Part III Appendix



### Particle Size Distribution

#### Sieving

The particle size distribution was determined using a dry sieving method. Depending on the equipment used, shaking, tapping and/or vibration was used to promote flow through the sieves. This can result in dispersing weak agglomerates and/or breaking weak particles. Materials with significant cohesive strength and/or adhesion to surfaces may not screen well, particularly at finer screen sizes.

Particle size results are dependent on the method, and methods that use different physical principles would be expected to give different results. With all methods, particle shape is an influencing factor that is not well captured by the results alone. A single particle, being a three-dimensional object, has multiple dimensions, and this can only be represented by a single value in the case of a perfect sphere.

The results are given as the percentage retained on a given sieve as well as a cumulative distribution. The terms  $p_{10}$ ,  $p_{50}$ , and  $p_{90}$  refer to the particle sizes at which 10%, 50%, and 90% of the sample is smaller, respectively. This assumes that there is sufficient data on either side of each value to provide proper interpolation; otherwise the values are not given. The sieving yield is the initial mass of material, less the sum of the retained masses after sieving, all divided by the initial mass, expressed as a percentage.

The opening sizes are nominal and are specified in ASTM standard E-11 or ISO 3310, as noted.



### Dust extinction moisture

The dust extinction moisture test is used to investigate the effects of moisture content on dust generation. This test is conducted using a rotating drum, based on Australian standard AS 4156.6 - 2000.

The test determines a dust number (mass of dust collected/original mass of sample multiplied by 100,000) for various moisture contents. The dust numbers are plotted on a log scale against their respective moisture contents on a linear scale to produce a dust/moisture curve.

The standard identifies the dust extinction moisture as the moisture at which a dust number of 10 is attained on the dust/moisture curve. Although the standard was originally developed for higher rank coals, it has been successfully used for years on many coals and other bulk materials. The curve, along with field experience and dust emission goals, can be used in selecting a moisture content limit(s) to suit your application(s), and establishing operating and monitoring practices that may be required.

The standard calls for removal of particles greater than 6.3 mm. The particle size used is reported, which may or may not meet this requirement.

The AS 4156.6 - 2000 standard states the reproducibility of the test to be 10% (relative), and errors in total moisture measurements to be  $\pm 0.2\%$  and in dust number  $\pm 6\%$ .

Attachment 6 - XRD Mineral Analysis (including Muscovite) for the 6% fine product



37 Kensington Street East Perth WA 6004

Client:	NAGROM
Job number:	18_1874
Sample:	18_1874_02
Client ID:	MM SC6 Fines
Date:	12/11/2018
Analysis :	Semi-quantitative XRD analysis

#### Sample preparation

The sample was supplied by the client to Microanalysis Australia on 5th November 2018 for the above mentioned analyses. A representative sub –sample was removed and lightly ground such that 90% was passing 20  $\mu$ m. Grinding to this size helps eliminate preferred orientation.

#### Analysis

Only crystalline material present in the sample will give peaks in the XRD scan. Amorphous (non crystalline) material will add to the background. The search match software used was Eva 4.3. An up-to-date ICDD card set was used. The X-ray source was cobalt radiation.

No standards were used in the quantification process. The concentrations were calculated using the peak area integration method where the area of the 100% peak for each mineral phase is summed and the relative percentages of each phase calculated based on the relative contribution to the sum. This method allows for some attention to be paid to preferred orientation but is limited in considering substitution and lattice strain.

#### Summary

The phases are listed in order of interpreted concentration:

Mineral phase	Concentration (%)	ICDD match probability
Spodumene (LiAlSi2O6)	69	good
Quartz, syn (SiO2)	11	good
Albite (Na0.986Al1.005Si2.995O8)	9	medium
Muscovite-2M1 (K(Al4Si2O9(OH)3))	3	medium
amphibole, syn   Sodium Magnesium Silicate Hydroxide (Na1.6Mg6.2Si8O22(OH)2)	3	medium
Microcline, sodian (K0.9Na0.1AlSi3O8)	2	medium
Phlogopite-3T (KMg3(Si3Al)O10(OH)2)	1	low
Lepidolite-1M (KLi1.56Al1.3Al0.51Si3.49O10F2)	1	low
Clinochlore-1MIIb ((Mg,Al)6(Si,Al)4O10(OH)8)	trace	medium
Vivianite (Fe3(PO4)2(H2O)8)	trace	low

The ICDD match probability is reported as an indication as to how well the peak positions and relative intensities for the sample matched those in the published literature (www.icdd.org) for that particular compound.



## Attachment 7 - XRD Mineral Analysis (including Muscovite) for the 6% coarse product



37 Kensington Street East Perth WA 6004

NAGROM
18_1874
18_1874_01
MM SC6 Coarse
12/11/2018
Semi-quantitative XRD analysis

#### Sample preparation

The sample was supplied by the client to Microanalysis Australia on 5th November 2018 for the above mentioned analyses. A representative sub –sample was removed and lightly ground such that 90% was passing 20  $\mu$ m. Grinding to this size helps eliminate preferred orientation.

#### Analysis

Only crystalline material present in the sample will give peaks in the XRD scan. Amorphous (non crystalline) material will add to the background. The search match software used was Eva 4.3. An up-to-date ICDD card set was used. The X-ray source was cobalt radiation.

No standards were used in the quantification process. The concentrations were calculated using the peak area integration method where the area of the 100% peak for each mineral phase is summed and the relative percentages of each phase calculated based on the relative contribution to the sum. This method allows for some attention to be paid to preferred orientation but is limited in considering substitution and lattice strain.

#### Summary

The phases are listed in order of interpreted concentration:

Mineral phase	Concentration (%)	ICDD match probability
Spodumene (LiAlSi2O6)	78	good
Quartz, syn (SiO2)	7	good
Albite (Na0.986Al1.005Si2.995O8)	6	medium
Muscovite-2M1 (K(Al4Si2O9(OH)3))	4	medium
amphibole group, syn   Sodium Calcium Magnesium Aluminum Scandium Silicon Oxide Fluoride (Na1.97Ca0.98Mg4.14Sc0.86Al0.79Si7.21O22F2)	2	medium
Microcline, ordered (KAlSi3O8)	2	medium
Lepidolite-1M (KLi1.56Al1.3Al0.51Si3.49O10F2)	2	low
Pollucite ((Cs10.37Na2.16)((Al13.44Si34.56)O96)(H2O)5.63)	trace	medium
Clinochlore-1MIIb ((Mg,Al)6(Si,Al)4O10(OH)8)	trace	medium

The ICDD match probability is reported as an indication as to how well the peak positions and relative intensities for the sample matched those in the published literature (www.icdd.org) for that particular compound.



## Attachment 8 - XRD Mineral Analysis (including Muscovite) for the 6% 50-50 product



37 Kensington Street East Perth WA 6004

nalysis

#### Sample preparation

The sample was supplied by the client to Microanalysis Australia on 5th November 2018 for the above mentioned analyses. A representative sub –sample was removed and lightly ground such that 90% was passing 20  $\mu$ m. Grinding to this size helps eliminate preferred orientation.

#### Analysis

Only crystalline material present in the sample will give peaks in the XRD scan. Amorphous (non crystalline) material will add to the background. The search match software used was Eva 4.3. An up-to-date ICDD card set was used. The X-ray source was cobalt radiation.

No standards were used in the quantification process. The concentrations were calculated using the peak area integration method where the area of the 100% peak for each mineral phase is summed and the relative percentages of each phase calculated based on the relative contribution to the sum. This method allows for some attention to be paid to preferred orientation but is limited in considering substitution and lattice strain.

#### Summary

The phases are listed in order of interpreted concentration:

Mineral phase	Concentration (%)	ICDD match probability
Spodumene (LiAlSi2O6)	75	good
Quartz, syn (SiO2)	8	good
Albite (Na0.986Al1.005Si2.995O8)	7	medium
Muscovite-2M1 (K(Al4Si2O9(OH)3))	3	medium
Microcline, ordered (KAlSi3O8)	2	medium
amphibole, syn   Sodium Magnesium Silicate Hydroxide (Na0.8Mg3.1Si4O11(OH))	2	medium
Lepidolite-1M (Li2KAl(Al0.13Si3.87O10)FOH)	1	low
Phlogopite-3T (KMg3(Si3Al)O10(OH)2)	1	low
Pollucite ((Cs10.37Na2.16)((Al13.44Si34.56)O96)(H2O)5.63)	trace	medium
Clinochlore-1MIIb ((Mg,Al)6(Si,Al)4O10(OH)8)	trace	medium

The ICDD match probability is reported as an indication as to how well the peak positions and relative intensities for the sample matched those in the published literature (www.icdd.org) for that particular compound.



## Attachment 9 - XRD Mineral Analysis (including Muscovite) for the 4% coarse product



37 Kensington Street East Perth WA 6004

Client:	NAGROM
Job number:	18_1874
Sample:	18_1874_04
Client ID:	MM SC4 Coarse
Date:	12/11/2018
Analysis :	Semi-quantitative XRD analysis

#### Sample preparation

The sample was supplied by the client to Microanalysis Australia on 5th November 2018 for the above mentioned analyses. A representative sub –sample was removed and lightly ground such that 90% was passing 20  $\mu$ m. Grinding to this size helps eliminate preferred orientation.

#### Analysis

Only crystalline material present in the sample will give peaks in the XRD scan. Amorphous (non crystalline) material will add to the background. The search match software used was Eva 4.3. An up-to-date ICDD card set was used. The X-ray source was cobalt radiation.

No standards were used in the quantification process. The concentrations were calculated using the peak area integration method where the area of the 100% peak for each mineral phase is summed and the relative percentages of each phase calculated based on the relative contribution to the sum. This method allows for some attention to be paid to preferred orientation but is limited in considering substitution and lattice strain.

#### Summary

The phases are listed in order of interpreted concentration:

Mineral phase	Concentration (%)	ICDD match probability good
Spodumene (LiAlSi2O6)	48	
Quartz, syn (SiO2)	20	good
Albite (Na0.986Al1.005Si2.995O8)	14	medium
Microcline, sodian (K0.85Na0.15AlSi3O8)	7	medium
Muscovite-2M1 (K(Al4Si2O9(OH)3))	4	medium
amphibole group, syn   Sodium Calcium Magnesium Aluminum Scandium Silicon Oxide Fluoride (Na1.97Ca0.98Mg4.14Sc0.86Al0.79Si7.21O22F2)	3	medium
Lepidolite-1M (KLi1.56Al1.3Al0.51Si3.49O10F2)	1	low
Clinochlore-1MIIb ((Mg,Al)6(Si,Al)4O10(OH)8)	1	medium
Calcite, syn (Ca(CO3))	1	low
Talc (Mg3Si4O10(OH)2)	trace	low
eucryptite, syn   Lithium Aluminum Silicate (LiAl(SiO4))	trace	low

The ICDD match probability is reported as an indication as to how well the peak positions and relative intensities for the sample matched those in the published literature (www.icdd.org) for that particular compound.


# Attachment 10 – Respirable XRD minerals (including respirable silica) for the 6% fine product



37 Kensington Street East Perth WA 6004

Client:	Nagrom
Job number:	18_1874
Sample:	18_1874_02 RFS
Client ID:	MM SC6 Fines
Date:	12/11/2018
Analysis:	Respirable alpha-quartz concentration analysis by x-ray diffraction (XRD) and scanning electron microscopy (SEM) using the modified SWeRF method <sup>1</sup>

### **Sample Preparation**

The sample was supplied to Microanalysis Australia as a bulk sample. The sample was tested as received.

A representative sub-sample was wet sieved at 63  $\mu$ m, and the < 63  $\mu$ m fraction (suspension) was thoroughly homogenized and sized by laser diffraction reporting size between 63  $\mu$ m and 20 nm.

The respirable fraction was abstracted by settling and decantation, and the abstracted particle size, composition and morphology was verified by scanning electron microscope (SEM) for equivalent aerodynamic diameter (EAD).

Once the equivalent aerodynamic size was verified by SEM, the abstracted fraction was analysed qualitatively and quantitatively by x-ray diffraction to assess the alpha-quartz concentration.

#### Analysis

The wet sieving was conducted using a light-flow (approximately 1 L /min) water spray jet on a 63  $\mu$ m stainless steel Endecotts sieve. The < 63  $\mu$ m fraction was collected in a bucket for laser diffraction analysis. Each size fraction was then oven dried at 105 °C. The dried weights of each of the fractions were noted and the fraction percentage calculated based on the original dried starting weight.

The laser diffraction size distribution analyses were conducted using a Malvern Mastersizer MS2000 calibrated using QAS3002 certified reference material and certified within specification. The analyses were conducted following ISO13320-1:1999.

For the sedimentation, the time for a specific fall height for PM4 (EAD) particles was calculated using Stokes Law. The samples were then homogenised and allowed to settle for the calculated time before the supernatant was decanted off, down to the limit of the fall height. The density and viscosity of water at 21 °C, and an assumed particle density of 2.65 g/cc were used.

The electron microscope used was a Carl Zeiss EVO50 equipped with an Oxford Instruments INCA energy dispersive spectrometer (EDS). All images were acquired using backscatter electrons, unless otherwise specified to highlight particle composition. The contrast in backscatter electron images is proportional to average elemental composition i.e. the brighter the particle the higher the atomic number. Some images with contrasting brightness particles were examined by EDS for elemental composition.

The extracted fraction was deposited on a filter membrane for XRD analysis. Quantification was by the peak area integration method. Only crystalline material present in the sample will give peaks in the XRD scan. Amorphous (non crystalline) material will add to the background. The search match software used was EVA (Bruker). The ICDD card set was ICDD PDF4/Minerals 2018. The x-ray source was cobalt radiation. ICCD match probabilities are reported as an indication of how well the diffraction peaks of this sample compare with currently published

literature on the quoted mineral. No Rietveld refinement was conducted on the acquired spectrum unless otherwise stated.

The respirable quartz concentration of the bulk was calculated by multiplying the volume percent of the respirable-only (PM4) fraction by the alpha-quartz concentration of the respirable only fraction.

# Summary

The size distribution of the sample by wet sieving and laser diffraction is shown below:

	Size fraction (by aerodynamic diameter) volume percent			
Client ID	Non-inhalable	Inhalable, PM100	Thoracic, PM10	Respirable, PM4
MM SC6 Fines	73.99	26.01	4.81	2.13

Assuming all mineral phases occur at the same relative concentrations across all size intervals, a volume percent distribution equates to a mass distribution. The respirable fraction, PM4 is therefore 2.13 wt %.

The normalised, interpreted semi-quantitative mineralogy by X-ray diffraction of the abstracted PM4 fraction is shown below:

Mineral phase	Concentration (wt %) of PM4 only	ICDD match probability
Spodumene (Li Al Si2 O6)	45	good
Albite low (Na ( Al Si3 O8 ))	12	good
Muscovite (K Al2 ( Si3 Al ) O10 ( O H )2)	12	medium
Quartz, syn (Si O2)	11	good
Nontronite-15A (Na0.3 Fe2 Si4 O10 ( O H )2 ·4 H2 O)	9	low
Clinochlore-1M#I#I#b, ferroan (( Mg , Fe )6 ( Si , Al )4 O10 ( O H )8)	7	medium
Amphibole (Al3.2 Ca3.4 Fe4.0 K.6 Mg6.0 Na1.0 Si12.8 O44 ( O H )4)	2	medium
Talc-2M (Mg3 Si4 O10 ( O H )2)	1	low

The XRD interpretation determined the PM4 fraction to be approximately 27 wt % amorphous. The above percentages represent only the crystalline fraction.

The respirable (PM4) crystalline silica concentrations with respect to the bulk sample are shown below:

		Respirable (PM4) wt % of the bulk material for mineral phase		
Lab number	Client ID	α-quartz	Cristobalite	Tridymite
18_1874_02	MM SC6 Fines	0.179	<0.001	<0.001

Note: Three polymorphs of crystalline silica are scheduled as Group 1 carcinogens by IARC – quartz, cristobalite and tridymite<sup>2</sup>.

Analysed: Sumudu Ariyawansa, B.Sc.(Agriculture)(Hons), Dip.(Laboratory Technology) Dan Cukierski, B.Sc.(Geology), M.Sc.(Geoscience) Ian Davies, B.Sc.(Chemistry)

Reported: Ian Davies, B.Sc.(Chemistry)

**Approved:** Owen Carpenter, B.Sc.(Physics)

<sup>1</sup> https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3979281/

<sup>2</sup> https://monographs.iarc.fr/ENG/Monographs/vol100C/mono100C-14.pdf

# Attachment 11 - Respirable XRD minerals (including respirable silica) for the 6% coarse product



37 Kensington Street East Perth WA 6004

Client:	Nagrom
Job number:	18_1874
Sample:	18_1874_01 RFS
Client ID:	MM SC6 Coarse
Date:	12/11/2018
Analysis:	Respirable alpha-quartz concentration analysis by x-ray diffraction (XRD) and scanning electron microscopy (SEM) using the modified SWeRF method <sup>1</sup>

### **Sample Preparation**

The sample was supplied to Microanalysis Australia as a bulk sample. The sample was tested as received.

A representative sub-sample was wet sieved at 63  $\mu$ m, and the < 63  $\mu$ m fraction (suspension) was thoroughly homogenized and sized by laser diffraction reporting size between 63  $\mu$ m and 20 nm.

The respirable fraction was abstracted by settling and decantation, and the abstracted particle size, composition and morphology was verified by scanning electron microscope (SEM) for equivalent aerodynamic diameter (EAD).

Once the equivalent aerodynamic size was verified by SEM, the abstracted fraction was analysed qualitatively and quantitatively by x-ray diffraction to assess the alpha-quartz concentration.

#### Analysis

The wet sieving was conducted using a light-flow (approximately 1 L /min) water spray jet on a 63  $\mu$ m stainless steel Endecotts sieve. The < 63  $\mu$ m fraction was collected in a bucket for laser diffraction analysis. Each size fraction was then oven dried at 105 °C. The dried weights of each of the fractions were noted and the fraction percentage calculated based on the original dried starting weight.

The laser diffraction size distribution analyses were conducted using a Malvern Mastersizer MS2000 calibrated using QAS3002 certified reference material and certified within specification. The analyses were conducted following ISO13320-1:1999.

For the sedimentation, the time for a specific fall height for PM4 (EAD) particles was calculated using Stokes Law. The samples were then homogenised and allowed to settle for the calculated time before the supernatant was decanted off, down to the limit of the fall height. The density and viscosity of water at 21 °C, and an assumed particle density of 2.65 g/cc were used.

The electron microscope used was a Carl Zeiss EVO50 equipped with an Oxford Instruments INCA energy dispersive spectrometer (EDS). All images were acquired using backscatter electrons, unless otherwise specified to highlight particle composition. The contrast in backscatter electron images is proportional to average elemental composition i.e. the brighter the particle the higher the atomic number. Some images with contrasting brightness particles were examined by EDS for elemental composition.

The extracted fraction was deposited on a filter membrane for XRD analysis. Quantification was by the peak area integration method. Only crystalline material present in the sample will give peaks in the XRD scan. Amorphous (non crystalline) material will add to the background. The search match software used was EVA (Bruker). The ICDD card set was ICDD PDF4/Minerals 2018. The x-ray source was cobalt radiation. ICCD match probabilities are reported as an indication of how well the diffraction peaks of this sample compare with currently published

literature on the quoted mineral. No Rietveld refinement was conducted on the acquired spectrum unless otherwise stated.

The respirable quartz concentration of the bulk was calculated by multiplying the volume percent of the respirable-only (PM4) fraction by the alpha-quartz concentration of the respirable only fraction.

## Summary

The size distribution of the sample by wet sieving and laser diffraction is shown below:

	Size fraction (by aerodynamic diameter) volume percent			
Client ID	Non-inhalable	Inhalable, PM100	Thoracic, PM10	Respirable, PM4
MM SC6 Coarse	99.80	0.20	0.03	0.01

Assuming all mineral phases occur at the same relative concentrations across all size intervals, a volume percent distribution equates to a mass distribution. The respirable fraction, PM4 is therefore 0.01 wt %.

The normalised, interpreted semi-quantitative mineralogy by X-ray diffraction of the abstracted PM4 fraction is shown below:

Mineral phase	Concentration (wt	ICDD match
	%) of PM4 only	probability
Spodumene (Li Al Si2 O6)	23	good
Albite low (Na ( Al Si3 O8 ))	18	good
Nontronite-15A (Na0.3 Fe2 Si4 O10 ( O H )2 ·4 H2 O)	14	low
Muscovite-3T (( K , Na ) ( Al , Mg , Fe )2 ( Si3.1 Al0.9 ) O10 ( O H )2)	11	medium
Quartz, syn (Si O2)	10	good
Clinochlore-1M#I#I#b, ferroan (( Mg , Fe )6 ( Si , Al )4 O10 ( O H )8)	9	medium
Maghemite-Q, syn (Fe2 O3)	6	low
Calcite, magnesian (( Mg0.129 Ca0.871 ) ( C O3 ))	2	medium
Natrojarosite, syn (Na Fe3 ( S O4 )2 ( O H )6)	2	low
Amphibole (Al3.2 Ca3.4 Fe4.0 K.6 Mg6.0 Na1.0 Si12.8 O44 ( O H )4)	2	medium
Petalite (Li Al Si4 O10)	1	low
Talc-2M (Mg3 Si4 O10 ( O H )2)	1	low
Microcline (K Al Si3 O8)	1	low
Pollucite (Cs12 Na4 Al16 Si32 O96 ( H2 O )4)	trace	low

The XRD interpretation determined the PM4 fraction to be approximately 30 wt % amorphous. The above percentages represent only the crystalline fraction.

The respirable (PM4) crystalline silica concentrations with respect to the bulk sample are shown below:

		Respirable (PM4) wt % of the bulk material for mineral phase		
Lab number	Client ID	α-quartz	Cristobalite	Tridymite
18_1874_01	MM SC6 Coarse	0.001	<0.001	<0.001

Note: Three polymorphs of crystalline silica are scheduled as Group 1 carcinogens by IARC – quartz, cristobalite and tridymite<sup>2</sup>.

Analysed: Sumudu Ariyawansa, B.Sc.(Agriculture)(Hons), Dip.(Laboratory Technology) Dan Cukierski, B.Sc.(Geology), M.Sc.(Geoscience) Ian Davies, B.Sc.(Chemistry) **Reported:** Ian Davies, B.Sc.(Chemistry)

Owen Carpenter, B.Sc.(Physics) Approved:

<sup>1</sup> <u>https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3979281/</u> <sup>2</sup> https://monographs.iarc.fr/ENG/Monographs/vol100C/mono100C-14.pdf

# Attachment 12 - Respirable XRD minerals (including respirable silica) for the 6% 50-50 product



37 Kensington Street East Perth WA 6004

Client:	NAGROM			
Job number:	18_1411			
Sample:	18_1411_02			
Client ID:	MM Sc6 Enviro Comp Respirable			
Date:	7 <sup>th</sup> of September 2018			
Analysis:	Respirable alpha-quartz concentration analysis by x-ray diffraction (XRD) and scanning			
	electron microscopy (SEM) using the modified SWeRF method <sup>1</sup>			

### Sample Preparation

The sample was supplied to Microanalysis Australia as a bulk sample in a plastic bag. The sample was tested as received.

A representative sub-sample was wet sieved at 150  $\mu$ m, and the < 150  $\mu$ m fraction (suspension) was thoroughly homogenized and sized by laser diffraction reporting size between 150  $\mu$ m and 20 nm.

The respirable fraction was abstracted from the < 150  $\mu$ m suspension by settling and decantation, and the abstracted particle size, composition and morphology was verified by scanning electron microscope (SEM) for equivalent aerodynamic diameter (EAD).

Once the equivalent aerodynamic size was verified by SEM, the abstracted fraction was analysed qualitatively and quantitatively by x-ray diffraction to assess the alpha-quartz concentration.

#### Analysis

The wet sieving was conducted using a light-flow (approximately 1 L /min) water spray jet on a nested stack of stainless steel Endecotts sieves at 150  $\mu$ m. The < 150  $\mu$ m fraction was collected in a 1 L bucket. Each size fraction was oven dried at 105 °C. The dried weights of each of the fractions were noted and the fraction percentage calculated based on the original dried starting weight.

The laser diffraction size distribution analyses were conducted using a Malvern Mastersizer MS2000 calibrated using QAS3002 certified reference material and certified within specification. The analyses were conducted following ISO13320-1:1999.

For the sedimentation, the time for a specific fall height for PM4 (EAD) particles was calculated using Stokes Law. The samples were then homogenised and allowed to settle for the calculated time before the supernatant was decanted off, down to the limit of the fall height. The density and viscosity of water at 21 °C, and an assumed particle density of 2.65 g/cc were used.

The electron microscope used was a Carl Zeiss EVO50 equipped with an Oxford Instruments INCA energy dispersive spectrometer (EDS). All images were acquired using backscatter electrons, unless otherwise specified to highlight particle composition. The contrast in backscatter electron images is proportional to average elemental composition i.e. the brighter the particle the higher the atomic number. Some images with contrasting brightness particles were examined by EDS for elemental composition.

The extracted fraction was deposited on a filter membrane for XRD analysis. A calibration suite of known alphaquartz content, PM4 sized alpha-quartz particulate (NBS 1878a), loaded membranes were used as a calibration series against which the abstracted respirable fines on the filter membranes from the processed sample were compared. Additional scan time was undertaken to achieve better signal to noise ratios in the spectrum. Quantification was by the peak area integration method. Only crystalline material present in the sample will give peaks in the XRD scan. Amorphous (non crystalline) material will add to the background. The search match software used was EVA (Bruker). The ICDD card set was ICDD PDF4+ 2016. The x-ray source was cobalt radiation. ICCD match probabilities are reported as an indication of how well the diffraction peaks of this sample compare with currently published literature on the quoted mineral. No Rietveld refinement was conducted on the acquired spectrum unless otherwise stated.

The respirable quartz concentration of the bulk was calculated by multiplying the volume percent of the respirable-only (PM4) fraction by the alpha-quartz concentration of the respirable only fraction.

# Summary

The size distribution of the sample by wet sieving and laser diffraction is shown below:

	Size fraction (by aerodynamic diameter) volume percent			
Client ID	Non-inhalable	Inhalable, PM100	Thoracic, PM10	Respirable, PM4
MM Sc6 Enviro Comp Respirable	85.15	14.85	2.03	0.85

Assuming all mineral phases occur at the same relative concentrations across all size intervals, a volume percent distribution equates to a mass distribution. The respirable fraction, PM4, is therefore 0.85 wt %.

The normalised, interpreted semi-quantitative mineralogy by X-ray diffraction of the abstracted PM4 fraction is shown below:

Mineral phase	Concentration (wt	ICDD match
	%) of PM4 only	probability
Spodumene (Li Al Si2 O6)	27	good
Muscovite 2M1 (( K0.82 Na0.18 ) ( Fe0.03 Al1.97 ) ( Al Si3 ) O10 ( O H )2)	25	medium
Clinochlore-1M#I#I#b (( Mg5 Al ) ( Si , Al )4 O10 ( O H )8)	14	medium
Nontronite-15A (Na0.3 Fe2 Si4 O10 ( O H )2 ·4 H2 O)	12	low
Albite low (Na ( Al Si3 O8 ))	12	good
Quartz, syn (Si O2)	8	good
Amphibole (Al3.2 Ca3.4 Fe4.0 K.6 Mg6.0 Na1.0 Si12.8 O44 ( O H )4)	2	medium

The XRD interpretation determined the PM4 fraction to be approximately 20 wt % amorphous. The above percentages represent only the crystalline fraction.

The respirable (PM4) crystalline silica concentrations with respect to the bulk sample are shown below:

		Respirable (PM4) wt % of the bulk material for mineral phase		
Lab number	Client ID	α-quartz	Cristobalite	Tridymite
18_1411_02	MM Sc6 Enviro Comp Respirable	0.055	<0.001	<0.001

Note: Three polymorphs of crystalline silica are scheduled as Group 1 carcinogens by IARC – quartz, cristobalite and tridymite<sup>2</sup>.

Analysed:Sumudu Ariyawansa, B.Sc.(Agriculture)(Hons), Dip.(Laboratory Technology)Dan Cukierski, B.Sc.(Geology), M.Sc.(Geoscience)Ian Davies, B.Sc.(Chemistry)

**Reported:** Ian Davies, B.Sc.(Chemistry)

**Approved:** 

<sup>1</sup> <u>https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3979281/</u> <sup>2</sup> https://monographs.iarc.fr/ENG/Monographs/vol100C/mono100C-14.pdf

# Attachment 13 - Respirable XRD minerals (including respirable silica) for the 4% coarse product



37 Kensington Street East Perth WA 6004

Client:	Nagrom
Job number:	18_1874
Sample:	18_1874_04 RFS
Client ID:	MM SC4 Coarse
Date:	12/11/2018
Analysis:	Respirable alpha-quartz concentration analysis by x-ray diffraction (XRD) and scanning electron microscopy (SEM) using the modified SWeRF method <sup>1</sup>

### **Sample Preparation**

The sample was supplied to Microanalysis Australia as a bulk sample. The sample was tested as received.

A representative sub-sample was wet sieved at 63  $\mu$ m, and the < 63  $\mu$ m fraction (suspension) was thoroughly homogenized and sized by laser diffraction reporting size between 63  $\mu$ m and 20 nm.

The respirable fraction was abstracted by settling and decantation, and the abstracted particle size, composition and morphology was verified by scanning electron microscope (SEM) for equivalent aerodynamic diameter (EAD).

Once the equivalent aerodynamic size was verified by SEM, the abstracted fraction was analysed qualitatively and quantitatively by x-ray diffraction to assess the alpha-quartz concentration.

#### Analysis

The wet sieving was conducted using a light-flow (approximately 1 L /min) water spray jet on a 63  $\mu$ m stainless steel Endecotts sieve. The < 63  $\mu$ m fraction was collected in a bucket for laser diffraction analysis. Each size fraction was then oven dried at 105 °C. The dried weights of each of the fractions were noted and the fraction percentage calculated based on the original dried starting weight.

The laser diffraction size distribution analyses were conducted using a Malvern Mastersizer MS2000 calibrated using QAS3002 certified reference material and certified within specification. The analyses were conducted following ISO13320-1:1999.

For the sedimentation, the time for a specific fall height for PM4 (EAD) particles was calculated using Stokes Law. The samples were then homogenised and allowed to settle for the calculated time before the supernatant was decanted off, down to the limit of the fall height. The density and viscosity of water at 21 °C, and an assumed particle density of 2.65 g/cc were used.

The electron microscope used was a Carl Zeiss EVO50 equipped with an Oxford Instruments INCA energy dispersive spectrometer (EDS). All images were acquired using backscatter electrons, unless otherwise specified to highlight particle composition. The contrast in backscatter electron images is proportional to average elemental composition i.e. the brighter the particle the higher the atomic number. Some images with contrasting brightness particles were examined by EDS for elemental composition.

The extracted fraction was deposited on a filter membrane for XRD analysis. Quantification was by the peak area integration method. Only crystalline material present in the sample will give peaks in the XRD scan. Amorphous (non crystalline) material will add to the background. The search match software used was EVA (Bruker). The ICDD card set was ICDD PDF4/Minerals 2018. The x-ray source was cobalt radiation. ICCD match probabilities are reported as an indication of how well the diffraction peaks of this sample compare with currently published

literature on the quoted mineral. No Rietveld refinement was conducted on the acquired spectrum unless otherwise stated.

The respirable quartz concentration of the bulk was calculated by multiplying the volume percent of the respirable-only (PM4) fraction by the alpha-quartz concentration of the respirable only fraction.

## Summary

The size distribution of the sample by wet sieving and laser diffraction is shown below:

		Size fraction (by aerodynamic diameter) volume percent					
Client ID		Non-inhalable	Inhalable, PM100	Thoracic, PM10	Respirable, PM4		
	MM SC4 Coarse	99.74	0.26	0.05	0.02		

Assuming all mineral phases occur at the same relative concentrations across all size intervals, a volume percent distribution equates to a mass distribution. The respirable fraction, PM4 is therefore 0.02 wt %.

The normalised, interpreted semi-quantitative mineralogy by X-ray diffraction of the abstracted PM4 fraction is shown below:

Mineral phase	Concentration (wt	ICDD match
	%) of PM4 only	probability
Spodumene (Li Al Si2 O6)	17	good
Clinochlore-1M#I#I#b, ferroan (( Mg , Fe )6 ( Si , Al )4 O10 ( O H )8)	16	medium
Albite low (Na ( Al Si3 O8 ))	15	good
Quartz, syn (Si O2)	14	good
Muscovite-3T (( K , Na ) ( Al , Mg , Fe )2 ( Si3.1 Al0.9 ) O10 ( O H )2)	12	medium
Amphibole (Al3.2 Ca3.4 Fe4.0 K.6 Mg6.0 Na1.0 Si12.8 O44 ( O H )4)	11	medium
Nontronite-15A (Ca0.1 Fe2 ( Si , Al )4 O10 ( O H )2 ·4 H2 O)	7	low
Talc-2M (Mg3 Si4 O10 ( O H )2)	4	low
Augite (Ca ( Fe , Mg ) Si2 O6)	3	low
Microcline, intermediate (K Al Si3 O8)	2	low

The XRD interpretation determined the PM4 fraction to be approximately 26 wt % amorphous. The above percentages represent only the crystalline fraction.

The respirable (PM4) crystalline silica concentrations with respect to the bulk sample are shown below:

		Respirable (PM4) wt % of the bulk material for mineral phase			
Lab number	Client ID	α-quartz	Cristobalite	Tridymite	
18_1874_04	MM SC4 Coarse	0.002	<0.001	<0.001	

Note: Three polymorphs of crystalline silica are scheduled as Group 1 carcinogens by IARC – quartz, cristobalite and tridymite<sup>2</sup>.

- Analysed:Sumudu Ariyawansa, B.Sc.(Agriculture)(Hons), Dip.(Laboratory Technology)<br/>Dan Cukierski, B.Sc.(Geology), M.Sc.(Geoscience)<br/>Ian Davies, B.Sc.(Chemistry)
- **Reported:** Ian Davies, B.Sc.(Chemistry)
- Approved: Owen Carpenter, B.Sc.(Physics)

<sup>1</sup> <u>https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3979281/</u> <sup>2</sup> https://monographs.iarc.fr/ENG/Monographs/vol100C/mono100C-14.pdf

# Attachment 14 - Asbestos content (%) for the 6% fine product

37 Kensington Street East Perth WA 6004



Client:	Nagrom
Job number:	18_1874
Sample:	18_1874_02
Client ID:	MM SC6 Fines
Date:	12/11/2018
Analysis:	Fibre characterisation and quantification by scanning electron microscopy (SEM) with elemental
	analysis by energy dispersive spectroscopy (EDS)

## Sample preparation

The sample was supplied to Microanalysis Australia as a bulk sample.

A representative sub-sample of the bulk material was dried and sieved at 150µm. A representative sub-sample of the undersize material was placed on a carbon stub. Non-conducting samples require coating prior to SEM analysis to prevent charging whilst being analysed by the electron beam.

### Analysis

The sample was analysed using a Carl Zeiss EVO50 scanning electron microscope (SEM) fitted with an Oxford INCA X-Max energy dispersive spectrometer (EDS).

EDS is a semi-quantitative technique (at best) on well prepared, optically flat samples. Factors such as sample unevenness may adversely bias elemental concentration interpretation. EDS has a spatial resolution of  $\sim$ 5 µm meaning spectra from particles less than this size may contain elemental concentrations biased by their surroundings.

All images were acquired using backscatter electrons. Image brightness is proportional to average atomic number – the brighter the pixel, the higher the atomic number of the element.

Actinolite has the stoichiometric formula Ca2(Fe,Mg)5Si8O22(OH)2. The relative concentration of elements in decreasing order is: O, Si, Fe, Mg, Ca and H (H is not detectable by EDS). Actinolite is an amphibole asbestos mineral with a fibrous habit characterised by parallel sided, blocky fibres with irregular terminations. Actinolite forms a solid solution mineral series with Tremolite.

Anthophyllite is an amphibole mineral which is polymorphic with Cummingtonite. It has the stoichiometric formula (Mg, Fe)7Si8O22(OH)2. The relative concentration of elements in decreasing order is: O, Si, Fe/Mg and H (H is not detectable by EDS). Cummingtonite is the magnesium endmember of the Cummingtonite-Grunerite mineral series. The more highly asbestiform fibres are commonly towards the iron-rich end member Grunerite. The series has the stoichiometric formula Mg2Mg5Si8O22(OH)2 – Fe2Fe5Si8O22(OH)2.

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## Summary

Following NOHSC:3003 "The Membrane Filter Method" (2005), a fibre is countable if its diameter is < 3  $\mu$ m and its length is > 5  $\mu$ m and has an aspect ratio of greater than 3 to 1. Following the DMP document "Management of Asbestos in Mining Operations", Section 9.33.3 a fibre is countable if its diameter is < 1  $\mu$ m and its length is > 5  $\mu$ m. For the purposes of this analysis the NOHSC definition has been used. **As the concentration using these counting criteria was < 0.01%, the DMIRS/DMP approach was not required.** 

A total of **200** images/fields were examined. Each field was approximately 70  $\mu$ m by 55  $\mu$ m - a total area of 3.85 x 10<sup>-3</sup> mm<sup>2</sup>.

In the **200** images/fields examined, a total of **16** countable asbestos fibres were observed. A majority of the observed countable asbestos fibres had an elemental composition indicative of actinolite, with a minor concentration of anthophyllite. The w/w% of countable asbestos fibres in the bulk sample was determined to be **0.002** %. The ore density was assumed to be 3.1 g/cc.

A selection of images/fields and associated elemental spectra are reported below. The fields are not representative of the 100 fields analysed. The images/fields were reported due to their higher fibre count.

Fibre	Image/F	Diameter	Length	Aspect	Major			Assigned
#	ield #	(µm)	(µm)	ratio	Elements	<b>Minor Elements</b>	Morphology	mineralogy
1	1/1	1.1	17.3	16 :1	O, Si	Mg, Fe	Non-parallel sides	Anthophyllite
2	7/1	0.6	5.4	9 :1	O, Si	Al, Ca, Fe, Mg	Non-parallel sides	Actinolite
3	19/1	0.5	12.1	24 :1	O, Si	Al, Na, Fe	Non-parallel sides	Albite
4	22/1	0.7	9.1	13 :1	O, Si	Al, Ca, Fe, Mg	Irregular ends	Actinolite
5	23/1	0.9	16.9	19 :1	O, Si	Al, Ca, Fe, Mg	Non-parallel sides	Actinolite
6	24/1	1.1	24.5	22 :1	O, Si	Mg, Fe	Parallel sides	Anthophyllite
7	27/1	0.6	7.3	12 :1	0, Si	Al, Ca, Fe, Mg	Non-parallel sides	Actinolite

It should be noted that the higher resolution of the SEM may increase the number of fibres observed when compared with optical microscopy (as specified in the Membrane Filter Method).

A concerted attempt has been made to ensure that the sample analysed is representative, but due to the nonhomogeneity of the sample, some variation in calculated concentration may be observed.

Analyst: Sandy Lam, B.Sc.(Multidisciplinary)

**Reported:** Sandy Lam, B.Sc.(Multidisciplinary)

**Approved:** Nimue Pendragon, B.Sc.(Nanotechnology)











microcaballyssis.au australia









microcola allo sistema australia

Sample: 18\_1874\_02 Type: Default ID: MM SC6 Fines

Project: 18\_1874 Owner: lab Site: Site of Interest 19









microcola all sisteman australia Sample: 18\_1874\_02 Type: Default ID: MM SC6 Fines Project: 18\_1874 Owner: lab Site: Site of Interest 22 Spectrum 1







microcola all sestin au australia Sample: 18\_1874\_02 Type: Default ID: MM SC6 Fines

Project: 18\_1874 Owner: lab Site: Site of Interest 23









microcola australia

Sample: 18\_1874\_02 Type: Default ID: MM SC6 Fines Project: 18\_1874 Owner: lab Site: Site of Interest 24 Spectrum 1





microcaballyssis.au australia Sample: 18\_1874\_02 Type: Default ID: MM SC6 Fines

Project: 18\_1874 Owner: lab Site: Site of Interest 27







microchanyssis.au australia Attachment 15 - Asbestos content (%) for the 6% coarse product

37 Kensington Street East Perth WA 6004



Client:	Nagrom
Job number:	18_1874
Sample:	18_1874_01
Client ID:	MM SC6 Coarse
Date:	12/11/2018
Analysis:	Fibre characterisation and quantification by scanning electron microscopy (SEM) with elemental
	analysis by energy dispersive spectroscopy (EDS)

## Sample preparation

The sample was supplied to Microanalysis Australia as a bulk sample.

A representative sub-sample of the bulk material was dried and sieved at 150µm. A representative sub-sample of the undersize material was placed on a carbon stub. Non-conducting samples require coating prior to SEM analysis to prevent charging whilst being analysed by the electron beam.

### Analysis

The sample was analysed using a Carl Zeiss EVO50 scanning electron microscope (SEM) fitted with an Oxford INCA X-Max energy dispersive spectrometer (EDS).

EDS is a semi-quantitative technique (at best) on well prepared, optically flat samples. Factors such as sample unevenness may adversely bias elemental concentration interpretation. EDS has a spatial resolution of  $\sim$ 5 µm meaning spectra from particles less than this size may contain elemental concentrations biased by their surroundings.

All images were acquired using backscatter electrons. Image brightness is proportional to average atomic number – the brighter the pixel, the higher the atomic number of the element.

Actinolite has the stoichiometric formula Ca2(Fe,Mg)5Si8O22(OH)2. The relative concentration of elements in decreasing order is: O, Si, Fe, Mg, Ca and H (H is not detectable by EDS). Actinolite is an amphibole asbestos mineral with a fibrous habit characterised by parallel sided, blocky fibres with irregular terminations. Actinolite forms a solid solution mineral series with Tremolite.

Anthophyllite is an amphibole mineral which is polymorphic with Cummingtonite. It has the stoichiometric formula (Mg, Fe)7Si8O22(OH)2. The relative concentration of elements in decreasing order is: O, Si, Fe/Mg and H (H is not detectable by EDS). Cummingtonite is the magnesium endmember of the Cummingtonite-Grunerite mineral series. The more highly asbestiform fibres are commonly towards the iron-rich end member Grunerite. The series has the stoichiometric formula Mg2Mg5Si8O22(OH)2 – Fe2Fe5Si8O22(OH)2.

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## Summary

Following NOHSC:3003 "The Membrane Filter Method" (2005), a fibre is countable if its diameter is < 3  $\mu$ m and its length is > 5  $\mu$ m and has an aspect ratio of greater than 3 to 1. Following the DMP document "Management of Asbestos in Mining Operations", Section 9.33.3 a fibre is countable if its diameter is < 1  $\mu$ m and its length is > 5  $\mu$ m. For the purposes of this analysis the NOHSC definition has been used. **As the concentration using these counting criteria was < 0.01%, the DMIRS/DMP approach was not required.** 

A total of **200** images/fields were examined. Each field was approximately 70  $\mu$ m by 55  $\mu$ m - a total area of 3.85 x 10<sup>-3</sup> mm<sup>2</sup>.

In the **200** images/fields examined, a total of **11** countable asbestos fibres were observed. A majority of the observed countable asbestos fibres had an elemental composition indicative of actinolite, with a minor concentration of anthophyllite. The w/w% of countable asbestos fibres in the bulk sample was determined to be **less than 0.001 %**. The ore density was assumed to be 3.1 g/cc.

A selection of images/fields and associated elemental spectra are reported below. The fields are not representative of the 100 fields analysed. The images/fields were reported due to their higher fibre count.

Fibre	Image/F	Diameter	Length	Aspect	Major			Assigned
#	ield #	(µm)	(µm)	ratio	Elements	<b>Minor Elements</b>	Morphology	mineralogy
1	3/1	0.4	7.9	22 :1	O, Si	Al, Ca, Fe, Mg	Non-parallel sides	Actinolite
2	5/2	0.7	49.5	74 :1	O, Si	Mg, Fe	Parallel sides	Anthophyllite
3	6/1	0.3	12.4	41 :1	O, Si	Al, Ca, Fe, Mg	Non-parallel sides	Actinolite
4	7/1	0.6	17.4	28 :1	O, Si	Al, Ca, Fe, Mg	Non-parallel sides	Actinolite
5	9/1	1.4	11.8	8 :1	O, Si	Al, Ca, Fe, Mg	Non-parallel sides	Actinolite
6	10/5	0.8	10.6	14 :1	O, Si	Al, Ca, Fe, Mg	Non-parallel sides	Actinolite
7	13/1	0.7	7.8	12 :1	O, Si	Al, Ca, Fe, Mg	Non-parallel sides	Actinolite

It should be noted that the higher resolution of the SEM may increase the number of fibres observed when compared with optical microscopy (as specified in the Membrane Filter Method).

A concerted attempt has been made to ensure that the sample analysed is representative, but due to the nonhomogeneity of the sample, some variation in calculated concentration may be observed.

Analyst: Sandy Lam, B.Sc.(Multidisciplinary)

**Reported:** Sandy Lam, B.Sc.(Multidisciplinary)

**Approved:** Nimue Pendragon, B.Sc.(Nanotechnology)







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Sample: 18\_1874\_01 Type: Default ID: MM SC6 Coarse

Project: 18\_1874 Owner: lab Site: Site of Interest 5









microcola all sisteman australia Sample: 18\_1874\_01 Type: Default ID: MM SC6 Coarse

Project: 18\_1874 Owner: lab Site: Site of Interest 6









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# Attachment 16 - Asbestos content (%) for the 6% 50-50 product





Client:	Nagrom
Job number:	18_1874
Sample:	18_1874_03
Client ID:	MM SC6 50:50
Date:	12/11/2018
Analysis:	Fibre characterisation and quantification by scanning electron microscopy (SEM) with elemental
	analysis by energy dispersive spectroscopy (EDS)

### Sample preparation

The sample was supplied to Microanalysis Australia as a bulk sample.

A representative sub-sample of the bulk material was dried and sieved at 150µm. A representative sub-sample of the undersize material was placed on a carbon stub. Non-conducting samples require coating prior to SEM analysis to prevent charging whilst being analysed by the electron beam.

#### Analysis

The sample was analysed using a Carl Zeiss EVO50 scanning electron microscope (SEM) fitted with an Oxford INCA X-Max energy dispersive spectrometer (EDS).

EDS is a semi-quantitative technique (at best) on well prepared, optically flat samples. Factors such as sample unevenness may adversely bias elemental concentration interpretation. EDS has a spatial resolution of  $\sim$ 5 µm meaning spectra from particles less than this size may contain elemental concentrations biased by their surroundings.

All images were acquired using backscatter electrons. Image brightness is proportional to average atomic number – the brighter the pixel, the higher the atomic number of the element.

Actinolite has the stoichiometric formula Ca2(Fe,Mg)5Si8O22(OH)2. The relative concentration of elements in decreasing order is: O, Si, Fe, Mg, Ca and H (H is not detectable by EDS). Actinolite is an amphibole asbestos mineral with a fibrous habit characterised by parallel sided, blocky fibres with irregular terminations. Actinolite forms a solid solution mineral series with Tremolite.

# Summary

Following NOHSC:3003 "The Membrane Filter Method" (2005), a fibre is countable if its diameter is < 3  $\mu$ m and its length is > 5  $\mu$ m and has an aspect ratio of greater than 3 to 1. Following the DMP document "Management of Asbestos in Mining Operations", Section 9.33.3 a fibre is countable if its diameter is < 1  $\mu$ m and its length is > 5  $\mu$ m. For the purposes of this analysis the NOHSC definition has been used. **As the concentration using these counting criteria was < 0.01%, the DMIRS/DMP approach was not required.** 

A total of **200** images/fields were examined. Each field was approximately 70  $\mu$ m by 55  $\mu$ m - a total area of 3.85 x 10<sup>-3</sup> mm<sup>2</sup>.

In the **200** images/fields examined, a total of **19** countable asbestos fibres were observed. All of the observed countable asbestos fibres had an elemental composition indicative of actinolite. The w/w% of countable asbestos fibres in the bulk sample was determined to be **0.001** %. The ore density was assumed to be 3.1 g/cc.

A selection of images/fields and associated elemental spectra are reported below. The fields are not representative of the 100 fields analysed. The images/fields were reported due to their higher fibre count.

Fibre	Image/F	Diameter	Length	Aspect	Major			Assigned
#	ield #	(µm)	(µm)	ratio	Elements	<b>Minor Elements</b>	Morphology	mineralogy
1	13/2	0.8	10.4	13 :1	O, Si	Al, Ca, Fe, Mg	Non-parallel sides	Actinolite
2	13/3	0.9	8.3	9 :1	O, Si	Al, Ca, Fe, Mg	Non-parallel sides	Actinolite
3	16/1	0.9	9.4	10 :1	O, Si	Al, Ca, Fe, Mg	Non-parallel sides	Actinolite
4	20/1	0.8	12.0	15 :1	O, Si	Al, Ca, Fe, Mg	Non-parallel sides	Actinolite
5	25/1	0.6	14.7	25 :1	O, Si, Al	-	Non-parallel sides	Aluminosilicate
6	27/1	1.7	10.8	6 :1	O, Si	Al, Ca, Fe, Mg	Non-parallel sides	Actinolite

It should be noted that the higher resolution of the SEM may increase the number of fibres observed when compared with optical microscopy (as specified in the Membrane Filter Method).

A concerted attempt has been made to ensure that the sample analysed is representative, but due to the nonhomogeneity of the sample, some variation in calculated concentration may be observed.

Analyst: Sandy Lam, B.Sc. (Multidisciplinary)

**Reported:** Sandy Lam, B.Sc.(Multidisciplinary)

**Approved:** Nimue Pendragon, B.Sc.(Nanotechnology)

Sample: 18\_1874\_03 Type: Default ID: MM SC6 50:50

Project: 18\_1874 Owner: lab Site: Site of Interest 13









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Sample: 18\_1874\_03 Type: Default ID: MM SC6 50:50

Project: 18\_1874 Owner: lab Site: Site of Interest 25





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Client:	Nagrom
Job number:	18_1874
Sample:	18_1874_04
Client ID:	MM SC4 Coarse
Date:	12/11/2018
Analysis:	Fibre characterisation and quantification by scanning electron microscopy (SEM) with elemental
	analysis by energy dispersive spectroscopy (EDS)

### Sample preparation

The sample was supplied to Microanalysis Australia as a bulk sample.

A representative sub-sample of the bulk material was dried and sieved at 150µm. A representative sub-sample of the undersize material was placed on a carbon stub. Non-conducting samples require coating prior to SEM analysis to prevent charging whilst being analysed by the electron beam.

#### Analysis

The sample was analysed using a Carl Zeiss EVO50 scanning electron microscope (SEM) fitted with an Oxford INCA X-Max energy dispersive spectrometer (EDS).

EDS is a semi-quantitative technique (at best) on well prepared, optically flat samples. Factors such as sample unevenness may adversely bias elemental concentration interpretation. EDS has a spatial resolution of  $\sim$ 5 µm meaning spectra from particles less than this size may contain elemental concentrations biased by their surroundings.

All images were acquired using backscatter electrons. Image brightness is proportional to average atomic number – the brighter the pixel, the higher the atomic number of the element.

Actinolite has the stoichiometric formula Ca2(Fe,Mg)5Si8O22(OH)2. The relative concentration of elements in decreasing order is: O, Si, Fe, Mg, Ca and H (H is not detectable by EDS). Actinolite is an amphibole asbestos mineral with a fibrous habit characterised by parallel sided, blocky fibres with irregular terminations. Actinolite forms a solid solution mineral series with Tremolite.

# Summary

Following NOHSC:3003 "The Membrane Filter Method" (2005), a fibre is countable if its diameter is < 3  $\mu$ m and its length is > 5  $\mu$ m and has an aspect ratio of greater than 3 to 1. Following the DMP document "Management of Asbestos in Mining Operations", Section 9.33.3 a fibre is countable if its diameter is < 1  $\mu$ m and its length is > 5  $\mu$ m. For the purposes of this analysis the NOHSC definition has been used. **As the concentration using these counting criteria was < 0.01%, the DMIRS/DMP approach was not required.** 

A total of **200** images/fields were examined. Each field was approximately 70  $\mu$ m by 55  $\mu$ m - a total area of 3.85 x 10<sup>-3</sup> mm<sup>2</sup>.

In the **200** images/fields examined, a total of **5** countable asbestos fibres were observed. All of the observed countable asbestos fibres had an elemental composition indicative of actinolite. The w/w% of countable asbestos fibres in the bulk sample was determined to be **less than 0.001 %**. The ore density was assumed to be **3.1** g/cc.

A selection of images/fields and associated elemental spectra are reported below. The fields are not representative of the 100 fields analysed. The images/fields were reported due to their higher fibre count.

Fibre	Image/F	Diameter	Length	Aspect	Major			Assigned
#	ield #	(µm)	(µm)	ratio Elements Minor Elements		Morphology	mineralogy	
1	5/1	0.8	6.5	8 :1	O, Si	Al, Ca, Fe, Mg	Non-parallel sides	Actinolite
2	7/1	0.5	10.3	21 :1	0, Si	O, Si Al, Ca, Fe, Mg Parallel sides		Actinolite
3	9/1	0.5	9.4	21 :1	O, Si	O, Si Al, Ca, Fe, Mg Parallel sides		Actinolite
4	12/2	0.7	8.5	12 :1	O, Si	O, Si Al, Ca, Fe, Mg Non-parallel side		Actinolite
5	17/1	1.5	16.0	10 :1	O, Si	Al, Ca, Fe, Mg	Non-parallel sides	Actinolite

It should be noted that the higher resolution of the SEM may increase the number of fibres observed when compared with optical microscopy (as specified in the Membrane Filter Method).

A concerted attempt has been made to ensure that the sample analysed is representative, but due to the nonhomogeneity of the sample, some variation in calculated concentration may be observed.

Analyst: Sandy Lam, B.Sc.(Multidisciplinary)

**Reported:** Sandy Lam, B.Sc.(Multidisciplinary)

**Approved:** Nimue Pendragon, B.Sc.(Nanotechnology)

Sample: 18\_1874\_04 Type: Default ID: MM SC4 Coarse

Project: 18\_1874 Owner: lab Site: Site of Interest 5







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Sample: 18\_1874\_04 Type: Default ID: MM SC4 Coarse

Project: 18\_1874 Owner: lab Site: Site of Interest 7





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# Attachment 18 - ICP Analysis for Radiation Calculation (4% product = ST3 and 6% product = ST2)



# Process Minerals International Analytical Report

KM-1811-037665 November 16 2018 5 November 15 2018

AUTHORISATION

ShaneWelson

Shane Wilson - Senior Chemist

CLIENT	Process Minerals International
ADDRESS	1 Sleat Road, Applecross Locked Bag 3, Canning Bridge LPO
PROJECT	PTH.KM
P/O#	Mt Marion GC 181114



KM-1811-037665	U	Th	к	Rb
Method	ICP004	ICP004	ICP004	ICP004
Units	ppm	ppm	ppm	ppm
LLD	0.5	0.5	1000	1
ST1 180825 - 180917	2.5	4.0	17000	1773
ST2 180825 - 180917	2.0	2.5	4000	657
ST3 180825 - 180917	2.5	4.0	10000	1385
CV25 180825 - 180917	2.0	2.0	21000	2070
CV25 180825 - 180917 REP	1.5	2.5	21000	2051
TH01 180825 - 180917	3.5	4.5	18000	1927
NCS_DC73317A STD	2.0	6.5	15000	60
ARA09-01 STD	309.5	3344.5	8000	41

Attachment 19 – Concentrations of radionuclides in products of the Mt Marion site (Calytrix Consulting Pty Ltd)



Memorandum

Subject:	Concentrations of radionuclides in products of the Mt Marion site
Date:	18 November 2018
From:	N Tsurikov
То:	K Dennison

## Dear Kim,

On 18<sup>th</sup> of November updated values for uranium and thorium concentrations have been received from the Nagrom laboratory.

The summary of available data:

- 4% concentrate: U = 2.5 ppm, Th = 4 ppm, Rb-87 = 1385 ppm
- 6% concentrate: U = 2 ppm, Th = 2.5 ppm, Rb-87 = 657 ppm

The following specific activities were used to calculate the sum for the 4% and 6% concentrates:

- Uranium-238 = 12,384 Bq/g
- Thorium-232 = 4,055 Bq/g
- Rubidium = 890 Bq/g

#### Uranium and thorium

- $\circ$  The combined concentrations of uranium and thorium are: 4% concentrate = 0.050 Bq/g. 6% concentrate = 0.035.
- The limit for natural uranium and thorium in transport safety regulations (and in DWER license conditions) is 10 Bq/g.
- Therefore, both products are meeting DWER license conditions and are exempt from transport safety regulations.

#### Rubidium

- The concentrations of rubidium are: 4% concentrate = 1.233 Bq/g, 6% concentrate = 0.585 Bq/g.
- The limit for Rb-87 in transport safety regulations is 10,000 Bq/g and in DWER license conditions 30 Bq/g.
- Therefore, both products are meeting DWER license conditions and are exempt from transport safety regulations.

Please let me know if any additional information will be required.

Kind regards Nick Tsurikov Attachment 20 - Metals DI Leachate Concentration for the 6% fines (A-2), 6% coarse (A-1) and 4% coarse (A-3) products







# **ASLP Laboratory Report**

Job Number:	18-16599-A
<b>Revision:</b>	00
Date:	12 November 2018

ADDRESS:	Microanalysis Australia
	37 Kensington street

ATTENTION: Michael Simeoni

DATE RECEIVED: 6 November 2018

YOUR REFERENCE: 18\_1874

PURCHASE ORDER:

**APPROVALS:** 

from

East Perth WA 6004

Sam Becker Inorganics Manager

### **REPORT COMMENTS:**

This report is issued by Analytical Reference Laboratory (WA) Pty Ltd Extractions performed according to ARL No. 069 - Preparation of Leachates - Bottle Leaching Procedure ASLP Extraction Fluid: Reagent Water Samples are analysed on an as received basis unless otherwise noted.

#### **METHOD REFERENCES:**

ARL No. 29/402/403	Metals in Water by AAS/ICPOES/ICPMS
ARL No. 040	Arsenic by Hydride Atomic Absorption
ARL No. 406	Mercury by Cold Vapour Atomic Absorption Spectrophotometry









# LABORATORY REPORT

Microanalysis Australia ARL Job No: 18-16599-A

Revision:

00

Date: 12 November 2018

ASLP for Metals Sample No: Sample Description:	LOR	UNITS	18-16599- A-1 18_1874_01	18-16599- A-2 18_1874_02	18-16599- A-3 18_1874_04
Silver - Dissolved	0.01	ma/l	<0.01	<0.01	<0.01
Aluminium - Dissolved	0.1	ma/L	0.3	0.1	0.4
Arsenic - Dissolved	0.001	ma/L	0.006	0.002	0.009
Barium - Dissolved	0.01	ma/L	<0.01	0.03	0.08
Cadmium - Dissolved	0.002	mg/L	<0.002	< 0.002	<0.002
Cobalt - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01
Chromium - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01
Copper - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01
Iron - Dissolved	0.01	mg/L	0.08	0.09	0.06
Lithium - Dissolved	0.01	mg/L	0.25	0.28	0.16
Mercury - Dissolved	0.0002	mg/L	<0.0002	<0.0002	<0.0002
Manganese - Dissolved	0.01	mg/L	<0.01	0.02	<0.01
Nickel - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01
Lead - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01
Antimony - Dissolved	0.001	mg/L	0.001	<0.001	<0.001
Thorium - Dissolved	0.001	mg/L	<0.001	<0.001	<0.001
Uranium - Dissolved	0.001	mg/L	<0.001	<0.001	<0.001
Zinc - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01

### **Result Definitions**

LOR Limit of Reporting

[ND] Not Detected at indicated Limit of Reporting

[NR] Analysis Not Requested