Radiation Advice & Solutions Pty Ltd
ABN 31 891 761 435

116 Pennine Drive
South Maclean
Queensland 4280
Australia

phone/fax (07) 3297 7653
mobile 0447 755 598
email: sontermj@tpg.com.au

Rum Jungle Radiation Monitoring Report

Introduction

A radiological assessment of the Rum Jungle mine site by Bollhofer *et.al.* (2008) determined that if activities such as drilling and digging were undertaken onsite, the Occupational, Health and Safety (OH&S) management plan for the site would need to incorporate monitoring of various exposure pathways.

A dust and radiation monitoring program therefore formed a component of the excavation works undertaken on the waste rock dumps at Rum Jungle during October and November 2014, running the duration of the excavation works.

Radiation Advice & Solutions was contracted by the DME to produce a report of the radiation monitoring results.

Radiation Dose Pathways

The material stored in the waste rock dumps at Rum Jungle is the by-product of uranium mining. As such, it may represent a radiological hazard during excavation works. Uranium is the ‘parent’ of a series of radioactive elements that emit alpha, beta, and gamma radiation. There are four potential pathways for delivery of radiation doses to the human body that should be considered at this project, and that may require monitoring and active control, depending on the circumstances. They are:

a) Direct irradiation by gamma radiation from mineralised material. This is only significant if long periods are spent close to large volumes of ore grade material.
b) Inhalation of airborne dust containing long-lived alpha-emitting uranium, thorium, and radium. This is a potential concern for any dust-producing activity, like excavation, in mineralization.
c) Inhalation of radon daughters. This is generally only a concern in enclosed volumes, where they can accumulate.
d) Ingestion of radioactive contamination transferred from hands to mouth when eating or smoking.

Control of these four pathways therefore require:

a) Minimization of time spent near mineralized material, where possible;
b) Dust minimization, where possible, and use of respiratory protection, if necessary;
c) No specific control for radon daughters for open air operations; and
d) Good personal hygiene and workplace cleanliness.

Monitoring Program

A summary of the radiation monitoring is shown below. For further details of the monitoring program and sampling methodology, see the DME document *Rum Jungle Dust and Radiation Monitoring Program 2014*.

Radiation source	Monitoring Instrument	Purpose
Area gamma	Gamma survey monitor	Shed only, to ensure TLD control board is in low background
Personnel gamma	Electronic personal dosimeters and TLD badges	Calculate occupational dose to workers
Long-lived alpha activity in airborne dust	Dust pump with IOM inhalable sampling head	Calculate occupational dose to workers
	Microvol with TSP sampling head	Environmental monitoring
Radon daughters in air (short-lived alpha activity)	Environmental radon daughter monitor (ERDM)	Environmental monitoring
Contamination	Surface alpha contamination monitor	Clearance of vehicles departing project

Respirable dust was also monitored using the dust pump with a cyclone sampling head, but has not been discussed in the body of this report. Refer to Appendix 5 which details the respirable dust interpretation of results and advice for future monitoring work at Rum Jungle. .

Dose Assessment

Based on the monitoring results, the total effective dose received by workers on the project was calculated using the formula below:

> **Total Effective Dose = Gamma dose + dust dose**, *where:*
>
> *Gamma dose = average daily gamma dose[1] (μSv) x days on site*
>
> *Dust dose = average activity concentration (adps/m^3) × hours on site × 1.2 m^3/hour breathing rate x Dose Conversion Factor[2] (μSv/αdps)*

Appendix 1 shows the monitoring results used to calculate gamma and dust dose. Dose calculations are shown in Appendix 2.

The maximum project dose that could have been received by a worker, if they were working 12 hour shifts every day during the project, was 0.02 mSv. This would give a hypothetical annual dose of 0.15 mSv, if work continued in the same conditions for a full 3000 hour working year (50 weeks a year x 5 days a week x 12 hours a shift).

The maximum dose received from the project (0.02 mSv) is very low, well below the member of public annual dose limit of 1 mSv, let alone the worker annual dose limit of 20 mSv.

The hypothetical annual dose that would have been received from the project (0.15 mSv) is still well below the member of public annual dose limit, as well as below the average annual dose for Australian uranium mine workers due to gamma radiation of 1.1 mSv[3], and below the average annual natural background radiation dose worldwide of 2.4 mSv.

Radon daughters were not included in the worker dose for reasons discussed in the following section.

Radon Daughters

Long-term exposure to high levels of radon daughters is a cancer risk. Although there is no observable risk at low levels, such as in the open air, a confined space that is poorly ventilated can accumulate radon daughters up to dangerous concentrations.

The concentration of radon daughters in outdoor air depends mainly on two factors:

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[1] doses were calculated twice, using EPD then TLD readings for comparison, and gave the same results

[2] Where the Dose Conversion Factor is given in ARPANSA RPS 9 as 3.5 μSv/αdps for U-bearing ore, for 5 μm AMAD (activity median aerodynamic diameter) dust particle size.

[3] Personal Radiation Monitoring Service and Assessment of Doses Received by Radiation Workers (2004), ARPANSA Technical Report 139

- Rock properties (eg uranium content, porosity, moisture content), which affect radon exhalation from the material;
- Weather conditions (eg wind, temperature), which affect dispersion and dilution of radon into the atmosphere;

Due to the open-air conditions at this project, radon daughter concentrations could not accumulate. The ERDM results gave an average of 0.12 $\mu J/m^3$, which is much lower than the usually used occupational limit of 7.1 $\mu J/m^3$. This limit assumes a 2000 hour working year, however, so adjusted for a 3000 hour year (to account for 12 hour shifts), the limit becomes 4.8 $\mu J/m^3$, but the monitored radon daughter concentration is still well below that.

The graphed ERDM results showed the typical outdoor diurnal pattern (see Appendix 3 – Example ERDM Results), peaking early in the morning when atmospheric conditions tend to be cooler, and more stable, and then dropping during the day when air mixing increases due to thermal convection and wind. Outdoor radon daughter concentrations will naturally vary by factors of 10-100, making it almost impossible to separate radon daughters originating from a particular source from natural background.

Due to the very low results, and difficulty in separating from natural background, radon daughters were considered to have an insignificant effect on total dose, and so were excluded from the worker dose calculations.

Other Dust Monitoring

Microvol monitoring results showed very low long-lived alpha activity concentration in airborne dust, with an average of 0.0004 Bq_α/m^3 (shown in Appendix 4) This is very much lower than the occupational limit for uranium-bearing dust of 1.6 Bq_α /m3 (adjusted for a 3000 hour working year), indicating it is of negligible concern in terms of radiation hazard.

Equipment Clearances

In order to minimise the spread of radioactive material offsite, all earth moving equipment and heavy vehicles were washed and checked at the end of the project, and only released after they were certified clean of radioactive contamination.

The project did not have access to an alpha surface contamination monitor, so the clearance procedure consisted of a visual inspection for dirt, and a radiation check with an alpha/beta/gamma monitor (comparing to background readings). There was also a radiation check with a gamma monitor in case of any radioactive material in internal spaces (again, comparing to background readings).

There was some breakdown of equipment clearance procedure, however, in that one truck (registration number 1CW 9MN) failed its first check and was sent for further cleaning, but was not re-checked before departure.

Summary

The maximum dose received by workers engaged in these excavation works at Rum Jungle has been assessed to be negligible, and even in the hypothetical case of full-year exposure would have remained well below member of public limit.

Based on these results, similar excavation works in the future, with the same controls in place, would not require this same level of radiation monitoring. In lieu of the full monitoring program undertaken during the 2014 excavation project, we would recommend all earth moving equipment undergo radiation clearance before release from site, and for reassurance, monitoring of radioactive dust levels via microvol.

25 May 2015

Samantha Sonter BSc Hons (Geol), Grad Dip Sci Comm, Consultant
Reviewed by Mark Sonter MAppSc (Med Phys), MARPS, ARPAB, Senior Consultant

Appendix 1 – Monitoring results used in dose calculation

EPD Results

EPD #	Date	Start time	End time	Recorder/s	Worker	Location and description of works	Hp (10) Dose (uSv)
1	Check	13:25	N/A	CS, BC, SS	N/A	N/A	0
1	7.10.14	6:23	16:28	CS, BC, SS	Daniel	Main WRD 2014-TP3, Operator - excavator	0
1	8.10.14	8:25	16:16	CS	Travis	Main WRD 2014-TP3, Operator - truck	0
1	15.10.14	9:09	17:53	CS	JD	Main WRD 2014-TP2, Operator - dozer	0
1	16.10.14	6:11	16:16	CS	Allan	Main WRD 2014-TP3, Operator - truck ~7.5m deep	1
1	21.10.14	8:11	16:46	CS, BC	Paul	Main WRD 2014 - TP1, Sampler +10m deep	1
1	22.10.14	6:15	16:16	CS	Travis/Lee	Intermediate WRD, Operator - Dozer	0
1	28.10.14	7:33	16:01	CS, MG	Lee	Intermediate WRD, Operator - Excavator ~5m	0
1	31.10.14	7:04	14:37	CS, MG	Travis	Intermediate and Dysons backfilling, Operator - Dozer	0
2	Check	13:25	N/A	CS, BC, SS	N/A	N/A	0
2	6.10.14	13:25	18:21	CS, BC, SS	Paul Ferguson	Main WRD 2014-TP3, Sampler	0
2	7.10.14	6:23	16:05	CS, BC, SS	Paul Ferguson	Main WRD 2014-TP3, Sampler	1
2	8.10.14	8:04	16:10	CS	David Jones	Main WRD 2014-TP3 &TP1, Sampler	0
2	15.10.14	9:15	15:55	CS	Tara (RGC)	General site, Sampler	0
2	16.10.14	7:41	16:18	CS	Travis	Main WRD 2014-TP3 , Operator - Truck ~7.5m deep	1
2	21.10.14	9:13	15:57	CS, BC, SS	Geno	Main 2014-TP1, Operator - Excavator 10-20m deep	2
2	22.10.14	7:12	16:41	CS	Paul Ferguson	Main TP1 , Sampler +10m deep	2
2	28.10.14	7:24	15:53	CS, MG	Allan	Intermediate TP2, ~5m deep	0
2	31.10.14	7:01	14:30	CS, MG	Lee	Dysons and Intermediate WRD, Operator - Roller Backfilling	0
						Average	**0.47**

TLD Results

Badge No.	Start Date	End Date	Max days worn	Photon Hp(0.07) (μSv)	Dose per day (μSv)
M1437-35936	5/09/14	7/12/14	36		
M1437-35937	5/09/14	7/12/14	36	0	0.000
M1437-35938	5/09/14	7/12/14	36	0	0.000
M1437-35939	5/09/14	7/12/14	36	0	0.000
M1437-35940	5/09/14	7/12/14	36	70	1.944
M1437-35941	5/09/14	7/12/14	36	0	0.000
M1437-35942	5/09/14	7/12/14	36	0	0.000
M1437-35943	5/09/14	7/12/14	36	0	0.000
M1437-35946	5/09/14	7/12/14	36	0	0.000
M1437-35948	5/09/14	7/12/14	36	0	0.000
M1437-35949	5/09/14	7/12/14	36	0	0.000
M1437-35950					
M1437-35951					
M1437-35952	5/09/14	7/12/14	36	70	1.944
M1438-40963	12/09/14	14/12/14			
M1438-40964	12/09/14	14/12/14	36	0	0.000
M1438-40965	12/09/14	14/12/14	36	0	0.000
M1438-40966	12/09/14	14/12/14	36	0	0.000
M1438-40967	12/09/14	14/12/14	36	130	3.611
M1438-40968	12/09/14	14/12/14	36	0	0.000
M1438-40969					
				Average	**0.469**

Air Sampling Pumps - with inhalable dust IOM attachment

Date	Start time	End time	Time lapsed	Start Flow rate (L/min)	End Flow rate (L/min)	Recorder/s	Work Area	Filter ID	Sampling Pump ID	Cyclone ID or IOM	Activity concentration (Bqα/m3)	Error
6.10.14	13:25	18:21	296	2	2	CS, BC, SS	Main WRD 2014-TP1	RJMLLA01	PCXR8-5	IOM #1	3.5E-03	± 0.6
7.10.14	6:23	16:13	551	2	2	CS, BC, SS	Main WRD 2014-TP1 & Old Tailings Area	RJMLLA02	PCXR8-5	IOM #1	2.2E-03	± 0.3
15.10.14	9:10	18:01	532	2	2	CS	Main WRD 2014-TP1	RJMLLA03	PCXR8-5	IOM #1	9.7E-04	± 1.9
16.10.14	7:41	16:18	504	2	2	CS	Main WRD 2014-TP1 ~7.5m deep	RJMLLA04	PCXR8-5	IOM #2	3.1E-03	± 0.5
21.10.14	8:12	16:39	507	2	2	CS, BC	Main TP1 +10m deep	RJMLLA05	PCXR8.1	IOM #1	4.4E-03	± 0.8
22.10.14	6:15	16:05	583	2	2	CS	Main TP1 +10m deep	RJMLLA06	PCXR8.1	IOM #2	1.9E-03	± 0.3
28.10.14	7:24	15:55	511	2	2	CS, MG	Intermediate TP2 ~5m deep	RJMLLA07	PCXR8.1	IOM #1	1.7E-03	± 0.3
31.10.14	7:04	14:37	440	2	2	CS, MG	Intermediate WRD and Dysons - Backfilling	RJMLLA08	PCXR8.1	IOM #2	3.1E-03	± 0.5
										Average	**2.6E-03**	

Appendix 2 – Dose Calculations

EPD Ave daily dose (uSv) 4.71E-01

Ave activity conc. (adps/m3) 2.6E-03

	TOTAL DAYS	TOTAL HOURS (12 hr shifts)	Total Gamma Dose (uSv)	Total LLA Activity Inhaled (adps)	Total Dust Dose (uSv)	Total Dust Dose with RPF (10 for P2 masks) **	TOTAL DOSE (uSv)	TOTAL DOSE with RPF (uSv)
Potential maximum dose during project	36	432	1.69E+01	1.35E+00	4.73E+00	4.73E-01	2.17E+01	1.74E+01
Hypothetical full working year *	250	3000	1.18E+02	9.39E+00	3.29E+01	3.29E+00	1.51E+02	1.21E+02

TLD Ave daily dose (uSv) 4.69E-01

Total Gamma Dose (uSv)
1.69E+01
1.17E+02

TOTAL DOSE (uSv)	TOTAL DOSE with RPF (uSv)
2.16E+01	1.73E+01
1.50E+02	1.20E+02

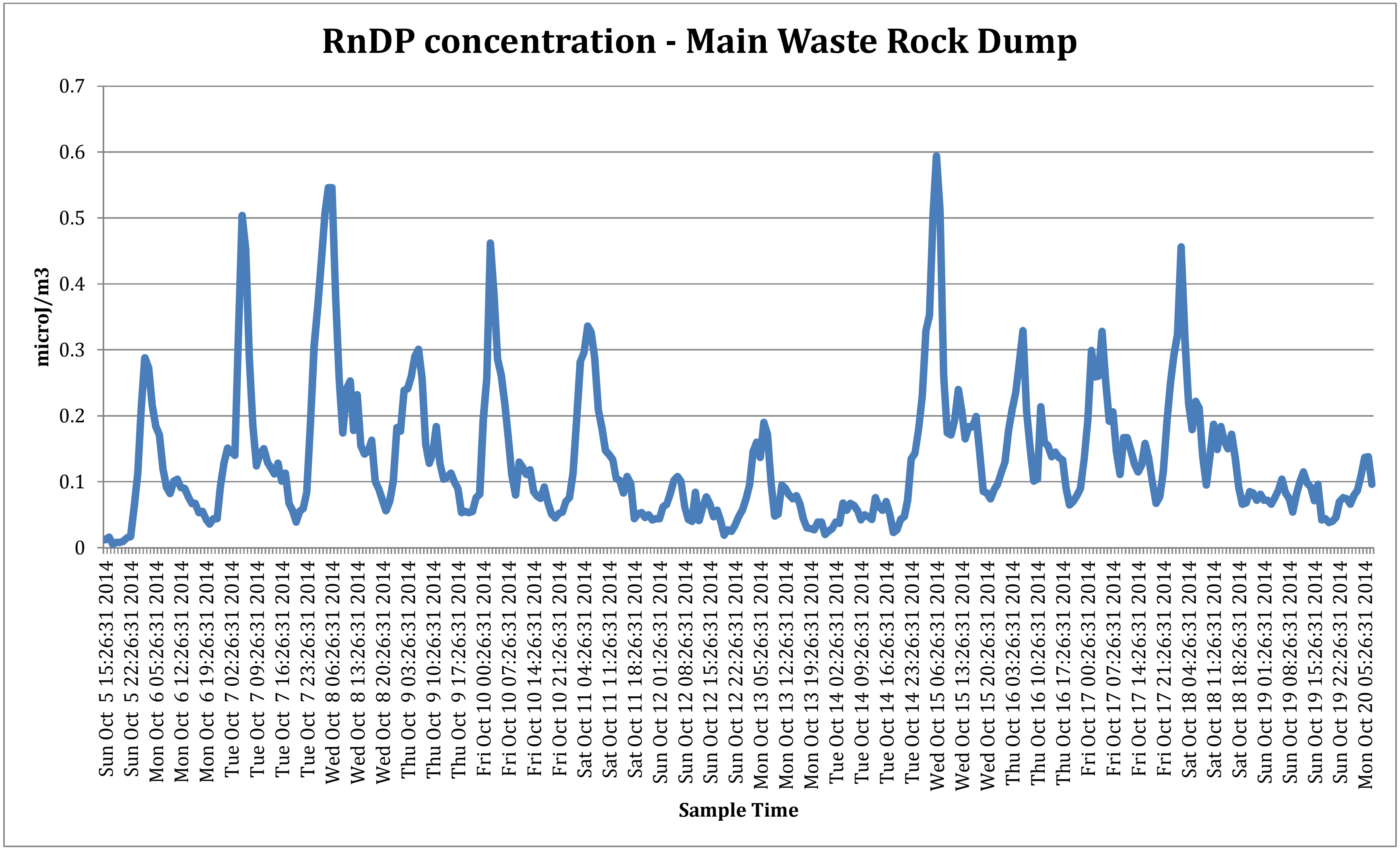
* 50 wks x 5 days x 12 hours

** Just calculating this just for interests sake, as you cannot assume people are wearing their PPE correctly…

Divide raw results by RPF (respiratory protection factor), where RPF = 10 for the P2 masks listed below

Umatta P2 - Aus/NZ Stnd.1716, PRO Choice P2 - Aus/NZ Stnd.1716, 3M FFP2 - Aus/NZ Stnd.1716
(if you used other brands, check their standard…)

Appendix 3 – Example ERDM Results



Appendix 4 – Example ERDM Results

MicroVol

Sample ID	Start Date	Start Time	End Date	End Time	Recorder/s	Start Flow (L/min)	End Flow (L/min)	Start Volume (L)	End Volume (L)	Location	GPS Datum WGS 84 S:	GPS Datum WGS 84 E:	Activity concentration (Bqα/m3)	Error
MVol01	6.10.14	15:20	21.10.14	9:32	CS, BC, SS	3.00	3.00	25045	88814	Main WRD	12º 59.690'	131º 00.518'	7.9E-04	± 1.7
MVol02	22.10.14	15.09	31.10.14	7:10	CS	3.00	3.00	88814	126255	Intermediate WRD	12º 59.540'	131º 00.216'	3.0E-04	± 0.7
MVol03	31.10.14	11:00	10.11.14	10:10	CS	3.00	3.00	126255	169311	Dyson's WRD	12º 59.212'	131º 01.286'	2.1E-04	± 0.3
												Average	**4.3E-04**	

Appendix 5 – Respirable dust advice

Radiation Advice & Solutions Pty Ltd
ABN 31 891 761 435

Principal: Mark Sonter MAppSc (Med Phys), MARPS, ARPAB, MAIOH.

116 Pennine Drive
South Maclean Qld 4280
phone / fax: (07) 3297 7653
mobile: 0447 755598
email: sontermj@tpg.com.au; sonterw@tpg.com.au

Advice on respirable dust, Rum Jungle

Personal air sampling was carried out in the course of earthworks on Rum Jungle waste rock dumps, during October 2014.

An Excel spreadsheet of results for respirable dust (as collected using cyclone sampler) is attached below. The results for total respirable dust ranged (for 8 samples) from 0.05 to 1.22 mg/m^3, with average 0.38 mg/m^3.

The question arises, for interpretation of these results, as to what *proportion* of this respirable fraction might be crystalline free silica.

A chemical assay was supplied which gave 'SiO2' as 45 to 77%, average 55%, for waste rock dump material. It must be realised that not all of the chemically assayed silica content will be in the form of *crystalline silica*, as at least some of the Si will be in the form of various *silicate* minerals. This number therefore represents an upper limit.

An old technical paper from Rum Jungle Operational period was supplied which gave the mineralogical description of the materials excavated from the White's and Dyson's open pits. There was very substantial quantity of quartzite in the waste, along with slate, dolomite, and other materials. The presence of quartzite means that a significant proportion of the chemically reported silica *would indeed have been in the form of crystalline free silica.*

To take a conservative approach therefore, we assume that ***all*** of the assayed silica is crystalline, and thus the proportion of the average respirable dust which is silica will be on average:

(0.55 x 0.38=) **0.209 mg/m^3.**

The standard (OEL) for workplace respirable crystalline silica is 0.1 mg/m^3.

This means that in any future works on this material, active dust suppression should be used if feasible. If material conditions such as trafficability (slipperiness, load bearing etc) do not permit water application, then simple PPE (P1 or P2 half face mask) must be instituted. Personal respirable dust sampling should again be instituted.

The interesting conclusion is that this is a case where dust control for limitation of silicosis risk is in fact important, rather than, (as might have been expected) dust control for radiation dose limitation...

Mark Sonter, 1-07-2015

Air Sampling Pumps - with respirable dust cyclone attachment

Sample No.	Date	Start time	End time	Time lapsed	Worker	Work Area	Filter ID	wt. before	wt. after	TSP (mg)	vol m3	mg/m3
1	7.10.14	6:23	16:05	580	Paul Ferguson Sampler	Main WRD 2014-TP3	#41	0.01129	0.01186	0.57	1.16	0.49
2	8.10.14	8:25	16:16	456	Travis Operator	Main WRD 2014-TP3	#42	0.01113	0.01128	0.15	0.91	0.16
3	15.10.14	9:23	15:55	392	Paul Ferguson Sampler	Main/general site area	#43	0.01147	0.01155	0.08	0.78	0.10
4	16.10.14	6:13	16:20	608	Jumbo Operator - dozer	Main WRD 2014-TP3 ~7.5m deep	#44	0.01147	0.01162	0.15	1.22	0.12
5	21.10.14	9:13	17:57	42	Lee Operator - Excavator	Main TP1 10-20m deep	#46	0.01087	0.01093	0.06	0.08	0.71
6	22.10.14	7:12	16:41	567	Paul Ferguson Sampler	Main TP1 +10m deep	#45	0.0113	0.01136	0.06	1.13	0.05
7	28.10.14	7:33	16:01	508	Lee Operator - Excavator	Intermediate TP2 ~5m deep	#47	0.01066	0.01196	1.3	1.02	1.28
8	31.10.14	7:01	14:42	457	Lee Operator - Roller	Intermediate and Dysons Backfilling	#48	0.01089	0.01101	0.12	0.91	0.13
											average =	***0.38***

Average Respirable Crystalline Free Silica might therefore be at worst 55% of 0.38 = 0.209 mg/m^3.