



MONITORING RESPIRABLE CRYSTALLINE SILICA EXPOSURE INDUSTRY CONSIDERATIONS

***Air Quality Working Group
Information Package - Part 11 of 12***

December 2018

Monitoring RCS Exposure

The Australian Tunnelling Society (ATS) recognises the importance of health and safety in our industry in addition to valuing the strong experience and contribution of its members to support key stakeholders in our ever-growing sector. The ATS recognise that collaboration with industry stakeholders is essential to both raise awareness of the important issue of silica dust control, but also to enable effective strategies to be developed that will ultimately be practical and a positive step forward.

The Air Quality Working Group (AQWG) was formed in 2017 as a collaborative platform to enable industry to work together to develop and implement strategies to improve occupational health outcomes, with an initial focus on respirable crystalline silica (“silica dust”).

The AQWG membership collectively produced reference material for purposes of communicating information that currently does not exist in the tunnel construction industry’s body of knowledge. There are 12 parts to the information package, and each part must be considered in the context of the other. This document represents Part 11 of 12 total parts as listed in **Table 1**. Documented material is considered to benefit the wider tunnelling industry and therefore is freely available on the ATS website.

Table 1 – Complete list of material produced by the AQWG

Part	Document Title	Document Reference
Part 1	NSW Air Quality Working Group Background & Methodology – Silica Dust Exposure and the Tunnelling Industry	Doc No. AQWG_0_0.07
Part 2	Good Practice to Control Silica Dust Exposure During NSW Tunnel Construction	Doc No. AQWG_1_0.08
Part 3	Silica Dust Awareness Package	Doc No. AQWG_2_0.21
Part 4	Silica Dust Awareness Package Speakers Notes	Doc No. AQWG_2a_0.04
Part 5	Design and Procurement - Industry Considerations	Doc No. AQWG_3_0.09
Part 6	Scrubber System - Case Study	Doc No. AQWG_4_0.09
Part 7	Ventilation During Tunnel Construction - Industry Considerations	Doc No. AQWG_5_0.08
Part 8	Portal Misting System - Case Study	Doc No. AQWG_6_0.05
Part 9	Roadheader Cabin Air Filtration - Case Study	Doc No. AQWG_7_0.06
Part 10	Respiratory Protective Equipment - Industry Considerations	Doc No. AQWG_8_0.07
Part 11	Monitoring RCS Exposure - Industry Considerations	Doc No. AQWG_9_0.07
Part 12	Health Monitoring for NSW Tunnel Construction Workers – Industry Considerations	Doc No. AQWG_10_0.14

This document provides practical information on methods that can be applied to monitor personal exposure of tunnel construction workers to respirable crystalline silica (RCS).

1. Minimum Requirements

Standardised methods for sampling and the analysis of respirable dust are prescribed in AS/NZ 2985 (Standards Australia, 2009). The reader is encouraged to consult such reference in addition to this document.

2. Principles of Monitoring

Exposure monitoring provides critical information regarding the extent of worker exposure and the associated risks, so that the person conducting a business or undertaking (PCBU) can confirm if current control measures are sufficient to protect the health of the workforce and if additional control measures are necessary.

Fundamentally PCBU's cannot make a meaningful assessment of RCS exposure risk without the following two elements:

- A reliable estimate of exposure, and
- A standard for means of comparison.

Reliable exposure estimates should be established by applying the information documented in Section 6, whereas the standard of comparison should be determined by applying the regulatory Workplace Exposure Standard (WES) (SafeWork Australia, 2013) (refer to Section 4).

3. Legislative Requirements

In Australia, harmonised *Work Health and Safety Regulation* prescribes PCBU's must manage risks associated with exposure to RCS and includes:

- **Regulation 49**, which requires PCBU's to ensure no person in a workplace is exposed to RCS at a concentration above the WES; and
- **Regulation 50**, which requires PCBU's to conduct air monitoring to determine workers RCS exposure concentration(s) in circumstances where:
 - The PCBU is uncertain if the concentration of RCS exceeds the WES; or
 - Monitoring will inform the determination of risk to workers health.

In general terms, "*compliance*" with the WES can only be determined by commissioning an air monitoring program, which is termed "*personal exposure monitoring*" and involves occupational hygienists who conduct sampling to determine a workers RCS exposure (or "dose") during the performance of their work activities, along with determining the exposure profile of worker groups (also known as "*Similar Exposure Groups*" or "*SEG's*").

4. Silica Workplace Exposure Standard

The RCS WES is 0.1 mg/m^3 and represents the legal concentration a worker can be exposed to over an 8-hour workday. Based on current knowledge, compliance with the WES will reduce the occurrence of silicosis and lung cancer (AIOH, 2009). It must be noted however, in circumstances where persons work unusual roster patterns involving more than 8-hours per day or 40-hours per week, an occupational hygienist should be consulted to advise on the suitable time weighted adjustment of the WES, commonly referred to as a “Time Weighted Average” WES (TWA-WES) (SWA, 2013).

4.1. Action Limit

PCBU’s should establish action values, which focus efforts to prevent worker overexposure. Typically, action limits are established to represent 50% of the WES, which is the same point at which health monitoring for RCS is recommended (AIOH, 2009).

5. How do I know if I Need to Monitor?

RCS is generated when quartz-containing materials (such as sandstone, concrete, granite and slate) are broken down. Breakdown activities during tunnel construction are typically mechanical in nature and include grinding, cutting, drilling, jackhammering, crushing and blasting.

A risk assessment should be conducted by a competent person to identify which work groups are anticipated to be exposed to RCS, along with determining the potential risk to health associated with such exposure. This is performed by an occupational hygienist.

6. Monitoring Silica Exposure

During tunnel construction, particular activities generate high RCS concentrations. Occupational hygienists perform exposure monitoring to measure these concentrations and perform an exposure assessment. This determines if control measures are effective at reducing exposure to a level that does not present a significant risk to the health of the workforce.

It is important to note that exposure monitoring to assess compliance with the WES should only be conducted after control measures have been put in place. Therefore, priority should be placed on implementing control measures to eliminate or reduce exposures prior to commencing an exposure monitoring program. It is important that such control measures are documented which may include recording them in a management plan, risk register, and Safe Work Method Statements (SWMS).

6.1. How is Monitoring Conducted?

6.1.1. AS/NZ 2985

Respirable dust and RCS personal exposure samples should always be collected in accordance with Australian Standard 2985 (2009) “*Workplace atmospheres - Method for sampling and gravimetric determination of respirable dust*”. Sampling instrumentation includes a sampling pump, fitted with tubing and connected to a size selective sampling head, which is attached to a person to sample the air within their breathing zone for a duration that is representative of their exposure period, however no less than 4 hours.

There are a number of sampling heads, or “cyclones” used to collect the sample. The current industry standard used to minimise variability while still conforming to the Australian Standard is to utilise a Higgins Dewell cyclone (manufactured by Casella Measurement, UK) sampling head, loaded with a 25 mm, 5 µm PVC membrane filter.

6.1.2. Sample Analysis and Reporting of Results

The sample head is loaded with a sample filter, which is to be sent to a NATA-accredited laboratory for analysis following the sampling event. Current industry standard is to have these samples analysed at TestSafe NSW, where X-ray diffraction (XRD) is utilised for analysis.

Two (2) field-sampling blanks should always be submitted to the laboratory with every sample “batch” to determine any contamination during sample handling and storage. All blank samples should be treated in the same manner as personal exposure samples; however no air should be drawn across the filter membrane.

The results of exposure monitoring are reported as a concentration in terms of milligrams of respirable quartz (crystalline silica) per cubic metre of air sampled (mg/m³). The measured exposure concentration is then compared with the TWA-WES.

6.2. What Workers Should be Monitored?

Workers performing any task that alters or disturbs quartz-containing material are at risk of exposure to RCS at high concentrations, particularly tunnel construction workers who work in environments where ventilation may be compromised.

Based on industry experience, the exposure monitoring process is most efficiently managed through assigning workers into specific categories, or Similar Exposure Groups (SEGs) where a risk assessment is then performed to assess the risk of exposure to each SEG. **Appendix 1** contains a list of SEGs that support tunnel projects that are commonly included in exposure monitoring programs for further information.

6.3. What Do The Results Mean?

Exposure to RCS at concentrations above the WES that are not adequately controlled represent a breach of Regulation 49 of the NSW Work Health and Safety Regulations (2017). An immediate review (and improvement) of control measures will be required in these cases.

Exposures above the WES significantly increases an individual’s risk of developing silicosis and other diseases. In such circumstances, controlling RCS exposure should be prioritised and control measures immediately implemented to minimise the risk of exposure, as consequences to workers health are irreversible.

6.3.1. Managing Individual Sample Results

The acceptability of personal exposure monitoring results should be determined by comparing the calculated RCS exposure concentration to the TWA-WES.

Due to the serious nature of RCS concentrations being measured above WES, it is recommended that such occurrences are recorded by the PCBU as an incident, or similar, and include efforts applied to investigate sources of exposure, along with the evaluation of controls required to improve the control of RCS in the workplace and prevent worker

exposure. The results of all investigation activities, including corrective actions should be recorded in a systematic manner such that evidence can be retrieved and presented if required.

All personal exposure results collected should be communicated to the affected workers. This is typically done via toolbox talks and displaying the results on the site noticeboard. An Exposure Category Rating system is commonly used, which is a simple way to group results dependant on the level of exposure relevant to the Workplace Exposure Standard (an example template is provided in **Appendix 2**).

6.3.2. Managing Group Exposure Data

Where comprehensive exposure monitoring programs are implemented that create a sizeable number of results, a Certified Occupational Hygienist (COH[®]) should be engaged to analyse the group exposure data to produce exposure profiles for each SEG. Exposure profiles are important as they can be applied to estimate the exposure intensity, understand exposure variation over time and make judgement regarding the exposure acceptability of the whole worker group.

6.4. How often should monitoring be conducted?

The frequency of exposure monitoring should be comparable to the assessed risk to health. This can be performed through a review of the PCBU's risk management standard, and linking the frequency of risk review to the level of assessed risk, for example.

Typical frequencies adopted on some major tunnelling projects include a sampling event no less than monthly per tunnelling site for risks assessed as High or Very High; no less than two-monthly per tunnelling site for risks assessed as Medium; and Quarterly otherwise. A sampling event typically consists of collecting approximately 10 to 12 personal exposure samples per event. In all cases, the level of protection afforded through the use of PPE is not taken into account when determining the level of risk to health.

7. Limitations of monitoring

While personal exposure sampling is useful in understanding the magnitude of risk associated with RCS exposure, such samples require laboratory analysis, often contributing to a lag time between sampling and a PCBU's ability to proactively implement controls to prevent worker exposure. In such circumstances PCBU's can utilise direct reading sampling instruments for purposes of measuring the ambient respirable dust concentration throughout the workplace in real-time which can be beneficial to evaluate controls or determine respirable dust emission sources.

It must be noted that numerous direct reading devices are commercially available; however the use of such are typically limited to very specific situations, therefore consideration should be given to the instrument selection and its use, with particular regard to the size, shape and reflectivity of total airborne particles, along with interference sources, where moisture is present in the air (e.g. water sprays, mist and humidity). Additionally, when using direct reading devices it is important to understand that the instrument needs to be fitted with devices such that only the respirable fraction is measured, and often requiring professional judgement with regard to extrapolating the likely concentration of RCS in the total respirable dust measured.

Monitoring personal exposure is the only way to understand compliance with the WES. “Static” sampling, or setting up sampling pumps in workplace areas are useful when seeking to understand the effectiveness of controls measures, or the identification of where additional control measures are needed. Such results however, cannot be compared to the WES for compliance purposes.

Exposure sampling, calculation and interpretation should only be carried out by a competent professional. In Australia, the *Australian Institute of Occupational Hygienists* (AIOH) has a directory of consultants who provide such services – find out more at www.aioh.org.au

Disclaimer

This document has been developed by volunteers of the ATS Air Quality Working Group and draws on the collective experience of those working across some of Australia’s largest tunnelling projects. The publication comprises 12 parts, and each part should be considered in the context of the other parts.

The information contained in this document is for general information and educational purposes only; it is not a comprehensive list of all factors to be considered and is not a substitute for legal or technical advice. Accordingly, you should consult with appropriate professionals and make your own inquiries as to the suitability of the information for your specific purposes. This document should not be reproduced in whole or in part, in any manner or form, without the prior written permission of the ATS.

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Appendix 1

Typical Similar Exposure Groups (SEGs)

This section provides a list of typical Similar Exposure Groups (SEGs) that are involved in the construction phase of tunnelling projects.

For each SEG, an associated recommendation for inclusion in an Exposure Monitoring Program for RCS is noted. This has been developed from a review of previous tunnelling projects and using the experience from members of the New South Wales AQWG, where the majority of tunnel construction occurs in quartz containing rocks such as Hawkesbury Sandstone, Mittagong Formation and Shale. Notwithstanding this, significant exposures to RCS can occur from non-host rock sources such as cement dust and shotcreting. The tables presented below include all anticipated sources of RCS when making a recommendation for monitoring exposure to the workers in these SEGs.

The recommendations may be used to assist with planning for those organisations that may not have any historical exposure data or information to assess whether RCS presents a significant risk to health. It cannot be relied upon as a quantitative or definitive decision that such listed SEGs are at significant risk, as this will depend on many factors that will be unique to each tunnel construction project. Competent persons such as Certified Occupational Hygienists (COH)[®] should be consulted in conjunction with project management teams to determine site specific requirements as part of an initial Risk Assessment prior to commencing work activities.

Generally, where there is uncertainty in determining if a significant risk to health exist, it is recommended that exposure monitoring be undertaken.

Table A - Typical SEGs associated with Precast Facilities to support Tunnel Construction

SEG No.	SEG Name	Description	Recommendation for Exposure Monitoring
SEGP1	Precast - Plant Operators and Supervisors	Plant operators and supervisors at a Precast Facility. Includes those plant operators who supply goods and materials to the facility.	
SEGP2	Precast – Gantry Crane Operators	Personnel operating gantry cranes at a Precast Facility.	
SEGP3	Precast – Maintenance Crew	Maintenance personal who service conveyors, components, and heavy machinery at a Precast Facility.	
SEGP4	Precast – General Labour	General labour that performs precast operations such as working on carousels and general clean up at a Precast Facility.	Yes
SEGP5	Precast – Concrete Testers	Those workers who perform concrete and materials testing at a Precast Facility (wet concrete works only).	
SEGP6	Precast – External Storage and Logistics	Workers involved in the logistics outside of the precast facility, including crane operations.	

Table B - Typical SEGs associated with Civil Construction to support Tunnel Construction

SEG No.	SEG Name	Description	Recommendation for Exposure Monitoring
SEGC1	Temporary Works Construction	Personnel operating cranes, forklifts, installing temporary services such as stormwater, water, sewer, utilities services, and scaffolding.	
SEGC2	Ground Support	Personnel involved in the installation of bored cast-in piles and pile head breaking and ground anchoring. This includes all workers involved in form, reo, pour concrete works, including capping beams.	Yes
SEGC3	Cut and Cover (C&C) Heavy Plant Operators	This includes personnel who operate heavy plant such as excavators, hammers, ADT (Moxy's) and compactors inside a cut and cover structure (either full or partially covered).	Yes
SEGC4	C&C Ground Crew	This includes all personnel performing ground work inside a C&C structure, including labouring and general spotter duties.	Yes
SEGC5	Shotcrete Crew	This includes all personnel involved in shotcreting activities and waterproofing, when applied using spray methods.	Yes
SEGC6	Heavy Plant Operators – Above Ground	This includes personnel who operate heavy plant outside of an excavation such as truck and dogs transporting deliveries across or to and from site, or the watercart etc.	
SEGC7	Traffic control	Workers performing traffic control activities.	
SEGC8	Peggy	The Peggy provides general cleaning including washing and drying work clothes, and maintaining the showers and laundry.	Yes
SEGC9	Bullgang	The bullgang crew perform a range of above-ground activities to support operations.	
SEGC10	Supervisors / Surveyors / Engineers	Supervisors / surveyors and engineers who work with the crews on an intermittent and non-routine basis. This applies to above ground and C&C works.	Yes
SEGC11	Stores	Maintain store and lay down material, equipment. Control materials, equipment orders, deliveries used by workforce.	

Table C – Typical SEGs associated with Shaft / Station Box Construction

SEG No.	SEG Name	Description	Recommendation for Exposure Monitoring
SEGS1	Heavy Plant Operators – Shaft / Box Construction	Personnel who operate heavy plant such as excavators, hammers, ADT (Moxy's) inside a shaft or box construction.	Yes
SEGS2	Bolt, Mesh, Shotcrete Crew	Personnel involved in bolt/mesh/shotcreting activities and waterproofing, when applied using spray methods.	Yes
SEGS3	General Labour	Persons on-foot in the shaft / box during construction.	Yes
SEGS4	Heavy Plant Operators – Spoil Transfer	Plant operators involved in spoil removal to surface via ADT. Also includes operators who drive Concrete agitator tucks (Agi's) to deliver shotcrete.	Yes
SEGS5	Mechanical / Electrical Crew	Mechanics and electricians who work in a shaft/station box.	Yes
SEGS6	Supervisors and Surveyors	Supervisors and surveyors on-foot in the shaft / box during construction.	Yes

Table D – Typical SEGs associated with Mined Tunnel Construction

SEG No.	SEG Name	Description	Recommendation for Exposure Monitoring
SEGT1	Road Header (RH) Operator – Open Cabin	Road header operators working within an open cabin road header.	Yes
SEGT2	Road Header (RH) Operator – Closed Cabin	Road header operators working within a closed and pressurised cabin road header.	Yes
SEGT3	Drill & Blast	All persons involved in drill and blast activities who enter the tunnel post-blast.	Yes
SEGT4	Bolt, Mesh, Shotcrete Crew	Personnel involved in bolt/mesh/shotcreting activities and waterproofing, when applied using spray methods.	Yes
SEGT5	Tunnellers	Tunnellers are required to complete a range of ancillary tasks in the tunnel including service relocation, relocation and extension of ventilation and extraction and high pressure water blasting. This SEG includes RH offside work and all ground personnel not performing any other specific activity listed in this table.	Yes
SEGT6	Underground Heavy Plant Ops	Plant operators that work underground. This SEG includes operators who drive the Concrete agitator tucks (Agi's) which deliver shotcrete to the tunnel face underground.	Yes

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SEG No.	SEG Name	Description	Recommendation for Exposure Monitoring
SEGT7	Spoil Shed Heavy Plant Ops	Heavy plant operators including telehandlers, FEL, watercart inside the spoil shed.	Yes
SEGT8	Spoil Shed Ground Crew	Ground crew performing refuelling, supervision, spotters, gantry crane operator, general labour inside spoil shed enclosures not otherwise classified in this table.	Yes
SEGT9	Mechanics	This crew comprises mechanics installing ventilation and systems and extending these services as the tunnel advances. It includes mobile equipment maintainers such as boilermakers and welders, and those that perform maintenance activities on heavy plant.	Yes
SEGT10	Supervisors / Surveyors / Engineers	Supervisors / surveyors and engineers who work with the crews on an intermittent and non-routine basis. This applies to works where a portion of the shift is spent underground.	Yes
SEGT11	Electricians	This crew comprises electricians installing lighting systems and extending these services as the tunnel advances. This crew installs HV & Comms pits; fire mains etc. This crew work both above and below ground.	Yes
SEGT12	Cross Passage Fit Out	This includes workers erecting blockwork and precast structures, drilling to install anchors; joint sealing; grouting; and connection of services.	Yes

Table E – Typical SEGs associated with Back End Work (BEW) Operations

SEG No.	SEG Name	Description	Recommendation for Exposure Monitoring
SEGB1	Road Profiler Operators and Offsiders	This includes personnel who operate a road profiler, which is an open-cabin machine. Operation typically involves approximately two workers, one who stands on top of the profiler, and one who is located adjacent to it during operation. Road profiling activities occur a far distance back from the ventilation extraction system.	Yes
SEGB2	Surface Miner Operators	This includes personnel who operate surface miners which typically have enclosed cabins.	Yes
SEGB3	BEW Excavation Heavy Plant Operators	This includes personnel that operate involving excavators performing hammering or mucking out activities that are not located adjacent to the ventilation extraction system. It includes Moxy's trucking out spoil from back end works; and draining trench excavation which involves saw cutting of the trench.	Yes
SEGB4	BEW Spotters	This includes all personnel performing spotting activities adjacent to heavy plant performing Back End Works such as spotters for Surface Miners who help direct the machine.	Yes
SEGB5	FRP Crew	This includes all workers involved in form, reo, pour activities for cross passage construction, underground concrete paving, and drainage trenches. Typical significant exposures include diesel exhaust from concrete agi's, dermal exposure to hazardous substances, thermal heat stress, and manual handling.	Yes
SEGB6	BEW Painting	This includes persons involved in painting the tunnel roof, and includes use of elevated work platforms and application of paint through spray methods.	Yes
SEGB7	Pit & Pipe Installation	This includes personnel operating drills to install saddle clamps and brackets; placing pipes and pits to tunnel; and HDPE Welding activities.	Yes

Table F – Typical SEGs associated with Tunnel Boring Machine (TBM) Operations

SEG No.	SEG Name	Description	Recommendation for Exposure Monitoring
SEGM1	TBM Operator	TBM Operator working for the majority of the time in the enclosed TBM operators cabin	Yes
SEGM2	Ring Builders	Includes ring builders and ring build assistants who install precast segmental lining.	Yes
SEGM3	TBM Back End	Includes grouters, segment handlers, services extension and operators of the TSP/MSV who work at the back-end of the TBM.	Yes
SEGM4	XP Tunneller	Workers performing labouring duties on-foot to support cross-passage construction.	Yes
SEGM5	XP Excavation	Personnel operating equipment to excavate a cross-passage (e.g. Brokk)	Yes
SEGM6	XP Transfer	Personnel operating ADT (Moxy's) to transfer spoil from cross-passage excavation	Yes
SEGM7	XP Formwork	Personnel installing formwork in preparation for concrete installation	Yes
SEGM8	XP Steelfixer	Personnel installing reo and steel fixes	Yes
SEGM9	XP Waterproofing	Personnel applying waterproof membrane.	Yes

Appendix 2

Communication of Results

Project Site		Supervisor	
Date		Shift	

Similar Exposed Groups (SEG) Assessed			
SEGT1	Roadheader Operator (open cabin)	SEGT5	Tunnellers
SEGT7	Spoil Shed Heavy Plant Operators	SEGT6	Underground Heavy Plant Operators

Control Measures Observed	
List...	

Exposure Category*	SEG	Activity	Hazardous Agent	Measured Result	Exposure Category post-PPE* ¹	Minimum Recommended RPE
4	SEGT5	Tunneller #2 (Grouting)	RCS	0.34 mg/m ³	3	Full Face RPE with P3 filters
4	SEGT1	RH Operator	RCS	0.15 mg/m ³	2	P2
4	SEGT5	Tunneller #1	RCS	0.14 mg/m ³	1	P2
4	SEGT7	Loader – Spoil Shed	RCS	0.10 mg/m ³	1	P2
3	SEGT5	Tunneller #2 (Grouting)	RD	1.0 mg/m ³	1	P2
2	SEGT1	RH Operator	RD	0.3 mg/m ³	1	-
2	SEGT7	Loader – Spoil Shed	RD	0.6 mg/m ³	1	-
2	SEGT5	Tunneller #1	RD	0.5 mg/m ³	1	-

- RD = Respirable Dust; RCS = Respirable Crystalline Silica; DPM = Diesel Particulate Matter
- Exposure Category post-PPE*¹ – assumes that assessed workers effectively utilized P2 RPE.
- For details whether such workers utilised this type of RPE, refer to complete Exposure Assessment Report.

Exposure Category*	
5	10x Exceedance of the Workplace Exposure Standard (WES)
4	Exceedance of the WES
3	Exposure between 50% of the WES and the WES
2	Exposure between 10% of the WES and 50% of the WES
1	Exposure below 10% of the WES

Workplace Exposure Standards (WESs) for persons working on the XYZ Project have been adjusted¹ for persons working 12 hour shifts for a roster period averaging 63 working hours per week² and are outlined in the table below:

Shift-Adjusted Workplace Exposure Standards	
Parameter	Time Weighted Average (TWA-WES)
Respirable Dust (RD)	1.4 mg/m ³
Respirable Crystalline Silica (RCS)	0.06 mg/m ³

¹ Adjusted in accordance with Safe Work Australia's ["Guidance on the interpretation of Workplace Exposure Standards for Airborne Contaminants"](#) (SWA, 2013).

² Average 63 hours per week.