Dust in mines other than coal mines

Brief to the Coal Workers' Pneumoconiosis Select Committee

8 June 2017

Queensland Government

This publication has been compiled by Mines Safety and Health, Department of Natural Resources and Mines.

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1 SUMMARY

The breadth and diversity of the Queensland mineral mines and quarries industry is significant, in terms of its geographical spread, range of materials extracted, mining methods, number of people employed on each site, hazards present and, consequently, safety and health risk profile. The regulatory framework for safety and health in Queensland mineral mines and quarries is established by the *Mining and Quarrying Safety and Health Act 1999* (the Act) and *Mining and Quarrying Safety and Health Regulation 2001* (the Regulation), and is administered by the Mines Inspectorate, DNRM.

This brief provides an overview of the regulatory framework for dust in mineral mines and quarries, its enforcement by the Mines Inspectorate, and trends in dust-related exposure and disease in industry. The brief is divided into three primary sections, covering:

1. The Act and Regulation, as they apply to dust in mineral mines and quarries;
2. The regulatory response from the Mines Inspectorate; and
3. Future initiatives for dust-related regulatory action in mineral mines and quarries.

The Act and Regulation place a range of risk-based safety and health obligations on site senior executives (SSEs), who are the most senior officers responsible for and located at or near mines. The Regulation requires SSEs to manage risk from exposure to hazards generally by undertaking, where appropriate, health assessments for all prospective mine workers, limiting worker's exposure to hazards by implementing appropriate risk reduction controls, monitoring exposure and conducting health surveillance, and keep records in respect of all of these activities.

The Mines Inspectorate has maintained strong engagement with industry to ensure both the safety and health of mine workers are protected. Most recently, the Mines Inspectorate has collaborated with the tripartite Mines Safety and Health Committee (MSHAC)[1] to produce a guideline for management of Respirable Crystalline Silica in Queensland Mineral Mines and Quarries, which incorporated learnings identified in the Monash Review. The Mines Inspectorate and MSHAC also collaborated to determine a list of reportable diseases, now prescribed in the Regulation.

The Mines Inspectorate has also undertaken studies of RCS exposure in Queensland mines and quarries, which has included a comparative assessment of RCS health effects in Queensland and other major mining jurisdictions. Where necessary and proportionate to risks on site, the Mines Inspectorate has relied on its regulatory powers to ensure compliance with dust-related provisions in the Act and Regulation.

Ongoing engagement, education and enforcement activity by the Mines Inspectorate has supported continuous safety and health improvement in Queensland mineral mines and quarries, including in respect of dust-related hazards.

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[1] MSHAC is a tripartite body established under the Act, with representation from Australian Workers' Union (AWU); Australian Manufacturers' Workers Union (AMWU); Queensland quarrying industry, Queensland Resources Council (QRC), and DNRM - Mine Safety and Health.

2 LEGISLATION: THE CURRENT REGULATORY FRAMEWORK

Statutory framework and regulatory instruments

The Act	Establishes the Commissioner for Mine Safety and Health, MSHAC, Mines Inspectorate, District Worker Representatives (DWRs) and Site Safety and Health Representatives (SSHRs). Mines must have a Safety and Health Management System, and a management structure including key statutory officers (certified as competent by a board of examiners, based on MSHAC competencies).
The Regulation	Prescribes duties in respect of worker safety and health, and ways of achieving an acceptable level of risk.
Guidelines	Made by the Minister under the Act. Where guidelines state a way or ways of achieving an acceptable level of risk, a person must adopt and follow the stated way or adopt and follow another way that achieves an equal or better than acceptable level of risk.
Safe Work Australia (formerly NOHSC) guidelines	Guidelines produced by SafeWork Australia, and cited in the Regulation. The SSE must as a minimum consider relevant guidelines unless otherwise prescribed.
Australian standards and national standards	SSEs must also consider any Australian or national standard in discharging their safety and health obligations under the Regulation.
Guidance notes	The Mines Inspectorate produce guidance material to ensure industry understand are supported in complying with the Act and Regulation.
Reasonable available industry information	The SSE is required to consider reasonably available industry information in assessing risk and applying control measures.

Key safety and health concepts for mineral mines and quarries

Site senior executive (SSE)	Most senior person employed/engaged for mine who is located at or near the mine, and has responsibility for the mine
Risk monitoring	Monitoring the occurrence of incidents, injuries and ill health; levels of hazards in a mine's work and local environment
Risk management record	Record of risk management process, including name of persons involved, description of hazard to which process relates, method used for assessing likelihood and consequence of risk, controls to reduce risk
Exposure limit	General exposure limit, or lower exposure level for worker shown following health assessment
Health assessment	Assessment of physical and medical condition of a mine worker for any condition that may impair the worker's ability to tolerate hazard
Exposure monitoring	Monitoring of hazard at a mine that has the potential to exceed exposure limit, or for which the risk level may vary
Health surveillance	Surveillance done by or under the direction of an appropriate doctor to assess the effects on a worker's health related to exposure to a hazard and the need, if any, for remedial action
Health surveillance report	Information, provided by an appropriate doctor, other than a medical record, about the effects on a worker's health related to exposure to a hazard and the need, if any, for remedial action

What are the obligations of SSEs?

With regard to ensuring the health of workers, SSEs owe obligations across four key areas: risk monitoring, health assessment, hazard exposure, and health surveillance. In respect of **risk monitoring**, SSEs must:

- Monitor risks and, if appropriate, this must include: personal monitoring of workers, self-monitoring by workers, biological monitoring, and health surveillance.
- Keep risk management record until the relevant hazard is no longer present at the mine.
- Keep risk monitoring records for 30 years for a hazard with a cumulative or delayed effect, or otherwise for 7 years.
- Seek and comply with Chief Executive directions about storage of risk monitoring records, if mine operations cease.

In respect of **health assessments**, SSEs must:

- Carry out a health assessment where the hazard has a potential to cause a significant adverse effect, before a worker is exposed to a hazard at the mine and periodically as necessary to assess changes in the worker's tolerance.
- Keep records of health assessment.
- Carry out appropriate health assessment for visitors.

In respect of **hazard exposure**, SSEs must

- Ensure a worker's exposure does not exceed the exposure limit applying to the worker for a hazard, and is as low as reasonably achievable. The applicable exposure limit could either be the defined 'general exposure limit' (Figure 1), or a lower limit based on a workers' health assessment and personal factors.
- The occupational exposure limit (OEL) for silica is 0.1 mg/m^3, which mirrors limits set in NSW and WA. This reflects the SafeWork Australia standard.
- Ensure exposure level is adjusted to account for non-standard work cycles. This includes work cycles in variance to an 8-hour workday with 40 per week; cycles that decrease the available time for a worker to recover from the adverse effect of the hazard, and cycles involving strenuous work that may increase the effects of a hazard.
- Undertake exposure monitoring of workers. Two standards apply: AS 3640 for inspirable dust and AS 2985 for respirable dust.
- If exposure exceeds a worker's limit, the SSE must implement control measures, in accordance with the hierarchy of control measures to ensure the worker's exposure is below the exposure limit and as low as reasonably achievable.
- If a worker suffers adverse effects from exposure to a hazard, the SSE must remove the worker from, and ensure the worker does not resume, work that would increase effects or prevent effects from decreasing.

- If exposure exceeds a worker's limit, the SSE must implement control measures, in accordance with the hierarchy of control measures to ensure that worker exposure is below the exposure limit and as low as reasonably achievable.
- Provide personal protective equipment (PPE) if necessary to reduce exposure, and ensure it is used competently and is effective in reducing the worker's exposure.

In respect of **health surveillance**, SSEs must:

- Arrange health surveillance if the SSE believes or ought reasonably believe exposure may result in an adverse health effect, the effect may happen under work conditions, and a valid monitoring procedure is available to detect the effect.
- Arrange for surveillance to be done by or under the direction of an appropriate doctor.
- Ask the doctor to give health surveillance report to SSE and worker.
- Keep health surveillance reports for 30 years for hazards with a cumulative or delayed effect, or otherwise for 7 years.
- Seek and comply with Chief Executive directions about storage of health surveillance reports, if mine operations cease.

Figure 1 - General exposure limits under the Regulation

Hazard	General exposure limit
Atmospheric contaminant	Exposure standard assigned to the contaminant in NOHSC document 'Adopted National Exposure Standards for Atmospheric Contaminants in the Occupational Environment [NOHSC:1003]'
Crystalline silica (cristobalite, quartz, tridymite)	0.1 mg/m^3
Inspirable dust	10 mg/m^3
Ionising radiation	Dose limit stated into NOHSC document 'National Standard for Limiting Occupational Exposure to Ionising Radiation [NOHSC:1013]'
Noise	Dose limit stated in NOHSC document 'National Standard for Occupational Noise [NOHSC:1007]
Respirable dust	5 mg/m^3
Respirable synthetic mineral fibre	0.5 fibre/mL air

What are the obligations of employers and workers?

Employers must pay for a workers' health assessment and surveillance, and associated reports. If a worker is given PPE, the worker must use it when their level of risk from a hazard is unacceptable.

What are the obligations of DNRM?

The Chief Executive, through DNRM, must keep and maintain records, including a database of information about hazards and methods of controlling them, data on Lost Time Injuries (LTIs) and High Potential Incidents (HPIs) and current guidelines published by the Mines Inspectorate. The Chief Executive must also give direction about the storage of risk monitoring records and health surveillance reports, if mine operations cease during the relevant recordkeeping period.

Alerts, bulletins and notices published by the Mines Inspectorate are available here.

3 IMPLEMENTING THE CURRENT REGULATORY FRAMEWORK

The Mines Inspectorate applies an effective, risk-based approach to reduce safety and health risks in Queensland mineral mines and quarries. The Mines Inspectorate has regulatory responsibility for than 1,000 sites in Queensland. These sites range from sole operators, tourist mines and small mines employing fewer than five workers to major surface and underground operations with more than one thousand workers on site. An indicative illustration of the breadth and variability of Queensland's mineral mines and quarries is set out at Appendices A and B.

To respond to the diverse safety and health imperatives of the mineral mining and quarrying industry in Queensland, the Mines Inspectorate conducts inspections and audits, investigate incidents and complaints, and take enforcement action where appropriate. Critically, the Mines Inspectorate also shares information and knowledge with industry to reduce risk, and maintain close engagement with key stakeholders.

Education and engagement

Since 2007, the Mines Inspectorate undertook a study to approximate RCS exposure at mines and quarries, including dimension stone and sand processing operations. Results showed some quarries did not have adequate health surveillance in place. These findings were relayed to industry through:

- Delivery of papers on preliminary findings at the Australian Institute of Occupational Hygienists (AIOH) 2007 and 2008 annual conferences– **Attachments 1 and 2.**
- Delivery of a paper outlining final conclusions of the study at the AIOH 2011 annual conference – **Attachment 3**

In January 2009, the Mines Inspectorate expanded the study to cover 420 small to medium sized mineral mines, quarries and exploration sites in Queensland. This study found most mines are monitoring for dust, but that personal monitoring programs in place at a number of mines were inadequate. Findings and recommendations to industry from this study were communicated through:

- Publication of 'RCS Questionnaire Feedback Report' in 2009 – **Attachment 4**
- Delivery of the 'Dust Self-Assessment Feedback Report: Part B – Metal' in 2010 – **Attachment 5**
- Publication of 'Mines Safety Bulletin No. 88 – Management of dust containing crystalline silica (quartz)' in 2010- **Attachment 6**
- Presentations to industry regarding dust-related hazards– see **Attachment 7** for a sample presentation
- Publication of a 'Silica and the lung' factsheet in 2013 – **Attachment 8**

The Mines Inspectorate emphasises the importance of adequate control strategies, in line with the hierarchy of controls: elimination, substitution, engineering, and administrative controls and finally control through PPE. Bulletin No. 88 provided clear guidance on how monitoring should be carried out to determine baseline exposure levels for particular jobs and tasks.

In 2010, the Mines Inspectorate also published results from a trial of pre-cleaner, filter and pressurisation (PFP) units at sandstone mines, the 'RESPA™ Trial 2009' – **Attachment 9**. The trial confirmed the efficacy of PFP units to reduce exposure to RCS. The Mines Inspectorate issued a directive requiring all operators in sandstone cutting operations to wear suitable respiratory protection equipment, measure RCS exposure levels, and take action to remediate any overexposure.

Incidents and complaints

There is one confirmed case of silicosis, which was reported directly by the individual to the Mines Inspectorate, and is currently under investigation. There have been approximately 120 complaints from workers or other stakeholders regarding dust-related hazards received by the Mines Inspectorate since the year 2000.

Compliance action

Where a mine is not managing a hazard to an acceptable level of risk, the Mines Inspectorate has a range of compliance tools under the legislation to address this, including issuing directives, directing the mine's SSE or senior management to attend a compliance meeting or prosecution. The Mines Inspectorate may also issue a notice of Substandard Conditions or Practice, or an "SCP". An SCP is advice given to mine operators, SSEs or other obligation-holders about how to manage risk to an acceptable level.

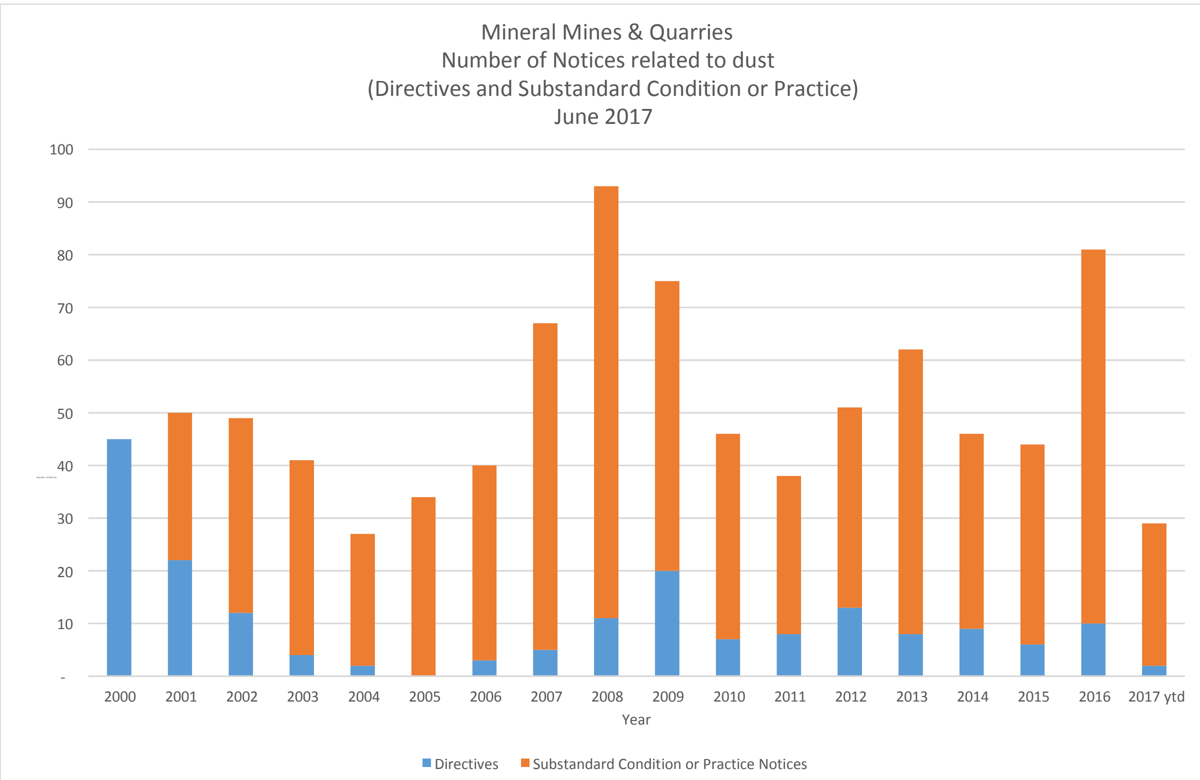
The Mines Inspectorate will determine the most appropriate course of action on a case-by-case basis.

In responding to issues concerning respirable crystalline silica, a compliance response which is conducive to immediately addressing the risk is preferred so as to minimise worker exposure and enable the mine to develop sustainable dust controls.

When taking compliance action, inspectors will make a mine record entry (MRE). This is information entered into the mine record that operators must maintain under the Act, detailing compliance action taken or advice given.

Since 2000, the Mines Inspectorate has made 918 MREs – comprising 178 directives and 731 SCPs - concerning issues with dust in mineral mines and quarries, as illustrated in the graph below.

Figure 2 - MREs related to dust



Directives issued have included requirements to:

- Provide health surveillance for workers
- Review the mine's safety and health management system
- Provide exposure monitoring and at times
- Suspend particular activities or operations for unacceptable level of risk.

The MREs relating to dust represent a small percentage (approximately 5%) of total MREs for all hazards.

DNRM is compiling these MREs and will provide them to the committee for its consideration.

4 Future Directions

Learning from the Monash Review

Upon receipt of the Monash Review in July 2016, the Mines Inspectorate have commenced a project to produce a guideline on 'Management of RCS in Mineral Mines and Quarries' along with a 'Management of RCS' SIG. The guideline references relevant recommendations from the final report of the Respiratory Component of the Coal Mine Workers' Health Scheme by the Monash Centre for Occupational Health (Monash Review), particularly:

- Recommendations 4-5, concerning health assessment forms
- Recommendations 7-10, concerning registration and training of doctors
- Recommendation 11, concerning the competency of staff performing and interpreting CXRs
- Recommendation 12, concerning the competency of staff performing and interpreting spirometry
- Recommendation 13, concerning the handling and storage of health assessment forms
- Recommendation 16, concerning employee exit respiratory health assessments.

The draft RCS guideline and SIG are attached at **Attachment 10** and **Attachment 11**.

A review of the Monash recommendations and how they are addressed is also included in the draft RCS guideline.

Reportable diseases

In response to the Monash Review, the Regulation was amended to list a range of reportable diseases agreed on by MSHAC. The Regulation commenced on 1 January 2017, and lists the following reportable diseases:

- Asbestosis
- Chronic obstructive pulmonary disease
- Legionellosis
- Occupational asthma
- Occupational cancer

- Silicosis

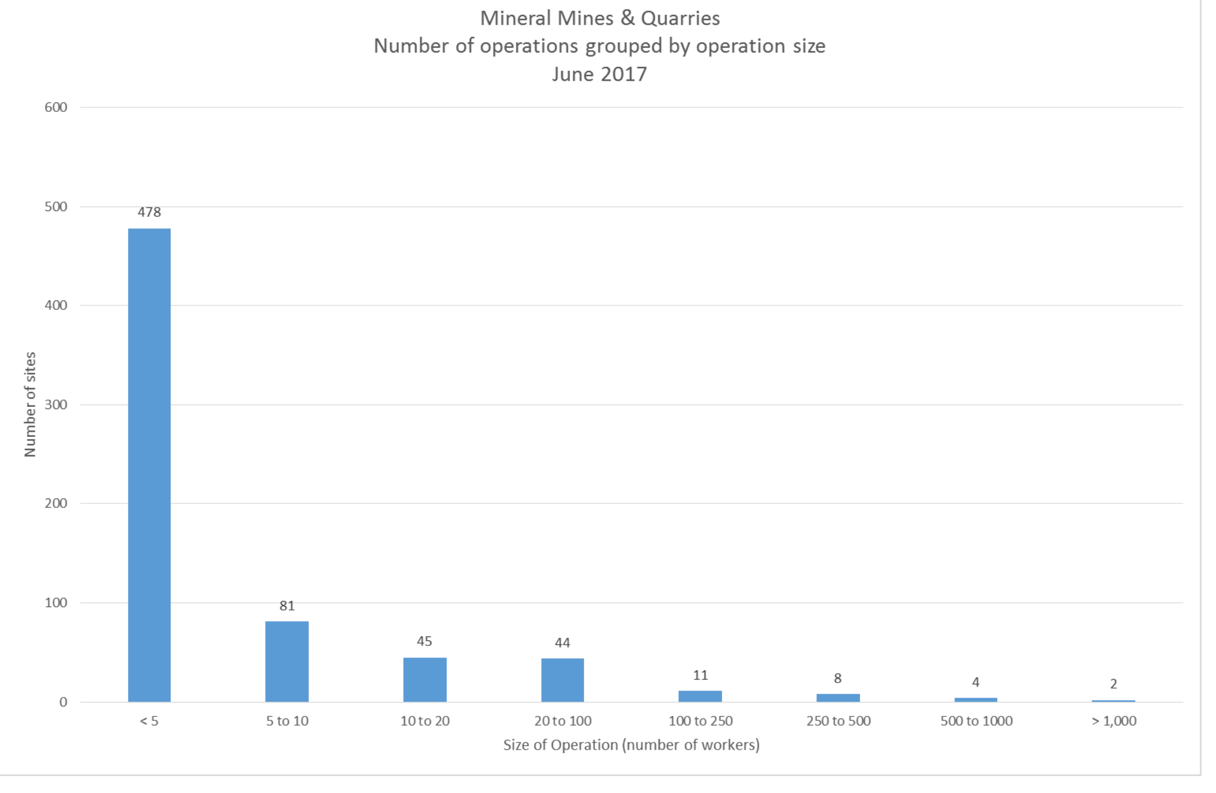
The draft RCS guideline (**Attachment 10**) requires SSEs to report an exceedance of RCS above prescribed exposure limits. The SSE must also implement health surveillance for workers or workgroups with a mean exposure in excess of 50% of the exposure limit.

Supporting small operations

The Mines Inspectorate works to ensure small mines and quarries can comply with the Act and Regulation. The RCS guideline has been developed to be scalable; the critical obligation is the reduction of exposure to RCS through the implementation of high order control measures. Exposure monitoring must be undertaken by a competent person under the direction of a qualified occupational hygienist, and in compliance with AS 2985. The exposure monitoring verifies the effectiveness of the control measures, and is linked to the size of the operation. In this way, the Mines Inspectorate aims to provide regulatory support to operators of all sizes.

Figure 3 below shows the number of mines and quarries in Queensland, grouped by operation size.

Figure 3 - Operation size of Queensland mines and quarries



Risk-based inspections

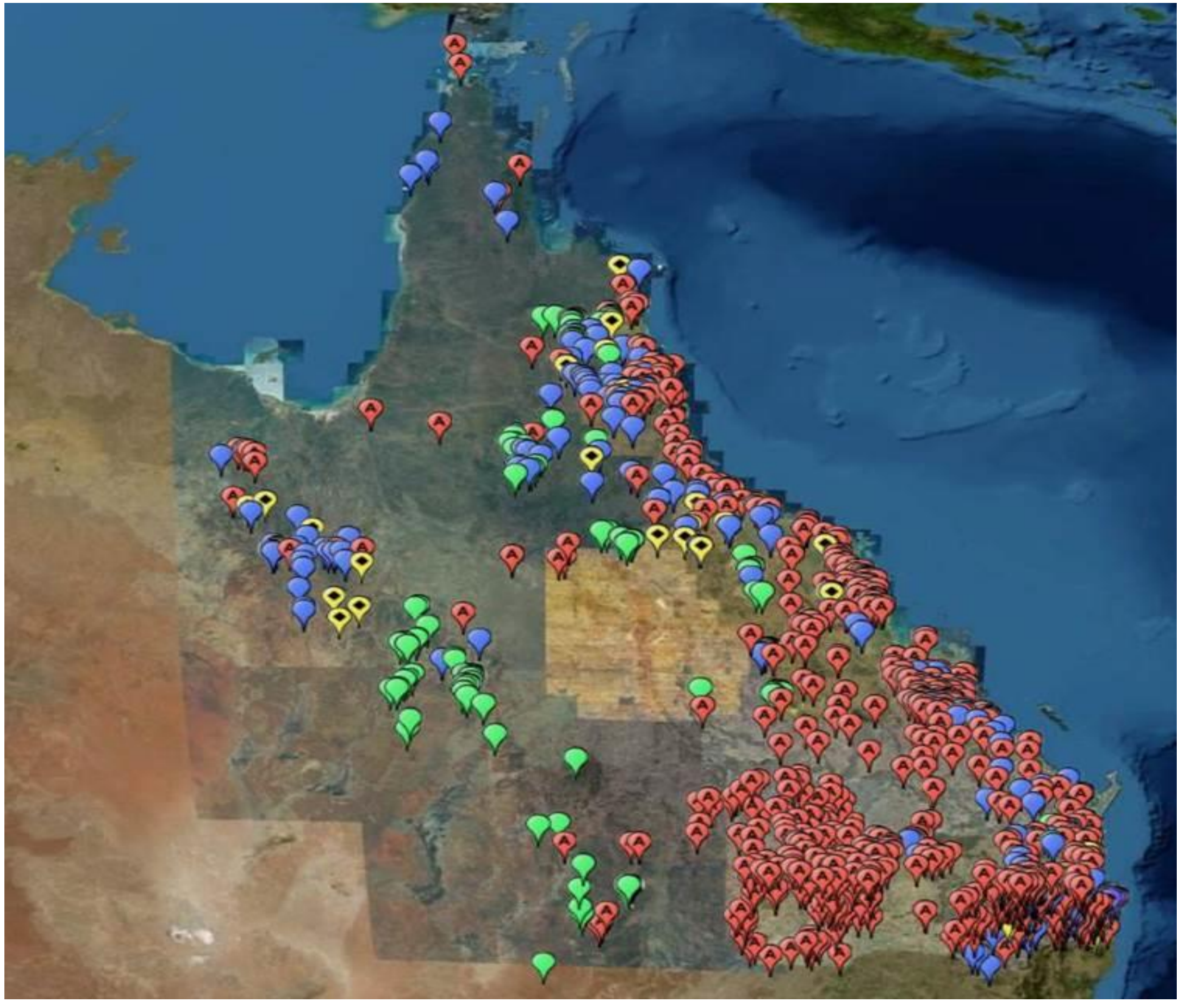
For the 2016-17 year, the Mines Inspectorate have prioritised inspections at underground metalliferous mines and sandstone mines, based on their dust-related risk profiles.

Figure 4 outlines recent and planned inspections at sandstone and underground metalliferous mines and quarries. Appendices A and B also highlight the diversity of Queensland mineral mines and quarries.

Figure 4 - High-risk sites in Queensland

Inspection Status	Operational status	Region/District Office	Mine Type
8-Dec-16	Operating	N/West - Mt Isa	Metalliferous - Underground
9-Dec-16	Operating	N/West - Mt Isa	Metalliferous - Underground
17-Mar-17	Operating	N/West - Mt Isa	Metalliferous - Underground
28-Mar-17	Operating	N/West - Mt Isa	Metalliferous - Underground
29-Mar-17	Operating	N/West - Mt Isa	Metalliferous - Underground
6-Apr-17	Operating	North - Townsville	Metalliferous - Underground
7-Apr-17	Operating	North - Townsville	Metalliferous - Underground
10-Apr-17	Operating	South - Brisbane	Sandstone
11-Apr-17	Operating	South - Brisbane	Sandstone
11-Apr-17	Operating	South - Brisbane	Sandstone
12-Apr-17	Care & Maintenance	South - Brisbane	Sandstone
12-Apr-17	Operating	South - Brisbane	Sandstone
3-May-17	Operating	N/West - Mt Isa	Metalliferous - Underground
4-May-17	Operating	N/West - Mt Isa	Metalliferous - Underground
15-May-17	Operating	South - Brisbane	Sandstone
15-May-17	Operating	South - Brisbane	Sandstone
16-May-17	Operating	South - Brisbane	Sandstone
16-May-17	Operating	South - Brisbane	Sandstone
17-May-17	Operating	South - Brisbane	Sandstone
17-May-17	Operating	South - Brisbane	Sandstone
18-May-17	Operating	South - Brisbane	Sandstone
Planned for June 2017	Operating	Central - Rockhampton	Metalliferous - Underground
Yet to be planned	Operating	North - Townsville	Metalliferous - Underground

APPENDIX A: QUEENSLAND'S MINERAL MINES, QUARRIES



Gemstone mine

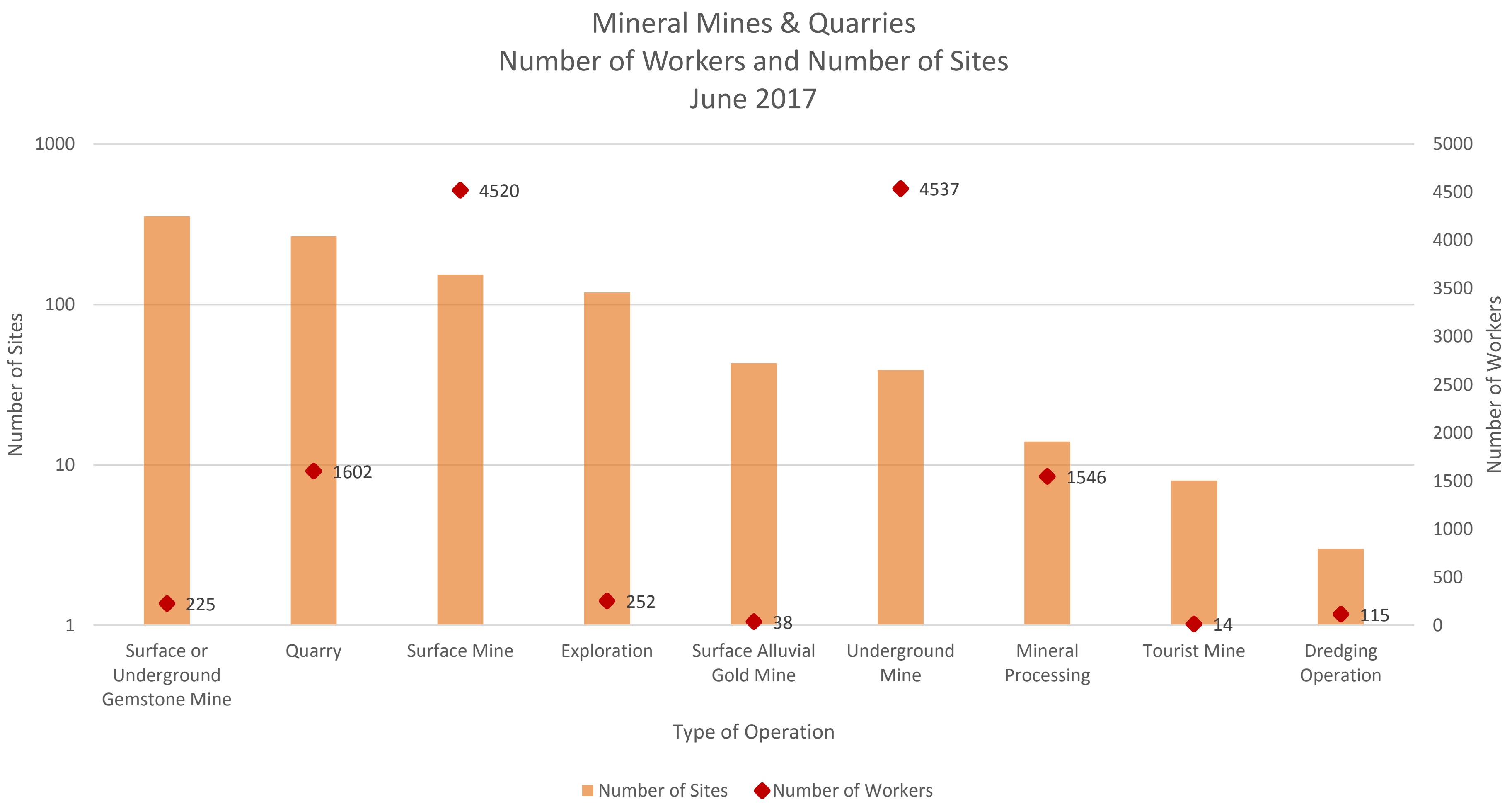
Surface mine

Underground mine

Quarry

This graphic is illustrative of the number, type and distribution of operations for which the Mines Inspectorate has regulatory responsibility.

APPENDIX B - THE QUEENSLAND MINERAL MINES AND QUARRIES SECTOR



AIRBORNE CRYSTALLINE SILICA (RCS) IN QUEENSLAND QUARRYING PROCESSES, PARTICLE SIZE AND POTENCY.

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1. ABSTRACT

In Queensland, quarry operators are potentially exposed to freshly cut quartzite. Alpha quartz is a form of crystalline silica, which can lead to silicosis. There is also a growing body of evidence to suggest that respirable crystalline silica (RCS) is one of the causative agents that leads to chronic obstructive pulmonary disease (COPD). This paper presents findings from an ongoing literature survey, to explore if the current method of sampling for RCS in Australia for gravimetric determination of respirable dust compares to international practices. This paper also provides an update on particle size, crystal properties and potency. Information presented, can be used to raise awareness about the hazardous nature of RCS in industry.

2. INTRODUCTION

Quarries are the primary source for "extractive materials" or "aggregates" used for building roads, ports, airports, bridges, railways, factories, hospitals and homes. A variety of rock types are extracted in Queensland. Crushed aggregates are generally derived from deposits of intrusive and extruded igneous and volcanic rocks, including granite, trachyte and trachyandsite, rhyolite, basalt and a variety of metamorphic rocks including greywacke, greenstone, hornfels and quartzite. Crushing operations in quarries are potentially dusty operations and the crusher operator has potential to be exposed to respirable dust including respirable crystalline silica (DME 2006).

Silicosis is considered to be a slowly developing and progressive disease, not always diagnosed during a working life. There are a number of studies that demonstrate the relationship between loss of lung function and cumulative exposure to respirable dust and respirable crystalline silica (Ulvestad et al 2001, Meijer et al 2001). Some studies demonstrate a loss of lung function below the current Australian Safety and Compensation Council (ASCC) exposure standard – time weighted average of 0.1 mg m^{-3} (Kim et al 2002). Exposure to respirable crystalline silica, a common contaminant of mining and quarry operations, results in the lung damaging diseases known as silicosis and chronic obstructive pulmonary disease (NIOSH 2002). Long-term exposure to respirable crystalline silica can lead to an increased risk of lung cancer. The International Agency for Research on Cancer (IARC 1997) published a monograph which reported that respirable crystalline silica was a cause of lung cancer in humans (Group 1). According to the National Occupational Health and Safety Commission Exposure Standards for Atmospheric Contaminants in the Occupational Environment (NOHSC 3008, NOHSC 1003: 1995), exposure standards, "according to current knowledge, should neither impair the health of nor cause undue discomfort to nearly all worker*s*" (NOHSC, 1995 p4). The current Australian Safety Compensation Commission exposure standard for the most common form of crystalline silica is 0.1 mg m^{-3} (measured as respirable crystalline silica). The Health and Safety Executive 2002 acknowledged that exposure to crystalline silica at concentrations below 0.1 mg m^{-3} over a long period could lead to silicosis.

From the above, it is important that industry understand that Occupational Exposure Limits (OEL) are not fine dividing lines between safe and unsafe exposures.

The current sampling methodology has limitations, in quantifying similar group exposure concentrations with statistical confidence below 0.1 mg m^{-3}. In addition, the literature is suggesting that a sub-fraction of respirable crystalline silica is more likely a pre-cursor to silicosis.

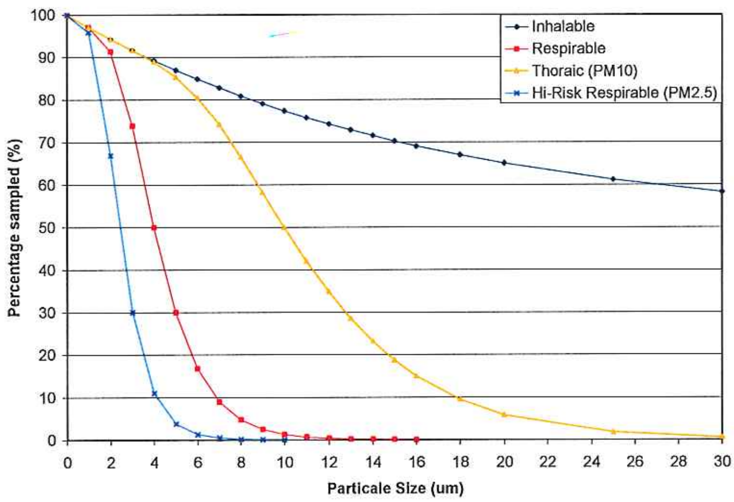
Further research is required towards improve sampling methodologies and understanding the crystalline silica properties, such as particle size and shape that may exert detrimental effects on the lung.

3. DISCUSSION

3.1 Sampling and particle size.

Currently the method used to sample airborne dust containing respirable crystalline silica is AS 2986 (2004) which follows ISO 7708:1995, Air quality – Particle size fraction definitions for health related sampling. According to AS 2986 (2004), respirable dust, is the proportion of airborne particulate matter which, when inhaled, penetrates to the un-ciliated airways.

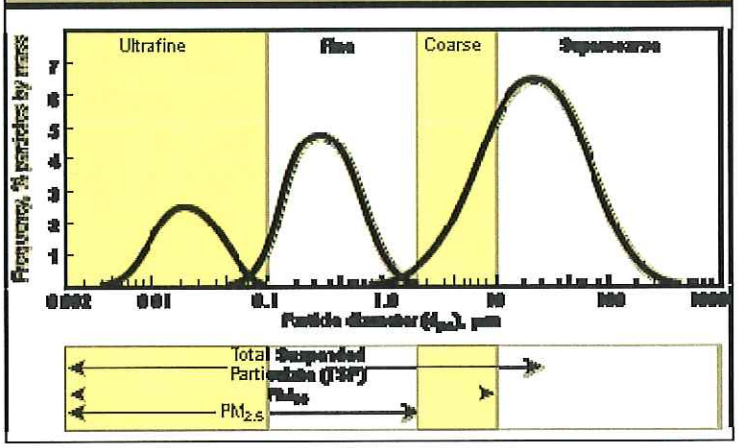
Figure 1 Particle size distributions and collection efficiency curves according to ISO 7708
(Adapted from ISO 7708:1995, p7)



$PM_{2.5}$ is the size fraction that has a high probability of deposition in the smaller airways and alveoli.

Figure 2 Different particle size ranges and naming conventions.
(Source: US Environment Protection Agency
http://www.epa.gov/eogapti1/module3/category/category.htm#pm2.5)

Figure 2. Ambient Particulate Matter Size Distributions



According to Vincent (2001) "for assessment of the true health-related dose received by a worker leading (possibly) to ill-health, occupational aerosol measurement ideally requires full characterization of the aerosol as a function of particle size distribution and chemical species". (p.1)

Vincent (2001) also states that "some occupational health experts have expressed concerns about fine particles and ultra-fine particles as they might relate to workplace aerosols". (p.1)

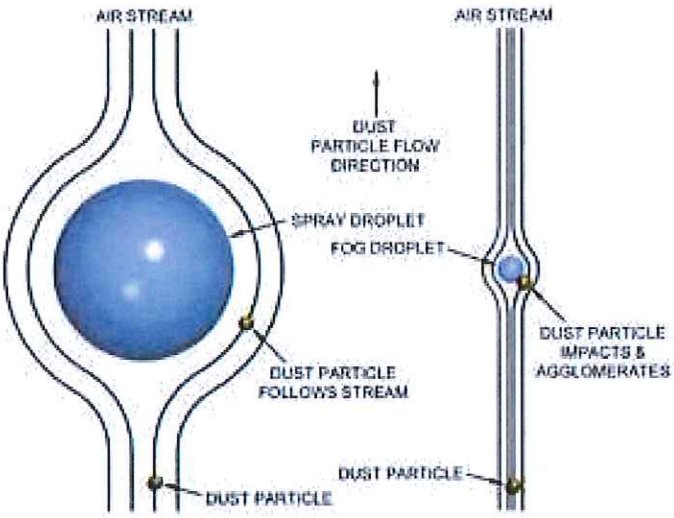
This is an important point as it is generally assumed that silicosis is caused by the fraction of silica that reaches the alveoli (OEHHA, 2005; King et al., 1953). Weissner et al. (1989) on the other hand, observed that relatively larger particles ≥ 5µm were more fibrogenic than 1µm particles. The more recent literature suggests that total surface area is more important than mass. Surface area is related to particle size; smaller particles possess a larger surface area per unit mass compared to larger particles (HSE, 2002). Fine particles also have much longer residence times than coarse particles when airborne. Exposure to excessive numbers of fine particles may also overwhelm the alveolar macrophages ability to engulf and remove foreign particle.

The literature also suggests that the toxicity of silica may depend on a combination of particle size, particle morphology and surface chemical reactivity.

Removing respirable particulate matter from the air using fogging systems is one option that dusty operations can use to reduce fine airborne dust.

Figure 3 Mechanism by which water droplets in fog removes respirable dust.

(Source: ADS^{TM} Fog based dust control technology. Online at http://www.raringcorp.com/ADS_Tech.htm)

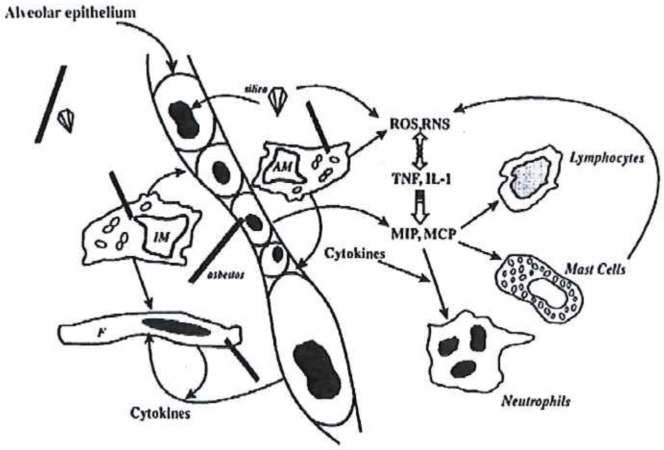


3.2 Respirable crystalline silica and surface chemical reactivity.

There is general agreement that freshly fractured crystalline silica particles are more toxic than aged surfaces as demonstrated by in vitro tests conducted in animal studies (HSE, 2002). The crushing crystalline silica can result in breakage of the Si-Si and Si-OH bonds at the surface. This results in the formation of reactive radicals at the particle surface. These species are highly reactive and through cellular activation resulting in superoxide, hydrogen peroxide and nitric oxide. The formation of reactive oxidative species (ROS) are damaging to cells DNA. Superoxide can also react rapidly with nitric acid to form peroxynitrite, an agent that oxidizes and nitrates macromolecules. Studies also indicate that reactive nitrogen species (RNS) are released from affected alveolar macrophages (Brooke et al., 1998). The mechanism in the pathogenesis of silicosis is complex. One model of this pathway is shown in Figure 4..

Figure 4 A conceptual model of events occurring in the lung following exposure to pathogenic mineral dusts.

(Source: Brooke et al., 1998, p.1674).



The HSE notes that the activity of free radicals decays with time (ageing) and occurs slowly in air, but rapidly in water. Wet-processes that quench freshly cut quartz will help reduce this reactivity. Metal contaminants may either exasperate the potential for silicosis or provide a protective mechanism.

Driscoll (1995) notes that iron contamination can potentially increase the toxicity of silica by catalyzing the production of reactive oxygen species. This reaction is termed Fenton's reaction which can be described by the following reactions:

$$Fe^{2+} + H_2O_2 \text{ ----> } Fe^{3+} + .OH + OH^-$$

$$Fe^{3+} + H_2O_2 \text{ ----> } Fe^{2+} + .OOH + H^+$$

Aluminium on the other hand has been suggested as providing a protective layer. Studies in rats and sheep have demonstrated that pulmonary inflammation is reduced by aluminium. The presence of aluminium in coal mines for instance has been used as justification that crystalline silica is less toxic in this environment. The research has challenged this notion by saying that the protective effect is transient and over time the protective effect is lost as aluminium is removed from the silica surface (HSE, 2002).

3.3 Respirable crystalline silica morphology and action of macrophages.

It has been suggested by Champion (2006) that the shape of a particle in the lung, plays a dominant role the macrophages capacity to engulf and remove the particle.

Figure 5 Time-elapsed video showing macrophages interacting with synthetic particles
(Source: Champion et al,.2005 p. 4931)

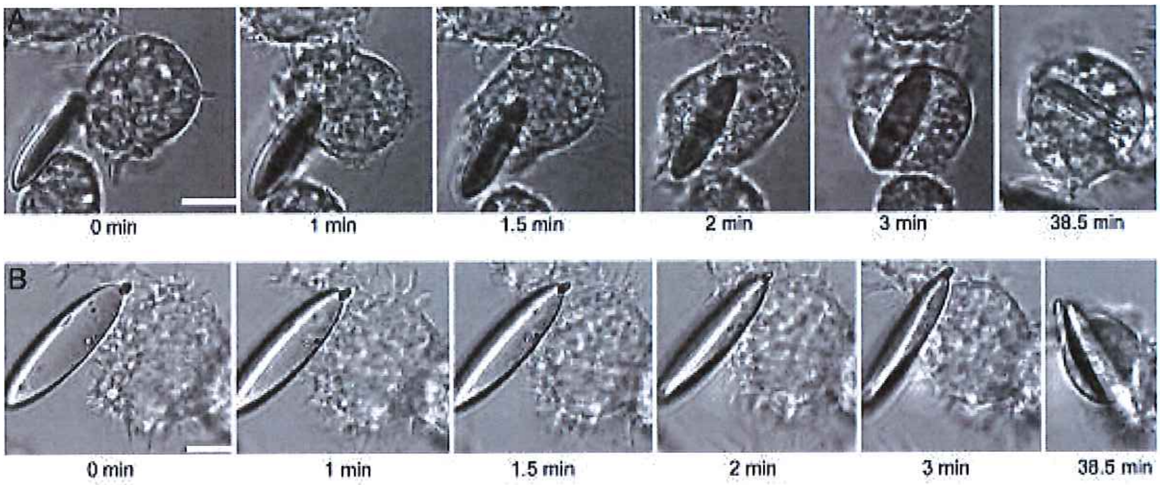
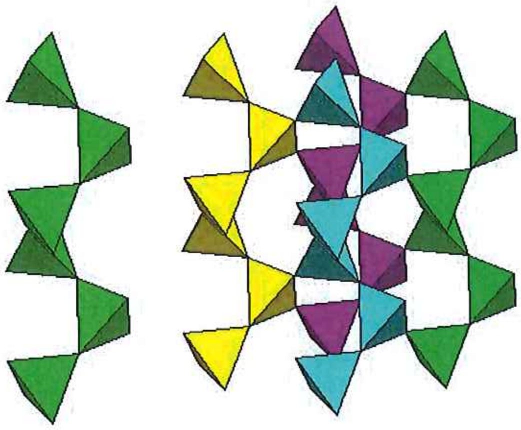


Figure 5 demonstrates that the particle shape and angle at which the macrophage approaches the particle is one determining step in phagocytosis. The crystal system of alpha quartz is trigonal.

The basic structure of quartz consists of spiral chains (helices) of tetrahedra around a three-fold and six-fold screw axes. Figure 6 shows the align of the screw axes with the three-fold helices illustrated on the left and on the right diagram shows the helices connected into a framework.

Figure 6 Models of the basic structure of quartz
(Source: Dutch, S, 2002)



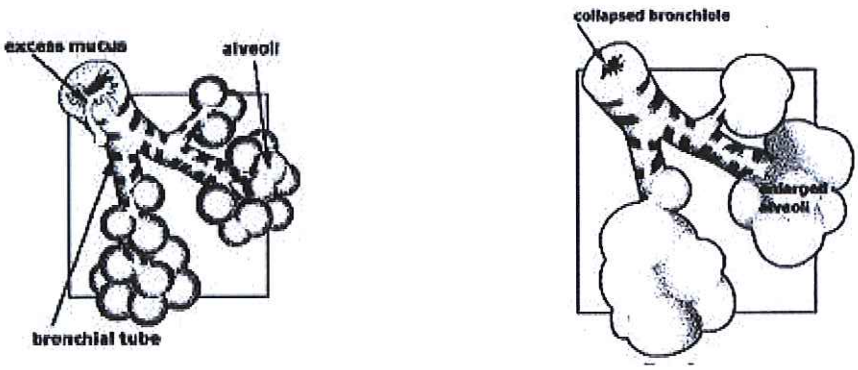
Further research is required to assess crystalline silica morphology and the effect that the shape has on macrophages and phagocytosis.

3.4 Respirable crystalline silica and chronic obstructive pulmonary disease (COPD).

Chronic obstructive pulmonary (lung) disease is a general term used for several lung diseases. The most common types are chronic bronchitis and emphysema. Most patients with COPD have a combination of both of these diseases. COPD worsens gradually causing limited airflow in and out of the lungs. Smoking causes COPD and it is now known that dust exposure also causes COPD.

Figure 7 Mechanism of COPD

(Source: Health Information Home; Understanding COPD. http://www.cchs.net/health/health-info/docs/2400/2416.asp?index=8709)



Figures 7 shows how the alveoli and bronchial tubes are affected in chronic bronchitis and emphysema. Emphysema is the destruction, or breakdown, of the walls of the alveoli. Chronic bronchitis is irritation and inflammation of the lining in the bronchial tubes.

Driscoll (2005) cites a study carried out by Korn et al. (1987) who found that in developed countries the relative risk for COPD is 1.0, 1.4 and 1.8 (controlled for smoking) which correlates with non-dust exposed, low exposure and high exposure respectively. Exposure concentrations aren't provided, however mining in developed countries is in the high dust exposed group.

The mechanism of dust exposure and COPD is uncertain. Examination of lungs of workers with occupational dust exposure shows airway fibrosis with thickening of the airway wall and narrowing and distortion of airways. It has been suggested that the membranous bronchioles and respiratory bronchioles are points of high dust deposition. The respiratory bronchioles are the bridge between bronchioles and alveolar spaces and serve both air-conducting and gas exchange functions.

Table 1 Dimension of human airway model.
(Source: Weibel 1963 cited in Lindstrom 2004 p.10)

Anatomical structure		Generation	Number per generation	Mean diameter (cm)	Mean length (cm)	Cross sectional area (cm^2)
	LARGE AIRWAYS	0	1	1.80	12	2.54
Trachea		1	2	1.22	4.8	2.33
Main bronchi		2	4	0.83	1.9	2.13
Lobar bronchi		3	8	0.56	0.76	2.00
		4	16	0.45	1.27	2.48
Segmental bronchi		5	32	0.35	1.07	3.11
Sub-segmental bronchi		6	64	0.28	0.90	3.94
		7	128	0.23	0.76	5.31
		8	256	0.186	0.64	6.95
Terminal bronchi	SMALL AIRWAYS	9	512	0.154	0.54	9.53
Bronchioles		10	1024	0.130	0.46	13.6
		11	2048	0.109	0.39	19.1
		12	4096	0.095	0.33	29.0
		13	8192	0.082	0.27	43.2
		14	16384	0.074	0.23	70.4
		15	32768	0.066	0.20	112
Terminal bronchioles	ACINUS	16	65536	0.060	0.165	185
		17	131907	0.054	0.141	300
Respiratory bronchioles		18	262144	0.050	0.117	534
		19	524288	0.047	0.099	944
Alveolar ducts		20	1489576	0.045	0.083	1600
Alveolar sacs		21 - 23	15000000	0.042	0.060	~ $140m^2$

According to Girod 2007, the chronic characteristic of COPD is caused by a mixture of small airway disease (obstructive bronchiolitis) and parenchymal destruction (emphysema). Table 1 provides dimensions of the small airways. Particles larger than 10 µm are deposited in the upper airways. Particles 3 – 10 µm are deposited in the trachea and larger airways due to impaction. Smaller particles 0.5 – 3 µm are deposited in the terminal airways and in the alveoli. Ultra fine particles less than 100 nm are deposited in the alveolar region and the larger fraction is inhaled (Lindstrom, 2004). Based on this the current methods of sampling for respirable dust may not collect the dust fraction that may be responsible for COPD. Respirable dust sampling collects both the particle size fraction responsible for COPD and particles >3 µm which may not cause COPD. $PM_{2.5}$ may provide a better indication of the risk when attempting to identify a dose response relationship.

4. CONCLUSION.

The mechanism by which respirable crystalline silica causes silicosis and COPD has been an area of considerable research. For crystalline silica particles to exhibit adverse health effects, particle size, shape, age of fractured surface, chemical activity and surface metals must be taken into account. Further research is required especially to identify the particle size distribution and shape that poses the greatest risk.

A number of sources claim that wetting respirable crystalline silica reduces the reactivity of the freshly cut crystalline silica but further research is required to confirm this theory. Wetting respirable crystalline silica will suppress airborne dust and fogging systems may possibly reduce the airborne dust fraction that is respirable. Trials are also required to confirm if these systems meet their objective.

The current method to sample respirable crystalline silica, using as 2985-2004, requires further evaluation. It may be that sampling for $pm_{2.5}$ and analysis of this fraction may be a better estimate of the exposure risk.

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Occupational exposure to respirable crystalline silica in Queensland quarries, exploration sites and small mines.

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Summary

Mining and quarrying operators are potentially exposed to freshly cut quartzite (alpha quartz) in the form of crystalline silica. Exposure to fine particles of airborne quartz, at sufficient concentrations, may result in the operators developing silicosis, a debilitating respiratory condition which may not be diagnosed during their working lifetime. There are approximately 33,000 people employed in the Queensland mining industry and to date there has been no extensive research to quantify the levels of exposure to crystalline silica, and therefore the risk of contracting silicosis, using standard air sampling and health assessment methods. The fieldwork for this project will use data collected from a survey undertaken by the Queensland Department of Mines and Energy, and dust monitoring in mines, quarries and mineral exploration sites. The questionnaire, distributed by the DME to approximately 400 mines, quarries and explorations sites in March 2008, was designed to assess how well silica dust is being managed in Queensland. The survey has had a 25% return rate in the first 6 weeks. Information from the questionnaires will be used to select potential sites for quantitative exposure assessment. The Queensland, Mining and Quarrying Safety and Health Regulation 2001, puts the onus on the Site Senior Executive (SSE) to assess the risk and ensure that appropriate control measures are in place. Preliminary analysis of the questionnaires revealed that many work sites do not know the concentration of airborne crystalline silica present in a range of work stations and that no routine monitoring takes place. Nearly 50% of the responses also indicated that there is no ongoing health surveillance of employees even though there may be a risk of workers breathing crystalline silica dust. This study will provide the Queensland mining industry with information that will assist development of workplace practices to reduce the risk of exposure of workers to crystalline silica.

Background

The research is demonstrating that adverse health outcomes are predicted from exposure to airborne dust at levels previously considered as acceptable. Driscoll et al (2005), quantifies the risk for occupational asthma, pneumoconiosis and chronic obstructive occupational disease. This paper reports a higher level of risk of morbidity and mortality for workers in the mining industry. Driscoll et al (2005), qualifies the information as being based on exposure estimates prior to 2001, which will include historically, high exposures. Driscoll et al (2005), also implies that, estimating exposures and risk for specific groups is not possible because there is a lack of exposure data. Not withstanding, the prediction is documented for low level cumulative exposure to respirable crystalline silica.

Respirable crystalline silica is a lung damaging disease. Metalliferous mines, quarry and exploration site workers are regularly exposed. The senate inquiry workplace exposure to toxic dusts May 2006 identified respirable crystalline silica and potential adverse health outcomes as a high priority, as has the Australian Safety and Compensation Council. Additionally there is substantial literature to indicate that RCS is a cause of chronic obstructive pulmonary disease (COPD).

A search through the Queensland Government Department of Mines and Energy Merlin data base has shown that 304 tenure leases have been granted for quarry operations. Another search has demonstrated 290 mining leases, of these, 81 are actively carrying out exploration. Quarries are the primary source for “extractive materials” or “aggregates” used for building roads, ports, airports, bridges, railways, factories, hospitals and homes. Crushing operations in quarries are potentially dusty operations and the crusher operator has potential to be exposed to respirable airborne dust including respirable crystalline silica. To secure future reserves in Queensland there is considerable exploration being carried out for mineral resources.

Gemstones are also mined including sapphire, opal, chrysoprase, agate, topaz and zircon (Queensland Government, DME, 2006). Reverse circulation drilling (RCD) is commonly used in exploration activities which may generate airborne respirable dust containing respirable crystalline silica. Small operations including opal mining, also has the potential to expose opal miners to respirable dust and crystalline silica.

This study will approximate the exposure to airborne quartz (crystalline silica) and determine whether there is potential for subsequent adverse respiratory health by carrying out a quantitative exposure assessment.

Health Effects

Silicosis is considered to be a slowly developing and progressive disease, not always diagnosed during a working life. Personal exposure monitoring and evaluating the efficacy of controls will provide a better estimate of the extent of exposure during working life and will guide development of standards to assist with assessment of the risk of developing silicosis. Early detection of lung disease is crucial to survival. There are a number of studies that demonstrate the relationship between loss of lung function and cumulative exposure to respirable dust and respirable crystalline silica (Ulvestad et al 2001, Wang et al 1997, Meijer et al 2001). Some studies demonstrate a loss of lung function well below the current Australian Safety and Compensation Council (ASCC) exposure standard – time weighted average of 0.1 mg m^{-3} (Kim et al 2002). Other studies note that silicosis can be symptomatic where there is no significant effect on lung function (de Klerk et al 2002). Exposure to respirable crystalline silica, a common contaminant of mining and quarry operations, results in the lung damaging diseases known as silicosis and chronic obstructive pulmonary disease (NIOSH 2002). Long-term exposure to respirable crystalline silica can lead to an increased risk of lung cancer.

The International Agency for Research on Cancer (IARC 1997) published a monograph which reported that respirable crystalline silica was a cause of lung cancer in humans (Group 1). According to the National Occupational Health and Safety Commission Exposure Standards for Atmospheric Contaminants in the Occupational Environment (NOHSC 3008, NOHSC 1003: 1995), exposure standards, “according to current knowledge, should neither impair the health of nor cause undue discomfort to nearly all workers” (NOHSC 1995 p4). The current Australian Safety Compensation Commission exposure standard for the most common form of crystalline silica is 0.1 mg/m^3 (measured as respirable crystalline silica). In a review of causes of silicosis (Health and Safety Executive 2002), it was acknowledged that exposure to crystalline silica at concentrations below 0.1 mg m^{-3} over a long period could lead to silicosis.). This review presented quantitative risk estimates for silicosis (EH75/4 Respirable Crystalline Silica – Phase 1 Hazard Assessment Document). The risk estimates were based on a study of hundreds of workers from a Scottish coalmine where major seams of sandstone were encountered in one part of the mine. Of particular significance in this study was the need for workmen to cut through the sandstone for a period of about 10 years in order to get to the coal.

Statistical analyses showed that the risk of contracting silicosis could be largely explained by exposure to respirable crystalline silica during the 1970s, and were not strongly related to previous exposures to workplace dusts. Therefore, in order not to extrapolate beyond the region of relevant data, the risk estimates from this study refer only to a 15-year period of exposure, and not to the more traditional 40-year working lifetime occupational risk estimates which are shown in Table 1.

Table 1: Estimated quantitative risks of developing silicosis
(Source: Health and Safety Executive 2002, p 73)

15 years daily exposure to respirable crystalline silica dust at average airborne concentrations for an 8-hour shift of mg m^{-3}	Risk of developing silicosis within 15 years following cessation of exposure
0.02	0.25%
0.04	0.5%
0.1	2.5%
0.3	20%

In this review only workers exposed to freshly cut surfaces of respirable crystalline silica generated by mechanical cutting into sandstone were included. The United Kingdom Health and Safety Executive (HSE) consider that the risk estimates presented in Table 1 are likely to have widespread relevance and applicability. The National Institute for Occupational Health and Safety (NIOSH, 2002) have also estimated the prevalence of silicosis in the United States of America. NIOSH have provided a number of studies that predicted the incidence of silicosis of approximately 1 to 7 silicosis cases per 100 workers at respirable quartz concentrations of 0.025 mg m^{-3}. Cumulative exposure, not average exposure, has also been noted as the best predictor for disease (Steenland 1995).

Ongoing health surveillance should involve lung function tests (spirometry), although this test cannot be used alone to diagnose any particular disease. NIOSH (2002) suggests that although lung function tests can measure impairment, the test is not a diagnostic tool for silicosis alone or a measure of silica exposure, because no single pattern of abnormality exists. However NIOSH (2002) refer to studies which prove that cumulative exposure to respirable dust containing silica does lead to loss of lung function and adverse health effects. Research is needed to determine the relationship between occupational exposure to silica dust and clinically significant changes in the lung function of non smokers.

Ghotkar et al (1995) noted that even when stone quarry workers are exposed to silica dust at concentrations within the permissible range, and measured as cumulative dust exposure, there is a risk of impaired lung function. Although there are numerous studies that quantify the annual loss of lung function in mL per year, the values are inconsistent and in most cases the dose response curves are based on exposure estimates made from non statistically valid occupational hygiene monitoring data.

The ACOEM (2006) and NIOSH (2002) note that significant decrements in neither lung function, nor respiratory symptoms are likely in the early stages of silicosis.

ACOEM (2006) also recommended that both cross sectional and longitudinal spirometry needs be carried out to provide better estimates of risk. Longitudinal spirometry will monitor a worker's health over time which means that their lung function tests can be compared with their baseline test, whereas cross sectional testing is carried out to assess lung function against predicted values. It should be noted that spirometry needs to be undertaken in conjunction with an exposure study.

In cases where occupational exposures to respirable crystalline silica have been estimated, no statistically valid exposure monitoring data was found nor was any comparison undertaken with loss of lung function. Buchanan et al (2003) expands on this by noting that quantification of the risk of silicosis should take into account the variations of quartz exposure intensity, particularly for exposure to concentrations of greater than 1 or 2 mg m^{-3}, even if exposure is for relatively short periods. Buchanan (2003) implies that the risk of silicosis can rise dramatically with even brief exposures to high quartz concentrations. Real time monitoring is therefore required to characterise exposures and identify events and duration of high exposure.

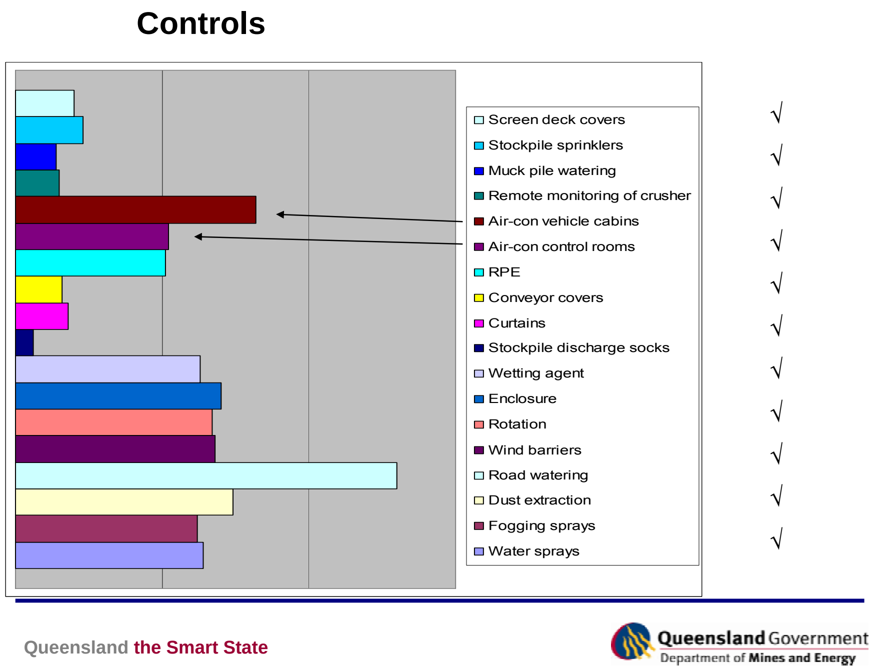
Evaluation of sampling methods to understand particle size distribution and the relationship of crystalline silica in the host rock and respirable crystalline silica is required. Real time analysis of $PM_{2.5}$ and $PM_{1.0}$ will identify processes and activities that produce airborne dust within these size fractions. The intensity of exposure can then be quantified. Gupta et al (2006) has noted that crystalline silica less than 1 µm is believed to be most pathogenic.

Characterisation of particle size distribution will assist in providing control technology, designed specifically to wet and suppress respirable dust, such as fogging systems.

Some findings from Questionnaire Feedback

The questionnaire sent to sites is provided in appendix I.

Figure 1: has been provided to compare what controls are used to reduce exposure to respirable crystalline silica:



From the above it can be noted that there is a lot of reliance on road watering, air conditioned vehicle cabins and air-conditioned control rooms. What is uncertain is whether the air is fan forced and HEPA filtered.

Respiratory protective equipment

When asked how often respiratory protective equipment is worn most responses noted "respirators or dust masks are worn when it is dusty". It should be noted that respirable silica containing dust is hazardous to the lung and less than 7 micrometres in aerodynamic diameter – this fraction of dust is invisible. Relying on "individual's perception" of dusty conditions as a precursor to the use of respirators won't allow adequate protection.

Health Surveillance

One of the main findings to come out of the survey was that nearly 50% of respondents noted that health surveillance wasn't carried out. Considering that respirable crystalline silica or quartz is present in most rock types, operators may be at risk without health surveillance being conducted.

The Australian Institute of Occupational Hygienists (AIOH) recently drafted a position paper on respirable crystalline silica.

In this document the AIOH notes that

"Where there is a **likelihood** of 50% of the exposure standard being exceeded, control strategies and health surveillance should apply".

Rio Tinto also ***requires health surveillance*** *at 50% of the exposure standard.*

Conclusion

Findings to date, along with some preliminary exposure monitoring (unpublished data) has indicated the potential risk for respirable crystalline silica to pose a risk for adverse health effects.

Low level cumulative exposure to respirable crystalline silica may lead to chronic silicosis many years after a worker has retired. Therefore, it is imperative that the level of awareness around health effects, dust control (effectiveness) and health surveillance be improved.

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(Appendix I) **Questionnaire to identify activities in Queensland mining sites where there may be potential exposure to respirable crystalline silica**

Many minerals contain silica, and produce silica dust known as Respirable Crystalline Silica (RCS). RCS is also known as respirable α-quartz, cristobalite, or 'free silica'.

Type of site? □ Quarry □ Mine □ Exploration Site

Number of workers on site? □ Less than 10 □ 10 - 20 □ More than 20

1.0 Silica content:

1.1 Do you know whether the rock excavated on your site contains "free silica"?			
□ yes	□ no	□ don't know	
1.2 If yes, how much free silica is there in the rock?			
□ < 10%	□ > 10% < 50%	□ > 50%	□ don't know

2.0 Exposure:

2.1 Are workers at your site exposed to airborne dust?				
□ yes	□ no	□ don't know		
2.2 What do you consider is the dustiness of your operations?				
□ low	□ medium	□ high	□ don't know	
2.3 How many months a year does your site operate?				
□ up to 3-months	□ 3 to 6 months	□ 6 – 9 months	□ full year	□ don't know

3.0 Monitoring:

3.1 Has your site had personal airborne exposure monitoring carried out?			
□ yes	□ no	□ don't know	
3.2 If yes, have your workers been provided with their own personal results?			
□ yes	□ no	□ don't know	
3.3 If yes, how often is monitoring conducted?			
□ Has only been done once.	□ Yearly	□ Every 1 - 3 months.	□ Every 6 months.

4.0 Respiratory protective equipment:

4.1 Do workers on your site wear respirators and if so what type?		
□ Dust masks (disposable).	□ Cartridge (non disposable)	□ Powered air purifying
□ No they don't wear respirators.		
4.2 Have your workers received training in the use of respirators/dust masks?		
□ yes	□ no	□ They don't wear respirators.
4.3 Where dust masks or cartridge type respirators are worn have the workers been fit tested?		
□ yes	□ no	□ Don't know.
4.4 How often are respirators worn?		
□ Always.	□ Only when dust.	□ Never.

5.0 Dust control:

5.1 Please indicate what dust controls are present on you site? (tick as many as required)	
□ Water sprays.	□ Curtains.
□ Fogging sprays.	□ Conveyor covers.
□ Dust extraction systems.	□ Respiratory protection.
□ Road watering.	□ Air-conditioned control rooms
□ Wind barriers.	□ Air-conditioned vehicle cabins
□ Worker rotation between dusty and non-dusty jobs.	□ Remote monitoring of crusher from camera within control room
□ Enclosed crushing and screening plants	□ Muck pile watering
□ Wetting agent.	□ Stockpile sprinklers.
□ Stockpile discharge socks.	□ Screen deck covers.

6.0 Health Surveillance:

6.1 Do your workers have regular health surveillance?				
□ yes		□ no	□ don't know	
6.2 If yes, please indicate what health surveillance is conducted?				
□ Lung function tests.		□ Full chest x-rays.	□ Respiratory questionnaires.	
6.3 If yes please indicate how often this health surveillance is conducted?				
□ Yearly	□ 2-yearly	□ 3-yearly	□ 5-yearly	> 5-yearly

7.0 Training and awareness.

7.1 Do you provide workers with training to raise awareness about the hazards of crystalline silica?		
□ yes	□ no	□ don't know

8.0 Participation in study:

Thankyou for providing this information and are you willing, for your site, to participate in the personal exposure monitoring study?		
□ yes	□ no	□ don't know but am happy to discuss

An analysis of international studies to assess silica exposure and health effects: Can exposure monitoring and health surveillance raise awareness to improve worker health in Queensland quarries?

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Abstract

Exposure to respirable crystalline silica (RCS) is a major concern for worker health in quarries and mines. This paper reports the findings of an ongoing study of RCS exposure in Queensland quarries.

Lung function tests and exposure monitoring results for 40 workers, from dimension stone, road base and aggregate quarries and a silica sand mining and processing plant in Queensland were analysed. In 3 of 8 quarries studied, exposure exceeded the Safe Work Australia Exposure Standard (ES) for respirable crystalline silica occupational exposure limit (OEL) of 0.1mg/m^3. When data were pooled and analysed within similar worker exposure groups (SEG) there was a positive correlation between reduced lung function and exposures at or above the exposure standard. The distribution of exposures for each SEG, were log-normally distributed, which indicates that the data were representative for each job type. Using Australian Exposure Standards 7 out of 13 SEGs monitored had unacceptably high exposures. These data indicate the importance and need to reduce RCS exposures in Queensland quarries, to conduct ongoing exposure monitoring, and to carry out regular health surveillance of workers, with prompt follow-up action when required.

Strengths and weaknesses of a long term study of granite workers in Vermont USA, and a study of lifetime-risk of silicosis among a cohort of pottery workers in China are also discussed in relation to data collected in the current study. A study of West Australian (WA) miners has also been evaluated. The data collection methods used in the Vermont and WA studies are compared with methods used in the Queensland study.

Keywords

Silica exposure, Lung function, Exposure assessment

Introduction

In Queensland, the Mining and Quarrying Act (2000) and Regulation (2001) place the obligation on the Site Senior Executive (SSE) to assess risks and ensure that appropriate control measures are in place to reduce RCS exposures to acceptable levels. A survey sent to small mines and quarries in Queensland found that many sites were unaware of the hazards of silica exposure and many did not conduct ongoing health surveillance as required by legislation (DEEDI 2009). In a project being undertaken collaboratively between the University of Western Sydney (UWS) and Queensland Department of Mines and Energy (DME), monitoring is being conducted to assess the risk of silica exposure in quarries, dimension stone mines and a silica sand mining / processing operation. Hedges et al, (2010) previously reported that 34% of air samples monitored in Queensland quarries exceeded the shift adjusted Safe Work Australia Exposure Standard (ES) for silica of 0.1 mg/m^3. They also reported that lung function testing showed a correlation between predicted forced vital capacity (FVC) and respirable crystalline silica exposure, with higher exposures associated with reduced lung function. However, fifty seven percent (57%) of workers monitored were smokers, and smoking is also known to reduce FVC.

Background: National and International Studies

Western Australian (WA) Miners

In a study of Western Australian miners (Hewson, 1996) exposure estimates made between 1925 and 1993 demonstrated reduced exposure to respirable dust (Figure 1). These measurements were based on a method that used different types of konimeter to monitor short-term exposures between 1925 and 1977. In 1950 the Kotze konimeter was replaced by a Watson Victor circular konimeter. In 1961, a different type of illuminator was used with the konimeter, which revealed that there were differences in the particle size collected by each of these konimeters. Nevertheless, Hewson (1996) attempted to transform the konimeter results from short term samples of particles per cubic centimetre (ppcc) to full shift samples of respirable dust as mg/m^3.

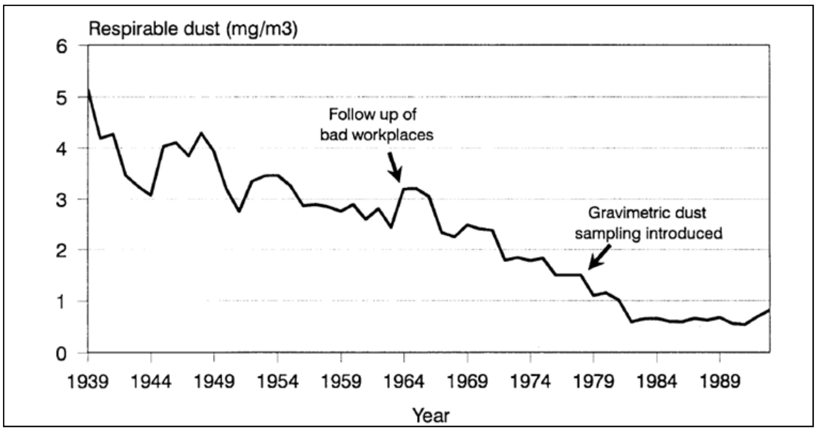

Figure 1: Estimates of mean respirable dust concentrations in Western Australian underground metalliferous mines (1939-1993). Pre-1979 data have been converted from konimeter count data using a factor of 1 mg/m^3 per 100 ppcc
(Source: Hewson 1996, p873)

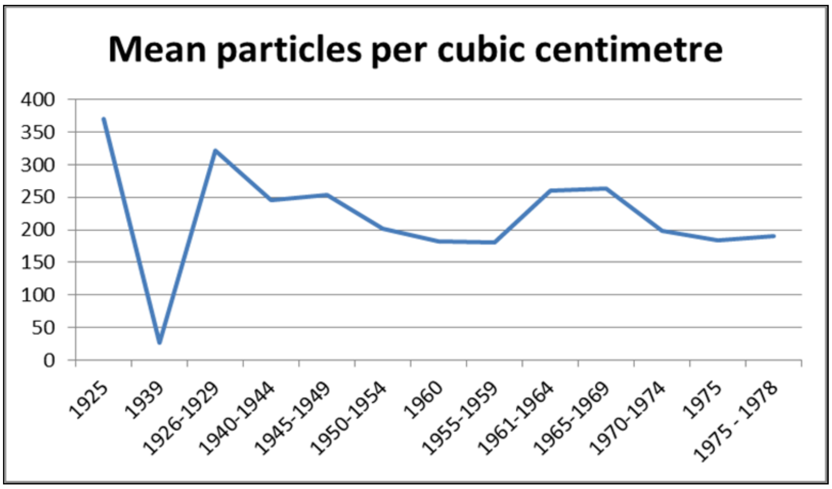

Figure 2: Mean Particles per cubic centimetre in Western Australian underground metalliferous mines (1939-1993)
(Adapted from: Hewson, 1996)

It is interesting to note that when the original data were graphed as shown in Figure 2, the downward trend over time for particles per cubic centimetre (ppcc) is not as obvious. Figures 3 and 4 show the results of tabulated respirable silica concentrations for underground metalliferous mines for exposure results (1979 to 1993).

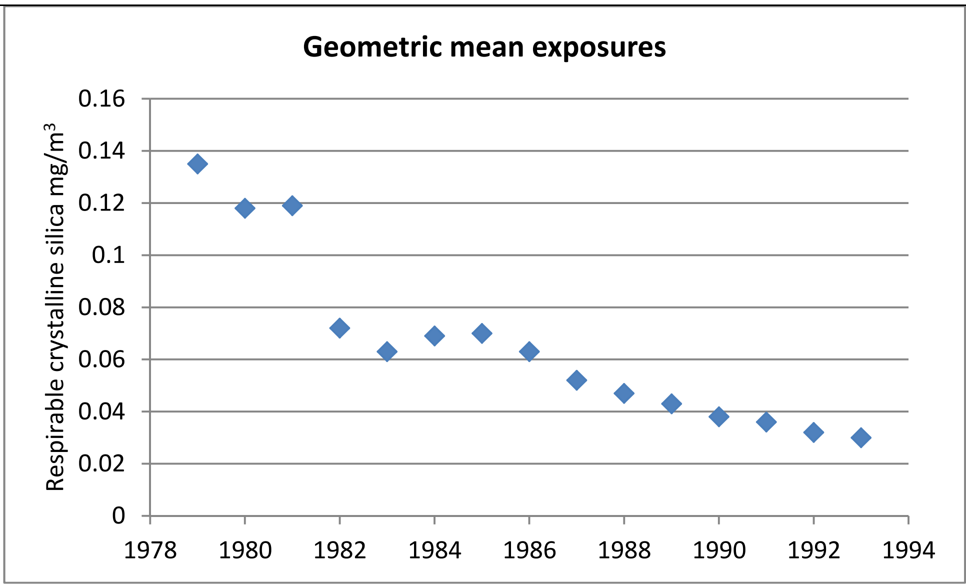

Figure 3: Mean Exposure to respiarble silica in undergaround metalliferous mines in WA (Source: Hewson, 1996, p.873).

When (measured) respirable crystalline silica exposures are compared between 1979 and 1993, there is a reduction in geometric mean exposures (Figure 3). However this is not the case when maximum exposures are graphed (Figure 4).

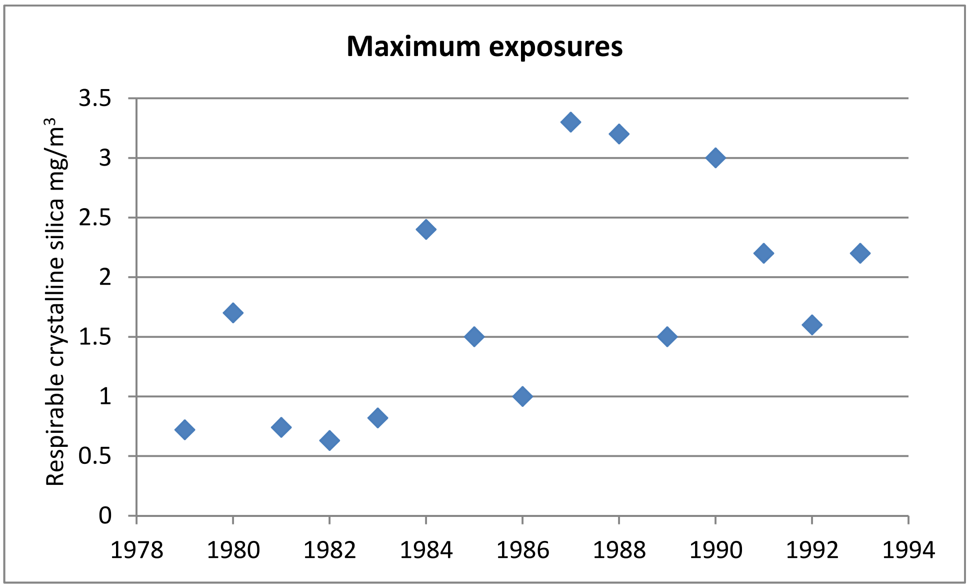

Figure 4: Maxiumun exposures to respiarble silica in undergaround metalliferous mines in WA (Source: Hewson, 1996, p.873).

In the same study, Hewson (1996) reported the incidence of silicosis since 1925 (Figure 5). A new silicosis case is one defined previously as normal but on re-examination indicated early silicosis (>ILO classification1 / O). The X-rays were read by independent respiratory physicians employed by the WA health department (Hewson,1996).

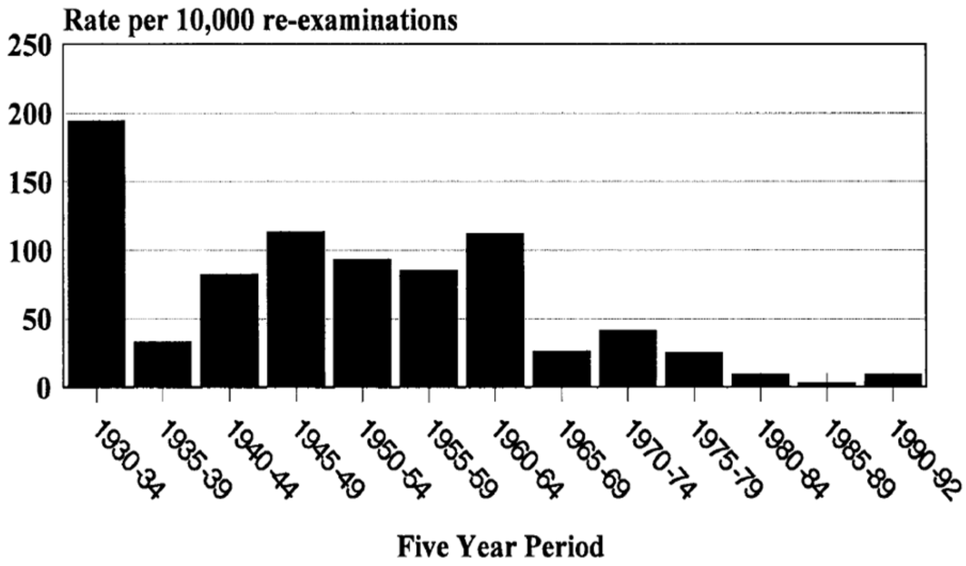

Figure 5: Incidence of new cases of silicosis following X-ray re-examination of Western Australian metalliferous miners form 1925 to 1992 (Adapted from: Hewson, 1996)

Hewson (1996) cited a study by Larcombe (1912) undertaken in the early 1900s where the mass of dust collected on the surface of respirators was used to indicate exposure. In that study it was estimated that inspirable dust concentrations typically exceeded 10mg/m^3, and concentrations of 110mg/m^3 were estimated for dry boring operations. Most cases of silicosis are likely to have been from workers performing high exposure tasks. The improvement in work conditions in the 1950s (lower dust exposures) was attributed to the increased use of water sprays and improved ventilation for most SEG's.

Buchanan et al (2003) noted that quantifying the risk of silicosis should take into account the variations of quartz exposure intensity, particularly for exposure to concentrations of greater than 1mg/m^3, even if exposure is for relatively short periods. These authors also implied that the risk of silicosis rises dramatically with brief exposures to high quartz concentrations.

USA Vermont granite workers.

One of the most extensive studies published is the silica exposure assessment and mortality study of Vermont granite workers (Verma et al, 2010). In that study a job exposure matrix was developed that used 5204 exposure measurements collected from 1924 to 2004. The percent free silica (alpha-quartz) in respirable dust was estimated to be 11%. About 60% of all measurements made prior to 1972 were obtained using the impinger method which had a typical sampling time of 20 – 25 minutes.

In the study by Verma et al (2010) NIOSH recommended the use of a conversion factor of 10 million particles per cubic foot (mppcf) for equivalence to a RCS concentration of 0.1mg/m^3. This is different to conversion factors used in other studies, for which there is inconsistency. The study by Verma et al (2010) also categorised (SEGs) arbitrarily and it is difficult to verify whether SEGs were classified and grouped correctly for analysis.

Vacek et al (2011) studied mortality records for 7052 workers employed in the granite industry from 1947 to 1998. They found no significant link between low level exposure to airborne silica and lung cancer, but reported an odds ratio (OR) of 1.13 (1.05 to 1.21) for silicosis for each 1 mg/m^3 increase in cumulative exposure equating to 0.1 mg/m^3 for 10 years or 0.05 mg/m^3 for 20 years. Although an excess risk was estimated for < 0.1mg/m^3 RCS long-term exposure of 55 deaths resulting from silicosis, only 6 began work after 1940 and 3 began work after 1949 but only worked for less than 10 years in the Vermont granite industry (Vacek et al, 2011). Using mortality records to examine a relationship between silica exposure and silicosis is questionable because the number of workers affected from low level exposure (during their lifetime) has not been established.

Vacek et al (2011) has estimated levels of exposure for each "job class". From this dataset geometric means have been calculated for all job types combined for each period and reported along with maximum exposed job class as shown in table 1.

Period	Geometric mean RCS mg/m^3	Maximum (exposed) job class RCS mg/m^3
<1940	0.16	1.07#
1940 - 1949	0.12	0.56##
≥1950	0.04	0.10###

Note: # Jackhammer; ## Jackhammer; ### Labourer

Table 1: Estimated exposure concentrations of respirable crystalline silica by time period, for all job classes. (Source: adapted from Vacek et al 2011)

Vacek et al (2011) did not provide any analysis where RCS exposure for each job-type was compared with mortality from selected diseases.

Reassessing the historical data and comparing the level of pooled exposure for each job-type with mortality from disease will be worthwhile. This will allow statistical analysis across all job types and grouping workers where the nature of exposure, including particle size distribution, would be similar. It may improve how dose response assessment is undertaken and identify "job-types" that have an increased risk of disease.

Chest x-rays were investigated in 1983 to determine whether low level granite dust exposure could lead to lung abnormalities after a lifetime exposure to dust containing silica (Graham et al, 1991). Workers who had been exposed to dust from 1938 to 1940 were assessed. In that study 972 out of 1,400 chest x-rays were read by 3 "B" readers using the ILO classification system. Of these, 28 (3 percent) were interpreted as showing (1/0) pneumoconiosis and 7 (0.7 percent) showed uncomplicated silicosis. Of those remaining, 21 showed irregular opacities, which were reported as having: "uncertain significance". The average dust concentration was estimated to be 0.06 mg/m^3 with 12% exceeding 0.1 mg/m^3 (Graham et al, 2001). Years worked in the industry ranged from 9 to 60 years. Many of the chest x-rays were irregular and interpretation varied between readers. The estimated exposure to RCS for the 0.7% of workers diagnosed to have (1/0) silicosis was 0.06 mg/m^3. This reported risk generally agrees with a similar Scottish study which estimated that an exposure of 0.04 mg/m^3 for 15 years resulted in a increased silicosis (2/1) risk of 0.5% (HSE 2002).

A study by Graham et al (1994) examined lung function where exposures were below the OSHA permissible exposure limit of 0.1 mg/m^3. After adjusting for variables such as age, height and smoking status, the assessment failed to demonstrate a relationship between low level silica exposure and loss of lung function. In the study of tunnel workers, it was noted that lung function would have been affected by smoking, but it was found that at low exposures for alpha quartz (0.02 mg/m^3 to 0.04 mg/m^3), an annual decrement of FEV1 of 50 to 63 mL was observed (Ulvestad et al, 2001). Gamble et al (2004) noted that smoking must always be considered, as adverse changes in lung function have been attributed to smoking. This means that all studies of lung function will be biased if workers who smoke are not considered. A relationship between smoking and radiographic opacities has also been reported however this is not independent of respirable crystalline silica (RCS) exposure and pneumoconiosis (Hessel et al, 2004). There is a weak association between loss of lung function, smoking, and dust exposure, and increased loss of lung function with higher categories of silicosis (Gamble et al, 2004).

The American College of Occupational and Environmental Medicine ACOEM (2006) recommended that both cross sectional and longitudinal spirometry needs to be carried out to provide a better estimate of risk.

Canada Ontario hard rock miners.

Muir et al (1989) examined 2109 miner's x-rays which were read by 5 "B" readers. Of the 32 cases of 1/1+ silicosis identified; years since first exposure and age at diagnosis was recorded. Where 3 or more readers agreed on the classification, the case was confirmed and allocated into an exposure band which was based on historical exposure data (Table 2).

Reader	No. of cases	Mean respirable silica exposure (mg/m^3)[a]			
		0.05	0.10	0.15	0.20
1	14	0.5 (0.2–0.9)	1.2 (0.7–2.1)	2.1 (1.3–3.6)	3.2 (1.8–5.7)
2	24	0.6 (0.3–1.1)	2.0 (1.3–3.0)	3.8 (2.6–5.6)	6.1 (4.0–9.3)
3	24	0.5 (0.2–0.9)	1.8 (1.1–2.8)	3.9 (2.6–5.7)	6.7 (4.4–10.0)
4	14	0.4 (0.2–0.8)	1.1 (0.7–2.0)	2.2 (1.3–3.8)	3.6 (2.0–6.3)
5	7	0.1 (0.0–0.4)	0.5 (0.2–1.1)	1.1 (0.5–2.4)	2.1 (1.0–4.5)
Any reader	32	0.9 (0.6–1.5)	2.7 (1.9–3.8)	5.0 (3.5–7.0)	7.7 (5.3–11.1)
Majority (3 or more)	15	0.4 (0.2–0.8)	1.2 (0.7–2.1)	2.4 (1.4–3.9)	3.8 (2.2–6.5)
All readers	6	0.1 (0.0–0.4)	0.4 (0.2–1.1)	1.0 (0.4–2.2)	1.0 (0.4–2.2)

Table 2: Ontario hard rock miners - Estimates of cumulative risk and range in brackets corresponding with an "estimated" mean respirable silica exposure (mg/m^3) after 40 years of exposure. (Source: Muir et al, 1989, p.40).

Table 2 demonstrates the importance of having more than one "B" reader classify chest x-rays, and conducting health surveillance many years after exposure. (Muir et al, 1989).

Chinese pottery workers.

Sun et al (2011) in their study of 3250 Chinese pottery workers estimated the exposure response relationship between RCS and the incidence of category 1/1 silicosis for workers until the age of 65. The follow up period was approximately 37 years. This study differed from the previous studies in that both long term average concentrations were estimated as well as the highest annual concentration and the time since initial exposure. The risk of silicosis was 1.5 /1,000 (0.15%) for workers with a long term average exposure < 0.1mg/m^3.

Figures 6 and 7 show that low long term average exposures with a relatively lower maximum annual exposure (over a lifetime), 0.05 – 0.1 and < 0.1 respectively, have a much lower risk of causing silicosis than do lower average exposures with relatively higher maximum annual exposure of 0.05 – 0.1 and 0.1 – 0.5 respectively.

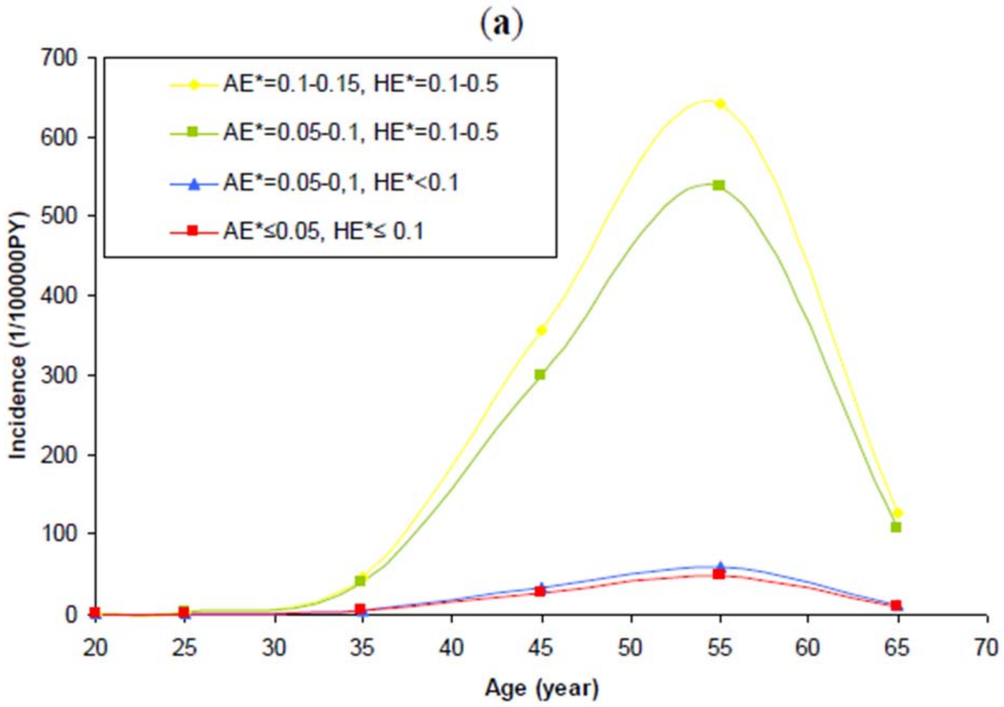

Figure 6: Chinese pottery workers incidence of silicosis, estimates of exposure and age that silicosis was determined.
(Source: Sun et al, 2011, p.2931)

Note: AE refers to long term estimated average exposure whereas HE means highest annual estimated average exposure.

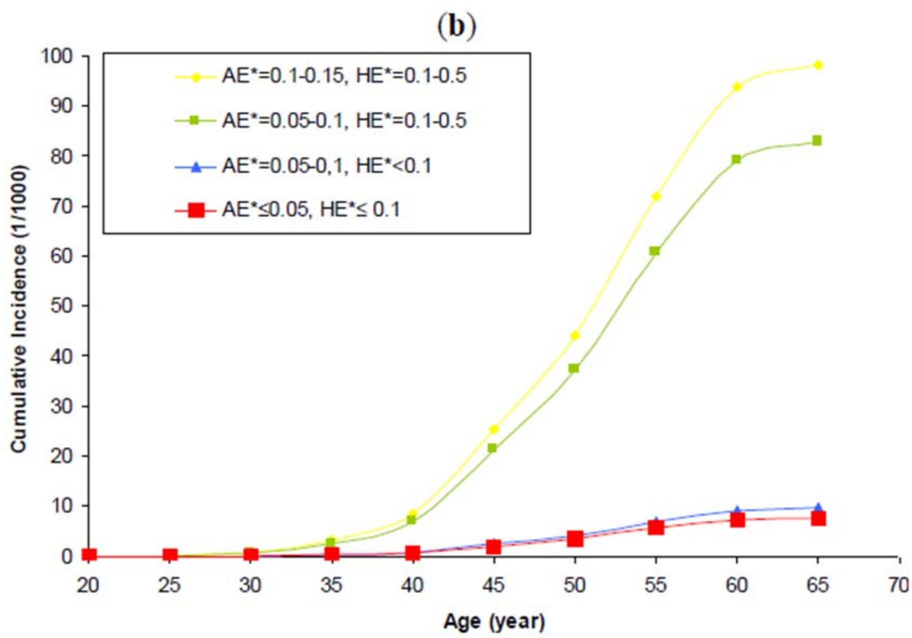

Figure 7: Chinese pottery workers cumulative incidence of silicosis, estimates of exposure and age that silicosis was determined. (Source: Sun et al, 2011, p.2931)

Note: AE refers to long term estimated average exposure whereas HE means highest annual estimated average exposure.

These results challenge the findings from previous studies, which have indicated that the risk of contracting silicosis is higher with an increase in cumulative RCS exposure based on a time weighted average long-term exposure typically reported as mg/m^3 years.

Methodology

Respirable crystalline silica (RCS)

Personal samples were collected according to AS2985-2004 using a cyclone sampling head attached to a sampling pump at a flow rate of 2.2 ($\pm$5%) L/min using SKC AirCheck 2000 Model 210-2002 sampling pumps.

The pumps were calibrated using a TSI 4100 series (Serial No.4146 0629 001) mass flow meter. The TSI secondary flow-meter was calibrated against a primary soap film flow-meter as per appendix B of AS2985-2004. A correction factor was calculated and all sampling volumes were adjusted to align with the primary standard.

The samples were collected on SKC GLA-5000 PVC 25mm 5 µm pore size filters. The analysis of samples for respirable silica was undertaken at the Simtars (Safety in mines testing and research station) laboratories in Queensland in accordance with the National Health and Medical Research Council NH&MRC (1994) document – Methods for Measurement of Quartz in Respirable Dust by Infrared Spectroscopy.

Exposure standards for respirable dust and respirable silica were adjusted applying the Brief and Scala model using the average weekly hours adjustment equation as recommended by Simtars (nd):

$$RF = \frac{40}{h} * \frac{168 - h}{128}$$

Where: h = average hours worked per week over full roster cycle.

Lung function testing (spirometry)

Lung function testing was carried out using an Easyone® spirometer (Model 2001, Serial No 66033/2008). The method used to undertake the lung function test followed the method detailed by Brusaco, Crapo and Viegi cited by Miller et al, (2005). The spirometer prediction parameter was set on NHANES III, the system interpretation was GOLD/Hardie, and the best value result was used for interpretation.

Results

Respirable crystalline silica (RCS) exposures

Results from personal exposure monitoring, carried out in 8 quarries including dimension stone and sand processing operations, shows that many sites have respirable crystalline silica exposures in exceeding the Safe Work Exposure Standard (ES) (8-hour TWA) of 0.1 mg/m^3 as seen in Figure 8.

Of the 40 workers monitored, 34% (14) exceeded the shift adjusted occupational exposure standard (ES) and 22% (9) had greater than twice the ES. The majority of workers whose personal exposure exceeded the ES were not wearing respiratory protective equipment and indicated that they do not routinely wear respiratory protective equipment.

Figure 8 provides a comparison of the pooled exposure data for each quarry. As the working hours for many operators exceeded 8 hours the occupational exposure limit has been adjusted accordingly.

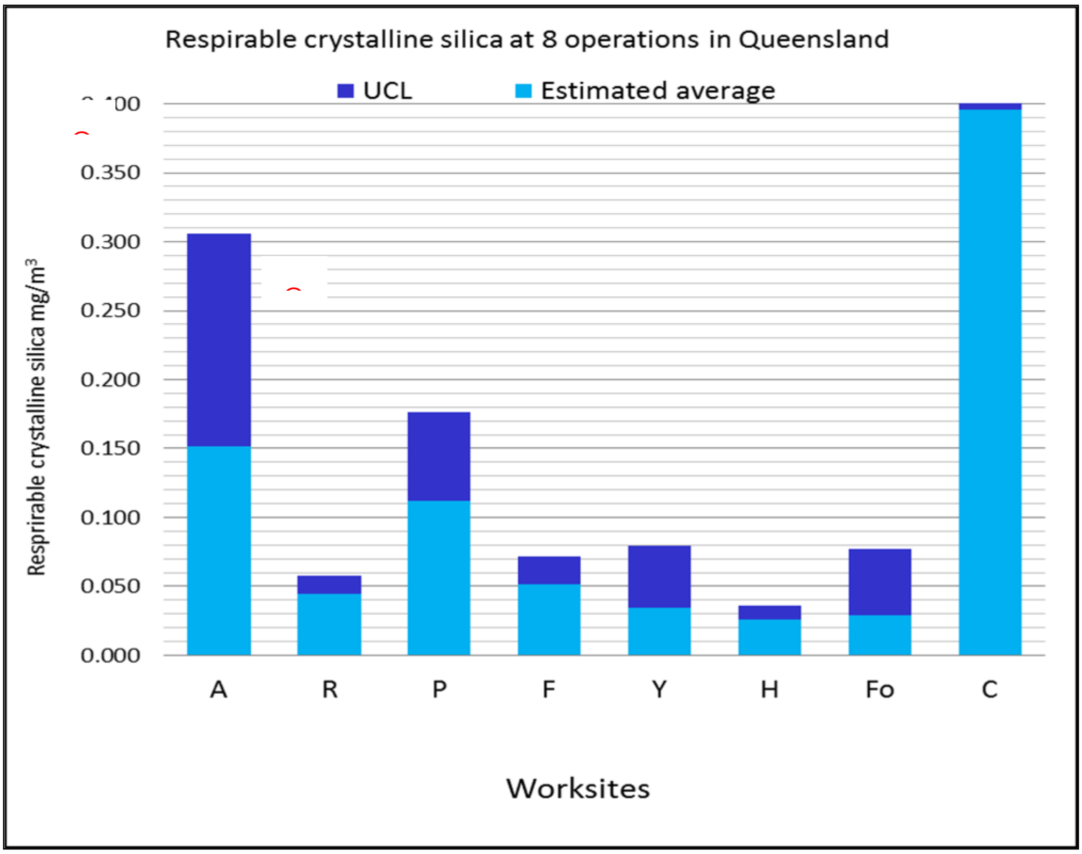

Figure 8: estimated average exposures and upper confidence limits to respirable crystalline silica each across eight operations throughout Queensland.

Statistical analysis carried out for each site failed to demonstrate any positive correlation between loss of lung function and RCS exposure. To get a clearer picture of the risk, further analysis was undertaken, initially to estimate average exposures for each job type (Figure 9) and then to examine if there was a correlation between RCS exposure for each job type and loss of lung function measured as FEV1 % of predicted (Figures 1 to 4 in *appendix A*).

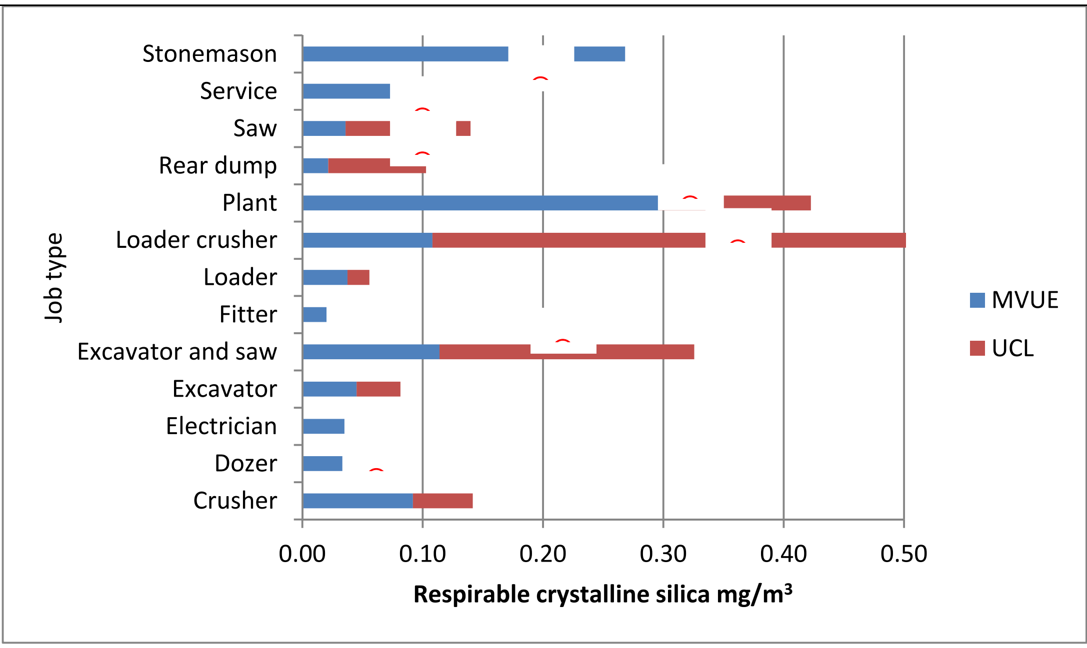

Figure 9: estimated average exposures and upper confidence limits to respirable crystalline silica for each SEG across eight operations throughout Queensland throughout Queensland.

Note: MVUE: Estimated average of a log-normally distributed data set.

UCL: Upper confidence limit (lands exact) of a log-normally distributed data set.

☹ : Unnaceptable exposures where respiratory protective equipment is not used.

In Figure 9, when exposures were pooled for each job type the exposure distributions for each job-type were found to be log-normally distributed. When the upper confidence limit UCL (Lands exact) was calculated for each job type and compared with the occupational exposure limit 7 of the 13 job types had an upper confidence limit that exceeded the OEL which means that these exposures are unacceptable where respiratory protective equipment is not used.

Initially the correlation between RCS exposure and loss of lung function was weak. However, when the analysis was repeated without the higher values of RCS exposure above 0.2mg/m^3, the correlation was much stronger.

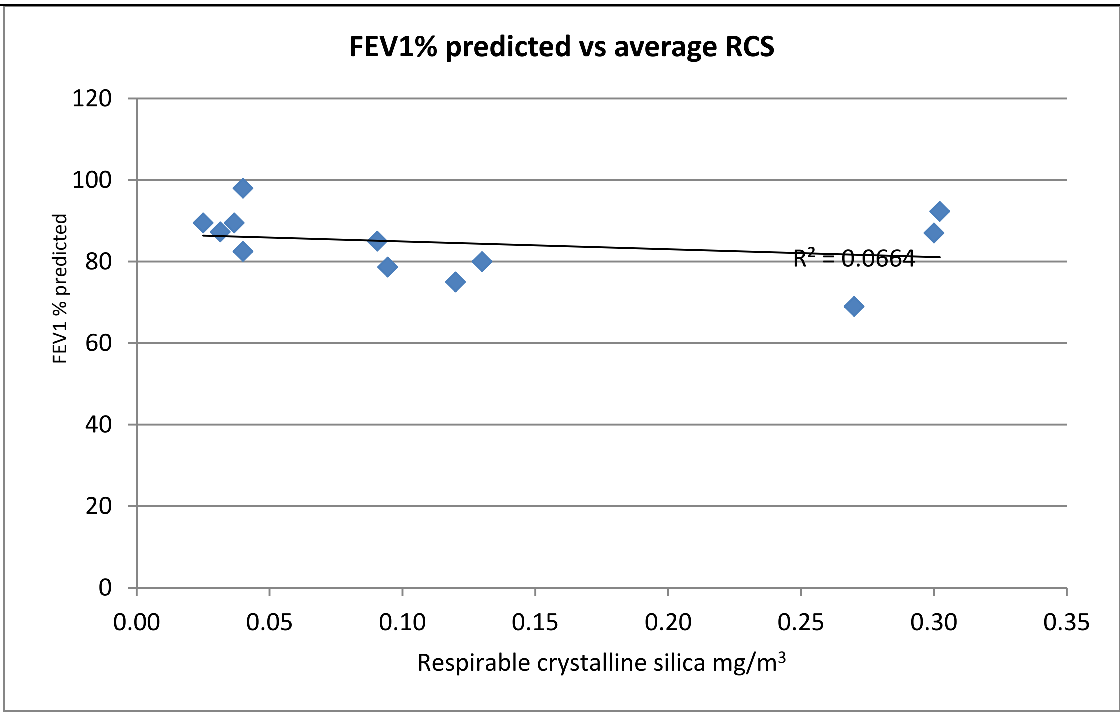

Figure 10: Graph showing correlation between FEV1% of predicted and average full shift exposure for each job type.

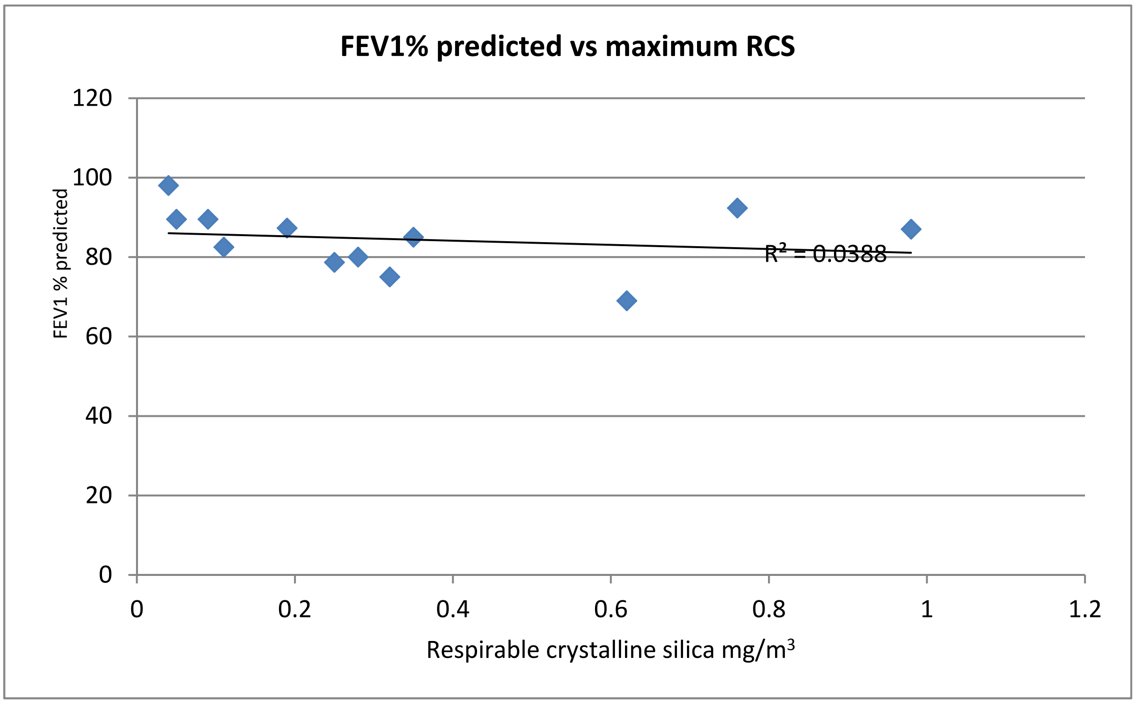

Figure 11: Graph showing correlation between FEV1% of predicted and maximum full shift exposure determined for each job type.

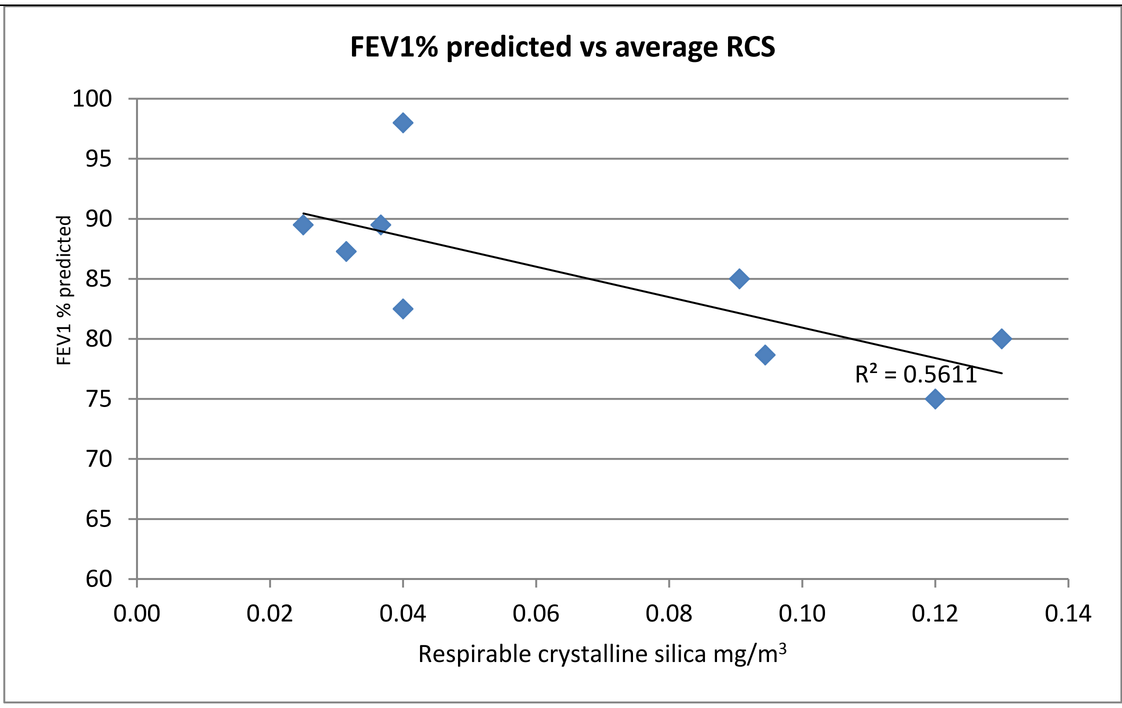

Figure 12: The same plot as figure 10, with a reduced y-axis scale and without including data points above 0.2mg/m^3.

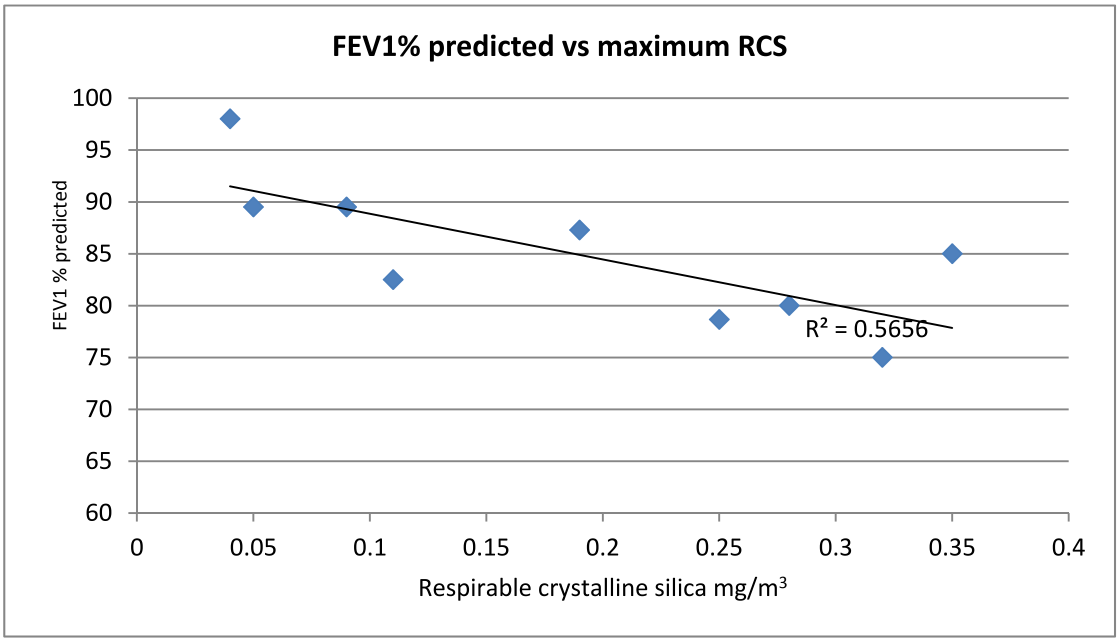

Figure 13: The same plot as figure 11, with a reduced y-axis scale and without including data points above 0.4mg/m^3.

Figures 10 and 12 use average RCS exposures for each job type, whereas Figures 11 and 13 use maximum RCS exposures. The difference between using average RCS exposures compared to maximum exposures is minimal. Comparison between Figures 11 and 13 show a marginally stronger correlation when maximum RCS exposures are used.

Discussion

In the last 25 years many consider that the risk of silicosis has been greatly reduced. However, in Australia it is unclear what impact long-term low level exposure to RCS has on health as monitoring is not undertaken once a worker leaves the industry, such as in retirement.

Shortcomings of studies, described in this paper, including studies of Western Australian miners (Hewson, 1996),Vermont granite workers (Vacek et al, 2011, Graham et al, 1991, Graham et al 1994, Verma et al, 2010), Ontario hard rock miners (Muir et al, 1989), and Chinese pottery workers (Sun et al, 2011) are discussed. All of these studies used historical data based on either: konimeter, impinger or Chinese total dust measurements. The accuracy of the konimeter varied based on the illuminator used, as discussed by Hewson (1996). Conversions were made using different conversion factors and results from short-term samples were used to estimate long term average exposures. All of the studies were based on either mortality or classification of silicosis, which is not curable.

If a correlation can be confirmed between loss of lung function and low level RCS exposure the authors believe that the appropriate use of lung function measurement (spirometry) can further prevent progression of lung disease resulting from RCS exposure. In this study, of the 40 workers tested for lung function, 3 were found to have restrictive lung function patterns and 10 had obstructive lung function patterns, although the majority of workers monitored were smokers. The correlation between forced expiratory volume in one second as a percentage of predicted (FEV1 % of predicted) and RCS exposure (Figures 13 &14) was demonstrated, showing that there is a downward trend of lung function performance with higher RCS exposure. Further statistical analysis is required to determine the level of significance.

Of the 8 sites monitored, 3 had average exposures to RCS across all personal samples collected that exceeded the Safe Work Exposure Standard (TWA) adjusted for extended shifts. The study by Vacek et al (2011) assessed the risk from mortality records while studies by Hewson et al (1996), Muir et al (1989) and Sun et al (2011) determined the incidence of silicosis diagnosed as part of a longitudinal study. As noted previously silicosis is irreversible and monitoring to identify early symptoms of lung disease (such as lung function) is preferred.

The study of Chinese pottery workers described by Sun et al (2011), demonstrated that periods of higher exposure with a relatively low long term exposure greatly increased the risk of silicosis. This means that long term averaging of exposure may not be the best indicator of risk and challenges cumulative exposure measured as mg/m^3/year as the best indicator of risk. The study of Chinese pottery workers has reinforced the importance of considering both average and maximum exposure.

The American College of Occupational and Environmental Medicine (ACOEM), recommends health surveillance where exposure to respirable crystalline silica is > 0.05mg/m^3 (ACOEM 2005). ACOEM noted that, as specified in the OSHA Special Emphasis Program (OSHA 2006), components of the surveillance evaluation should include the following:

- Occupational and medical history (questionnaire)
- Physical examination
- Purified protein derivative (PPD) tuberculin skin test
- Chest radiography
- Spirometry

OSHA (2008) now has a national emphasis program and the program also recommends that a respiratory questionnaire be included in health surveillance. The test results from the current study show that 14 workers have an abnormal lung function pattern.

A restrictive lung function test result may indicate interstitial lung disease that includes silicosis. Although changes in lung function may not be seen in simple silicosis changes in lung function are likely to occur in workers who have been exposed to intense levels or excursions of airborne dust. Spirometry can indicate that further investigation is warranted and that the worker may be exposed to elevated airborne concentrations of airborne respirable dust and crystalline silica prompting the need for urgent control.

Spirometry should therefore be an integral part of exposure assessment and health surveillance, and results of spirometry testing should be clearly explained to the worker and manager.

Conclusion

Historical exposure monitoring data including results from the use of a konimeter or impinger has been used to estimate past exposures. Conversion factors used to convert particles per cubic centimetre (ppcc) to respirable crystalline silica (RCS) have varied depending on the study and organisation. Converting short term sampling data to exposures representative of full shifts is questionable. A number of organisations including NIOSH have endorsed these conversions and most studies discussed have relied on these conversions to quantify the risk. However, these data should be replaced with full shift monitoring for RCS wherever possible, using a method that conforms to the particle size distribution and collection efficiency curve according to ISO 7708. Monitoring should also be ongoing at quarries, and data collected in cross sectional and longitudinal studies.

Even though the sample size of the current study is small when compared with international studies, the data show how useful spirometry can be in determining lung function. Communication of results to both workers and the Senior Site Executive (SSE) or manager, along with results from RCS exposure monitoring, can raise awareness and prompt further health assessment and dust control.

This study serves as a prompt to re-evaluate how worker health and health surveillance should be managed and regulated in Queensland mines and quarries. It has also highlighted that controlling exposure to RCS should still be seen as a priority in mining and this is reinforced by findings from international studies described in this report.

Further follow-up, including assessment of chest x-rays by trained “B” readers for the workers in this study may strengthen the findings. Tracking these workers with regular dust monitoring, and health surveillance will also increase the focus and raise awareness for worker health at industry and Australian Government levels.

Further research is required, to look at how exposures are monitored and assessed, incorporating both maximum and average exposures. It may be that a short term exposure limit (STEL) is considered for the mining industry, and when the measurement is technically feasible the Government should consider setting a STEL for RCS.

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Questionnaire feedback – Respirable crystalline silica.

File 040861

Report provided back to the metal mining and quarrying industry in response to a questionnaire sent in March 2008

Final report prepared 1 July 2009

Queensland **the Smart State**

Queensland Government

EXECUTIVE SUMMARY

Exposure to fine particles of airborne quartz, at sufficient concentrations, may result in the operators developing silicosis, a debilitating respiratory condition which may not be diagnosed during their working lifetime. The literature is indicating that adverse health outcomes are predicted from exposures to airborne dust at levels previously considered as acceptable.

It is also becoming evident that there is not a substantiated “no observable adverse effects level” (NOAEL) at which it can be stated that exposure to crystalline silica has no adverse health effects.

Mining, quarrying and exploration operators are potentially exposed to freshly cut quartzite (alpha quartz) in the form of crystalline silica. There is also an increased risk of developing chronic obstructive pulmonary disease (COPD) which includes bronchitis and emphysema.

To get a better understanding of how well dust containing respirable crystalline silica, is being managed, a questionnaire, attached as *appendix A*, was distributed by Queensland Mines and Energy to 420 smaller mines, quarries and exploration sites.

131 completed questionnaires were received which equates to a 31% return rate.

Preliminary analysis of the questionnaires revealed that many work sites do not know the concentration of airborne crystalline silica present in a range of work stations and that no routine monitoring takes place. Nearly 50% of the responses also indicated that there is no ongoing health surveillance of employees even though there may be a risk of workers breathing crystalline silica dust.

The questionnaire and feedback provided in this report has identified gaps in management of silica dust. The information provided reinforces the importance of preventative measures to control exposure.

It should be noted, that this report is based on feedback received from 131 sites which accounts for only 31% of all sites. It may be that a greater number of sites, with better dust management practices, responded, whilst many sites with sub-optimal dust management practices did not respond. If this is the case, then this report may be biased toward sites with better management practices and therefore underestimate the risk by not including sites with sub-optimal practices.

Table of Contents

1.0 Introduction

Silica is silicon dioxide, one of the most abundant minerals in the earths crust. Silicon dioxide occurs in non-crystalline and in crystalline form. Crystalline silica is sometimes referred to as “free silica”. The main forms of crystalline silica are quartz, cristobalite and tridymite, the most prevalent of which is quartz. Crystalline silica is an aggressive, lung damaging dust when it is able to penetrate deep into the lung in sufficient quantity. The non-crystalline form of silica does not cause such lung damage. In order for the crystalline dust particles to reach the extremities of the lung where they have the potential to do damage, they must be particularly small less than 18µm in diameter, with a median equivalent aerodynamic diameter (EAD) of 4.25µm and this size is defined as “respirable”. Therefore we call the toxic form of this dust “respirable crystalline silica” or RCS.

All forms of RCS of occupational relevance have the potential to cause silicosis, an irreversible and progressive condition in which healthy lung becomes replaced with areas of fibrosis. However human experience and experimental evidence both indicate that at specified levels of exposure, the potential to cause silicosis may be influenced by several factors. Occupational exposure to RCS also causes bronchogenic (lung) cancer but there is little support for the hypothesis that occupational silica exposure is a direct acting cancer initiator. There is however compelling evidence that many forms of pulmonary fibrosis, including silicosis, can lead to lung cancer.

Silicosis is a fibrotic lung disease caused by the inhalation of RCS. It has been described as chronic silicosis (including simple and complicated silicosis), accelerated silicosis and acute silicosis.

The pathology of silicosis has been described as the presence of discrete, rounded and whorled hyalinised (glass-like) fibrous nodules that are sharply separated from the surrounding lung tissue.

The Queensland, Mining and Quarrying Safety and Health Regulation 2001, places the obligation on the Site Senior Executive (SSE) to assess the risk and ensure that appropriate control measures are in place.

The questionnaire (in *appendix A*) was sent out to 420 operating sites. There were 131 responses and of these, there were 82 quarries, 24 mines and 25 exploration sites. 68 of these employed less than 10 workers, 39 employed 10 to 20 employees and 19 employed more than 20 workers.

This questionnaire feedback has provided the Queensland mining industry with information that will assist development of workplace practices to reduce the risk of exposure of workers to crystalline silica.

Metalliferous mines, quarry and exploration site workers are potentially exposed. Crushing operations in quarries are dusty operations and the crusher operator has potential to be exposed to respirable airborne dust including respirable crystalline silica. Reverse circulation drilling (RCD) used in mineral exploration is also a dusty process.

The World Health Organization (WHO) in their priorities for 2009 – 2012, under their objective to devise and implement policy instruments on workers' health plans to:

"Develop and disseminate evidence-based prevention tools and raise awareness for the elimination of silica-related diseases".

The questionnaire has therefore been designed to assess how operations manage respirable crystalline silica. The questionnaire covers the following:

1. Awareness of crystalline silica content.

   (Hazard identification as per the *Mining and Quarrying Safety and Health Regulation 2001, s.6*)

2. Whether workers are exposed.

   (Hazard identification as per the *Mining and Quarrying Safety and Health Regulation 2001, s.6*)

3. Whether personal exposure monitoring is carried out and how often.

   (Risk monitoring as per the *Mining and Quarrying Safety and Health Regulation 2001, s.9*)

4. Whether respiratory protective equipment (dust masks), is used and if so, are requirements of AS/NZS 1715:2009, such as face fit testing and training in place.

   (Limiting workers exposure as per the *Mining and Quarrying Safety and Health Regulation 2001, s.135*)

5. The main and most common dust controls.

   (Risk reduction as per the *Mining and Quarrying Safety and Health Regulation 2001, s.8*)

6. Whether health surveillance is carried out, what type of health surveillance is undertaken and how often.

   (Health surveillance as per the *Mining and Quarrying Safety and Health Regulation 2001, s.138*)

2.0 Awareness of crystalline silica (quartz) content.

Hazard identification.

Many sites do not know whether free silica is present. Numerous sites are also unaware about how much silica is present in the rock. The risk management process as per *Division 2* of the *Mining and Quarrying Safety and Health Regulation 2001*, must start with hazard identification. Failure to identify hazards will mean that the risk is not being monitored which means that there is no driver to ensure that the risk is appropriately controlled.

Figure 2.1

Do you know whether rock excavated on your site contains free silica?

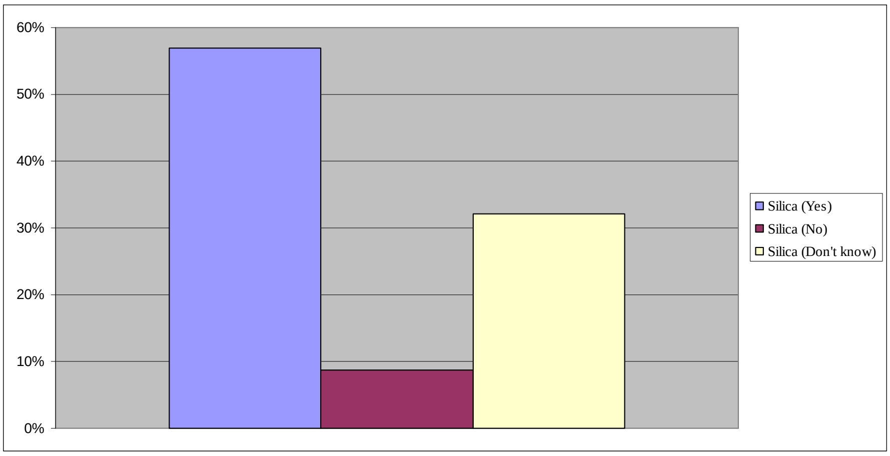
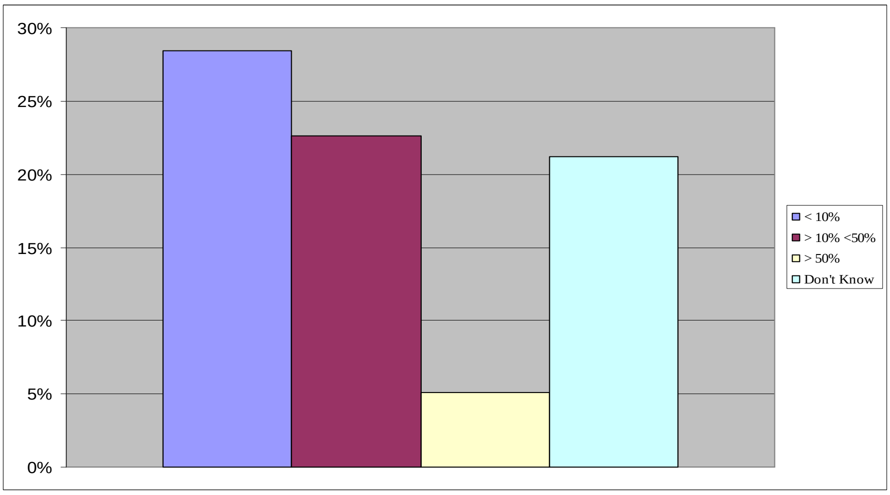


Figure 2.1, only represents sites that responded to the questionnaire where the return rate was 31%. It is uncertain whether non-respondents are aware about how much free silica is in the rock and whether there is in fact a problem.

Figure 2.2

If yes, how much free silica is there in the rock?



Silica is silicon dioxide, one of the most abundant minerals in the earths crust. It is present in almost all types of rock, sands, clays, shales and gravel. It is also a major constituent of construction materials such as bricks, tiles and concrete. Crystalline silica will be present in most mining, quarrying and exploration operations.

3.0 Workers exposure.

Figure 3.1

Are workers exposed to airborne dust?

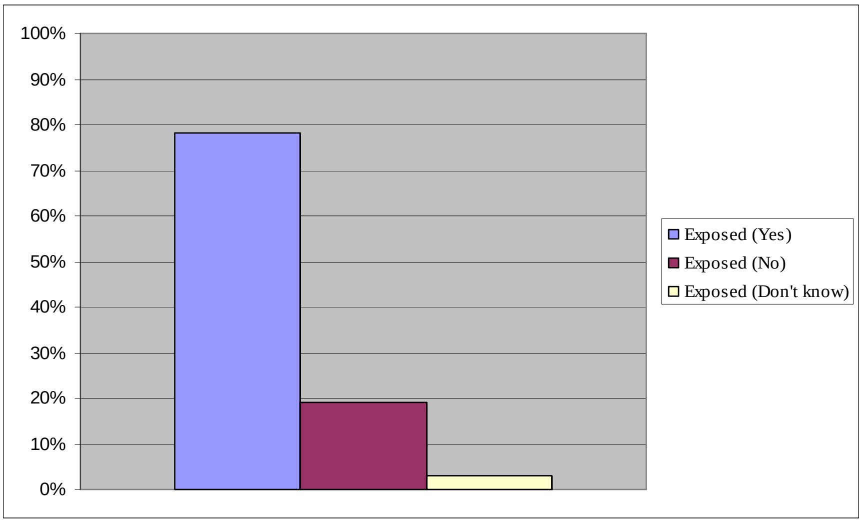
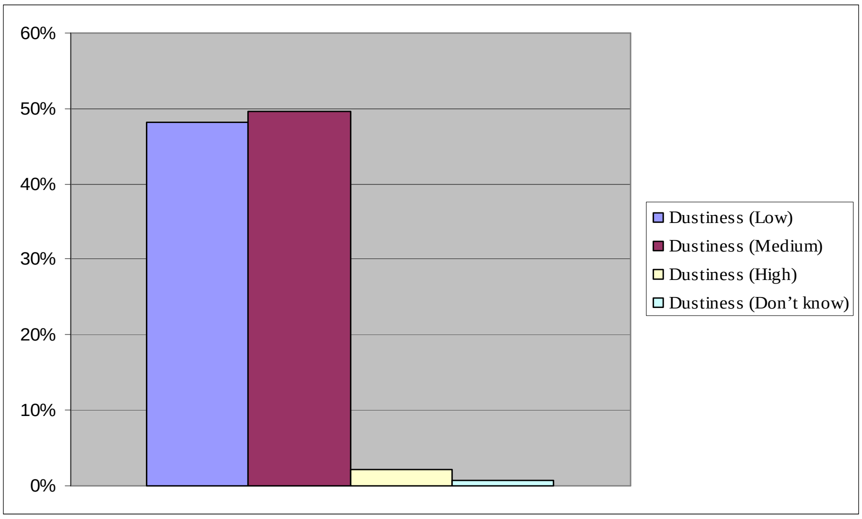


Figure 3.2

Dustiness of operation.



Figures 3.1 and 3.2, indicate, that workers will be exposed to airborne dust containing respirable crystalline silica, that is, if exposures are not controlled through a well implemented respiratory protective equipment program.

4.0 Monitoring.

Figure 4.1

Has personal exposure monitoring been carried out?

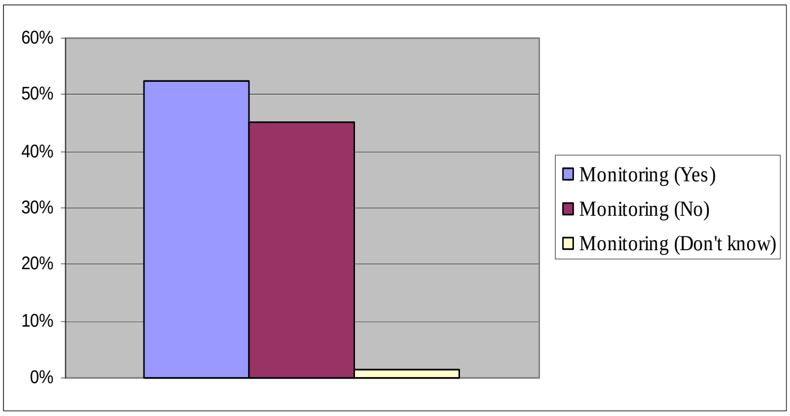


Figure 4.2

Where monitoring is carried out are workers provided with their own personal results?

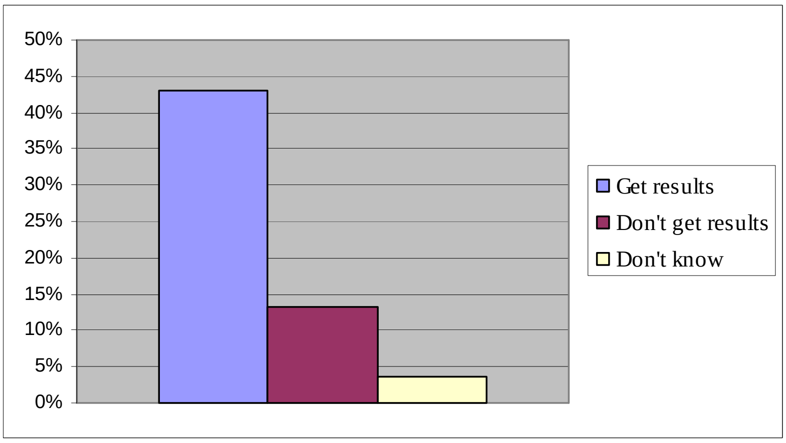
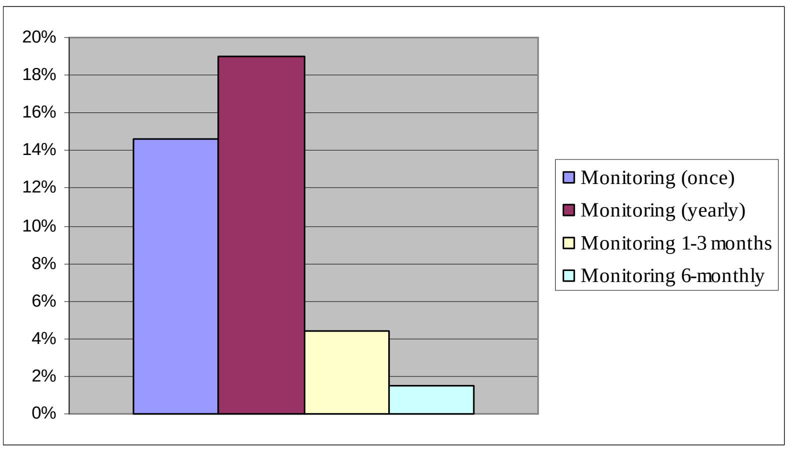


Figure 4.3

How often is monitoring carried out?



In figure 4.1, nearly 50% noted that personal exposure monitoring hasn't been carried out. This means that there may be a number of workers being exposed to RCS. If monitoring hasn't been carried out, both they and the SSE will not know the level of exposure and hence whether their health is at risk. The frequency of monitoring should be risk based. That is, for rock with higher concentrations of free silica and where exposures are higher monitoring should be carried out more frequently. The following tables provide suggestions upon which to establish an ongoing monitoring program.

Table 4.1

Suggested ongoing monitoring frequency, based on maximum and average concentrations (1):

		Maximum concentration measured as a % of the Exposure Standard (TWA)			
		< 25%	25 to 50%	50 to 100 %	> 100%
Average concentration measured as a % of the Exposure Standard (TWA)	< 25%	1 per 24 months	1 per 12 months	1 per 6 months Ensure appropriate RPE pogram is implemented and HOC followed.	1 per 6 months Ensure appropriate RPE pogram is implemented and HOC followed.
	25 to 50%		1 per 12 months	1 per 6 months Ensure appropriate RPE pogram is implemented and HOC followed.	1 per 6 months Ensure appropriate RPE pogram is implemented and HOC followed.
	50 to 100 %			1 per 6 months Ensure appropriate RPE pogram is implemented and HOC followed.	1 per 3 months Ensure appropriate RPE program is implemented and HOC followed
	>100%				1 per 3 months Ensure appropriate RPE program is implemented and HOC followed

RPE: Respiratory protective equipment.
HOC: Hierarchy of Controls

Table 4.2

Suggested ongoing monitoring frequency based on maximum concentration (2):

Maximum exposure concentration as a % of Exposure Standard (TWA)	**Monitoring frequency**
< 10	5-yearly
10 - 25	2-yearly
25 - 50	Yearly
50 - 100	6-monthly
> 100	3-monthly

Source: "A strategy for assessing and managing occupational exposures – third edition, 2006, American Industrial Hygiene Association p.115".

Notes:

1. Both tables 4.1 and 4.2 provide alternatives upon which to develop an ongoing personal exposure monitoring program.
2. Initially 3 days of monitoring should be undertaken for each job type (similar exposure group) within a year.
3. The ongoing monitoring frequency applies to each similar exposure group (SEG).

   A similar exposure group is a group of workers having the same general exposure profile for the agent(s) being studied because of the similarity and frequency of the tasks they perform, the materials and processes with which they work and the similarity of the way they perform the tasks. (Mulhausen et al, 1998)
4. The highest result for each job type should then be used to determine the ongoing monitoring frequency.
5. As the exposure reduces then monitoring may be carried out less frequently.
6. Tables 4.1 and 4.2, apply to processes that are fairly constant. Where there is a significant change to a process it is recommended that the monitoring as per note 2 be repeated.
7. Where the exposure concentration exceeds 50% of the Exposure Standard (TWA), **controls should be implemented immediately** and follow-up monitoring should be undertaken to demonstrate that the controls effectively reduce exposure.
8. The hierarchy of control should always be followed where RPE is either a last resort or used until such time that the risk is reduced by higher order controls (refer to section 6.1).
9. Where a respiratory protection program is implemented and shown to conform to AS/NZS 1715:2009, "selection use and maintenance of respiratory protective equipment", the monitoring frequency may be reduced.

5.0 Respiratory protective equipment (RPE).

Figure 5.1 How often is respiratory protective equipment worn?

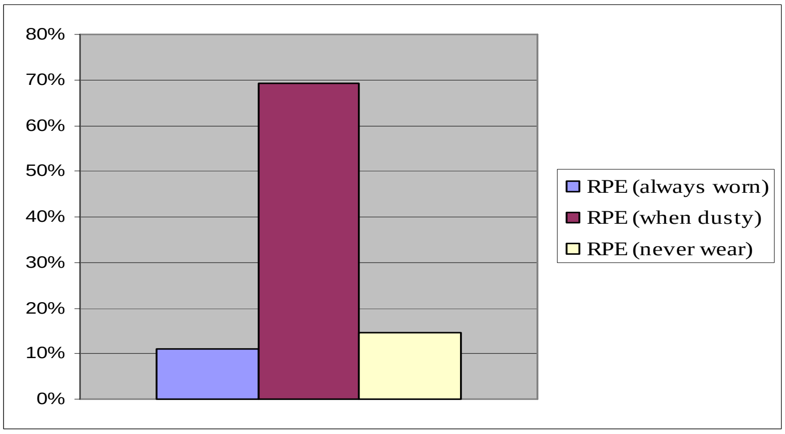
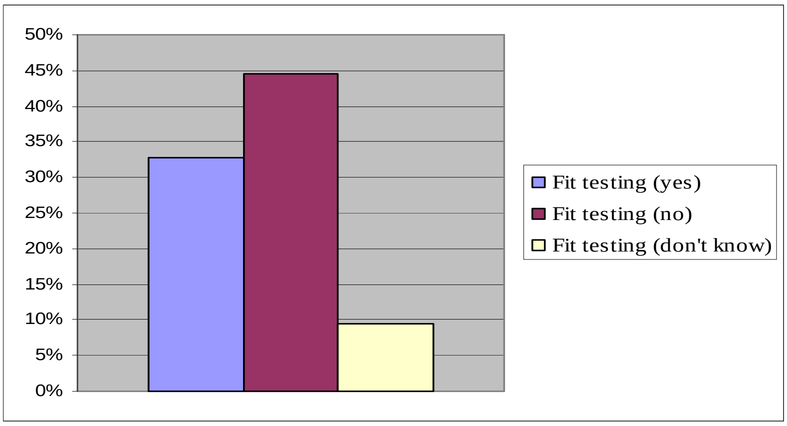


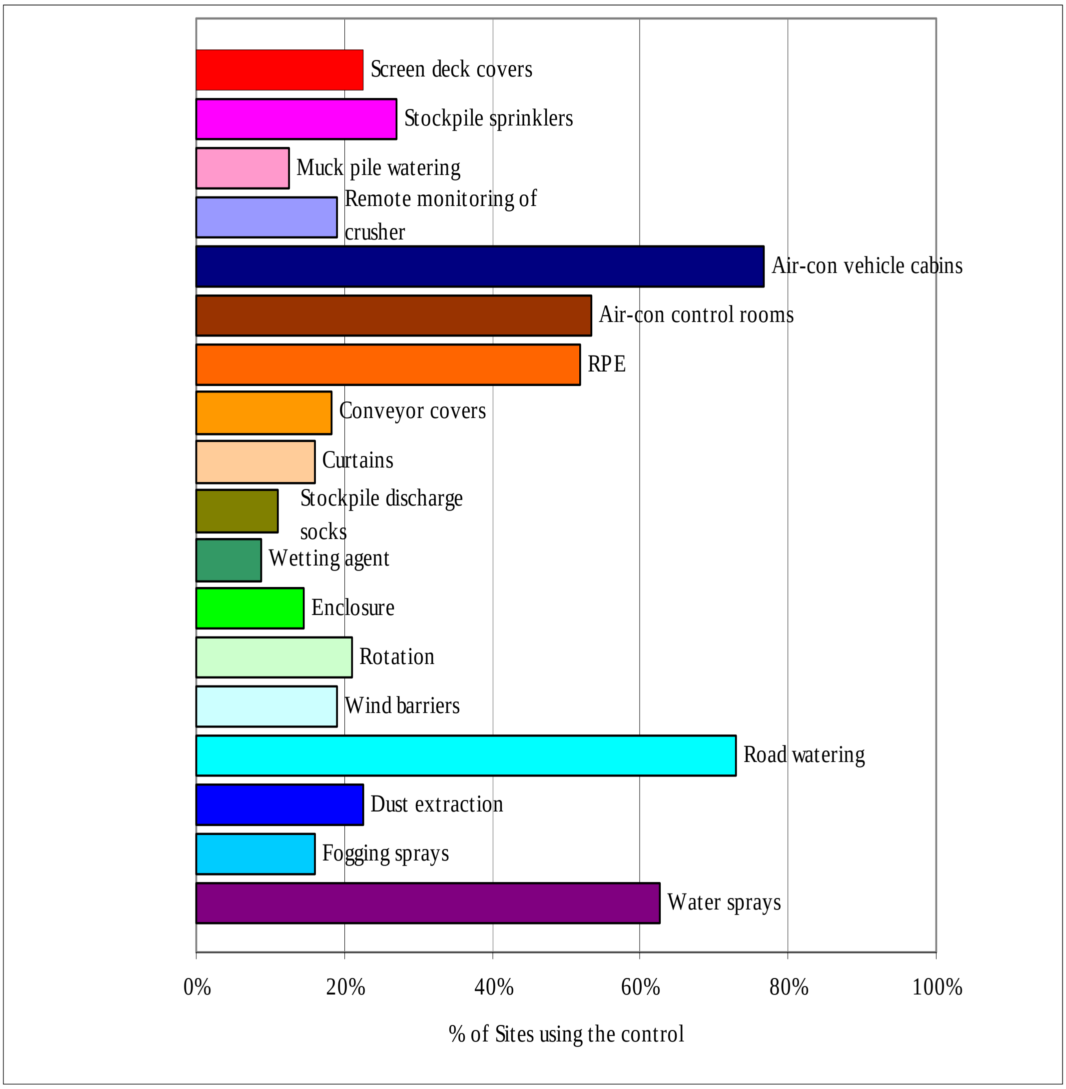
Figure 5.2 Is face-fit testing carried out?



The feedback notes that most sites use respiratory protective equipment "when dusty". Observation of visible dust shouldn't be the only indicator to demonstrate that a respirator is necessary. In other words it is the fine invisible dust particles which are most hazardous. That is why it is important that personal monitoring be carried out for respirable crystalline silica in order to identify job types and specific tasks where control is necessary. From the monitoring an RPE job and task matrix should be established. In addition the respiratory protective equipment program should conform to AS/NZS 1715:2009, Selection, use and maintenance of respiratory protective equipment. The respiratory protective equipment program should include a clean shaven policy, fit testing and training. Furthermore *Section 140 of the Mining Quarrying Safety and Health Regulation 2001* sets out requirements around the use of personal protective equipment as a means of reducing a person's exposure to a hazard. This includes the suitability of RPE provided and training in its correct use.

6.0 Dust controls

Figure 6.1 The percentage of sites responding that they use the dust controls listed.



There is a high level of reliance on air-conditioned vehicle cabins. It is uncertain whether standard air conditioning systems provide an effective barrier and offer acceptable protection against RCS, especially for ultrafine particles. Monitoring should therefore be carried out in enclosed cabins to verify that the filtration system is effective.

When implementing controls, the order in which controls are implemented must follow the hierarchy of controls.

6.1 Hierarchy of Controls

Under the *Mining and Quarrying Safety and Health Regulation 2001, section 8, risk reduction, the following is stated:*

(1) A person who has an obligation under the Act to manage risk at a mine must, as far as reasonably practicable, apply hazard controls in the following order –

a. Elimination of the hazard;

b. Substitution with a lesser hazard;

c. Separation of persons from the hazard;

d. Engineering controls;

Examples of engineering controls -

i. Using fans and ducting to remove dust

ii. Using guards on conveyors

e. Administrative controls;

Examples of administrative controls –

i. A restriction on the time a worker is exposed to a hazard

ii. A procedure or standard work instruction

f. Personal protective equipment.

(2) The site senior executive must ensure hazard controls used to reduce risk in the mine's work and local environments are appropriate having regard to the following-

a. The interaction of the hazards present in the environments;

b. The effectiveness and reliability of the controls;

c. Other reasonably available relevant information and data from, and practices in, other industries and mining operations.

7.0 Health surveillance

Figure 7.1 Do workers have regular health surveillance?

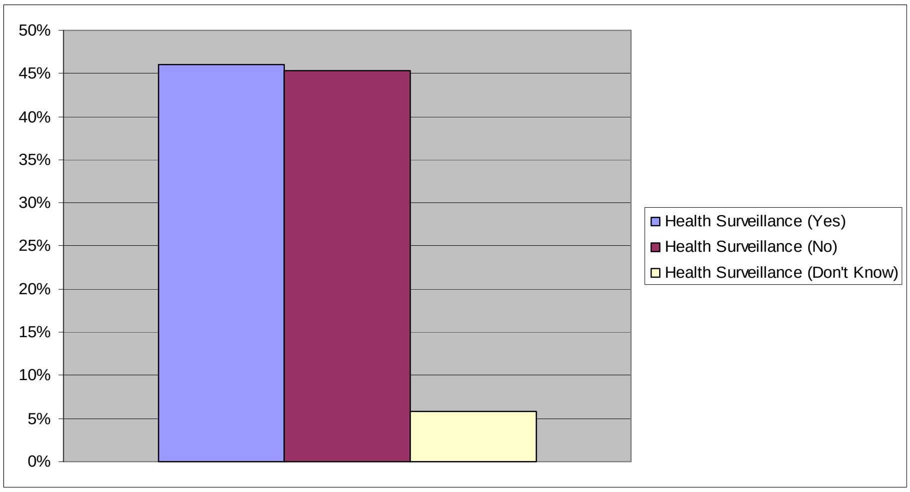
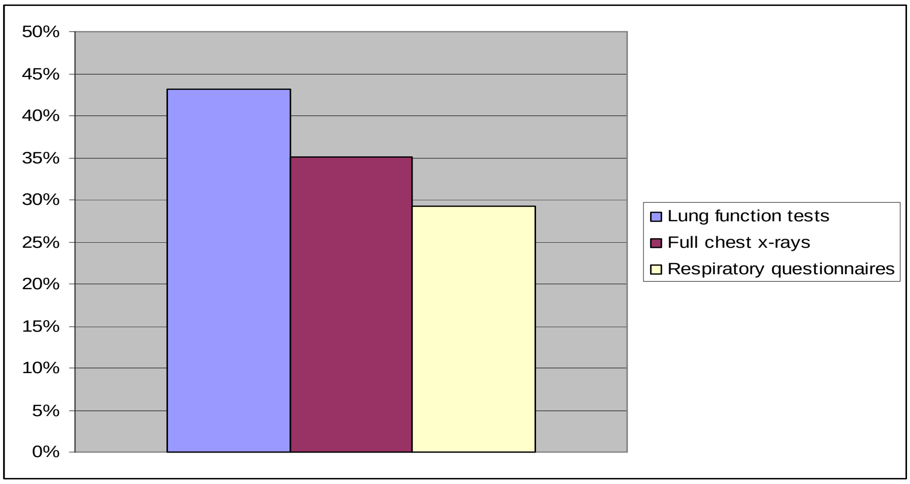


Figure 7.2

Type of health surveillance: - as a percentage of all responses.



Where there is potential for exposure to RCS the following health surveillance is recommended:

- Demographic information, such as date of birth, descriptive job title, should be collected, including information relating to occupational and medical history of employees.
- The worker should be informed of the potential health effects associated with exposure.
- A physical examination should take place if the need for one is indicated by the workers occupational or medical history, with emphasis on the respiratory system.
- A standardised respiratory questionnaire should be completed.
- Standardised respiratory function tests should be conducted, as well as a chest X-ray (full size posterior-anterior view).
- Records of personal exposure should be kept. The data that should be kept with the health records of a worker include descriptive job titles, with relevant start and finish dates, records of any assessments carried out and the results of personal exposure monitoring.

Refer to the Safe Work Australia Guidelines for Health Surveillance NOHSC : 7039 (1995).
Refer to: http://safeworkaustralia.gov.au/

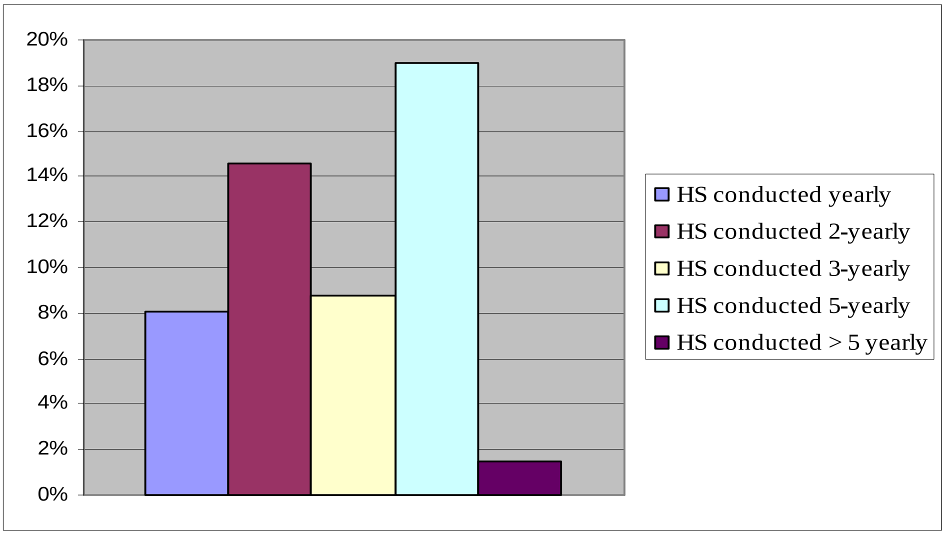
The Australian Institute of Occupational Hygienists (AIOH) position paper for respirable crystalline silica (February 2009) recommend that:

> *Where there is a continued likelihood of 50% of the exposure standard being exceeded, exposure monitoring and health surveillance shall apply*

Refer to: http://www.aioh.org.au/industry_index.asp

Figure 7.3

Frequency of health surveillance.



The American College of Occupational and Environmental Medicine (ACOEM) has a provided a health surveillance strategy as follows:

Health surveillance for workers exposed to crystalline silica.

Where exposure to respirable crystalline silica is > 0.05 mg/m^3:

Occupational and medical history.
Physical examination.
Full chest x-ray.
Respiratory questionnaire.
Spriometery.

Baseline evaluation. *If at any point, the worker is suspected of having silicosis during a surveillance evaluation, remove from exposure and refer immediately for definitive diagnosis.*

1. Follow-up evaluation within 12 months: Evaluate need for repeat chest x-ray at this time.
2. If worker exposure is < 0.05 mg/m^3, assess need for frequency of future follow-up evaluations.
3. If worker exposure is ≥ 0.05 mg/m^3, for less than 10 years follow-up evaluation every 3 years.
4. If worker exposure is > 0.05 mg/m^3, for 10 or more years follow-up evaluation every 2 years.

Exit evaluations may serve as the baseline evaluation for the next job if the worker is moving on to a new job with silica exposure.

Source ACOEM http://www.acoem.org/guidelines.aspx?id=746
http://www.systoc.com/outcomes_protocols/CrystallineSilica.htm

The frequency of health surveillance should increase with the level of exposure (risk) and how long the worker has worked in this industry.

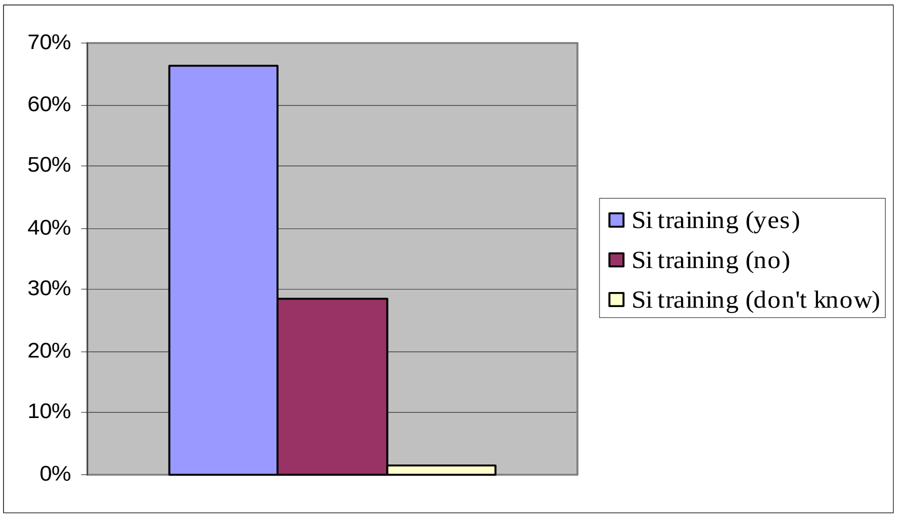
In addition, section 138 of the MQSHR 2001, states that: a health assessment of workers must be carried out in an appropriate way, including for example, by a medical examination, having regard to the nature of the hazard. The assessment must be done by, or under, the supervision of an "appropriate doctor".

An appropriate doctor for health surveillance or health assessment of a person at a mine, means a doctor with demonstrated knowledge of the risks associated with activities performed by the workers.

8.0 Training / awareness.

Figure 8.1

Do workers receive awareness training about the hazards associated with crystalline silica?



Nearly 30% of respondents, have noted, that no training is provided to raise awareness about the hazardous nature of crystalline silica.

9.0 Discussion.

Overall the response rate provides a good sample representing small mines, quarries and exploration sites. From the responses it is evident that the awareness about crystalline silica being present is low. Even though it is likely that a number of workers will be exposed to airborne dust, nearly 50% of respondents noted that no personal monitoring is carried out.

When asked how often respiratory protective equipment is worn most responses noted "respirators or dust masks are worn when it is dusty". It should be noted that respirable silica containing dust is hazardous to the lung. At less than 18 micrometres in aerodynamic diameter – this fraction of dust is invisible. Relying on "individual's perception" of dusty conditions as a precursor to the use of respirators won't allow adequate protection.

With regard to controls, a break down of controls shown in figure 6.1 indicates that industry places reliance on air conditioned vehicle cabins. What is uncertain is whether, air conditioned air is fan forced and whether the filtration is adequate to filter respirable and ultra fine particles.

One of the main findings to come out of the survey was that nearly 50% of respondents noted that health surveillance wasn't carried out. Considering that respirable crystalline silica or quartz is present in most rock types, operators may be at risk without health surveillance being conducted.

10.0 Conclusion.

Findings to date, along with some preliminary exposure monitoring (unpublished data) has indicated the potential risk for respirable crystalline silica to pose a risk for adverse health effects.

Low level cumulative exposure to respirable crystalline silica may lead to chronic silicosis many years after a worker has retired. Therefore, it is imperative that the level of awareness around health effects, dust control and health surveillance be improved.

Where there is likelihood for any result exceeding 50% of the exposure standard, the use of respiratory protective equipment and implementation of an RPE program should be enforced until exposures are reduced following the hierarchy of control.

The RPE program should conform to AS/NZS 1715:2009, selection use and maintenance of respiratory protective equipment.

To obtain further information about health effects and good practices refer to the AIOH position paper on RCS via the following web link: http://www.aioh.org.au/industry_index.asp

To access additional good control practice information refer to the following UK Health and Safety Executive web link http://www.hse.gov.uk/pubns/guidance/index.htm

It should be noted, that this report is based on feedback received from 131 sites which accounts for only 31% of all sites. It may be that a greater number of sites, with better dust management practices, responded, whilst many sites with sub-optimal dust management practices did not respond. If this is the case, then this report may be biased toward sites with better management practices and therefore underestimate the risk by not including sites with sub-optimal practices.

11.0 References

1. Mining and Quarrying Safety and Health Regulation 2001.

2. Australian Institute of Occupational Hygienists (AIOH) February 2009, position paper on respirable crystalline silica and occupational health issues. Refer to http://www.aioh.org.au/industry_index.asp

3. World Health Organization (WHO) Global Workplan of the Collaborating Centres in Occupational Health; Table of Priorities for 2009 – 2012. Refer to http://www.who.int/gb/ebwha/pdf_files/WHA60/A60_R26-en.pdf

4. Safe Work Australia Guidelines for Health Surveillance NOHSC : 7039 (1995). Refer to: http://safeworkaustralia.gov.au/

5. American Industrial Hygiene Association (2006), A strategy for assessing and managing occupational exposures. Third Edition. American Industrial Hygiene Association Exposure Assessment Strategies Committee.

Appendix A

Questionnaire to identify activities in Queensland mining sites where there may be potential exposure to respirable crystalline silica

Many minerals contain silica, and produce silica dust known as Respirable Crystalline Silica (RCS). RCS is also known as respirable α-quartz, cristobalite, or 'free silica'.

Type of site? □ Quarry □ Mine □ Exploration Site

Number of workers on site? □ Less than 10 □ 10 - 20 □ More than 20

1.0 Silica content:

1.1 Do you know whether the rock excavated on your site contains "free silica"?			
□ yes	□ no	□ don't know	
1.2 If yes, how much free silica is there in the rock?			
□ < 10%	□ > 10% < 50%	□ > 50%	□ don't know

2.0 Exposure:

2.1 Are workers at your site exposed to airborne dust?				
□ yes	□ no	□ don't know		
2.2 What do you consider is the dustiness of your operations?				
□ low	□ medium	□ high	□ don't know	
2.3 How many months a year does your site operate?				
□ up to 3-months	□ 3 to 6 months	□ 6 – 9 months	□ full year	□ don't know

3.0 Monitoring:

3.1 Has your site had personal airborne exposure monitoring carried out?			
□ yes	□ no	□ don't know	
3.2 If yes, have your workers been provided with their own personal results?			
□ yes	□ no	□ don't know	
3.3 If yes, how often is monitoring conducted?			
□ Has only been done once.	□ Yearly	□ Every 1 - 3 months.	□ Every 6 months.

4.0 Respiratory protective equipment:

4.1 Do workers on your site wear respirators and if so what type?		
□ Dust masks (disposable).	□ Cartridge (non disposable)	□ Powered air purifying
□ No they don't wear respirators.		
4.2 Have your workers received training in the use of respirators/dust masks?		
□ yes	□ no	□ They don't wear respirators.
4.3 Where dust masks or cartridge type respirators are worn have the workers been fit tested?		
□ yes	□ no	□ Don't know.
4.4 How often are respirators worn?		
□ Always.	□ Only when dust.	□ Never.

5.0 Dust control:

5.1 Please indicate what dust controls are present on you site? (tick as many as required)	
□ Water sprays.	□ Curtains.
□ Fogging sprays.	□ Conveyor covers.
□ Dust extraction systems.	□ Respiratory protection.
□ Road watering.	□ Air-conditioned control rooms
□ Wind barriers.	□ Air-conditioned vehicle cabins
□ Worker rotation between dusty and non-dusty jobs.	□ Remote monitoring of crusher from camera within control room
□ Enclosed crushing and screening plants	□ Muck pile watering
□ Wetting agent.	□ Stockpile sprinklers.
□ Stockpile discharge socks.	□ Screen deck covers.

6.0 Health Surveillance:

6.1 Do your workers have regular health surveillance?				
□ yes	□ no	□ don't know		
6.2 If yes, please indicate what health surveillance is conducted?				
□ Lung function tests.	□ Full chest x-rays.	□ Respiratory questionnaires.		
6.3 If yes please indicate how often this health surveillance is conducted?				
□ Yearly	□ 2-yearly	□ 3-yearly	□ 5-yearly	> 5-yearly

7.0 Training and awareness.

7.1 Do you provide workers with training to raise awareness about the hazards of crystalline silica?		
□ yes	□ no	□ don't know

8.0 Participation in study:

Thankyou for providing this information and are you willing, for your site, to participate in the personal exposure monitoring study?		
□ yes	□ no	□ don't know but am happy to discuss

Department of Employment, Economic Development and Innovation

Dust Self Assessment Feedback Report

Part B – Metal

File 04241

Toward Q2 Tomorrow's Queensland
Queensland Government

EXECUTIVE SUMMARY

Metal mine workers may be exposed to airborne dust whilst undertaking a variety of processes during mining and processing activities.

Mine workers may be exposed to respirable crystalline silica (RCS) and other airborne contaminants, including metals that may be present in the extracted rock.

The prevalence of disease associated with dust exposure in Australia over recent decades has reduced. This may be attributed to advances in dust suppression technologies, an increased awareness of the hazard and a general rise in the level of health and safety standards across the mining industry. Nonetheless it is essential that exposure to airborne dust continues to be tightly monitored and controlled. To do this effectively it is necessary to have in place a dust management program that is able to identify, characterise and assess personal exposures.

In order to gain a better understanding of how mines are managing hazards associated with airborne dust, a self assessment (questionnaire) (attached as Appendix A), was developed and distributed to the Site Senior Executives of metal mine operations throughout Queensland.

Thirty-two completed self assessments were received resulting in an 86% response rate. The completed self assessments were reviewed and this report was prepared based on information provided by the mines.

Analysis of the questionnaire revealed that most mines have in place safety and health management systems that provide for the management of airborne dust hazards. Mines are assessing the personal exposures of mine workers who may be exposed to airborne dust, or hazardous constituents of the dust. However, the majority of personal monitoring programs do not include the concept of similar exposure groups (SEGs) or include statistical analysis of personal exposure data.

The use of personal respiratory protective equipment (RPE) in all mines is relied upon as part of the overall dust control strategy. Few operations have in place a respiratory protection program that includes fit testing and training in the selection, use and maintenance of these devices. Only 34% of mines have in place a clean shaven policy for personnel required to wear respiratory protective equipment. Australian Standard 1715 *Selection, Use and Maintenance of Respiratory Protective Equipment*, requires that fit testing be conducted and that there must be a clean shaven policy in place.

Information received from the self assessment indicates the following is **required** at a number of mines:

- risk based monitoring programs that incorporate SEGs and use of the data generated to identify areas requiring control
- implementation of controls in accordance with the hierarchy of control
- RPE fit testing and adoption of a clean shaven policy
- training in health surveillance, health effects of dust and the use of RPE
- a more risk based and systematic approach to programs for health surveillance and personal exposure monitoring
- results from both personal monitoring and health surveillance should be analysed together to evaluate whether the controls are effective and that there is no deterioration in workers health.

Table of Contents

1.0 Introduction

On 22 January 2009 a dust self assessment and covering letter was sent to metalliferous mines listed in the Queensland Mines and Quarries Safety Performance and Health Report 2007–2008. The self assessment (questionnaire) was sent along with a covering letter from the Chief Inspector of Mines (Metalliferous) asking mines to submit information.

This dust self assessment is part of a strategy supported by the tripartite Health Improvement and Awareness Committee (HIAC) to improve workers health in the Queensland mining and quarrying industries. Information being sought relates to all facets of dust management including:

- dust control strategies
- personal exposure monitoring
- analysis of monitoring results
- health surveillance
- record keeping
- training.

Processes involved in mining and processing may potentially expose workers to harmful levels of airborne dust. There is potential for exposure to respirable crystalline silica and metals including lead, arsenic, cadmium, zinc and copper.

Silica is silicon dioxide, one of the most abundant minerals in the earth's crust. It occurs in non-crystalline and in crystalline form. Crystalline silica is sometimes referred to as 'free silica'. The main forms of crystalline silica are quartz, cristobalite and tridymite, the most prevalent of which is quartz. Crystalline silica is an aggressive, lung damaging dust when it is able to penetrate deep into the lung in sufficient quantity. All forms of respirable crystalline silica (RCS) of occupational relevance have the potential to cause silicosis, an irreversible and progressive condition in which healthy lung becomes replaced with areas of fibrosis. The World Health Organization (WHO) in their priorities for 2009–2012, under their objective to devise and implement policy instruments on workers' health plans to:

'Develop and disseminate evidence-based prevention tools and raise awareness for the elimination of silica-related diseases.'

RCS is also known to cause chronic obstructive pulmonary disease (COPD) which includes bronchitis and emphysema.

Workers in some metal mining operations and associated processes may be exposed to dust containing lead, cadmium or arsenic.

Elevated exposures to lead in dust may lead to adverse health effects. Lead in blood is used as the primary indicator of exposure. Where blood levels are greater than 40 µg/dL, health effects can possibly include anaemia, hypertension and kidney disease (refer to Table 3 (AOEC, 2007)). Kidney disease is more likely in individuals exposed for more than 10 years. Damage to the sperm has been reported and long term exposure has also been reported to adversely affect the nervous system (ACGIH, 2001). The main risk from lead exposure is to pregnant women which may cause harm to the unborn child. (Refer to the following link for more information on lead: www.aioh.org.au/downloads/documents/PositionPapers/AIOH_LeadPositionPaper.pdf)

Unacceptable exposures to cadmium above the Safe Work Exposure Standard (TWA) of 0.01 mg/m^3 (refer to: www.hsis.ascc.gov.au/SearchES.aspx), may lead to the development of pre-clinical kidney dysfunction and lung cancer (ACGIH, 2001).

Elevated exposures to arsenic may cause adverse effects on the skin, liver, upper respiratory tract, and lungs, including cancer and obstruction of large arteries (ACGIH, 2001).

There may also be rare circumstances where there is potential for miners to be exposed to asbestiform fibrous minerals in dust. Only under rare geological conditions do asbestiform (i.e. fibrous) minerals occur. If present they usually occur in veins or small veinlets with the occurrences generally being small and isolated and therefore not often noticed. Elevated exposure to asbestos fibres may lead to pleural plaques which are a thickened patch on the layers of membrane that line the chest wall and cover the lungs; asbestosis, which is a progressive scarring of lung tissue, lung cancer and mesothelioma which is cancer of the chest cavity (plaura).

For the management of airborne dust and contaminants, the Mining and Quarrying Safety and Health Regulation 2001 (MQSHR 2001), places the obligation on the Site Senior Executive (SSE) to assess the risk and ensure that appropriate control measures are in place.

The dust self assessment was sent to 37 metal mines and 32 have responded. This equates to a response rate of 86%.

2.0 Legislative requirements

Section 135 of the MQSHR 2001 requires that an SSE at a mine must ensure:

a) a worker's exposure to a hazard does not exceed the exposure limit for a hazard, and
b) the exposure to the hazard is maintained as low as reasonably achievable (ALARA).

The regulation also requires that where there is potential for the exposure standard to be exceeded, the workers exposure to the hazard is monitored and the monitoring results are analysed.

Schedule 5 of the MQSHR 2001 refers to the 'Adopted National Exposure Standards for Atmospheric Contaminants in the Occupational Environment' (NOHSC:1003) and also refers specifically to a general exposure limit of 0.1 mg/m3 for crystalline silica (cristobalite, quartz and tridymite). It also applies limits for inhalable dust and respirable dust at concentrations of 10 mg/m^3 and 5 mg/m^3 respectively.

Where health surveillance is carried out it must be overseen by an 'appropriate doctor', that is a doctor with demonstrated knowledge of the risks associated with the activities performed by the mine workers. Hence there is a statutory requirement to engage a doctor with industry experience.

An occupational hygiene program that identifies hazards and assesses the risk is a fundamental first step in developing a health surveillance program.

According to the Australasian Faculty of Occupational Medicine (1998)[2] (now the Australasian Faculty of Occupational and Environmental Medicine):

'The aim of the pre-placement health assessment is to evaluate a person's physical and mental capacity to carry out the tasks inherent in a job and in the environment in which they are to work. The assessment helps to ensure that the job does not cause or aggravate any existing disease or injury and that the characteristics of any disease or disability will not cause harm to others, including fellow employees and members of the public, through inappropriate actions by the employee'.

The requirement for pre-employment is covered under the MQSHR 2001 Division 1 'Fitness'.

The pre-employment also provides a baseline so that subsequent assessments can be compared and interpreted against it.

Ongoing health surveillance is covered under the MQSHR 2001 Division 1 'Fitness' and s138 'Health Surveillance'. Health surveillance is required wherever hazards pose a risk to workers.

According to the *Mining and Quarrying Safety and Health Act 1999* schedule 2, **a worker** is an individual who carries out work at a mine and includes:

a) an employee of the operator; and

b) a contractor or employee of a contractor.

Under Division 1, covering 'Fitness' and s.138 covering health surveillance, the SSE has responsibility for health surveillance of **all workers**.

One of the most important steps in setting up an occupational hygiene monitoring program is establishing similar exposure groups (SEGs). It is important that the SEGs are clearly defined.

The vast majority of mines have provision in their Safety and Health Management System (SHMS) that provide for the control of exposure to airborne dust.

Seventy-eight per cent of mines are currently measuring and recording personal exposures of mine workers to dust and 84% of mines provide results to individuals who have participated in personal exposure monitoring. Seventy-eight per cent of mines also conduct ongoing health surveillance.

Only 59% of mines are reviewing the efficacy of controls.

Figure 2.1 General legislative requirements

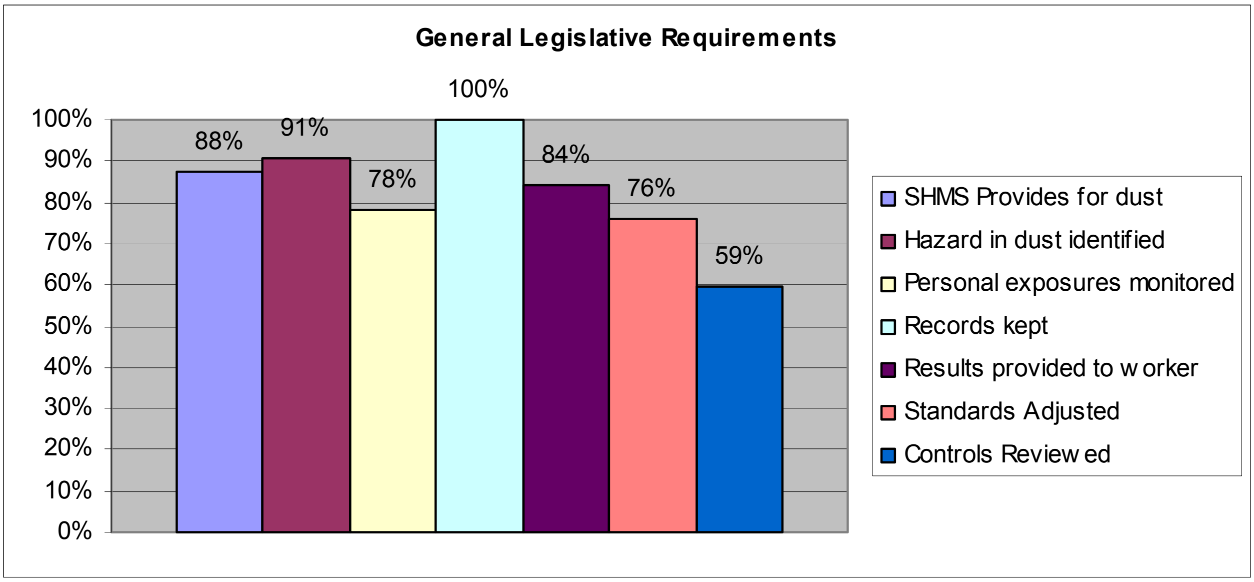
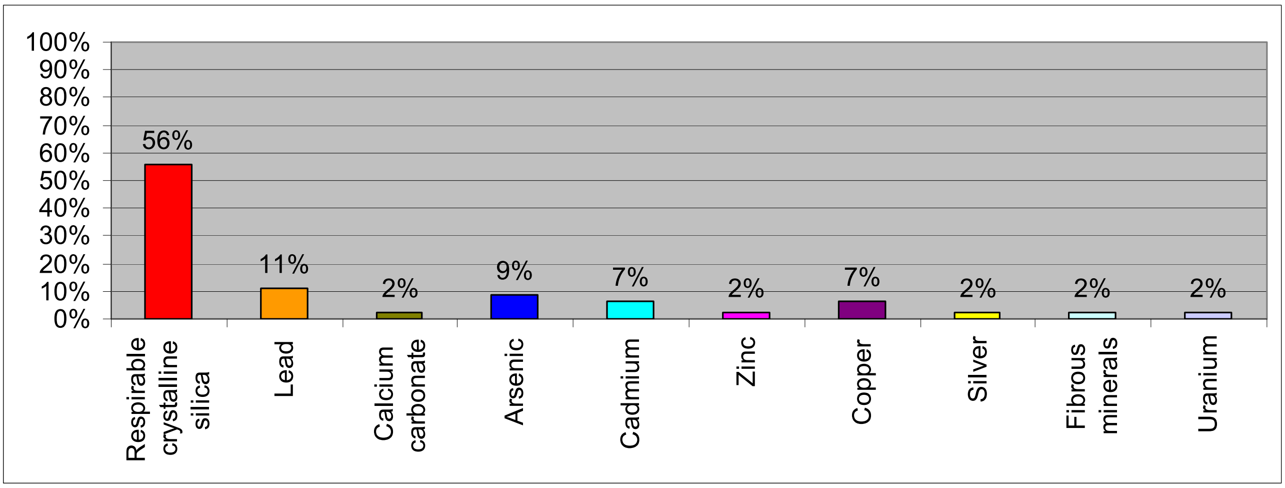


Figure 2.2 What is hazardous in the dust at your mine site?

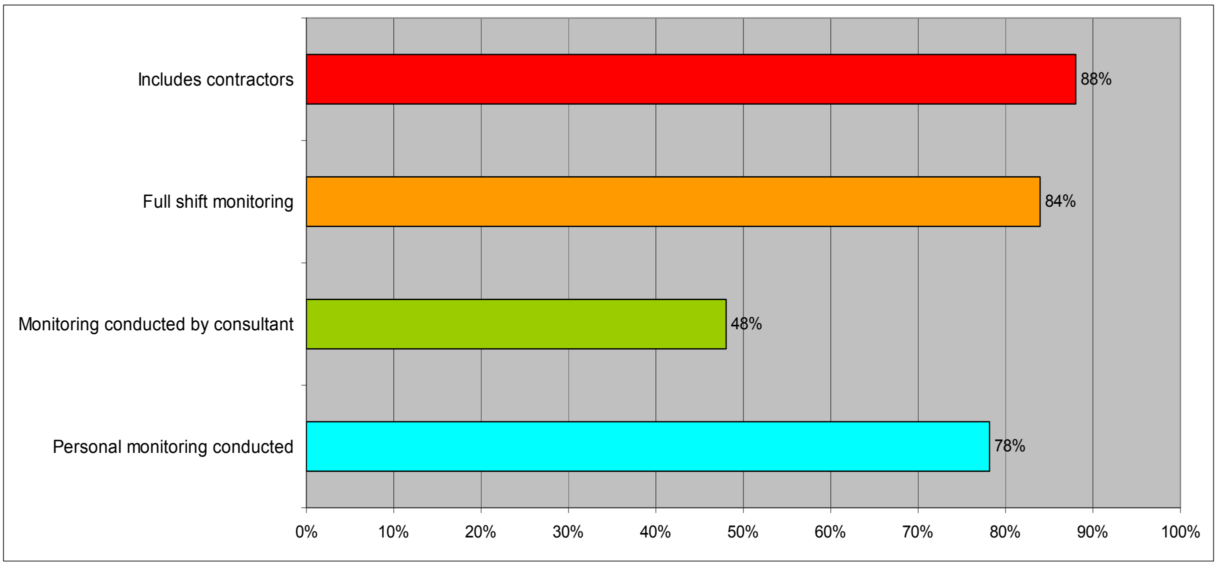


The majority of mines noted crystalline silica as being a hazardous constituent of the dust at the mine site.

The effects of exposure to respirable crystalline silica (RCS) are well documented. (Refer to the Australian Institute of Occupational Hygienists (AIOH) position paper on respirable crystalline silica and occupational health issues: www.aioh.org.au/downloads/documents/PositionPapers/AIOH%20RCS%20-%20Position%20Paper.pdf)

3.0 Personal exposure monitoring

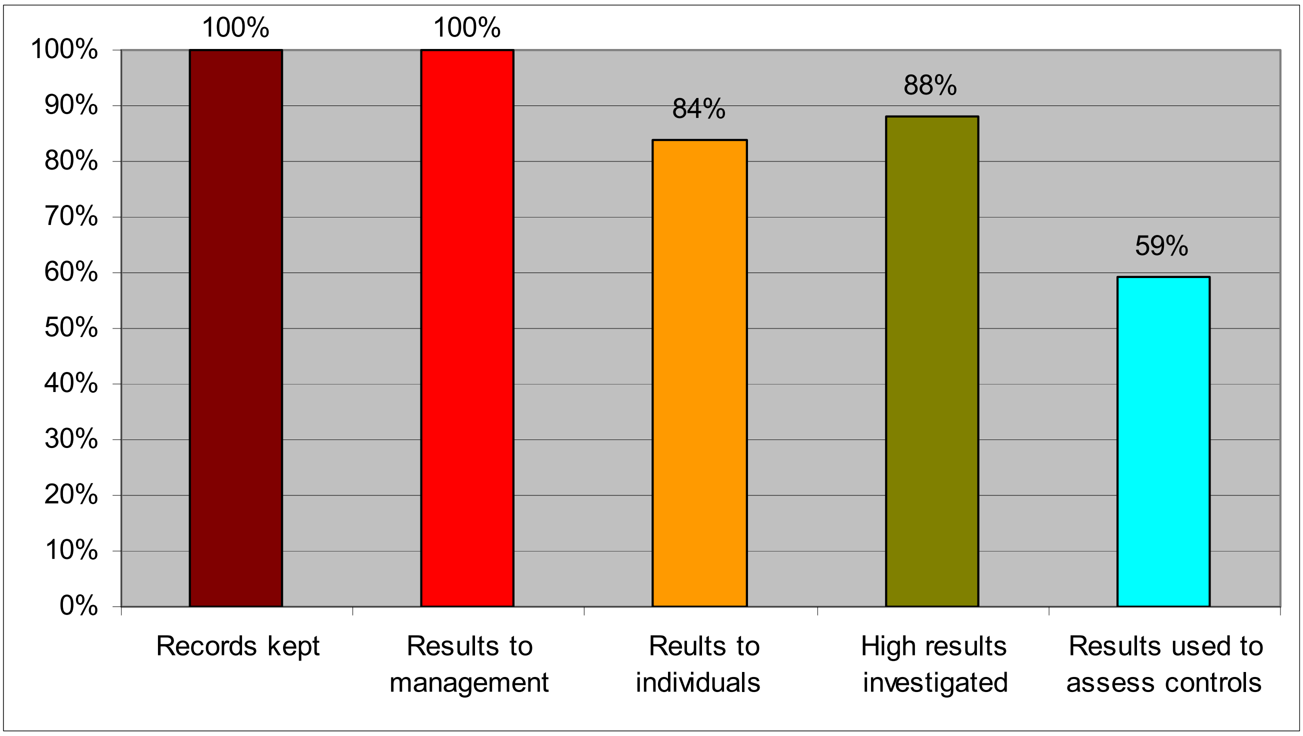
Figure 3.1 Personal monitoring programs details



Seventy-eight per cent of metal mines carried out some form of personal exposure monitoring, whilst most sites included contractors as part of their monitoring program. Eighty-four per cent of mine sites conduct monitoring over a full shift. Australian Standard (AS) 2985 (2009): *Workplace Atmospheres – Method for sampling and gravimetric determination of respirable dust,* states that the monitoring period should be as long as reasonably practicable and representative of the working period of individuals exposed (but for not less than four hours).

It is possible that a significant portion of the entire exposure may be attributed to specific tasks that occur over a relatively short period, such as clean up. If monitoring is only conducted for four hours of a 12-hour shift, it is possible that periods of significant exposure may be missed. For this reason full shift monitoring should be conducted wherever possible. The exception to this may be for job types that do not vary in terms of task and environment such as a dump truck operator and control room operator.

Figure 3.2 Treatment of results



Only 59% of sites utilise the results from monitoring to assess the effectiveness of control. For exposures to be further reduced as low as reasonably achievable it is important that the controls are assessed to show whether they are indeed effective. Results from fixed position monitoring may be used as an indicator for example in a crusher control room to determine whether an effective barrier is provided. The majority of mines indicate that they review monitoring data in order to investigate the reason behind excessive exposures and to assess the effectiveness of control measures in place. It is unclear if this process is documented and records are kept.

Although it is good practice at site level to investigate each excessive exposure as they occur, it is also very important (and adds statistical validity) to review exposure data that has been collected across a similar exposure group over a period of time. This will reduce the effect of bias and the impact of any outlying or erroneous results. To do this effectively it is necessary to apply some form of statistical analysis.

Figure 3.3 Analysis of results

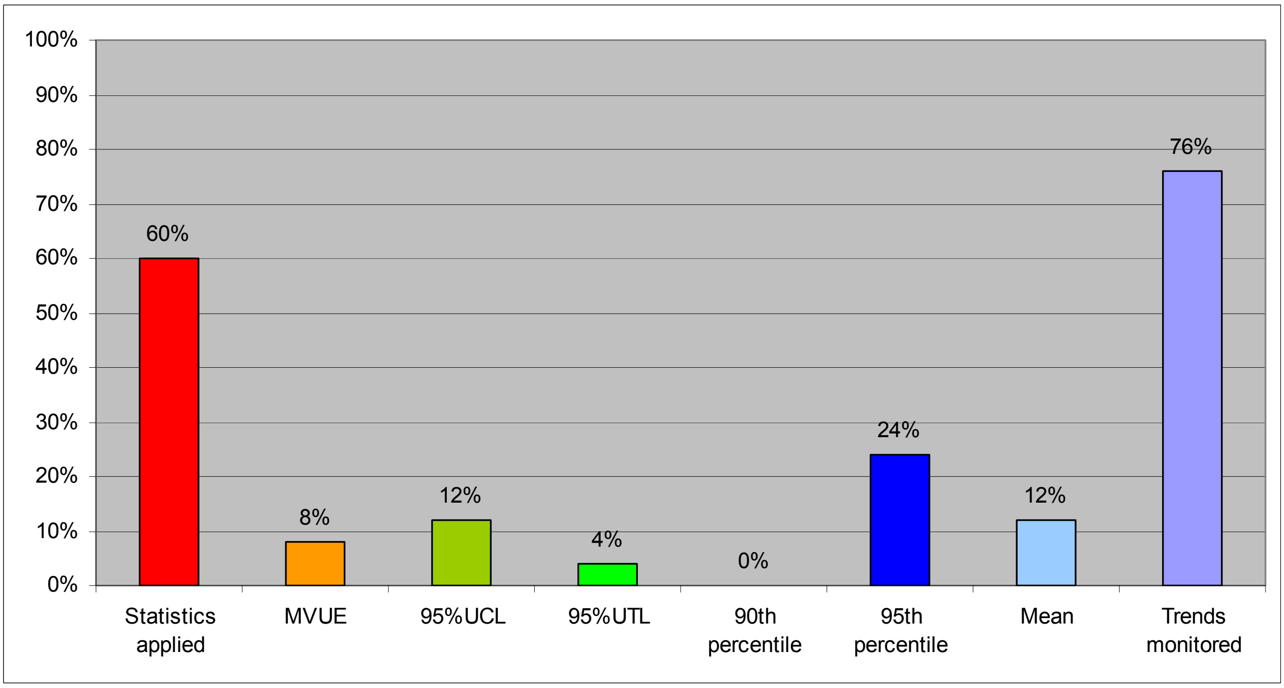


Figure 3.3 shows the number of sites applying some form of statistical analysis in assessment of results. Twenty-four per cent of sites compared the 95th percentile against the occupational exposure limit, whereas 76% of sites monitored trends.

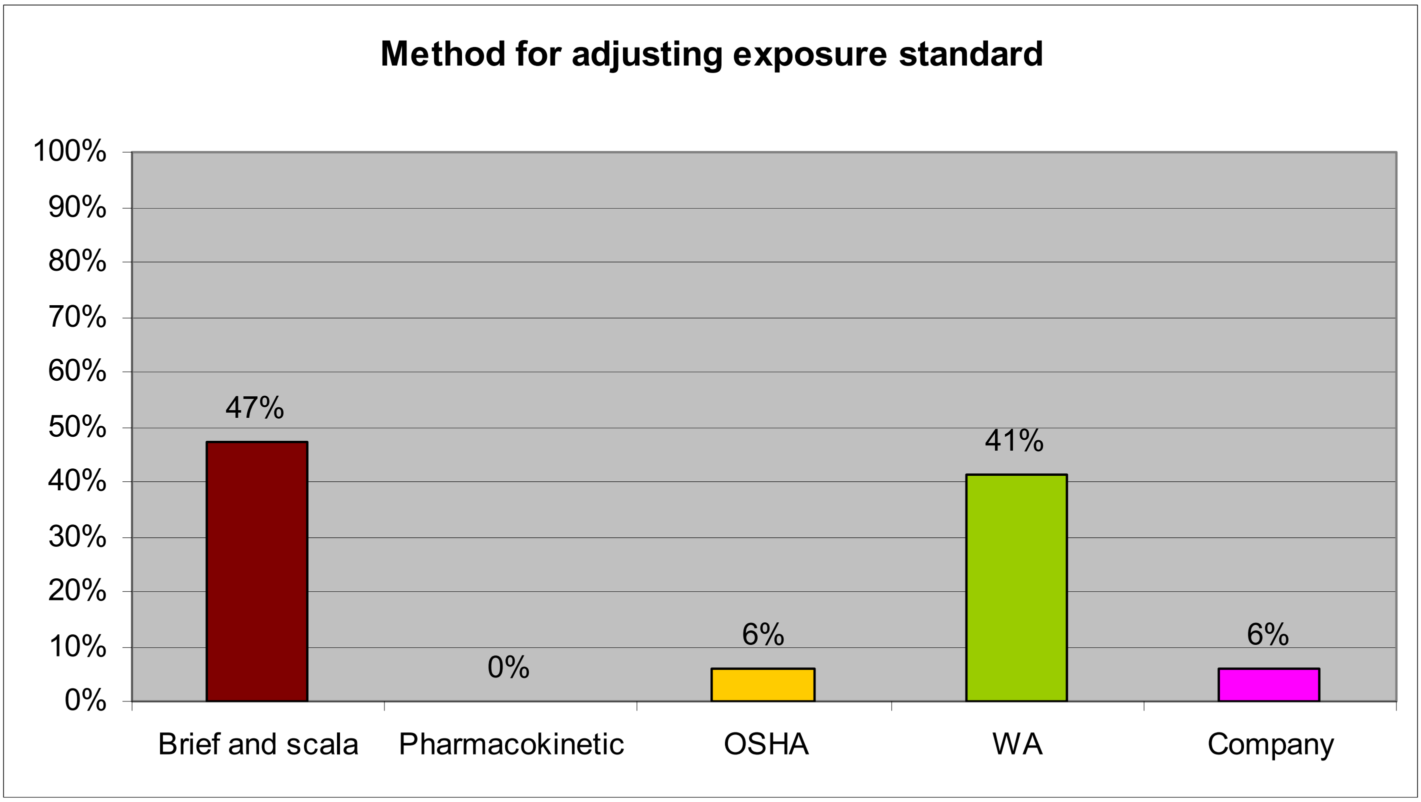
In order to be able to make informed decisions about measured exposures with some degree of confidence, it is necessary to apply some statistical analysis to the results. Generally when dealing with occupational hygiene monitoring data, it is important to know the estimate of the mean exposure for a given SEG and the confidence limits expressed around the mean. This provides a method for identifying exposure groups who are potentially at risk and a system for prioritising the implementation of controls and the need for further monitoring.

There are a number of computer programs available that enable the user to enter exposure data directly into a spreadsheet and it will calculate the estimate of the mean and associated confidence limits. Generally this is the Minimum Variance Unbiased Estimator (MVUE) and the 95% upper confidence limit (lands exact) of the arithmetic mean. The following links provide statistical programs that are freely available from the internet and may be used for the analysis of personal monitoring data.

www.aiha.org/insideaiha/volunteergroups/Documents/EASC-IHSTAT.xls

www.iras.uu.nl/speed/

Figure 3.4 Method for adjusting exposure standard



The majority of mines operate under altered shift working arrangements, whereby the conventional eight-hour day, five day week no longer applies. The occupational exposure limits prescribed in the legislation were derived with the conventional working week in mind. In order to ensure that mine workers operating under modern working arrangements (typically 12-hour shifts) are provided with adequate protection, it is imperative that the prescribed limits are reduced by a suitable factor. While the legislation does not stipulate the method to be used, there are a number of recognised methods available for adjusting exposure standards that are currently used throughout the coal mining industry (Figure 3.4). These include:

- Brief and Scala
- Pharmocokenetic (Hickey and Riest)
- OSHA method (Occupational Safety and Health Administration method)
- Western Australian Department of Minerals and Energy guideline

Of the 76% of sites that adjusted exposure limits for extended shifts, 47% used the Brief and Scala model, whereas 41% used the Western Australia model.

Safety and Health provides guidance on the Department of Employment, Economic Development and Innovation (DEEDI) website for adjusting exposure standards. This method incorporates the work schedule listing of the OSHA model to determine the appropriate Brief and Scala weekly or daily adjustment calculation to be used. This information can be accessed at the following link:

http://svc115.wic512d.server-web.com/zone_files/inspectorate_pdf/exp_standards_adj.pdf

Another method that has recently been introduced for adjusting exposure standards is the Quebec Model. This model is supported by a freely downloadable tool on the IRSST website that performs all calculations in a user friendly spreadsheet: www.irsst.qc.ca/en/_outil_100011.html

Figure 3.5 Selection methods for personal exposure monitoring participants

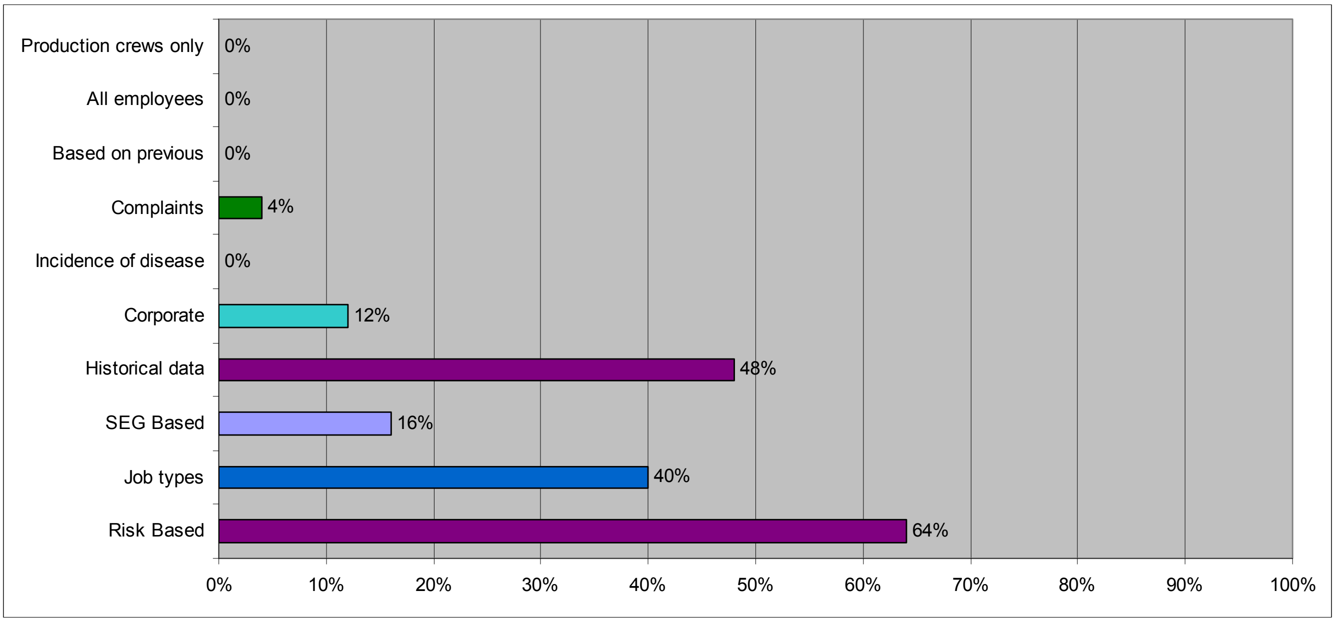


Figure 3.5 illustrates various factors considered when selecting personnel to participate in personal exposure monitoring. Most mines select operators to participate in personal exposure monitoring based on associated risk (64%). Selection that is truly risk based must involve statistical analysis of the results. It is likely that a number of operations that claim to have a risk based monitoring programs in actual fact have selected workers based on perceived risk.

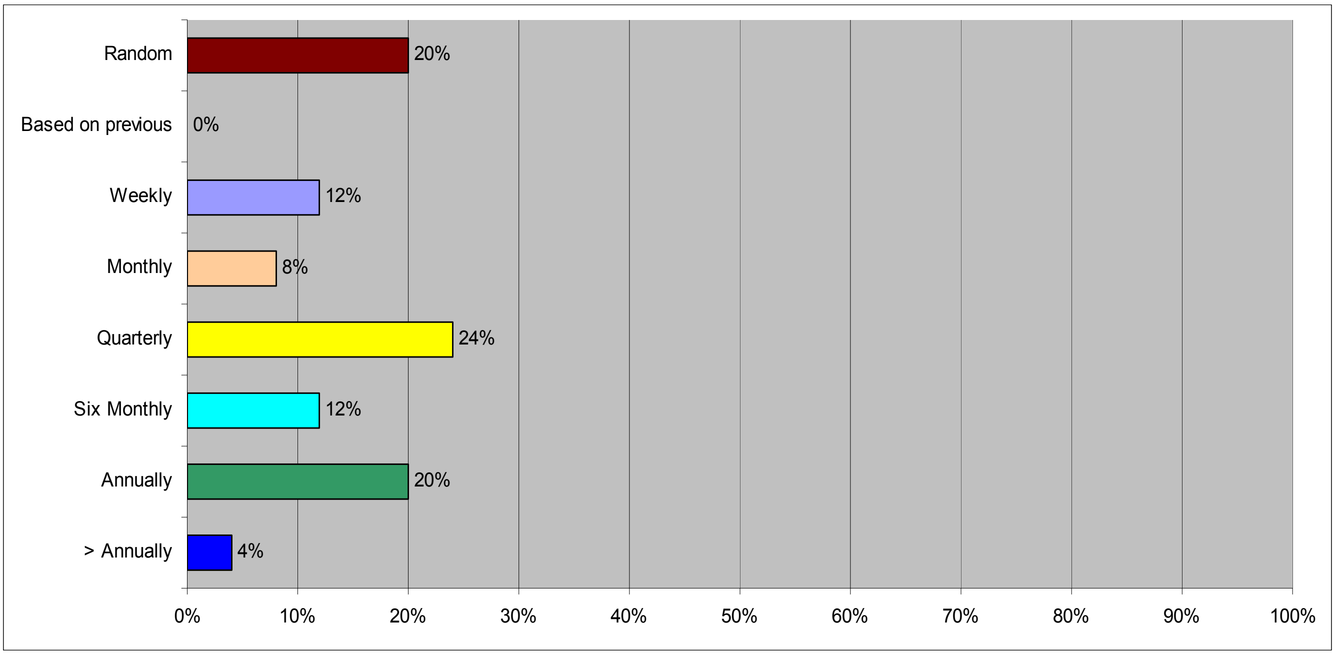
Sixteen per cent of mines have implemented monitoring programs where exposures have been characterised and SEGs established. A SEG is defined as:

> '*a group of workers having the same general exposure profile for the agent(s) being studied because of the similarity and frequency of the tasks they perform, the materials and processes with which they work and the similarity of the way they perform the tasks.*' (Mulhausen et al. 1998)

There are a number of advantages to establishing monitoring programs with properly defined SEGs. The major advantage is being able to use a smaller number of personal monitoring samples to make accurate assessments about the exposures of the larger population of workers in that group. In addition this can have considerable advantages in both savings in cost, resources and time. However, it is emphasised that clearly defined and appropriately assigned SEGs are essential to the success of these programs.

A list of suggested SEGs for metal mines has been provided (Table B1) in Appendix B.

Figure 3.6 Frequency of personal exposure monitoring



Self assessment responses indicate that the frequency at which sites perform monitoring varies from weekly to greater than annually. Most mines conduct quarterly monitoring.

There is no value in monitoring for the sake of monitoring. This is irrespective of how often monitoring is undertaken or how many samples are collected. The purpose of monitoring should be to identify unacceptable exposures so that control measures can be implemented to reduce exposures to within acceptable limits or to ensure exposure remains under control.

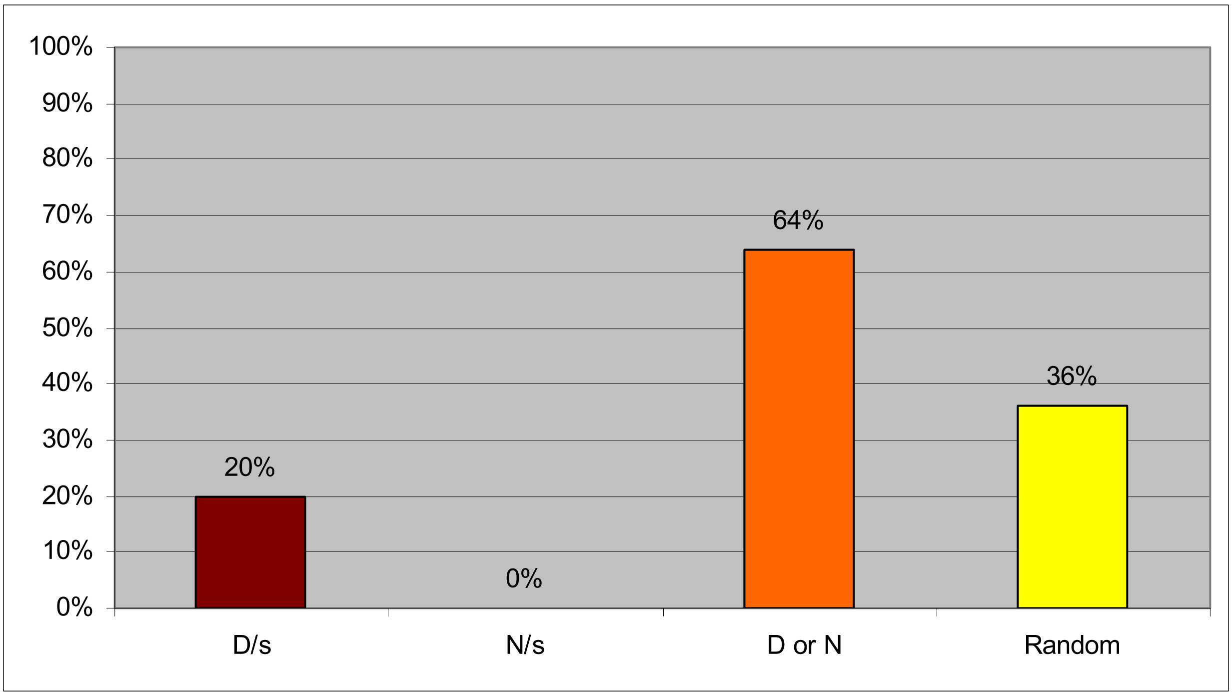
A comprehensive monitoring strategy should involve the concept of SEGs. The frequency for ongoing monitoring should be related to a measure of the group's exposure. This may be an estimate of the arithmetic mean exposure (least conservative), the 95% upper confidence limit on the mean (generally considered most appropriate for chronic toxins), or the 95% upper tolerance limit of the 95% upper confidence limit on the mean (most conservative and generally more applicable to acute toxins).

A combination of these may also be used. Guidance on how to establish an occupational hygiene monitoring program has been included as Appendix C. This will be of particular benefit to sites that have not identified SEGs or have not conducted baseline exposure monitoring. This information is provided as guidance only. More comprehensive information on personal monitoring strategies can be obtained from the following texts.

American Industrial Hygiene Association, 2006, *A Strategy for Assessing and Managing Occupational Exposure*, 3rd edn, American Industrial Hygiene Association Exposure Assessment Strategies Committee.

Grantham D., 2001, *Simplified Monitoring Strategies: Guidebook on how to apply the National Occupational Health and Safety Commissions' Exposure standards for Atmospheric Contaminants in the Occupational Environment to Australian hazardous Substance Legislation,* 1st edn, Australian Institute of Occupational Hygienists Inc, Tullamarine, Victoria.

Figure 3.7 On what shift is personal exposure monitoring conducted?



Sixty-four per cent of mines conduct monitoring on a combination of day and night shifts. Thirty-six per cent of these select the shift to be monitored randomly whilst 20% conduct monitoring on day shift only.

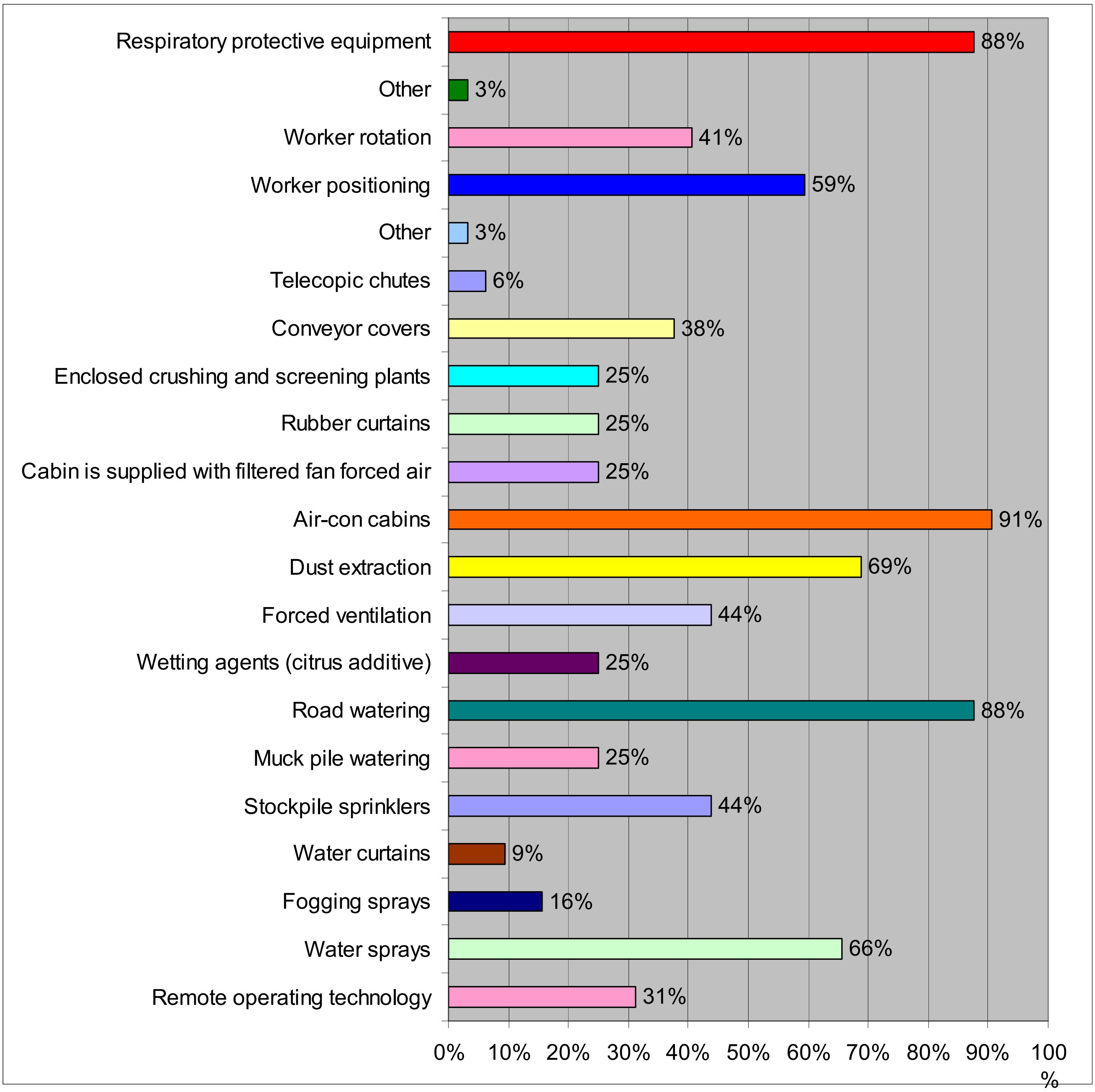
It is important that monitoring programs be structured in such a way to cover all variables and avoid potential sources of bias in the results. Some ways that bias may be introduced include:

- sampling the same crew disproportionately to other crews
- sampling the same coal mine worker disproportionately to other workers
- sampling during the same shift (day or night)
- sampling the same piece of mobile equipment disproportionately to other equipment
- sampling during the same season.

The way to successfully avoid sources of bias is to have a random sampling program in place. Random sampling programs are extremely resource intensive and will generally require the equipment and expertise for monitoring to be coordinated and conducted by onsite personnel. Only one mine currently has a monitoring program in place that could be considered 'random'.

4.0 Dust control

Figure 4.1 Percentage of mines using the dust control listed



In metal mines control measures focus on air-con cabins (91%), respiratory protective equipment (RPE) (88%), and road watering (88%). Only 25% of sites stipulate the use of positive pressure, filtered air-conditioned cabins. Recent research conducted by the Safety and Health division of DEEDI has found that standard air-conditioning systems may not provide adequate protection against the ultra fine particles. In order to remove these respirable dust particles, filtration systems need to be of high efficiency grade (i.e. HEPA) and cabins should be well sealed and operating under positive pressure to prevent the ingress of dust.

Independent trials conducted by the United States' National Institute of Occupational Safety and Health (NIOSH) and Safety and Health have demonstrated the effectiveness of a pre cleaning, filtration and pressuring system for the removal of ultrafine dust including RCS. These reports may be accessed at the following links:

www.cdc.gov/niosh/mining/pubs/pubreference/outputid3237.htm

www.dme.qld.gov.au/zone_files/hiac_files/respa_trial_2009__final_.pdf

This technology extracts the coarse dust to atmosphere prior to a fine filter and thus may not be suitable for environments where other workers are in close proximity.

Control measures should always be implemented in accordance with the hierarchy of controls.

Elimination of the hazard

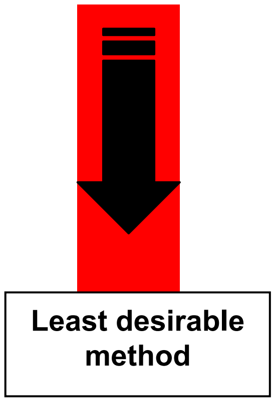
Substitution with lesser hazard

Separation of persons from the hazard

Engineering controls

Administrative controls

Personal Protective Equipment



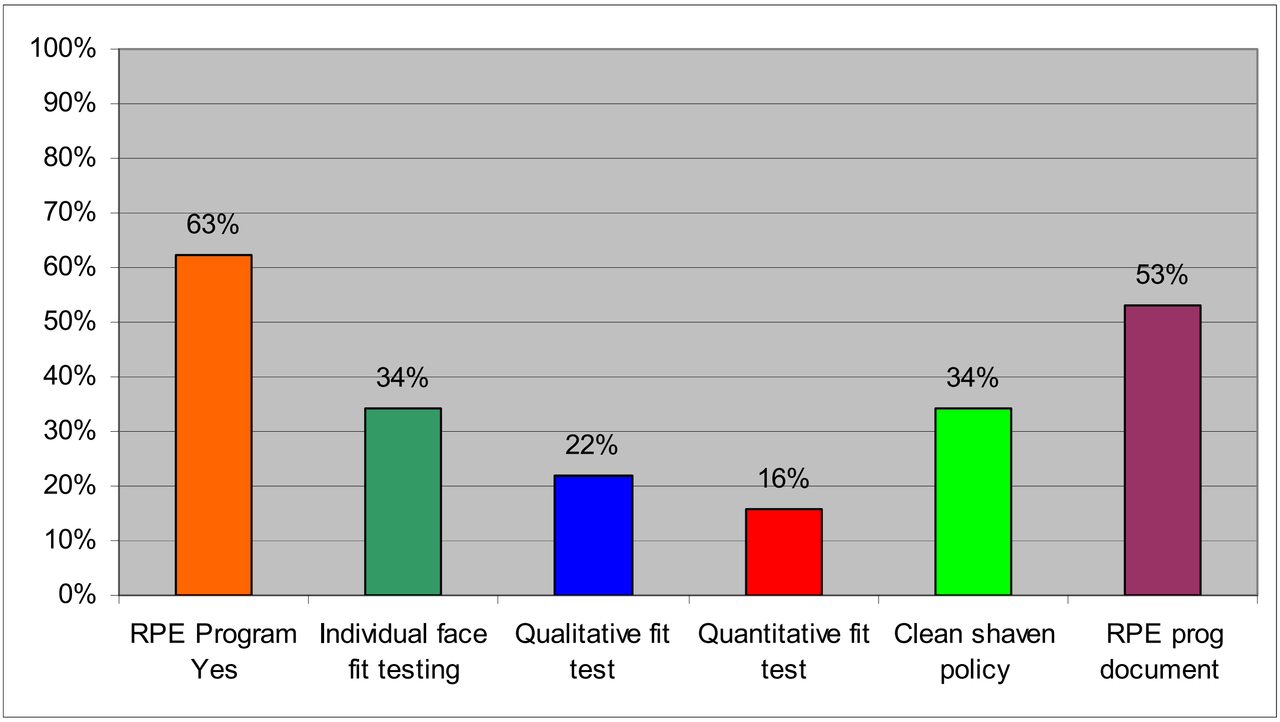
Engineering controls such as water sprays and fogging systems are routinely fitted to crushers, conveyors and transfer towers. Frequent inspection and maintenance of spray nozzles and fogging systems is important to ensure the effective capture of dust.

The use of administrative controls and Personal Protective Equipment (PPE) must always be reinforced through appropriate training, supervision and leadership. The requirement for RPE should be determined through a risk assessment process that involves measurement of worker exposure.

It is suggested that if the mean exposures for a SEG can not be reduced to below 50% of the Occupational Exposure Limit (OEL) by other means, then the requirement for RPE should be considered.

5.0 Respiratory protective equipment

Figure 5.1 Respiratory protection programs



Most mines rely on the use of personal RPE as part of the overall dust control strategy (88%). However with this in mind, only 63% of mines have RPE programs in place. It is important that the use of RPE is supported by a program that addresses the selection, use and maintenance of these devices. The program should include individual fit testing, donning and doffing procedures and a clean shaven policy if the program incorporates negative pressure respirators. As a minimum this program should meet the requirements of AS/NZS 1715:2009 *Selection, Use and Maintenance of Respiratory Protective Equipment*.

Currently only 34% of mines (overall) provide individual fit testing for workers required to use negative pressure respirators. The purpose of fit testing is to ensure the mine worker is provided with a respirator that fits to their facial features and will provide adequate protection. Fit testing should be performed during the respirator selection process or whenever there is a change in respirator supply. Fit testing may be quantitative and/or qualitative. Some qualitative and all quantitative methods require the use of specialist equipment and trained operators.

Once respiratory protection has been selected it is important to train those required to use it on how to correctly fit (don) and how to check for leaks. Leak tests do not substitute for fit testing. They should however be performed each time after donning the respirator.

OSHA provides a freely downloadable training tool that demonstrates respirator donning procedure and leak check. This is available at the following link:

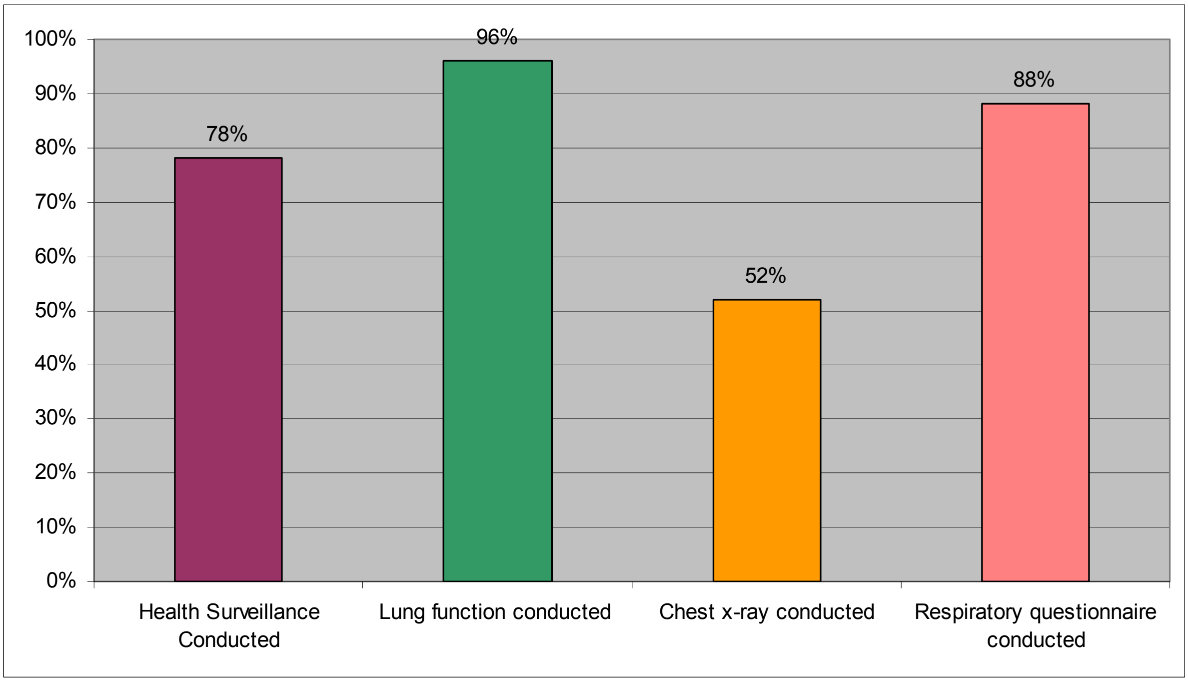
www.osha.gov/SLTC/respiratoryprotection/index.html#trainingvideos

Only 34% of mines have a clean shaven policy in place for personnel required to wear RPE.

The presence of facial hair does not allow for a perfect seal and will provide a pathway for respirable dust to enter around the edges of the respirator. The human hair can range from 40 to 200 micrometres in diameter. Respirable dust generated during mining process can be as fine as 0.5 micrometres. For this reason all personnel required to wear negative pressure respiratory protection should be clean shaven.

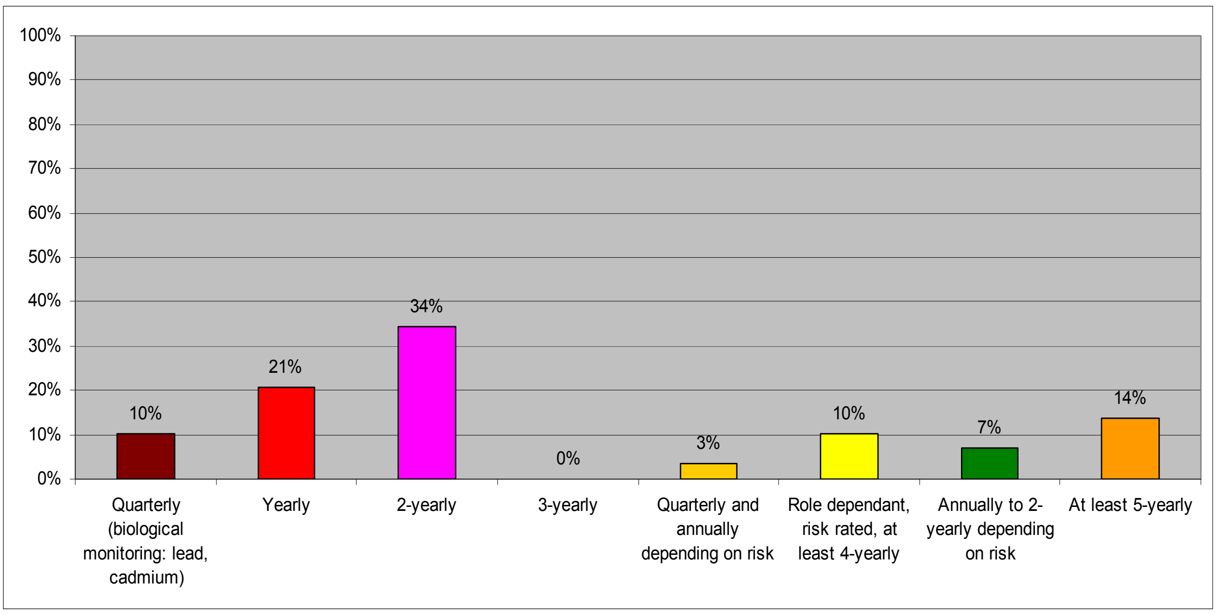
6.0 Health surveillance

Figure 6.1 Metal mines – health surveillance



Note: For those sites that do conduct health surveillance, the percentage of these sites have been further broken down to show the percentage that conduct lung function tests, chest x-rays and respiratory questionnaires.

Figure 6.2 Frequency of health surveillance



There is a requirement under the legislation for mine workers at risk to undergo health assessment. The assessments must be conducted by or under the supervision of an 'appropriate doctor'.

The frequency of health surveillance such as spirometry and audiometric testing should also be risk based and should consider the individual's work history, age and personal exposure data for the SEG to which they are assigned. It is important that the content and the purpose of health surveillance is understood by all relevant personnel including the mine worker. Currently there is no system in place for the mines to access health surveillance data that is de-identified or otherwise. Despite this, approximately 92% of mines indicate that they review health surveillance data periodically. It is not clear from the responses provided what data is reviewed or what the review process involves. Ideally the use of de-identified health surveillance data such as audiometric test results and spirometry could be used in conjunction with personal exposure monitoring data to identify exposure groups at risk and prioritise control strategies. Throughout this process the confidentiality of the individual must be maintained and protected.

Where there is potential for exposure to respirable crystalline silica the Safe Work Australia Guidelines for Health Surveillance NOHSC: 7039 (1995) requires the following:

- Demographic information, such as date of birth, descriptive job title, should be collected, including information relating to occupational and medical history of employees.
- The worker should be informed of the potential health effects associated with exposure.
- A physical examination should take place if the need for one is indicated by the worker's occupational or medical history, with emphasis on the respiratory system.
- A standardised respiratory questionnaire should be completed.
- Standardised respiratory function tests should be conducted, as well as a chest x-ray (full size posterior-anterior view).
- Records of personal exposure should be kept. The data that should be kept with the health records of a worker include descriptive job titles, with relevant start and finish dates, records of any assessments carried out and the results of personal exposure monitoring.

(Refer to: www.safeworkaustralia.gov.au/)

The Australian Institute of Occupational Hygienists (AIOH) position paper for respirable crystalline silica (February 2009) recommends that:

> *Where there is a continued likelihood of 50% of the exposure standard being exceeded, exposure monitoring and health surveillance shall apply*

(Refer to: www.aioh.org.au/industry_index.asp)

The American College of Occupational and Environmental Medicine (ACOEM) has a provided a health surveillance strategy as follows:

Health surveillance for workers exposed to crystalline silica.

Where exposure to respirable crystalline silica is > 0.05 mg/m3:

- Occupational and medical history.
- Physical examination.
- Full chest x-ray.

- Respiratory questionnaire.
- Spirometry.
- Baseline evaluation.

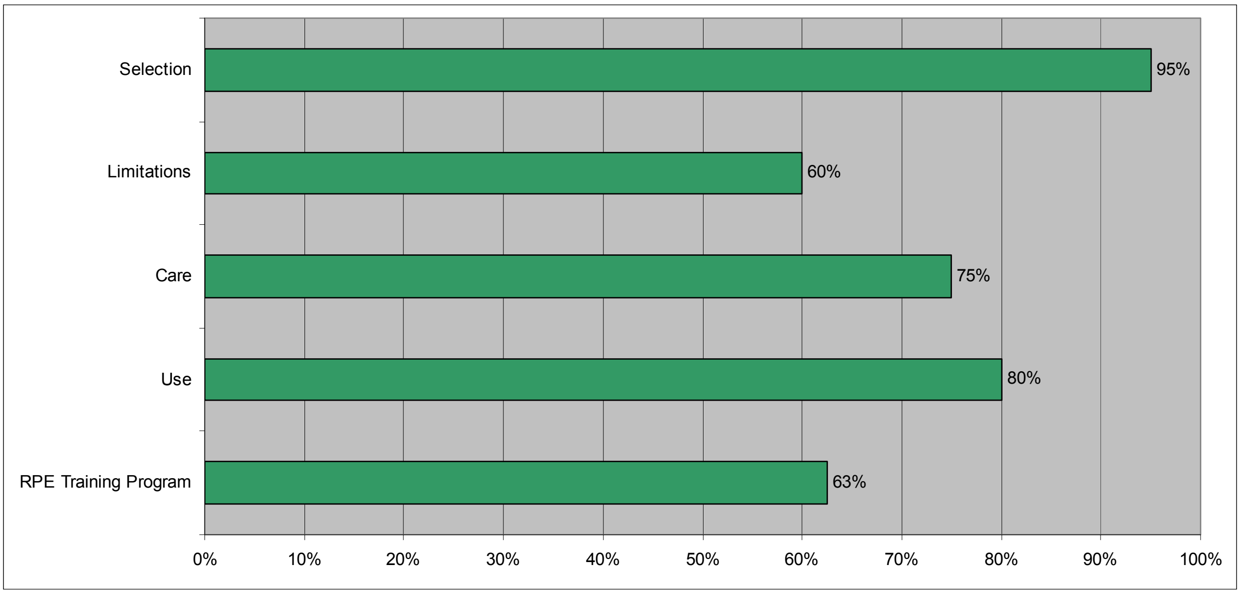
If at any point, the worker is suspected of having silicosis during surveillance evaluation – remove from exposure and refer immediately for definitive diagnosis.

1. Follow-up evaluation within 12 months: Evaluate need for repeat chest x-ray at this time.
2. If worker exposure is < 0.05 mg/m3, assess need for frequency of future follow-up evaluations.
3. If worker exposure is ≥ 0.05 mg/m3, for less than 10 years follow-up evaluation every 3 years.
4. If worker exposure is > 0.05 mg/m3, for 10 or more years follow-up evaluation every 2 years.

Exit evaluations may serve as the baseline evaluation for the next job if the worker is moving on to a new job with silica exposure. (Source ACOEM www.acoem.org/guidelines.aspx?id=746 www.systoc.com/outcomes_protocols/CrystallineSilica.htm)

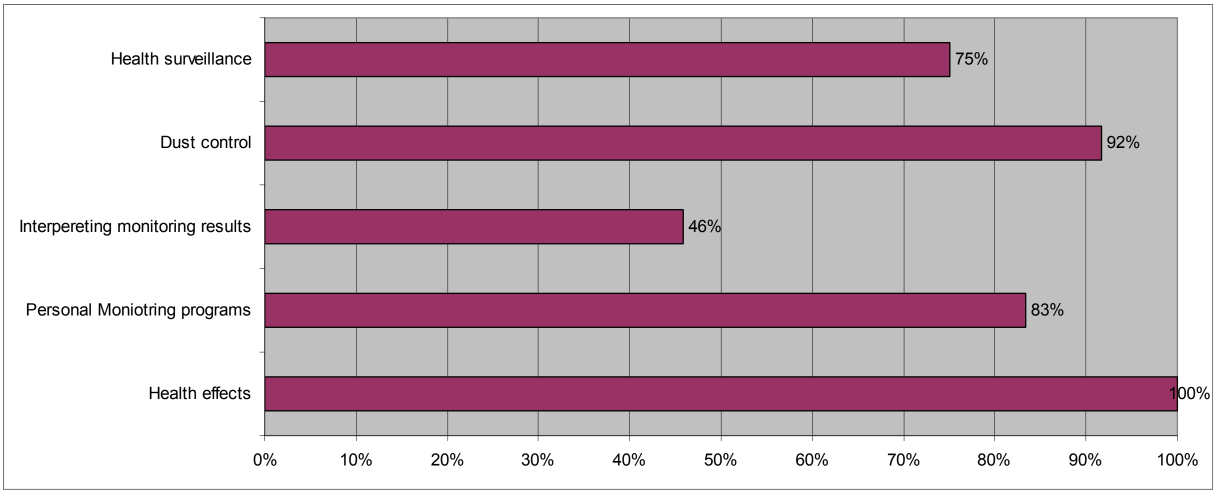
7.0 Training

Figure 7.1 Topics covered in training that relate to RPE



As previously stated, the majority of mines include the use of RPE as part of their dust control strategy. Figure 7.1 lists topics covered in RPE training. RPE should only ever be used as part of a RPE program that has been established in accordance with AS/NZS 1715: 2009 *Selection, Use and Maintenance of Respiratory Protective Equipment.* Where PPE is provided on site there must be training provided on the selection and use of this equipment.

Figure 7.2 Topics covered in training on dust exposure



In total 92% of mines indicate that they provide some form of training on dust exposure. Generally this training is focused around health effects (100%) and dust control (92%). It is essential that training indentifies what is hazardous in the dust on their mines and the health effects that may be associated with exposure to this dust.

Workers who are exposed to dust and who are required to participate in personal monitoring programs should receive basic training that includes:

- why monitoring is performed
- who is included in the monitoring program
- how is the monitoring conducted
- how are the results provided
- what do the results mean
- how are excessive results (exposures) dealt with.

8.0 Conclusion

Exposure to dust must continue to be tightly monitored and controlled. For this reason it is important that mines identify whether there are hazardous components of the dust; assess exposure and implant controls in a timely manner; and follow the hierarchy of control. In addition, mine workers should be provided with training on the potential health effects that may result from exposure to the dust. Most mines are monitoring for dust but the personal monitoring programs that are in place at a number of mines (78%) are not considered to be in line with good occupational hygiene practice. For all sites the mine workers should be divided into SEGs and baseline monitoring should be conducted to identify those SEGs who may be at risk. Where monitoring results indicate that the mean exposure for a SEG exceeds 50% of the occupational exposure limit, controls should be implemented in accordance with the hierarchy of controls. The emphasis should always be on **dust control** rather than dust monitoring.

Wherever practicable, monitoring should be conducted over a full shift to ensure that all tasks that may contribute significantly to the time weighted average exposure are captured. Personal monitoring results should be adjusted to account for extended shifts.

It is imperative that personal monitoring results are provided to the individual participating in sampling program. Currently this does not happen at all mine sites.

Responses indicate that air-conditioned cabins are often used (91%) to control exposure to airborne dust. Only a small percentage of these cabins (25%) supply filtered air under positive pressure. In order to be able to filter out the sub micron particles, filtration systems need to be of high efficiency grade (e.g. HEPA) and the cabin should be operating under positive pressure to prevent the ingress of dust.

Although there is a heavy reliance on RPE to control dust exposures, very few mines (34% overall) provide fit testing. Only 34% of mines have a clean shaven policy where there is a requirement to wear negative pressure RPE for the purpose of controlling dust exposure. Fit testing should be performed during the respirator selection process or whenever there is a change in respirator supply. In addition mine workers should be provided with training on correct donning procedures and leak testing for negative pressure RPE. The use of RPE should always be supported by a program that meets the requirements of AS/NZS 1715:2009 *Selection, Use and Maintenance of Respiratory Protective Equipment*.

It is important that mine workers and management understand the importance and the content of health surveillance. Ideally de-identified data obtained through health surveillance such as audiometric test results and spirometry could be used in conjunction with personal exposure monitoring data to identify exposure groups at risk and prioritise control strategies. Mine workers should be educated on the purpose and requirements of health surveillance.

References

1. *Mining and Quarrying Safety and Health Act 1999.*

2. Queensland Mining and Quarrying Safety and Health Regulation 2001.

3. Australian Institute of Occupational Hygiene, 2009, *AIOH Position Paper: Respirable Crystalline Silica and Occupational Health Issues*.

4. Australian Standard 2985 (2009): *Workplace Atmospheres – Method for sampling and gravimetric determination of respirable dust.*

5. American Industrial Hygiene Association, 2006, *A Strategy for managing occupational exposure*, 3rd edn, American Industrial Hygiene Association Exposure Assessment Strategies Committee.

6. Grantham D., 2001, Figure 3.3 Selection method for personal exposure monitoring participants 1st edn, Australian Institute of Occupational Hygienists Inc, Tullamarine, Victoria.

7. Australian Safety and Compensation Council, 2006, *Occupational Respiratory Diseases in Australia*, Australian Government, Canberra.

8. AS/NZS 1715 (2009): *Selection, Use and Maintenance of Respiratory Protective Equipment*.

Appendix A

Dust Self Assessment Tool

Mine site:	**Date assessment was completed :**	
☐**Underground coal mine** ☐**Open cut coal mine** ☐**Underground metaliferous mine** ☐**Surface metaliferous mine** ☐ **Quarry**		
Person completing questionnaire:	**Position:**	**Contact number:**
Site Senior Executive:		**Contact number:**

ITEM	RESPONSE	INDUSTRY PRACTICE (where applicable)
Commitment to occupational hygiene activities		
1. Does the mine's Safety and Health Management System (SHMS) provide ways for ensuring that a mine worker's exposure to dust is kept as low as reasonably achievable.	☐ Yes ☐ No	Personal exposure to airborne dust is included on the site's risk register. A risk assessment involving a cross section of the workforce and those that have appropriate knowledge of the hazard, has been conducted and from this appropriate documentation (standards/SOP/SWG) has been developed and integrated into the mine's SHMS. All workers, with roles and responsibilities, have been trained in this documentation and procedures.
2. Does the mine know what is in the dust that may be hazardous to health?	☐ Yes ☐ No If yes what is in it? ☐ respirable crystalline silica ☐ lead ☐ other…………..	Dust to which personnel may be exposed has been analysed for expected and possible contaminants, e.g. crystalline silica, lead, cadmium, arsenic, etc.

3.	Does the SHMS require the monitoring of a worker's exposure to a hazardous dust at this mine?	☐ Yes ☐ No – go to Question 27 How? ☐ Air monitoring and/or health surveillance ☐ Health surveillance only – go to Question 20	The mine's SHMS has addressed the requirement for monitoring of a worker's exposure to dust. The monitoring program is documented and made available to all mine workers. Senior management has approved and signed off on the monitoring program.
4.	Who is responsible for conducting the personnel monitoring?	☐ Mine employee ☐ Consultant Are the mine employees trained? ☐ Yes ☐ No Are the consultants qualified? ☐ Yes ☐ No ☐ Don't know If monitoring is conducted by a consultant, please list consultant(s) ______________________________ ______________________________ ______________________________ ______________________________	Personnel undertaking the monitoring have the necessary training and skills. This will include: • knowledge of appropriate standards and methods (e.g. AS 2985, AS 3640) • calibration of sampling pumps • selection and placement of sampling heads • charging and maintenance of sampling pumps • correct sample handling procedures.

5. Who is responsible for coordinating the monitoring program at the mine site?	☐ SSE ☐ Mining Manager ☐ Open Cut Examiner ☐ Shift Supervisor ☐ Technical Services ☐ Health and Safety Manager ☐ Site Occupational Hygienist ☐ Corporate Occupational Hygienist ☐ Monitoring is coordinated by the consultant ☐ Other, please specify	The person responsible for establishing and coordinating the monitoring program should have the necessary skills and knowledge to ensure the following factors are considered: • similar exposure groups • sampling biases • number of samples required • sampling methods and analysis. Functions of the personnel responsible are included in their position description.
Monitoring logistics		
6. What portion of the shift is monitored?	☐ Full shift ☐ ½ shift ☐ ¾ shift ☐ less than ½ shift ☐ Other, please specify	Monitoring should be conducted for the full duration of the shift. This will ensure that all tasks are included such as travel, preparation, crib and clean up periods. This will provide a more accurate assessment of the true exposure.
7. Which shifts are monitored?	☐ Day shift only ☐ Week-day only ☐ Night shift only ☐ Combination of day and night shifts ☐ Shifts are randomly selected	Monitoring programs should be coordinated to take into account variations in exposure that may be caused by shift and seasonal differences. This will provide a more accurate picture of the true exposure. Care must be taken to ensure sampling bias is not introduced by repeated sampling of: • an individual worker • the same crew • the same shift • the same environmental conditions • the same work conditions.

8. How often is personal monitoring for dust conducted at this mine?	☐ Continuously ☐ Weekly ☐ Fortnightly ☐ Monthly ☐ Quarterly ☐ Six monthly ☐ Yearly ☐ Randomly ☐ Not conducted	
9. How are work groups selected for monitoring?	☐ Risk based i.e. high exposure jobs are monitored ☐ Job types ☐ Exposure groups selected based on distribution and geometric standard deviation. ☐ Production crews selected only ☐ Chosen based on historical information and monitoring data ☐ Corporate standards ☐ Incidence of disease ☐ No method – whoever is available ☐ Complaints driven ☐ Other, please Specify ______________________	Similar exposure groups (SEGs) are identified for all parts of the site. A SEG is a group of people, generally performing the same task for the same period of time, such that exposure measured on any one person in the group will be representative of the exposure of the whole group. Identify the SEGs potentially exposed to airborne dust in the mine. Baseline monitoring is conducted to provide a quantitative assessment of those work groups at risk. Where baseline monitoring indicates that the mean or estimated mean exposure is above an agreed action level (e.g. the AIHA stipulate ≥ 26 % of the OEL), then that SEG should be subject to routine monitoring. Those subject to routine monitoring are defined as critical SEG which may be further prioritised and sub-divided.

10. Does the monitoring program include contractors?	☐ No ☐ Yes (see below) ǂ Only contractors working with mine employees are included ǂ Only contractors deemed to be at risk are included	Full time contractors are managed in accordance with the same occupational hygiene monitoring program as for full time employees. Exposures for short term contractors should be risk assessed and monitoring conducted accordingly. Consideration should be given to the toxicity of the substance, the level of control, the level and frequency of exposure and the nature of the health outcome (chronic or acute).
11. Are records of monitoring kept?	☐ Yes ☐ No	Records are retained for future comparison and to satisfy legislative requirements (30 years).
12. Are monitoring results communicated to management and supervisors?	☐ Yes ☐ No If Yes, where are the records displayed/kept	Results of sampling are communicated to line management in a timely manner. Comparison and trends from previous data are provided. Appropriate recommendations are included.
13. Are mine workers provided with a copy of their individual personal exposure results?	☐ Yes ☐ No	Systems are in place to ensure the employee sampled is advised of the result as soon as information becomes available.
14. Are personal exposure results exceeding the regulatory limits or site action levels investigated?	☐ Yes ☐ No	Personal exposures exceeding exposure standards and site action levels are investigated by personnel with relevant experience and knowledge of the task. Investigations are documented.

15. Who is monitored	Tick where applicable.	Tick where applicable.
	14.1 Open cut coal operations (production) ☐ Dragline operator ☐ Rear dump operator ☐ Stockpile dozer ☐ Pre strip dozer ☐ Service truck ☐ Belt service men ☐ Shovel operator ☐ Grader operator ☐ Water truck operator ☐ Excavator operator ☐ Field maintenance ☐ Coal haulage drivers ☐ Blast drilling crews ☐ Overburden drilling crews ☐ Shot firers ☐ Blast crews ☐ Exploration drillers ☐ Open cut examiner Other, please specify ____________________ ____________________ ____________________ ____________________ ____________________ ____________________	**14.4 Surface metalliferous mines (production)** ☐ Supervisor ☐ Light vehicle driver ☐ Crusher operator ☐ Grinding operator ☐ Paste plant operator ☐ Charge-up crew ☐ Tippler operator ☐ Screening plant operator ☐ Flotation plant operator ☐ Process plant operator ☐ Filtration plant operator ☐ Gold room operator ☐ Loader operator ☐ Grader operator ☐ Excavator operator ☐ Haul truck operator ☐ Water truck operator ☐ RC drill rig operator ☐ Diamond drill operator Other, please specify ____________________ ____________________ ____________________ ____________________ ____________________

	14.2 Underground coal mine (production) ☐ Chock/shield operators ☐ Shearer operators ☐ Maingate operator ☐ Longwall fitter ☐ Longwall electrician ☐ Longwall deputy (ERZ controller) ☐ Continuous miner operator ☐ Development deputy (ERZ controller) ☐ Roof bolter ☐ Cable hand ☐ Shuttle car/ram car driver ☐ Outbye deputies (ERZ controller) ☐ Outbye fitters/electricians ☐ Secondary support ☐ Ventilation device installers ☐ Outbye services including road maintenance ☐ Stone dust applicators ☐ Stone dust samplers Other, please specify ____________________ ____________________ ____________________ ____________________	**14.5 Underground metalliferous mine (production)** ☐ Jumbo driller ☐ Diamond driller ☐ Air-leg driller ☐ Shot-creter ☐ Nipper ☐ Service crew production ☐ Service crew development ☐ Loader operator ☐ Haul truck operator ☐ Grader operator ☐ Crusher operators Other, please specify ____________________ ____________________ ____________________ ____________________

	14.3 Surface personnel (coal) ☐ CHPP operator maintainers ☐ Workshop personnel ☐ Train load out ☐ Coal laboratory technicians ☐ Stockpile dozer ☐ Warehouse attendants Other, please specify __________ __________ __________ __________ __________	**14.6 Surface personnel (metalliferous mine)** ☐ Electrician ☐ Fitter ☐ Diesel fitter ☐ Sampler ☐ Sample preparation ☐ Chemist/technician/metallurgist ☐ Rail loading crew ☐ Ship loader Other, please specify __________ __________ __________
Assessing the Results		
16. What limits are used to assess personal exposures?	☐ ASCC Hazardous Substances Information System (HSIS) exposure standards ☐ Limits specified in Regulation ☐ Corporate standards ☐ Other, please specify __________	Assessment of results is in line with the national exposure standards recommended in the ASCC HSIS.
17. Is there a process for adjusting exposures to accommodate for extended working hours?	☐ Yes ☐ No If **yes,** what method is used? ☐ Brief and Scala ☐ Pharmacokenetic (Hickey and Reist) ☐ OSHA ☐ DOCEP extended work shift guideline ☐ Other, please specify __________ ☐ Not Known	A process is in place to adjust exposures to account for mine workers operating over extended working hours. This process gives consideration to the complete shift cycle and the toxic effect of the substance.

18. Are the results subject to statistical analysis?	☐ Yes ☐ No If **yes,** what parameter is used for comparison with the exposure limit? ☐ MVUE ☐ 95% UCL ☐ 95% UTL ☐ 90th percentile ☐ 95th percentile ☐ Mean ☐ Other If other, please provide information. ______________________________ ______________________________ ______________________________	Results of personal monitoring campaigns for each exposure group are statistically analysed to assess compliance with corporate standards and national exposure standards. The distribution of sample results is established and an appropriate estimate of the mean and confidence levels is calculated.
19. Are trends monitored?	☐ Yes ☐ No	Monitoring can be used to: • provide an indication of the effectiveness of a dust management program over time • provide an indication of the effectiveness of any controls implemented • identify changes in production methods/ equipment that may have increased personal exposures • identify particular exposure groups at risk.

Health Surveillance		
20. At what frequency are workers at this mine required to participate in a health surveillance program?	☐ Continuously ☐ Weekly ☐ Fortnightly ☐ Monthly ☐ Quarterly ☐ Annually ☐ 2 yearly ☐ 3 yearly ☐ At least once every 5 years (required under section 46(4)(c) (CMSHR) ☐ Not conducted ☐ Other, please specify	Health Surveillance is conducted for the hazard at a frequency based on the risk, previous personal results, gender (in some cases) and in line with regulatory requirements.
21. Does the health surveillance program include an assessment of lung function?	☐ Yes ☐ No	
22. Does the health surveillance program include a full chest x-ray?	☐ Yes ☐ No	
23. Does the health surveillance program include a respiratory questionnaire?	☐ Yes ☐ No	
24. How is the frequency for health surveillance determined?	☐ Risk based ☐ In accordance with standards and/or codes ☐ In accordance with site protocols ☐ In accordance with legislation ☐ Other ______________________________	

25. Are records of health surveillance kept?	☐ Yes ☐ No If yes, for how long are they kept and by whom are they kept ________________________________	Medical records are held securely and confidentiality is maintained. Lung function results and chest x-rays are kept securely for a minimum of 30 years.
26. Is health surveillance data reviewed to verify that controls are in fact working?	☐ Yes ☐ No	An assessment is carried out by the nominated medical adviser, appropriate doctor or occupational health nurse and the SSE is informed wherever health surveillance data indicates that there is a risk to worker health. The risk is controlled where adverse health effects are encountered.
Training		
27. Is training provided on exposure to health hazards including dust?	☐ Yes ☐ No If yes what does this training include: ☐ Health effects ☐ Personal monitoring programs ☐ Interpreting personal results ☐ Dust control ☐ Health surveillance Other, please specify	Mine workers exposed to a health hazard are formally trained in the health hazard. This training includes but is not limited to: • health effects • personal monitoring programs • interpreting personal results • dust control • health surveillance. The training will cover any related documentation from the SHMS including standards, SOP and SWG.
28. Are records of training kept?	☐ Yes ☐ No	Records of this training are maintained and included in the mine's training matrix. Refresher training is provided as required.

Control of airborne dust		
29. What controls are used to control dust exposures at the mine?	Tick where applicable: ☐ none ☐ natural ventilation **Engineering** ☐ remote operating technology ☐ water sprays ☐ fogging sprays ☐ water curtains ☐ stockpile sprinklers ☐ muck pile watering ☐ road watering ☐ road salting ☐ wetting agents (e.g. citrus additive) ☐ forced ventilation ☐ dust extraction systems ☐ air-conditioned cabins ☐ cabin is supplied with filtered fan forced air ☐ rubber curtains ☐ enclosed crushing and screening plants ☐ conveyor covers ☐ telescopic chutes ☐ Other **Administrative** ☐ worker positioning ☐ worker rotation ☐ Other, please list ____________________ **PPE** ☐ respiratory protection	A risk assessment involving a cross section of the workforce is conducted. This risk assessment involves review of quantitative data including trends from personal exposure monitoring. Control measures are identified and implemented in accordance with the hierarchy of control. The effectiveness of controls are reviewed. Controls are implemented in accordance with the control hierarchy. Respiratory protection is used as a last resort or interim control.

30. Is the effectiveness of controls assessed?	☐ Yes ☐ No	Reviewing personal monitoring trends before and after control interventions. Using real time continuous or personal exposure monitoring or static monitoring to demonstrate reduction in airborne concentrations before and after control interventions.
Respiratory protective equipment (RPE)		
31. Does the mine have a respiratory protection program in place?	☐ Yes ☐ No If **yes** does the program include ☐ selection of respiratory protection ☐ use (fitting) of respiratory protection ☐ care and maintenance of respiratory protection ☐ limitations of RPE	A respiratory protection program is in place at the mine. The program includes respiratory protection policy, respirator selection, training fit testing rules, clean shaven policy, maintenance and storage of respirators. Each mine worker required to negative pressure respirators have undergone individual fit testing for a variety of these respirators. The mine has a clean shaven face policy for workers required to wear half face piece respiratory protection.
32. Have mine workers been individually fit tested for respiratory protective equipment?	☐ Yes ☐ No If yes how: ☐ Qualitative fit test ☐ Quantitative fit test ☐ Other ____________________	

33. Does the mine have in place a clean shaven policy for workers required to wear half face piece or full face negative pressure respiratory protection?	☐ Yes ☐ No	
34. Is the RPE program documented and accessible to all mine workers?	☐ Yes ☐ No	Mine workers have received training on the details of the respiratory protection policy. Records of this training have been kept.
Review		
35. Is there a process in place to review the mine's SHMS with particular reference to the sections relating to managing airborne dust?	☐ Yes ☐ No If **yes**, how often is this review conducted? ____________________	A process exists to periodically audit and review the effectiveness of the system in line with AS/NZS 4801 or AS/NZS ISO 9001:2000.

Appendix B

Suggested similar exposure groups (SEGs)

for

metal mines

Table B1: Suggested SEG listing for metal mines

Metal mining	
SEG	**Task description**
Jumbo driller	A Jumbo Drill uses rock drills to drill a number of holes at the mining face. The holes are then filled with explosives for subsequent blasting.
Diamond driller	Diamond core drilling utilises a drill bit attached to the end of hollow drill rods to cut a cylindrical core of solid rock.
RC drill operator	Reverse circulation drilling is generally used in exploration and produces dry rock chips for testing. Reverse circulation is achieved by blowing air down the rods and the pressure forces water and cuttings up the inner tube. **Where not controlled this type of drilling can be dusty.**
Air-leg driller	This is a hand held or hand operated drill used for drilling into narrow veins or where access is limited for larger drill rigs. **Due to the limited space and placement of the driller to the face this job can be dusty.**
Shot-creter	A shot-creter sprays grout (concrete) from an agi truck to the mine rock wall surface. **Although the material is applied wet, this job can be dusty.**
Nipper	A general duties light vehicle driver, transporting workers and equipment to different areas throughout the mine.
Service crew production	Normally carries out work associated with services in the production area such as rock bolting and installing grid mesh.
Service crew development	Normally carries out work associated with providing services such as hanging ductwork and cables from a man carrier basket.
Beltman	Operations involving conveyor belts.
Cable bolter	Operations involving cable bolting.
Timbermen	Timberman activities.
Manual scalers	Manual scaling activities.
Raise borers	Operations involving raise boring.
Blast crew	Operations involved with blasting.
Ring firers	Operations involving ring firing.
Tele-remote loader operator	Operates a Loader from a designated tele-remote control room.
Loader operator	A loader operator operates a front end loader (FEL) by directly or remotely operating the FEL to load rock onto a haul truck or tip ore into an ore pass. **A line of site FEL operator may be exposed to elevated levels of airborne dust as the machine is operated by a hand held device and the worker is positioned outside the**

	cabin.
Haul truck operator	An operator that drives a haul truck to transport rock from underground to the surface, or transports rock on the surface. Includes Kress Haulers.
Grader operator	The grader operator drives a grader which uses a blade to level road surfaces to allow smoother transport.
Crusher operator	An operator who operates and maintains a crusher to crush ore. **This job can be dusty.**
Water truck operator	An operator who drives a water truck that has a water tank used for dust suppression.
Electrician	General electrical work carried out by an electrician.
Fitter	General mechanical work carried out by a fitter.
Diesel fitter	Mechanical work carried out on mobile diesel powered machinery by a fitter.
Sampler	A worker that collects samples for subsequent analysis.
Sample preparation	Prepares samples (i.e. crushing, grinding, subdividing) for analysis. **This job can be dusty.**
Chemist/technician/ metallurgist	Typically supervises/facilitates the operation of a processing plant or carries out laboratory duties (i.e. analysis).
Rail loading crew	Loads rail wagons with concentrate. **This job may expose workers to elevated airborne concentrations of concentrate containing metal (i.e. lead).**
Ship loader	General work associated with loading concentrate into ship hulls. **This job may expose workers to elevated airborne concentrations of concentrate containing metal (i.e. lead).**
Asphalt plant operator	An operator, who operates a plant that mixes asphalt (bitumen) with crushed gravel and sand.
Boilermakers	General welding.
Maintenance crew	General repair and maintenance work.
Rear dump operator	Work involved with a stockpile. Driving a FEL, etc.
Stockpile dozer	Using a bulldozer to maintain stockpiles.
Process plant operators	Operators who operate and inspect process plants.
Copper smelter operator	Stacker reclaimer operations, feed prep operation, HBF legman, wet and dry legman, gas handler, matte tapper, RHF operator,

	converterman, anode wheel attendant, anode furnace operator, east aisle crane driver, day gang, etc.
Copper concentrator operator	Activities associated with copper concentrator operations.
Lead smelter operator	Casting, furnace man/attendant, spoutman, drosser, crane driver, feederman, charge car driver, filter floor operator, bag house operator, flux handler, day gang, etc.
Lead zinc concentrator operator	HMP operators, day gang, thickener, Zn filter plant, etc.
Lab technician/analyst	Carries out laboratory analysis/material testing.
Crane driver	Crane operation.
Bobcat operator	Bobcat operation.
Grinding operator	Plant operator that operates and maintains a grinding mill (i.e. semi-autogenous grinding mill).
Light vehicle driver	Drives a light vehicle to deliver workers, material and equipment to various areas of the mine.
Supervisor	General supervision.
Flotation plant operator	Operates flotation within a process plant.
Excavator operator	Drives a mobile machine with an articulated arm and bucket attached to extract rock.
Cleaners	General cleaning.
Road sweepers	Road sweeping.
Mill production crew	Mill production.
Screening plant operator	Operates a screening plant which separates rock into different size fractions. **This job can be dusty.**
Administration/office	General administration work.
Charge-up crew, charging operators.	Involves charging drill holes with explosives for subsequent blasting. **This job can be dusty.**
Filtration plant operator	Operates the filtration process within a process plant.
Stockpile	Maintains stockpile.
Production	General production.
Paste plant operator	Operates paste plant. **This job can expose the worker to contaminants in the tailings where tailings are a constituent**

	of the paste (i.e. arsenic).
Tippler operator	A tippler is used to load rail wagons.
Trainers	General trainer.
Trainees	General trainee.
Gold room operator	Operates a gold room as part of a gold mining operation.
Regeneration officer	Environmental officer work.
Bagging plant operators	Operates a machine for bagging product. **This job can be dusty.**
Bulldozer operator	Drives a bulldozer for moving rock/material.
Civil – water and tailings team	Maintains waste water and tailing dams.
Outside workers	General outside work.
Geologists	Field work including sampling, observation, inspection.
Long hole production	Holes are drilled between the two excavations and loaded with explosives.
Bore hole production	Extracting mineral resources through boreholes by means of high pressure water jets.

Appendix C

A guide for metal mines establishing an occupational hygiene monitoring program

C1

Step 1 – PLAN: Divide mine workers into similar exposure groups (SEGS).

Where exposure is considered excessive initiate controls immediately in accordance with the hierarchy of control.

Note: Refer to section 3 of this report for information about SEGs and Appendix B for a list of suggested SEGs for metal mines.

Step 2 – MONITOR: Conduct baseline monitoring for each SEG over a period of one to two years to account for seasonal and other variations. Enough samples need to be collected to enable statistical analysis of the results. After each period of monitoring, exposures should be reviewed. Where individual exposures exceed the OEL, the result should be reviewed, investigated and, if necessary, interim controls should be implemented immediately (e.g. RPE). When more samples are collected the level and type of control can be reviewed. It is important that the effectiveness of the control is assessed through follow-up monitoring.

As a guide at least 20% of the total number of mine workers in each SEG should be sampled or a minimum of six samples (which ever is the lesser number).

Note: Be careful not to introduce potential sources of bias as outlined on page 11 of this report.

Step 3 – ASSESS and CONTROL: For each SEG apply statistical analysis using an appropriate occupational hygiene statistical package (freely downloadable web based programs are provided on page 5 of this report). This step is important to identify the need for, and to justify control strategies and to determine the appropriateness of how the SEGs have been defined.[2]

The statistical measures of importance for log-normally distributed data[1] are the estimate of the mean or minimum variance unbiased estimator (**MVUE**), the 95% upper confidence limit (**UCL** Lands exact) and the geometric standard deviation (**GSD**).

The statistical measures of importance for normally distributed data are the arithmetic mean, the 95% upper confidence limit and the standard deviation.

Where baseline monitoring indicates that the mean or MVUE of exposures exceed 50% of the shift adjusted occupational exposure limit (**OEL**), controls should be implemented in accordance with the hierarchy of control and follow up monitoring conducted to evaluate their effectiveness.

Note:

1. The statistical program will tell you whether your dataset is normally or log normally distributed. Typically occupational hygiene dust exposure data is log normally distributed.
2. If the geometric standard deviation (GSD) of a log normally distributed data set or the standard deviation of a normally distributed data set is greater than 3.0, this typically indicates that some workers or work groups do not belong to this SEG, that more samples are required or that the exposures could be better controlled.

THE EMPHASIS SHOULD ALWAYS BE ON DUST CONTROL NOT DUST MONITORING

Step 4 – ONGOING MONITORING: After completing baseline monitoring, statistical analysis, clearly defining similar exposure groups and implementing controls for any excessive exposures, the frequency of ongoing personal monitoring needs to be determined.

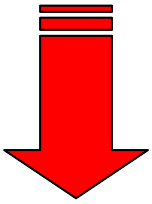
To do this use the 95% UCL calculated from base line monitoring data initially and then periodically from ongoing monitoring data collected. The following table provides a guide for establishing the frequency of ongoing monitoring.

95% UCL of the MVUE or the mean in relation to the shift adjusted OEL[1]	Monitoring frequency and number of samples[2]	Action
95% UCL ≥ 100%OEL	5% of SEG or minimum of 6 samples every 3 months[3]	Implement controls immediately and conduct follow up monitoring to verify effectiveness.
50%OEL ≤ 95%UCL < 100%OEL	10% of SEG or minimum of 6 samples every 3 months[3]	Review effectiveness of existing controls and investigate the availability of higher control options. Review exposure data (refer step 5).
10 %OEL ≤ 95%UCL < 50% OEL[4]	5% of SEG or minimum of 6 samples every 6 months[3]	Conduct monitoring as required and review exposure data (refer step 5).
0 < 95 %UCL < 10% of OEL[4]	Monitoring not usually required.	Conduct baseline monitoring every 5 years or if the process changes.

NOTE:

1. Reference to the OEL in this table always assumes adjustment for extended shifts.
2. In general, monitoring is important where the 95% UCL approaches the OEL. Where the 95% UCL exceeds the OEL the priority should be on control rather than on monitoring.
3. Mines may wish to set up random sampling programs. Such programs run over a selected period that is representative of all factors that may impact on exposure such as seasons and production variations. For dust it is usually just longer than one year e.g. 64 weeks, so that samples are not collected at the same time each year. Setting up such programs will require occupational hygiene expertise.

THE EMPHASIS SHOULD ALWAYS BE ON DUST CONTROL NOT DUST MONITORING



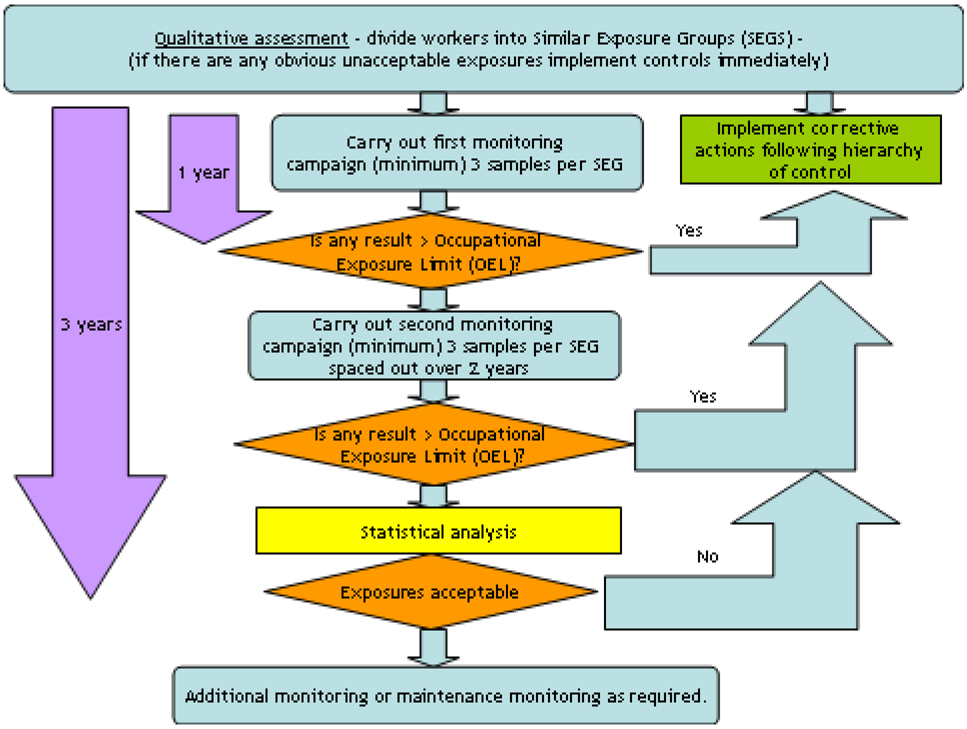
Step 5 – REVIEW: In addition to the review of exposure data that should occur after each monitoring survey, a periodic review of all data for each SEG should be conducted (e.g. bi annually or annually). This will provide evidence based information on:

- the extent of personal exposure for each SEG
- the effectiveness of existing controls
- the requirement for further controls
- the validity of the SEG groupings (through review of GSD or SD)
- the basis for determining the frequency of on going monitoring for each SEG for the next year.

IMPORTANT
In order to comply with the **word of the legislation**, the 95% UCL should be below the shift adjusted OEL for each SEG. In order to conform to the **intent of the legislation**, the 95% UCL should be as low as reasonably achievable.

C2

Alternative monitoring strategy



This alternative strategy collects at least three samples per SEG during each sampling campaign. If any of the samples collected exceed the exposure standard, then this requires immediate control, which in the first instance, may mean respiratory protective equipment (RPE) then followed by higher order controls such as removing the job task from the dusty area, containing the emission, or providing localised exhaust ventilation to extract the dust. Statistical analysis will be carried out when at least six samples per SEG are collected. Exposures will be deemed acceptable if the upper confidence limit of the average or 95 percentile is within the occupational exposure standard (TWA). The process will then mirror step 5, review, as described in the initial guide.

Management of dust containing crystalline silica (quartz)

Mines safety bulletin no. 88 | 23 February 2010 | Version 1

1.0 Introduction

Respirable dust (ie dust small enough to penetrate the very small breathing vessels within the lung) containing crystalline silica is known as respirable crystalline silica (RCS). The predominant form of crystalline silica is quartz. In sufficient quantity RCS can cause silicosis; an irreversible, progressive and potentially fatal condition that results in healthy lung tissue being replaced by fibrous scar tissue. Scientific evidence also suggests that silicosis can lead to lung cancer. These diseases can develop after many years of exposure to high dust levels.

A survey questionnaire aimed at assessing the potential for exposure to excessive levels of RCS was sent to 420 small to medium sized metalliferous mines, quarries and exploration sites in Queensland. The questionnaire was prompted by the finding that some quarries visited by the Mines Inspectorate do not have adequate health surveillance in place for their workers, nor have completed an assessment carried out to measure RCS exposure.

Survey results:

Operation	Questionnaires	Reply rec	% Respondents
Quarries	177	85	48
Small to medium mines	188	25	13
Exploration sites - coal	30	10	33
Exploration sites - non coal	25	12	48
Total	420	131	31

Note this report is based on feedback received from 131 sites, accounting for 31% of all sites surveyed.

2.0 Survey findings

The survey findings indicate that many sites may not be adequately addressing the risk of RCS exposure resulting in the potential for adverse health effects from respirable crystalline silica Chronic exposure to respirable crystalline silica, even at relatively low levels, may lead to chronic silicosis many years after a worker has retired.

A significant number of operations did not respond to the survey. This may mean there are many more sites without adequate controls in place.

Significant findings of the survey are summarised as follows:

- 32% of sites didn't know if their rock contained free silica
- 21% of sites didn't know how much free silica was present
- 78% of sites believed onsite workers were exposed
- 98% of sites rated onsite dust levels as low to medium
- 52% of sites carried out personal monitoring
- 43% of sites provided results back to workers
- 14% of sites have carried out monitoring on one occasion
- 19% of sites carry out monitoring annually
- 69% of sites use respiratory protection during dusty conditions
- 45% of sites do not perform respiratory protection fit testing
- 46% of sites provide health surveillance for workers at 1 to 5 year intervals
- 67% of sites provide training about the hazards associated with RCS.

Observation of visible dust should not be the only indicator to demonstrate that respiratory protection is necessary. Invisible fine dust particles are the most hazardous, highlighting the importance of personal monitoring to identify job types and specific tasks requiring control measures.

The types of dust controls used by respondents are detailed in Figure 1 below.

There is a high level of reliance on air-conditioned vehicle cabins. However many standard air conditioning systems don't provide an effective barrier or offer acceptable protection against RCS, due to the small size of the dust particles concerned. Therefore it is necessary to carry out monitoring in enclosed cabins to verify that filtration systems are effective.

3.0 Control strategies

The order in which controls are implemented must follow the hierarchy of controls - elimination, substitution, engineering, administrative and lastly personal protective equipment. **It is critical that awareness of the potential health effects from respirable dust, dust control and health surveillance be improved.**

4.0 Monitoring

Where there is a risk of exposure, monitoring should be carried to determine baseline levels of exposure for each job or task. Personnel should be grouped into similar exposure groups (SEGs) - groups of workers with similar exposure levels. The need for ongoing monitoring is based on the level of exposure in relation to the occupational exposure standard (OES) or general exposure limit. Schedule 5, of the Mining and Quarrying Safety and Health Regulation 2001, has assigned an exposure limit (8h, time weighted average (TWA)) at 0.1mg/m_3.for RCS. If shifts are longer than 8h this limit shall be reduced accordingly. Simtars' Occupational Hygiene, Environment and Chemistry Centre, Adjustment of Occupational Exposure Limits for Unusual Work Schedules, provides guidance on how to reduce exposure limits where shifts are longer than 8 hours. The suggested ongoing monitoring frequency, based on maximum and average concentrations in relation to the OES, is provided in Table 1.

Concentration range	Monitoring frequency
Average concentration < 10% of the OES andmaximum concentration < 10% of the OES	Monitor once every 5 years (baseline survey)

Concentration range	Monitoring frequency
Average concentration 10-25% of the OES andmaximum concentration 10-25% of the OES	Monitor once every 2 years or continuously#sampling personnel once every two years
Average concentration < 50% of the OES andmaximum concentration 25-50% of the OES	Monitor once per year or continuously#sampling personnel once per year
Average concentration < 25% of the OES andmaximum concentration >100% of the OES Average concentration < 50% of the OES andmaximum concentration >50% of the OES	Monitor twice per year or continuously#sampling personnel two times per year*
Average concentration >50% of the OES andmaximum concentration >100% of the OES	Monitor quarterly or continuously#sampling personnel four times per year*

** the maximum and average concentration refers to that for a SEG

continuous sampling refers the establishment of a random on-going sampling program

* mandatory respiratory protection program should be in place and follow hierarchy of controls

Notes:

Preliminary monitoring should be carried for each SEG to establish baseline exposure.These monitoring frequencies apply to processes that are fairly constant. Where there is a significant change to a process each different process may have to be monitored.

5.0 Health surveillance

Where exposure to RCS may cause an adverse health effect, health surveillance is required. Health surveillance for RCS should include the following:

- Demographic information (date of birth etc.) should be collected, as well as information relating to occupational history (descriptive job title with relevant start and finish dates) and medical history.
- The worker should be informed of the potential health effects associated with RCS exposure.
- A physical examination should take place, with emphasis on the respiratory system.
- A standardised respiratory questionnaire should be completed.
- Standardised respiratory function tests should be conducted, as well as a chest X-ray (full size posterior-anterior view).
- Records of personal exposure monitoring should be kept with the health records of the worker.

Health surveillance should be conducted on commencing work in a job where exposure to RCS may cause an adverse health effect. The frequency of health surveillance, based on RCS exposure levels, should be as follows:

- Follow-up evaluation within 12 months: Evaluate need for repeat chest x-ray at this time.
- If exposure is < 0.05 mg/m_3, assess need for frequency of future follow-up evaluations.
- If exposure is equal to or greater than 0.05 mg/m_3 for less than 10 years, follow-up evaluation every 3 years.
- If exposure is equal to or greater than 0.05 mg/m_3 for 10 or more years, follow-up evaluation every 2 years.
- An exit evaluation should be conducted when the worker leaves their job.

6.0 Respiratory protective equipment (RPE)

Where there is a likelihood of exposure exceeding 50% of the exposure standard, a mandatory respiratory protective equipment program should be put in place until exposures are reduced using higher order controls.

Respiratory protective equipment programs should conform to AS/NZS 1715:2009, 'Selection, use and maintenance of respiratory protective equipment'. The program should include a 'clean shaven policy' (if negative pressure respirators are used), fit testing and training.

7.0 References

1. Mining and Quarrying Safety and Health Regulation 2001.

2. Simtars, Queensland Government, Occupational Hygiene, Environment and Chemistry Centre, Adjustment of Occupational Exposure Limits for Unusual Work Schedules3. , viewed on 23 February 2010.

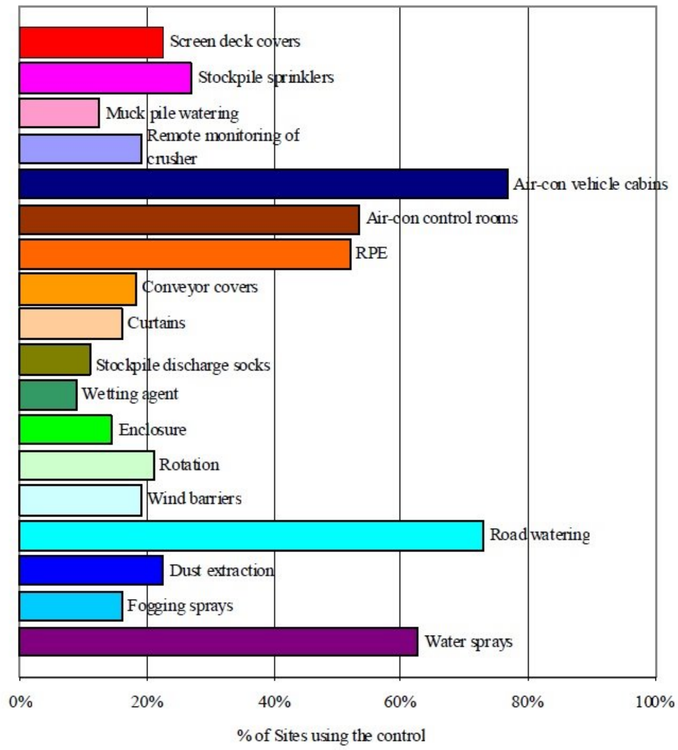
4. Australian Institute of Occupational Hygienists (AIOH), position paper on Respirable crystalline silica and occupational health issues5. , 2009 - viewed on 23 February 2010.

6. World Health Organization (WHO), Global Workplan of the Collaborating Centres in Occupational Health for 2009-20127. , Table of Priorities, 2012 - viewed on 23 February 2010.

8. Safe Work Australia, Guidelines for Health Surveillance NOHSC: 70399. , 1995 - viewed on 23 February 2010.

10. American Industrial Hygiene Association (2006), A strategy for assessing and managing occupational exposures. Third Edition. American Industrial Hygiene Association Exposure Assessment Strategies Committee.

ACOEM website11. .



Authorised by Roger Billingham - Chief Inspector of Mines Contact: minesafetyandhealth@dnrm.qld.gov.au
Issued by the Queensland Department of Employment, Economic Development and Innovation

Placement: Place this announcement on noticeboards and ensure all relevant people in your organisation receive a copy.

Silica Dust – Controlling the Risk

Mining Quarrying Safety and Health Regulation 2001.

Aims of this Presentation

- The **health hazards** of working with Silica specific for **quarry operators.**
- Legislation – (ALARA).
- Controls.
- The way forward.

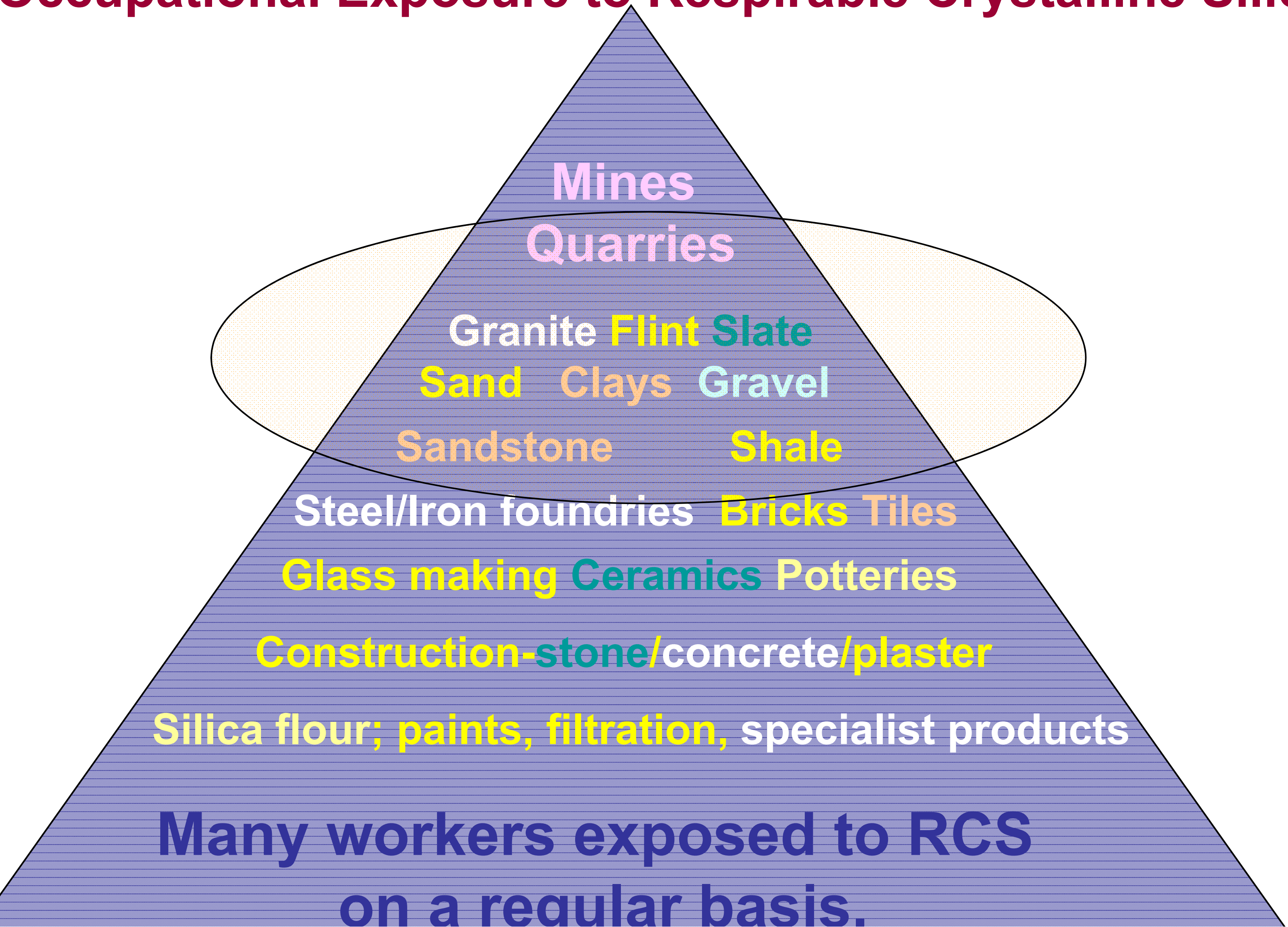
What is respirable crystalline silica?

Crystalline silica is a common mineral (SiO_2) found in most types of rock/stone, sands, shale, clays and gravel.
It mainly occurs in the form of quartz.

Sandstone – > 70% quartz.
Granite - up to 30% quartz.
Clays - 6-30% quartz.

Respirable" : airborne particles small enough to reach the eep lung (less than 10 microns diameter).

Occupational Exposure to Respirable Crystalline Silica



The Hazard

Significant risk from dust containing silica, in:

- Rock
- Sands
- Clays
- Shale
- Gravel

RC Drilling

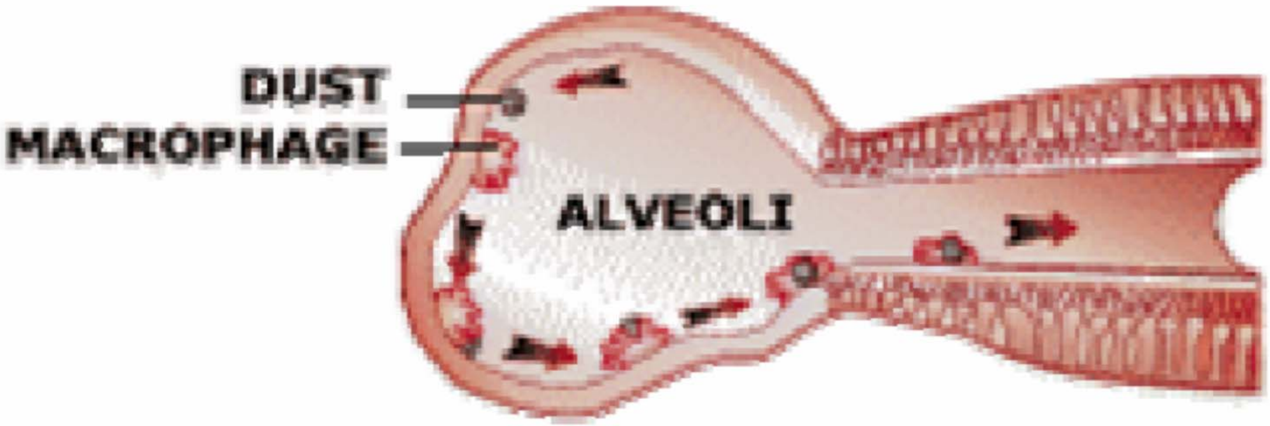
Toxicity

ccording to the UK Health and Safety xecutive (HSE),

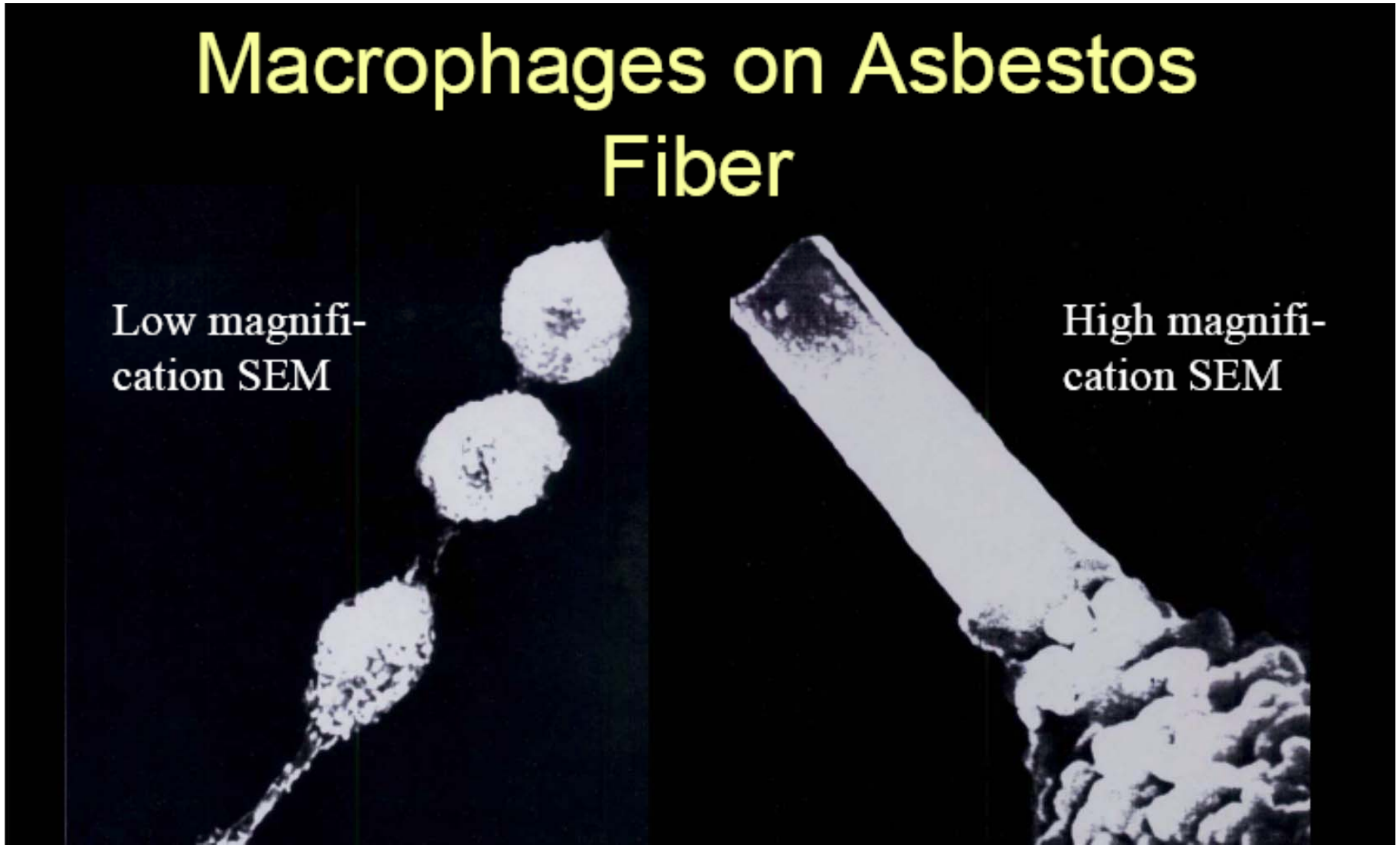
exposures to freshly cut surfaces of crystalline silica will pose greater risks than those exposures to aged surfaces".

Toxicity

Schematic of Phagocytosis



Similar mode of action to clearing asbestos fibres.



he Hazard

hat are the health effects of respirable ystalline silica (RCS)?

an cause lung damage known as cosis.

mall nodules of scar tissue velop in the lungs.

mpaired lung function, leading to chronic onchitis with cough and breathlessness.

ung Cancer

What are the symptoms of silicosis?

rly stages

- Without medical exam may go unnoticed

ntinued exposure

- Shortness of breath upon exercising
- Possible fever
- Bluish skin at ear lobes or lips
- Susceptibility to infectious lung diseases such as tuberculosis.

ogression of the disease

- Fatigue
- Extreme shortness of breath
- Loss of appetite
- Pain in the chest
- Respiratory failure

Silicosis

Silicosis is a slowly progressive, **irreversible disease** that usually takes some years to develop.

In severe cases, silicosis leads to premature death. In people who have had exceptionally high exposures over just **a few months** or years, a rapidly progressive and often fatal condition known as "acute silicosis" can occur.

*Silicosis is not treatable and may **further develop** even when exposure to silica has ceased.*

Vhat is the risk?

Study in Scottish coal miners & Vermont Granite workers

5 years exposure to RCS in $mg.m^{-3}$	Predicted risks of developing silicosis within 15 years following exposure
0.02	0.25%
0.04	0.5%
0.1	2.5%
0.3	20%

Concentration of silica in air.

many grains of sand is equivalent to $0.1 mg/m^3$?

mg (milligram) is 1000th of a gram.

m^3 is 1000 litres.

grain of sand weighs approximately 65 mg.

0.1 mg.m^{-3} is the same as **1/650th of one grain of sand** dispersed in 1000 litres of air.

Assuming that we breath at about 30 litres per minute, or 14,400 litres (or 14.4 m^3) over a period of 8 hours.

To reach the limit of 0.1 mg.m^{-3} all we need to breath in to our lungs is 1/45th of one grain of sand over a period of 8-hours.

Martin Jenning's comments (past President of AIOH)

"in fact, silicosis precedes lung cancer, so I think at a level of 0.1 you are still going to see some cases of silicosis. You might not actually see the cancers but you will still see silicosis"

(Section 5.68 Senate inquiry toxic dust)

Deaths according to disease for the NSW dust diseases scheme since 1968.

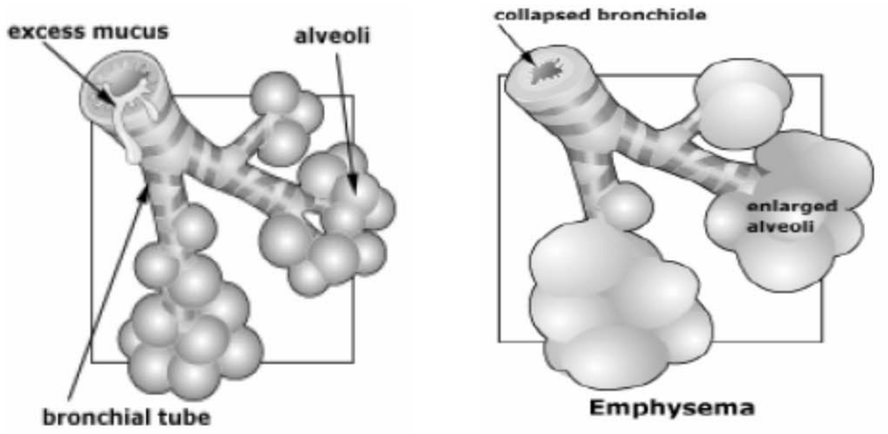
Disease	Total	Average age of death due to disease
Silicosis	1379	71
Silicosis/Lung Cancer	25	71
Asbestosis	643	73
Mesothelioma	1820	68

Compensation payments 2004 – 2005 for NSW dust diseases scheme.

Disease	Total
Silicosis	464
Silica/Lung Cancer	5
Asbestosis	538
Mesothelioma	1470

Chronic obstructive pulmonary disease (COPD)

COPD encompasses chronic bronchitis and emphysema.



Symptoms:chronic cough, sputum production, breathlessness. Condition is slow to develop. Rarely seen in people under 40 years old. It can be very disabling and is a leading cause of death. Severe unremitting asthma is classed as a COPD.

Senate Inquiry – Workplace exposure to toxic dust May 2006.

Some witnesses stated silicosis was now not a problem while other witnesses argued that silicosis was the "the new asbestosis".

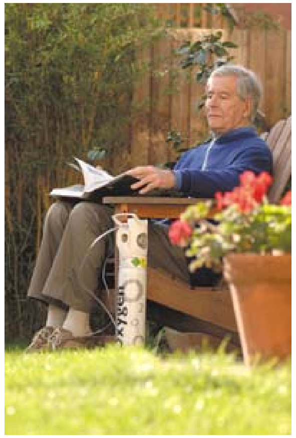
(Section 3.31 of senate inquiry)

I don't believe we have sufficient information to even start to understand the extent of these problems in Australia and well designed studies are urgently needed.

(Section 3.49 of senate inquiry – Professor Trevor Williams)

Quality of life

“HSE has noted that the average length of suffering prior to death ranges between 5 and 10 years”.



Quality of life

Chronic silicosis can result in breathing difficulties when lying down, and limits walking upstairs, up slopes and walking long distances. Severe anxiety and depression has also been reported.

Vhat does the legislation say?

ining and Quarrying Safety and Health Regulation 2001

---

35 Limiting workers' exposure

1) The site senior executive must ensure a worker's exposure to a hazard at the mine:-

a) does not exceed the exposure limit applying to the worker for the hazard; **and**

o) **is as low as reasonably achievable.**

Vhat does the legislation say?

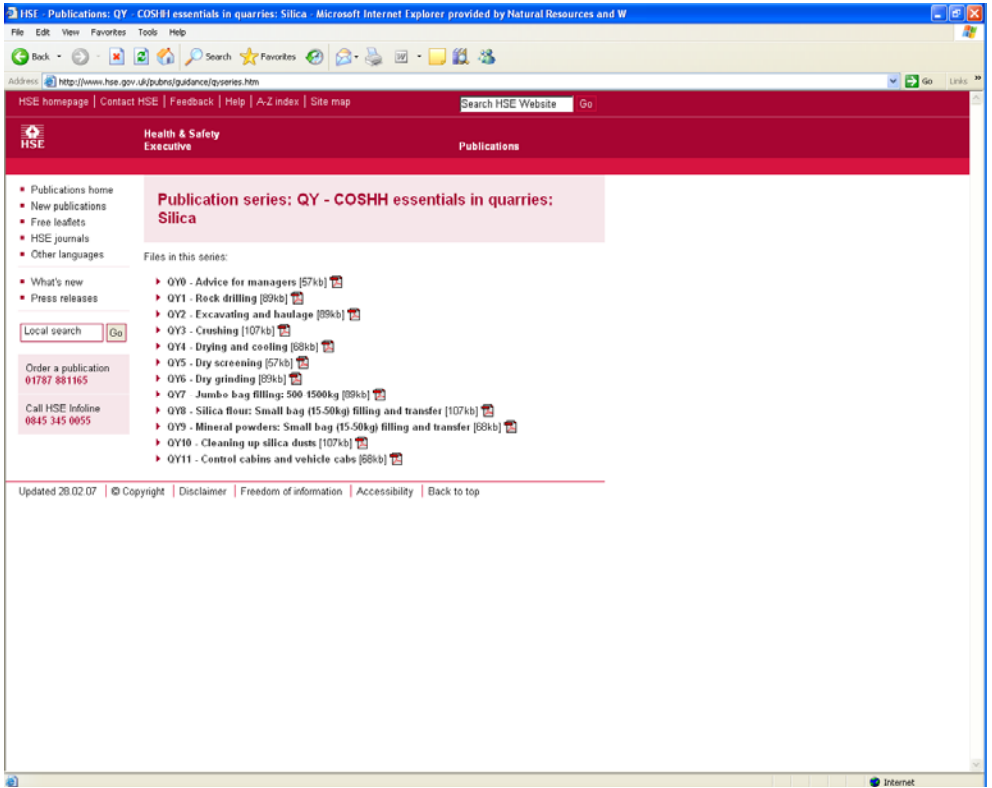
s low as is reasonably achievable!

e definition of as low as reasonably achievable LARA) is a basic radiation protection concept or ilosophy. It is an application of the Linear No reshold Hypothesis.

urrently there is no "safe" level of xposure to respirable crystalline silica.

low can we control the risk?

http://www.hse.gov.uk/pubns/guidance/qyseries.htm



OHH Essentials in Quarries Silica

Health and Safety Executive

Control cabins and vehicle cabs

Control approach 2 Engineering control

Hazard

- ✓ Quarry work can produce airborne respirable crystalline silica (RCS).
- ✓ All RCS is hazardous, causing silicosis. This is a serious lung disease causing permanent disability and early death.
- ✓ Silicosis is made worse by smoking.

Control cabins with forced filtration

- ✓ Consult a qualified ventilation engineer to assure that the design will cope with the anticipated dust levels. The design should cover the following points:

- pre-filters, to protect the main filter if coarse silica dusts are present;
- HEPA filters (BSEN 1822):
  - type H11 for external RCS concentrations below 1 mg/m^3;
  - type H12 or H13 for external RCS concentrations above 1 mg/m^3;
- pressure gauges to show the system is working properly;
- alarms to sound when filters clog;
- overpressure around 10 Pa inside the cabin to prevent dusty air ingress;
- flaps to release excess pressure;
- door seals - heavy-duty neoprene or other suitable material; and
- self-closing doors.

Using control cabins

- ✓ Abrasive dusts can wear out equipment quickly. Plan regular checks and maintenance of the critical parts.
- ✓ Check that the clean air supply is turned on and working at the start of work
- ✓ Check pre-filters regularly - keep spares
- ✓ Check integrity of filter seals daily if they are accessible. If they are not, check monthly and carry out a smoke test at the mid-point of the month.

- ✓ Change inlet air HEPA filters as advised by the manufacturer, but at least after every 250 hours' use.
- ✓ Keep doors and windows closed.
- ✓ Reduce dust being trailed in - use sticky mats or overshoes.
- ✓ Clean the control cabin at least once a week. Use a Type H vacuum cleaner fitted with a HEPA filter, or wet clean.
- ✓ Define and provide personal protective equipment (PPE) for work outside the cabin.

Don't clean up with a brush or with compressed air.

Maintenance, examination and testing

- ✓ Get a competent ventilation engineer to examine the system thoroughly and test its performance at least once every 14 months. See the HSE publication HSG54 - see 'Further information'.
- ✓ Keep records of all examinations and tests for at least five years.
- ✓ Review records - failure patterns show where preventive maintenance is needed.
- ✓ Carry out air sampling to check that the controls are working well. See sheet G409.

Vehicle cabs with forced filtration

- ✓ High dust levels result from transferring material to the vehicle and haulage on unmade roads in dry weather.
- ✓ Can you time mineral extraction for the wetter seasons?
- ✓ Wash down metalled roadways regularly and limit vehicle speed.
- ✓ The cab should have the following features:
- pre-filter to protect the main HEPA filter;
- pressure gauge to show the system is working properly;
- overpressure around 10 Pa inside the cab to prevent dusty air ingress; and
- door and window seals - heavy-duty neoprene or other suitable material.

Using cabs with filtered air

- ✓ Abrasive dusts can wear out equipment quickly. Plan regular checks and maintenance of the critical parts.
- ✓ Check that the control cab clean air supply is turned on and working at the start of work.
- ✓ Check pre-filters regularly - keep spares.

Maintenance, examination and testing

- ✓ Get a competent ventilation engineer to examine the system thoroughly and test its performance at least once every 14 months. See the HSE publication HSG54 - see 'Further information'.
- ✓ Keep records of all examinations and tests for at least five years.
- ✓ Review records - failure patterns show where preventive maintenance is needed.
- ✓ Carry out air sampling to check that the controls are working well. See sheet G409.

low can we control the risk?

now how much crystalline silica is in your
uarry!

ndstone / quartzite	> 70%
nale	40 to 60%
ate	up to 40%
ranite	up to 30%
asalt / dolerite	up to 5%
mestone / marble	up to 2%

ut these can contain silica layers)

low can we control the risk?

ain workers / supervise.

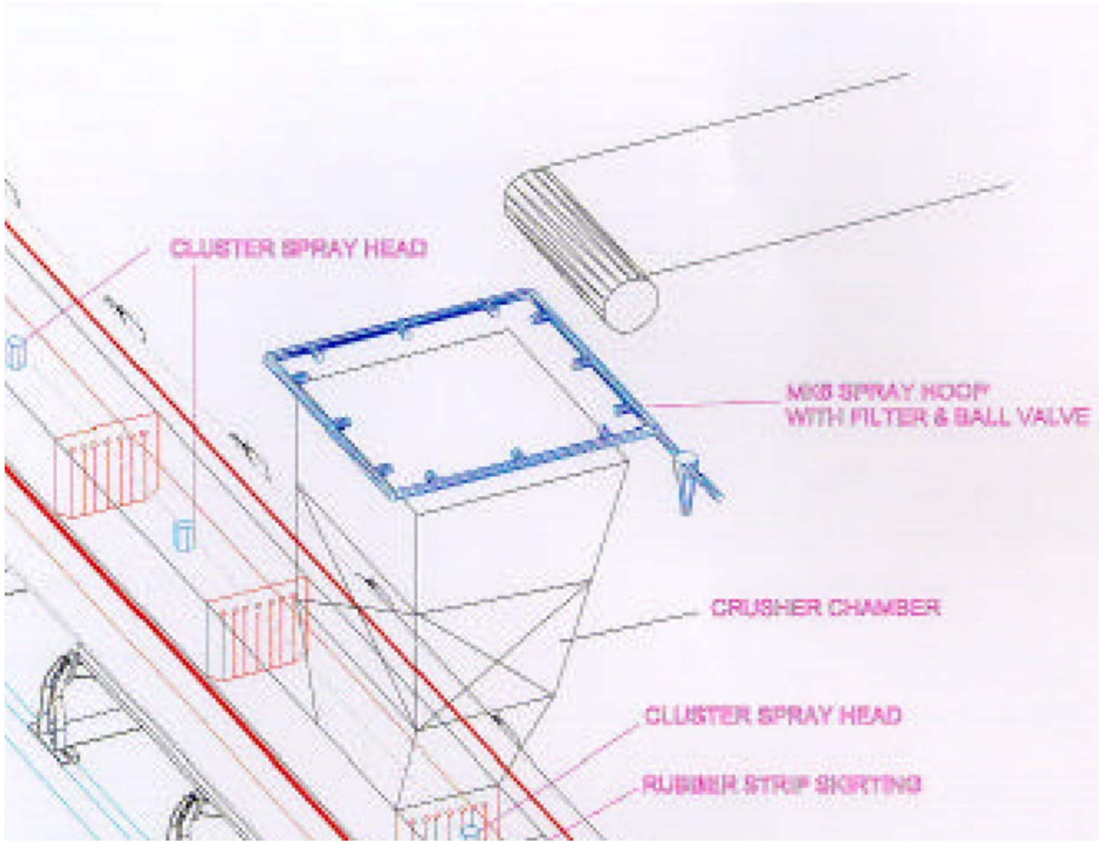
- ☹ Do not generate airborne dust.
  - ☹ Do not use compressed air or dry sweeping.
- ☺ Clean using vacuum or wet methods.
- ☺ Always use dust suppression.

e a dust mask as a last resort, as an interim control or if
u are uncertain about the level of risk.

Use of an industrial (HEPA) vacuum cleaner is preferred.

NEDERMAN P 160
Portable high vacuum dust extraction unit

Fog systems


CLUSTER SPRAY HEAD
MKS SPRAY HOOP
WITH FILTER & BALL VALVE
CRUSHER CHAMBER
CLUSTER SPRAY HEAD
RUBBER STRIP SKIRTING

Fog systems

Before: No dust control

Fog systems

After: With windfence and fog

Fog systems

Beware !

f exposing operators to airborne bacteria
n mist (ie legionella).

low can we control the risk?

- Where ever possible enclose operations.
- Can you reduce the need for people being in dusty areas.
- Keep roadways damp.
- Keep vehicle windows closed.

Rock drilling

- If you use a drill rig with a control cabin provide HEPA filtered air to the control cabin.
- Use equipment with an integral dust collector and/or water suppression.
- Confirm that dust control is turned on and working prior to starting work.
- Fit a manometer or pressure gauge near the extraction point, to show that the system is working properly.
- Adequate water supplies

Crushing

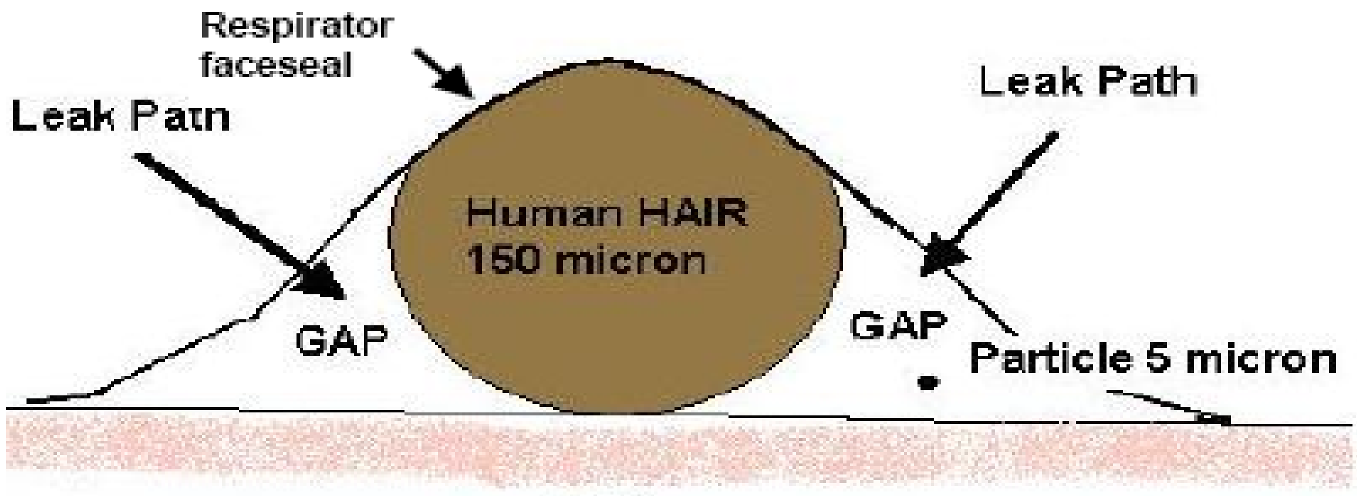
- Segregate operator in a control cabin.
- Where possible use CCTV to monitor the process.
- Locate the crusher outdoors away from occupied buildings.
- Fit water suppression.
- Provide HEPA filtered air to operator.
- Ensure preventative maintenance is in place.

/here negative pressure respirators are worn operators must be clean shaven daily?

/here a respirator (dust mask), is worn, any facial hair will nterfere with the face seal making the respirator ineffective.

Why clean shaven daily?

Airborne Contaminants can range from several microns (1 micron = 1/1000th mm) down to fractions of a micron. A human hair has an average thickness of about 150 micron. A single hair width will hold the mask off the face like a steeple and create spaces for the micron sized particles to leak past - See diagram below.



Qualitative Fit Test

Observations to date

Of the 5 quarries, with silica bearing rock, inspected in the north region (by the Senior Principal Occupational Hygienist):

- **Only 1 out of the 5, carried out pre-employment and periodic health surveillance including spirometry and full chest x-rays.**

In one quarry there was inadequate understanding about the control of airborne dust.

Mines Inspectorate where to from here?

- Carry out an assessment, targeting those quarries, with elevated amounts of crystalline silica in rock.
- Through mine record entries (MRE), continue to note that each quarry **should** carry out health surveillance including periodic full chest x-rays and spirometry.
- Leverage proven control technologies such as that provided in good practice guides (European Economic Community and Health and Safety Executive).
- From the above, publish a study that will be disseminated to industry.

Silica and the lung

What is silica?

Silica is a mineral found in the earth's crust. The crystalline form of silica which is called quartz has been associated with a variety of diseases primarily affecting the lung. Crystalline silica is therefore present in the aggregate added to concrete, in asphalt, bricks, concrete, concrete and terracotta tiles and pavers, in sandstone and in granite. Small amounts are present in cement. Silica can be released if using power tools to cut fibre cement sheeting.

Construction or building material	Amount of crystalline silica (quartz)
Sand and sandstone	96 -100 %
Calcium-silicate bricks	50 - 55%
Aggregate in concrete	30%
Clay bricks	15 - 27%
Fibre cement sheets	10 - 30%
Demolition dust	3 – 4%

Table 1: Typical concentrations of crystalline silica in building materials

How does silica get into the lung?

Airborne silica dust is generated when you chase or drill into concrete, rip up old concrete or bitumen roads, jackhammer or saw old concrete, excavate sites with sandstone, clay or granite or generally get exposed to airborne dust on a construction site. Particles of silica dust can be very fine and as small as one to six microns (millionths of a metre) in diameter.

We breathe and exhale them. Our lungs have scavenger cells called macrophages (see Figure 2). These cells dissolve dust particles by surrounding them. But if there is too much dust, an overload situation, the scavenger cells cannot completely clear the dust. Scarring is the lung's reaction to dust which gets deposited in the air sacs. When there is a lot of scarring you can get shortness of breath.

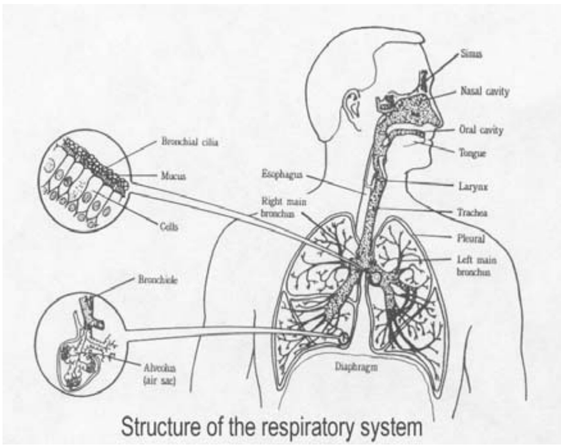


Figure 1: The lung

Figure 2: Lung scavenger cell

What diseases does exposure to crystalline silica cause?

Crystalline silica exposure can cause:

- chronic bronchitis – inflammation of the airways resulting in cough and irritation
- emphysema – destruction of the lung tissue and loss of surface area for the exchange of gases such as oxygen and carbon dioxide
- acute silicosis – extremely high dust exposures after just a few months or years can result in severe inflammation and an outpouring of protein into the lung
- silicosis – scarring of the lung tissue causing shortness of breath and interfering with the exchange of gases which takes place in the air sacs – usually requires 10 or more years exposure unless the dust concentration is very high (see Figures 3, 4 and 5)
- lung cancer – occurs with heavy exposure to silica but smokers have a higher risk
- kidney damage – may require dialysis if severe
- scleroderma – a disease of the connective tissue of the body resulting in the formation of scar tissue in the skin, joints and other organs of the body – pins and needles in the hands can be a symptom.

Figure 3 Chest X-ray showing nodular silicosis

Figure 4: Chest X-ray showing progressive massive pulmonary fibrosis (scarring)

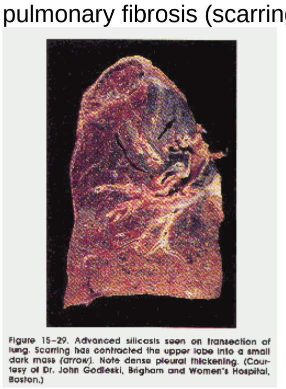


Figure 5: Section of lung with advanced silicosis at autopsy

How do I know if I have silicosis?

In the early stages, silicosis causes no symptoms. It usually takes decades of breathing in quartz-containing dust to develop silicosis. However, there is a disease called acute silicosis which can occur after only a few months to years of breathing in very high concentrations of quartz.

What are the symptoms of silicosis?

The first symptoms of silicosis are often shortness of breath on exertion, a cough, occasional chest pain, loss of appetite and minor fatigue. As the disease progresses, the shortness of breath gets worse on minor exertion and can be present all the time, the cough is more severe and persistent, the chest pain can worsen, and there is associated fatigue, weight loss and night sweats. Workers with silicosis are more at risk of getting tuberculosis (TB) and lung cancer. The disease can be detected by a chest X-ray in the early stages before symptoms develop. There is no cure for silicosis and therefore prevention is the only option.

Do I need a chest X-ray?

If it is more than 10 years since you first came into contact with silica dust, and you think you have had regular and high exposure, see your doctor to discuss what tests are appropriate. Generally those most at risk are workers who have had extensive exposure to chasing, overhead drilling, and grinding for many years and without any protective measures such as vacuum bag attachments, water or a dust mask.

If your employer's risk management process for the job shows that health monitoring is required, you should be reviewed by a registered medical practitioner[1] and complete a respiratory symptom questionnaire, have testing which may include lung function tests (see Figure 6) and a chest X-ray. The registered medical practitioner will decide what tests are required based on your exposure history.

Figure 6: Lung function testing

[1] A registered medical practitioner is a doctor who will have experience in health monitoring and can conduct silica health monitoring.

What are typical exposures to silica in the building and construction industry?

The Safe Work Australia[2] Exposure Standard for respirable crystalline silica is 0.1 mg/m^3, measured in the dust sampled according to a specified lung penetration curve. This means that most people whose exposures are maintained less than 0.1 milligrams of crystalline silica dust in each cubic metre of air, eight hours a day, 48 weeks a year for a working lifetime have a low risk of getting silica-related disease.

The risk of silica-related lung disease can be virtually eliminated in workers who control the dust and wear respiratory protection.

How much silica am I exposed to?

Data collected by researchers in Western Australia and in the Netherlands in typical construction jobs is summarised below:

Activity	***Respirable Silica (quartz) mg/m^3***
Overhead drilling	0.15
Chasing	60.0
Drilling holes in brick or concrete	0.18 – 0.37
Cleaning (sweep/vacuum)	0.03
Dismantling equipment (scaffolding used by bricklayers)	0.1
Demolition - jack hammering	0.25
Tuck pointers chasing mortar	0.56
Background dust	0.03 – 0.05
National Exposure Standard	**0.1**

Table 2: Respirable silica dust concentrations

Who is at risk?

From 1992 - 2004 there were six workers' compensation claims for silicosis in Queensland. Four of these claims were in mining and quarrying, two were in clay, brick and concrete manufacture. It is not clear whether there is little disease due to silica

[2] Safe Work Australia is the Federal agency responsible for harmonising regulations in health and safety. This includes setting exposure standards for chemicals at work.

exposure or whether the disease is simply not diagnosed because of the lack of health monitoring (which includes chest X-rays and lung function tests).

High risk jobs exist in the construction industry and workers at risk of silicosis are largely employed as excavators, jackhammer operators or abrasive blasters. Silicosis results in shortness of breath and people are usually diagnosed when they are near retirement. It is therefore essential to prevent disease by not exposing workers to silica dust to preserve their quality of life in retirement.

Any person in the construction industry is at risk who:

- blasts, excavates or tunnels into sandstone, clay or granite
- drills, cuts or chases into concrete and brickwork
- cuts bricks dry
- angle grinds on concrete or masonry
- jackhammers, scabbles or chisels concrete
- cleans up the dust and debris created by the above activities
- dismantles equipment covered in dust
- demolishes buildings.

Figure 7: Cutting bricks

Figure 8: Drilling into bricks

How do I manage the hazard?

Identify the hazard

Know what you are working with. Read the Safety Data Sheet (SDS) for the products that you work with and see if the ingredients listed include quartz.

If there is no SDS because the silica is generated in a tunnelling, excavating or drilling operation, you will need to seek alternative information about the likelihood of silica being present in the dust.

Management of the risk includes:

- What activities will you carry out?
- Will these activities generate dust?
- Who will be exposed?
- Do you need to control your exposures?
- How will you clean up?

Control the risk, observing the control hierarchy:

- minimise the generation of dust
- use drills and routers with dust collecting bags
- use tools fitted with a water attachment to suppress dust (on power saws, jack picks, scabbling picks.)
- fit large machinery (excavators and bulldozers) with cabs that have an effective air filtering system
- use metallic shot, slag products or grit for abrasive blasting, not sand
- wet down dusty work areas and processes
- clean up the dust with an industrial vacuum cleaner or by wet sweeping.

Important: Local exhaust ventilation or wet dust suppression has been shown to reduce dust by up to 99 per cent.

How can I protect myself?

Wear respiratory protection (see Figure 9). This generally means a P1 or P2 (particulate) or half-face filter respirator. Remember, you must be clean shaven for a respirator (dust mask) to work effectively. For abrasive blasting, an airline respirator is required.

Don’t smoke as smoking reduces the lung’s ability to clear dust and increases the risk of lung cancer.

Figure 9: Worker with P2 respirator

Case reports

The case reports below are on construction industry workers in the United States of America. More information is available at www.cdc.gov/niosh/topics/silica/

Case one

A 39-year-old man was diagnosed with silicosis (progressive massive fibrosis) and tuberculosis after working 22 years as a sandblaster. He had noticed a gradual increase in shortness of breath, wheezing, and discomfort from minimal exertion. Tissue taken from his lungs showed extensive fibrosis (scarring).

His job involved sandblasting welds during water tank construction to prepare the metal for painting. While sandblasting, he wore a filter respirator (an airline respirator would have offered better protection). During a 10 - 11hour day, he spent six hours sandblasting.

Case two

A 55-year-old man was diagnosed with simple silicosis after working 30 years as a building renovation mason. A lung biopsy revealed silicotic nodules.

Case three

A 47-year-old man was diagnosed with severe silicosis after working 22 years as a rock driller. He was diagnosed after he was brought to a hospital with respiratory failure and right heart failure and was put on a ventilator, but died. His autopsy confirmed advanced silicosis.

Before this worker's diagnosis, he had never seen a doctor and had never had a chest X-ray. The drills he used were equipped with dust controls, but they were routinely inoperable.

Need more information?

For advice on dust monitoring visit www.worksafe.qld.gov.au or call the WHS Infoline on 1300 369 915.

Visit the website to download:

- *Tunnelling Code of Practice 2007*
- *Silica – Identifying and managing crystalline silica dust exposure. Information guide. Workplace Health and Safety Queensland 2013*
- *Silica – Technical Guide to Managing exposures in workplaces. Work-related Disease Strategy 2012 – 2022. Workplace Health and Safety Queensland*

Other references

- *Public Health Guidance Note: Silica and your health. March 2002*
- *Preventing silicosis and deaths in construction workers. DHHS (NIOSH) Publication No 96-112, 1996*
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Department of **Employment, Economic Development and Innovation**

RESPA™ Trial 2009

Occupational hygiene monitoring for airborne particulate matter and respirable crystalline silica inside of an excavator cabin - before and after fitting a pre-cleaner, filter and pressurisation unit.

File 042066

Toward Q2 Tomorrow's Queensland

Queensland Government

Executive Summary

Exposure to respirable crystalline silica (RCS) particularly in dimension stone (sandstone mines) is of concern. Studies in the United Kingdom, United States of America along with a trend in reduction of occupational exposure limits (OEL) supports this view.

Monitoring undertaken inside an excavator (with saw attachment) cabin has demonstrated that there is reduced exposure to both airborne particulate matter and RCS after installing a RESPA™ pre-cleaner, filter and pressurisation (PFP) unit.

Preliminary data indicate that installation of these units will be beneficial to the health and comfort of mobile plant operators while cutting or trenching through sandstone using an excavator and saw attachment. It is feasible that this technology may be effective in reducing exposure to particulate matter and RCS in other mining and quarrying applications such as crusher control rooms and other operator cabins associated with mobile and fixed plant.

Contents

1.0 Introduction

In Queensland, dimension stone (sandstone mine) workers are potentially exposed to airborne silica from freshly cut quartzite. There is evidence that exposure to respirable dust from freshly cut quartz is a significant factor in the development of lung disease (HSE, 2002). The Safe Work Australia Exposure Standard (TWA) of 0.1 mg/m^3 may not offer a suitable level of protection for workers. Air monitoring carried out within the cabin of 330 CAT and 350 LCH Hitachi excavators (with saw attachment) has revealed that the standard fitted cabin air-conditioning / filtration system does not provide sufficient protection against respirable crystalline silica (RCS). This has been shown during the cutting and trenching of sandstone at a dimension stone mine in Helidon, Queensland. To address this issue a mine record entry was issued to dimension sandstone mines throughout Queensland *(refer to appendix iii).*

A primary means of dust control on mechanised surface mining equipment is enclosed operator cabins with an air filtration system (NIOSH 2008, Queensland Mines and Energy 2009). Newer technology to prevent the ingress of dust into mine machinery cabins is the RESPA™ pre-cleaner, filter, pressurisation (PFP) technology. These RESPA™ PFP units can be mounted vertically of horizontally on stationary or mobile equipment and supply existing, heating, ventilation and air-conditioning (HVAC) systems with clean filtered fresh air, resulting in positive pressure within an operator cabin. This report therefore, provides preliminary findings from a series of trials to measure airborne dust and RCS, inside an excavator cabin, whilst sawing and trenching through sandstone. The trials have been conducted prior to and post installation of:

- a RESPA™ SD unit which pre-cleans and filters external supplied air and,
- a RESPA™ SDX which filters re-circulated air.

Photograph # 1; Airborne dust being generated from 350 LCH excavator saw attachment cutting sandstone.

Photograph # 2; 350 LCH excavator, with saw attachment, cutting sandstone with RESPA™ SD unit installed (mounted behind cabin).

Photograph # 3; 350 LCH excavator, showing close-up of RESPA SD™ (external air supply) unit showing un-housed filter.

Photograph # 4; 350 LCH excavator, showing close-up of RESPA SD^{TM} (external air supply) + RESPA SDX^{TM} (recirculated air) units showing housed filter.

2.0 Background

Exposure to fine particles of airborne quartz may result in quarry operators developing silicosis, a debilitating respiratory condition which may not be diagnosed during their working lifetime. Recent literature (HSE, 2002; ACGIH, 2006; HSE, 2006; Driscoll, 2006) indicates that adverse health outcomes are predicted from exposures to airborne dust at levels previously considered as acceptable.

Mining, quarrying and exploration operators are potentially exposed to freshly cut quartzite (alpha quartz) in the form of crystalline silica. There is also an increased risk of developing chronic obstructive pulmonary disease (COPD) which includes bronchitis and emphysema (Hedges et al. 2007). Analysis of feedback from questionnaires sent out to small mines, quarries and exploration sites in Queensland revealed that many work sites do not know the concentration of crystalline silica present the rock being mined and that no routine monitoring takes place (DME, 2009). The questionnaire and feedback provided in this report identified gaps in the management of silica dust. The information provided reinforces the importance of ensuring the effectiveness of controls to reduce exposure.

People undertaking certain job types such as excavator saw operators in dimension stone forming mines, are at increased risk of elevated exposures to RCS.
In a survey conducted by the United Kingdom Health and Safety Executive (HSE), the found that in many locations, engineering control equipment installed was of limited effectiveness, due either to the selection of unsuitable equipment or inadequate design or installation (HSE 2009).
Where controls are installed, such as mobile machinery air filtration systems, it is important that the effectiveness of these controls be evaluated.

3.0 Methodology

Personal samples were collected according to AS2985-2004 using a cyclone sampling head attached to a sampling pump at a flow rate of 2.2 (±5%) L/min using SKC AirCheck 2000 Model 210-2002 sampling pumps.

The pumps were calibrated using a TSI 4100 series (Serial No.4146 0629 001) mass flow meter. The TSI secondary flow-meter was calibrated against a primary soap film flow-meter as per *appendix B* of AS2985-2004. A correction factor was calculated and all sampling volumes were adjusted to align with the primary standard.

The samples were collected on SKC GLA-5000 PVC 25mm 5 µm pore size filters. The analysis of samples for respirable silica was undertaken at the Simtars (Safety in mines testing and research station) laboratories in Queensland in accordance with the National Health and Medical Research Council NH&MRC (1994) document – Methods for Measurement of Quartz in Respirable Dust by Infrared Spectroscopy.

Exposure standards for respirable dust and respirable silica were adjusted applying the Brief and Scala model using the average weekly hours adjustment equation as recommended by Simtars (nd):

$$RF = \frac{40}{h} * \frac{168-h}{128}$$

Where: h = average hours worked per week over full roster cycle.

The “reduction factor” is multiplied by the 8-hr exposure standard to obtain the new standard. The average number of hours worked per week at the site monitored was 45hrs. Applying the above formula means that the exposure standard is reduced from 0.1mg/m^3 to 0.09mg/m^3 to account for the additional exposure time.

Testing the potential impact of an PFP air cleaning device (RESPA™ SD / SDX) on the air quality inside the cabins was undertaken. The RESPA™ HVAC Precleaner + Filtration + Pressuriser units were supplied / installed by LSM Technologies Pty Ltd. The Site Senior Executive (SSE) provided the excavator for retrofitting and LSM Technologies fitted the RESPA system including associated plumbing and commissioning.

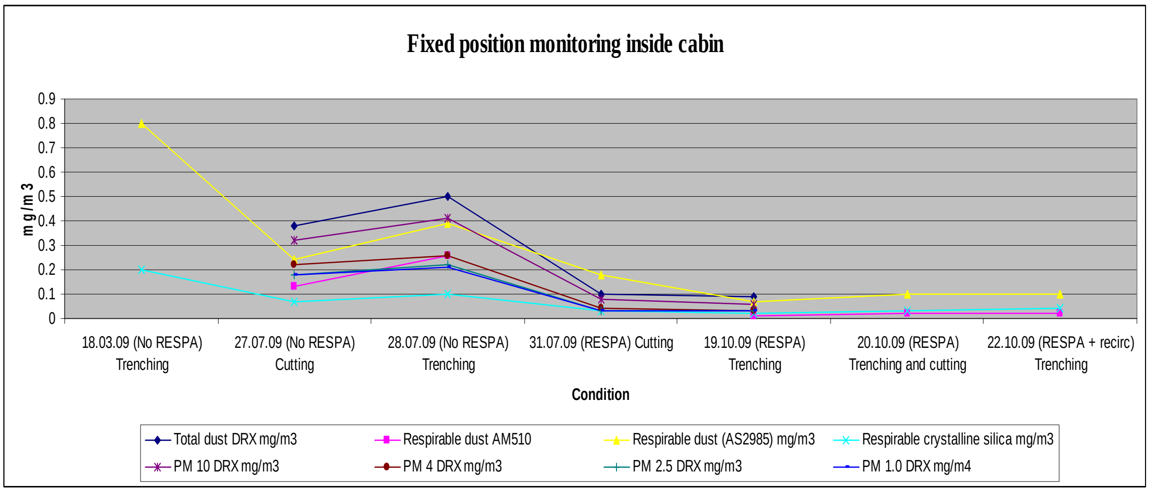
RESPA™ PFP units supplied in Australia by LSM Technologies Pty Ltd combines the technology of a Precleaner, Filtration and Pressurisation units that provides positive pressure HEPA filtered air to the existing air conditioning systems of fixed and mobile mining plant. Sampling for a range of particle sizes was carried out using a DRX® TSI dust analyzer (Model 8533, Serial No. 8533084003) which can sample for PM_1, $PM_{2.5}$, PM_{10} and respirable concentrations simultaneously.

Respirable dust was also measured in the same excavator cabin using a AM510® TSI dust analysers (Serial Nos 10809003, 10809004 & 10809005). Both these instruments allow for real time sequential measurements throughout the day in terms of changes in dust concentrations.

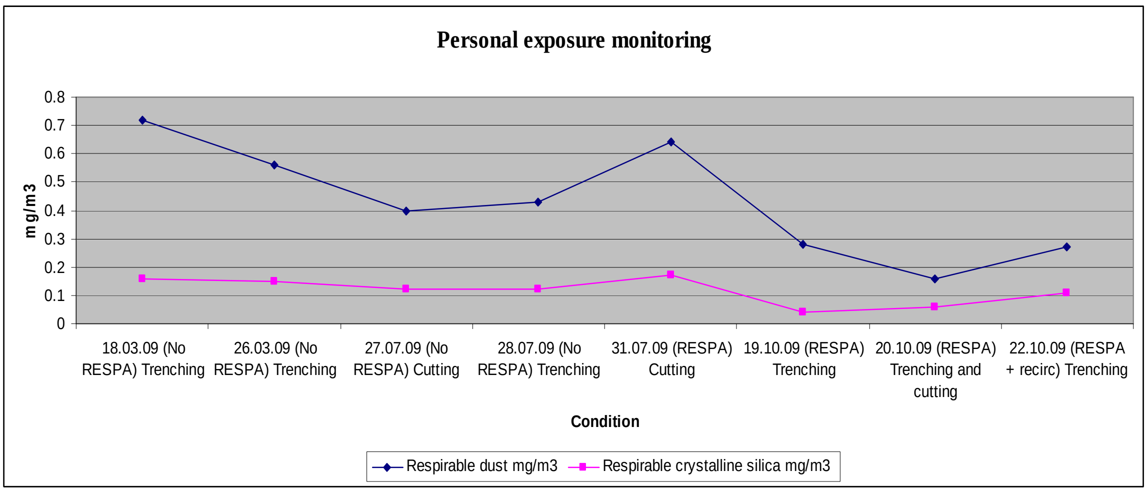
4.0 Results

Individual personal and fixed position (static) monitoring results can be viewed in Appendix i. Graphs 4.1 and 4.2 demonstrate that there is an overall reduction in particulate matter and respirable crystalline silica once the RESPA SD™ unit had been installed. It was observed that that the personal monitoring results for the excavator saw operator, were still elevated, on one occasion (31.07.09) even with the RESPA SD™ unit had been installed. This is because the operator left the cabin numerous times during the monitoring period which meant that most of the exposure would have occurred outside the cabin. Results recorded from fixed monitors located in the cabin on this same day support the rationale that the exposures occurred outside the cabin (see figure 4.2). Results from fixed position monitoring in graph 4.2 demonstrate a marked reduction for total dust, respirable dust, PM 10, PM 4, PM 2.5 and PM 1. Generally there was a 4-fold reduction of respirable crystalline silica (RCS) measured inside the cabin once the RESPA SD™ (external air) had been installed. On average the RCS concentration measured inside the cabin (with no RESPA™) was 0.12 mg/m^3. In comparison, once the RESPA SD™ (external air) unit had been installed, the average RCS concentration inside the cabin was 0.03mg/m^3. The Safe Work exposure standard (reduced) (TWA) limit is 0.09mg/m^3. A second RESPA SDX™ (recirculation air) unit was installed to remove particulate matter that enters the cabin when the operator enters or exits the cabin or opens doors and windows.

Graph 4.1



Graph 4.2



Appendix ii provides a graphical representation of the reduction in airborne dust from real time air monitoring using an AM510™ with cyclone attachment without RESPA (9a) and with RESPA (9b).

Appendix IV Graphs for real time air monitoring by AM510™ with cyclone attachment, measuring respirable dust, without RESPA™ (28 July 2009), with single RESPA™ (20 October 2009) and with second unit for recirculated air (22 October 2009) during trenching.

5.0 Discussion

Results have demonstrated a significant reduction in airborne dust including respirable dust, PM 4, PM 2.5 and PM 1 resulting from the installation of RESPA™ pre-cleaner, filtration, pressurization (PFP) unit. A marked reduction for respirable crystalline silica (RCS) (measured as alpha quartz) has also been demonstrated. On average the measured concentration of 0.12mg/m^3 RCS has been reduced to 0.03mg/m^3 after the RESPA unit has been installed. This is a four fold reduction and well below the adjusted exposure standard of 0.09mg/m^3 and marginally below 50% of the exposure standard being 0.045mg/m^3. The AIOH position paper on respirable crystalline silica has noted that where the exposure is likely to exceed 50% of the exposure standard, control strategies and health surveillance should apply.

Graphs from real time monitoring in *appendices ii and iv* show a graphical representation in the reduction in both PM1 using TSI DRX™ and respirable dust using an AM510™ with cyclone attachment respectively.

There is a high level of reliance on air-conditioned vehicle cabins in the mining industry and monitoring carried out for this study has demonstrated that air-conditioned systems to not provide an effective barrier. This is particularly evident, while cutting and trenching through sandstone using an excavator with saw. The mine record entry contained in appendix III, provides a staged approach to reduce the RCS exposure risk. Installation of a system such as a RESPA™ pre-cleaner, filtration, pressurization (PFP) unit is warranted. Installation of the RESPA unit should include an inspection of the existing HVAC system to determine effective operation. The RESPA unit is designed to supply the existing HVAC system with clean filtered air. Following installation, personal monitoring should be conducted to demonstrate that the system is working and effective.

Preliminary results to date haven't demonstrated any additional reduction from installing a second unit to filter re-circulated air, however this monitoring was only conducted over a single shift. During this shift the operator was estimated to have exited the cabin on up to sixty (60) occasions. These are not typical of the conditions experienced during other stages of the trial. To determine the effectiveness and benefits of installing a second RESPA unit in this application further monitoring needs to be conducted.

6.0 Conclusion

The installation the RESPA™ pre-cleaner, filtration, pressurization (PFP) unit has shown that there is a marked reduction of RCS getting into an excavator cabin while cutting / trenching sandstone. This report provides qualification that installation of units such as this will be beneficial to the health and comfort of machinery operators. In principle this technology should be adaptable to other mining and quarrying applications including fixed plant (crusher control rooms) and mobile plant in other operations, however, monitoring is still required to prove that the system is in fact effective.

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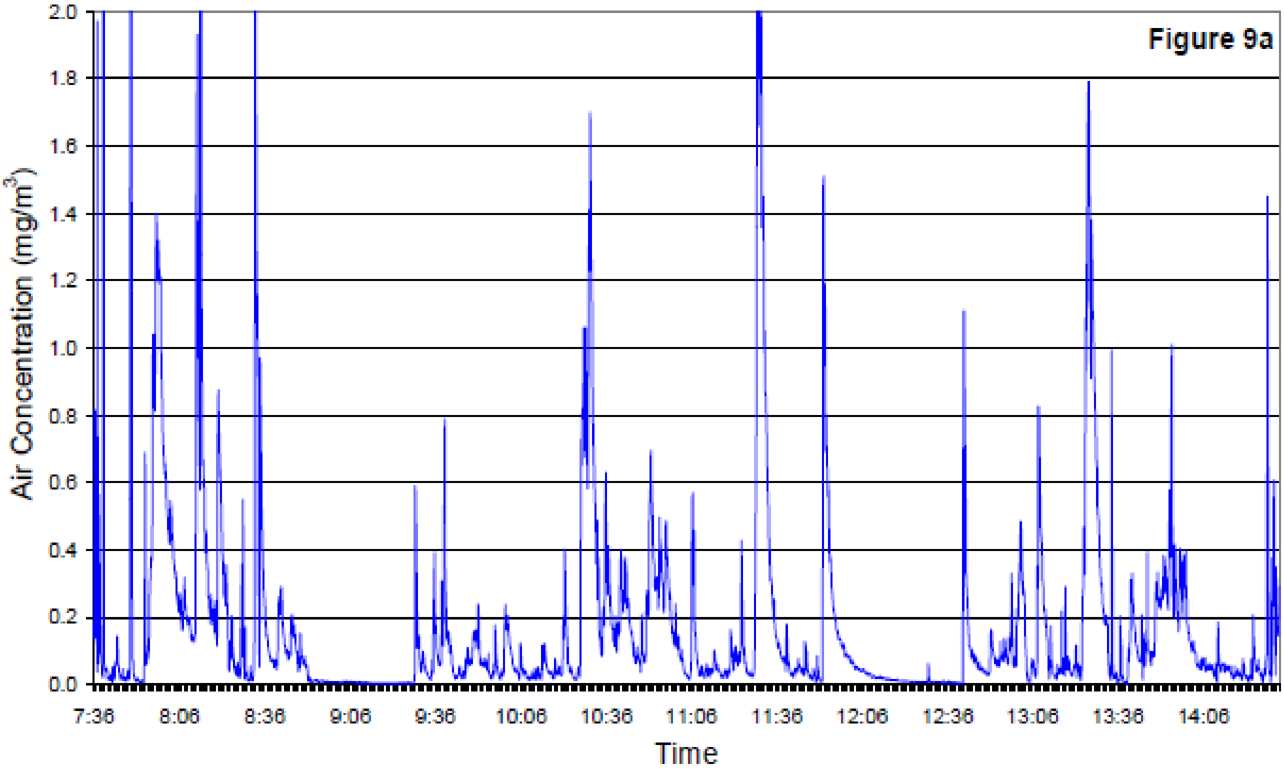
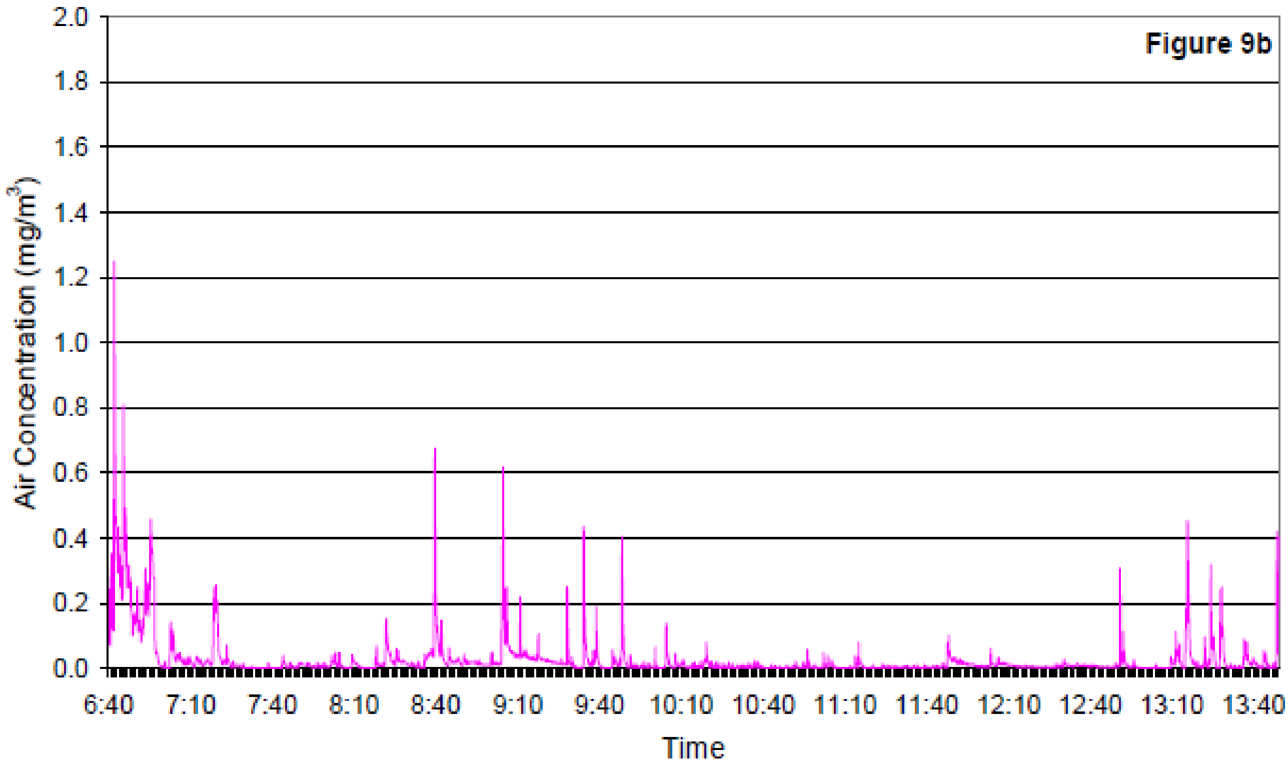
Appendix I monitoring results

Sample	Date	Location	Activity	Machine	Treatment	Total dust DRX mg/m^3	Respirable dust AM510 mg/m^3	Respirable dust (AS2985) mg/m^3	Respirable alpha-quartz (AS2985) mg/m^3	PM10 DRX mg/m3	PM4 DRX mg/m3	PM2.5 DRX mg/m3	PM1.0 DRX mg/m3
F5024	18.03.09	Personal	Trenching	CAT330 Exc + saw	None			0.72	0.16				
-	18.03.09	Static cabin	Trenching	CAT330 Exc + saw	None		0.73	0.80	0.20				
F5031	26.03.09	Personal	Trenching	CAT330 Exc + saw	None			0.56	0.15				
F6744	27.07.09	Personal	Cutting	Hitachi Exc + saw	None			0.40	0.12				
-	27.07.09	Static cabin	Cutting	Hitachi Exc + saw	None	0.38	0.13	0.24	0.07	0.32	0.22	0.18	0.18
F6727	28.07.09	Personal	Trenching	Hitachi Exc + saw	None			0.43	0.12				
-	28.07.09	Static cabin	Trenching	Hitachi Exc + saw	None	0.50	0.26	0.39	0.10	0.41	0.26	0.22	0.21
F6714	31.07.09	Personal	Cutting	Hitachi Exc + saw	RESPA			0.64	0.17				
-	31.07.09	Static cabin	Cutting	Hitachi Exc + saw	RESPA	0.10		0.18	0.03	0.08	0.04	0.03	0.03
F6348	19.10.09	Personal	Trenching	Hitachi Exc + saw	RESPA			0.28	0.04				
-	19.10.09	Static cabin	Trenching	Hitachi Exc + saw	RESPA	0.09	0.01	0.07	0.02	0.06	0.03	0.03	0.03
F5227	20.10.09	Personal	Trenching and cutting	Hitachi Exc + saw	RESPA			0.16	0.06				
-	20.10.09	Static cabin	Trenching and cutting	Hitachi Exc + saw	RESPA		0.02	0.10	0.03				
F5225	22.10.09	Personal	Trenching	Hitachi Exc + saw	RESPA + recirculation RESPA			0.27	0.11				
-	22.10.09	Static cabin	Trenching	Hitachi Exc + saw	RESPA + recirculation RESPA		0.02	0.10	0.04				
-	22.10.09	Static outside cabin	Trenching	Hitachi Exc + saw	RESPA + recirculation RESPA			2.4	0.83				
Safe work exposure standard (8hrs TWA)									**0.10**				
Safe work exposure standard (reduced for extended shifts)									**0.09**				

Appendix II Graphs for real time air monitoring by TSI DRX™ showing reduction in PM1 without RESPA™ (9a) and with RESPA (9b). The monitoring was carried out over 6-hours during the cutting of sandstone.

Graphs reproduced from concurrent paper presented at Australian Institute of Occupational Hygienists (AIOH) annual conference Canberra with permission from authors.





Appendix III Mine Record Entry sent to all Queensland stone forming mines

Safety & Health, Mines Inspectorate
South East Regional Office

Mine Record Entry

This report forms part of the Mine Record under s59 of the Mining and Quarrying Safety and Health Act 1999. It must be placed in the Mine Record and displayed on Safety Notice Boards.

An excavator with a large diameter saw attached to the boom is the equipment extensively used in Queensland sandstone mines to cut dimension sandstone blocks from their insitu state. Recently at a Helidon sandstone mine personal exposure monitoring, for respirable crystalline silica (quartz), of an operator in an enclosed excavator cabin has revealed unacceptable airborne levels, at twice the acceptable limit during cutting operations. This demonstrates that the cabin on this excavator is not providing an effective barrier to dust. The excavator operator, believing that the cabin provides adequate protection, does not use a respirator during the cutting activity. Unknowingly, the excavator operator is exposing himself to airborne silica that places him at risk of silicosis or chronic obstructive pulmonary disease. Consequently, to reduce the level of exposure of operators to respirable crystalline silica in enclosed excavator cabins during cutting operations to below the acceptable limit, the following directive is issued to all dimension sandstone stone quarries that operate excavators with saw attachments:

Number	Directive
1	**Reducing excavator operators' exposure to respirable crystalline silica**

1. Effective immediately excavator operators engaged in sandstone cutting operations must wear suitable respiratory protection equipment which complies with AS/NZS – 2009, Selection, use and maintenance of respiratory protective equipment to maintain their exposure to respirable crystalline silica below the acceptable limit of 0.1mg/m3 until the SSE can demonstrate that the exposure within the cab is below the acceptable level.

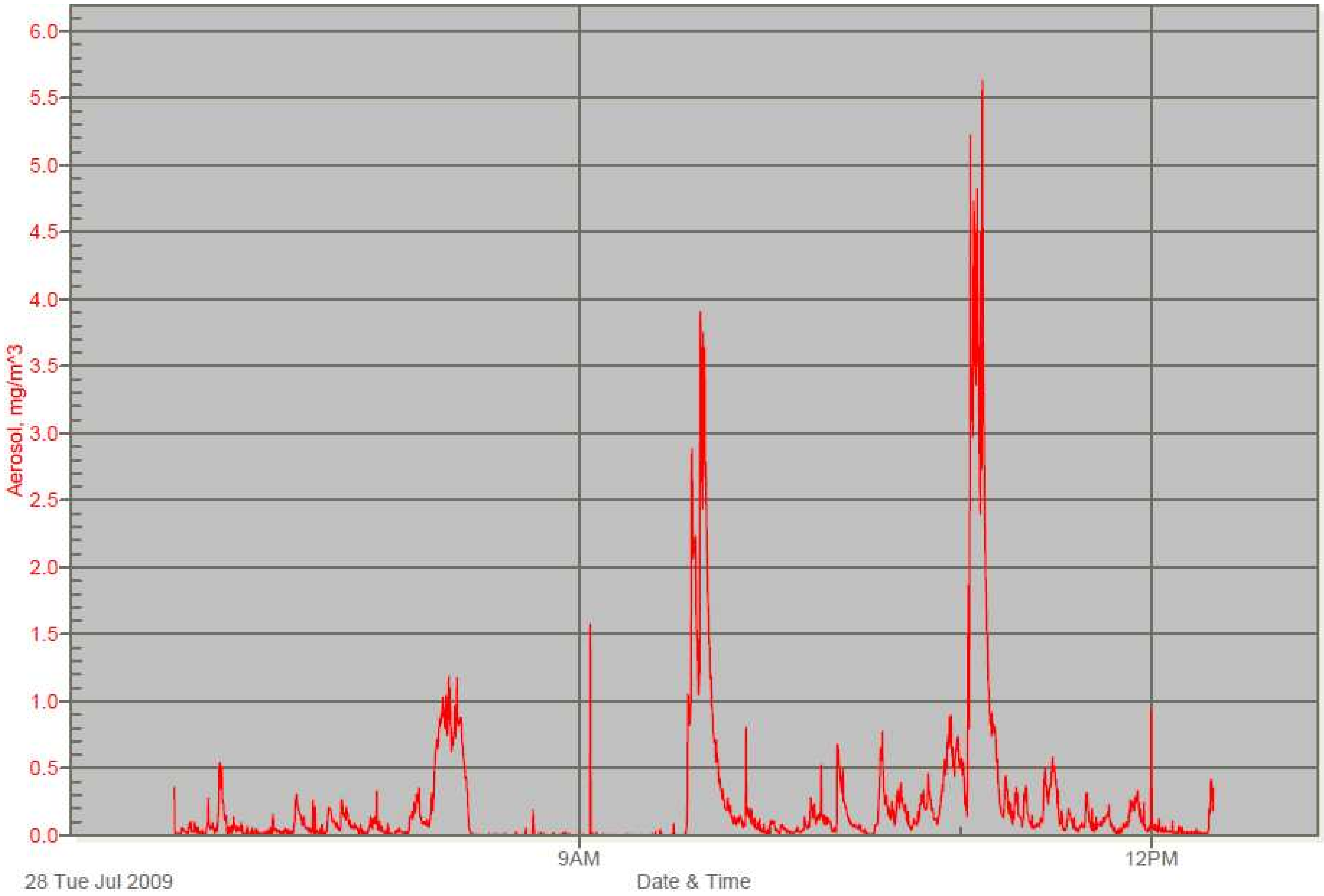
2. Within 3 months of the date of issue of this Directive establish by measurement, for each of your excavators with saw attachments, what the respirable crystalline silica personal exposure level is for the operator during cutting operations. The measurement(s) must be taken under operating conditions typically expected at the mine. The measurement results along with a description of the conditions prevailing during the monitoring period must be recorded in the Mine Record and a copy sent to Kevin Hedges*, Senior Principal Occupational Hygienist.

3. Where the measurements, as directed in item 2 above, demonstrate that operator exposure within the cab exceeds the acceptable limit, within six months of measurement implement suitable engineering controls (eg. improved cabin sealing, air filtration, dust suppression at source) to reduce operator exposure to below the acceptable limit.

4. Where measurements, as directed in item 2 above, demonstrate that exposure in the cab is below the acceptable limit, implement an appropriate on-going monitoring program to ensure that the exposure remains below the acceptable limit. Results of the monitoring program, including a description of the conditions prevailing during the period of measurement, must be recorded in the Mine Record.

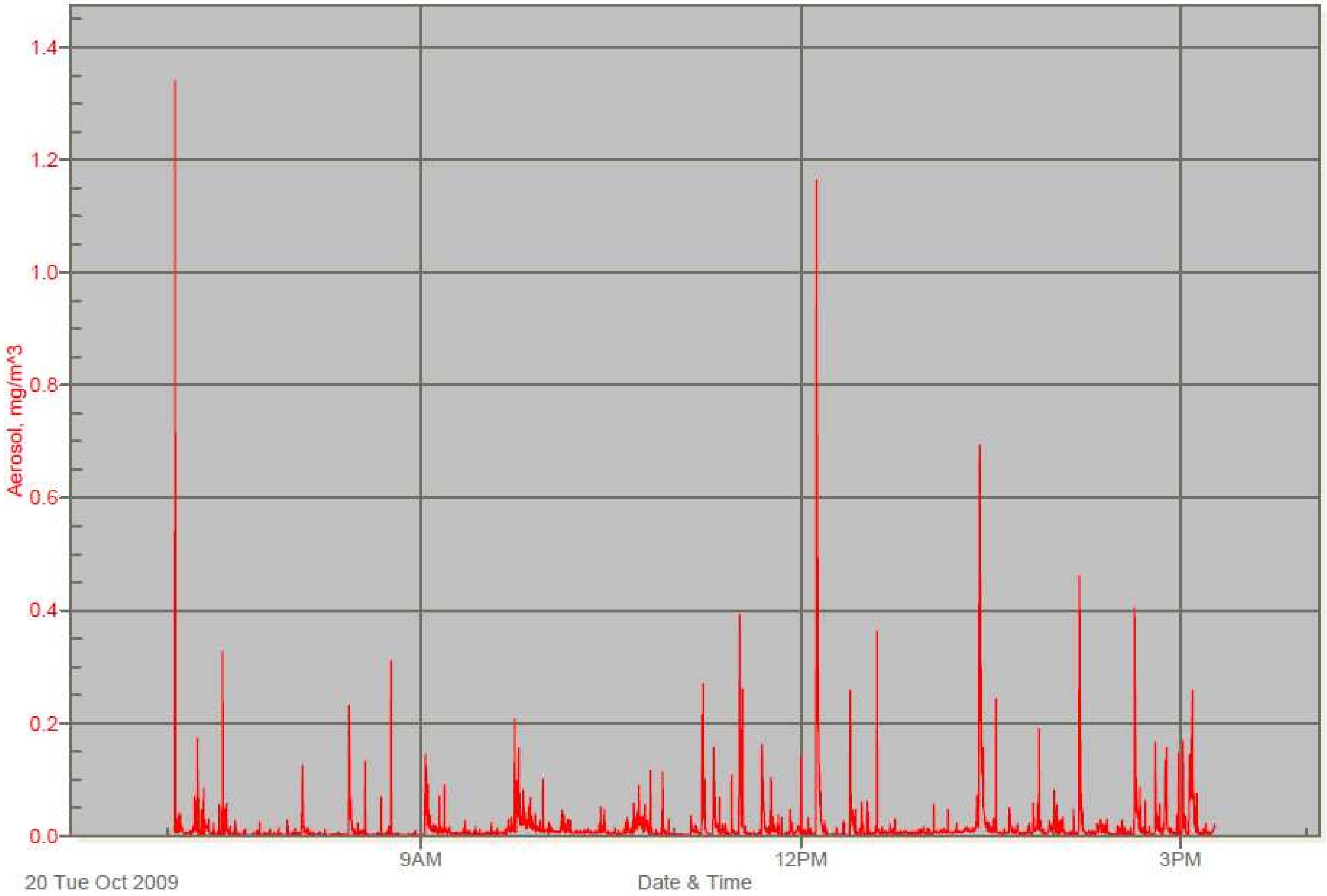
Appendix IV Graphs for real time air monitoring by AM510™ with cyclone attachment, measuring respirable dust, without RESPA™ (28 July 2009), with single RESPA™ (20 October 2009) and with second unit for recirculated air (22 October 2009) during trenching.

Trenching (no RESPA™)



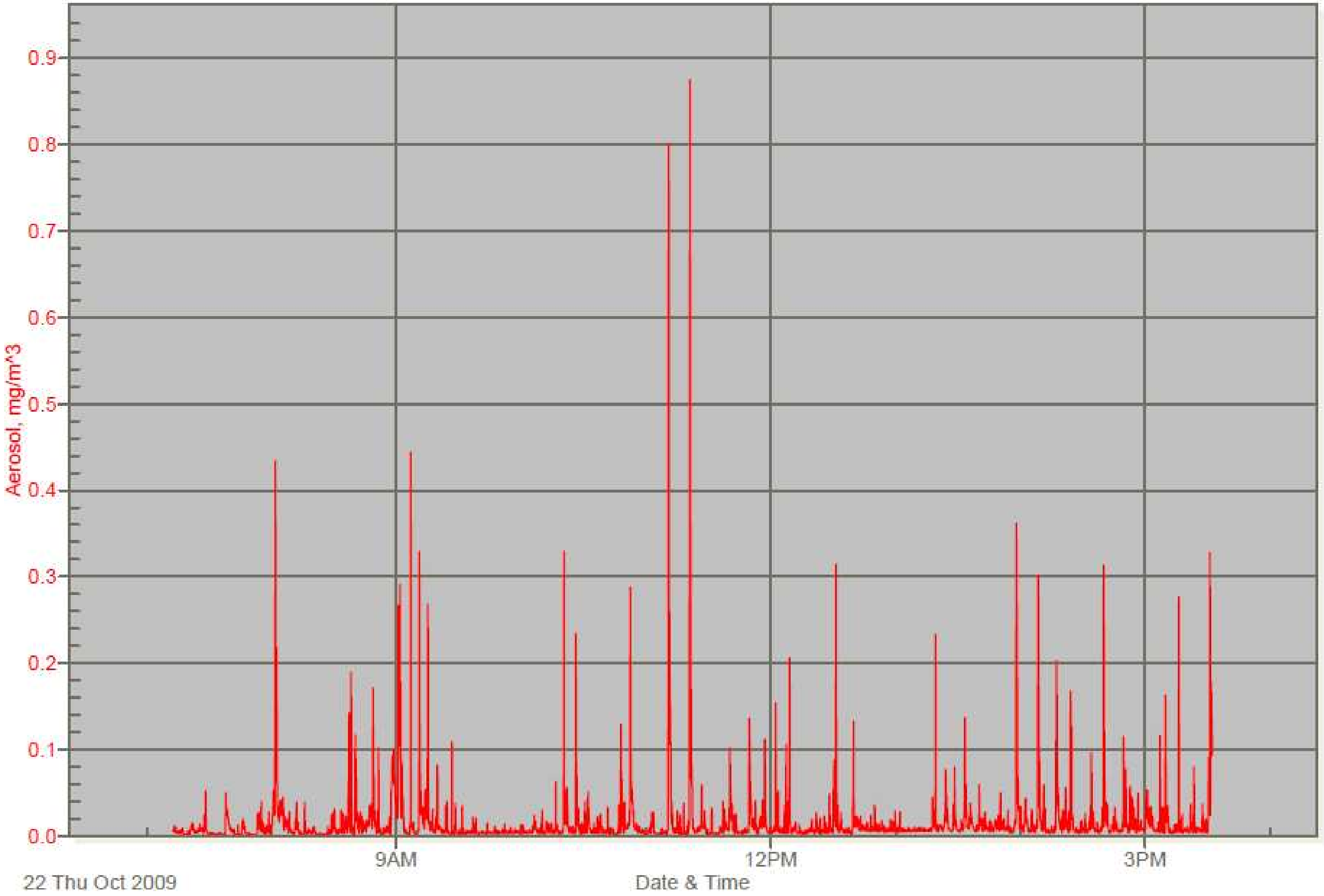
Appendix IV Graphs for real time air monitoring by AM510™ with cyclone attachment, measuring respirable dust, without RESPA™ (28 July 2009), with single RESPA™ (20 October 2009) and with second unit for recirculated air (22 October 2009) during trenching.

Trenching (single RESPA™)



Appendix IV Graphs for real time air monitoring by AM510™ with cyclone attachment, measuring respirable dust, without RESPA™ (28 July 2009), with single RESPA™ (20 October 2009) and with second unit for recirculated air (22 October 2009) during trenching.

Trenching (RESPA™ for external air and RESPA™ for recirculated air)



QGL02

Guideline for Management of Respirable Crystalline Silica in Queensland Mineral Mines and Quarries

Mining and Quarrying Safety and Health Act 1999

Date

Queensland Government

Acknowledgements

This guideline received input from and review by the Department of Natural Resources and Mines (DNRM) Mines Inspectorate occupational hygienists, and the Mine Safety and Health Advisory Committee (MSHAC). Organisations represented on the MSHAC include: the Australian Workers' Union (AWU); Australian Manufacturers' Workers Union (AMWU); Queensland quarrying industry, Queensland Resources Council (QRC), and DNRM - Mine Safety and Health.

This publication has been compiled by the Mines Inspectorate of Mine Safety and Health, Department of Natural Resources and Mines

This document is issued in accordance with PART 5—Guidelines and Section 63(1) of the Mining and Quarrying Safety and Health Act 1999.

PART 5—Guidelines

62 Purpose of guidelines

A guideline may be made for safety and health stating ways to achieve an acceptable level of risk to persons arising out of operations.

63 Guidelines

(1) The Minister may make guidelines.
(2) The Minister must notify the making of a guideline by gazette notice.
(3) The chief executive must keep a copy of each guideline and any document applied, adopted or incorporated by the guideline available for inspection, without charge, during normal business hours at each department office dealing with safety and health.
(4) The chief executive, on payment by a person of a reasonable fee decided by the chief executive, must give a copy of a guideline to the person.

64 Use of guidelines in proceedings

A guideline is admissible in evidence in a proceeding if—

(a) the proceeding relates to a contravention of a safety and health obligation imposed on a person under part 3; and
(b) it is claimed that the person contravened the obligation by failing to achieve an acceptable level of risk; and
(c) the guideline is about achieving an acceptable level of risk.

Control and management of risk

26 What is an acceptable level of risk

(1) For risk to a person from operations to be at an acceptable level, the operations must be carried out so that the level of risk from the operations is—
(a) within acceptable limits; and
(b) as low as reasonably achievable.
(2) To decide whether risk is within acceptable limits and as low as reasonably achievable regard must be had to—
(a) the likelihood of injury or illness to a person arising out of the risk; and
(b) the severity of the injury or illness.

34 How obligation can be discharged if regulation or guideline made

(3) if a guideline states a way or ways of achieving an acceptable level of risk, a person discharges the person's safety and health obligation in relation to the risk only by—

(a) adopting and following a stated way; or

(b) adopting and following another way that achieves a level of risk that is equal to or better than the acceptable level.

The words 'shall', 'must' or 'mandatory' place a legal obligation on the identified person or entity. The word 'should' indicates a recommended course of action, while 'may' indicates an optional course of action.

This guideline is issued under the authority of the Minister for State Development and Minister for Natural Resources and Mines

[Gazetted]

ISBN …………………

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1 Purpose

The purpose of this Guideline is to:

- provide guidance to Site Senior Executives (SSEs) and other persons on:
  - how to manage the monitoring of workers' exposure to respirable crystalline silica (RCS) and
  - to manage their health surveillance to achieve an acceptable level of risk from the hazard of exposure to RCS associated with mining silica bearing minerals and rock, and
- adopt the recommendations from the Monash Review that are applicable to mines and quarries as defined by the *Mining and Quarrying Safety and Health Act 1999 (MQSHA)*. Appendix 4 provides a summary of how each recommendation of the Monash report is addressed by this guideline.

2 Scope

This guideline applies to all mineral mines, quarries, opal mines and gemstone mines in Queensland.

The guideline has been developed to be scalable, and is applicable to all operations.

The guideline provides minimum criteria for operators to meet the statutory requirements for exposure monitoring and assessment, and for health surveillance pursuant to the *Mining and Quarrying Safety and Health Regulation 2001* (MQSHR), Part 14 Work environment, sections 134-140.

3 Introduction

Occurrence of crystalline silica is widespread

Silica or silicon dioxide occurs in two forms, either crystalline or amorphous.

The most common type of crystalline silica, quartz, is found in most igneous, metamorphic and sedimentary rock. The potential for worker exposure to crystalline silica is widespread within the minerals mining and quarrying industry.

While amorphous silica may cause lung disease, crystalline silica, due to its chemistry and shape, is particularly harmful when it is of respirable size and deposited into the lower parts of the lungs. Crystalline silica is classified as causing cancer to humans by the International Agency for Research on Cancer.

Exposure to airborne RCS may result in lung injury or disease

Crystalline silica is an aggressive, lung damaging dust when it is able to penetrate deep into the lung in sufficient quantities. In order for the crystalline dust particles to penetrate deep into the lung they must be very small (diameter less than 10 µm), a size fraction defined as respirable.

Respirable crystalline silica (RCS) has the potential to be generated during drilling, blasting, crushing, cutting and transporting, and is a hazard with the potential to cause a significant adverse effect on the health and safety of a person at a mine.

Workers exposed to elevated levels of RCS have an increased risk of developing simple pneumoconiosis, progressive massive fibrosis, silicosis, chronic obstructive pulmonary disease and lung cancer. In most cases

RCS can travel into the deep part of the lungs

Current OEL[1]

these diseases may not become apparent for many years after exposure has occurred.

The type of disease that occurs is influenced by the dust particle size, composition and concentration. Preventing exposure to RCS is an important part of the risk management process.

The occupational exposure limit (OEL) to RCS is an 8-hour Time Weighted Average of 0.1 mg/m³.

4 Process

4.1 Assess the RCS Risk

SSE must identify and evaluate RCS risk at their site

Almost all types of rocks, sands and gravel contain crystalline silica

The activities that create RCS will result in an unacceptable exposure if not controlled.

The Site Senior Executive (SSE) shall evaluate the RCS risk at their operations. The SSE should consider :

- materials containing crystalline silica on site or brought to site:
  - substances being processed or used for processing,
  - products, by-products or waste products of operations.
- activities that may generate RCS include (release of crystalline silica into the air):
  - drilling
  - blasting
  - excavating
  - grading
  - mucking or loading
  - tipping or transporting
  - crushing and conveying
  - cutting or grinding
  - drying or calcining
  - pelletising
  - bagging
  - plant maintenance and cleaning
- how, where, and for how long workers may be exposed to RCS
- the control measures for RCS at the site
- how the effectiveness of controls is monitored

The SSE shall implement controls to reduce the exposure to an acceptable level for any activity or task that may create an unacceptable RCS exposure.

Hierarchy of controls must be applied for the control of RCS[2]

The SSE shall ensure that controls to reduce RCS exposure are applied in the following order:

elimination of the hazard;
substitution with a lesser hazard;
separation of persons from the hazard;
engineering controls;
administrative controls;
personal protective equipment.

[1] *MQSHR Schedule 5 - General exposure limits for hazards*
[2] *MQSHR Section 8 Risk reduction*

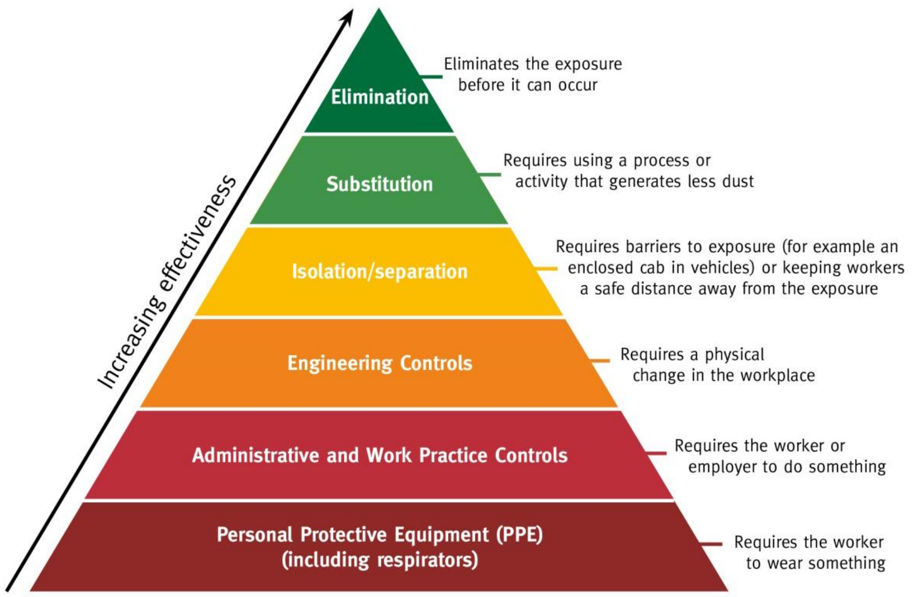

Figure 1 - Hierarchy of controls

PPE or RPE is a short term control measure for RCS exposure

The SSE shall ensure that use of personal protective equipment (PPE) is a short-term control until higher order controls are developed and implemented. The selection, use and maintenance of respiratory protective equipment must conform to AS/NZS 1715[3].

Further guidance for the risk analysis arising from workplace exposures is provided in the following references:

- *A strategy for assessing and managing occupational exposures (Ignacio & Bullock, 2006).*
- *Simplified occupational hygiene risk management strategies (Firth, van Zanten & Tiernan, 2006).*

Informing workers of RCS hazards

The SSE must ensure that workers are made aware of potential RCS hazards at a mine

- as part of the induction and refresher training,
- when RCS is a known hazard for a particular task or activity
- whenever significant changes are made at the mine that affect the RCS risk

The information should provide workers with an understanding of RCS, any controls relevant to their work and provide them with the ability to recognise substandard conditions or practices that can contribute to hazardous RCS exposure.

The following information about RCS hazards should be provided to workers:

- the distribution of crystalline silica at the mine
- activities that create RCS risk to workers and noting that a lack of visible dust is not a reliable indicator of RCS risk
- how RCS may affect workers – silicosis or lung cancer, noting that no symptoms may be present in the early stages of lung disease
- controls that have been implemented at the mine

[3] *AS/NZS 1715 Selection, use and maintenance of respiratory protection*

- selection, use, storage and maintenance of respiratory protection including respirator fit testing

4.2 Measuring the RCS Risk

4.2.1 Monitoring Worker Exposure

Develop an exposure monitoring program[4]

The SSE, in consultation with the occupational hygienist, shall develop an exposure monitoring program for activities that have been identified as having an RCS exposure risk.

In the development of the exposure monitoring program, consideration should also be given to monitoring other airborne contaminants at the mine that may have an additive effect on RCS exposure.

Consider the use of similar exposure groups (SEGs)

Rather than assess each worker's risk individually, it is possible to group workers of similar exposure to RCS. These groups are referred to as similar exposure groups (SEGs). SEGs should be based on logical associations, examples of SEG structure includes:

- work or functional groups,
- physical location,
- activity
- equipment used

The effective selection and use of SEGs may reduce the number of exposure monitoring samples that need to be collected for the assessment of RCS risk at a mine.

RCS samples must be collected in accordance with AS2985

Sampling to measure worker exposure to RCS must be undertaken by an occupational hygienist or occupational hygiene technician in accordance with *AS 2985 - Workplace atmospheres - Method for sampling and gravimetric determination of respirable dust.*

The sampling duration should span the full shift. If this is not possible, the sampling duration shall be as long as possible but not less than half the shift duration (that is, not less than 4 hours for an 8 hour shift or 6 hours for a 12 hour shift).

Equipment must be calibrated

The SSE shall ensure that the sampling equipment used for exposure monitoring has been tested and calibrated in accordance with AS 2985.

Workers shall take reasonable care not to interfere with the operation of the monitoring equipment or samplers.

sample integrity[5]

If a worker thinks that the sample may have been compromised, then they should tell the occupational hygienist or occupational hygiene technician.

The SSE shall ensure that information is collected and recorded during the RCS exposure monitoring, including:

- worker activities during the exposure monitoring,
- environmental conditions,
- production rates,

[4] *MQSHR Section 136 - Monitoring workers' exposure*
[5] *MQSHR Section 137 - Tampering with samples*

- operating conditions.

Samples analysed by an accredited laboratory.

The SSE shall ensure that the collected samples are analysed by a laboratory with third party technical accreditation (for example NATA) for the RCS analysis method used.

4.2.2 Minimum Sampling Requirements

Worker exposure monitoring measures RCS and does not consider the effect of PPE

The purpose of worker exposure monitoring is to provide a time weighted average of the concentration of RCS that has entered the worker's breathing zone in the course of their activities during the day, including rest-breaks.

The workers to be monitored should be randomly selected on the day of monitoring.

A single exposure monitoring result, on its own, can only be used to assess the worker exposure for the day of monitoring.

Reliable estimate of exposure requires sufficient number of samples

Taking too small a number of samples may lead to over or underestimation of the exposure risk. For the SSE to be able to demonstrate that the RCS monitoring is applicable to a longer period of time, additional samples and statistical analysis are necessary. Table 1 identifies the minimum number of samples required to enable reliable analysis of a workgroup or SEG's exposure to be undertaken.

Table 1 - Minimum sample numbers for statistical analysis of a workgroup or SEG.

No. of workers in group	Samples to be Taken
≤6	6
7	7
8-9	8
10	9
11-12	10
13 -14	11
15 -17	12
18 -20	13
21 -24	14
25 -29	15
30 -37	16
38 -49	17
50	18
50+	22

4.2.3 Exposure Limit for Workers

The OELs are levels to protect nearly all workers.

The occupational exposure limit (OEL) for a substance is based on the airborne concentrations of individual substances which, according to current knowledge, should not cause adverse health effects nor cause undue discomfort to nearly all workers.

The 0.1 mg/m³ OEL for RCS is a time-weighted average based on a standard work cycle. A standard work cycle is:

- a shift of not longer than 8 hours a day;
- not more than 5 shifts a week;
- at least 16 hours between consecutive shifts

The OEL must be adjusted for non-standard work cycles[6]

The SSE shall ensure that the OEL is adjusted for non-standard work cycles.

[6] *MQSHR Section 134 (1) Adjusting exposure limits for hazards for workers*

Examples of the adjustment for the OEL applied to typical shift patterns are provided in Appendix 7.

Further information on adjustment to exposure limits is provided in the Australian Institute of Occupational Hygienists (AIOH) guidance document *Adjustment of Workplace Exposure Standards (WES) for Extended Work Shifts.*

4.2.4 Communication of Exposure Monitoring Results

Review results and compare to OEL

The SSE shall ensure that an occupational hygienist reviews analysis results as soon as practicable after receipt.

The occupational hygienist shall compare the exposure monitoring results to the OEL or the adjusted OEL for the worker.

Report to SSE

Within 28 days of any exposure monitoring, the Occupational Hygienist shall provide the SSE a written report on the exposure monitoring. The report shall include:

- worker(s) monitored,
- monitoring date(s)
- duration of monitoring
- each worker's duties, roles or tasks at the time of monitoring,
- workgroup or SEG affiliation
- comment for each sample as to whether it is representative of the worker exposure
- exposure monitoring results compared to the applicable OEL
  - including whether any result is an exceedance
  - whether the worker wore respiratory protective equipment (RPE), and the type if worn.
- for each exceedance, a summary of observed or reported activity by the worker on the day of monitoring.
- any invalid samples
- practicable recommendations for actions or controls to reduce exposure to below the applicable OEL and as low as reasonably achievable.

Recommendations to reduce worker exposure[7]

Information to monitored workers

The SSE shall ensure that every worker who was sampled or monitored is provided with their exposure monitoring result as soon as practicable.

4.2.5 Exceedance of a Single Sample

Single exposure exceedance must be investigated and reported

The SSE shall ensure that an investigation is undertaken where exposure monitoring shows that there is an exceedance to the applicable OEL.

The investigation must identify the cause of the exceedance and the controls or action that will be taken to prevent or eliminate further exceedance.

The SSE shall ensure that the investigation report and corrective actions are communicated to workers and recorded in the mine record[8].

Within 28 days of becoming aware of the exceedance, the SSE shall notify the Mines Inspectorate of the exceedance. The notification shall include:

- date of the exceedance
- name of the worker
- exposure monitoring result – RCS level

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[7] *MQSHR Section 135 Limiting workers' exposure*
[8] *MQSHA Section 59 Mine record*

- location
- cause of the exceedance
- controls implemented to taken to prevent recurrence
- action by the mine to confirm the effectiveness of controls

4.2.6 Statistical Analysis of Exposure Monitoring Data

Mine must conduct statistical analysis.

The SSE shall ensure that an occupational hygienist conducts statistical analysis on the mine's exposure data every two years.

The number of samples (n) required for the statistical analysis are dependent on a number of factors including

- number of workers in the SEG (refer Table 1 - Minimum sample numbers for statistical analysis of a workgroup).
- RCS exposure profile (refer Appendix 6 - Descriptive Statistics of Exposure Data)
- variation in workers' exposure monitoring results (refer Table 6)
- variations in processing or production

The occupational hygienist shall review the validity of exposure monitoring results older than 2 years for inclusion in the statistical analysis.

Land's UCL must be below the OEL for compliance

The Minimum Variance Unbiased Estimate (MVUE) is an estimate of the mean exposure for the group or SEG. The accuracy of the estimate may be improved with increased number of samples. However, the potential range of values for the true mean exposure may evaluated. The Land's calculation of the confidence limits determines the upper and lower bounds of possible mean exposure for the dataset.

In determining whether the exposure for a SEG's data is compliant, the Lands upper confidence limit (UCL) must be below the OEL. This provides 95% confidence that the true mean exposure for the SEG will not be above the OEL.

Worker, workgroup or SEG exposure shall be considered unacceptable (non-compliant) if the Land's Upper Confidence Limit ($UCL_{95\%}$) is greater than the applicable OEL.

Develop plan to reduce exposure[9]

The occupational hygienist shall provide a written report on the statistical analysis to the SSE. The report shall include:

- compliance status for each workgroup or SEG
- recommendations for the reduction of RCS exposure
- future exposure monitoring plan.

The SSE shall ensure that the report is reviewed and control measures developed and implemented to reduce exposure.

Notify workers of results

The SSE shall ensure that the report and a summary of the control measures implemented are recorded in the mine record and communicated to all workers in the workgroup or SEG.

[9] *MQSHR Section 135 Limiting workers' exposure*

4.2.7 Periodic Monitoring for RCS

The effectiveness of control measures may be monitored by periodic sampling

The SSE shall ensure that exposure monitoring is be undertaken periodically to ensure that the mine's current controls continue to be effective. The occupational hygienist shall develop an exposure monitoring plan for each worker, workgroup or SEG based on their exposure profile.

The number and frequency of samples required for each workgroup or SEG shall be determined with reference to Table 2. For the purposes of calculation, the 'Exposure Ratio' is the ratio of the MVUE for the worker, workgroup or SEG data to the adjusted exposure limit for the workgroup or SEG:

$$\text{Exposure Ratio} = \frac{\text{group data MVUE}}{\text{Adjusted OEL}}$$

Frequency of monitoring is dependent on effectiveness of control measures

The occupational hygienist shall modify the exposure monitoring plan to include additional samples for workgroups or SEGs that have high variations in their RCS exposure, where the geometric standard deviation (GSD) of the group data is greater than 3.

Table 2 - Periodic exposure monitoring - minimum sampling and frequency

Exposure Ratio	Samples per 10 workers
>1	1 per quarter
0.5 to 1	1 per six months
0.1 to 0.5	1 per year
< 0.1	1 per 3 years

(adapted from Grantham & Firth, 2014)

4.2.8 Review and Audit RCS Hazard Management

The effectiveness of the SHMS and any specific hazard management plan for the control of RCS must be periodically reviewed

The Operator of the mine shall review and audit the effectiveness of the Mine's Safety & Health Management System (SHMS) including RCS management to ensure risk to persons is at an acceptable level, including:

- ensuring monitoring is undertaken at appropriate intervals
- sufficient samples are collected for statistical analysis
- sampling and analysis is undertaken by competent persons
- exceedances are identified, investigated and appropriate, effective, control measures are implemented
- health surveillance is appropriate to risks at the mine and completed to the required standard and at the required frequency

Guidance is provided in Guidance Note QGN09 – Reviewing the effectiveness of safety and health management systems.

4.3 Health Surveillance

Periodic health surveillance required for workers that may be exposed to RCS[10]

The SSE, in consultation with an appropriate doctor, should implement a health surveillance program where there is a risk to worker health due to RCS exposure.

[10] *MQSHR Section 138 Health surveillance*

A worker or all workers in a workgroup or SEG shall be subject to health surveillance if the mean exposure for the worker, workgroup or SEG is greater than 0.05 mg/m³ or 50% of the adjusted OEL.

Health surveillance to meet a minimum requirement

The SSE shall ensure that health surveillance is conducted:

- prior to a worker placed into a role where they may be exposed to RCS,
- at least every five years,
- and applied to any other person, including employees, contractors or labour hire that may be required to perform duties or tasks of a worker, workgroup, or SEG that is subject to health surveillance

An exit medical for the worker should also be considered.

Health surveillance must be conducted under the supervision of an appropriate doctor and shall conform with the requirements in Appendix 7, including:

- respiratory questionnaire
- lung function test – such as spirometry
- chest x-ray (reviewed against the ILO International Classification of Radiographs of Pneumoconioses)
- any other test deemed pertinent by the appropriate doctor.

The appropriate doctor shall provide the worker with a copy and an explanation of the health assessment report.

The SSE shall ensure that they have received a copy of the worker's health assessment report, which is no older than 5 years, prior to engaging the worker in duties or activities with a potential (or actual) exposure to RCS.

Where a worker, workgroup or SEG are no longer subject to RCS exposure, the SSE shall consult the appropriate doctor on additional specific or future periodic surveillance for any or all of the workers.

SSE to report on any case of silicosis[11]

The SSE must report the occurrence of silica related diseases including silicosis, progressive massive fibrosis, chronic obstructive pulmonary disease or lung cancer to the Mines Inspectorate as soon as practicable after the SSE has become aware of the diagnoses in a worker or former worker. The SSE shall report the name of the worker and other relevant details related to the worker, including:

- name
- date of birth
- work history at the mine

Managing workers with a silica related disease[12]

The SSE must ensure that a worker who has been diagnosed with a silica related disease is protected from further exposure to RCS. In consultation with the worker and the appropriate doctor, the SSE shall develop and resource a RCS management plan for the worker, which may require modifications to workplace, the use of powered air purifying respirators or the removal of the worker from certain roles or tasks.

[11] *MQSHA Section 195 Notice of accidents, incidents, deaths or diseases*
[12] *MQSHR Section 134 Adjusting exposure limits for hazards for workers*

The worker with a diagnosed silica related disease should consider alternative occupations that do not involve exposure to substances hazardous to the lungs.

4.4 Records Retention Requirements

Record retention[13]

The SSE shall ensure records of monitoring conducted for the mine in relation to a hazard with a cumulative or delayed effect, such as RCS, are kept for 30 years.

Which records must be kept

The records of monitoring include

- medical record of workers made prior to their employment and in the course of their assessment
- workers' health assessment reports and health surveillance reports
- employment record of the workers at the mine
- exposure monitoring records for workers
- any workgroups or SEGs identified at the mine

Maintain security of information[14]

The records may be retained either as hard copy or electronically in a form that is readily accessible, for example pdf.

A black and white or greyscale-version of a colour record is acceptable if colour is not an important aspect of a document.

The SSE must ensure that any archiving system used maintains confidentiality and security of the records.

Prior to the mine ceasing operation, the SSE shall ensure records of monitoring are securely archived and stored in accordance with directions from the chief inspector.

13 *MQSHR Section 138 (4) Health Surveillance*
14 *MQSHR Section 120 Confidentiality of worker's medical record*

5 Appendices

Appendix 1. Abbreviations

AHPRA	Australian Health Practitioner Regulation Agency
AIOH	Australian Institute of Occupational Hygienists
AQF	Australian Qualifications Framework
COPD	Chronic Obstructive Pulmonary Disease
GSD	Geometric Standard Deviation
DNRM	Department of Natural Resources and Mines
MSHAC	Mining Safety And Health Advisory Council
MQSHA	Mining and Quarrying Safety and Health Act 1999
MQSHR	Mining and Quarrying Safety and Health Regulation 2001
MVUE	Minimum Variance Unbiased Estimate
NOHSC	National Occupational Health and Safety Commission
OEM	original equipment manufacturer
PPE	Personal Protective Equipment
RCS	Respirable Crystalline Silica
RPE	Respiratory Protective Equipment
SEG	Similar Exposure Group
SHMS	Safety and Health Management System
SSE	Site Senior Executive
TWA	Time Weighted Average
UCL	Upper Confidence Limit

Units of measure

mg/m^3	milligrams per cubic metre of air
µm	Micron or micrometre $1 \text{ micrometre} = \frac{1}{1{,}000} \text{ millimetre}$

Appendix 2. Glossary of terms

Appropriate Doctor	A doctor registered with the Australian Health Practitioner Regulation Agency (AHPRA) as a specialist in occupational medicine or have an Australian Qualifications Framework (AQF) Level 8 or above in occupational medicine. The appropriate doctor must have demonstrated knowledge of the risks associated with activities performed by the mine's workers.
Breathing zone	A hemisphere of 300 mm radius extending in front of the face and measured from the mid-point of a line joining the ears.
Chronic obstructive pulmonary disease (COPD)	COPD is characterised by airflow limitation that is not fully reversible. The airflow limitation is usually progressive and associated with an abnormal inflammatory response of the lungs to noxious particles or gases. The primary cause of COPD is cigarette smoking or exposure to tobacco smoke. Other causes or aggravators include airborne dust particles, pollution, infectious diseases and genetic predisposition. The two main forms are chronic bronchitis and emphysema
Exceedance For Individual	When the measured time weighted average (TWA) of a worker's exposure to RCS is above the adjusted occupational exposure limit (OEL)
Exceedance for SEG	When the SEG Land's $UCL_{95\%}$ is above the adjusted exposure limit for RCS (determined after statistical analysis of the SEG exposure data)
Health Assessment	Medical assessment of the worker to evaluate the worker's ability to tolerate a hazard without harming the worker or the worker's offspring (MQSHR s131).
Health Surveillance	The monitoring or testing of a person to check for changes in the person's health because of exposure to a hazard (MQSHR s137).
Health Surveillance Report	Information, other than a medical record, about the effects on the worker's health related to the worker's exposure to a hazard at the mine and the need, if any, for remedial action.
Land's 95% Upper Confidence Limit (UCL)	Land's calculation of exposure assessment determines the upper and lower bounds of the Minimum Variance Unbiased Estimate (MVUE) to a 95% certainty. Hence in the interpretation of SEG data, there is a 95% certainty that the MVUE is below Land's UCL for that dataset. See Appendix 6.
Medical Record	Medical results or clinical findings obtained from a fitness or health assessment or health surveillance of the person
Mine Record	The collation of information that the operator must retain pursuant to section 59 of the MQSHA. Information that must be retained include reports of inspections and investigations, audits, directives issued and remedial action, reports about all serious accidents and high potential incidents and all other reports or information that may be prescribed under a regulation. Refer to QGN05 Guidance Note on Keeping and Using the Mine Record at Mining and Quarrying Operations in Queensland
Monitoring	A program or strategy that uses sampling to estimate workers' exposure or assessing the magnitude of dust levels
Minimum Variance Unbiased Estimate (MVUE)	An unbiased estimate of the true arithmetic mean (AM) of a log normal dataset. The MVUE is especially useful when a dataset is heavily influenced by high results.

Pneumoconiosis

Pneumoconiosis is a general term given to any lung disease caused by dusts that are breathed in and then deposited deep in the lungs causing damage. Pneumoconiosis can develop when respirable airborne dusts, particularly mineral dusts, are inhaled. The dust particles remain in the lung where they can cause inflammation or fibrosis (scarring). The effects of damage from inhaled mineral dusts may not show up for many years, so workers may not develop symptoms until long after they are no longer exposed to these dusts. The most common causes of pneumoconiosis are inhalation of asbestos, silica (sand or rock dust) or coal dust. Only some workers exposed to these dusts will develop pneumoconiosis.

Respirable Fraction

The proportion of airborne particulate matter that penetrates to the unciliated airways when inhaled. This fraction is further described in ISO 7708 as the percentage of inhalable matter collected by a device conforming to a sampling efficiency curve that passes through the points shown in Table 3.

Alternatively, it can be described by a cumulative log-normal distribution with a median equivalent aerodynamic diameter of 4.25 µm and a geometric standard deviation of 1.5 µm.

Table 3 - Respirability of dust by particle size

Equivalent aerodynamic diameter (µm)	Respirability (%)
0	100
1	100
2	97
3	80
4	56
5	34
6	20
7	11
8	6
10	2
12	0.5
14	0.2
16	0.1
18	0.0

Sampling

The process of collecting a measurement or series of measurements of worker exposure

Significant change

Any modification or change of process or equipment that has the potential to alter worker exposure to RCS. Examples of significant change include:

- changing the nature of operations, for example, from exploration to extraction and processing, transition to care and maintenance, rehabilitation or closure
- changing from an open cut to an underground mine or vice versa
- changing mining method, for example open stoping to block cave
- expansion of a pit operation from the original design
- upgrading or installing fixed plant (this may include new crushers, mills)
- replacing or introducing mobile plant
- reduction or downsizing of operational activities

Silicosis

A form of lung disease resulting from occupational exposure to silica dust over a period of years. Silicosis causes slowly progressive fibrosis (scarring) of the lungs and impairment of lung function. Workers with silicosis have a tendency to tuberculosis of the lungs and an increased risk of lung cancer.

Similar Exposure Group (SEG)

Group of workers who have the same general exposure to risk. (e.g. the same similarity and frequency of the tasks they perform; the materials and processes with which they work; or the similarity of the way they perform those tasks)

Specialist radiologist	Medical practitioner registered with Australian Health Practitioner Regulation Agency (AHPRA) as a Specialist radiologist

Appendix 3. Extract from Mining & Quarrying Safety & Health Regulation

Part 14 Subdivision 2 Limiting exposure to hazards

133 Exposure limits for workers

(1) This section applies if an assessment of a worker's health under section 131 shows the worker has an unacceptable level of risk from a hazard at a lower level of exposure than the general exposure limit for the hazard, including, for example, because a personal factor of the worker impairs the worker's ability to tolerate the hazard.

Example of personal factor—
fitness, diet, pregnancy, physical disability, allergy or phobia

(2) The site senior executive must ensure a personal exposure limit is set for the worker for the hazard to reduce the risk to an acceptable level.

134 Adjusting exposure limits for hazards for workers

(1) This section applies if a hazard is present in a mine's work environment and at least 1 of the following apply to a worker at the mine—
- (a) the worker's work cycle does not conform to the standard work cycle used in establishing the general exposure limit for the hazard;
- (b) the worker's work cycle decreases the rate at which the worker recovers from adverse effects of the hazard;
- (c) the effects of a hazard on the worker may increase if the worker does heavy strenuous work, or works under adverse climatic conditions.

(2) The site senior executive must ensure the exposure limit applying to the worker for the hazard is adjusted to account for the circumstances mentioned in subsection (1).

(3) If the national standard for the hazard or NOHSC's guidance note states a way of adjusting the general exposure limit for the hazard in the circumstances, the site senior executive must ensure the exposure limit applying to the worker for the hazard is adjusted in the stated way.

(4) If the work environment at a mine contains hazards that interact with each other to increase their adverse effects on a worker, the site senior executive must ensure the exposure limits that apply to the worker for the hazards are adjusted to account for the interaction.

(5) In this section—

NOHSC's guidance note means NOHSC's document entitled 'Guidance Note on the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment [NOHSC:3008]'.
standard work cycle, generally, means a work cycle consisting of the following—
- (a) a shift of not longer than 8 hours a day;
- (b) not more than 5 shifts a week;
- (c) at least 16 hours between consecutive shifts.

135 Limiting workers' exposure

(1) The site senior executive must ensure a worker's exposure to a hazard at the mine—
- (a) does not exceed the exposure limit applying to the worker for the hazard; and
- (b) is as low as reasonably achievable.

(2) This section does not apply to the worker's exposure to the hazard during an emergency evacuation.

136 Monitoring workers' exposure

(1) This section applies to a hazard at a mine—

a. that has the potential to exceed the exposure limit applying to a worker for the hazard; or
b. for which the level of risk may vary.

(3) The site senior executive must ensure the worker's exposure to the hazard is monitored, and the monitoring results are analysed, regularly.

(4) If a relevant Australian standard or national standard states a way of carrying out the monitoring or analysis, the site senior executive must ensure it is done in the stated way.

Examples of relevant Australian or national standard for subsection (3)—

(1) for inspirable dust—AS 3640 'Workplace atmospheres—Method for sampling and gravimetric determination of inhalable dust'
(2) for lead—NOHSC's document entitled 'National Standard for the Control of Inorganic Lead at Work [NOHSC:1012]'
(3) for respirable dust—AS 2985 'Workplace atmospheres—Method for sampling and gravimetric determination of respirable dust'

137 Tampering with monitoring samples and results

A person must not tamper, or allow another person to tamper, with a sample or the results of a sample taken to monitor a worker's exposure to a hazard at a mine.

138 Health surveillance

(1) The site senior executive must arrange for health surveillance of a worker at the mine if the site senior executive reasonably believes, or ought to reasonably believe—

a. exposure to a hazard at the mine may cause, or result in, an adverse health effect; and
b. the health effect may happen under the worker's work conditions; and
c. either—
   i. a valid technique capable of detecting signs of the health effect exists; or
   ii. a valid biological monitoring procedure is available to detect changes from the current accepted values for the hazard.

Examples of changes from current accepted values—

1 a higher than normal blood level of lead caused by exposure to substances containing lead
2 a raised urinary mercury level caused by exposure to mercury vapour

(2) The site senior executive must—

d. arrange for the health surveillance to be done by, or under, the instruction of an appropriate doctor; and
e. ask the appropriate doctor to give—
   i. the site senior executive a health surveillance report; and
   ii. the worker a copy and explanation of the health surveillance report.

(3) The worker's employer must pay for the worker's health surveillance and the health surveillance reports.
Maximum penalty for subsection (3)—30 penalty units.

(4) The site senior executive must ensure the health surveillance report is kept for the following period—

f. (a) for a hazard with a cumulative or delayed effect—30 years;

Example for paragraph (a)—
silica, noise or vibration

g. (b) for another hazard—7 years.

(5) If the mine ceases operations in the period the health surveillance report is required to be kept under subsection (4), the site senior executive must ask for, and comply with, the chief executive's directions about the report's storage.

(6) Subsection (3) is not a safety and health obligation for the Act.

(2) In this section—

health surveillance report means information, other than a medical record, about—
(a) the effects on the worker's health related to the worker's exposure to a hazard at the mine; and
(b) the need, if any, for remedial action.

139 Removing affected worker from work environment

(1) Subsection (2) applies if a worker has effects from a hazard, other than lead, at a mine exceeding the exposure limit applying to the worker for the hazard.
(2) The site senior executive must ensure the worker is removed from, and does not resume, work involving exposure to a level of the hazard that would increase the effects or prevent the effects decreasing.
(3) The site senior executive must ensure a worker—
   a. is removed from a lead-risk job if the worker has a blood lead level at or above the worker's removal level; and
   b. does not resume a lead-risk job until the worker's blood lead level is less than the level stated for the worker in the inorganic lead standard, section 15(27).
(4) In this section—

inorganic lead standard means NOHSC's document entitled 'National Standard for the Control of Inorganic Lead at Work [NOHSC:1012]'.
lead-risk job, for a worker, means work in which the blood lead level of the worker might reasonably be expected to rise, or does rise, above 1.45□mo/L (30□g/dL) or the worker's removal level, whichever is the lower.
removal level, for a worker, means the removal level stated for the worker in the inorganic lead standard, section 15(24).

140 Using personal protective equipment

(1) This section applies if a person's exposure to a hazard at a mine can not be prevented or reduced other than by using personal protective equipment.
(2) The site senior executive must ensure—
   a. the person is given suitable and effective personal protective equipment; and
   b. the person is competent in using the equipment; and
   c. the person's work load and work cycles are reduced to allow for the increased physical load of the equipment.
(3) A person who is given personal protective equipment under subsection (2) must use the equipment when the person's level of risk from the hazard is unacceptable.

Appendix 4. Monash Report Recommendations

As at December 2015, six confirmed cases of coal workers' pneumoconiosis (CWP) in Queensland coal mine workers were confirmed with a number of additional cases suspected. Prior to this, the Queensland Coal Mine Workers' Health Scheme had not identified any new cases for many years.

DNRM commissioned a review of the design and operation of the respiratory component of the Scheme. This multidisciplinary review team included expertise in occupational medicine, respiratory medicine, occupational hygiene, epidemiology, radiology and respiratory science from Monash University and the University of Illinois.

The aims of the review were to:

- determine whether the respiratory component of the health assessment performed under the Queensland Coal Mine Workers' Health Scheme is adequately designed and implemented, to most effectively detect the early stages of coal mine dust lung disease among Queensland coal mine workers, estimating the extent and providing feedback and, if not,
- recommend necessary changes to correct deficiencies identified under Aim A, recommend measures to follow up cases that may have been missed as a result of these deficiencies, and identify what additional capacity is needed in Queensland to improve this scheme

The recommendations made in the report were considered in the development of this guideline. In the table below, a summary of how each recommendation of the Monash report is addressed by this guideline.

The final report *The Review of Respiratory Component of the Coal Mine Workers' Health Scheme for the Queensland Department of Natural Resources and Mines* is available at https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0009/383940/monash-qcwp-final-report-2016.pdf

Table 4 - Application of the Monash Report

Recommendation Summary	Comment on Applicability
1. The main purpose of the respiratory component of the scheme should explicitly focus on the early detection of Coal Mineworker Dust Lung Disease (CMDLD) among current and former coal mine workers.	This guideline provides guidance on the respiratory component with an explicit focus on detection of lung diseases including respiratory questionnaire, spirometry and chest x-ray
2. Clinical guidelines for follow-up investigation and referral to an appropriately trained respiratory or other relevant specialist of suspected CMDLD cases identified among current and former coal miner workers should be developed and incorporated into the scheme.	This guideline references the SafeWork Australia paper on RCS which includes clinical guidelines
3. DNRM should require the reporting of detected cases of CWP and other CMDLDs in current and former coal miners identified by the scheme.	Silicosis is now recognised in MQSHR Schedule 1A - Diseases for section 195(6) of the Act
4. There should be a separate respiratory section of the health assessment form which includes all respiratory components, including the radiology report using the ILO format and the spirogram tracings and results.	This guideline includes respiratory questionnaire and examination –with reference to ILO readers

Recommendation Summary	Comment on Applicability
5. The form should include a comprehensive respiratory medical history and respiratory symptom questionnaire.	Include as per recommendation 1
6. The criteria to determine workers "at risk from dust exposure" should be based on past and current employment in underground coal mines and designated work categories in open-cut coal mines and CHPPs.	This guideline specifies 'at risk' workers as being a worker, workgroup or SEG at a mine that has a mean RCS exposure level in excess of 0.05 mg/m³ or more than 50% of the adjusted OEL
7. There should be a much smaller pool of approved doctors undertaking the respiratory component of health assessments under the scheme, taking into account geographical considerations and other workforce needs.	This guideline specifies competencies for appropriate doctor as being an occupational physician or respiratory specialist.
8. Doctors should undergo a formal training program, including visits to mine sites, prior to being approved by the DNRM, to ensure they reach a suitable standard of competence and have the necessary experience to undertake respiratory health assessments under the scheme.	This guideline specifies health surveillance is supervised by a doctor registered AHRPA as a specialist in occupational medicine or have an AQF Level 8 or above in occupational medicine.
9. The approval of doctors to undertake the respiratory health assessments for the early detection of CMDLD under the scheme should become the sole responsibility of the DNRM.	Not applicable, no equivalent process available in MQSHA or MQSHR
10. Doctors approved to undertake respiratory health assessments should have a different designation from 'NMA', which should reflect their specific responsibility for respiratory health assessments under the new scheme.	As per recommendation 8
11. Chest x-rays should be performed by appropriately trained staff to a suitable standard of quality and performed and interpreted according to the current ILO classification by radiologists and other medical specialists classifying CXRs for the scheme.	This guideline specifies that the chest x-ray for a worker be assessed against the ILO classification
12. Spirometry should be conducted by appropriately trained staff and performed and interpreted according to current ATS/ERS standards.	Standardised respiratory function tests (spirometry) shall be conducted by a person who has successfully completed the Queensland Health Spirometry Training Program or equivalent. (Appendix 5)

Recommendation Summary	Comment on Applicability
13. DNRM should transition to an electronic system of data entry and storage, whereby doctors undertaking these respiratory assessments enter the data for their assessment and can access previously collected data for the mine worker and to facilitate auditing.	Data entry and storage is not DNRM responsibility in mineral mines and quarries. This guideline requires that the mine's medical provider retain the workers medical records, that the SSE retains a copy of each worker's health assessment report
14. All coal mine workers, including contractors, subcontractors and labour hire employees, who meet the revised criteria for being "at risk from dust exposure" should be registered in the DNRM database on entry into the industry for the purposes of ongoing medical surveillance.	Not applicable to mineral mines and quarries.
15. DNRM should conduct ongoing individual and group surveillance of health data collected under the scheme, to detect early CMDLD and analyse trends to disseminate to employers, unions and coal mine workers.	This guideline and the MQSHR require periodic health surveillance and notification of the incidence of silicosis and other occupational lung diseases.
16. Coal mine workers should have exit respiratory health assessments regardless of whether they leave the industry due to ill-health, retirement or other reasons.	This guideline has guidance for the inclusion of exit medicals
17. An implementation group, including representatives of stakeholders and relevant medical bodies, should be established to ensure that the necessary changes to correct the identified deficiencies with the respiratory component of the current scheme are implemented in a timely manner.	No current scheme applicable to mineral mines and quarries – advice from the DNRM occupational physician and review of this guideline by MSHAC Development of a Structured Inspection Guide and inclusion of silica as a risk in the Mines Inspectorate Inspection Schedule database
18. There should be a further review of the revised respiratory component of the scheme within 3 years to ensure that it is designed and performing according to best practice.	As per recommendation 17

Appendix 5. Competencies for Exposure Monitoring Activities

Occupational Hygienist

An occupational hygienist must, as a minimum, be recognised as a Full Member of the Australian Institute of Occupational Hygienists (MAIOH) or hold an equivalent competency under an international certification scheme (for example Certified Industrial Hygienist), or have an Australian Qualifications Framework (AQF) Level 8 or above in occupational hygiene with a minimum of 5 years' experience.

The occupational hygienist is deemed competent to carry out the following work at a mine or quarry

- develop or review a mine's workgroups or SEGs
- estimate worker, workgroup or SEG exposure using qualitative analysis
- develop a sampling plan for RCS, representative of worker exposure as well as environmental and operating conditions
- conduct exposure monitoring at a mine
- determine exposure of workgroups or SEGs using descriptive statistics;
- review and update the RCS monitoring plan

Occupational Hygiene Technician

An occupational hygiene technician must have completed competency-based training that includes:

- sampling to AS2985- '*Workplace atmospheres—Method for sampling and gravimetric determination of respirable dust*
- selection, use and maintenance of monitors, detectors and calibrators used in field work

An occupational hygiene technician must also have completed one of either:

- An occupational hygiene qualification at AQF Level 5 or higher (Diploma or higher);
- Basic Principles of Occupational Hygiene course or equivalent approved by Occupational Hygiene Training Association (OHTA)

An occupational hygiene technician is deemed competent to conduct monitoring for RCS, and associated activities, in accordance with a developed RCS monitoring plan and conduct other duties under the supervision of an Occupational Hygienist.

Appendix 6. Descriptive Statistics of Exposure Data

Statistical analysis provides descriptive statistics that are generated to summarise the data set and estimate exposure.

Table 5 - Exposure monitoring descriptive statistics

Statistical Measure	Description
Number of samples (n)	At least 6 samples are required to perform statistical analysis of a data set; Number of samples required for statistical assessment of the SEG should be based on the estimate of exposure and the number of workers in the workgroup or SEG; Table 1 - Minimum sample numbers for statistical analysis of a workgroup or SEG.be used as guidance on sampling numbers required statistical analysis.
Minimum (min) / Maximum (max)	Describes the range of exposure values in a given data set for a SEG.
Minimum Variance Unbiased Estimate (MVUE)	The estimated average exposure of the SEG for a lognormal population. This datum may also be referred to as the Estimated Arithmetic Mean (est AM)
Geometric Standard Deviation (GSD)	A measure of the spread of data in a dataset. It is expected that most exposures in a SEG are generally the same. Where there is significant variation in a dataset, this will be reflected by the value of the GSD. High GSD values may indicate a need to undertake additional sampling or to review the accuracy of the SEGs definition.

Table 6 - Interpreting the GSD

GSD Value	Degree of data spread
1.0 – 2.0	Data clustered around the mean – minimal variation
2.0 – 3.0	Moderate variation in the data set – potentially due to: elevated individual exposure results samples below the limit of reporting insufficient number of samples
>3.0	Significant variation in data set – potentially due to: Significant outliers in data set Incorrectly defined SEG Insufficient number of samples

Lands Upper and Lower Confidence Limits 95% Upper Confidence Limit (UCL)	Land's calculation determines the error boundary of the MVUE to a 95% certainty. In the interpretation of the RCS risk to a SEG, it is certain (to 95% confidence) that the MVUE will not be greater than the upper confidence limit (UCL). If SEG's Lands UCL is below the OEL, the SEG is deemed complaint.

(adapted from Ignacio & Bullock, 2006)

Appendix 7. Adjustment to the OEL for Non-standard Work Cycles

As specified in Section 4.2.3 - Exposure Limit for Workers, the SSE must ensure that the occupational exposure limit (OEL) for the hazard is adjusted for non-standard work cycles.

Supporting information for the adjustment of the OEL is provided in the AIOH document *'Adjustment of Workplace Exposure Standards for Extended Work Shifts'* with further reference to the spreadsheet utilising the Quebec Model for exposure adjustment.

In Table 7 (below), the Quebec model was used to calculate the adjustment to the OEL for RCS. The application of the adjustment factor to other parameters may only be made after reference to the supporting information for the adjustment model.

Table 7 - Adjustment factor to RCS OEL for typical non-standard work cycles in mining

Roster work cycle	shifts worked in roster	number of days break in roster	hours per day	number of days in work cycle	number of hours worked per cycle	average number of hours per week	adjustment factor	adjusted OEL (mg/m³)
7 on/7 off - 12.5 hour days	7	7	12.5	14	87.5	43.75	0.91	0.091
4 on/3 off - 12 hour days	4	3	12	7	48	48	0.83	0.083
10 hour days, 5 day workweek	5	2	10	7	50	50	0.8	0.080
14 on/7 off	14	7	12	21	168	56	0.71	0.071
8 on/6 off - 12.5 hour days	8	6	12.5	14	100	50	0.8	0.080
short work week	4	3	7.2	7	28.8	32.4	1	0.10

Appendix 8. Health Surveillance for Crystalline Silica

Health surveillance monitoring includes a standardised respiratory questionnaire, spirometry, physical examination of the respiratory system and if required chest x-ray.

Health surveillance assessment shall be conducted under the supervision of doctor registered with the Australian Health Practitioner Regulation Agency (AHPRA) as a specialist in occupational medicine or who has have an AQF Level 8 or above in occupational medicine.

Supervision is defined as availability for consultation of the appropriate doctor at the time of the health monitoring assessment directly, either in person or by electronic communication. Supervision shall also include the oversight, interpretation and reporting of the health surveillance assessment.

A Medical Practitioner or a Registered Nurse shall administer the standardised respiratory questionnaire.

A Medical Practitioner shall perform physical examination including an examination of the respiratory system.

Standardised respiratory function tests (spirometry) shall be conducted by a person who has successfully completed the Queensland Health Spirometry Training Program or equivalent.

The Medical Practitioner shall ensure that calibration and maintenance of equipment conforms to Queensland Health guidelines for spirometry testing.

Chest X-ray, full size PA view

- A chest X-ray must be taken at least every 5 years for all workers.
- Chest x-rays shall be conducted by a Radiographer.
- Chest x-rays shall be reported by a Specialist Radiologist and shall be reported according to current International Labour Organisation classification.

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MRE SIG Rating Criteria	
1	Little or no documentation of SIG items within the SHMS **or** implementation of those items
2	Some evidence of documentation of SIG items within the SHMS, however implementation is on an inconsistent or ad hoc basis.
3	Documentation of SIG items within SHMS, reasonable but inconsistent implementation.
4	Documentation of SIG items within SHMS, fully implemented and consistently applied across the operation.
5	Documentation of SIG items within SHMS, total integration into normal operations, regularly reviewing and demonstrating continuous improvement.

Respirable Crystalline Silica (RCS) STRUCTURED INSPECTION GUIDE

Scope: To ensure that a suitable system is in place for the management of risk associated with respirable crystalline silica (RCS), including exposure monitoring, exposure reduction and medical assessments.

Inspector:__________________ **Date of Inspection:______________________** **Mine Site:_________________________**

	Legislation MQSHA/R	ITEM	COMMENTS / OBSERVATIONS / EVIDENCE	RATING
1		**Assess the RCS Risk**		
1.1	MQSHR 7, 8 GL 4.1	Has the SSE undertaken a formal documented risk assessment of RCS at the mine *(formally documented within SHMS or as separate process)*		
1.2		What sources of crystalline silica are present at the site? What activities at the site can generate RCS? ○ drilling ○ blasting ○ excavating ○ mucking or loading ○ tipping or transporting ○ crushing and conveying		

		○ cutting or grinding ○ drying or calcining ○ pelletising ○ bagging ○ plant maintenance and cleaning		
1.3		Have high order control measures been identified and implemented for every potential source of excessive RCS exposure?		
1.4		Does the site use respiratory protective equipment as interim control? If yes[1].: 1. How does the SSE ensure that RPE is selected used and worn correctly? 2. if RPE is mandatory for any role, task or area, does the mine have • a clean shaven policy • RPE fit testing • Range of RPE for workers • Prescribed minimum standard of RPE		
1.5		How are changes at the mine assessed to determine their impact on the RCS risk? Change management process – consultation with occupational hygienist incorporated		
1.6		How does the mine verify the continued effectiveness of control measures? Are control measures subject to preventative maintenance or inspection?		
2		**Training and awareness of RCS risks and control measures**		
2.1	MQSHR 91, 93 GL – 4.1	Are workers made aware or RCS risk at the mine? • Visitor, full induction and refresher training, • when RCS is a known hazard for a particular task or activity • Whenever significant changes are made at the mine that affect the RCS risk		
2.2		Does the mine's training program cover:		

[1] *AS/NZS 1715 Selection, use and maintenance of respiratory protection*

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		• the distribution of crystalline silica at the mine • activities that create RCS risk • how RCS may affect workers – silicosis or lung cancer • control measures that have been implemented at the mine • what they need to do to maintain the control measure's effectiveness RPE use, maintenance and RPE fit testing		
3		**Monitoring Worker Exposure**		
3.1	MQSHR 136 GL - 4.2.1	Has the mine developed an exposure monitoring program? Does the program also quantify other airborne hazards that target the lungs? • Coal dust • Diesel Particulate Matter (DPM) • Oxides of nitrogen (NO and NO_2) • Sulphur dioxide (SO_2)		
3.2		What qualification does the person conducting the monitoring hold? (occupational hygienist or occupational hygiene technician) If occupational hygiene technician conducts the monitoring, how does the occupational hygienist supervise?		
3.3		Protocol for exposure monitoring • Sampling SWI used by OH or OHT(refers to *AS 2985)* • sufficient duration • NATA certification for exposure monitoring analysis • Calibration of pumps and flow rate testing		
3.4		Are workers randomly selected or blanket selection		
3.5		How are conditions on the day of monitoring collected • worker activities during the exposure monitoring, • environmental conditions, • production rates, • operating conditions.		

3.6		how does the mine ensure that the worker has a personal history or RCS exposure risk (linkage to SEG) • If the site has workgroups or SEGs. is there a register of names of all persons in each workgroup or SEG? how are workers assigned to each workgroup or SEG when the attend work How does the mine track the worker history and their corresponding changes in SEG?		
4		**Minimum Sampling Requirements**		
4.1	GL 4.2.2	Does the exposure monitoring program provide sufficient numbers for statistical analysis of all workers, workgroups or SEGs with 2 years? No. of workers in group / Samples to be Taken: ≤6 – 6 7 – 8 8 – 8 9 – 8 10 – 9 11-12 – 10 13 -14 – 11 15 -17 – 12 18 -20 – 13 21 -24 – 14 25 -29 – 15 30 -37 – 16 38 -49 – 17 50 – 18 50+ – 22		
5		**Exposure Limit for Workers**		
5.1	134 (1) GL - 4.2.3	How is the OEL adjusted for non-standard work cycles?		
6		**Communication of Exposure Monitoring Results**		

6.1	GL - 4.2.	Is the reporting on the exposure monitoring timely? Does it contain sufficient detail to inform the SSE on the monitoring undertaken?		
6.2		How does the mine review the recommendations and operationalise them? • How are these actions recorded and tracked? • How does the mine ensure that the actions are effective? • How does the mine ensure that the control measure are maintained?		
6.3		Are workers notified of their own exposure monitoring results and of the other results for their workgroup or SEG? *verify by discussion with workers*		
6.4		*If additional airborne contaminant that have they been sampled and reported to the mine?*		
7		**Exceedance of a Single Sample**		
7.1	135 GL 4.2.5	Are all results above the OEL investigated and reported? *Review records for previous two years or further if older data is used for statistical analysis)*		
7.2		Is the investigation formally documented and include control measures (and implementation) to prevent recurrence? *Verify the implementation of control measures from recent OEL exceedances* – are the control measures still effective?		
7.3		Was the Mines Inspectorate notified with 28 days of the SSE receiving the report? *(review all reports with two years)*		
8		**Statistical Analysis of Exposure Monitoring Data**		
	135, 136 GL 4.2.6	Has statistical analysis been conducted for the mine's exposure monitoring results? • Sufficient number of samples? • Age of the oldest sample <2 years? • If GSD >2.5, • what review was undertaken to verify the cause of the variation?		

		• Were additional samples collected or are programmed to be collected If additional airborne contaminants have been identified, have they been subject to statistical analysis as well What objective evidence of review by the mine and implementation of control measures developed from recommendations?		
9		**Periodic Monitoring for RCS**		
	GL 4.2.7 MQSHR	Does the mine have a planned periodic monitoring with reference to the statistical analysis? (see table below)		
9.1		Are additional samples includes for groups with GSD > 3?		
10		**Review and Audit RCS Hazard Management**		
	GL 4.2.8	Has the operator conducted an audit to the site SHMS? Was RCS management considered in the review?		
11		**Health Surveillance**		
11.1	138 GL - **4.3**	Does the mine have a nominated appropriate doctor?		
11.2		Does the doctor meet the requirements for RCS surveillance • Registered with AHRPA as a specialist in occupational medicine or attained an AQF Level 8 or above in occupational medicine. • have demonstrated knowledge of the risks associated with activities performed by the mine's workers.		

Exposure Ratio	Samples per 10 workers
>1	1 per quarter
0.5 to 1	1 per six months
0.1 to 0.5	1 per year
< 0.1	1 per 3 years

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12		Records Retention Requirements		
12.1	138 (4) ,120 GL 4.4	• What records are held for the mine? Are they on site or in an archive facility • for electronic data, how does the site ensure forward compatibility of the data • what does the mine on transition to a new computer system or data base?	•	•

MRE SIG Rating Criteria	
1	Little or no documentation of SIG items within the SHMS **or** implementation of those items
2	Some evidence of documentation of SIG items within the SHMS, however implementation is on an inconsistent or ad hoc basis.
3	Documentation of SIG items within SHMS, reasonable but inconsistent implementation.
4	Documentation of SIG items within SHMS, fully implemented and consistently applied across the operation.
5	Documentation of SIG items within SHMS, total integration into normal operations, regularly reviewing and demonstrating continuous improvement.

References

Mining and Quarrying Safety and Health Act 1999
Mining and Quarrying Safety and Health Regulation 2001
QGL02 Management of Respirable Crystalline Silica in Queensland Mineral Mines and Quarries
QGN09 – Reviewing the effectiveness of safety and health management systems
AS/NZS 1715:2009 - Selection, use and maintenance of respiratory protective equipment', Standards Australia, New South Wales
AS 2985 - Workplace atmospheres - Method for sampling and gravimetric determination of respirable dust.
Adjustment of Workplace Exposure Standards for Extended Work Shifts, AIOH, Victoria.