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

Kevin Hedges[1], Dr Sue Reed[2] and Fritz Djukic[3]

1. Senior Principal Occupational Hygienist (North Region)
2. Senior Lecturer University of Western Sydney
3. Senior Principal Occupational Hygienist (Central Region)
   (Department of Mines and Energy – Safety and Health)

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.

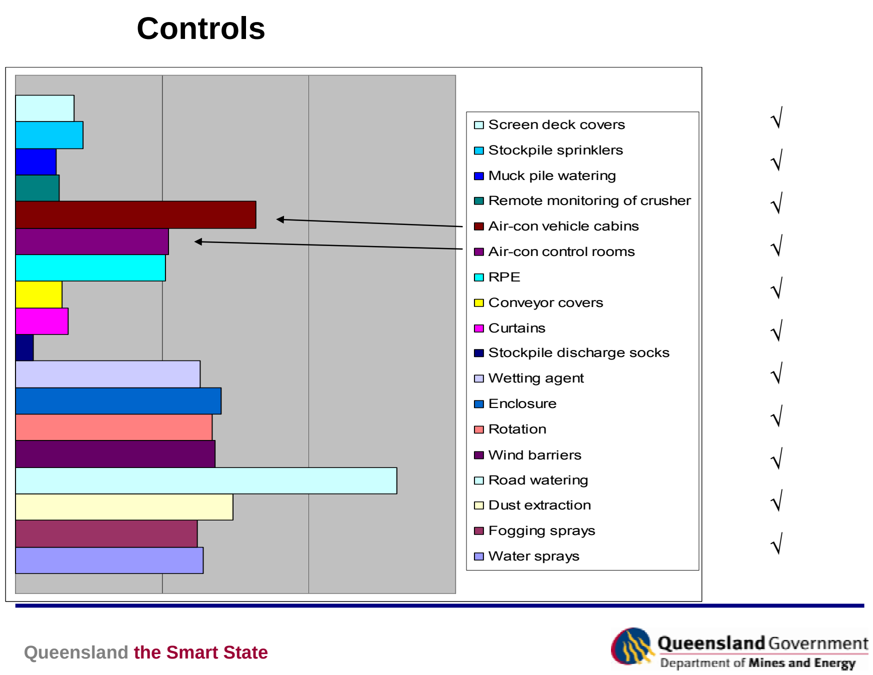
Evaluation of sampling methods to understand particle size distribution and the relationship of crystalline silica in the host rock and respirable crystalline silica is required. Real time analysis of $PM_{2.5}$ and $PM_{1.0}$ will identify processes and activities that produce airborne dust within these 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.

References

American College of Occupational and Environmental Medicine (ACOEM) 2006, Medical Surveillance of Workers exposed to crystalline silica. Retrieved 20 April, 2007from http://www.acoem.org/guidelines.aspx?id=746

Australian Safety and Compensation Council (ASCC) n.d, Adopted National Exposure Standards for Atmospheric Contaminants in the Occupational Environment. Retrieved 30 October 2007 from http://www.ascc.gov.au/NR/rdonlyres/317D25BA-E837-4F5B-AC65-24FE588888CA/0/ExposureStandards4AtmosphericContaminants_Nov06version.pdf

Australian Safety and Compensation Council (ASCC) n.d., Hazardous Substances Information System. Retrieved 20 April, 2007 from http://hsis.ascc.gov.au/Default.aspx

Banks, DE, Balaan, M & Wang ML 1997, 'American College of Chest Physicians Silicosis in the 1990s, revisited'. Chest, Vol 111, p 837-838.

Buchanan, D, Miller, BG & Souter, CA 2003, Quantitative relations between exposure to respirable quartz and risk of silicosis. Institute of Occupational Medicine, Edinburgh, Scotland, UK.

de-Klerk, NH, Musk, AW, Ambosi, SC & Pang SC 2002, 'Silicosis Compensation in Western Australian Gold Miners Since the Introduction of the Occupational Exposure Standard for Crystalline Silica'. Annals of Occupational Hygiene, Vol 46, No 8, p 687-92.

Drisccoll, T 2006, Review of Australian and New Zealand workplace exposure surveillance systems. Office of the Australian Safety and Compensation Council and the National Occupational Safety and Health Advisory Committee.

Ghotkar, VB, Maldure, BR & Zodpey, SP 1995, 'Involvement of lung function tests in stone quarry workers'. Proceedings of the 49th National Conference of Tuberculosis and Chest Diseases, Pondicherry.

Gupta, KB, Manav, M & Parveen, K 2005, 'Bilteral Spontaneous Pnemothorax in silicosis'. Chest Disease Allied Scientist, Vol 48, p 201 – 203.

Health and Safety Executive (UK) 2002, Control of Substances Hazardous to Health (COSHH) essentials in quarries. Retrieved 20 April, 2007 from Retrieved 20 April, 2007 from http://www.hse.gov.uk/pubns/guidance/qyseries.htm

Health and Safety Executive (UK) 2002, Respirable crystalline silica - phase 1: variability in fibrogenic potency and exposure-response relationships for silicosis. Hazard assessment document: Guidance note, environmental hygiene/EH75/4. Health and Safety Executive, UK

Health and Safety Executive (UK) 2005, Occupational Respiratory Diseases (other than Asthma) work-related chronic obstructive pulmonary disease (COPD) evidence-base intervention and evaluation plans (DRAFT). Retrieved 20 April, 2007 from ttp://www.hse.gov.uk/aboutus/hsc/iacs/acts/watch/051005/15annexe3.pdf.

HSE 2006, Control of Substances Hazardous to Health – COSHH. Retrieved 20 April, 2007 from http://www.hse.gov.uk/coshh/

IARC 1987, Monographs on the evaluation of carcinogenic risks to humans. Vol 42, Silica and some silicates. IARC, Lyon, France.

IARC 1997, Monographs on the evaluation of carcinogenic risks to humans. Vol 68, Silica, some silicates, coal dust and para-aramid fibrils.

Jennings, M 2004, Final Report – Review of the Health Effects associated with Exposure to Respirable Crystalline Silica in Coal Dust, Coal Services Pty Ltd.

Kim, TS, Kim, HA, Heo, Y, Park, Y, Park, CY & Roh YM 2002, 'Level of silica in the respirable dust inhaled by dental technicians with demonstration of respirable symptoms'. Industry Health, Vol 40, No 3, p 260 – 265.

L'Abbate, N, Di Pierri, C, Nuzzaco, A, Caputo, F, Carino, M 2005, 'Radiological and functional progression in silicosis' (Abstract only). La Medicina del lavoro, Vol 96, No 3, p 212-21. Retrieved April 30, 2007, from Pubmed database.

Meijer, E, Kromhout, H & Heederik, D 2001, 'Respiratory effects of exposure to low levels of concrete dust containing crystalline silica'. American Journal of Medicine, Vol 40, No 2, p 133-140.

Miller, MR, Hankinson, J, Brusasco, V, Burgos, F, Casaburi, R, Coates, A, Crapo, R, Enright, P, van der Grinten, CPM, Gustafsson, P, Jensen, R, Johnson, DC, MacIntyre, N, McKay, R, Navajas, D, Pedersen, OF, Pellegrino, R, Viegi, G & Wanger, J 2005, 'Standardisation of spirometry'. European Respiratory Journal, Vol 26, p 319–338

National Institute for Occupational Health and Safety (NIOSH) 2002, NIOSH Hazard Review: Health Effects of Occupational Exposure to Respirable Crystalline Silica, Department of Health and Human Services, Centre for Disease Control and Prevention.

National Institute for Occupational Safety and Health (NIOSH) 2002, NIOSH Hazard Review, Health Effects of Occupational Exposure to Respirable Crystalline Silica. Retrieved 20 April, 2007 from http://www.cdc.gov/niosh/02-129A.html

Ng, TP & Chan, SL 1992, 'Lung function in relation to silica exposure in granite workers'. European Respiratory Journal, Vol 5, No 8, p 986-991.

NH&MRC 1984, Methods for Measurement of Quartz in Respirable Airborne Dust by Infrared Spectroscopy. National Health & Medical Research Council, Canberra

NOHSC 1995, Guidance Note on the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment NOHSC 3008(1995) 3rd Ed. Australian Government Publishing Service Canberra, Retrieved 30 April, 2007 from http://www.ascc.gov.au/ascc/aboutus/publications/nationalstandards/guidancenoteontheinterpretationofexposurestandardsforatmosphericcontaminantsintheoccupationalenviron.htm

Queensland Mining and Quarrying Safety and Health Regulation (2001)

Senate Community Affairs Reference Committee 2006, Workplace exposure to toxic dust. Retrieved 30 April, 2007 from http://www.aph.gov.au/Senate/committee/clac_ctte/toxic_dust/report/report.pdf

Standards Australia 2004, Workplace atmospheres – Method for sampling and gravimetric determination of respirable dust. AS2985:2004 Retrieved January 10, 2006 from Standards Australia Online database.

Steenland, K & Brown, D 1995, 'Silicosis among gold miners: exposure--response analyses and risk assessment'. American Journal of Public Health, Vol 85, No 10, p 1346-1347.

Steenland, K 1995, Silicosis among gold miners: exposure response analysis and risk assessment. National Institute for Occupational Safety and Health, Cincinnati, OH 45226, USA.

Steenland, K 2005, 'One agent many diseases: exposure response data and comparative risks of different outcomes following silica exposure'. American Journal of Industrial Medicine, Vol 48, p 16 – 23.

Ulvestad, B, Bakke B, Eduard W, Kongerud J, Lund MB & Selmer, ASA 2001; ‘Cumulative exposure to dust causes accelerated decline in lung function in tunnel workers’. Occupational and Environmental Medicine, Vol 58, No 10, p 663-669.

(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