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™ (external air supply) + RESPA SDX™ (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.

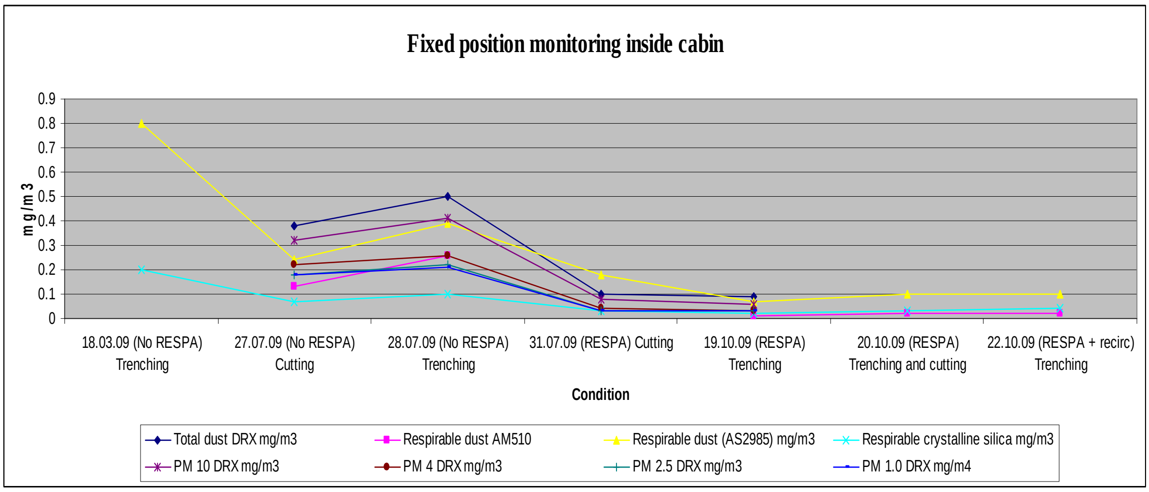
RESPA™ PFP units supplied in Australia by LSM Technologies Pty Ltd combines the technology of a Precleaner, Filtration and Pressurisation units that provides positive pressure HEPA filtered air to the existing air conditioning systems of fixed and mobile mining plant. Sampling for a range of particle 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.

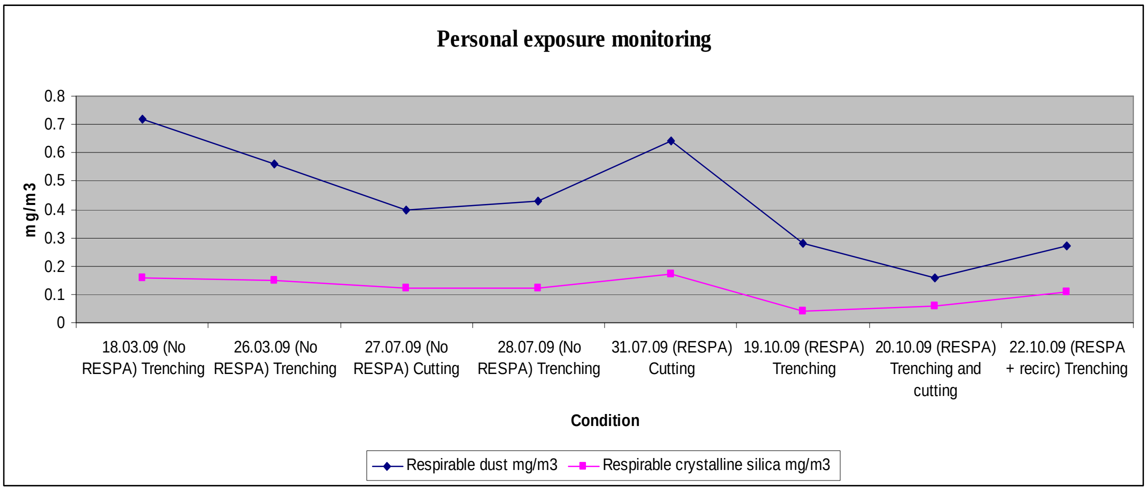
4.0 Results

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.

7.0 Bibliography

Australian Institute of Occupational Hygienists, 2009, *Respirable Crystalline Silica and Occupational Health Issues*, Available online at: http://www.aioh.org.au/downloads/documents/PositionPapers/AIOH%20RCS%20-%20Position%20Paper.pdf (accessed 15.08.09).

Cecala AB and Organiscak JA (2008). Minimizing Respirable Dust Exposure in Enclosed Cabs by Maintaining Cab Integrity. National Institute of Occupatianal Safety and Health (NIOSH). NIOSH Technology News 533. September 2008.

DME, 2009, *Questionnaire feedback – Respirable crystalline silica*: Report provided back to the metal mining and quarrying industry in response to a questionnaire sent in March 2008, Queensland Department of Mines and Energy.

Driscoll 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.

Glass WI, McLean D, Armstrong R, Pearce N, Thomas L, Munro G, Walrond J, McMillan A, O'Keefe R, Power P, Rayner C, Stevens M & Taylor R (2003); Occupational Health Report Series Number 9: 2003. *Respiratory Health and Silica Dust Levels in the Extractive Industry.*

Occupational Safety and Health Service, Department of Labour. Centre for Public Health Research, Massey University, Wellington. Department of Respiratory Medicine, Memorial Hospital, New Zealand.

Hedges K, Reed S & Djukic F, 2007, *Airborne crystalline silica (RCS) in Queensland quarrying processes, particle size and potency*. AIOH 25rd, Annual Conference Proceedings, Melbourne Vic., Australian Institute of Occupational Hygienists

Hedges K, Reed S, Mulley R, Tiernan, G & Djukic F, 2009, Preliminary findings in a study to evaluate exposure health effects and control of respirable crystalline silica (RCS) in Queensland quarries. AIOH 27th, Annual Conference Proceedings, Canberra ACT., Australian Institute of Occupational Hygienists.

HSE, 2002, *Guidance note, environmental hygiene 75/4*(GNEH75/4 Respirable crystalline silica – phase 1 hazard assessment. Health and Safety Executive, UK.

HSE, 2006, *Proposal for a Workplace Exposure Limit for Respirable Crystalline Silica* Available online at: http://www.hse.gov.uk/consult/condocs/cd203.pdf (accessed 15.08.09)

HSE 2009, *Silica baseline survey*, Annex 4 Quarry Industry prepared by the Health and Safety Laboratory for the Health and Safety Executive 2009.

Ghotar VB, Maldhure BR & Zodpey, SP, 1995; *Involvement of Lung Function Tests in Stone Quarry Workers*. Paper presented at the 49th National Conference on Tuberculosis and Chest Diseases, Pondicherry, 6 - 9 October 1994.

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, Eur Respir J; Vol 26, pp:319–338.

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

Simtars nd, *Adjustment of occupational exposure limits for unusual work schedules*. Occupational Hygiene, Environment & Chemistry Centre Safety in mines testing and research station, available online at: http://www.dme.qld.gov.au/zone_files/inspectorate_pdf/exp_standards_adj.pdf (accessed 2 October 2009).

Standards Australia 2004, *Workplace Atmospheres – Method for sampling and gravimetric determination of respirable dust*, SAI Glabal Sydney.

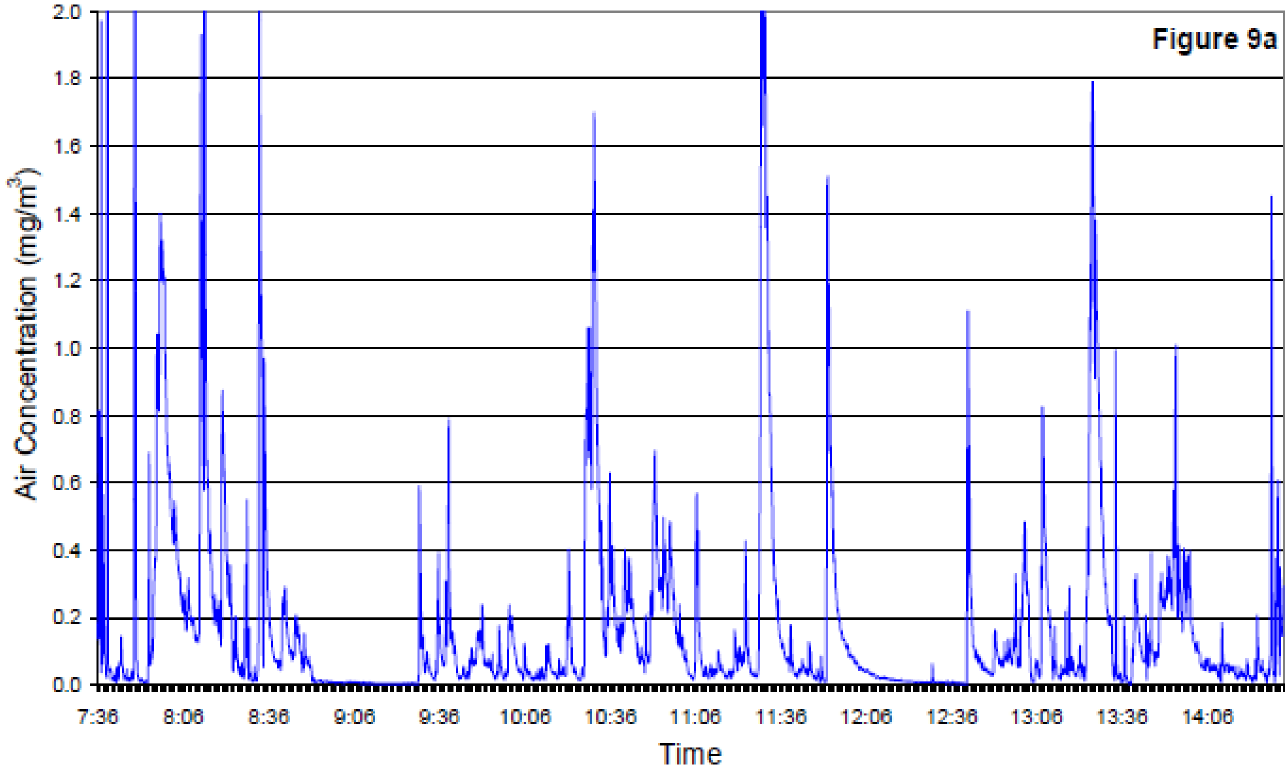
Ulvestad B, Bakke B, Eduard W, Kongerud J and Lund MB., 2001, *Cumulative exposure to dust causes accelerated decline in lung function in tunnel workers*, Occup Environ Med. Vol. 58, No. 10, pp:663-669.

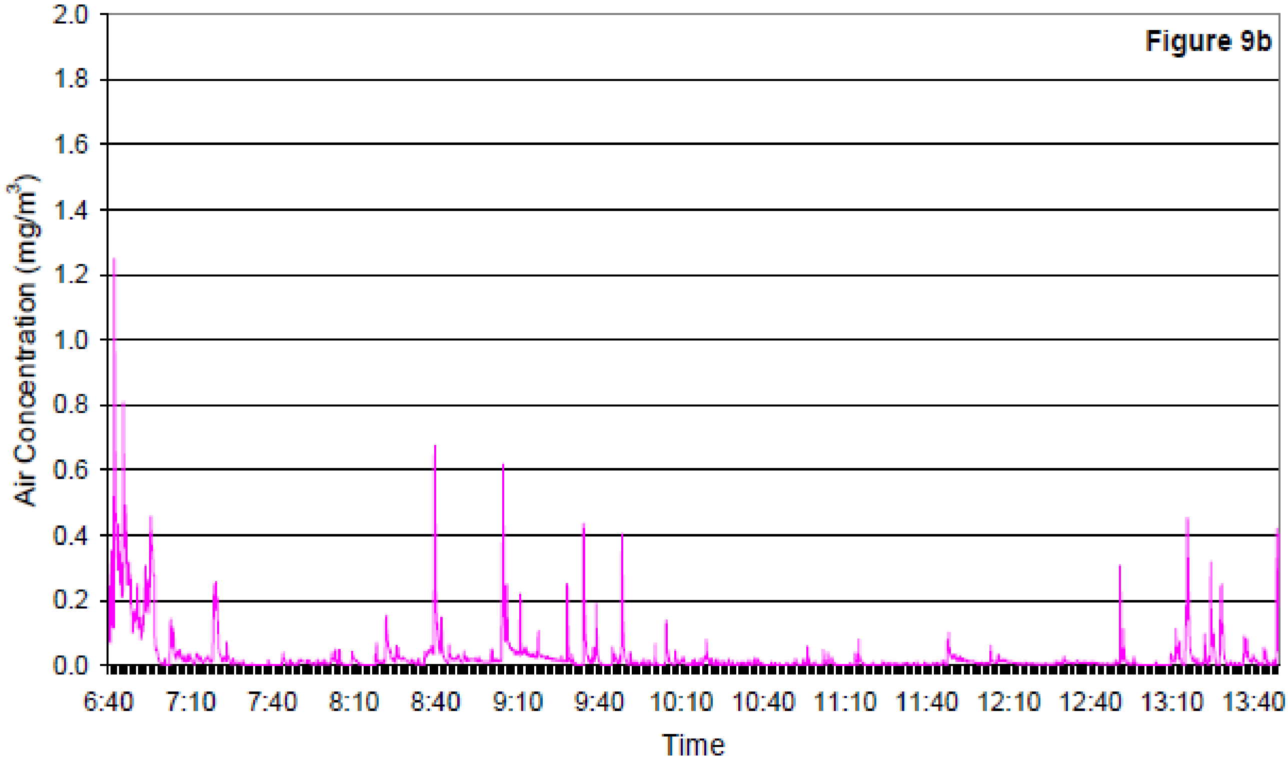
Appendix I monitoring results

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.

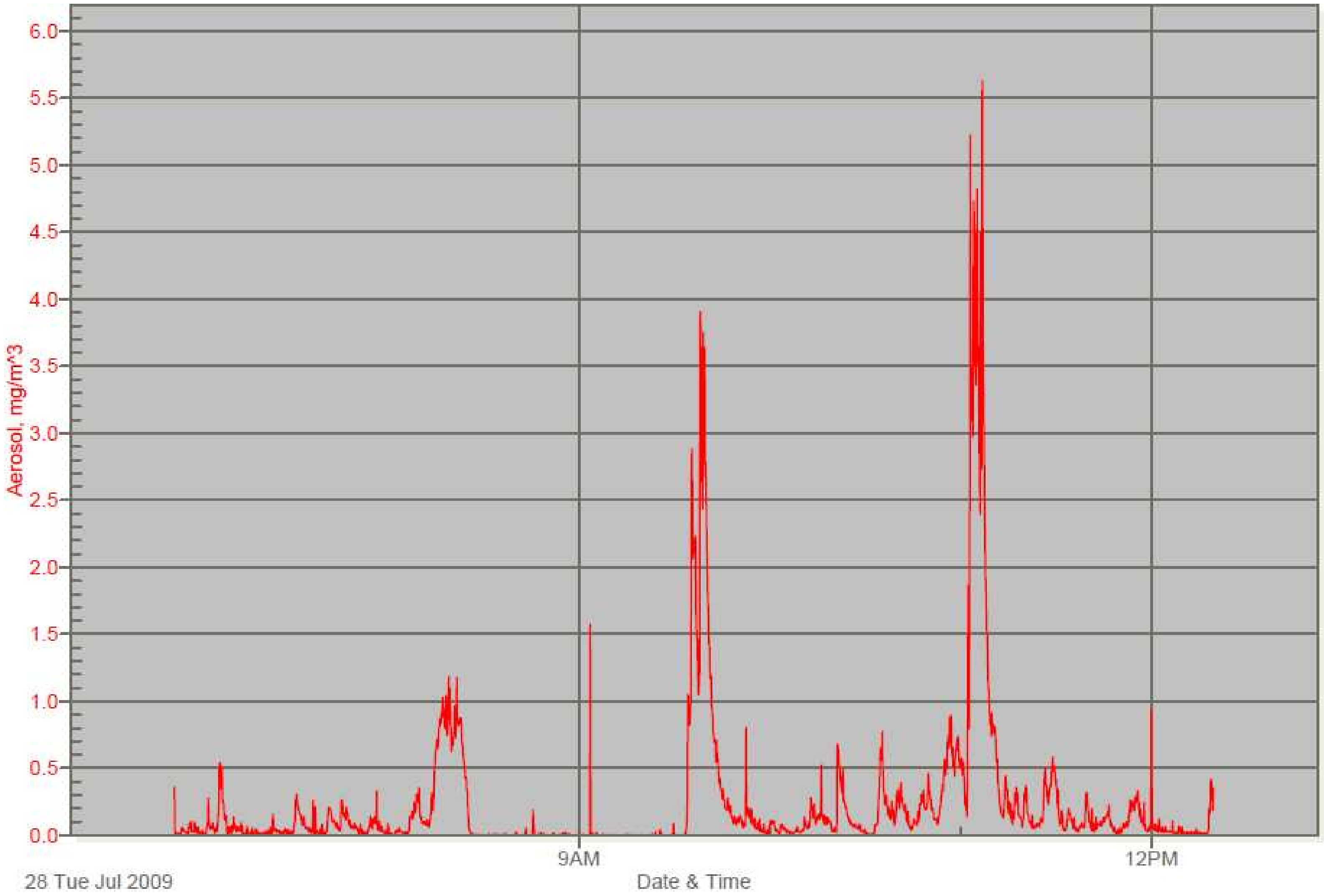
2. Within 3 months of the date of issue of this Directive establish by measurement, for each of your excavators with saw attachments, what the respirable crystalline silica personal exposure level is for the operator during cutting operations. The measurement(s) must be taken under operating conditions 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.

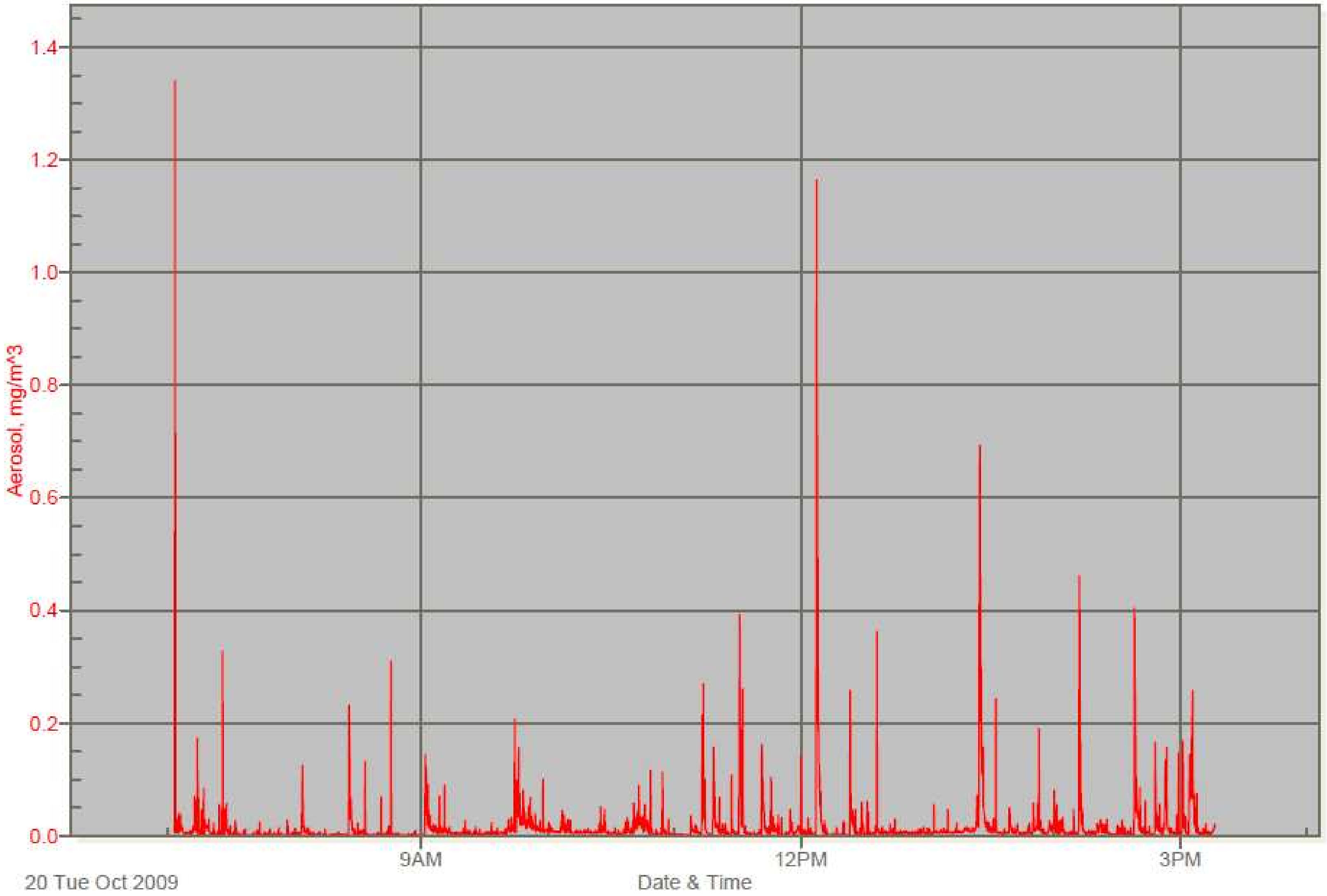
Appendix IV Graphs for real time air monitoring by AM510™ with cyclone attachment, measuring respirable dust, without RESPA™ (28 July 2009), with single RESPA™ (20 October 2009) and with second unit for recirculated air (22 October 2009) during trenching.

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™)



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