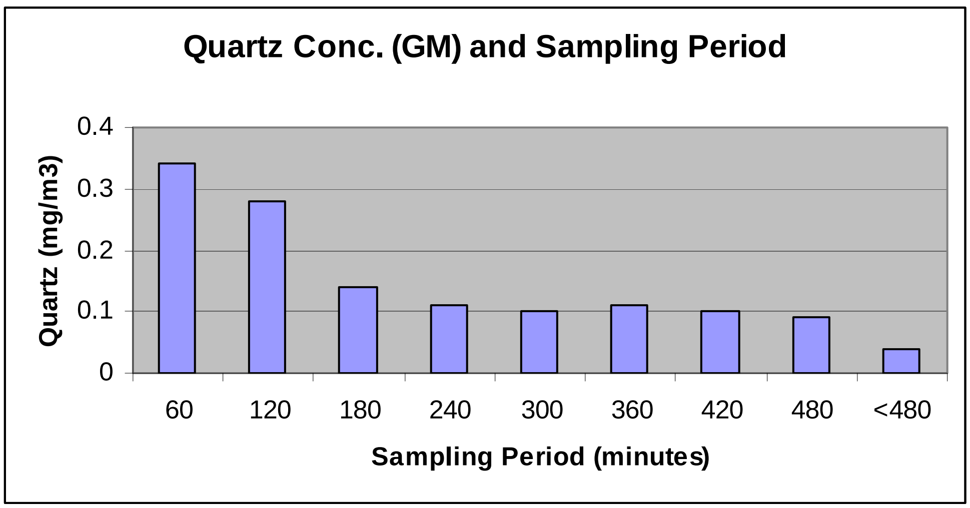
Respirator Guidance Based on Silica Exposure Modeling
for the Construction Industry

Silica exposures are often high for certain construction processes. The first choice for controlling dust should be to suppress it with water or remove it with vacuum before it has a chance to become airborne. There are times when that kind of control is not feasible and respirators are chosen to protect construction workers. This document describes a method for selecting a respirator based on exposure data from a large construction silica sampling data compilation project.

The silica data compilation project undertaken by the American Conference of Governmental Industrial Hygienists (ACGIH) Construction Committee collected 1,375 personal quartz samples from construction sites. The sampling duration varied widely and concentrations were higher for the shorter sampling periods (Figure 1). Samples were collected for various purposes, but it is assumed that the shorter samples are task samples rather than mixed exposure full shift samples. This exposure estimate assumes that samples up to 2 hours in duration are task samples.

Figure 1



These data were generally log normally distributed so quartz concentration was log transformed for analysis. Linear regression was run with predictors: tool used, degree of environmental enclosure, and sampling duration. These predictors were selected for the model because they were the most significant in prior modeling of the data set[1]. Model output is shown in Table 1. The mean square error (MSE) for the model is 2.4.

[1] Flanagan, M. et al. Silica Monitoring on Construction Sites: Results of an Exposure Monitoring Data Compilation Project. J. Occup. Env. Hyg. 3:138-146. (2006).

Table 1: Quartz Exposure Determinant Model (R^2 = 0.24)
Predictor Variables

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Intercept	-3.589
Tool	
Tuck point	3.413
Surface grinder	2.427
Drill	2.355
Jackhammer	2.034
Hand held saw	1.834
Road mill	2.067
Slab saw	1.532
Masonry table top saw	1.208
Cement mix	0.787
Broom/shovel	0.553
Backhoe, excavator, dozer	0
ENVIRON	
Confined	0.924
Enclosed	0.441
Open	0
SAMPMIN	-0.002
8 hr.	-0.960

Quartz exposure is predicted by summing the beta of the intercept and each predictor variable. A sample duration of 8 hours was used to estimate a full shift exposure with continuous exposure so 480 minutes x 0.002 was used for sampling minutes (Sampmin). The natural log intercept of this sum is the geometric mean (GM) concentration.

The modeled arithmetic mean is: $AM = E^{(\ln GM + MSE/2)}$

The geometric and arithmetic means for each predicator combination are shown in Table 2. Only those variable combinations with data in the compilation data set were calculated and displayed in Table 2. The large difference between GMs and AMs indicate high variability within this data set.

Table 2:Model Predicted Quartz Mean (mg/m^3) for 8 Hour Task

Tool	Confined		Enclosed		Open	
	GM	AM	GM	AM	GM	AM
Tuckpoint grinder	0.81	2.69	0.50	1.66	0.32	1.07
Surface grinder	0.30	1.00	0.19	0.62	0.12	0.40
Rock drill	0.28	0.93	0.17	0.58	0.11	0.37
Jackhammer/chip gun	0.20	-	0.13	0.42	0.08	0.27
Hand held saw	0.17	-	0.10	0.34	0.07	0.22
Road mill	0.21	-	0.13	-	0.08	0.28
Slab saw	0.12	-	0.08	0.25	0.05	0.16
Masonry table top saw	0.09	-	0.06	0.18	0.04	0.12
Cement mix	0.06	-	0.04	0.12	0.02	0.08
Broom/shovel	0.05	-	0.03	0.09	0.02	0.06
Backhoe,excavator,dozer	0.03	-	0.02	-	0.01	0.04

To develop respirator guidance, the exceedance percentage[2] was calculated for the PEL, 10 times the PEL, and 100 times the PEL. A PEL of 0.1 mg/m^3 was used. This is the Washington State PEL for quartz. It is equivalent to the OSHA quartz PEL if the quartz content of the sample is 100%.

Exceedance percentages are shown for task estimates that assume the dusty task will be done continuously for the full shift (Table 3). Respirator recommendations were made for dust mask, half face cartridge, full face cartridge and powered air purifying respirators. A 5% exceedance percentage was used as a cut off point. For example, the exceedance percentage is less than 5% for surface grinding in a confined situation at 100 times the PEL (Table 2). Therefore, a protection factor of 100 would be adequate and a full face cartridge respirator is recommended.

NIOSH has established protection factors for respirators as shown in Tables 3 and 4. The protection factor for half face respirators and NIOSH approved dust masks is 10. This assumes that respirators are fit tested and the respirators fit properly. On construction sites dust masks are seldom fit tested and the assumption of good fit can not always be made. Therefore, this guidance does not consider dust masks as protective as half face cartridge respirators. If the exceedance percentage is less than or equal to 1%, then dust masks could be used as an alternative to half face respirators.

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[2] Rappaport, S.M. The rules of the game: An analysis of OSHA's enforcement strategy. Am. J. Ind. Med. 6:291-303 (1984).

Table 3: Model Predicted PEL Exceedance Percentage (%) and Respirator Selection

Tool	Confined			Enclosed			Open		
	PEL	10 x PEL	100x PEL	PEL	10 x PEL	100x PEL	PEL	10 x PEL	100x PEL
If ≤ 5% recommend:	None	½ face	Full face	None	½ face	Full face	None	½ face	Full face
Tuckpoint grinder	92%	47%	6%	86%	35%	3%	80%	26%	1%
Surface grinder	77%	25%	2%	67%	17%	1%	56%	9%	<1%
Drill	76%	23%	1%	64%	15%	<1%	55%	9%	<<1%
Jackhammer/chipping gun	69%*	17%	<1%*	58%	12%	<1%	46%	6%	<<1%
Hand held power saw	64%*	13%*	<1%*	52%	5%	<1%	40%	5%	<<1%
Road mill	70%*	17%*	<1%*	60%*	11%*	<1%*	48%	6%	<<1%
Walk behind saw	58%*	10%*	<1%*	44%	6%	<<1%	34%	3%	<<1%
Masonry table top saw	50%*	7%*	<<1%*	36%	4%	<<1%	26%	2%	<<1%
Cement mixer	36%*	4%*	<<1%*	27%	2%	<<1%	18%	1%	<<1%
Broom/shovel	33%*	3%*	<<1%*	23%	1%	<<1%	15%	<1%	<<1%
Backhoe/dozer/excavator	22%*	1%*	<<1%*	14%*	<1%*	<<1%*	8%	<<1%	<<1%

* - no data in these cells

Table 4: Dust Control for Surface Grinding – Reduced Respiratory Protection with Engineering Controls (PEL Exceedance % and Respirator Selection)

Tool	Confined			Enclosed			Open		
	PEL	10 x PEL	100x PEL	PEL	10 x PEL	100x PEL	PEL	10 x PEL	100x PEL
If ≤ 5% recommend:	None	½ face	Full face	None	½ face	Full face	None	½ face	Full face
Surface grinder –no dust control	77%	25%	2%	67%	17%	1%	56%	9%	<1%
Surface grinder-60% dust reduction	56%	9%	1%	44%	5%	<1%	33%	<1%	<<1%
Surface grinder-90% dust reduction	23%	2%	<<1%	15%	1%	<<1	9%	< 1%	<<1%

PAPR -protection factor >100	
Full face -protection factor =100	
Half face -protection factor =10	
Dust mask (N95) –protection factor <10 if not fit tested	

Recent studies[3,4] of silica exposure and engineering controls have reported that with ventilation or water, exposures are reduced although some type of respirator is likely still needed. Intervention studies for surface grinders with a powerful vacuum system and excellent maintenance over the course of a task have reported very good dust reduction (approximately 90%). Full shift field studies with less controlled equipment and maintenance have reported dust reduction of approximately 60%. Respirator selection options for surface grinding with dust reduction of 60% and 90% are shown in Table 4.

This methodology provides a conservative estimate of respiratory protection for 11 common construction tools used in silica dust generation. Recommendations would protect up to 95% of construction workers if the variability represented in the compilation data set is accurate. Obviously, when working in an extreme dust exposure, greater respiratory protection may be needed.

The intent of this selection guidance is to provide direction to a contractor in planning a dust producing job. Once the job is underway, air monitoring should be done to verify silica dust levels for the project site conditions.

Respirator selection is just one part of a respirator protection plan. If respirators are used to protect for exposures over the PEL, then other actions are also needed including:

- Periodic air monitoring
- Training workers on exposure and respirator use and maintenance
- Medical evaluation of worker's ability to perform the work while wearing a respirator
- Respirator fit testing
- Regular evaluation of effectiveness of the program

[3] Croteau, G. et al. The efficacy of local exhaust ventilation for controlling dust exposures during concrete surface grinding. Ann.Occup. Hyg. 48(6):509-518 (2004).

[4] Akbar-Khanzadeh, F. et al. Respirable crystalline silica dust exposure during concrete finishing (grinding) using hand-held grinders in the construction industry. Ann. Occup. Hyg. 46(3):341-346 (2002).