Dust Control Measures in the Dutch Construction Industry

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Introduction

Exposure to respirable quartz in the construction industry often exceeds Occupational Exposure Limits (OELs), especially in jobs where work comprises of working on quartz containing material with equipment that can generate small particles, such as grinders, electrical saws, (jack-) hammers and drills. Common ways to reduce dust exposure in the construction industry are by the use of (local) exhaust ventilation systems, wet dust suppression by use of (cooling) water, use of personal protective equipment or influencing worker behaviour by training and education. Based on short-term sampling, it has been shown that local exhaust ventilation and wet techniques can reduce silica and respirable dust exposure by more than 90% [Hallin, 1983; Chisholm, 1999; Thorpe et al., 1999]. Full-shift measurements, however, showed lower exposure reductions [below 50%], when dust collection equipment was used [Nash and Williams, 2000]. In spite of these large reduction factors, reduction to exposure levels below OELs is difficult to achieve with isolated control measures [Akbar-Khanzadeh and Brillhart, 2002; Echt and Sieber, 2002]. The aim of the present study is to evaluate reduction of exposure by exposure modelling of full-shift measurements and by short-term measurements. To evaluate extensiveness in which control measures are used, use of different types of control measures in a larger population was studied by questionnaire.

Results of this study are described more extensively in a full paper [Tjoe Nij et al., 2003a]

Material and Methods

Full-shift exposure measurements

A total of 61 exposure measurements were carried out among 30 construction workers. Full-shift respirable dust samples were taken on one to three different days in November and December 1999 with Dewell - Higgins cyclones at a flow rate of 1.9 litre per minute. After gravimetric determination of dust on the PVC filters, α-quartz was analysed by infrared absorption spectrophotometry (IR) [Eller and Cassinelli, 1994]. The limits of detection for dust and α-quartz measurements were 0.14 mg/m^{3}and 1.6 mg/m^3 respectively.

Short-term exposure measurements

Personal short-term respirable dust measurements were performed with and without control measures, with a personal miniature real-time dust monitor (MiniRAM™, model PDM-3, USA). Respirable dust was sampled on Whatman GF/A 37mm glass fibre filters. Gravimetric determination of dust collected on the filters was used to estimate dust levels as produced by the MiniRAM™. The results were plotted and interpreted by comparing the variation in exposure to the results of the observations made synchronously at the workplace.

Questionnaires

Questionnaire data on use of control measures were retrieved from a population survey among 1335 Dutch construction workers (tuck pointers, demolition workers, concrete workers, natural stone workers, terrazzo workers, pile-top crushers, and road construction workers), performed from January to March, 1998 [Tjoe Nij et al., 2003b].

Data analysis

Hypothesis of normal distribution could not be rejected for logarithmically transformed full-shift dust and quartz exposure levels. Variance components were estimated using multiple linear mixed models [Rappaport et al., 1999]. Material worked on and control measures were introduced as fixed effects, while the worker identity was introduced as a random effect. Measurements on the same worker were assumed to be correlated. Between worker and within worker variance components were pooled for calculation of coefficients. Statistical analysis (Proc MEANS, Proc MIXED and Proc FREQ) were performed with SAS statistical software (version 6.12, SAS Institute, Inc. Cary, NC).

Results

Full shift exposure study

The full-shift average exposure measurements showed respirable quartz dust concentrations exceeding the Dutch MAC (maximum Accepted Concentration) for quartz in

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64% of the measurements, and the MAC for respirable dust in 16% of the measurements (table 1). Personal protective equipment was the most frequently used measure to control exposure among individuals who participated in the exposure study (N=18; 60%). Of the 22 workers exposed to quartz levels above 0.075 mg/m^3, fifteen wore respiratory protection, but for seven of these workers, the Assigned Protection Factor (British Standard Institution, 1997) of the respirators was too low to reach exposure levels below the MAC for quartz.

A mixed effects model (table 2) was constructed to evaluate the effect of the use of several control measures on the quartz exposure level, correcting for the influence of material worked on. Natural ventilation resulted in a factor 0.68 lower dust exposure. Working on moist material was associated with elevated exposure levels. In this study there was a negative association between level of dust and quartz exposure and the material being wet, but the association was not statistically significant (results not shown).

Short-term exposure study

Short-term dust exposure measurements showed that both local exhaust ventilation (LEV) and wet dust suppression can reduce dust levels with at least 80%, when tooling lime sandstone (table 3). The effect of spraying water varied widely (12% to 99%) when sweeping rubble.

Table 1 Respirable dust (mg/m^3) and respirable quartz (mg/m^3) exposure by construction workers sub-group.

Group	N[a]	n[b]	Respirable dust (mg/m^3) AM min-max	Respirable dust (mg/m^3) GM (GSD[c])	Respirable quartz (mg/m^3) AM min-max	Respirable quartz (mg/m^3) GM (GSD)	# above MAC (0.075 mg/m^3)
Total	30	61	2.6 0.14-14.3	1.4 (3.3)	0.44 0.0016-4.7	0.13 (5.4)	39 (64%)
Recess millers/ concrete workers	8	14	3.66 0.33-14.3	1.9 (3.3)	1.09 0.036-4.7	0.42 (5.0)	12 (86%)
Tuck pointers (chasing out mortar)	4	10	3.53 0.55-8.0	2.4 (2.7)	0.56 0.089-1.6	0.35 (2.8)	10 (100%)
Demolition workers	10	21	2.44 0.20-9.4	1.4 (3.0)	0.25 0.038-1.3	0.14 (2.7)	14 (67%)
Inner wall constructor	2	4	2.0 0.55-4.0	1.5 (2.5)	0.043 0.016-0.084	0.036 (2.0)	1 (25%)
Construction site cleaners	6	12	1.00 0.14-2.5	0.58 (3.2)	0.032 0.0016-0.097	0.017 (3.6)	2 (17%)

a Number of measured workers
b Number of measurements
c Geometric standard deviation

Table 2 Mixed effects model of material characteristics and control measures in association with log-transformed personal dust and quartz concentrations of 61 measurements[a].

Determinants of exposure:	N[b]	Respirable dust Regression coefficient ($\beta_{y,k}$)(se)[c]	Respirable dust p-value	Respirable dust Factor[d]	Respirable quartz Regression coefficient ($\beta_{y,k}$)(se)[e]	Respirable quartz p-value	Respirable quartz Factor
Intercept		NS[f]			-3.31 (0.56)	<0.0001	
Lime sandstone (1/0)[g]	6	1.30 (0.51)	0.02	3.7	1.91 (0.77)	0.02	6.8
Brick (1/0)	12	1.56 (0.33)	<0.0001	4.7	1.09 (0.54)	0.05	3.0
Concrete (1/0)	23	NS[f]			0.97 (0.42)	0.03	2.6
Material moist (1/0)	8	1.03 (0.39)	0.01	2.8	1.33 (0.51)	0.01	3.8
Local ventilation in tunnel (1/0)	4	0.29 (0.48)	0.6	1.3	0.56 (0.84)	0.5	1.8
Natural ventilation (1/0)	50	-0.39 (0.19)	0.04	0.68	-0.31 (0.49)	0.05	0.74
Respirator P3 (1/0)	20	0.13 (0.34)	0.7	1.1	1.44	0.007	4.2

a The reference group was exposed to rubble, floor dust, mortar from grinding, dust from building blocks or a combination of those materials. In the reference group control measures were absent.
b number of positive outcomes for a specific variable
c $_{ww}\sigma^2$=0.80, $_{bw}\sigma^2$=0.07 for respirable dust
d factor by which the estimated exposure changes when characteristic is present versus absent ($\beta_{y,k}$)
e $_{ww}\sigma^2$=1.06, $_{bw}\sigma^2$=0.49 for quartz
f fixed effect not significant, p>0.05
g (1/0) dummy variable: present vs. not present

Table 3 Results of personal respirable dust measurements (MiniRAM™) with and without local exhaust ventilation (LEV) or wet dust suppression.

Technique	Measurement time (min)	No control range (mg/m^3) (n)[a]	LEV range (mg/m^3) (n)[a]	LEV Dust reduction	Water range (mg/m^3) (n)[a]	Water Dust reduction	Water and LEV range (mg/m^3) (n)[a]	Water and LEV Dust reduction
Recess milling in lime sandstone	1	14.3 (1)	0.03 – 0.2 (3)	> 99%				
Drilling with down the hole (DTH) bits in lime sandstone	1.5	0.2– 0.4 (2)	0.04 – 0.06 (3)	70-90%				
Sawing in lime sandstone	1-3	37.3 (1)	0.10 – 0.14 (3)	> 99%	2.9 – 7.0 (2)	81-92%	0.03-0.4 (2)	> 99%
Clearing rubble (sweeping)	2-3	2.5– 11.3 (7)	0.10 – 0.4[b] (3)	84-99%	0.1-2.2[c] (14)	12-99%		

[a] *Number of measurements*
[b] *Vacuuming*
[c] *Spraying water*

Survey data

From the questionnaires of the 1335 construction workers that were studied in 1998, the utilization of several control measures up to 1998 could be reconstructed. The use of wet processes, LEV and respiratory protection was about equally divided among working-year groups, although the construction workers with less working years showed a slightly higher use of all control measures, especially the use of respiratory protection (figure 1). The use of control measures by occupation varied considerably (table 4).

Table 4 Use of control measures by occupation.[a]

Job category:	n	Tools with (cooling) water systems	Local exhaust ventilation	Tools with local exhaust ventilation	Respiratory protection
TOTAL	1335	453 (34%)	125 (9%)	184 (14%)	875 (66%)
Concrete driller	157	153 (97%)	12 (8%)	34 (22%)	115 (73%)
Concrete repairmen	104	8 (8%)	9 (9%)	14 (13%)	101 (97%)
Concrete worker	19	5 (26%)	2 (11%)	1 (5%)	8 (42%)
Asphalt cutter	17	15 (88%)	1 (6%)	-	10 (59%)
Pile top crusher	12	1 (8%)	-	-	10 (83%)
Crane driver (demolition)	18	3 (17%)	2 (11%)	2 (11%)	5 (28%)
Construction mechanic	18	-	-	5 (28%)	10 (56%)
Natural stone worker	246	185 (75%)	46 (19%)	42 (17%)	109 (44%)
Recess miller	13	10 (77%)	-	2 (15%)	12 (92%)
Demolition worker	244	39 (16%)	31 (13%)	31 (13%)	218 (89%)
Terrazzo worker	35	5 (14%)	5 (14%)	6 (17%)	20 (57%)
Floor layer	47	1 (2%)	7 (15%)	8 (17%)	23 (54%)
Pointer, chasing out mortar	17	2 (12%)	-	3 (18%)	16 (94%)
Pointer	328	14 (4%)	7 (2%)	27 (8%)	176 (54%)

[a] *Groups with less than 10 persons are not shown.*

Discussion

More than half of the measurements exceeded the MAC for quartz. More than half of the 30 workers in the study wore respiratory protection, but for 7 of these the type of respirator used was not sufficient to lower exposures to an acceptable level. Exposure modelling showed that the type of material worked on was the strongest determinant of exposure. Wet dust suppression and use of ventilation systems in tunnels were not very strongly associated with lower levels of exposure. When the material worked on was only moist, instead of wet, exposure levels were even elevated relative to working on dry material. The reason for this is unknown. The short-term measurements showed more convincingly large dust reduction factors (>70%) when wet dust suppression or LEV was used. The use of respiratory protection with the highest protection factor (P3) was associated with higher levels of quartz exposure, suggesting that these respirators are indeed used when needed most.

Both the exposure study and the results from the question-

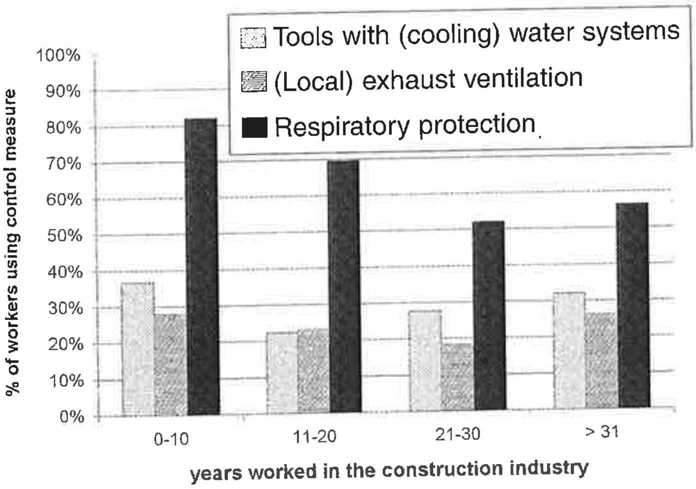

Figure 1 Use of control measures at the time of the study by working years.

naires show that respiratory protection is the most widely used preventive measure in the construction industry. For workers performing heavy labour it is often inconvenient to work with respirators and their effectiveness might be questioned. Use of wet dust suppression and exhaust ventilation is likely to be more effective and their use should be further implemented in the construction industry. Natural ventilation can effectively reduce exposure, as is also shown in a study among concrete grinders [Akbar-Khanzadeh and Brillhart, 2002], where in absence of LEV, exposure was 3.2 times higher when the wind velocity was low (< 1 m/s). However, construction workers are not likely to seek draught to lower their dust exposure.
The chance of lowering exposures to acceptable levels will be better when combining more than one measure to control exposure. The choice of which, should depend on the circumstances.

The short-term respirable dust measurements show that, theoretically, dust reduction of more than 70% can be achieved by local exhaust ventilation and wet dust suppression. Wet dust suppression during sweeping is not in all circumstances very effective. Improper use of control measures can reduce effectiveness. The amount of the effect of dust reduction as calculated by the short-term measurements are in agreement with other studies [Hallin, 1983; Chisholm, 1999; Thorpe et al., 1999]. The percentage of dust reduction calculated on the basis of the short-term measurements has to be interpreted with care. Apart from the high limit of detection of sampling methods, in combination with short-term measurements, these factors are also based on very few measurements not taking in to account variances, and the reduction factors do not represent the actual dust reduction achieved over a full working day. Results of full shift measurements presented in the literature show somewhat lower dust reduction factors [Nash and Williams, 2000]. Concrete grinding with LEV resulted in an average of 74% lower full shift quartz exposure [Akbar-Khanzadeh and Brillhart, 2002].
Results from the questionnaire show a trend of using fewer measures to control exposure among older or more experienced workers. This would place the older workers in a higher risk group for developing quartz related respiratory health effects. The results clearly describe that among many construction jobs, it is possible to use wet dust suppression or ventilation systems on a regular basis, and that the majority of the construction workers have access to respirators. The high levels of quartz exposure, often above the MAC, clarify the need for better and more measures to control exposure.

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