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Dust Control Measures in the Construction Industry

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Quartz is a human carcinogen and a causative agent of silicosis. Exposure levels often exceed exposure limits in the construction industry. The need for effective control measures is high, but the complex structure of the construction industry, the variability in sources of exposure and the frequent changes of worksite makes it difficult to implement even simple and potentially effective control measures. The aim of this study was to evaluate the impact of control measures for reducing quartz dust exposure and to assess the extent of their use. Full-shift respirable dust measurements (*n* = 61) and short-term measurements among construction workers were performed and results of a questionnaire study among 1335 construction workers were analysed. Full-shift measurements showed respirable quartz exposure levels up to 63 times the maximum allowable concentration (MAC) value (0.075 mg/m^3). More than half of the measurements were above the MAC value. Control measures were not very strongly associated with the full-shift exposure estimates, but the short-term measurements showed large reduction factors (>70%) when wet dust suppression or local exhaust ventilation was used. The effectiveness of control measures is potentially high, and a significant part of the construction worker population is indeed using them on a regular basis. Still, both the exposure study and questionnaire survey show that the use of respiratory protection is the most widely used preventive measure in the construction industry. Respiratory protection might not always reduce exposure sufficiently. Only the combined use of more than one control measure can reduce exposures to acceptable levels.

Keywords: construction industry; control measures; quartz; silica

INTRODUCTION

Exposure to respirable quartz is high in the construction industry and often exceeds occupational exposure limits (OELs). A large compilation of respirable quartz exposure measurements performed by OSHA shows that 35% of 728 samples were above the OEL for quartz (Linch, 1997). Even though this was based on a worst case sampling strategy, it clearly indicates that the risk of overexposure is high. Recently conducted risk analyses show that quartz exposure during a working life, even at levels near the present OEL, is associated with an increased risk of silicosis and lung cancer (Steenland and Brown, 1995; Steenland *et al.*, 2001). Especially in jobs that involve working on quartz-containing material with equipment that generates respirable particles, such as grinders, electrical saws, (jack)hammers and drills, exposure levels can easily exceed the OEL for quartz. The need for control measures seems obvious. Still, the effectiveness of control measures on exposure to dust in the construction industry has only been described for a limited number of tools and techniques.

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 (LEV) and wet techniques can reduce silica and respirable dust exposure by >90% (Hallin, 1983; Chisholm, 1999; Thorpe *et al.*, 1999). Full-shift measurements,

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however, showed lower exposure reductions (<50%) when dust collection equipment was used (Nash and Williams, 2000). In spite of these large reduction factors, reduction of exposure levels below OELs is difficult to achieve with isolated control measures (Akbar-Khanzadeh and Brillhart, 2002; Echt and Sieber, 2002). Reduction to levels below 10 times the OEL is already considered an accomplishment, because it allows workers to use a negative pressure half-mask respirator only (Nash and Williams, 2000). Therefore, to reduce quartz exposure to an acceptable level, a combination of control measures seems inevitable.

The effectiveness of control measures can be calculated by the degree of dust reduction by short-term measurements that focus on isolated tasks and control measures, but more realistically by full-shift measurements in multiple groups. The aim of the present study was to evaluate reduction of exposure by exposure modelling of full-shift measurements and by short-term measurements. To evaluate the extensiveness at which control measures are used, use of different types of control measures in a larger population was studied by questionnaire.

MATERIALS AND METHODS

Full-shift exposure measurements

Exposure measurements were carried out among construction workers performing the following specialized tasks: concrete drilling, recess milling, cleaning of construction sites, chasing out of mortar between bricks, inner wall construction and demolition. Concrete workers were involved with drilling concrete with jackhammers or hammer drills and with recess milling and sawing, either of concrete or lime sandstone. Tuck pointers were involved with chasing out of mortar between bricks with hand-held grinders or pneumatic chipping hammers prior to repointing. Cleaners were either clearing up work sites or sweeping. The inner wall bricklayers worked with concrete breezeblocks (a highly cellular material made from quartzite, lime and water). Demolition workers were demolishing with jackhammers, drills and excavators equipped with breakers; other tasks were welding, sawing and clearing up rubble. The primary purpose of the exposure measurement programme was to evaluate exposure for specific jobs in the construction industry for risk analysis in a health effects study and will be published elsewhere (E. Tjoe Nij, J. Spierings, F. Steffens *et al.*, unpublished data). A few measurements (of workers with minor exposure; $n = 4$) were left out for the purpose of the analysis described in this paper.

Personal respirable dust samples were taken on one to three different days in November and December 1999. Personal air sampling for respirable dust was conducted during full work days (average duration 6½ h), using Dewell–Higgins cyclones from The Casella Group (Bedford, UK), connected with Gilian® Gilair5™ portable pumps at a flow rate of 1.9 l/min. A total of 61 measurements on 30 subjects were used for analysis. After gravimetric determination of dust on the PVC filters (pore size 0.2 μm), α-quartz was analysed in Galten, Denmark, at the Danish Environmental Center (Miljø-Kemi). In all dust samples, quartz was determined by infrared absorption spectrophotometry (IR) according to NIOSH method 7602 (Eller and Cassinelli, 1994).

The limit of detection for respirable dust on the filters was 0.15 mg. Dust samples with dust levels <0.15 mg ($n = 5$) were set at 2/3 of this value, divided by the average sampling volume (0.72 m^3), which resulted in a limit of detection for dust measurements of 0.14 mg/m^3. The Miljø-Kemi Laboratory used a modified NIOSH 7602 method, which resulted in a limit of detection for α-quartz on the filters of 1.7 μg. The modification comprises initial ashing at 200°C for 24 h followed by ashing at 370°C for 48 h. Based on four parallel samples, the coefficient of variation (CV) was calculated at 13% for respirable dust and 7% for respirable quartz. The percentage of quartz was calculated from the mass of quartz and the total gravimetrically determined respirable dust on the filter. Samples with quartz levels below 1.7 μg ($n = 4$) were set at two-thirds of this value divided by the average sampling volume, which resulted in a limit of detection for quartz measurements of 1.6 μg/m^3.

During sampling, the type of tools used, materials worked on, presence of natural ventilation, wetness of the material, use of dust reducing techniques, personal protective equipment and general environmental conditions were recorded. Natural ventilation was graded on a four-point scale (none, minor, average and substantial air movement). For analysis this latter determinant was changed to a dummy variable: none or minor natural ventilation versus average or substantial natural ventilation. Only the use of respiratory protection with an assigned protection factor (APF) of 20 or higher [quarter- or half-mask air purifying respirators (P3) or full-face mask with P3 filter] (British Standards Institution, 1997) was considered for statistical modelling.

Short-term exposure measurements

In four situations, personal short-term respirable dust measurements were performed. Three different electrical tools (recess mill, drill and saw) were used to work lime sandstone, with and without the use of control measures. The influence of sweeping rubble with a broom with spraying water and a vacuum cleaner was also assessed. Measurements were performed during the actual use of a specific tool. As a result, measurement time depended on the duration of a specific task. To be able to calculate the level of dust reduction, measurements were performed with and without control measures with a personal miniature real time dust monitor (MiniRAM™, model PDM-3). This is a light scattering aerosol monitor that responds to particles in the range 0.1–10 µm. The MiniRAM™ is calibrated on Arizona Road Dust and not on 'construction' dust. Consequently, the results of these measurements can only be used to compare different situations. Respirable dust was sampled on Whatman GF/A 37 mm glassfibre filters, in combination with active air sampling using a Dewell–Higgins cyclone from The Casella Group (Bedford, UK) and a Gilian® Gilair5™ portable pump at a flow rate of 1.9 l/min. Gravimetric determination of dust collected on the filters was used to estimate dust levels as produced by the MiniRAM™. Measurement data from the MiniRAM™ were recorded on a data logging monitor (Metrosonics®). Metrosoft® software was used to record dust concentrations and produce graphs. The average of the minimum and maximum concentrations detected during the previous 10 s was recorded. The results were plotted and interpreted by comparing the variation in exposure with the results of the observations made synchronously at the workplace.

Questionnaires

Questionnaire data were retrieved from a population survey among 1335 Dutch construction workers, performed from January to March 1998 (Tjoe Nij *et al.*, 2002). Letters of invitation were sent to 4173 natural stone and construction workers, ≥30 yr old from occupational groups with expected high cumulative exposure to quartz-containing dust. The construction workers had the following occupations: tuck pointer (including workers involved with removing mortar between bricks), demolition worker (including workers who clear up demolition rubbish), concrete worker (involved with drilling, repairing or blasting concrete and cutting, grinding and sawing grooves in walls), natural stone worker (involved with sawing, engraving and polishing of natural stone), terrazzo worker, pile top crusher (involved with drilling to break up tops of concrete piles) and road construction worker.

Regular use of tools with (cooling) water systems, local exhaust systems or tools with exhaust systems was recorded. Participants were also asked when they had started using respiratory protection regularly.

Data analysis

The hypothesis of a normal distribution could not be rejected for logarithmically transformed full-shift dust and quartz exposure levels (Shapiro–Wilk statistic, 0.97, $P = 0.2$, and 0.98, $P = 0.8$, respectively). A log-normal distribution was assumed for all measurements in individual jobs. Exposure levels were described for different jobs in terms of arithmetic and geometric means as well as the corresponding geometric standard deviations and ranges. 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 worker identity was introduced as a random effect. The models have the following general form:

$$Y_{ijk} = \mu + \beta_k + \chi_{i(k)} + \varepsilon_{j(ik)}$$

In this model, Y_{ijk} represents the natural logarithm of the exposure concentration measured on the jth day of the ith worker in group k, μ is the true underlying mean of log-transformed exposure averaged over all groups, β_k is the fixed effects of group k, $\chi_{i(k)}$ is the random effect of the ith worker in group k and $\varepsilon_{j(ik)}$ is the random within-worker variation on day j for worker i in group k.

Separate models were constructed for respirable dust and quartz exposure. It is assumed that $\chi_{i(k)}$ and $\varepsilon_{j(ik)}$ are normally distributed with zero means and variances ${}_{\mathrm{bw}}\sigma^2_{yk}$ and ${}_{\mathrm{ww}}\sigma^2_{yik}$, respectively, which are mutually independent. Measurements on the same worker were assumed to be correlated (compound symmetry covariance structure). Variances are estimated as between-worker (${}_{\mathrm{bw}}\hat{\sigma}_{yk}$) and within-worker (${}_{\mathrm{ww}}\hat{\sigma}_{yik}$) variance components. Between-worker and within-worker variance components were pooled for calculation of coefficients. Estimated mean exposure for combination of determinants (k_1 and k_2) was calculated with the formula

$$\hat{\mu}_{x,\,k(i)} = e^{(\hat{\mu}_{y,\,k(i)} + 0.5\,{}_{\mathrm{ww}}\sigma^2)}$$

where $\hat{\mu}_{y,\,k(i)}$ is the true underlying fixed mean (logged) exposure level (mg/m^3) for determinants. Based on determinants calculated by the model, exposure levels for full-shift measurements were estimated and compared with the Dutch maximum allowable concentration (MAC) value for quartz (0.075 mg/m^3).

Simple frequency statistics are given for the outcome of the questionnaires. Statistical analysis (Proc MEANS, Proc MIXED and Proc FREQ) were performed with SAS statistical software (version 6.12; SAS Institute, Cary, NC).

RESULTS

Full-shift exposure study

The full-shift average exposure measurements showed respirable quartz dust concentrations exceeding the Dutch MAC value for quartz in 64% of the measurements (Table 1). In 16% of the measurements, even respirable dust exposures exceeded the MAC value for respirable dust (5 mg/m^3). Personal protective equipment ($N = 18$, 60%) was the most frequently used measure to control exposure among individuals who participated in the exposure study. Of the 22 workers exposed to quartz levels of >0.075 mg/m^3, 15 wore respiratory protection, but for seven of these workers the Assigned Protection Factor (APF) (British Standards Institution, 1997) of the respirators was too low to reach exposure levels below the MAC value for quartz. All workers ($N = 4$) using a full-face respirator with a P3 filter had sufficient protection during all measurements ($n = 10$).

A mixed effects model with pooled within- and between-worker variance components (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. Material worked on explained most of the variance in exposure. Working on either lime sandstone or brick was positively associated with the level of exposure for both respirable dust and quartz exposure. Natural ventilation was negatively associated with respirable dust exposure. Natural ventilation resulted in a factor of 0.68 lower dust exposure. When working outside or in unfinished buildings, natural ventilation was usually present. Working on moist material was associated with elevated exposure levels. In this study there was a negative association between the level of dust and quartz exposure and the material being wet, but the association was not statistically significant (results not shown). Wetting of the materials, with the specific aim of reducing formation of dust, was done in only four cases. In four other cases

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)		Respirable quartz (mg/m^3)		
			AM (min–max)	GM (GSD[c])	AM (min–max)	GM (GSD)	No. 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

Determinants of exposure	N[b]	Respirable dust			Respirable quartz		
		Regression coefficient ($\hat{\beta}_{y,k}$) (SE)[c]	P value	Factor[d]	Regression coefficient ($\hat{\beta}_{y,k}$) (SE)[e]	P-value	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			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 these materials. In the reference group control measures were absent.
[b]Number of positive outcomes for a specific variable.
[c]${}_{ww}\hat{\sigma}^2_k = 0.80$, ${}_{bw}\hat{\sigma}^2_k = 0.07$ for respirable dust.
[d]Factor by which the estimated exposure changes when characteristic is present versus absent ($e^{\hat{\beta}_{y,k}}$).
[e]${}_{ww}\hat{\sigma}^2_k = 1.06$, ${}_{bw}\hat{\sigma}^2_k = 0.49$ for quartz.
[f]Fixed effect not significant, $P > 0.05$.
[g](1/0) dummy variable: present versus not present.

the material worked on was wet because of rain. Use of respirators with P3 filters was associated with elevated quartz exposure levels, but not with elevated dust exposure levels. A positive correlation was observed for the use of respirators with a P3 filter and working on lime sandstone ($R_p = 0.47$, $P < 0.0001$).

To illustrate the influence of different conditions on quartz exposure, mean exposure levels were estimated and are presented relative to the MAC for the combination of materials worked on and determinants that could potentially lower exposure (Table 3). The coefficients calculated by the mixed effects model for quartz were used (Table 2). Based on this model, mean exposure levels are only below the MAC value for the group of 'other' materials when natural ventilation exists. The coefficients calculated for mechanical ventilation in a tunnel and general ventilation were not statistically significant, so these results only give a crude indication of the reduction in quartz exposure by ventilation. Based on the results of the model, the use of respirators with an APF of 20 or higher is not sufficient to reduce quartz exposure to levels below the MAC value when working with lime sandstone.

Short-term exposure study

Short-term dust exposure measurements with MiniRAM™ equipment showed that both LEV and wet dust suppression can reduce dust levels by at least 80% when tooling lime sandstone (Table 4). The effect of spraying water varied widely (12–99%) when sweeping rubble. When one of the operations, sawing in lime sandstone, was studied in more detail (Fig. 1), it became clear that local exhaust was not as efficient as expected. When the machine was shut off, the LEV was shut off as well, resulting in an increase in the dust concentration (white areas in Fig. 1). Exposure increased substantially (Fig. 1, peak around 15:42) when the LEV did not work effectively, because the sawing blade was positioned at an angle.

Survey data

From the questionnaires from the 1335 construction workers that were studied in 1998, the utilization of several control measures up to 1998 could be reconstructed. The construction workers had an average age of 42 years (range 27–75) and had worked on average for 19.1 years (standard deviation 9.5) in this industry. Of these workers, 95% reported exposure to dust from construction sites. The use of wet processes, LEV and respiratory protection was about equally divided among age groups and working-year groups, although the younger construction workers showed a slightly higher use of all control measures, especially the use of respiratory protection (Fig. 2). The use of control measures by occupation varied considerably (Table 5). While almost all concrete drillers used tools with cooling water, only one of the 12 pile top crushers used tools with (cooling) water systems. Respiratory protection

Table 3. Factor of quartz exposure relative to MAC (0.075 mg/m^3) for combination of determinants, based on the model described in Table 2

	Material moist	Local ventilation in tunnel[a]	General ventilation	Respirator P3
Lime sandstone	21	10	4	23
Brick	9	4	2	10
Concrete	8	4	2	9
Other materials	3	1.4	0.6	3

[a]Not significant, $P = 0.5$.

Table 4. Results of personal respirable dust measurements (MiniRAM™) with and without LEV or wet dust suppression

Technique	Measurement time (min)	No control	LEV		Water		Water and LEV	
		Range (mg/m^3) (n)[a]	Range (mg/m^3) (n)[a]	Dust reduction	Range (mg/m^3) (n)[a]	Dust reduction	Range (mg/m^3) (n)[a]	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.

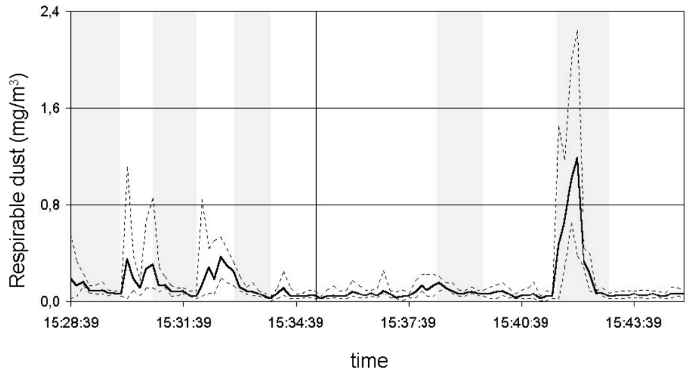

Fig. 1. Output of the data logger connected to the MiniRAM™ when sawing lime sandstone. Left of line shows dust exposure levels with local exhaust only. Right of line shows levels when water and LEV are both used. Grey areas represent exposure during activity; white areas represent exposure when machine is shut off. The peak around 15:42 shows the level when the sawing blade was positioned at an angle.

Table 5. Use of control measures by occupation[a]

Job category	*n*	Tools with (cooling) water systems	LEV	Tools with LEV	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.

was the only measure to reduce exposure among almost all concrete repairmen, pile top crushers, demolition workers and pointers chasing out mortar.

DISCUSSION

More than half of the measurements exceeded the MAC value for quartz. More than half of the 30 workers in the study wore respiratory protection, but for seven 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. Natural ventilation seem to be associated with lower quartz concentrations, but was not sufficient to reduce quartz exposure to levels below the MAC value when working on lime sandstone or bricks. 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. It could be that when the material is moist, working on it might seem less hazardous and as a result enhance the workers exposure or that working on moist material is just more laborious. The short-term measurements showed more convincing 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

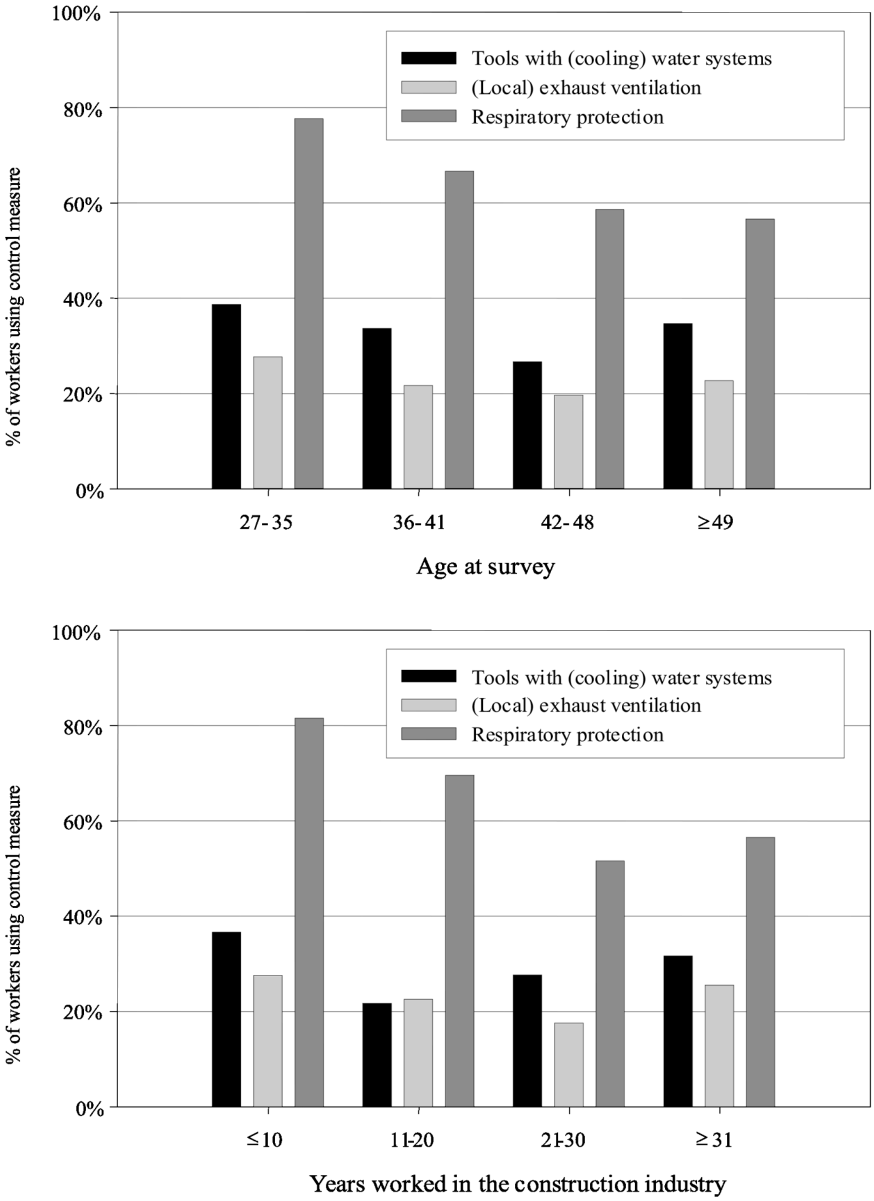

Fig. 2. Use of control measures at the time of the study by age category and working years.

quartz exposure, suggesting that these respirators are indeed used when needed most.

Both the exposure study and the results from the questionnaires 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. They provide insufficient protection when the APF is too low for a specific situation and when not used or maintained properly. 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, but construction workers are not likely to seek a 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.

Associations between exposure levels determined by the full-shift measurements and use of preventive measures were not very strong in this study. This could have been the result of the design of the measurement programme, which was carried out for risk assessment for an epidemiological study. The strength of natural ventilation was also estimated subjectively; wind speed measurements were not performed. Differences in tools used (speed, operating time, type of blade, etc.) by workers with the same job describtion were not taken into account either. However, the associations give a general idea of the determinants of influence. The results are in agreement with the results of a study among concrete grinders (Akbar-Khanzadeh and Brillhart, 2002), in which in the absence of LEV exposure was 3.2 times higher when the wind velocity was low (<1 m/s) compared with exposure levels when the wind velocity was high (>1 m/s).

The short-term respirable dust measurements show that, theoretically, dust reduction of more than 70% can be achieved by LEV and wet dust suppression. Wet dust suppression during sweeping is not very effective in all circumstances. Improper use of control measures can reduce effectiveness. The extents of dust reduction as calculated from short-term measurements are in agreement with other studies (Hallin, 1983; Chisholm, 1999; Thorpe *et al.*, 1999). As early as 1983, Hallin proved that LEV during recess milling in sand–lime bricks could reduce quartz dust exposure by over 95%. 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 the sampling method, in combination with short-term measurements, these factors are also based on very few measurements, not taking into account variances, and the reduction factors do not represent the actual dust reduction achieved over a full working day. The results of full-shift measurements presented in the literature show somewhat lower dust reduction factors. Full-shift measurements during tuck pointing showed an exposure reduction of between 37 and 47% when LEV was used. Only after equipment modification (rearranging the handle and hose attachment and readjusting the shroud) did a single measurement show a reduction of 94% (Nash and Williams, 2000). Concrete grinding with LEV resulted in an average of 74% lower full-shift quartz exposure (Akbar-Khanzadeh and Brillhart, 2002).

The results from the questionnaires showed 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 show that for construction jobs it is possible to use wet dust suppression or ventilation systems on a regular basis and that the majority of construction workers have access to respirators. On an individual basis, the effect of the reported control measures might not be optimal, because the construction worker might also be using dust-producing equipment or not using respiratory protection during part of the working time. Again, the combined use of more than one type of control measure will lower the chance of overexposure.

The high levels of quartz exposure, often above the MAC value, clarify the need for better and more measures to control exposure.

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