Comparison of quartz dust exposure with three methods of foundation pile top removal

Mieke Lumens[1], Ton Spee[2]

Samenvatting

Inleiding: In de Nederlandse bouwnijverheid wordt ongeveer 4% van de werknemers structureel blootgesteld aan concentraties respirabel kristallijn kwartsstof, die boven de MAC waarde liggen. Koppensnellers behoren tot de hoogst blootgestelde groep. In deze groep worden relatief veel gezondheidseffecten gevonden. De blootstelling van deze groep werknemers moet dringend worden verlaagd. In deze studie worden twee maatregelen om de blootstelling te beperken vergeleken met de conventionele manier van koppensnellen. Op 6 werkdagen zijn de blootstelling aan kwartsstof en de effectiviteit van de beheersmaatregelen gemeten. In totaal zijn 19 persoonlijke metingen verricht.
Resultaten: Bij conventioneel koppensnellen varieerde de blootstelling van 0,03 tot 1,57 mg/m³ (GM=0,93). Gebruik van de hydraulische hamer leidde tot blootstellingen van 0,03 tot 0,10 mg/m³ (GM=0.05) voor de kraanmachinist, en van 0,03 tot 0,05 mg/m³ (GM=0,04) voor de puinruimer. Bij hydraulisch kraken waren de blootstellingen voor de kraanmachinist 0,23 en 0,55 mg/m³ (GM=0,36), en voor de puinruimer 0,11 en 0,46 mg/m³ (GM=0,22).
Conclusie: Beide alternatieve methoden leidden tot een lagere blootstelling. Zowel de range als het GM van de blootstelling waren lager bij gebruik van de alternatieven. De meeste concentraties waren echter hoger dan de Nederlandse MAC voor kwarts (0,075 mg/m³).

Summary

Introduction: About 4% of workers in the construction industry are structurally exposed to concentrations of respirable crystalline quartz dust above the Dutch occupational exposure limit. Pile top crushers are among the highest exposed workers: a relatively large number of health effects related to quartz exposure have been found in this group of workers, and there is an urgent need to decrease their personal exposure levels. This study compared two methods of pile top removal, remote controlled hydraulic hammering and pile top crushing, with the conventional method. Exposures were measured on six working days. A total of 19 personal samples were taken.
Results: With conventional pile top removal, exposure to quartz dust ranged from 0.03 to 1.57 mg/m³ (GM = 0.93). Hydraulic hammering yielded exposures of 0.03-0,10 mg/m³ (GM = 0.05) for machine operators and 0.03-0.05 mg/m3 (GM = 0.04) for rubble cleaners. With hydraulic crushing the exposures were 0.23-0.55 mg/m³ (GM = 0.36) for machine operators and 0.11-0.46 mg/m³ (GM = 0.22) for cleaners.
Conclusion: The two alternative methods were demonstrated to have a positive effect on controlling exposure, with both lower ranges of exposure concentrations and lower geometric means. Most concentrations were still higher than the Dutch occupational exposure limit for quartz (0.075 mg/m³), however.

Introduction

About 48% of construction workers in the Netherlands complain of dust nuisance [Arbouw, 2000]. Dust in the construction industry can contain hazardous substances, e.g. wood dust and quartz dust. It is estimated that about 8,000 construction workers are structurally exposed to respirable crystalline quartz dust above the Dutch exposure limit of 0.075 mg/m³ [Tjoe Nij, 2003]. Occupational exposure to dust can cause considerable damage to the lungs, including obstruction and emphysema. Chronic exposure to high concentrations of respirable quartz can cause silicosis, as is well known from the mining industry. Hodel et al. [1977], wanting to draw attention to this previously little recognized health hazard, described two cases of silicosis among construction workers.

[1]*Institute for Risk Assessment Sciences, Division of Environmental and Occupational Health, Utrecht University, Netherlands, Postbus 80176, 3508 TD Utrecht Tel: +31 30 2539447 Fax: + 31 302535077, E-mail: M.Lumens@IRAS.UU.NL*
[2]*Arbouw Foundation, Amsterdam, Netherlands*

In 1996 the International Agency for Research on Cancer (IARC) reviewed recent data on the carcinogenicity of respirable quartz. As a result of this review quartz was placed in IARC group 1, meaning that "there is sufficient evidence of carcinogenicity in humans". The Dutch government considers respirable crystalline silica to be a confirmed human carcinogen.

In recent years the IRAS has carried out a number of research projects into quartz exposure among construction workers. Personal exposure levels were found to be well above the Dutch exposure limits of 5 mg/m³ for respirable dust and 0.075 mg/m3 for quartz dust.[Lumens and Spee, 2001; Tjoe Nij et al., 2004] It should be noted that the occupational exposure limit for respirable dust applies only to nuisance dust, not to toxic dusts. Information on respirable dust levels, however, may provide valuable information on the efficiency of control measures, especially since it is cheaper to analyse respirable dust than quartz dust, and respirable dust concentrations can be determined using direct reading instruments.

A health survey [Tjoe Nij et al. 2003] studied a population of 1,335 construction workers working in jobs associated with high exposure levels who had an average of 19 years' exposure, using lung function testing and radiology. Pile top crushers proved to be the group with the highest prevalence of radiographic abnormalities, indicative of mixed dust pneumoconiosis.

In addition to high exposure to dust, the conventional method of pile top removal causes high exposures to vibration and noise. A major overhaul of the method of operation for pile top removal is therefore needed [Swuste et al. 1997]. Alternatives to conventional pile top removal have been developed in which remote control methods are being applied. Some firms are currently using these alternatives regularly. There is no information available on the efficacy of these alternatives in reducing exposure to dust/quartz, however.

The objectives of this study were to investigate:
• the levels of quartz exposure to which pile top crushers are exposed
• which method of pile top removal results in the lowest exposure.

Pile top removal

The nature of the soil in the Netherlands makes pile foundations necessary for most buildings. Armoured piles have to be driven 10 to 30 meters into the ground. To connect the tops of these piles to the rest of the concrete foundation, the reinforcing rods of the pile head must be laid bare. This process is called pile top removal and is performed by specialized construction workers. Conventionally this is done by drilling with hand operated *pneumatic drills* (see photo 1). The construction workers applying these pneumatic drills clean the rubble after finishing the drilling.

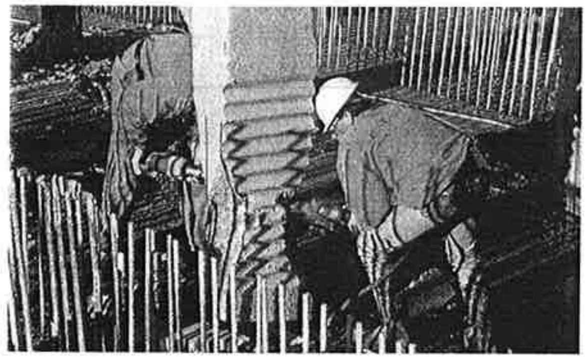

Photo 1: Conventional pile top removal using pneumatic drills

An alternative to hand operated pneumatic drilling is using a *hydraulic hammer* attached to a caterpillar crane/cat. This work is usually done by two people, a machine operator and a rubble cleaner. The machine operator works in a cabin and is thus protected from dust exposure. The other person removes the last remnants of the pile head by hand and clears the rubble (see photo 2).

Photo 2: Hydraulic hammer mounted on a crane truck

Depending on the size of the piles, their tops can also be removed by crushing. The concrete can be broken so as to lay the rods bare using a *hydraulic crusher*, again mounted on a crane truck. As with the hydraulic hammer two persons are involved in this operation, the crusher and the rubble cleaner (see photo 3). The exposure situation is similar to that of the second method: the operator is protected from dust, the cleaner is close to the dust source.

Materials and Methods

The respirable dust and quartz dust measurements were all carried out at one large construction site, where several methods of pile removal were being used simultaneously. The advantage of studying this site was that all the samples could be collected under similar circumstances, *i.e.* the weather conditions, the experience and behaviour of the workers and the layout of the site were comparable. There were two types of foundation piles on the site, round piles, which were poured *in situ*, and smaller

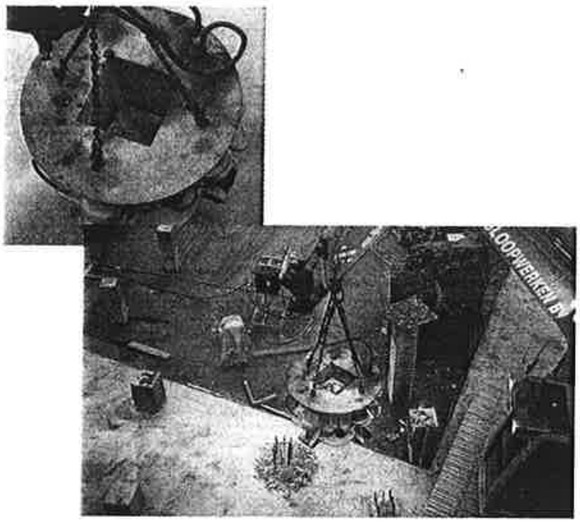

Photo 3: Pile top crusher mounted on a crane truck

prefab piles that were driven into the ground. The material to be removed however was not similar: the poured piles were much softer than the prefab piles, and the quartz content between the poured and prefab piles differed.
The hydraulic hammering method was only applied to the larger poured piles, whereas the hydraulic crushing method could only be applied to the smaller prefab piles.
19 personal measurements were carried out on six days in November and December 2001. Dust sampling was conducted over an average of 6 hours. Samples were collected on Millipore PVC membrane filters (0.8 µm) using Dewell-Higgins cyclones from the Casella Group Ltd (Bedford, UK). The cyclones collect the respirable fraction, which is relevant in determining exposure to respirable quartz. They were connected to Gilian® Gilair5™ portable pumps at a flow rate of 2.2 L per minute. The filters were weighed before and after sampling using a Mettler balance (type AT 261, DeltaRange, Switzerland). The limit of detection (LOD) for respirable dust on the filter is 0.15 mg. The _-quartz in all the samples was measured by an external laboratory. The analysis was performed by infrared spectroscopy (NIOSH method 7602[Eller and Cassinelli, 1994]). The LOD in the analysis was 10 µg/sample.

Results

15 out of the 19 personal measurements were analysed (the work being done during three of the measurements was too different from the regular work, and one sample got lost during analysis). Table 1 shows the results of the 15 personal respirable dust measurements. For these samples the chance of exceeding the Dutch OEL of 5 mg/m3 for respirable dust is calculated (Table1).

Table 2 shows the results of the personal α-quartz dust measurements. As is clear from the table, the risk of exceeding the Dutch OEL of 0.075 mg/m³ for quartz dust is 93% with the conventional method, and even 100% for workers using the hydraulic crusher. In case of the hydraulic hammer the risk of exceeding the OEL is 16% (27% for the hammer operator and nil for the rubble cleaner).

The dust control efficiency of the two alternative pile-removal methods was calculated by comparing the exposure levels caused by these methods to the exposure due to the conventional method of pile head removal. Since rubble cleaning is part of all three types of pile removal the comparison is made by comparing the combined average exposure due to crane operating and rubble cleaning with the exposure of the conventional pile head remover. The results of the comparison are shown in Table 3.

The difference in the reduction in dust and quartz exposure with the hydraulic hammer is due to the differing composition of the concrete piles. It is assumed that the variation in quartz content of the piles is reflected in the quartz content of the personal samples. Table 4 shows the quartz content for the 3 types of pile top removal.

Table 1. Levels of exposure to respirable dust, by method of pile top removal

Type of work	Number of samples	AM in mg/m³	GM in mg/m³	range	Chance of exceedance of OEL (5 mg/m³)
Pneumatic hammering	5	3,75	2,8	0,53-6,01	29%
Hydraulic hammering	6	0,52	0,48	0,36-1,01	0%
Crane operator	3	0,45	0,45	0,38-0,50	0%
Rubble cleaner	3	0,58	0,52	0,36-1,01	0%
Hydraulic crushing	4	1,14	1,08	0,68-1,65	0%
Crane operator	2	1,47	1,46	1,30-1,65	0%
Rubble cleaner	2	0,80	0,79	0,68-0,92	0%

Discussion

The number of measurements was limited, but the two alternative methods were shown to cause lower exposure levels than the conventional method.

In theory the measurement conditions were ideal: a single large construction site where different pile head removal techniques were used simultaneously over a fairly long period of time. This enabled measurements to be carried out under similar weather conditions and working conditions and at a similar stage in the building process-factors that have a major impact on levels of exposure, as described in an earlier study [Lumens and Spee, 2001]. As with all occupational health

Table 2. Level of exposure to respirable α-quartz, by method of pile top removal

Type of work	Number of samples	AM in mg/m³	GM in mg/m³	range	Chance of exceedance of OEL (0.075 mg/m³)
Pneumatic hammering	5	0,96	0,93	0,03-1,57	93%
Hydraulic hammering	6	0,05	0,05	0,03-0,10	16%
Crane operator	3	0,05	0,05	0,03-0,10	27%
Rubble cleaner	3	0,04	0,04	0,03-0,05	0%
Hydraulic crushing	4	0,34	0,29	0,11-0,46	100%
Crane operator	2	0,39	0,36	0,23-0,55	100%
Rubble cleaner	2	0,28	0,22	0,11-0,46	100%

Table 3: Reduction in respirable dust/quartz dust from two alternative methods of pile top removal as compared with hand-operated pneumatic drilling

Method of pile top removal	Reduction in dust exposure	Reduction in quartz exposure
Hydraulic hammering	83%	95%
Hydraulic crushing	63%	68%

Table 4: Quartz content for three types of pile top removal

Method of pile top removal	Number of measurements	Type of pile removed	Quartz content in personal samples in % (range)
Pneumatic hammering	5	Combination of poured and prefab piles	26 % (23-39%)
Hydraulic hammering	6	Only poured piles	10 % (5-20%)
Hydraulic crushing	4	Only prefab piles	30 % (17-49%)

studies in the construction industry, however, scheduling the measurements presented logistical problems, hence the small number of measurements.

In both crushing and hydraulic hammering the operator is inside the cabin of a truck crane. His *dust* exposure, however, is higher during crushing than during hydraulic hammering. A complicating factor is that the two removal methods were used on different types of piles, of differing hardness and differing quartz content, as shown in Table 4. This makes it hard to distinguish between the effects of the *method* and the *type of pile* being removed. The hydraulic hammer was used to remove the heads of poured piles, whereas the driven piles were removed by means of hydraulic crushing. The driven piles were much harder than the poured piles, so a higher energy input was needed which is expected to result in the release of smaller particles; also, the crusher had to be placed over the pile, so the distance between the crane and the exposure source was smaller than with hydraulic hammering. These two factors may explain the difference in dust exposure between the two methods.

Replacing pneumatic drilling with crushing yields about the same reduction (about 65%) in exposure to both dust and quartz. In pneumatic hammering and hydraulic crushing the same type of piles, consisting of the same material, were being processed. In the case of the poured piles (removed by hydraulic hammering) the reduction in dust exposure was 85% and the reduction in quartz exposure 95%. The larger reduction in quartz exposure with hydraulic hammering can be explained partly by the lower quartz content of the poured piles; the remainder of the reduction is explained by a combination of softer material and a larger distance from the source of exposure. These findings were consistent in both the crane operators and the rubble cleaners. In both control methods a cabin screened the workers from the dust source, but the effect was lessened because the windscreen was removed: the glass became soiled, especially on rainy days, restricting the view from the cabin. Solving this practical problem might lead to even lower exposures for crane operators.
It has to be borne in mind that pile tops cannot be removed completely using the methods investigated here: the lower part still has to be removed by pneumatic drilling. Also, with the hydraulic crushing method the rubble cleaners are still exposed to high levels of quartz . Using the alternative methods does result in a decrease in quartz exposure, however.

Conclusions

Conventional pile top removal leads to exposures to both respirable dust and quartz dust that can easily exceed the Dutch exposure limits. With the two alternative methods, hydraulic hammering and hydraulic crushing, personal exposure to respirable dust is decreased considerably. Hydraulic crushing can cause exposures above the Dutch OEL for quartz; the risk is lower with hydraulic hammering of relatively soft piles with a relatively low quartz content. The results of this limited number of measurements suggest that pile top removal by means of hydraulic hammering is the most efficient way of decreasing exposure to respirable quartz dust, and that hydraulic crushing should be considered as the next best alternative. Since the method used is dictated by the type of pile being removed, however, these results are not generally applicable.

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