Exposure to respirable crystalline silica in the construction industry—do we have a problem?

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ABSTRACT

AIMS: To assess personal exposure to respirable dust and respirable crystalline silica (RCS) in New Zealand construction workers.

METHODS: In a pilot study, 39 personal samples were collected from a cross-section of workers engaged in a range of tasks performed on construction sites that were expected to entail exposure to respirable crystalline silica. Nine static samples were taken at locations adjacent to these tasks. Particle size-selective sampling heads were used to collect the respirable fraction of airborne particulates. Dust concentrations were determined gravimetrically, while crystalline silica was analysed using x-ray diffraction.

RESULTS: Almost half of the personal crystalline silica samples exceeded the New Zealand Workplace Exposure Standard (NZ WES), while 56% exceeded the more stringent international recommendation (ACGIH TLV). The tasks associated with the highest RCS levels were concrete grinding and cutting. Two of four static samples collected close to (silica-containing) Linea board cutting exceeded the ACGIH TLV for RCS, indicating the potential for bystander exposure.

CONCLUSIONS: A large proportion of workers performing common tasks in the construction industry may be exposed to levels of respirable dust and crystalline silica exceeding national standards and international recommendations. These results suggest that workers in this industry may be at risk of developing silica-related diseases, including silicosis, lung cancer, COPD and chronic renal disease. Action is required to improve dust control to reduce silica exposure and the associated health risks.

Although often thought of as an historical issue, respirable crystalline silica (RCS) remains one of the most common occupational exposures worldwide.[1,2] Silicosis is a progressive and irreversible fibrotic lung disease, which can be either acute after very high exposure to RCS or chronic, manifesting 10 to 30 years after continued exposure at lower levels. RCS exposure occurs mainly in occupational settings (including construction) wherever materials such as rock, gravel, sand, concrete or brick, or the newer high-silica content building materials such as Linea board, are mechanically broken down through cutting, grinding, crushing, drilling or abrasive blasting. In the past there has been high silica exposure in the New Zealand mining industry, with 1,576 pensions awarded between 1915 and 1938 to miners suffering from silicosis.[3] RCS was classified by the International Agency for Research on Cancer as an IARC Group 1 carcinogen (sufficient evidence of carcinogenicity in humans) in 1997,[4–6] and more recently evidence has been accumulating showing that it is also associated with autoimmune conditions, including rheumatoid arthritis, scleroderma, Sjögren's syndrome and systemic lupus erythematosus,[7,8] and with chronic renal disease.[9] For this reason the New Zealand Workplace Exposure Standard (NZ WES) for RCS was updated to 0.1mg/m³ as recently as 2016,[10] and there is an even more stringent internationally-recommended exposure limit (ACGIH TLV) of 0.025mg/m³.[11,12]

Studies on work-related RCS exposures in New Zealand workers are rare. A survey of

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high-risk extractive industries (ie, quarries, lime works, gold mines and tunnels) in the late 1990s found average (geometric mean) levels of RCS ranging from 0.05mg/m^3 in quarries to 0.09mg/m^3 in tunnels, with highs of 0.57mg/m^3 and 1.29mg/m^3 respectively,[13] but current levels of exposure (and associated health risks) in the New Zealand construction industry are not known. We report here the results of a pilot study of respirable dust and silica exposure levels in construction workers involved in the post-earthquake Canterbury rebuild.

Methods

Construction companies working in the Christchurch rebuild were invited to participate in this pilot study of respirable dust and respirable crystalline silica exposure. In those that agreed, personal respirable dust samples were taken on 39 workers engaged in a range of tasks performed on construction sites that were expected to entail silica exposure. These tasks included: driving Bobcats and diggers; jackhammering, polishing, grinding, drilling or crushing concrete; cutting concrete or Linea board; and general labouring. All samples were taken according to the method AS2985, 2009 Workplace Atmospheres-Method for Sampling and Gravimetric Determination of Respirable Dust using portable pumps set at an airflow rate of 2.2 l/min attached to Higgins Dewell cyclones (Casella) and 25mm PVC filters. Sampling time varied according to work requirements, but most samples taken were for periods of five to eight hours. Using the same method and equipment nine static or area samples were also collected in locations adjacent to the above tasks.

Gravimetric measurements were conducted using a Sartorius balance with a resolution of 0.01mg to calculate respirable dust levels. Crystalline silica was analysed on each filter using x-ray diffraction (XRD) according to the US National Institute of Occupational Safety and Health Manual of Analytical Methods; Method 7500 to calculate airborne silica concentrations. The limit of detection for crystalline silica was 5µg. When filters were overloaded, analyses were conducted as if samples were solid powders rather than dust on filters. Five personal samples (representing general labouring tasks (n=3), drilling (n=2), jackhammering (n=1) and digging (n=1)) had very low dust levels so these were not assayed for crystalline silica. For the descriptive analyses of silica content in these cases it was assumed that silica levels were half of the lowest observed concentrations in this study, ie, 1.05mcg/m^3. As dust and RCS exposure data followed a log-normal distribution, results were expressed as geometric means (GM) and geometric standard deviations (GSD), stratified by work task.

Results

The personal respirable dust levels ranged from below the limit of detection to 47.4mg/m^3, with 12 of the 39 samples (ie, 31%) exceeding the NZ WES and the ACGIH TLV recommendation of 3mg/m^3. The majority of samples exceeding this limit were collected from workers polishing or grinding concrete, with average (GM) levels of 4.2 and 5.5mg/m^3 respectively. The average levels were considerably lower for other tasks, although samples taken from workers drilling concrete and cutting Linea board both included samples above 3mg/m^3. None of the nine static or area samples exceeded the respirable dust WES. The personal RCS levels ranged from below the limit of detection to a maximum of 4.767mg/m^3. In total, 17 of the personal samples (44%) exceeded the NZ WES of 0.1mg/m^3, while 22 (56%) exceeded the ACGIH TLV of 0.025mg/m^3 (Table 1). The highest levels were observed in concrete polishers and grinders with average (GM) concentrations of 0.306mg/m^3 and 0.657mg/m^3 respectively. While the levels measured in personal sampling varied widely, even within similar tasks, each task assessed included at least one sample in excess of the ACGIH TLV and in most the NZ WES was also exceeded at least once. None of the nine static RCS samples exceeded the NZ WES, but two out of four samples taken near the cutting of silica-containing Linea board did exceed the ACGIH TLV, indicating the potential for bystander exposure.

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Table 1: Personal respirable crystalline silica levels by work task.

Work task	N	GM (mg/m^3)	GSD	Range (mg/m^3)	>NZ-WES (%)	>ACGIH-TLV (%)
Grinding concrete	10	0.657	5.4	0.012–3.207	90	90
Polishing concrete	5	0.306	21.3	0.003–4.767	60	80
Cutting concrete	1	0.100	-	-	100	100
Crushing concrete	3	0.026	4.7	0.004–0.074	0	67
Cutting Linea board	4	0.017	11.2	0.002–0.486	25	25
Bobcat/digger driving	5	0.009	8.0	0.001–0.143	20	40
Drilling concrete	4	0.007*	23.7	0.001–0.762	25	25
Jackhammering	2	0.006	12.4	0.001–0.037	0	50
General labouring	5	0.004*	10.2	0.001–0.222	20	20

N=Number of samples. GM= Geometric mean. GSD=Geometric standard deviation.
*Non-detectable samples, assumed to be 0.001mg/m^3, were included in the calculation of the GM.

Discussion

This study has shown that both respirable dust and crystalline silica exposures in workers conducting common tasks in the construction sector regularly exceed the NZ WES and the ACGIH TLV recommendation. Our results may not be representative of average levels of exposure in all construction workers, but the silica levels measured are consistent with those reported for workers performing similar construction industry tasks in studies from other countries.[14–16] In addition, a recent large cross-sectional survey of the Australian working population has shown that 80% (95% CI 69.1, 90.9) of construction workers have some exposure to RCS, and that 61.8% (95% CI 48.6, 75.1) have exposures in excess of the WES.[17] From the results of our study, the exposure levels reported in other countries, and the Australian exposure prevalence, estimates it would be reasonable to assume that a substantial proportion of the New Zealand construction industry workforce experiences excessive exposure to RCS. This is of concern given that the construction industry is the fifth largest sector in the New Zealand economy, employing >8% of the workforce with more than 193,000 workers.[18]

When we compared the results of this survey with the current NZ WES of 0.1mg/m^3 for RCS we found that 44% of samples exceeded this standard. Occupational exposure limits are set in most countries after review of the available epidemiological evidence and consultation with industry. For example, the Australian exposure standard was reduced from 0.2 to 0.1mg/m^3 in 2004, the UK Workplace Exposure Limit was reduced from 0.3 to 0.1mg/m^3 in 2006, and in the US the enforceable Occupational Safety and Health Administration Permissible Exposure Limit was set at 0.05mg/m^3 in 2016. It should be noted that the methods available for sampling and analysis of personal worker exposures have an effective lower order of detection of 0.02mg/m^3 for quartz and 0.04mg/m^3 for cristobalite.[19] Although the NZ WES was updated in 2016,[10] it has not taken full account of the current epidemiological evidence showing significant adverse health effects at much lower levels. For example, a risk assessment based on international epidemiological data has indicated that 45 years of occupational exposure at the current NZ WES of 0.1mg/m^3 is associated with a lifetime excess mortality risk of 13 to 60 per 1,000 workers for lung cancer, 11 to 83 per 1,000 for silicosis and non-malignant respiratory disease, and 39 per 1,000 for renal disease.[11,12] The excess lung cancer risk in particular is much higher than the residual risk of 1 per 10,000 to 1 per 1,000,000 that is generally considered “acceptable” by organisations that perform quantitative risk assessment to derive occupational exposure limits.[20,21] We consider it more appropriate, therefore, to compare these results with the more stringent ACGIH TLV of 0.025mg/m^3, which was exceeded by 56% of the samples taken. Even at this level of exposure, risks remain, with lifetime mortality risk estimated to range from 3 to 23 per 1,000 workers for lung cancer, 4 to 22 per 1,000 for silicosis and non-malignant respiratory disease and 25 per 1,000 for renal disease.[11] While studies on work-related exposures and health outcomes in New Zealand construction workers are rare, there is some evidence of increased risk of lung cancer in this sector. One New Zealand study of mortality by occupation found an increased risk of lung cancer (SIR=130, 95% CI 120–433) in bricklayers and carpenters.[22] A more recent New Zealand population-based lung cancer case-control study showed that, after adjustment for smoking, both builder's labourers (OR=3.2, 95% CI 1.4–7.1) and bricklayers/stonemasons (OR=5.7, 95% CI 1.2–25.8) had significantly increased risk of lung cancer.[23]

In conclusion, in addition to the well-recognised risk to workers in mining, quarrying and sandblasting, this pilot study has shown that a sizeable proportion of workers performing routine tasks in the construction industry in New Zealand are also likely to be exposed to RCS levels that exceed national and international standards. These results suggest that workers in this industry may be at risk of developing silica-related diseases, including silicosis, lung cancer, COPD and chronic renal disease, and that there is a need for action to reduce exposure levels. As with all occupational diseases, the silica-related health effects are largely preventable provided that airborne exposures are minimised and/or workers are adequately protected against inhalation.

Competing interests:
Nil.
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