HSE

Respirable crystalline silica exposure during demolition activity

Prepared by researchers at the
Health and Safety Executive

RR1202 (2024)
Research Report

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Prepared 2023
First published 2024

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Demolition workers are exposed to various hazardous substances including respirable crystalline silica (RCS). This can cause chronic lung diseases like silicosis, lung cancer and chronic obstructive pulmonary disease (COPD). Research was commissioned to identify appropriate, achievable RCS control standards for demolition activity and to assess exposures with them applied. It involved both site visits and a literature search.

Nine site visits were undertaken to four different companies who were pro-actively focussed on managing RCS. Forty-one RCS exposure measurements were made for the demolition work seen. Results were compared against the Workplace Exposure Limit (WEL) for RCS of 0.1 mg/m3 as an 8-hr Time Weighted Average. The majority (75.6%) were less than 25% of this WEL. Only one exposure measurement exceeded it.

The literature search found little published data on RCS exposures in demolition. Exposures measured in this research are at the low end of the spectrum when compared to what exists. This could be expected given participant's pro-active focus on managing RCS and means they cannot be viewed as representative of the GB demolition sector overall.

Conclusions on effective exposure controls for the tasks seen during the site visits are summarised in this research. They inform HSE's position on adequate controls under the Control of Substances Hazardous to Health Regulations (COSHH) for demolition activities.

This report and the work it describes were funded by the Health and Safety Executive. Its contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy.

Respirable crystalline silica exposure during demolition activity

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Ethics Statement

All site visits were carried out in accordance with the internal ethics procedures in place at the time the visits were carried out.

Key Messages

HSE estimates that there are 12,000 deaths every year due to lung disease linked to past exposures at work. One of the biggest causes of these deaths is respirable crystalline silica (RCS). The construction industry, which includes demolition activity, is recognised as a sector with a significant incidence of lung disease linked to RCS.

The aim of this work was to identify appropriate, achievable exposure control standards for demolition and to assess RCS exposures where these standards are applied. It consisted of two elements: site visits to companies to assess actual RCS exposure during demolition activities and a literature search to highlight other exposure data already available.

HSE approached companies to take part on a voluntary basis. Those approached were pro-actively focussed on managing RCS exposures associated with their demolition activities. The data from this study therefore represents what was achievable with a range of controls in place. It cannot be taken as representative of the Great Britain demolition sector overall.

A total of nine visits to four different companies were carried out to assess RCS exposures. Exposure monitoring was undertaken and the effectiveness of controls in place was assessed. A total of 41 8-hour time weighted average (8-hr TWA) RCS exposures were measured. Of these, 31 (75.6%) were less than 25% of the workplace exposure limit (WEL) for RCS of 0.1 mg/m^3 as an 8-hr TWA. Only one exposure measurement of a crusher operator, exceeded the WEL. WEL's are set to help protect worker health.

Data is sparse in the published literature on RCS exposures in demolition. The exposures measured in this project are at the low end of the spectrum when compared with published data. This could be expected given participant's pro-active focus on managing RCS exposures.

Conclusions on effective exposure controls for the tasks seen are summarised in this research. These are based on good occupational hygiene practice, combined with the observations, intelligence and exposure data gathered. They inform HSE's position on adequate controls under the Control of Substances Hazardous to Health Regulations (COSHH) for demolition activities.

Executive Summary

Introduction

The Health and Safety Executive (HSE) has a number of strategic objectives including one to reduce work-related ill health. There are an estimated 12,000 deaths annually in Great Britain (GB) as a result of occupational lung disease (OLD). The construction industry, which includes demolition activity, is recognised as a sector with a significant incidence of OLD. It is therefore highlighted as one of a number of sectors where HSE would like to see greater improvements in prevention and control of exposure to agents causing OLD.

Demolition workers have the potential to be exposed to various substances hazardous to health, including respirable crystalline silica (RCS). RCS, if inhaled, can lead to chronic lung diseases such as silicosis, lung cancer and chronic obstructive pulmonary disease (COPD).

This report summarises HSE work carried out on the risk of RCS exposure during demolition. The aim of this work was to identify appropriate, achievable exposure control standards for demolition and to assess RCS exposures where these standards are applied.

Methods

HSE approached companies to take part on a voluntary basis and undertook nine visits to four companies and five different sites. Those approached were known to be pro-actively focussed on managing RCS exposures associated with their demolition activities. The data from this study represents what was achievable with a range of controls in place.

Main Findings

A total of 41 worker RCS exposure measurements were taken over the course of the visits. Exposures were categorised into one of nine different tasks, depending on the demolition task(s) carried out by each worker. The workplace exposure limit (WEL) for RCS is 0.1 mg/m^3 (expressed as an 8-hour time weighted average (8-hr TWA)). The table below summarises the exposure measurements taken.

Summary table of RCS exposures (not accounting for any respiratory protective equipment (RPE) worn)

RCS exposure level	Number of data points (total = 41)	Percentage of total results (%)	Notes
<25% WEL	31	75.6	Workers were undertaking various activities
25 - 50% WEL	4	9.8	Workers were carrying out breaking or floor sawing
51 - 75% WEL	4	9.8	Workers were carrying out breaking activities
76 - 100% WEL	1	2.4	Worker was carrying out breaking activities
>WEL	1	2.4	Worker was operating a crusher

A range of control measures were in place for the different tasks. Some deficiencies were noted during the visits. Water suppression was the most used exposure control technique but was not always present for the breaking activity. When water suppression was used, lower RCS exposures were measured, but it was found to be only partially effective as visible emissions were still observed. This suggests further improvements are possible. Not all sites had a robust and consistent water supply. This meant that not all water suppression systems could always be run simultaneously, especially if the water supply was required for other reasons.

All plant vehicles seen on the visits were fitted with in-cab filtration which was routinely serviced and maintained. RCS exposures of the ten plant drivers did not exceed 0.03 mg/m^3 and eight were less than the limit of detection (LOD) (approximately 0.02 mg/m^3) indicating good control.

On tool extraction was not seen in use on hand tools in any of the visits carried out. Information identified in the literature search indicated that this can be an effective control.

Respiratory Protective Equipment (RPE) with an assigned protection factor (APF) of 20, e.g., masks with P3 filters, was available at all sites visited. Face fit testing was confirmed to have been carried out at four of the five sites visited. RPE was observed in use at two sites with deficiencies noted in both cases.

Informal discussions with workers at all sites indicated that there was good general worker awareness of the potential ill health effects associated with the risk of RCS exposure.

A literature search was also carried of relevant material published up to 2022. This indicated that a relatively small amount of information and intelligence exists within the global occupational hygiene community on RCS exposures in demolition for developed nations such as GB. The data found suggests that the RCS exposures measured as part of this survey are lower than other countries with comparable health and safety standards, although there is limited data and, given the selection criteria for inclusion in this work, perhaps not unexpected.

Conclusions

A snapshot of RCS exposures and industry exposure control practice for the GB demolition sector has been obtained from companies that participated voluntarily. The results obtained cannot be taken as representative of the GB demolition sector overall.

Conclusions on effective exposure controls for the tasks seen are summarised in this research. These are based on good occupational hygiene practice, combined with the observations, intelligence and exposure data gathered. They inform HSE's position on adequate controls under the Control of Substances Hazardous to Health Regulations (COSHH) for demolition activities.

Contents

1 Introduction

This report summarises work carried out by the Health and Safety Executive on the risk of respirable crystalline silica (RCS) exposure in the demolition sector of the construction industry. The aim of this work was to identify appropriate, achievable exposure control standards for demolition and to assess RCS exposures where these standards are applied. The programme of work also included carrying out a literature review to identify information on RCS exposures and exposure controls in the demolition industry.

The Health and Safety Executive (HSE) has several strategic objectives including one to reduce work-related ill health. There are an estimated 12,000 deaths annually in Great Britain (GB) as a result of occupational lung disease (OLD). Construction is recognised as a sector with a significant incidence of OLD. It is therefore highlighted as one of a number of sectors where HSE would like to see greater improvements in prevention and control of exposure to agents causing OLD.

Workers in the demolition industry have the potential to be exposed to various substances hazardous to health, including RCS. RCS, if inhaled, can lead to chronic lung diseases such as silicosis, lung cancer and chronic obstructive pulmonary disease (COPD) (NIOSH 2002).

There is a legal requirement to adequately control exposure to such substances under the Control of Substances Hazardous to Health Regulations (COSHH) (2013a). Under COSHH Regulation 7(7), control is defined as adequate only if the principles of good practice (in Schedule 2A of COSHH) are applied, exposure is below the workplace exposure limit (WEL), and if the control measures are proportionate to the health risk. The WEL for RCS in GB is 0.1 mg/m^3 as an 8-hour time weighted average (8-hr TWA) exposure (HSE, 2020a). WELs are a starting point for action and must not be exceeded. The COSHH Regulations also state that any dust (which includes dust generated by demolition activity) can be hazardous to health, even if it does not contain RCS, “when it is present at concentrations in the air equal to or greater than 10 mg/m^3 (as a time-weighted average over an 8-hour period) of inhalable dust or 4 mg/m^3 (as a time-weighted average over an 8-hour period) of respirable dust.”

There is a variety of information and guidance of relevance to the demolition sector available to help understand and control the risks of RCS exposures. This is discussed in Section 4.4.

2 Site Visits

A summary of the visits, activities studied, and samples taken is shown in Table 1. A full description of each visit is included in the appendices. Participation in the research was voluntary, and the companies approached to take part were selected on the basis that they carried out activities of interest and were generally good health and safety performers.

Table 1. Summary of HSE demolition visits.

Visit details	Activities performed	Type of site	Number of workers sampled (Number of 8-hr TWA exposures determined)	Number of static sample locations
Company 1, site 1	Munching of concrete rubble by 360 ° excavator	Demolition site	2 (0)	9
Company 2, visit 1	Manual demolition by non-powered hand tools and cutting torches, breaking concrete by excavator	Demolition of multiple buildings on single site	7 (7)	5
Company 2, visit 2	Grading of soil by excavator, demolition, and processing by excavator	Demolition of multiple buildings on single site	7 (7)	5
Company 3	Crushing and screening of demolition debris	Recycling of demolition waste	3 (3) *	10*
Company 4	Removal of decorative stone cladding by handheld breaker	Building refurbishment	4 (4)	0

Visit details	Activities performed	Type of site	Number of workers sampled (Number of 8-hr TWA exposures determined)	Number of static sample locations
Company 1, site 2, visit 1	Core hole drilling and manual demolition of a structure	Demolition of multi storey car park	4 (4)	2
Company 1, site 2, visit 2	Floor sawing, breaking and core hole drilling	Demolition of multi storey car park	6 (6)	3
Company 1, site 2, visit 3	Floor sawing, breaking, core hole drilling, crushing	Demolition of multi storey car park	5 (5)	3
Company 1, site 2, visit 4	Floor sawing, breaking, remote breaking, crushing and processing of rubble	Demolition of multi storey car park	8 (8)	2

*Note, data for Company 3 is not included in dataset as due to sampling flow rate fluctuations, the monitoring results are likely to be overestimates.

3 Methods

3.1 Full-shift air monitoring

Air samples for respirable dust and RCS were taken at both personal and fixed locations. In a small number of cases inhalable dust monitoring was also carried out (fixed locations only). Personal samples were taken from within the worker's breathing zone.

The method used to collect the air samples is described in Methods for the Determination of Hazardous Substances (MDHS) 14/4 "General methods for sampling and gravimetric analysis of respirable, thoracic and inhalable aerosols" (HSE, 2014). Cyclone samplers (Casella) were used to sample respirable dust. Each sampler was loaded with a GLA 5000 filter. The sampler was connected to an air sampling pump with the flow rate set to 2.2 litres/min.

IOM sampling heads, fitted with metal cassettes and GF/A filters, were used to sample inhalable dust. The sampler was connected to an air sampling pump with the flow rate set to 2 litres/min. The purpose of inhalable dust monitoring was to inform the inhalable/respirable composition of the dust present.

3.2 Short-term task specific monitoring

For some specific activities, task-based short-term samples were also taken. Utilisation of high-volume cyclone samplers was required, as the higher flow rate allowed a greater volume of air to be sampled thus lowering the limit of detection (LOD) to a more acceptable level.

High volume cyclone samplers (Mesalabs Rascals) were used to sample respirable dust. Each sampler was loaded with a GLA 5000 filter. The sampler was connected to an air sampling pump with the flow rate set to 9 litres/min.

Simultaneous real time measurements were taken using a TSI Side-Pak real time dust monitor, with the data logged to provide time resolved information. The TSI Side-Pak detects particles which pass through an optical cell and is based on the principle of light scattering. These types of instruments are not specific to RCS particles and detect all particles in a particular size range (up to around 10 microns in diameter). Hence the results generated are normally considered to be approximate to the sampling results provided by respirable pumped samplers.

Post sampling, comparisons between the pumped high volume respirable sampling results and the real time data were made to review the validity of the real time monitoring results.

3.3 Sample analysis

The IOM and cyclone samples were analysed gravimetrically for inhalable dust and respirable dust respectively. The cyclone samples were then analysed for RCS content using X-ray diffraction (XRD) based on MDHS 101/2 “Crystalline silica in respirable airborne dusts. Direct-on-filter analyses by infrared spectroscopy and X-ray diffraction” (HSE, 2015). Where considered necessary to assist with understanding the exposure measurements, bulk samples of materials worked on over the various visits were taken and analysed by XRD to determine crystalline silica content.

The 8-hr TWA exposures were calculated on the assumption that the workers were exposed at the measured air concentration for their entire shift, except during breaks. Samples were taken over sufficiently long periods of time, and additional contextual information was gathered to ensure that this was a valid assumption.

3.4 Contextual information

On each site visit the HSE occupational hygienist collected relevant information to enable better contextual interpretation of the results. Information was collected as per the details of paragraph 223 in the Approved Code of Practice (ACoP) to COSHH (HSE 2013a). It is summarised in the appendices.

3.5 Data classification

Exposure data were classified by the following tasks:

- Plant vehicle driver – covers workers driving/operating plant machinery, including excavators and loading shovels;
- Manual demolition – covers workers carrying out demolition activities without the use of powered hand tools;
- Breaking – covers workers using pneumatic jackhammers/breakers;
- Breaking plus other activities – as ‘Breaking’ but with other (unspecified) activities being carried out as well;

- Banksman/groundworker - covers workers acting as banksmen or carrying out ground based activities not directly related to dust generating activities but who may be affected by them;

- Core drilling – covers workers carrying out core drilling using either handheld or rig mounted core drills;

- Floor sawing – covers workers carrying out floor sawing, using walk behind floor saws;

- Crusher operator – covers workers operating rubble crushing or screening equipment; and

- Other – covers any workers carrying out duties not already categorised.

3.6 Literature search

A search was carried out by HSE staff on relevant literature published up to 2022. An initial search was scoped to find information on "worker exposures during demolition activities" to "respirable dust" and/or "respirable crystalline silica". A subsequent search for information on "exposure controls for demolition activities which reduce airborne exposures" was also made. Searches focussed on obtaining information from developed nations in order to keep it relevant to GB.

The HSE search team used a number of databases including Web of Science, Oshupdate, Proquest (inc; Iconda, Healsafe, ABI Inform, Medline, DH Data, Global Health and GG Trade & Industry). A search of so- called "grey literature" was also carried out.

The abstracts highlighted by the searches were sifted by a chartered occupational hygienist for relevance. Where considered to be of interest, the full texts were requested. The dust/RCS exposure data search gave 46 abstracts of potential interest, from which 15 full texts were requested. Six of the 15 were considered of direct relevance and interest and are referenced in this report. The exposure control search gave 26 abstracts of potential interest, from which 13 full texts were requested. Three of the 13 were considered of direct relevance and interest and are referenced in this report.

On reading the relevant papers obtained in the initial sift, , further abstracts of interest were found, and the full texts were requested; three on exposure data and nine on exposure control. The full texts were reviewed and two on exposure data and five on exposure control are referenced in this report.

A search of the HSE National Exposure Database (NEDB) was carried out for exposure data in demolition in the following categories "Demolition and wrecking and buildings, earth moving", "General construction and demolition work" and "Renting of construction and demolition equipment with operator" were found. The search indicated that very little exposure data exist for demolition activities, most of which relate to asbestos and heavy metal exposures.

A broader search of NEDB was conducted covering RCS in the construction sector but no data relating to demolition were found for the year 2000 onwards except for two visits carried out as part of the silica baseline survey (HSE, 2009).

Data from activities such as screening, crushing, and heavy plant driving from other industries such as quarrying were not used. The project team were interested in demolition industry specific exposures.

4 Results

4.1 Exposure data and control information obtained on site visits

Table 2 summarises the RCS exposure data and control information gathered during visits to four companies at five sites, when classified by task as described in section 3.5. Respirable dust results are summarised in Appendix 6. The air sampling data obtained from Company 3 were subject to significant flow rate variation and so are likely to be overestimates - as a result, they are not presented in Table 2 or Appendix 6. A geometric mean (GM) was not calculated for each task category as there were insufficient data to so do. Given the high prevalence of results less than the LOD, a GM was not calculated for the overall RCS dataset, as it is not statistically valid to do so.

The exposure data in this report were collected between November and April, in the cooler and wetter months. There is the possibility of higher exposures in the warmer months as the ground is likely to be drier and thus the potential for airborne dust generation is greater.

Table 2. Summary of worker RCS exposure data, presented by task type (not adjusted for any respiratory protective equipment (RPE) worn).

Task	**Number of 8-hour TWA RCS exposure data** **(Number of sites visited shown in brackets)**	**Number of RCS exposures <LOD****	**8-hour TWA RCS exposure range (mg/m³)**	**Exposure controls used at sites carrying out these tasks**
Plant driver	10 (2)	8	<0.01 – 0.03	Both sites - In cab filtration used (standard of filtration not known)
Manual demolition	4 (2)	4	All <0.02	Site 1 – None
Breaking	6 (1)	0	0.024 – 0.085	None although reportedly company policy to use water suppression, inconsistent use of RPE (some deficiencies where worn)
Breaking plus other activities	5 (2)	1	<0.018 – 0.06	Site 1 - Water suppression (partially effective) used and RPE (some deficiencies)
Banksman / groundworker	5 (2)	5	<0.02	Segregation of activities, general dust suppression, bespoke water suppression

Task	Number of 8-hour TWA RCS exposure data (Number of sites visited shown in brackets)	Number of RCS exposures <LOD**	8-hour TWA RCS exposure range (mg/m^3)	Exposure controls used at sites carrying out these tasks
Core drilling	3 (1)	3	<0.02	Water suppression on core drilling, no exposure control during pilot hole drilling for stabilising rigs
Floor sawing	4 (1)	3	<0.015 – 0.045	Water suppression
Crusher operator	1 (1)	0	~0.12*	Water suppression
Other	3 (2)	3	<0.021	Both sites - Segregation of activities, general dust suppression
All data	41 (5)	27	<0.01 – 0.12*	-

* Minor flow rate discrepancy, result considered approximate

** Note the LOD varies.

4.2 Real-time monitoring summary

Table 3 shows a summary of real time monitoring data obtained together with matched pumped sampling data.

Table 3. Summary of real time monitoring data and matched pumped sampling data.

Description	**Sample duration (minutes)**	**Real time dust (Reported concentration mg/m³)**	**RCS MDHS 101 (Reported concentration mg/m³)**	**Respirable dust MDHS 14/4 (Reported concentration mg/m³)**
Core drilling worker	63	0.061	<0.02	<0.07
Core drilling worker	65	0.018	<0.02	<0.07
Manual demolition worker	69	0.194	<0.02	0.31
Floor saw operator	67	0.066	<0.017	0.117
Floor saw operator	60	0.032	<0.019	<0.47
Worker carrying out breaking	47	0.026	0.039	<0.128
Background static 1	390	0.02	<0.02	<0.03
Background static 2	359	0.03	<0.02	<0.03
Background static 3	414	0.02	<0.02	<0.03
Background static 4	329	0.04	<0.01	<0.02
Background static 5	345	0.04	<0.01	0.04
Background static 6	318	0.10	<0.01	0.02

4.3 Efficacy of in-cab filtration

On one of the site visits, static dust monitoring was carried out both inside and outside the cab of an excavator which was being used in a fixed location to load the hopper of a crusher. The data are shown in Table 4. Although this was a single sample it demonstrates the potential reduction possible as a result of in-cab filtration and that respirable dust can often be a small proportion of the inhalable dust present.

Table 4. Summary of static air monitoring data taken inside/outside an excavator cab at Company 4.

Sample type	Outside cab Concentration (mg/m^3)	Inside cab Concentration (mg/m^3)	Percentage reduction in-cab (%)
Inhalable dust	5.54	0.19	97
Respirable dust	0.089	<0.008	>91
Respirable dust (real time measurement)	0.067	0.008	88
RCS	0.019	<0.011 (LOD)	>42*

* This figure is likely imprecise as the outside cab result is quite close to the LOD figure.

There is the possibility that in warmer months, in vehicles without air-conditioned cabs, the windows or doors are opened to provide cooling, thus adversely affecting the efficiency of the in-cab filtration systems and increasing the RCS exposure of the operators.

4.4 Summary of literature review

4.4.1 Summary of exposure information

Previous HSE work in the construction sector includes a large silica baseline survey project (HSE, 2009). As part of this work, two visits were made to sites carrying out the processing of demolition waste i.e. screening and crushing of rubble. RCS exposures of six workers did not exceed 0.06 mg/m^3 (8-hr TWA), the highest exposure being that of a crusher operator. No other demolition activities were studied as part of the silica baseline survey.

A group of American researchers assembled a large body of RCS exposure data from the construction industry, covering the period 1992 - 2002 from Government, academic and private sources (Flanagan *et al,* 2006). A total of 1374 RCS exposures were found, and the data analysed in a number of ways, including sorting by task, tool and trade. By task, the GM of RCS exposures for "hand-held demolition" was 0.14 mg/m^3 (n=226), although it is not clear whether this includes the use of powered hand-held tools. For the task "heavy equipment demolition" the GM of RCS exposures was 0.03 mg/m^3 (n=45). By tool, the GM RCS exposures were 0.15 mg/m^3 (n=178) for use of "jackhammer/chipping gun" and 0.09 mg/m^3 for use of "walk behind saw".

A group of Canadian researchers carried out a review of construction workers RCS exposure compiling a database from literature, databases and public and private sources (IRSST 2013a, 2013b). In compiling the database, exposure data and exposure control information was extracted covering the period 1987 - 2007 and included data from a number of countries not just Canada. This database comprised of more than 4000 RCS exposure measurements, including data relevant to the demolition sector. In the database there were 1346 entries categorised by occupation, including 115 data points on demolition which had a GM RCS exposure of 0.09 mg/m^3 (8-hr TWA). These data can be seen in Table 5 of report R-801 (IRSST 2013b). The researchers also categorised exposures by task carried out, which included tasks of interest for demolition. Breaking gave the following task-based GM RCS exposures (taken from Table 6 of report R-801);

- Breaking by jackhammer GM 0.46 mg/m^3 (n=56);
- Breaking by multiple tools (including jackhammer/percussion tools) GM 0.94 mg/m^3 (n=88);
- Breaking by other tools GM 0.13 mg/m^3 (n=21);
- Demolition GM 0.03 mg/m^3 (n=32).

Table 5 of report R-771 (IRSST, 2013a) summarises the reported percentage reductions in RCS and respirable dust exposures for exposure controls on certain tasks. This included breaking (jackhammering) of concrete, for which the authors found five papers that looked at the efficacy of LEV and integrated water suppression systems. Reported reductions in RCS exposure were between 64 and 86%.

Table 9 of report R-801 summarises the estimated effects of different exposure determinants including the nature of the project; renovation work, new construction or demolition. Renovation was taken as the reference point (100%). New construction exposures were 55% of the reference and demolition exposures were 107% (i.e., they estimated that RCS exposures in demolition are nearly double that of those working in new construction projects).

A Dutch paper (Tjoe Nij et al. 2002) was included in the Canadian work (IRSST 2013a, 2013b). The RCS exposures of 10 demolition workers, included as part of a group of 30 construction workers, were measured. The RCS exposure range for the 10 workers (from 21 exposure measurements) was 0.038 – 1.3 mg/m^3 with a GM of 0.14 mg/m^3.

The literature search highlighted five papers of relevance after the work reported in R-771 and R-801. Radnoff et al. (2014) reported RCS exposures collected in Alberta between 2009 and 2013 at 40 sites across 13 industry groups. A total of 332 RCS exposures from 287 workers were reported. This included 10 exposures from the demolition sector, for which the range was 0.017 – 0.065 mg/m^3 and the GM was 0.027 mg/m^3.

Van Deurssen et al. (2014) reported the exposures of 116 Dutch constructions workers, including 32 workers carrying out demolition activities. 45 exposure measurements were taken on the 32 different workers (at two different companies) and RCS exposures were in the range 0.01 – 0.91 mg/m^3 with a GM of 0.12 mg/m^3.

Van Duerssen et al. (2015) also later reported the findings following an intervention exercise with the same cohort used in their 2014 reported study. In the follow up exercise 25 RCS exposures of demolition workers were determined in the range 0.01 – 0.44 mg/m^3 with a GM of 0.04 mg/m^3. This included 13 exposures from a control group (where no intervention was made) and 12 exposures from the intervention group. For the control group the GM RCS exposure was 0.08 mg/m^3. For the intervention group the GM RCS exposure was 0.02 mg/m^3. The intervention carried out comprised four main elements; two plenary sessions, a workplace visit and a workshop. The intervention did result in increased usage of existing control measures and development of new controls in some cases.

Kirkeskov et al. (2016) compared the RCS exposures of Danish carpenters to those of demolition workers, both whilst working indoors. Eleven RCS exposures were measured for demolition, with a range from less than the LOD (not specified) to 0.92 mg/m^3 and a GM of 0.12 mg/m^3. The four work activities by which the work was categorised were manual demolition, mechanical demolition, waste management and cleaning. Although based only on a handful of data, they noted higher exposures for manual demolition (although it is not clear whether this includes the use of powered hand-held tools) compared to mechanical demolition.

Bello et al. (2018) measured RCS exposures during demolition, crushing and chipping (assumed to be the same task as that classified in this report as breaking) activities at eight sites. The exposures were classified by the following tasks: chipping workers, crushing machine tenders, demolition labourers and operating engineers (during both demolition and crushing). It is assumed that operating engineer classification is broadly similar to the task of plant driver used in this report. The highest RCS exposures were associated with chipping (GM = 0.53 mg/m^3, range 0.1 – 1.55 mg/m^3) followed by the crushing machine tenders (GM = 0.093 mg/m^3, range 0.021 – 0.22 mg/m^3). Lowest exposures were associated with demolition labourers and operating engineers (see Table 5).

It should be noted that, as is normal in the presentation of occupational hygiene data, all exposures quoted in this section do not take account of any RPE worn.

Table 5 summarises the relevant exposure data found in the literature search, sorted by task. Table 6 summarises the exposure data by occupation.

It was not possible to draw any meaningful information on overall trends in exposure controls used for demolition from the papers. There was useful information relating to the efficiency of some exposure controls and this is discussed later in this section.

Table 5. Summary of exposure data gathered during literature search, by task.

Source	**Year**	**Country data came from**	**Task**	**Number (total in entire dataset)**	**RCS exposure mg/m^3 Geometric Mean (GM)**	**RCS exposure mg/m^3 Range**
Flanagan et al. (2006)	1992-2002	Various	Handheld demolition	226 (1374)	0.14	n/a
Flanagan et al. (2006)	1992-2002	Various	Heavy equipment demolition	45 (1374)	0.03	n/a
IRSST (2013)	1987-2007	Various (>80% North American, 17% European)	Breaking by jackhammer	56 (1466)	0.46	n/a
IRSST (2013)	1987-2007	Various (>80% North American, 17% European)	Breaking by multiple tools*	88 (1466)	0.94	n/a

Source	Year	Country data came from	Task	Number (total in entire dataset)	RCS exposure mg/m³ Geometric Mean (GM)	RCS exposure mg/m³ Range
IRSST (2013)	1987-2007	Various (>80% North American, 17% European)	Breaking by other tools	21 (1466)	0.13	n/a
IRSST (2013)	1987-2007	Various (>80% North American, 17% European)	Demolition	32 (1466)	0.03	n/a
HSE Report RR689 Annex 2	2005 - 2007	GB	Processing of demolition waste	6 (29)	n/a**	<0.01 – 0.06
Kirkeskov et al. (2016)	2015***	Denmark	Manual demolition	2 (11)	0.69	0.67 – 0.71
Kirkeskov et al. (2016)	2015***	Denmark	Mechanical demolition	4 (11)	0.23	0.02 – 0.45
Bello et al. (2019)	2018***	North America	Chipping workers	31 (51)	0.53	0.1 – 1.55
Bello et al. (2019)	2018***	North America	Crushing machine tenders	8 (51)	0.093	0.021 – 0.22

Source	Year	Country data came from	Task	Number (total in entire dataset)	RCS exposure mg/m³ Geometric Mean (GM)	RCS exposure mg/m³ Range
Bello et al. (2019)	2018***	North America	Demolition labourers	3 (51)	0.017	0.008 – 0.05
Bello et al. (2019)	2018***	North America	Operating engineers	9 (51)	0.0062	<LOD**** - 0.029

* Including jackhammer/percussion tools

** GM not calculated due to small amount of data and four of the six results were <LOD

***Estimated date

**** LOD not quoted

Table 6. Summary of exposure data gathered during literature search, by occupation.

Source	Year	Country data came from	Occupation	Number (total in entire dataset)	RCS exposure mg/m³ Geometric Mean (GM)	RCS exposure mg/m³ Range
IRSST (2013)	1987-2007	Various (>80% North American, 17% European)	Demolition	115 (1346)	0.09	n/a
Tjoe Nij et al. (2002)	2002	Netherlands	Demolition	10 (30)	0.14	0.038 – 1.3
Radnoff et al. (2014)	2009-2013	Canada	Demolition	10 (332)	0.027	0.017 – 0.065
Van Duerssen et al. (2014)	2011-2012	Netherlands	Demolition	45 (149)	0.12	0.01 – 0.91
Van Duerssen et al (2015)	2013-2014*	Netherlands	Demolition	25** (132)	0.04	0.01 – 0.44
Kirkeskov et al. (2016)	2015*	Denmark	Demolition	11 (11)	0.12	<LOD*** – 0.92

*Estimated date

** Overall dataset, includes data from control and intervention groups

*** LOD not quoted

4.4.2 Exposure control guidance

There are a series of HSE COSHH essentials guidance sheets available for various RCS generating construction activities. These include a number of sheets which are relevant for common demolition activities:

- CN4 – Crushing and screening demolition material (HSE, 2016a).
- CN8 – Diamond coring/hole cutting (HSE, 2016b).
- CN9 – Breaking in enclosed spaces (HSE, 2016c).

HSE information sheet CIS36 (HSE, 2020b) contains information on the risks from RCS and includes exposure control recommendations for a variety of constructions tasks. Information sheet CIS69 (HSE, 2013b) gives guidance on the use of on-tool extraction to control construction dust.

HSE has also published quarry industry guidance on controlling RCS exposures in control cabins and vehicle cabs (HSE, 2006a) which is of relevance for demolition.

HSE has previously carried out a review of the efficacy of on-tool extraction to control dust from a number of tools used in the construction sector (HSE, 2012). Whilst the tools and tasks are not directly relevant for demolition there is still potentially useful information to draw on regarding the efficacy of certain control types.

HSE has published a report on the use of in-cab filtration to control hazardous exposures in the quarry industry (HSE, 2018). The work included a number of respirable dust measurements taken inside and outside vehicle cabs. In general, concentrations were lower inside the cab than outside except in one instance. This was considered likely to be the result of the resuspension of contamination from surfaces inside the cab.

Echt et al. (2003) investigated the effect of water suppression and LEV (using two different shroud designs) on jackhammers. They found water suppression to be more effective at controlling respirable dust than LEV, with an exposure reduction of 72% compared to LEV where reductions were 48 and 59% for the different shroud types.

Publication BS 6187:2011 (BSI, 2011) is a “code of practice for full and partial demolition”, the scope of which includes “health and safety of people on or off site”. Sections of the document consider health-related issues, including dust and reference to EH40 (HSE, 2020a), but there is no specific mention of RCS. The standard also includes general guidance on demolition techniques using a hierarchy of control.

The British Occupational Hygiene Society (BOHS) has been running its “Breathe Freely” initiative since 2015, with the purpose of controlling exposures to prevent occupational lung disease. The construction sector is one of the priority areas of the campaign and there are a variety of resources to assist industry. This includes a fact sheet for demolition operatives (BOHS), which specifically mentions the risk of RCS exposure and gives useful information on potential control options.

The US Occupational Safety and Health Administration (OSHA) have published its small entity compliance guide for the respirable crystalline silica standard for construction (OSHA, 2017). This includes specifying acceptable control scenarios for a total of 18 different constructions tasks where RCS exposure may occur. This includes a number of scenarios that are of relevance for the demolition sector.

5 Discussion

A total of 41 worker RCS exposure measurements were taken over the course of nine visits to four companies and five different sites. This gives only a snapshot of exposures and working practices. It cannot be taken as representative of the GB demolition sector overall. Exposure measurements can vary significantly depending on several factors including workload, process, worker behaviour and weather conditions. Those involved were also participating on a voluntary basis and known to be pro-actively focussed on managing RCS exposures associated with their demolition activities. A range of control measures were in place for the different tasks although some deficiencies with these were noted during the visits. These were fed back to the participating companies to address.

The 8-hour TWA RCS exposures were all less than the WEL except for one result from a worker operating a crusher. Table 7 below summarises the results relative to the RCS WEL of 0.1 mg/m^3. The remaining five RCS exposures greater than 50% of the WEL (a total of five workers) were associated with breaking. Two of these five workers wore RPE. Informal discussions with workers at all sites indicated that there was good general worker awareness of the potential ill health effects associated with RCS exposure.

Table 7 Summary of RCS exposures (not accounting for any RPE worn).

RCS exposure level	Number of data points	Percentage of total results (%)	Notes
<LOD*	27	67.5	Workers were undertaking various activities
<25% WEL	31	75.6 #	Workers were undertaking various activities
25 - 50% WEL	4	9.8	Workers were carrying out breaking or floor sawing
51 - 75% WEL	4	9.8	Workers were carrying out breaking activities
76 - 100% WEL	1	2.4	Worker was carrying out breaking activities

RCS exposure level	Number of data points	Percentage of total results (%)	Notes
>WEL	1	2.4	Worker was operating a crusher

* Highest LOD was 0.023 mg/m^3, typically it was 0.02 mg/m^3

Those results that were <LOD are also included in the <25% WEL category.

Short term sampling, which included the use of high-volume sampling equipment, was carried out to identify any short duration tasks where there may be a risk that a notional short-term exposure limit (STEL) of 3 x RCS WEL might be exceeded (i.e., 0.3 mg/m^3 over a 15 minute period). The results obtained indicate that, for the activities seen, there was not a significant issue with elevated short-term exposures.

5.1 Crushing

The RCS exposure of a worker using a crusher to process demolition rubble was measured at Company 1 (site 2). The task involved both operating the crusher and working in the immediate area. However, there was a minor flow rate discrepancy for part of the sampling period and hence the result was considered approximate at 0.12 mg/m^3 (8-hr TWA). The result is indicative of significant exposure at or around the RCS WEL. Nearby static sampling data further support this, with RCS concentrations on the crusher platform being greater than 0.2 mg/m^3 (static sampling data not reported elsewhere in report). Whilst it is only a single data point, it is in the range reported by Bello et al. in their study of crushing machine operators (RCS exposure range 0.021 – 0.22 mg/m^3, GM = 0.093 mg/m^3). The worker operating the crusher did not wear RPE. The crusher was fitted with mains fed water suppression. Visible airborne water mist was produced from the edge of the conveyer belt at the transfer point. It is possible that some of this mist could contain RCS depending on the silica content of the debris being processed. The crusher was reportedly sometimes run without the water suppression providing the debris material being loaded into it was already wet. On occasions during the visit, the water line was detached from the impact crusher and used by an operative to wet down the main roadway through the site. On these occasions visibly more dust was generated by the crushing process. While the damping of roadways is an example of good control practice, there should be sufficient water supply to allow the crusher to be run with water suppression at the same time as general damping down. It was noted that the water line was not always refitted to the crusher immediately after finishing the damping down. Although the exposure measurement for the crusher operator was considered approximate, it still indicates that continuous water suppression and correct use of RPE with an APF of 20 (e.g. mask with P3 filter) would be appropriate controls for this task as outlined in HSE COSHH essentials guidance sheet CN4 (HSE, 2016a). The risk could be reduced or even eliminated if equipment design and use enable more remote operation by the worker.

From the visits to companies 1 (site 2) and 2, it was noted for crushing and screening tasks that the drop from the end of the crusher conveyor of processed debris material created a potentially significant source of dust depending on the drop height. The greater the drop height the greater the visible dust observed. Minimising the drop height and / or addition of a sock to contain some dust generated as the debris fell through it could reduce the amount of airborne dust produced.

5.2 Breaking

After crushing, the highest RCS exposures were measured during breaking activities. The literature search highlighted that breaking was typically associated with elevated exposures, including that reported by Bello *et al* where RCS exposures of up to 1.5 mg/m^3 were measured with a GM of 0.53 mg/m^3. Breaking was seen at two of the companies visited. Water suppression was in use at both companies and could have been improved in both cases. The system at Company 4 used a domestic garden sprayer which had a small reservoir (estimated 10 litre capacity) spraying out through a nozzle held by the second worker. The nozzle used created more of a direct water jet than a spray, and the water jet was directed at the point of impact. The reservoir also required regular refilling. This further slowed operations as there was no local water supply. The operations were viewed with a dust lamp and visible dust was observed routinely under these conditions. At the other site carrying out breaking, operated by Company 1 (site 2), it was reported that company policy was to use water suppression on breaking activities unless there were good reasons not to. Company 1 (site 2) used similar equipment to that described for Company 4. However, its use was inconsistent. On one occasion it was used and on another where longer periods of breaking were noted, it was not. Higher exposures were measured on the occasion where water suppression was not used.

For the two companies visited, the time spent breaking was limited by the need to manage vibration exposure by ensuring trigger times did not exceed that specified by the risk assessments. This was around two hours for Company 4. At Company 4 the work had only just started and comprised breaking of decorative stone cladding and precast concrete sections behind the cladding. The breaking of the cladding was relatively straightforward. However, breaking of the precast concrete sections was not and progress was very slow. Following the visit, Company 4 reported that core drilling was going to be used to remove the precast concrete sections to allow them to be lifted out by crane as complete sections. The breakers were also to have extraction fitted to them. Based on our observations, the water suppression used during breaking activities at the two companies visited did not seem to be an effective control. Despite control not being considered effective, no exposures greater than the WEL were measured during any breaking related activities. However, 5 of 11 exposures were at least 50% of the WEL. It is possible that better application of water suppression may provide better control and thus reduce exposures.

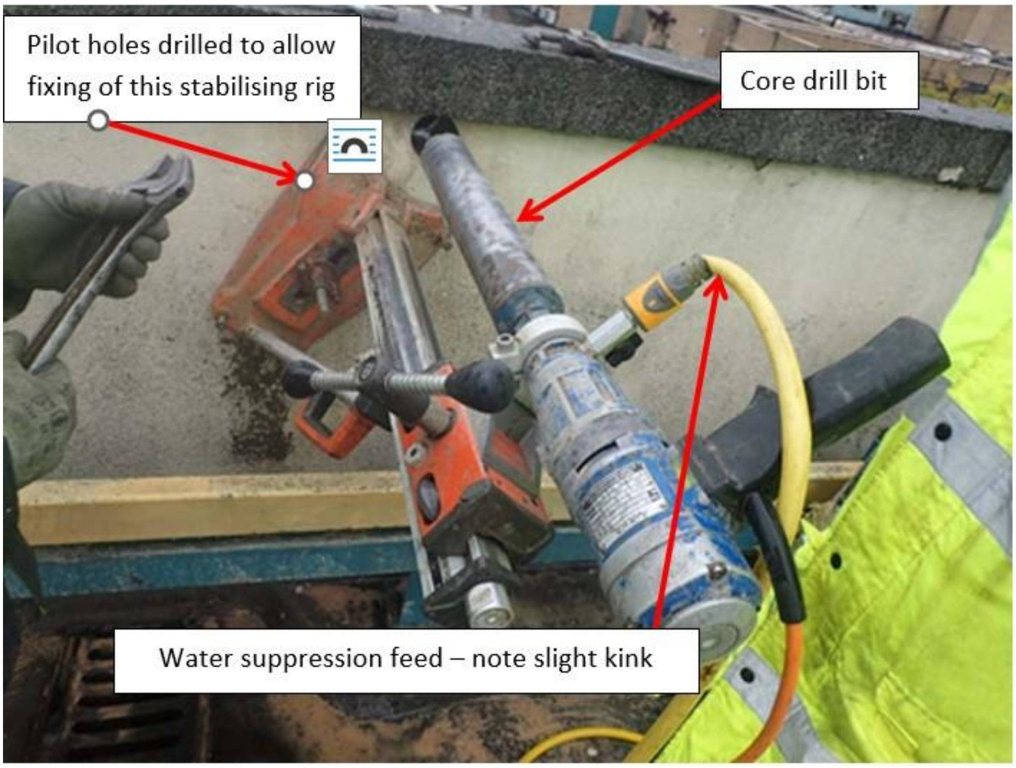
Echt et al. (2003) reviewed exposure control efficacy during breaking and found water suppression built into the tool reduced respirable dust concentrations during jackhammering by 72%. This was greater than the reduction achieved by two different types of LEV shroud (48% and 59% reductions). A further option for breaking seen on one site was the use of a remote-controlled breaker (see Photograph 1). This did not have any additional engineering controls fitted and worked by separating the worker from the exposure source. This could potentially reduce RCS, noise and vibration exposures as well as reducing musculoskeletal risks. Use of the remote breaking equipment would still require operator training and design considerations (for example to ensure that operators were not located downwind of the breaker if used without water suppression or other engineering control). Photograph 1 shows the length of the control wiring available and that the operator could be positioned further away if visibility was not unduly restricted.

Photograph 1. Use of remote breaking equipment.

The worker operating the remote breaking equipment also carried out floor sawing on the same day so it was not possible to determine any potential reductions in exposure by use of this remote breaking technique alone.

5.3 Core drilling

Core drilling was observed at Company 1, site 2, and appeared well controlled. The exposure data supported this. All three 8-hr TWA RCS exposures were less than LOD meaning they were all less than 0.02 mg/m^3. However, in areas where the core hole was being drilled horizontally through a vertical surface, it was necessary to drill a number of small pilot holes to allow a stabilising rig to be fixed (see Photograph 2). The pilot drilling created some visible dust as the process was not water suppressed and on tool extraction was not fitted. RPE was not worn for this or any of the core drilling observed. Where this was carried out workers would rotate between core drilling and pilot hole drilling. Based on what was seen, this differed from vertical core drilling through a horizontal surface (i.e. the floor) which is generally carried out using a bespoke freestanding, wheeled drilling rig. This does not require pilot holes to be drilled as the weight of the rig is sufficient to provide the stability needed. Good control practice for core drilling would be to use a freestanding water suppressed drilling rig wherever possible. Where a stabilising rig is required then on drill extraction may provide adequate control for the pilot hole drilling. Water suppression for pilot hole drilling using an electrically powered drill would introduce safety concerns. Once the stabilising rig is in place, water suppression should be used on the core drill itself. Photograph 3 shows the use of a handheld core drill, with water suppression, which was used on a relatively small number of occasions where access restrictions prevented the use of the larger free-standing rig.

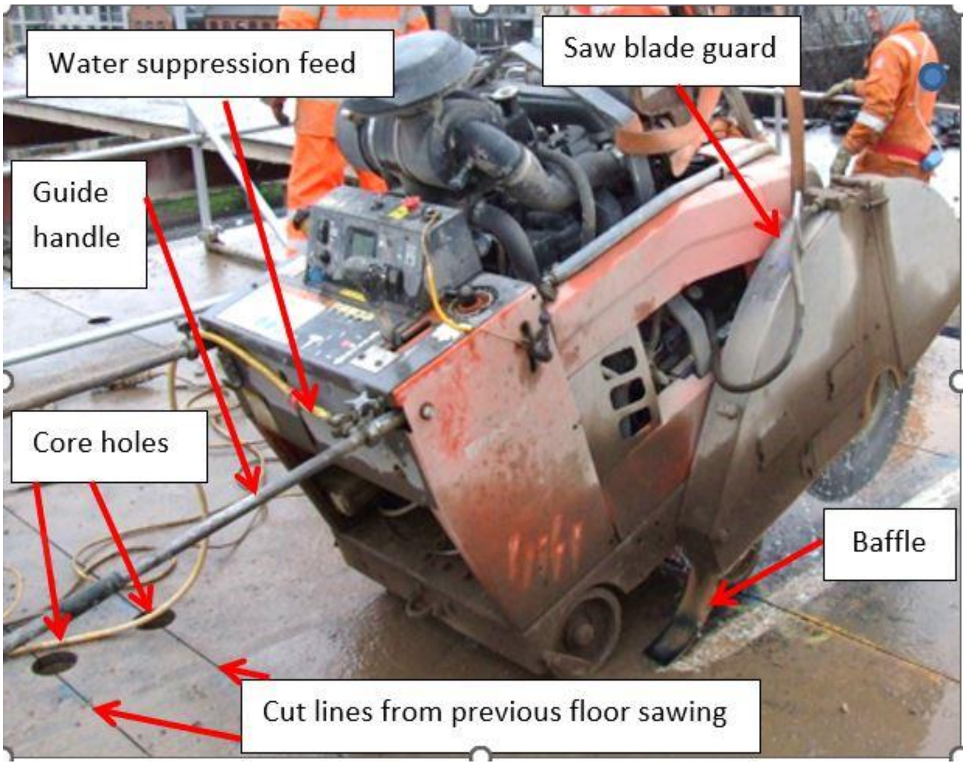


Photograph 2. Horizontal core drilling rig (bolted to vertical surface).

Photograph 3. Use of handheld core drill.

5.4 Floor sawing

Floor sawing was carried out at Company 1, site 2, and subject to water suppression applied to the cutting blade. The blade is also partially covered by a guard and had a small baffle to the rear (see Photograph 4). The guard was in a fixed position and even when the floor saw was at its lowest working point, there was still an exposed section of the saw blade.



Photograph 4. Floor saw.

Visible emissions were present from the floor sawing process. Previous work carried out in the stone sector on water suppressed primary and secondary saws demonstrate this would be water mist and could contain RCS. All four RCS exposures were less than 50% of the WEL, with three less than 0.02 mg/m^3 and the fourth was 0.045 mg/m^3, suggesting adequate exposure control could be achieved. Further improvements were considered possible, for example if a shroud could be made to enclose the blade more, perhaps by use of an additional spring-loaded section that could move depending on the angle of the floor sawing rig. There was also concern over the possible exposure of anyone working on the floor underneath, although during the visits this was not the case.

5.5 General water suppression

General water suppression including damping down, in both targeted and general areas was used at all sites visited except that operated by Company 4, although this was a small part of a much larger job. Depending on the site, this was done by either hose, area sprays or bespoke water suppression equipment. The bespoke equipment, illustrated in Photograph 5, sprayed water through a number of nebulisers and was capable of misting in a fixed position or in an oscillating mode with a fan pattern up to 335 °. It was only observed working in fixed mode. It was fed from a 2000 litre tank, which provided between 60 and 85 minutes run time. Given a suitable water supply the equipment is capable of running continuously. At one of the sites a suitable supply wasn't available, and the equipment had to be taken elsewhere on site for filling. This reduces work throughput and introduces the possibility of working without the system in operation. It was reported the positioning was down to individual operator discretion. Ensuring drivers of any nearby plant equipment had sufficient visibility was reportedly one of the primary factors in deciding where to place the spray. It was also reported by operators that visibility can be particularly impaired when using water suppression in strong sunlight. Not emptying the water misting systems water tank when not in use could lead to the promotion of microbiological growth (e.g. legionella) which could present a health risk when aerosolised. Ideally the tank should be emptied when not in use.

For general damping down it appeared that where and when it was used was down to operator discretion. It was reported in some cases that operator discretion was also used when determining what level of water flow was required. On occasions where it had been raining prior to the visits it wasn't always used as the ground was still damp and the use of general damping was deemed unnecessary.

Water connections were limited on some of the sites visited. This meant that machinery using water suppression had to be stopped whilst the hoses were used for general damping down or were run without water suppression for a period of time, thereby increasing the exposure risk. Another particular issue noted with the water suppression supply hoses was that, depending on placement, they were prone to being crushed by moving vehicles. This happened on at least one of the visits resulting in the water suppression being temporarily unavailable and there were other occasions where water lines were nearly crushed by vehicles. Good control practice for any type of water suppression, be it damping or on a specific piece of plant or machinery, would include that an appropriate water supply with robust piping and connections is present. This would allow all systems to work simultaneously.

Exposure data from 5 banksmen/groundworkers was collected at two sites. All RCS exposures were less than LOD and therefore all less than 0.02 mg/m^3. Whilst they do not directly measure the efficacy of general water suppression, they do suggest that adequate control was achieved in these instances and water suppression was part of the exposure control package used.

Photograph 5. Bespoke water suppression equipment.

5.6 Plant vehicles

Over the visits there was a lot of activity involving plant vehicles. For example, loading shovels and 360 ° excavators were used for a variety of tasks including demolition and ancillary processes such as crushing and the initial grading of the demolition debris. All plant vehicles seen on the visits were fitted with some sort of in-cab filtration, although the standard of filtration was not established, and it was not verified that air conditioning systems were present. The filtration systems were subject to service contracts. RCS exposures of the ten plant vehicle drivers did not exceed 0.03 mg/m^3 (8-hr TWA) and eight were less than the LOD (approximately 0.02 mg/m^3) indicating adequate control. A published HSE report (HSE, 2018) found that in-cab filtration systems in quarry plant reduced respirable dust concentrations in-cab, except in one case where it was thought internal contamination within the cab may have been re-suspended, creating an elevated dust concentration. Some static monitoring data was carried out inside and outside a vehicle cab at Company 1, site 2. This is shown in Table 4. The data obtained supports the findings, with a reduction in RCS concentrations within the cab of more than 42%. The exact RCS reduction could not be determined as the concentration inside the cab was less than the LOD. Reduction in the respirable dust inside the cab was greater than 91%.

Good control practice for vehicles used on demolition sites as part of the main activities would be that in-cab filtration is fitted with an appropriate filtration standard (dictated by risk assessment). The cabs should be air conditioned so that windows can be kept closed maintaining a comfortable working environment with good visibility in the cab regardless of weather conditions, as opening doors or windows could introduce RCS into the vehicle cab. Additionally, where required, cabs are cleaned using type M or H vacuum cleaner and/or wet cleaning techniques. One site reported cleaning of the cabs using brushes and compressed air. This is considered poor practice and could lead to elevated RCS exposures. The use of a simple floor mat to wipe boots on prior to entering the cab may reduce the amount of cleaning required. Ideally working practices would be such that cabs do not become contaminated internally, although over time some degree of cleaning is unavoidable given these cabs are entered and exited regularly. Best practice could include that interlocks are fitted to prevent operation with doors/windows open or when the in-cab filtration system is not running.

For plant vehicles which are carrying out crushing or other demolition activity good control practice would be to consider whether some form of water suppression may be applied at the tool head, as was seen at Company 2 with the high reach demolition machine (see Photograph 6).

Photograph 6. High reach demolition machine.

5.7 Manual demolition

Four exposures for workers carrying out manual demolition were obtained from two different sites. All four exposures were less than LOD meaning they were less than 0.02 mg/m^3. In all four cases no powered hand-held tools were used, and the work was carried out in an open environment. Water suppression was not used in either instance, although at one of the two sites it was damp from recent rainfall and so water suppression was deemed unnecessary. These results indicate a low exposure potential associated with manual demolition of the type seen. The paper by Flanagan et al reported a GM RCS exposure for handheld demolition of 0.14 mg/m^3, although it is not clear if this includes the use of hand-held powered tools.

RPE, with an APF of 20 (e.g. a mask with P3 filter) was available at all companies visited, with face fit testing confirmed at four of the five sites visited. RPE was used, during the visits, at two of the five sites, both of which had undertaken fit testing. Deficiencies were noted in both cases.

At Company 1 (site 2) RPE with P3 filtration was worn for manual demolition and the use of hand-held breakers. RPE was not always used consistently despite being required by site rules in some circumstances. The RPE was qualitatively face fit tested to the workers, but at least one worker was not clean shaven at this site. Good control practice relating to RPE was that monthly maintenance was carried out on reusable RPE and it was stored in rigid containers when not in use, although during break times workers were seen to hang their RPE around the work area, and not place in these boxes. At Company 4, FFP3 masks were worn during the use of hand-held breakers. These masks had been qualitatively face fit tested to the workers, but two of the four workers did not have the RPE retaining straps correctly positioned. The FFP3 masks were reportedly changed every 1-2 hours.

5.8 Literature review

As part of this programme of work a literature search was carried out to review RCS exposures and exposure controls during demolition activity reported by others up to 2022. A relatively small amount of information was gathered. When considering exposure for the occupation of “demolition” six different data sources were found, and these have already been summarised in Tables 5 and 6. The GM of RCS exposure data for the six sources ranged between 0.027 and 0.14 mg/m^3. As was reported in the results section a GM was not calculated for the HSE dataset reported here (which represents current good exposure control practice), as given the small data set and high prevalence of results less than LOD it was not considered statistically valid to do so. Note that several of the six sources mentioned above had similar sized datasets and calculated geometric means. To give some context to the results in comparison to other data we can consider the median for the data which will be less than the LOD which was no more than 0.021 mg/m^3. Although this is not an exact value, it is lower than the GM of any of the six data sources previously mentioned.

5.9 Real time measurement

Real time measurement was carried out as part of the measurement strategy for this work. This included assessing its suitability as a screening tool for industry. To summarise, real time measurement gives a reading akin to the respirable fraction, but it is not suitable for giving a definitive exposure measurement, for which conventional pumped sampling would be required. It can be useful for monitoring relative changes in concentration, but may require occupational hygiene expertise to determine when, where and how to use effectively. There were varying levels of agreement between real time and conventional pumped sampling techniques. Particular issues were noted with real time monitoring when used in the presence of water vapour whether from rain or from control measures using water suppression/misting.

5.10 Good exposure control practice summary

Table 8 summarises suggested good exposure control practice for the tasks seen. These are based on good occupational hygiene practice combined with the observation, intelligence and exposure data gathered during the course of this work. For good exposure control practice there is also an assumption that the controls are subject to appropriate maintenance and checks and that all workers have an appropriate level of information, instruction and training in how to use them and the potential consequences of failure. Where control uses water suppression, it is assumed that there will be an adequate water supply available together with robust piping and connections to enable the running of all required systems simultaneously.

Table 8. Possible good RCS exposure control practices for demolition tasks.

Demolition task / Job role	Good exposure control practice
Plant vehicle driver	In-cab filtration fitted with an appropriate filtration standard (dictated by risk assessment), air-conditioned cab, cleaning of cabs by type M or H vacuum cleaner and/or wet cleaning techniques, measures in place to minimise in-cab contamination. Plant not to be operated with doors/windows open or without in-cab filtration system running. Interlocks would help achieve this reliably.
Manual demolition (using handheld non-powered tools)	Water suppression/spraying or mobile LEV could be used to control the build-up and spread of dust (if practicable). RPE likely to be required in most instances.

Demolition task / Job role	**Good exposure control practice**
Breaking	Use of remote equipment (if feasible), use of effective water suppression or alternatively on-tool extraction. RPE likely to be required especially for longer duration tasks.
Banksman/groundworker	Damping of road and walkways, using water suppression (unless rained recently), control of adjacent processes at source.
Core drilling	Use of freestanding water suppressed core drilling rig wherever possible, (if a stabilising rig is required then on drill extraction or other engineering control for the pilot hole drilling required). RPE may be required.
Floor sawing	Water suppressed floor saw with good enclosure around the blade, possibly sprung loaded to maintain control with depth of cutting, baffle to rear of blade. RPE may be required.
Crusher operator	Remote operation (where possible), mains water for water suppression for use on the crusher, transfer conveyors and debris pile, minimisation of debris drop height and possible use of sock to control dust from drop, segregation, RPE required if need to be near crusher.

6 Conclusions

A snapshot of RCS exposures and industry exposure control practice for the GB demolition sector has been obtained from companies that participated voluntarily. The results obtained cannot be taken as representative of the GB demolition sector overall.

A total of nine visits to four different companies carrying out demolition related activities have been carried out.

Thirty-one (75.6%) of the 41 measured exposures, as 8-hr TWA values, were less than 25% of the WEL for respirable crystalline silica which is 0.1 mg/m^3. One exposure measurement, for a debris crusher operator, exceeded the WEL. The research sought to identify effective exposure control practice and was not designed to be representative of the whole industry. These exposures represent a benchmark of what can be achieved where such practice is implemented.

Conclusions on effective exposure controls for the tasks seen are summarised in this research. These are based on good occupational hygiene practice, combined with the observations, intelligence and exposure data gathered. They inform HSE’s position on adequate controls under the Control of Substances Hazardous to Health Regulations (COSHH) for demolition activities.

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APPENDIX 1 - Company 1 Site 1 Summary

The activity seen during this visit was the processing of concrete debris from recently demolished buildings. This was done by a 360 ° excavator with a muncher attachment. The weather had been dry prior to the visit and it was throughout. The work area was segregated with an exclusion zone. There were only two workers potentially exposed inside the exclusion zone: the 360 ° excavator driver and the banksman who was approximately 10 metres away from the excavator. Dust suppression was used on the debris pile using equipment which sprayed the area with water. The dust suppression was in a fixed position although the system could be used in an oscillating mode of up to 335 ° and delivered 23-32 litres/min of water. In-cab filtration was present and was subject to a service contract although the filtration standard was not established. RPE was not worn, although was available. Workers were aware of the health effects of RCS exposure.

APPENDIX 2 - Company 2 Summary

Visit 1

The activities seen included manual demolition work using hammers and bars to remove a concrete roof and brick walls. Burning equipment was also used to burn the steel roof supports. This work was carried out by two workers operating out of a cradle suspended from a crane.

There were also two 360 ° excavators in operation on the site breaking up concrete: one was munching debris produced by the demolition process whilst the other was removing concrete steps. Each 360 ° excavator had a single operator housed in an enclosed cab and a banksman located close by. In-cab filtration was subject to a service contract but the filtration standard was not established. Work areas were segregated. Water misting was deemed unnecessary on the day of the visit due to rainfall on the previous days, although a water hose was used in the areas where the concrete steps were being removed. RPE was available but was not used. The RPE was a half face mask with P3 filters and qualitative face fit testing had been carried out. Weather conditions were dry on the day of the visit.

Visit 2

The primary task being undertaken was demolition using a 35m high reach demolition machine. Two banksmen as well as the machine operator were involved in this task. One banksman was at the same height as the machine cab and the other was on a pedestrian walkway bridge on the same level as the top of the building being demolished. The 35m high-reach machine was used until midday. Water suppression was used on the high-reach demolition machine, with the water being applied at the tool head. Water hoses were also in use in this area. They were substituted for a dust misting system mid-morning.

In the afternoon two 360 ° excavators were in use in the same area where the 35m high reach machine was used in the morning. One of the excavators was used to move debris. The other was used to crush and sort demolition debris and included the use of a muncher. The latter also loaded trucks with the crushed and sorted debris. The dust misting system was in use during this time.

In the afternoon the banksman at the pedestrian walkway level moved to the ground level and looked after the water misting machine. Work areas were segregated. RPE was available but not used. The RPE was a half face mask with P3 filters and qualitative face fit testing had been carried out.

There was also another activity seen. This was grading of demolition debris/soil by a 360 ° excavator. This was done visually on the basis of size and there were two people potentially exposed, the 360 ° operator and the banksman.

There was visible mist/fog present in the air during the visit with light rain during the afternoon.

APPENDIX 3 – Company 3 Summary

This company operated an urban quarry, taking in demolition waste / debris and processing it to provide aggregate.

The demolition debris was delivered in HGV tipper lorries. The debris consisted of concrete, bricks and stone. Some debris was also supplied by a separate company on an adjacent site, which processed scrap metal.

Debris was normally deposited directly into an appropriate storage bay for the material. The tipper lorry drivers open windows to communicate with the site staff. Where necessary the site staff use a loading shovel to move the deposited debris into the correct storage bay.

The debris was crushed using a mechanised crusher. The crusher's hopper was loaded using a 360 ° excavator. The crushed material was fed directly into a 3-way screener located in line which sorted the crushed material into three size fractions. A loading shovel moved the size-fractionated aggregate into storage bays or to another 4-way screener. Oversized material was recycled back into the crusher using the loading shovel. The loading shovel also loaded aggregate onto customer's vehicles as necessary.

During the visit, three workers were involved in processing the debris pile. These were the driver of the excavator, a loading shovel driver and a banksman. The banksman had been driving a 360 ° excavator fitted with a grab, until it broke down during the morning. There was also a weighbridge operator whose exposure was not measured as he never left the weighbridge building.

The weather on the day the sampling occurred was dry and overcast with no wind. On the previous night the weather was also dry.

The site reported processing up to 1,000 tonnes of debris a day, with a capacity to process 200,000 tonnes per year.

Other tasks undertaken on the site included loading one cubic metre woven bags with aggregate. This operation was not observed but was reported to consist of using a forklift truck to hold the bag open while aggregate is tipped into it by a loading shovel.

The work area was segregated from other activities and access was restricted. There was a water misting system present to control dust produced when processing debris. This consisted of water misting spray bars on the crusher and screens. At one point the spray bar failed on the crusher (due to damage to the hosepipe) affecting the dust control. When this occurred area water jets were used to control the dust from the crusher. These were located on poles at the end of the bays. They were fed from a water silo and could be operated manually from the weighbridge or automatically at set time intervals. It was reported that in the winter the silo is emptied to avoid damage from ice meaning that there will be no water suppression available.

The excavator and loading shovels had in-cab filtration fitted. This was under a service contract and serviced at intervals recommended by the manufacturer (every 500 hours use). The filtration standard of the filters was not known. The cabs were clean and the doors were always shut during operation.

The machine cabs were cleaned using a hand brush by the drivers. The weighbridge, welfare facilities and office were cleaned using a broom.

APPENDIX 4 – Company 4 Summary

This visit was to a building under major refurbishment, including adding additional floors. The work of interest was the removal of decorative stone cladding (less than 5% silica content) and precast concrete panels, both using handheld breakers. The pieces removed fell onto the scaffolding boards and were then periodically removed by hand or shovel into a wheelbarrow and taken away for disposal. The work was on the outside of the building, working off a sheeted scaffold which created a degree of enclosure of the work area.

The removal work was being carried out by two teams of two workers, with only one team working at a time. One team member carried out the breaking and the other held a water spray used for dust control purposes. The workers swapped around every 10-15 minutes. The reasons for this were primarily to limit vibration exposure but also to allow rest periods as the breaker was heavy and the task was physically demanding.

The other tasks carried out by the workers, when not removing cladding or precast sections, included general cleaning duties. This involved (reportedly) some use of dry sweeping.

The decorative stone cladding broke up relatively easily while the precast concrete sections required significantly more effort. The work had only just begun and, following the visit, it was reported that the precast sections would not be subsequently removed by breaking but by other means. This would probably have been by core drilling and lifting out complete sections by crane.

The engineering control used was dust suppression. Water was sprayed using a domestic garden sprayer. This used a small (estimated 10 litre capacity) reservoir and water was sprayed out through a nozzle held by the second worker. The nozzle used created more of a direct water jet than a spray, and this water jet was directed at the point of impact. During the course of the visit, the nozzle was changed for a different one, although it still created more of a jet than a spray. The second nozzle blocked more quickly than the one use initially which slowed work down. The reservoir also required regular refilling, and, as there was no local water supply, this further slowed operations. The work was viewed with a dust lamp. Visible dust was observed routinely under these conditions irrespective of the nozzle used in the dust suppression equipment.

During the removal/breaking operations, workers wore dust masks to P3 standard (FFP3). Qualitative fit tests had been performed. All workers wore the RPE with the retaining straps correctly positioned. Two of the four workers were clean shaven and the other two were not. RPE was reportedly changed typically every period of breaking activity (i.e. every 1-2 hours).

On the day of the visit, two workers who had started the shift with clean workwear were observed with significant contamination after two hours of breaking activity.

The workers carrying out the cladding removal/breaking activity were subject to an occupational health programme which included hearing and respiratory checks.

APPENDIX 5 - Company 1 Site 2 Summary

Visit 1

There were a total of four visits carried out to this contractor who was demolishing a multi-storey car park. A number of different tasks were witnessed as part of the demolition. These are listed in Table 1. Briefly, visit 1 comprised manual demolition of a brick wall in a partially enclosed space by use of hammer and wrecking bars together with core drilling of vertical sections of wall. The manual demolition was carried out by two workers. This initially involved removing some internal walls comprising of plaster board, rock wool insulation and a timber frame using hammers and wrecking bars. A window was removed and then the external brick wall below was part dismantled with a lump hammer. Three courses two bricks wide (around 108 bricks) were removed one brick at a time to ensure no bricks fell out of the building. The remaining wall was left standing to prevent falls until a temporary barrier could be erected. When viewed with a dust lamp, fine clouds of dust from the mortar could be seen during brick removal, generally drifting away from the worker (i.e. outward) However, some dust was blown back into the room. This was followed by a period of dry brushing up of the debris which created further airborne dust. No RPE was worn for this task.

The core drilling initially involved creating pilot holes (by handheld hammer drill), to allow a large core drill rig to be fixed in place onto the concrete wall before the main core drilling could start. The pilot bolt holes were approximately 20 mm diameter. Typically, the distance between core holes was 2 to 2.5 m and the two processes were operated sequentially, with the pilot hole drilling taking place ahead of the core drilling. Visible airborne dust was emitted during pilot hole drilling, and was blown by a breeze towards the core drilling position, nearby. Typically, six core holes were drilled every hour. There was no engineering control applied during the pilot hole drilling and the workers did not wear RPE. The core drill was fitted with water suppression. There were two workers involved in this process who rotated between pilot and core hole drilling. The worker carrying out the core drilling always remained in close proximity to the drill as they were periodically required to make adjustments to the rig as the drilling progressed. The core holes were 78 mm diameter and were drilled through a 340 mm wide wall which included a 90 mm internal cavity. The drilling had mains supplied water suppression and, when viewed with a dust lamp, a mist could be seen emitted during the initial stages of drilling (that is until the drill reached the cavity). The mist emitted fell towards the floor (i.e. it was away from the workers breathing zone).

Visits 2 to 4

The activities seen were centred around removal of sections of the car park floor. The car park floors were cut into rectangular sections approximately 4 m by 1 m prior to removal via crane.

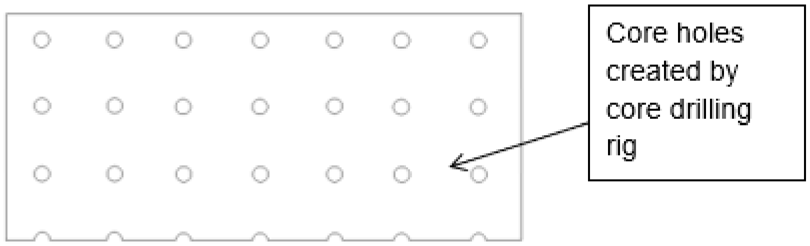
Coring

To begin with, core holes were drilled through the car park floor by a petrol-powered core hole drilling rig. Holes were drilled at set intervals across the floor as seen in Figure 1.

Once all holes had been drilled the rig was lifted by a crane to the floor below to repeat the same process.

Where additional holes needed to be drilled and the drill rig was unavailable, a hand-held core drill was used which was powered by electricity generated by a diesel generator. Both the handheld and rig based core drills were fitted with mains fed water suppression. A single worker was required to operate either drill.

Figure 1: Diagram showing pattern of core holes on car park floor.

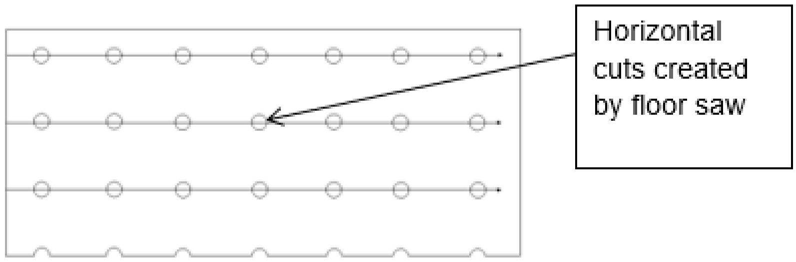


Floor sawing

Once the core holes had been drilled a self-propelled floor saw was used to cut horizontal lines across the car park floor as seen in Figure 2. The horizontal cuts were made all the way through the concrete floor.

Two models of floor saw were used on site, both of which were diesel powered. Both were fitted with water suppression together with a fixed guard largely covering the blade and a baffle to the rear of the blade.

Figure 2: Diagram showing floor sawing lines along car park floor.



Crane lifting

An overhead crane was used to remove the concrete panels. Two sets of chains were fed through the core holes creating a loop around the section of floor to be removed. Once the chains were appropriately secured, a floor saw was used to make two perpendicular cuts either side of the chains (Figure 3). The crane then lifted the concrete panel from the building.

On occasions remainders of metal were encountered within the concrete panel hindering the lifting operation. In these instances, either a gas torch or disc cutter was used to cut the metal and free the panel. The disc cutter had water suppression supplied by an 8-gallon water cylinder.

Figure 3: Diagram of chaining and floor saw cuts prior to lifting.

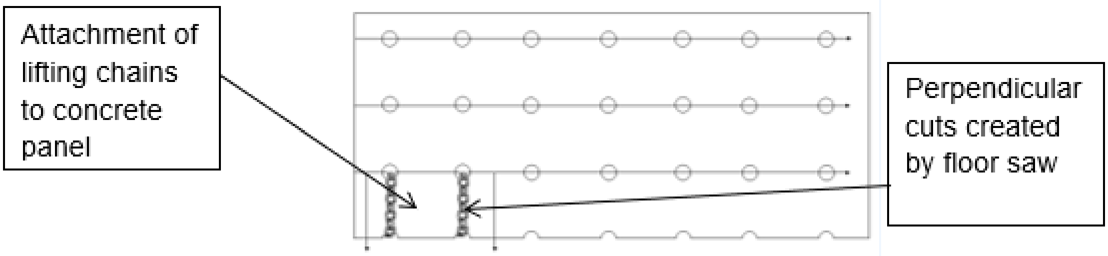
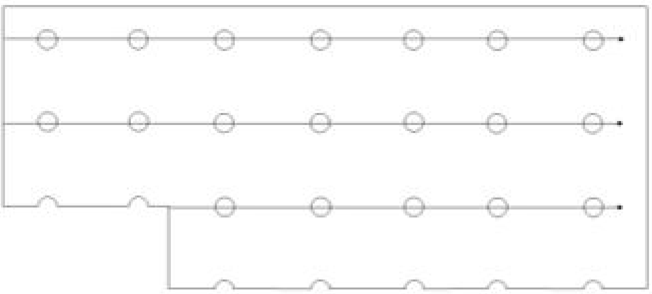


Figure 4 shows the car park roof after the panel is lifted. Once the panel was removed it was lowered to ground level where it was unchained by an operative to await crushing. The process shown in Figure 3 is then repeated until the whole floor is removed. Around ten panels were removed per day using this process.

Figure 4: Diagram of car park roof after lifting the first section.



Demolition Breaking

On occasions manual breaking of concrete using demolition hammers was required. This was monitored in three separate instances across visits 2 to 4.

The first instance observed was on removal of the concrete floor panels, when steel joists were encountered hindering the process of the floor saw. In these instances demolition hammers were used to free the concrete panel from the joist so the panel could be lifted by the crane. Typically there were two workers carrying out this task, taking no more than 10 minutes per floor section removed. Both these workers wore FFP3, although one was not clean shaven.

The second instance involved the removal of steel pillars encased in concrete. The pillar was secured by a crane before manual demolition hammers reduced the concrete around the pillar down to the steel. The pillar was then lifted after the metal was cut. This process was not directly observed and so task durations were not established. It was understood that water suppression was not used and the worker did not wear RPE.

On the third visit manual breaking using demolition hammers took place for most of the shift on the top floor of the car park. This was in areas around the perimeter of the floor that were difficult for the floor saw and crane to operate.

Water suppression was reported as being used for breaking. The company's reported policy was to work in teams with one operative using an 8 gallon hand pressurised container to douse the working area with water. When empty the container was refilled by water from the mains supply. The equipment for water suppression was seen around the site during the visits, however it was not seen in use at any point. When use of water suppression was not practical, the company policy was to use RPE. Based on observations made during the visits, RPE use was inconsistent. Half face masks fitted with P3 filters were supplied to workers. This RPE was reportedly qualitatively fit tested and on a monthly maintenance program. The RPE was stored in a rigid container when not in use. Worker rotation was used on the breaking activities to manage the risk from Hand Arm Vibration Syndrome (HAVS).

Remote Breaking

A remote demolition machine was used to break down concrete from the edges of overhead joists. The machine has a hydraulic breaker attachment and was electrically powered from a nearby diesel generator. The worker operating the machine by remote control was typically 3 - 5 metres away from the breaking head. There was no water suppression or other engineering control applied.

Crushing and processing rubble

The rubble and waste from the car park demolition consisted primarily of concrete and metal. The concrete waste was processed into aggregate. An excavator fitted with a demolition breaker attachment was used to break down larger pieces of rubble prior to crushing. This same excavator, with a large magnet attachment, was also seen moving metal waste screened out by the crusher.

The rubble was loaded into the hopper of the impact crusher by an excavator. The crusher then processed the rubble into type 1 aggregate which typically has a diameter of around 50 mm. The crushed product was then deposited onto the ground by the crusher's conveyor. Any metal debris was screened out to the sides of the crusher.

A loading shovel then transported the aggregate to a storage pile and, when required, loaded HGVs for transportation of aggregate off site.

The crusher was fitted with mains fed water suppression that doused the crushing mechanism. The conveyor that transported the newly formed aggregate from the impact crusher to the ground was also water suppressed to reduce dust emissions.

All excavators and loading shovels were fitted with in-cab filtration. The filtration standards of the filters reportedly conformed to high efficiency particulate arrestor (HEPA) standards. However, the exact standard was not known. All vehicles fitted with in-cab filtration were under a service contract with the manufacturer and were serviced at intervals recommended by the manufacturer. This included the changing of the filters.

The cabs were cleaned by brush, compressed air and vacuum cleaners at regular intervals.

APPENDIX 6 – Respirable dust exposures summary

Table 9. Summary of worker respirable dust exposure data, presented by task type (not accounting for any RPE worn).

Task	Number of 8-hour TWA exposure data (number of companies visited shown in brackets)	Number of respirable dust exposures less than LOD	8-hour TWA respirable dust exposure range (mg/m^3)	8-hour TWA RCS exposure range (mg/m^3)
Plant driver	10 (2)	2	<0.03 – 0.19	<0.01 – 0.03
Manual demolition	4 (2)	0	0.29 – 0.77	All <0.02
Breaking	6 (1)	0	0.09 - 0.33	0.024 – 0.085
Breaking plus other activities	5 (2)	0	0.11 – 0.42	<0.018 – 0.06
Banksman / Groundworker	5 (1)	0	0.02 - 0.13	<0.02
Core drilling	3 (1)	1	<0.073	<0.02
Floor sawing	4 (1)	1	<0.069 – 0.194	<0.015 – 0.045
Crusher operator	1 (1)	0	~0.479*	~0.12*
Other	3 (2)	0	0.03 – 0.079	<0.021

Task	Number of 8-hour TWA exposure data (number of companies visited shown in brackets)	Number of respirable dust exposures less than LOD	8-hour TWA respirable dust exposure range (mg/m^3)	8-hour TWA RCS exposure range (mg/m^3)
All data	41 (3)	4	<0.03 – 0.77	<0.01 – 0.12*

* Minor flow rate discrepancy, result considered approximate.

Demolition workers are exposed to various hazardous substances including respirable crystalline silica (RCS). This can cause chronic lung diseases like silicosis, lung cancer and chronic obstructive pulmonary disease (COPD). Research was commissioned to identify appropriate, achievable RCS control standards for demolition activity and to assess exposures with them applied. It involved both site visits and a literature search.

Nine site visits were undertaken to four different companies who were pro-actively focussed on managing RCS. Forty-one RCS exposure measurements were made for the demolition work seen. Results were compared against the Workplace Exposure Limit (WEL) for RCS of 0.1 mg/m3 as an 8-hr Time Weighted Average. The majority (75.6%) were less than 25% of this WEL. Only one exposure measurement exceeded it.

The literature search found little published data on RCS exposures in demolition. Exposures measured in this research are at the low end of the spectrum when compared to what exists. This could be expected given participant's pro-active focus on managing RCS and means they cannot be viewed as representative of the GB demolition sector overall.

Conclusions on effective exposure controls for the tasks seen during the site visits are summarised in this research. They inform HSE's position on adequate controls under the Control of Substances Hazardous to Health Regulations (COSHH) for demolition activities.

Published by the Health and Safety Executive 01/24