Asbestos exposures to workers in the licensed asbestos removal industry

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In Great Britain there are around 5,000 cancer deaths a year attributed to asbestos, mainly due to past industrial exposures. The import and use of all types of asbestos was banned by 1999. However, asbestos can be present in any building built or refurbished before 2000 and continues to be removed as part of ongoing risk management. Higher-risk removal work can only be undertaken by HSE licensed contractors. Under the Control of Asbestos Regulations, exposure must be prevented or effectively controlled.

The aim of this research was to provide information on asbestos exposures to licensed removal workers in Great Britain and to assess compliance of work practices with HSE guidance. HSE scientists visited eight removal sites during 2016 to 2019. Removals included asbestos insulating board (AIB), insulation and sprayed coating. The researchers monitored airborne fibre concentrations using samplers and observed work practices. The removal contractors and workers participated on a voluntary basis. The findings are therefore likely to indicate exposure levels and working practices for contractors and workers undertaking licensed asbestos removal who are attempting to adopt good practice. The findings are not intended to be representative of the removals industry as a whole. There are three main research findings. (1) Asbestos fibres were present in the airborne fibres samples. (2) Some airborne fibre concentrations measured in the study were above the limit. (3) There is scope for further exposure reduction, for example by ensuring that workers wear respiratory protective equipment (RPE) during set up and dismantling of the enclosure used for removal activities. These findings are being used to inform HSE communication with stakeholders and updates to HSE guidance.

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Asbestos exposures to workers in the licensed asbestos removal industry

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Key Messages

There are around 5,000 cancer deaths each year attributed to historical exposure to asbestos, mainly in an occupational setting. The Control of Asbestos Regulations are designed to prevent or minimise exposure to asbestos. Where those employing asbestos removal workers comply with the detailed requirements and guidance in the Approved Code of Practice and other associated guidance, they will be protecting their workers so far as is reasonably practicable. The manufacture and installation of all asbestos materials was banned in GB by 1999 and so asbestos removal workers are one of the last cohort of workers who need to regularly and deliberately break into asbestos-containing materials as part of their work. This active, frequent and substantial work carries a risk of exposure to asbestos not only to the removal workers but also to those adjacent and those who reoccupy the space later. These risks must be controlled and minimised.

The aim of this research was to provide information on asbestos exposures to licensed removal workers in Great Britain and to assess compliance of work practices with HSE guidance. HSE scientists visited eight sites between 2016-19, where licensed asbestos removal was taking place, carried out air monitoring and observed work practices throughout the work. These eight sites covered the most frequently removed licensed asbestos materials, including asbestos insulating board and pipe insulation. Air monitoring in this context is drawing airborne fibres through filters using sampling pumps, attached to the workers or static samplers. The airborne fibre measurements and observations presented in this report probably represent the best possible practice that licensed asbestos removal workers are capable of when they follow guidance as they understand it. The airborne fibre concentrations and work practices observed do not necessarily represent what would occur if HSE scientists were not present. The findings are not intended to be representative of the removals industry. The research identified the following.

- Analysis of personal monitoring samples indicated that there is exposure to asbestos during tasks other than the actual asbestos removal. These activities included construction and dismantling of enclosures and waste transfer.
- RPE use was not consistent for these tasks, particularly for enclosure construction. This led to instances where the exposure to asbestos of removal workers experienced during these tasks was higher than the exposures in the enclosure. This suggests that guidance on RPE use may need to be strengthened. Poor practice that deviated from HSE guidance regarding waste transfer was observed.
- Some personal exposure measurements were above the control limit.
- Sprayed coating was being removed on one of the eight sites. This is a friable high asbestos content material, which is highly likely to release fibres if disturbed. At this site there were higher personal exposures than the other seven sites, with some 80% of the personal exposure measurements above the control limit.

Executive Summary

Background

Asbestos remains a health concern in Great Britain (GB) including in occupational settings. There are around 5,000 cancer deaths a year attributed to historical exposure to asbestos, exposure which will have mainly occurred at work, but because asbestos remains present in many older buildings there remains a potential risk to those building maintenance workers liable to encounter it. Their risk of exposure must be properly managed.

The Control of Asbestos Regulations (CAR 2012) works to prevent or minimise exposure to asbestos by ensuring that asbestos-containing materials (ACMs) remaining in buildings and premises are properly managed and maintained. The manufacture and installation of asbestos and all ACMs were banned in GB by 1999 and so asbestos removal workers are one of the last cohort of workers that regularly and deliberately break into ACMs as part of their work. This active, frequent and substantial work carries a risk of exposure to asbestos, not only to the removal workers but also to those adjacent and those who reoccupy the space later, unless effective control measures are in place. These risks must be controlled and minimised. Provisions are made within the regulations to minimise, and where possible prevent, their exposure. Removal which requires a licence under CAR 2012 is defined as work which: is not of 'sporadic and low intensity', where it cannot be demonstrated that the control limit will not be exceeded (0.1 f/ml averaged over four hours), work on surface coatings (excluding textured decorative coatings) and work on asbestos insulation or asbestos insulating board (AIB), where the risk assessment demonstrates that the work is not sporadic and of low intensity, the control limit will be exceeded and it is not short duration work.

The Approved Code of Practice (ACOP) sets out several requirements on how licensed removal must be carried out. Among the control measures outlined are temporary enclosures which are constructed around the removal area, the wetting of ACMs prior to removal and the use of respiratory protective equipment (RPE). All workers must be trained in the use of RPE and for removal work inside the enclosure, full-face powered RPE with a P3 filter must be worn.

Aim

The aim of this work was to provide an update on the exposures of asbestos removal workers whilst undertaking their normal work activities and to assess compliance with HSE guidance relating to licensed, ie high risk asbestos removal. It was also designed, in part, to provide a measure of the extent to which industry is able to implement and ensure good practice is followed with respect to minimising removal workers exposure to asbestos.

Method

HSE scientists visited eight sites between 2016 and 2019, to observe, record (using CCTV) and take air samples, whilst licensed asbestos removal contractors (LARCs) removed ACMs under controlled conditions. LARCs were invited to volunteer to participate in this project and it was anticipated that only the better performing LARCs would volunteer. Therefore, the selection of sites was not intended to be representative and was reliant on which LARCs responded and the type of work they were undertaking at the time. The sites were chosen, where possible, to cover the removal of a range of ACM types, including AIB, insulation and sprayed coating. These materials represent either the most common ACMs (in particular, insulating board), or highly friable materials (sprayed coatings) more likely to release asbestos fibres during licensed removal. During these visits, personal and static air monitoring samples were taken for all work tasks, from the beginning of work on site and the completion of the clearance procedure (which marks the end of removal work). Work carried out inside enclosures was recorded by CCTV to allow HSE scientists to monitor working practices.

All air monitoring samples were analysed by phase contrast microscopy (PCM) to determine the total fibre concentration, the standard method for this type of analysis as outlined in the ACOP for the CAR 2012. Further analysis by transmission electron microscopy (TEM) was undertaken on selected samples, to give additional information about the asbestos concentrations.

The study was designed so that it included personal monitoring during the entire process of asbestos removal, from setting up enclosures, asbestos removal within the enclosures, enclosure dismantling and waste removal. The work included removal of the main ACMs requiring licensed contractors – asbestos insulating boards, thermal insulation and sprayed coating, although in relatively small numbers. The measurement of airborne fibre concentrations by PCM with TEM of selected samples allowed quantification of asbestos fibres.

Findings

Personal Exposure Measurements

The highest individual personal measurement results were above the 0.1f/ml control limit on four out of eight sites visited. Personal monitoring samples taken inside enclosures during removal work indicated that the average fibre concentration for all workers was above the 0.1 f/ml 4-hour control limit on one site. However, there were differences between sites. Sprayed coating was being removed on one of the sites. This is a friable high asbestos content material, which is highly likely to release fibres if disturbed. At this site, personal exposures were higher than the other seven sites, ie some 80% of the personal exposure measurements were above the control limit.

Further differences were observed when the results from PCM and TEM analysis for non-removal activities were compared. During construction of enclosures, fibre concentrations

derived from PCM analysis were higher on average than the corresponding TEM concentrations, suggesting that many of these fibres were not asbestos. However, during enclosure dismantling, the opposite was the case with the asbestos concentrations derived by TEM higher than the PCM concentrations, confirming that most of the fibres counted were asbestos.

Worker Behaviour

Observations on work practices, made during the visit or subsequently after watching CCTV footage suggested that removal workers were able to follow guidance (although in the knowledge that were being observed and filmed). However, as time passed, bad practices started to appear as the workers relaxed as they became accustomed to the researchers' presence and time pressures of the work took effect.

We consider that the knowledge that workers knew they were being observed had a significant effect on their behaviour, particularly during the early stages of a removal job. Asbestos removal work is very demanding and difficult work. Maintaining a high standard of fibre containment depends on the competence, constant diligence and compliance of every individual worker involved. The human factor is very important and it may be difficult for workers to be fully focused all the time.

Use of baglocks

An observation was made that the worker outside the enclosure (whilst wearing RPE and PPE) was seen to physically enter the baglock rather than simply retrieve the bags whilst standing outside. A baglock is a type of airlock which allows asbestos waste to be transferred safely out of the enclosure. This practice is contrary to industry guidance.

RPE outside enclosures

HSE guidance requires the completion of a suitable risk assessment before work starts. This assessment needs to consider whether RPE use is necessary and if so, what type. Previous air monitoring by the removal contractor should be used to support the decisions made. Guidance for RPE use outside enclosures depends on the activities undertaken. RPE should be worn during waste transfer and dismantling of the enclosure but is not specifically identified as a requirement in guidance for construction of the enclosure. The results from personal monitoring samples taken during tasks performed outside the enclosure showed measurable asbestos fibre concentrations. These tasks included enclosure construction, enclosure dismantling and waste transfer. The use of RPE during these tasks was less consistently observed, particularly for enclosure construction. This led to instances where the exposure to asbestos experienced during these tasks was higher than the exposures in the enclosure (workers exposures inside the enclosures were reduced by wearing RPE). Greater use of RPE during enclosure construction would be necessary to reduce exposures as low as reasonably practicable.

RPE inside enclosures

Guidance requires the use of RPE for anyone working inside an asbestos removal enclosure, as the process involves the deliberate disturbance of ACMs. Without suitable

RPE it is likely that personal exposures would exceed the control limit. All removal workers wore full-face powered respiratory protection, fitted with a P3 filter during work inside the enclosure. When the assigned protection factor for this type of RPE is applied (40x) the average personal monitoring result for each site ranged from 0.0002 f/ml to 0.006 f/ml with a peak individual result of 0.03 f/ml, across all sites. Employers must provide employees with suitable respiratory protective equipment which will reduce the asbestos exposure to below the control limit and 'as low as reasonably practicable'. The average personal measurement results from this work suggest that this was being achieved.

Comparison with findings of previous research

When compared with previous similar HSE research completed in 1999, the airborne fibre concentrations measured inside enclosures during this project have reduced significantly. However, there were several differences between the two studies which will almost certainly have influenced this. In particular, the types of asbestos material being removed were different, with much more friable materials being removed in the 1999 study compared with this one. There has also been a change to the definition of a countable fibre, since the 1999 study, which makes it difficult to make direct comparisons between the two sets of data (the European Reference Method was replaced by the World Health Organisation method in the UK in 2006).

Discussion

Given the caveats discussed, the fibre measurements and observations presented in this report should be viewed as representing circumstances when the removal workers knew they were being observed by HSE researchers and behaved accordingly. It should also be noted that the airborne fibre concentrations and work practices observed do not necessarily represent what would happen if the researchers were not present. The researchers did note that workers tended to change their behaviour over the course of a site visit. When they became accustomed to the presence of HSE scientists, they tended to work in a more relaxed manner and carried out tasks more quickly than at the start of visit. Time pressures may also have played a part as workers attempted to make up time to complete the job by the required deadline after a slow start (probably because they were being observed by HSE scientists).

As noted above it is important to note that these findings represent examples of the best work practices and standards and are not intended to be representative of the industry.

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* These pages are in landscape orientation to enable compliance with accessibility standards.

1. Introduction

1.1 Background

Asbestos remains a health concern in GB, with around 5,000 cancer deaths a year attributed to historical exposure to asbestos (HSE statistics, 2019). The latency period for these cancers can be 15 – 50 years and therefore many of the current deaths will be related to exposures that occurred before the current regulatory framework for asbestos was in place. Workers in the asbestos manufacturing and the construction sector would have regularly and intentionally worked with and disturbed asbestos and asbestos-containing materials (ACMs). The importation of all asbestos and its use in buildings in GB was banned in 1999, with the use and importation of amphibole asbestos having been banned earlier in 1985. However, asbestos remains an occupational health problem because it can be present in any premises built or refurbished before the year 2000 - this includes domestic dwellings, as well as workplaces. Since 2004, the Control of Asbestos Regulations (CAR) (HSE, 2012) has required dutyholders to manage asbestos on their properties by identifying where it is present and monitoring its condition. When ACMs are in poor condition, or a building is being refurbished or demolished, they should be removed.

Asbestos removal workers are therefore one of the last cohort of workers in GB who regularly, and intentionally, break into and disturb asbestos. Other trades may also occasionally disturb asbestos, either intentionally or unintentionally. ACMs are split into two categories with respect to removal (or other work activities); those that require a company to hold a licence to remove and those that do not. Materials which require a licence to work on are those which are inherently more hazardous (ie contain higher proportions of asbestos and are more likely to release fibres when disturbed). Licensed materials comprise AIB, asbestos insulation and asbestos coating. The detail of how different work is categorised can be found in CAR 2012 and the associated Approved Code of Practice (ACOP), L143 Managing and working with asbestos (HSE, 2013).

Regulation and guidance relating to asbestos removal have evolved and extended, with the aim of reducing worker exposure and the spread of asbestos fibres as well as ensuring that “removal” areas are in satisfactory condition for others to reoccupy, when the work is completed. This, together with better technical controls would be expected to decrease the risk of exposure to asbestos during the removal process over time. A post-implementation review of CAR 2012 (HSE, 2017), evaluated current epidemiological data to assess how effective regulations were at reducing negative health outcomes. HSE’s Mesothelioma Projections Model suggests that the fall in exposures from 1980 will result in a significant reduction in deaths from mesothelioma and lung cancer because of the tighter regulatory controls now in place. The model suggests that the fall in exposures to asbestos between 1980 (which is approximately when measures to control exposures started to be introduced) and 2015 will lead to 25,700 fewer deaths from mesothelioma and lung cancer in the 100 years between 2001 and 2100.

National trends in mesothelioma mortality can be used to infer how asbestos exposures in general, ie averaged over the whole population, must have changed over time. These data provide strong evidence that asbestos exposures were (on average) far lower from the 1980s onwards than during the previous three decades. It is now clear that the phasing out of new installation of amphibole-containing products by around 1980, due to the voluntary ban on amosite (crocidolite use had ceased ten years earlier), was a key driver in substantially lowering exposures from that time. However, overall mesothelioma patterns tell us nothing about how exposures may have changed since then, and in any case, it would be very difficult to make a direct link between any general trend and specific control initiatives to further reduce exposures, such as: the introduction of the asbestos licensing regime, revised regulations in 1987, and initiatives to raise awareness among general building maintenance workers during the 1990s, culminating in the introduction of the Duty to Manage asbestos regulation in 2004.

Darnton et al., (2008) published a paper based on responses to the GB Asbestos Survey up to 2005. This paper showed that the longer asbestos removal workers spent working in asbestos removal enclosures, the higher their risk of mortality. In 2008, it was not possible to draw a link between reduced fibre levels in the enclosure (due to improvements in guidance and working practices) and a reduced mortality rate. However, considering the latency period for asbestos related diseases (15 – 50 years) and that many of the improvements in the asbestos removal process have been relatively recent, it was difficult to draw firm conclusions at the time of publication. No follow up work has yet been published, but the study indicated that updating the work in 10 years or more would be useful.

The ACOP (HSE, L143) revised in 2013 outlines the measures that should be taken when working with asbestos, including removal work. More detailed sets of working procedures for asbestos removal and assessment for reoccupation of areas after removal are given in HSE guidance HSG247 (HSE 2006) and HSG248 (HSE 2021). Some of the guidance in HSG 247 was based on earlier HSE research which looked at the exposures of removal workers during wet stripping of ACMs (Burdett, 1999). More recent detailed research on ventilation of enclosures has also been published separate to HSG247 (Gibson 2014).

The site visits for this work were carried out in 1997 and 1998 and this was the last time HSE systematically collected its own evidence on the exposure of removal workers. The aim of guidance was to reduce operative exposure and the fibre levels on removal sites generally. One way to assess whether these changes have had the intended effect is to carry out on-site measurements of current fibre levels. However, any sampling exercise will only give a snapshot of current exposure.

It is a regulatory requirement that air sampling is carried out by analytical companies that are accredited by the United Kingdom Accreditation Service (UKAS). This includes personal monitoring, which allows employers to properly assess the risks associated with their work. However, this data is held by individual removal companies and not publicly

available. Additionally, for this data to be useful, it would have to include accurate contextual descriptions. This research work allows HSE to collect its own data and record observations.

1.2 Project setup

The main aims of the work were to provide an update on the exposures of asbestos removal workers and to assess compliance with HSE guidance relating to licensed, ie high risk asbestos removal. These aims were achieved by visiting eight sites throughout the whole removal process from enclosure construction to the dismantling of the enclosure after the four-stage clearance procedure (4SC). A range of measurements, including static and personal monitoring were collected, together with direct observations of work practices, supported by CCTV recordings inside asbestos removal enclosures.

This report focuses on the personal exposures of the removal workers on the eight sites visited and observed work practices. All licensed asbestos removal contractors (LARCs) that took part in this project, did so on a voluntary basis. Individual workers were able to opt out, even if the LARC had agreed to participate. This report is one of a series produced from this project, the others cover the effectiveness of control measures during licensed asbestos removal and the four-stage clearance procedure.

HSE scientists selected the sites from the work the volunteer LARCs were carrying out. LARCs were informed in advance that the objective of the research work was to observe and monitor the various site activities. It was also explained that if HSE scientists had any concerns whilst on site, these would be raised with the site supervisor to resolve them without the need to involve an HSE inspector. However, LARCs were aware that HSE scientists be required to inform an inspector if the site supervisor's actions in response to any concerns were not considered satisfactory, or if the issue was sufficiently serious that it could not be swiftly resolved by the supervisor. No enforcement action was necessary during any of the site visits.

2. Methods

2.1 Selection of volunteer companies and asbestos removal sites

The recruitment of volunteer LARCs was assisted by the two main trade association bodies, the Asbestos Removal Contractors Association (ARCA) and Asbestos Control & Abatement Division (ACAD). HSE produced a short description of the project, which included a summary of what would be required of the volunteer LARCs, this was distributed by ARCA and ACAD to their members. The information was also published on the asbestos licensing community forum on the HSE website. LARCs were encouraged to reply directly to HSE and any that did, were given more information on the project (information sheets can be found in Appendix C) and supplied with volunteer forms to fill out.

At the beginning of the project, 10 one-week site visits were planned. However, as the project developed, this was changed to eight site visits: six of one week and two of two weeks duration. Given that there have been approximately 35 000 licensed removal notifications per year for the last 5 years in GB (according to internal memos from HSE's asbestos licence unit) and the total number of licence holders, around 400 during this period, it was not possible to make the selection of eight sites and companies representative. The very nature of requiring LARCs to volunteer has probably resulted in only the most confident (that they can demonstrate best practice) coming forward. An effort was made to monitor as wide a variety of material types being removed as possible.

Once a LARC had agreed to take part, their asbestos removal notifications to HSE were monitored to see whether they were planning to undertake any work that would be suitable for the project. All LARCs must notify upcoming licensed work to a central HSE database by filling out an ASB5 form and submitting it online at least two weeks before the job is scheduled to start. This form gives details about the work such as the duration of the job, the address of the planned removal work, the material type and amount being removed and who the client is. Volunteer LARCs were also asked, wherever possible, to let HSE know if there were any jobs planned that might be suitable but had not yet been notified. Suitable sites were initially considered to be where the work was going to last one week. The intention was across the course of the project to make sure the removal of different ACM types was monitored. Discussions with volunteer LARCs and monitoring of notifications to the ASB5 database by HSE scientists indicated that AIB was the most common type of material notified to be removed, with insulation and sprayed coating being significantly less common. Another common type of work was the removal of small amounts of debris, often insulation debris left behind after previous poor removal jobs and sometimes referred to as an "environmental clean".

Once a suitable site was identified, the LARC was approached by HSE so that an agreement for HSE to visit could be made (unless the site had been specifically put forward by the LARC, as was the case for one site). Only one LARC refused to let HSE scientists visit at this point, saying they did not feel the site was suitable as it was too small

to accommodate both the required number of removal operatives and HSE scientists. No suitable sites were identified for this LARC during the remainder of the project.

Later in the project, jobs lasting two weeks were also considered in order that a greater volume of samples could be taken on site and so that sites where sprayed coating was being removed could be selected. Jobs of this type tended to last longer than a week.

The process of selecting companies and sites was more difficult than expected, with only a relatively small number of LARCs volunteering to take part and consequently there was only a small number of ASB5 notifications to monitor. Eleven LARCs volunteered after receiving information about the project for which five were included in the project. In the original project plan, it was anticipated that there would be a two-month gap between site visits. However, the difficulties in recruiting companies to take part and selecting sites, resulted in a gap of 6 months, on average.

To achieve the aim of including as many different ACM types as possible, sites where insulation and sprayed coating were being removed were specifically sought for the last three site visits. The LARCs who had already volunteered did not have any suitable work of this type at a time when HSE scientists could visit. Therefore, a slightly different approach was taken for selecting sites. The ASB5 database was monitored for all jobs where these types of material were being removed. Whenever suitable jobs were identified, the LARC was contacted and invited to participate in the project. A total of ten companies were contacted in this way, with five responding. One agreed to allow HSE access to the site identified and the other four agreed to allow HSE visit a different site. In these cases, the LARCs indicated that the chosen site was not suitable or there was not enough to time to arrange a visit before that job ended.

Consideration was also given to the type and size of volunteer LARCs with a view to observing a range of different companies. However, while a range of companies did take part, the small number of volunteer LARCs meant that the main consideration was whether the company was working on a suitable site at a time when the HSE scientists could visit. A description of each site and associated LARC is given in Table 1 below.

Table 1. Description of the volunteer LARCs and the sites visited

Site visit Number	LARC description	Material type and amount of ACM being removed	Type of building (occupied or not)
1	ARCA member based in the north-west of England	Asbestos Insulating Board (AIB) door headers and boxwork - 8 m^2	University (occupied, for refurbishment)
2	ACAD member with offices across the UK.	AIB debris - 12 m^2 (area size said to be contaminated in survey)	Post office (unoccupied, for refurbishment)
3	National Federation of Demolition Contractors (NFDC) and ARCA member based in the East of England	AIB partition walls - 16 m^2	Office (unoccupied, for demolition)
4	ARCA and ACAD member based in the north-west of England	AIB casing to steel columns - 6 m^2	Factory (unoccupied, for demolition)
5	ARCA member based in Essex	AIB Ceiling - 50 m^2	Shopping centre (unoccupied, for refurbishment)
6	Based in Essex. Not a trade association member.	Sprayed - coating to steel beams 80 linear m	Office (Occupied, for refurbishment)
7	NFDC and ARCA member offices across the UK	Insulation debris - (unknown amount of debris in 3 risers and behind two radiator housings)	University (unoccupied, for demolition)
8	NFDC and ARCA member based in the northeast of England	Pipe Insulation -1 linear m and debris in 5 linear m of ducts	University accommodation (unoccupied, for demolition)

An analytical company was present on all sites. Their activities included carrying out air monitoring during the removal work and the 4SC procedure at the end of the removal work. This sampling was independent of HSE's. The different analytical companies were also informed in advance of the HSE site visit and sent information sheets about the project. There was normally at least one employee from the analytical company on site

and occasionally, where the company required, two or three. In this report they are referred to as the 4SC analyst.

2.2 Overview of work on site

Two HSE scientists were present for each site visit. In most cases, the visit covered the beginning of work, enclosure construction, asbestos removal, the 4SC and continued until the enclosure had been dismantled. Static air monitoring was carried out throughout the site visit to assess fibre levels during all aspects of work. In most cases, personal monitoring was undertaken for all work activities and work practices were observed or recorded on CCTV.

The work on each site followed a schedule of enclosure construction; removal work; inspection by the site supervisor; the 4SC carried out by an independent analyst and enclosure dismantling. The duration of each stage varied from site to site and for some sites there was more than one enclosure included in the visit and therefore the process was repeated more than once. For enclosure work, removal workers generally worked in two shifts one in the morning and one in the afternoon with a break in between. The shifts varied in length from one to four hours depending on the site and the type of work being carried out.

Most air samples were analysed on site using phase contrast microscopy (PCM). All filters were cut in half before PCM analysis, so that further analysis by transmission electron microscopy (TEM) could be performed as required later, to determine the actual asbestos fibre concentration.

HSE scientists observed all aspects of the work and all observations were recorded in site notebooks and sampling sheets. Paperwork for each site visit, including risk assessments and plans of work were normally obtained from the LARC in advance of the site visit. This allowed HSE scientists to understand the planned approach. Work inside the enclosure was monitored and recorded using CCTV cameras. These cameras were set up during enclosure construction and then decontaminated as part of the 4SC procedure before being to be used on the next site.

Figure 1. An enclosure being constructed on a removal site visited by HSE scientists

2.3 Sampling Methods

2.3.1 Air Sampling

HSE scientists carried out personal and static sampling using low-flow personal and high-flow static air sampling pumps, as appropriate. The sampling was carried out in accordance with guidance set out in HSG248. The flowrate for each sample was selected to obtain as large a sample volume as possible without the risk of the filter being overloaded. Where possible, personal samples were taken over the whole duration of a shift. On some sites the work created an unexpected level of dust and some filters were overloaded. When this occurred, flowrates were reduced for subsequent shifts. Details of all air monitoring samples can be found in Appendix A.

Figure 2. A removal worker wearing a sampling pump while removing waste from an enclosure

The sample flowrate, duration and volume sampled were recorded for each sample taken and for personal samples the name of the worker, the activity being carried out and the type of respiratory protective equipment (RPE) worn were also recorded. For the purposes of this report, workers names are not used. For static samples, the location and type (eg background, leak or reassurance) were recorded.

On one site (Site 5), removal workers wore two personal sampling pumps when removal work was carried out. This was to test the feasibility of wearing two sampling pumps at the same time. The two pumps, tubes and cowls were attached to high-vis vests with cable ties. If the vests were worn inside the enclosure, they were removed on exit from the enclosure and disposed of as asbestos waste. The pumps, tubes and cowls were detached from the vest and decontaminated in the airlocks, as was also the case for all personal sampling carried out inside the enclosure.

2.4 Analysis methods

2.4.1 PCM analysis

For all air monitoring samples (personal and static), membrane filters were analysed first by phase contrast microscopy (PCM). Filters were cut in half, with one half cleared and

mounted on microscope slides for PCM analysis at 500x magnification in accordance with the method described in HSG 248. All visible fibres >5 µm long and <3 µm wide with an aspect ratio of >3:1 were counted. PCM cannot detect fibres will diameters less than roughly 0.2 µm and this method does not allow discrimination between fibre types. The majority of PCM samples were counted on site. Quality Control (QC) checks were carried out on a selected number of samples after the site visit. Results are reported as less than the limit of quantification where appropriate. The other filter half was stored for potential analysis by TEM.

2.4.2 TEM analysis

Selected half filters from the air samples were analysed by TEM to determine the asbestos fibre concentration, as PCM only gives the total fibre concentration. The sample filters for TEM analysis were selected to cover all types of samples taken. This selection process was carried out after each site visit by an HSE scientist who had been on site. As well as looking to select a range of different sample types, the number of fibres counted, the morphology of fibres counted and whether the activity undertaken whilst the sample was being taken. Samples taken outside the enclosure were also chosen to confirm whether measurable asbestos fibre concentrations were present.

The TEM method was based on the identification and fibre classification procedure set out for asbestos analysis in the International Standards Organization method ISO 10312:1999. At least two TEM sample grids were prepared and analysed for each filter sample, with sufficient numbers of grid openings searched at X5000 magnification to achieve an analytical sensitivity of <0.001f/ml. ISO 10312 uses the term ‘fibrous structures’ which is defined as a fibre, or connected grouping of fibres, with or without other particles (ie fibres, bundles, clusters and matrices of fibres). All fibres >5µm long, with morphology consistent with amphibole or chrysotile asbestos were measured (length, width and aspect ratio) to determine whether they could be classed as phase contrast microscopy equivalent (PCME) fibres (ie fibres >5.0 µm long, 0.2-<3 µm width and with an aspect ratio > 3:1). For samples where three or fewer fibres were counted, the result was considered below the limit of detection (LoD). If no fibres were counted, the LoD was taken to be the upper 95% confidence limit of the concentration, corresponding to 2.99 times the analytical sensitivity. Similarly, if one, two or three fibres were present, the LoD was calculated as 4.74, 6.30 or 7.75 times the analytical sensitivity, respectively. This approach assumes a Poisson distribution of fibrous structures on the filter.

The analytical sensitivity is a measure of how well the method can resolve the difference between two fibre concentrations. It is measured in f/ml and is calculated using the sample volume, the number of TEM grid openings examined, the area of filter analysed and the total filter area.

3. Results

3.1 Introduction to results

This section presents the results from sampling carried out during the eight site visits, which relate to the potential personal exposure of removal workers. The main tasks considered were, removal work inside the enclosure, enclosure construction, enclosure dismantling and waste transfer.

Results for all air monitoring samples analysed by PCM are presented as summaries and averages (Sections 3.3 and 3.4). Given the high number of samples taken, this was considered a more useful way to present them. All individual results can be found in Appendix A. Section 4.2, in the discussion section of the report outlines and explains the methods used to summarise results.

For TEM analysis of air monitoring samples, summaries of results are shown where they offer a useful comparison to PCM results (Section 3.6). However, as less TEM samples were analysed, tables of individual results are also given (Section 3.5).

3.2 The number of samples taken across all sites

Tables 2 and 3 present the total number of airborne fibre measurements taken across all eight site visits. Static samples are listed in Table 2 and personal samples are listed in Table 3.

The static samples are divided into types, based on where and why they were taken during the site visit:

- Background samples, which were taken before work started on the construction of the enclosure (this was only possible on four sites).
- Enclosure construction samples, taken during work to put up the enclosure.
- Leak samples, taken as live removal work was taking place inside the enclosure.
- Parallel clearance samples, taken alongside the 4SC analyst's clearance samples.
- Enclosure dismantling samples, taken as the enclosure was taken down after the clearance air tests had passed.

Personal samples are broken down by the work activity that was being carried out when the sample was taken:

- 'Removal' refers to all work associated with the removal of the ACM inside the enclosure.
- 'Enclosure construction' refers to all work that took place to construct the enclosure

- Enclosure dismantling' refers to all activities associated with dismantling the enclosure following the passing of the visual inspection and clearance air tests carried out as part of the 4SC.
- Waste transfer' refers to the carrying or transporting of sealed waste bags from the enclosure to the waste skip.

The ACM type that was being removed on each site is also given. Small scale AIB removal is defined as being less than 5 m^2 of AIB in any enclosure monitored.

Some of the sample numbers in these tables relate to results which will be published in other reports. This is noted in tables as appropriate.

Table 2. Number of static monitoring samples at each site

Site visit	Material type	Background*	Enclosure Construction	Leak*	Parallel Clearance*	Enclosure Dismantling
1	Small scale AIB	-	4	2	8	3
2	Low level contamination (AIB)	2	8	5	3	4
3	AIB	2	7	6	7	0
4	Small scale AIB	-	8	4	9	3
5	AIB	4	2	13	5	2
6	Sprayed coating	5	7	52	11	2
7	Low level contamination (Insulation)	-	6	14	4	2
8	Insulation	-	4	4	5	2

*Results presented in a separate report

Table 3. Number of personal monitoring samples at each site

Site visit	Material type	Enclosure construction	Removal	Analyst visual*	Waste transfer	Enclosure dismantling
1	Small scale AIB	5	4	1	0	2
2	Low level contamination (AIB)	3	5	1	0	0
3	AIB	2	12	1	1	1
4	Small scale AIB	3	6	3	2	3
5	AIB	5	31†	1	5	4
6	Sprayed coating	0	56	7	6	0
7	Low level contamination (Insulation)	10	34	5	3	3
8	Insulation	6	16	2	3	4

*Results presented in a separate report
†Removal workers wore two samplers at the same time on this visit

3.3 Summary of results from personal samples taken inside the enclosure

Tables and figures relating to this section are in section 3.7 below (landscape format.)

Table 4 summarises the PCM results from all personal samples taken inside enclosures on each site. The results are presented by site, with the highest, lowest and average result given. The average result has been calculated using the actual calculated concentration for all samples (any samples where the number of fibres counted was less than three, were given an actual concentration of zero). The 'low' results shown in the table are the reported values, which for six out of eight sites were reported as the LoQ (for the other two sites all results were above the LoQ). Results are also given as a four-hour time weighted average (TWA). A full list of samples and the results for each can be found in Appendix A. An explanation for the chosen methods for summarising and averaging results can be found in Section 4.2 of this report.

Approximately 26% of personal measurements taken inside removal enclosures were above the control limit (0.1 f/ml 4-hour TWA). When the results from individual removal workers are considered, then 32% had at least one measurement above the control limit (0.1 f/ml 4-hour TWA). It should be noted that these results are heavily influenced by Site 6, which contributed 35 of the 43 results (81%) above the control limit.

Figures 3, 4 and 5 show the results given in Table 4 in the form of a graph. Figure 3 shows the fibre concentration results calculated using the actual sampling time, Figure 4 shows the four-hour TWA and Figure 5 shows the results from Figure 3 plotted with a log scale to highlight the difference between the sites with lower fibre concentrations.

Figure 6 shows each individual PCM result across all sites. Figure 7 shows each individual PCM result for all sites apart from site 6 to better show the differences between these sites.

3.4 Summary of PCM results for personal and static samples taken outside the enclosure

Tables and figures relating to this section are in section 3.7 below (landscape format.)

Tables 5a and 5b present the numbers of personal monitoring samples taken during tasks performed outside the enclosure on each site. It also outlines how many of the PCM results were above the LoQ and gives the full details of samples where results were over the LoQ. Tasks outside the enclosure are split between enclosure construction, enclosure dismantling and waste transfer.
Figure 8 shows all PCM results from these types of samples plotted as actual concentration rather than their reported concentration (which for results below the LoQ would normally be reported as the LoQ). Tables 6a and 6b, and Figure 9 do the same for static samples taken during enclosure construction and dismantling.

3.5 Summary of TEM results for personal and static samples taken outside the enclosure

Tables and figures relating to this section are in section 3.7 below (landscape format.)

Table 7 summarises the number of samples of each type analysed by TEM for both personal and static samples.

Tables 8, 9 and 10 give details of TEM analysis for all sets of samples. Table 8 shows samples taken inside the enclosure during removal, Table 9 shows personal monitoring samples for tasks undertaken outside enclosures and Table 10 shows static samples for tasks undertaken outside enclosure.

Figures 10 and 11 show TEM results for personal monitoring and static monitoring tasks undertaken outside enclosures, respectively. Results below the LoD are plotted as half the LoD.

3.6 Comparison of TEM and PCM results for personal and static samples taken outside the enclosure

Tables and figures relating to this section are in section 3.7 below (landscape format.)

Table 11 gives a summary comparison of the PCM and TEM results of all personal samples taken during tasks carried out outside the enclosure and static samples taken during enclosure construction or dismantling. For each task type the highest result across all sites, the lowest result and the average of all results is given. The averages for the PCM results have been calculated using the actual concentration for results below the limit of quantification. Results with less than three fibres detected were given a zero value. The averages for the TEM results have been calculated using half the detection limit, for results below it. For both TEM and PCM results, the number of samples has been given together with the number of samples where the analysis result was over the LoQ (PCM) or LoD (TEM).

3.7 Tables and figures relating to sections 3.3 to 3.6 (landscape orientation pages)

Table 4. Summary of PCM results from personal monitoring inside enclosure during removal

Site visit	Material type	Percentage of samples above LoQ	Number of air samples taken on each site	Reported fibre conc. (f/ml) High	Reported fibre conc. (f/ml) Low	Reported fibre conc. (f/ml) Average	4-hour TWA (f/ml) High	4-hour TWA (f/ml) Low	4-hour TWA (f/ml) Average
1	Small scale AIB	67%	4	0.107	0.044	0.061	0.066	0.027	0.031
2	Low level contamination (AIB)	20%	5	0.014	<0.028	0.01	0.005	<0.007	0.005
3	AIB	92%	12	0.39	<0.023	0.134	0.28	<0.009	0.075
4	Small scale AIB	67%	6	0.04	<0.023	0.021	0.013	0.013	0.011
5	AIB	97%	31†	0.46	<0.014	0.064	0.316	<0.01	0.049
6	Sprayed coating	98%	56	1.12	<0.018	0.27	1.129	<0.017	0.246
7	Low level contamination (Insulation)	12%	34	0.04	<0.018	0.019	0.03	<0.02	0.009
8	Insulation	97%	16	0.23	0.03	0.085	0.205	0.025	0.063

†Removal workers wore two samplers at the same time on this visit

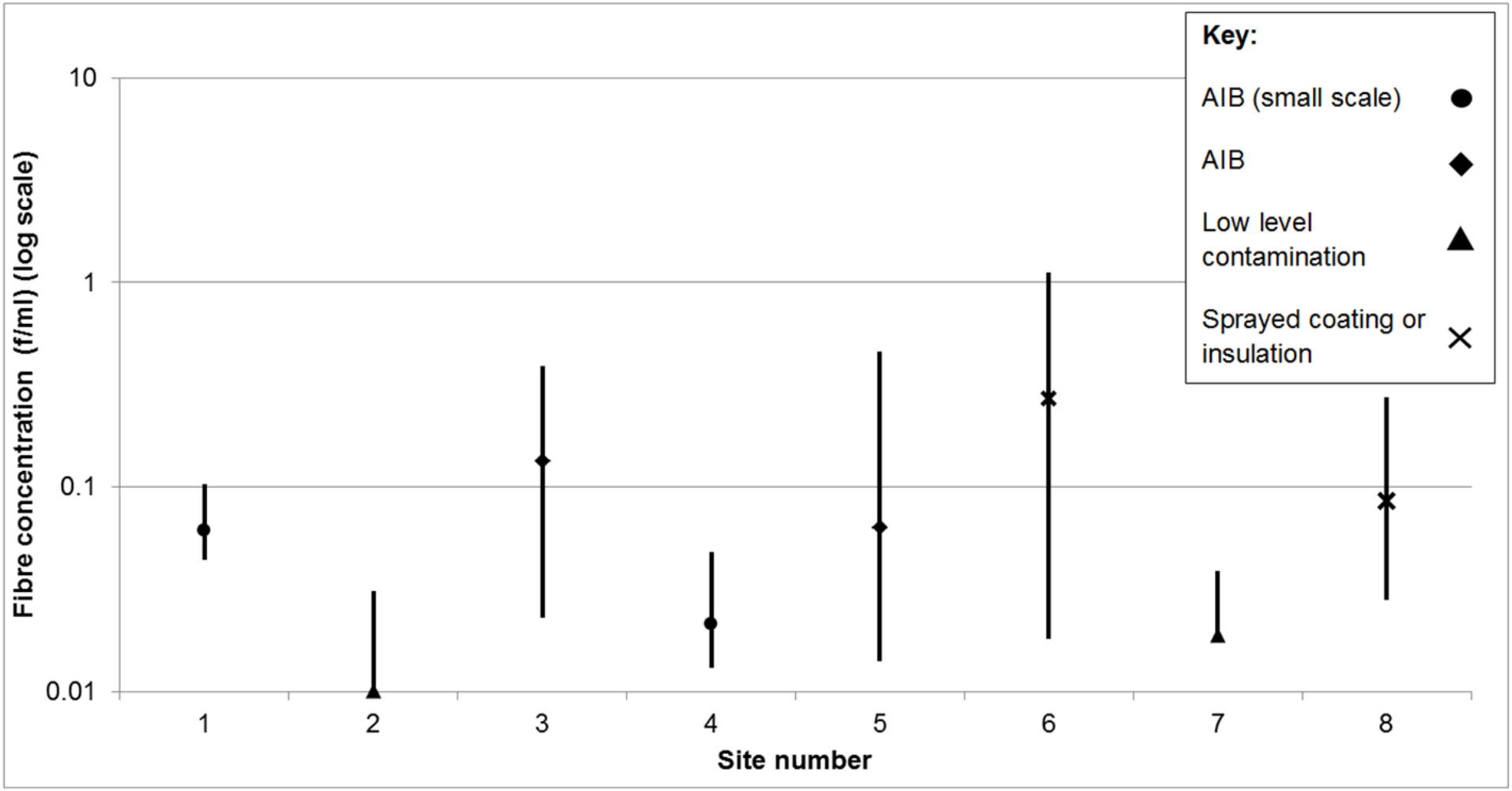

Figure 3. Summary by site of PCM personal monitoring results during removal (not 4-hour TWA)

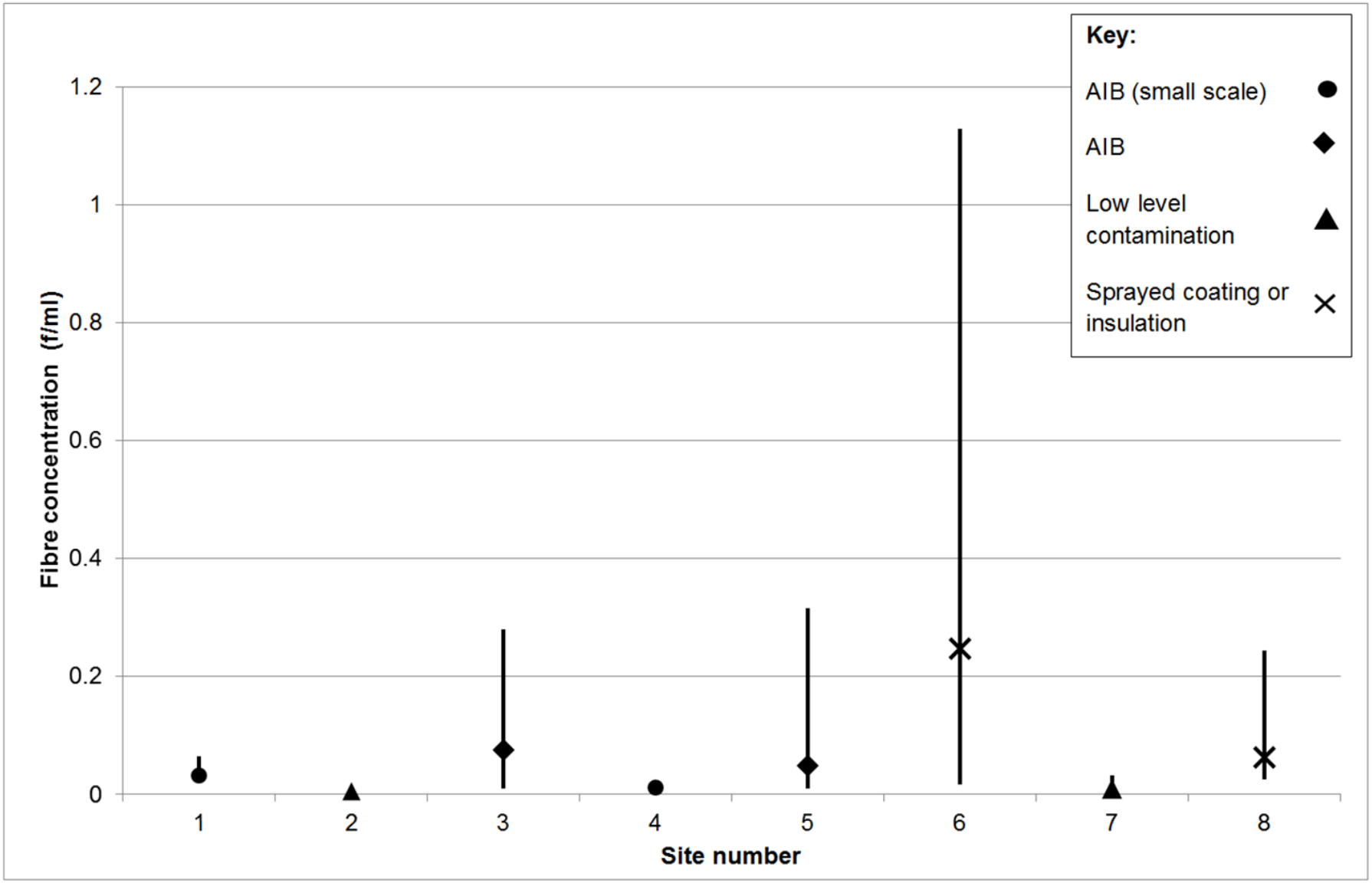

Figure 4. Summary by site of PCM personal monitoring results during removal (4-hour TWA)

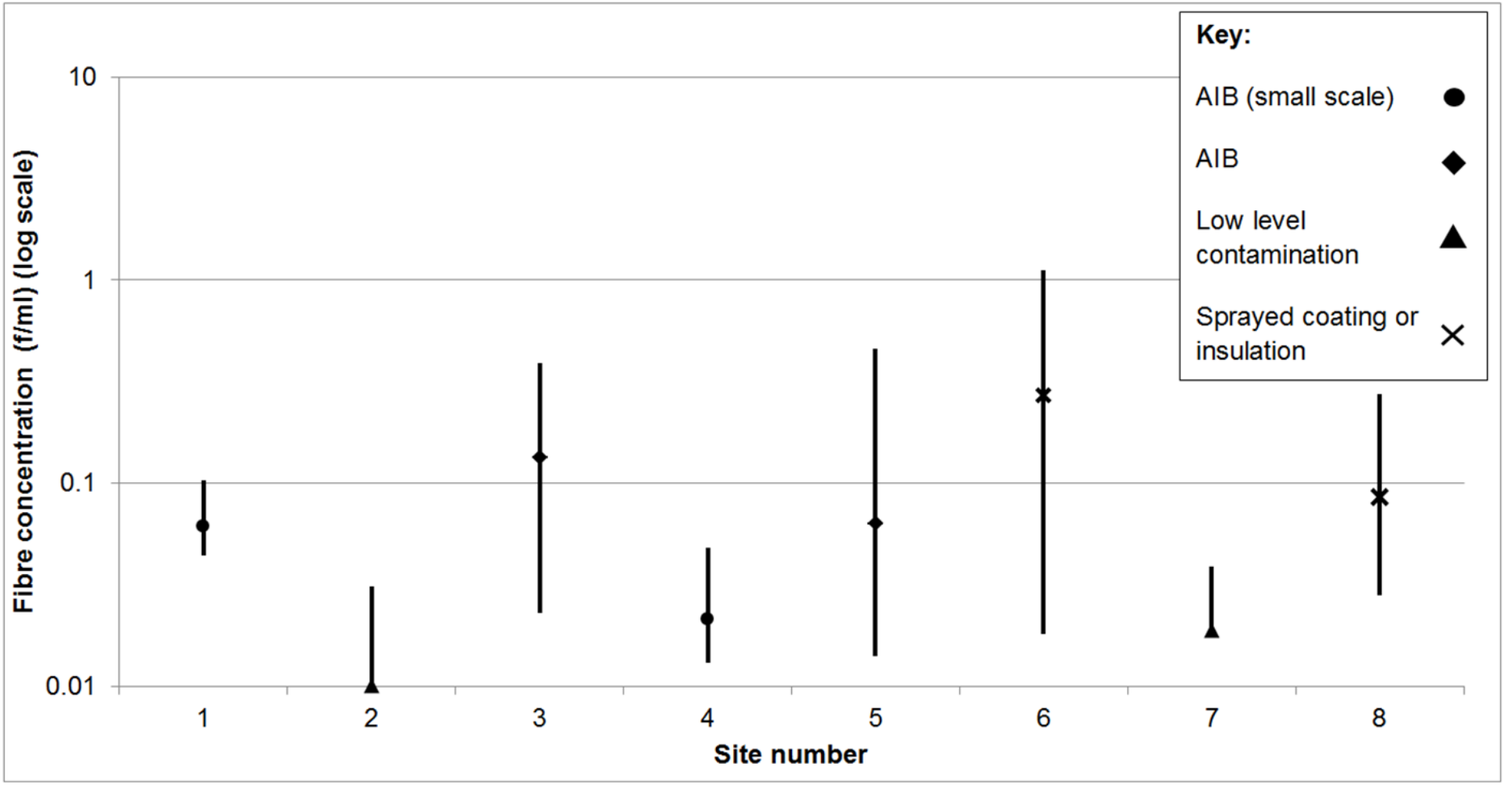

Figure 5. Summary by site of PCM personal monitoring results during removal (Not 4-hour TWA, log scale)

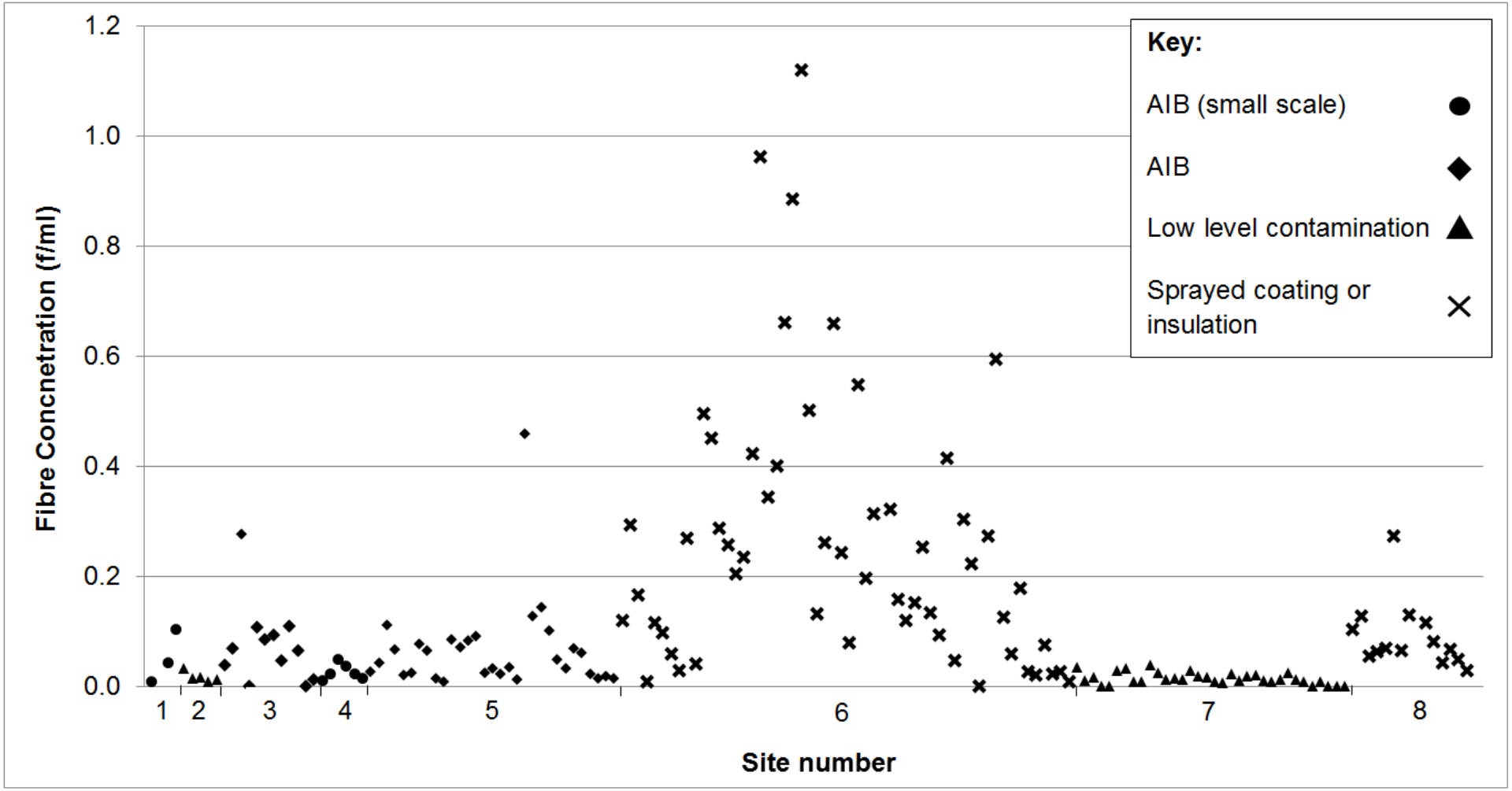

Figure 6. All PCM results for personal samples taken inside enclosures during removal

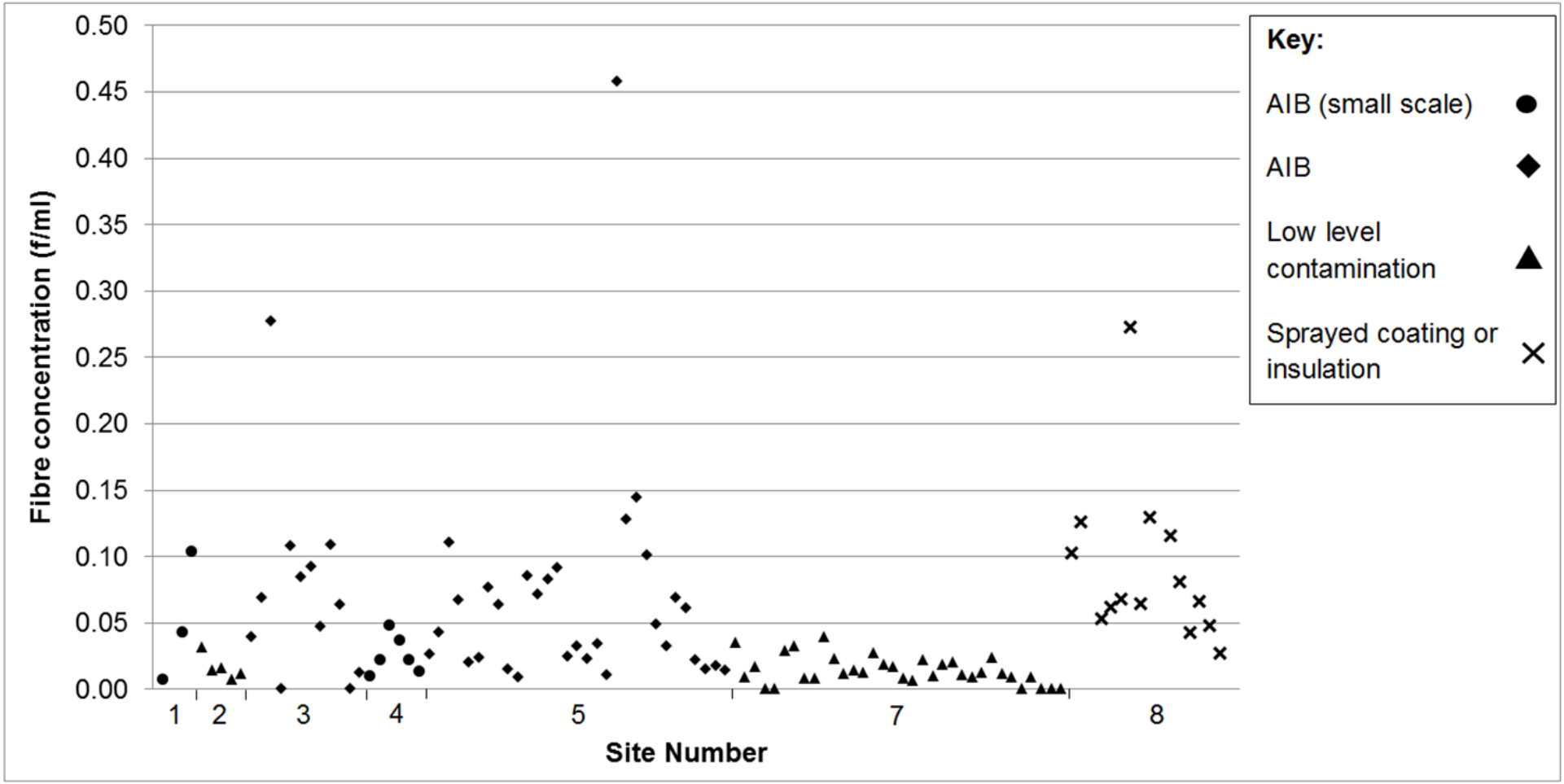

Figure 7. All PCM results excluding site 6 for personal samples taken inside enclosures during removal

Table 5a. Site details and number of PCM personal monitoring results above detection limit for outside enclosure task

Site visit	**Material type**	**Number of samples (Above LoQ)** **Enclosure Construction**	**Number of samples (Above LoQ)** **Enclosure Dismantling**	**Number of samples (Above LoQ)** **Waste transfer**
1	Small scale AIB	5 (1)	2 (0)	0 (0)
2	Low level contamination	3 (0)	0 (0)	0 (0)
3	AIB	2 (0)	1 (1)	1 (1)
4	Small scale AIB	3 (0)	3 (0)	1 (0)
5	AIB	5 (0)	3 (0)	4 (0)
6	Sprayed coating	0 (0)	0 (0)	6 (0)
7	Low level contamination	10 (0)	3 (0)	3 (0)
8	Insulation	7 (2)	4 (2)	3 (0)
	Total	35 (3)	16 (3)	18 (1)

Table 5b. Details of PCM personal monitoring results above detection limit for outside enclosure task

Site visit	Sample number	Activity/ RPE	Sample duration (min)	Sample volume (L)	Fibre conc. (f/ml) (Not weighted for time)	Fibre conc. (f/ml) (TWA)
1	01-014	Enclosure construction/ Half-face RPE	52	104	0.051	0.011
3	03-040	Carrying waste bags to skip/ Half-face RPE	63	126	0.09	0.02
3	03-054	Enclosure dismantling/ Half-face RPE	60	180	0.07	0.016
8	08-004	Enclosure Construction/ Half-face RPE	169	169	0.02	0.014
8	08-005	Enclosure Construction/ Half-face RPE	169	245	0.03	0.024
8	08-047	Enclosure dismantling/ Half-face RPE	83	170	0.03	0.01
8	08-048	Enclosure dismantling/ Half-face RPE	89	178	0.03	0.012

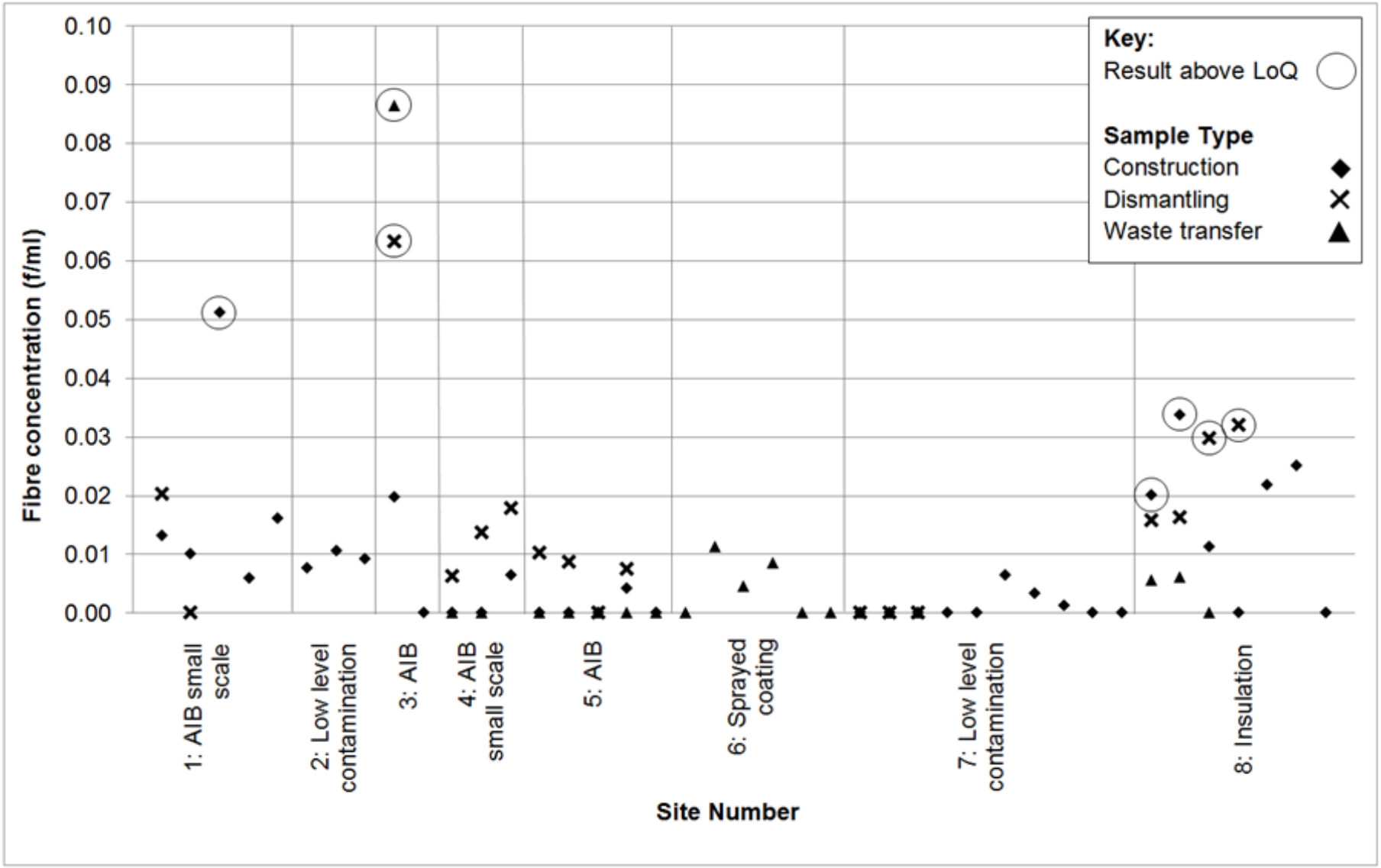

Figure 8. All PCM results from personal samples taken during tasks outside the enclosure, given as actual calculated concentrations (not weighted for time)

Table 6a. Site details and number of PCM static results above detection limit for enclosure construction and dismantling

Site visit	Material type	Number of samples (Number above LoQ) Construction	Number of samples (Number above LoQ) Dismantling
1	Small scale AIB	5 (4)	2 (1)
2	Low level contamination	10 (4)	1 (0)
3	AIB	7 (0)	0 (0)
4	Small scale AIB	9 (1)	3 (0)
5	AIB	2 (0)	2 (0)
6	Sprayed coating	7 (2)	2 (0)
7	Low level contamination	6 (0)	2 (0)
8	Insulation	4 (0)	2 (2)
	Total:	50 (11)	14 (3)

Table 6b. Details of PCM static results above detection limit for enclosure construction and dismantling

Site visit	Sample number	Activity	Sample duration (min)	Sample Volume (L)	Fibre concentration (f/ml) (not weighted for time)
1	01-001	Construction	68	544	0.02
1	01-002	Construction	120	960	0.01
1	01-003	Construction	120	960	0.011
1	01-016	Construction	112	874	0.008
1	01-013	Dismantling	60	480	0.012
2	02-006	Construction	125	1025	0.005
2	02-007	Construction	124	955	0.007
2	02-010	Construction	120	984	0.008
2	02-011	Construction	120	966	0.006
4	04-021	Construction	60	468	0.02
6	06-021	Construction	122	958	0.006
6	06-022	Construction	222	1193	0.008
8	08-049	Dismantling	120	612	0.015
8	08-050	Dismantling	120	744	0.012

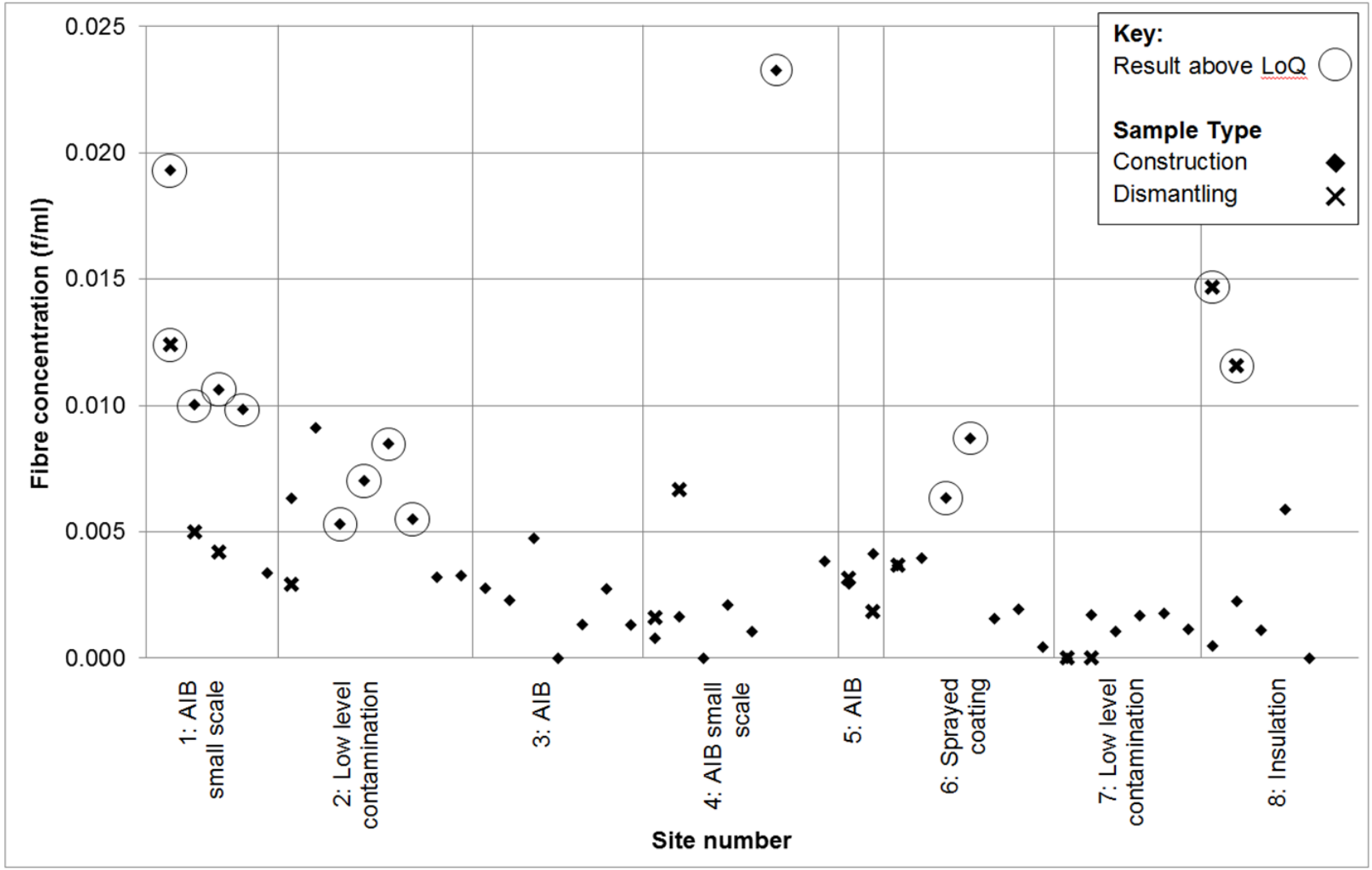

Figure 9. All PCM results from static samples taken during enclosure construction and dismantling (not weighted for time), concentrations plotted as actual calculated concentrations

Table 7. Summary of numbers and type of samples analysed by TEM

Site visit	Material Type	Enclosure construction (Static)	Enclosure construction (Personal)	Removal (Personal)	Leak (Static)*	Visual inspection (Personal)	Parallel clearance (Static)*	Enclosure dismantling (Static)	Enclosure dismantling (Personal)
1	Small scale AIB	3	0	0	0	1	6	1	1
2	Low level contamination (AIB)	2	2	0	1	0	2	0	0
3	AIB	1	1	1	2	1	4	0	1
4	Small scale AIB	2	1	0	2	1	2	1	2
5	AIB	1	1	2	2	1	5	1	1
6	Sprayed coating	2	0	5	8	3	2	1	0
7	Low level contamination (Insulation)	2	0	3	2	1	1	1	0
8	Insulation	1	1	1	2	1	1	1	1

*Results given in a separate report

Table 8. Individual TEM personal monitoring results for samples taken inside the enclosure

Sample number	Sample volume (Litres)	Activity	Analytical sensitivity (f/ml)	Number of asbestos fibres counted	Fibre concentration (f/ml)
03-019	344	Removal (AIB)	<0.001	41 Amosite	0.53
04-037	492	Removal (AIB)	<0.001	13 Amosite	0.012
05-014	336	Removal (AIB)	<0.001	28 Amosite 2 Chrysotile	0.12
05-059	594	Removal (AIB)	<0.001	22 Amosite	0.022
06-039	226	Removal (Sprayed coating)	<0.001	40 Amosite	0.54
06-061	241	Removal (Sprayed coating)	<0.001	30 Amosite	0.7
06-131	238	Removal (Sprayed coating)	<0.001	30 Amosite	0.04
06-137	293	Removal (Sprayed coating)	<0.001	31 Amosite	0.05
07-014	183	Removal (Insulation debris)	<0.001	2 Amosite	<0.0063
07-030	235	Removal (Insulation debris)	<0.001	0	<0.003
07-035	179	Removal (Insulation debris)	<0.001	3 Amosite 2 Crocidolite 1 Actinolite	0.0060
08-020	124	Removal (Pipe Insulation)	<0.001	31 Amosite	0.008

Table 9. Individual TEM personal monitoring results for tasks undertaken outside enclosures

Sample number	Sample vol. (Litres)	Activity/RPE	Analytical sensitivity (f/ml)	Number of asbestos fibres counted	Fibre conc. (f/ml)
01-012	100	Enclosure dismantling/ Half-face RPE	<0.001	5 Amosite	0.0050
02-012	264	Enclosure construction/ Half-face RPE	<0.001	None	<0.0030
02-021	252	Enclosure construction/ Half-face RPE	<0.001	None	<0.0030
03-009	180	Enclosure construction/ No RPE	<0.001	2 Amosite	<0.006
03-040	126	Waste Transfer/ Half-face RPE	0.003	40 Amosite	0.113
03-054	180	Enclosure dismantling/ Half-face RPE	<0.001	22 Amosite	0.022
04-003	132	Enclosure construction/ No RPE	<0.0012	8 Amosite	0.009
04-020	360	Enclosure dismantling/ Half-face RPE	<0.001	1 Amosite	<0.005
04-049	99	Enclosure dismantling/ Half-face RPE	<0.001	3 Amosite	<0.012
05-007	483	Enclosure construction/ No RPE	<0.0010	0	<0.003
05-048	147	Waste Transfer/ Half-face RPE	<0.0010	0	<0.003
05-054	124	Waste Transfer/ Half-face RPE	0.0012	1 Amosite	<0.006
05-070	248	Enclosure dismantling/ Half-face RPE	<0.001	8 Amosite	0.008
06-052	310	Waste Transfer/ Half-face RPE	<0.001	18 Amosite	0.018
06-080	255	Waste Transfer/ Half-face RPE	<0.001	5 Amosite	0.005
07-083	138	Enclosure dismantling/ Half-face RPE	<0.001	1 Chrysotile	<0.005
08-004	340	Enclosure construction/ Half-face RPE	<0.001	1 Amosite	<0.005
08-023	314	Waste Transfer/ Half-face RPE	<0.001	1 Amosite	<0.005
08-048	178	Enclosure dismantling/ Half-face RPE	<0.001	8 Amosite 1 Chrysotile	0.009

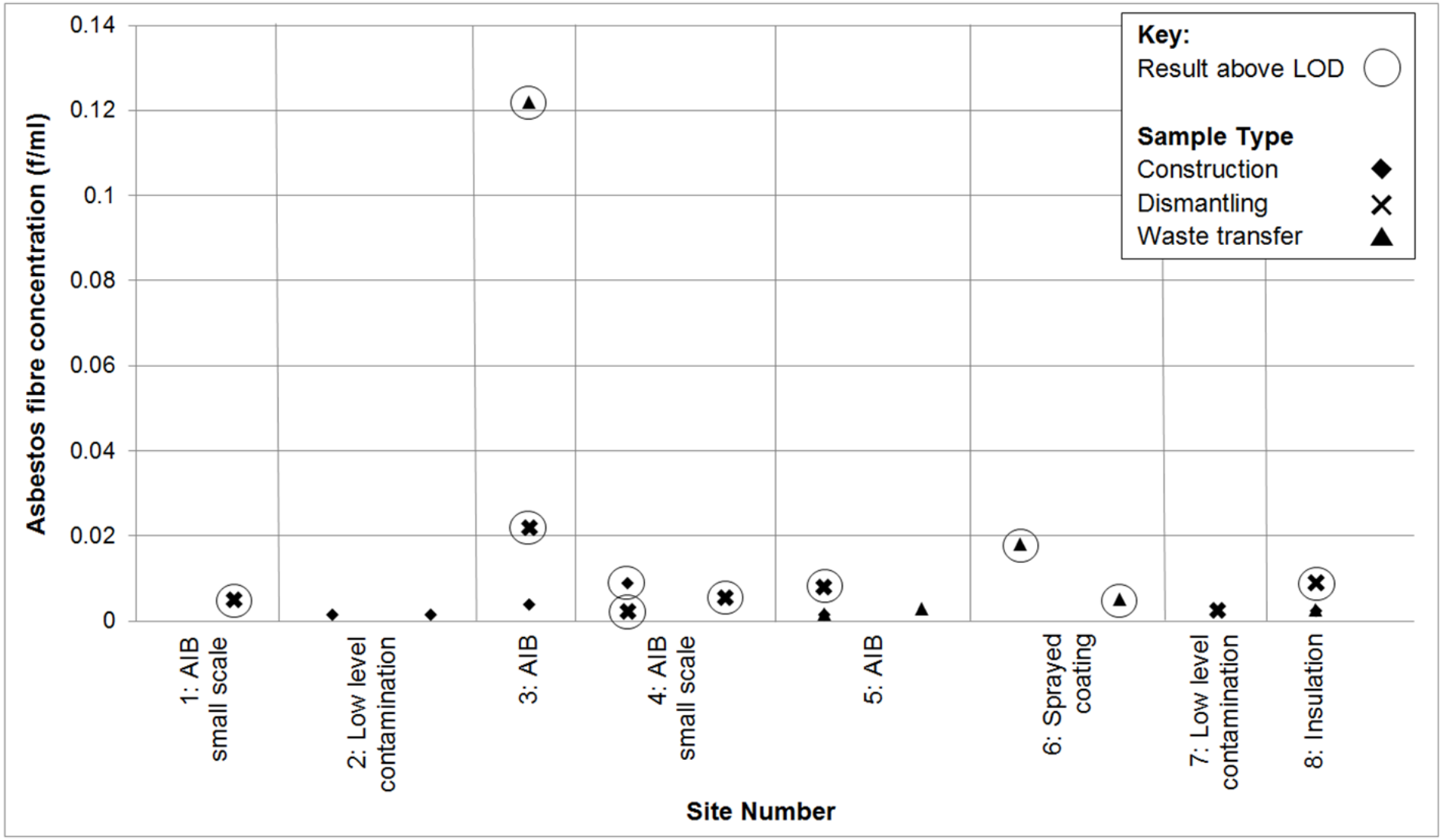

Figure 10. TEM results for personal samples taken during enclosure construction, dismantling and waste transfer

Table 10. TEM static monitoring results for enclosure construction and dismantling

Sample number	Sample Volume (Litres)	Activity	Analytical sensitivity (f/ml)	Number of asbestos fibres counted	Fibre concentration (f/ml)
01-001	544	Construction	<0.001	0	<0.0030
01-003	960	Construction	<0.001	1 Amosite	<0.0047
01-013	480	Dismantling	<0.001	3 Amosite	<0.0078
01-016	874	Dismantling	<0.001	2 Amosite	<0.0063
02-004	540	Construction	<0.001	None	<0.0030
02-006	1025	Construction	<0.001	2 Chrysotile	<0.0062
03-008	948	Construction	<0.001	0	<0.003
04-002	924	Construction	<0.0010	0	<0.003
04-021	468	Construction	<0.0010	0	<0.003
04-040	480	Construction	<0.0010	0	<0.003
04-048	474	Dismantling	<0.0015	5 Amosite	0.005
05-009	980	Construction	<0.0010	4 Amosite	0.004
05-076	753	Dismantling	<0.0010	8 Amosite	0.008
06-021	958	Construction	<0.001	16 Amosite 1 Chrysotile	0.017
06-022	1332	Construction	<0.001	11 Amosite	0.011
07-005	1181	Construction	<0.001	1 Chrysotile	<0.005
07-010	1069	Construction	<0.001	0	<0.003
07-080	550	Dismantling	<0.001	0	<0.003
08-008	688	Construction	<0.001	6 Amosite	0.006
08-049	612	Dismantling	<0.001	3 Amosite	<0.008

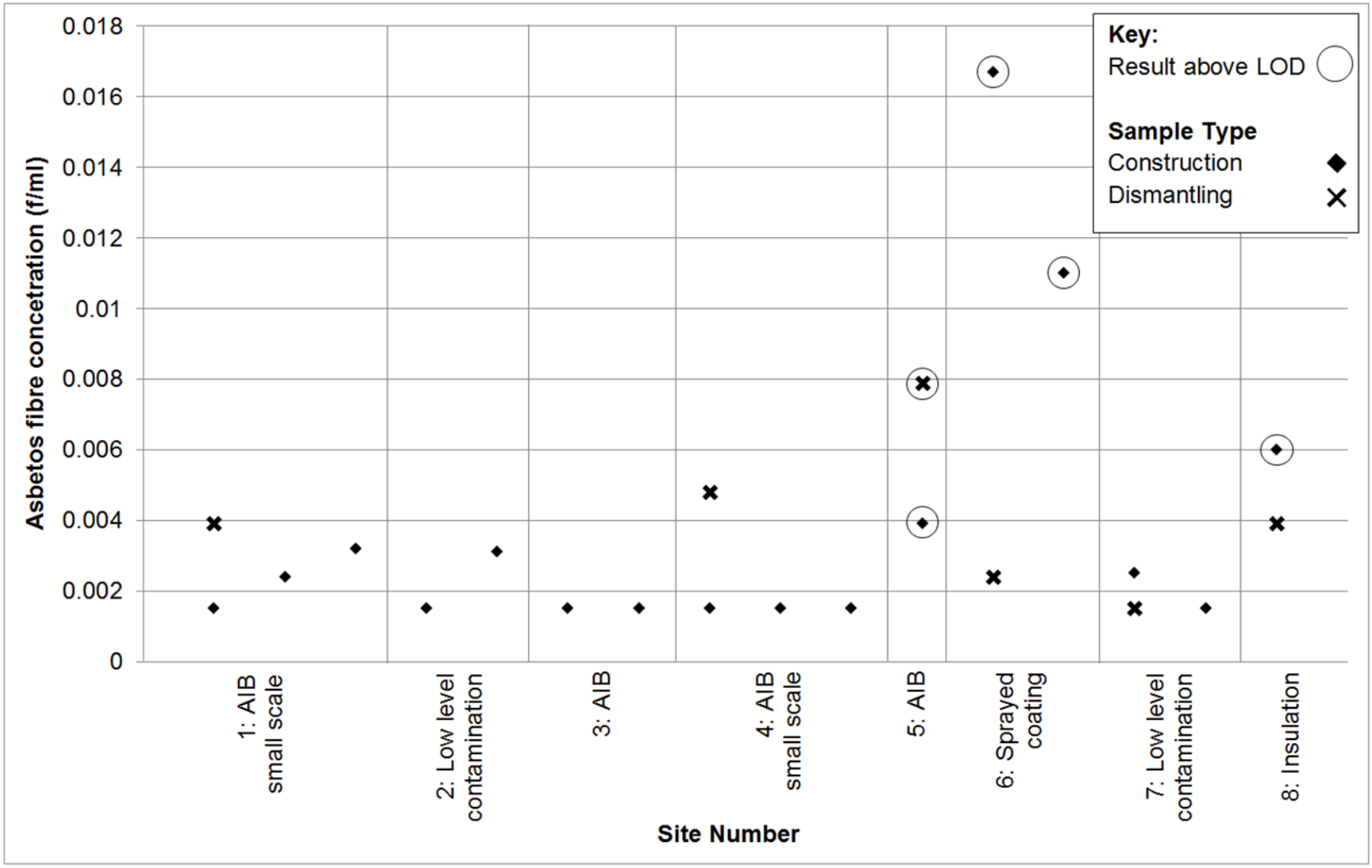

Figure 11. TEM results for static samples taken during enclosure construction and dismantling

Table 11. Summary comparison results from different outside enclosure tasks. All sites (not weighted for time)

Task	PCM fibre conc. (f/ml) High	PCM fibre conc. (f/ml) Low	PCM fibre conc. (f/ml) Average	PCM no. of samples (>LoQ)	TEM asbestos conc. (f/ml) High	TEM asbestos conc. (f/ml) Low	TEM asbestos conc. (f/ml) Average	TEM no. of samples (>LoD)	TEM total no. of asbestos fibres from all samples	TEM average no. of asbestos fibres per sample
Construction (personal)	0.051	<0.01	0.0086	35 (3)	0.0089	<0.003	0.0033	6 (1)	11	1.8
Dismantling (personal)	0.063	<0.019	0.0148	16 (3)	0.022	<0.0046	0.008	7 (4)	49	7
Waste transfer (personal)	0.08	<0.013	0.0038	18 (1)	0.1219	<0.003	0.0339	6 (3)	65	9.3
Construction (static)	0.019	<0.004	0.004	50 (11)	0.023	<0.003	0.004	15 (4)	45	2.8
Dismantling (static)	0.015	<0.005	0.005	14 (3)	0.008	<0.003	0.004	6 (2)	20	3.3

4. Discussion

4.1 Introduction to discussion

In this section, the results from the previous section are interpreted to understand how they inform our knowledge of exposures during licensed removal work. Where relevant, the observations of HSE scientists during their time on site will be included to add context to the results. The aim of the section is, using these results and observations, to make assessments of the exposure risk presented by different work activities during licensed asbestos removal. It will also compare the results obtained during this work to past work by HSE and other similar studies.

4.2 Methods used to summarise results

Each individual result described in this report is listed in Appendix A and the numbers of samples taken across all sites are shown in Tables 2 and 3. Summaries of air monitoring results (including results from both PCM and TEM analysis) are given in Tables 4 to 11 and Figures 3 to 11. The data has been split into the different tables and figures based on the type of work being carried out during the sampling. In some cases, average values have been used to aid interpretation. This section outlines what methods were used to obtain those averages and why those methods were chosen.

Individual results from air monitoring samples that are below the LoQ are reported as ‘less than’ (<) the LoQ value. When assessing airborne fibre concentrations on site this represents a precautionary approach with results assumed to be the LoQ value. This is a pragmatic approach when individual results are being used to inform on-site decisions about the level of risk present and the appropriate control measures. Different approaches are possible, when fibre concentrations are below the LoQ, when calculating averages or presenting ranges of data from a wide set of samples. The aim here, was to ascertain whether there were consistent patterns and differences in results from different sites and for different activities across all sites.

Particles sampled onto a filter have at best a random distribution. This means that the precision of the count is limited by the underlying Poisson statistics. The precision is usually expressed in terms of the confidence interval, which defines the upper and lower limits expected for a defined percentage of repeat counts. For example, 95% confidence limits mean that on average 19 of the 20 values from repeat counts on different areas of the same filter would be within the upper and lower limits. For low counts, the lower confidence limit is 0, so a one-sided upper 95% confidence interval is used. For a count of 0 fibres, it is 95% probable that the true number is < 3 fibres. For PCM counting, the analytical sensitivity (based on counting one half-fibre in 200 graticule areas (the lowest count possible above zero), a sample volume of at least 480 litres and an effective diameter greater than 20 mm) is between 0.0002 and 0.0003 f/ml. However, due to the

presence of some fibres on blank tested filters, the LoD is ~0.003 f/ml and the limit of quantification (LOQ) of the method is 0.010 f/ml. This is equivalent to a count of 40 fibre ends (20 fibres) in 200 graticule areas on a 480-litre sample. However, in theory the LoQ can be lowered indefinitely by filtration of progressively larger volumes of air and by extending the examination of the specimens in the microscope.

For TEM, the lowest achievable limit of detection for a particular area of filter examined is controlled by the total suspended particulate concentration. The LoD for fibre concentrations for TEM analysis is calculated by using the upper 95 % confidence limit of 2,99 structures predicted by the Poisson distribution for a count of zero fibres (ISO 10312, 1999). All results where three fibres or less are counted are given as below the LoD, with the fibre count a factor in the calculation of the LoD.

Where average concentrations have been calculated from TEM results, figures below the LoD have been assumed to be half the LoD. This is a simplistic approach and assumes a uniform distribution of results below the LoD.

A different approach was used to calculate the averages of PCM concentrations. The calculation of the LoQ for PCM analysis does not consider the number of fibres counted, only the sample volume and the number of graticule areas counted. For samples with concentrations below the LoQ, the number of graticule areas counted was almost always 200 and so the LoQ in this case was a function of the sample volume. In order to maintain the relationship between the number of fibres counted and the fibre concentrations, the actual calculated fibre concentration value was used. This was achieved by inserting the actual number of fibres counted into the formula used to calculate PCM fibre concentrations. Where the number of fibres counted was below three, the fibre concentration was taken to be zero (ie 0 f/ml). This would be considered an acceptable background level when assessing blank filters for use in sampling for PCM analysis (HSG248, HSE 2021).

In both cases (TEM and PCM averages), as the number of results below the LoD/LoQ, respectively, increased (included in the calculation to give an average result), the greater the uncertainty. In some statistical models, when over 50% of the results are below the LoQ, the model would not be valid (Hornung and Reed, 1990). For samples taken inside enclosures, the percentage of results below the LoQ was low, with six of the eight sites having 67% of the results above the LoQ and four of the eight having over 90% of the results above the LoQ (Table 4). For samples taken outside the enclosure, the majority of results were below the LoQ, with only between 10-20% of samples being above the LoQ, depending on the activity. Averages calculated for these tasks give a useful indication of the likely fibre levels during these activities, but it should be noted that there is a higher level of uncertainty compared with the actual fibre concentrations.

Results for personal samples can be reported as four-hour TWAs or as the concentration calculated over the period of sampling. TWAs for asbestos air sampling are normally

calculated for a four-hour period. This allows comparison to the four-hour control limit as set out in the regulations. The control limit is 0.1 f/ml averaged over four hours and compliance below this limit helps to assess whether the personal exposure of the removal worker was adequately controlled, (though the requirement is to reduce as far below it as reasonably practicable) (CAR 2012, Regulation 11). The control limit is also relevant to determining whether work with asbestos requires a licence. If the risk assessment cannot demonstrate that the control limit will not be exceeded, then the work requires a licence holder. It is useful to consider the fibre concentration during the activity as this result provides information on the magnitude of fibre release during the work activity itself. If a worker performs multiple short duration tasks during a working day, calculating each as a TWA would not give an accurate reflection of their exposure. During this project, removal workers were not monitored for every task they carried out during a working day. Unless otherwise stated, all averages in this report and referenced in this discussion section are calculated using the averages of fibre concentrations calculated using the sampling time.

Samples were selected for TEM analysis using several criteria, including how many fibres were counted by PCM (on the same filter), where the sample was taken and what the implications of finding asbestos fibres would be. Some of these criteria were subjective and based on the HSE analysts' opinion of the fibres observed using the optical microscope. The objective was to focus the TEM analysis in specific areas and not to give a representative selection of the samples overall.

Table 12 shows a broadly similar fibre distribution profile for PCM results compared with the corresponding TEM analysis. However, for results below 0.01f/ml, where there are similar numbers of PCM and TEM samples analysed, the PCM results are often below the LoQ. TEM samples will therefore have been selected for TEM analysis from this category because they had a high PCM fibre count, even if the result was below the TEM LoD. This will have potentially increased the likelihood that the TEM detected asbestos fibres and this should be taken into account when comparing TEM averages for a specific task to PCM averages.

Table 12. Number of samples within given PCM fibre concentration range

PCM fibre concentration range (f/ml)	**Percentage of PCM results within range**	**Percentage of samples within range selected for TEM analysis**
<0.01	60	65
0.01 – 0.1	28	31
0.1 - 1	12	4

4.3 Airborne fibre concentrations during asbestos removal

Figures 3, 4 and 5 show the average fibre levels measured inside enclosures during removal work, based on the personal samples taken on each site visit. Figure 6 shows each individual result.

The data indicates that the average fibre levels inside enclosures, when using results that have not been time weighted, ranged from 0.01 f/ml to 0.27 f/ml, with the highest results ranging from 0.014 f/ml to 1.12 f/ml, across several sites.

TEM analysis was carried out on some of the personal samples taken inside the enclosure during removal work. For most sites there was a reasoned assumption that fibres present inside the enclosure, during removal work, would be asbestos and therefore TEM analysis was not generally seen to be necessary. However, a small number of samples were analysed (12 in total) and the results are shown in Table 8. These samples were selected where the PCM fibre concentration in the enclosure was low or to find out if the asbestos fibre concentration was significantly different to the PCM fibre concentration. There were not enough personal monitoring samples taken inside the enclosure that were analysed by TEM, to calculate meaningful averages.

The removal workers wore only full face powered RPE with a P3 filter, when working inside the enclosure. When face fitted and worn correctly, this type of RPE should give an assigned protection factor (APF) of 40 (Tannahill et al.,1990). This means it should reduce fibre levels inside the mask by at least 40 times. If this factor is applied to the fibre concentrations measured during this project, this would result in all exposures being reduced by a factor of 40x. Table 13 shows the APF for powered full-face masks applied to some of the fibre concentration results from personal sampling inside enclosures.

Table 13. Full face APF applied to results from personal samples inside enclosures

	PCM concentration (f/ml) (TWA)	**Concentration after APF applied (f/ml)**
Low average result (site 2)	0.009 f/ml	0.0002 f/ml
High average result (site 6)	0.25 f/ml	0.006 f/ml
Peak result (site 6)	1.12 f/ml	0.03 f/ml

The primary requirement of CAR 2012 for employers, is that worker exposure must be either prevented or where unavoidable, be reduced to as low as reasonably practicable. Observations made on site confirmed that the fibre levels observed from personal sampling in the enclosure could vary depending on the working practices of the removal

workers. Where single enclosures were monitored over a one or two-week period, the working practices of removal workers frequently started in a careful and considered way. Then, as time went by, as they became accustomed to the presence of HSE scientists, more instances of less careful work practices were seen. They may also have felt pressure to complete the job on time, after a slow start (due to the presence of HSE scientists) and therefore rushed their work as time went on. This was particularly evident for the AIB removal work observed on Sites 3 and 5, where instances of AIB breaking were more common in the latter half of the removal process. The two peak fibre concentration measurement results for these sites, 03-019 and 05-040, both occurred during shifts in the latter half of the visits. This demonstrates that while removal workers know how to follow guidance and best practice, there are times when they do not, even when observed (see Figure 12). The reasons for this are likely to include, being under pressure to rush jobs when required to meet a deadline, fatigue after long shifts or inadequate supervision. The difference between these two peak results and the average results on each site show the potential implications in terms of the increase of exposure when guidance is not followed.

Figure 12. CCTV still of removal operative on Site 5 breaking AIB boards as they are removed

A further discussion of the possible impact of different wetting and removal techniques on fibre levels inside the enclosure will be published in a report entitled: “The Use of Control Measures during Licensed Removal”.

The highest average and highest peak fibre concentrations occurred on Site 6 (0.27 f/ml and 1.12 f/ml respectively), where 80 linear metres of sprayed coating to steel beams was removed. Sprayed coating is a friable material that generally contains a high percentage of

asbestos, usually around 55-85% (HSG264, HSE 2012). For these reasons, this material has the potential to release significant quantities of fibres during removal.

On Site 8, one linear metre of pipe insulation and associated debris in 5 linear metres of ducts was removed. This material had similarly friable properties to sprayed coating, and can also contain up to 85% asbestos, though with a greater variation. The airborne fibre concentrations on this site were lower than Site 6, with an average of 0.08f/ml compared to 0.27 f/ml. This was most likely due to the difference in the nature of the material and the reduced amount of material removed per shift. The material removed on Site 8 was mostly present in the form of insulation residues. The average fibre concentration for Site 8 was higher than for Site 5, where 50 m^2 of AIB was removed across a similar timeframe. This was a much greater amount of material, but AIB is a less friable material than sprayed coating or insulation.

Comparing the sites where AIB was removed (Sites 1, 3, 4 and 5), there was some variation in the fibre concentrations measured inside the enclosures. In view of the work undertaken, it was expected that average fibre concentrations for Sites 1 and 4, where small scale AIB was removed (less than 5 m^2 in any one enclosure), would be lower than average concentrations on Sites 3 and 5, where 16 m^2 and 50 m^2 were removed, respectively. It is also important to consider the amount of time required to complete each removal job and the effect this may have on fibre release and worker exposure. However, it is likely that similar airborne fibre concentrations are possible for large and small AIB removal jobs, if the duration of both jobs is similar. It is also likely that AIB panels are removed one by one, rather than multiple panels simultaneously. The most important factor is always how well controlled the removal is. Removing larger amounts of AIB does give more opportunity for the material to break or be disturbed, but if the removal is carried out in a methodical and controlled manner the difference should be minimal.

Comparing the results, presented in Table 4, the average fibre concentration for Site 4, where less than 5 m^2 of AIB was removed per enclosure, was much lower than the average fibre concentrations for Sites 3 and 5, where the scale of removal was much larger. However, for Site 1, where less than 5 m^2 of AIB was removed per enclosure, the average fibre concentration was almost equal to that on Site 5, despite the difference in the amount of AIB removed; 8 m^2 across two enclosures on Site 1, compared to 50 m^2 in one enclosure, on Site 5. This supports the argument that the amount of material being removed is not necessarily the largest factor in determining how many airborne fibres are generated. The suitability and effectiveness of control is likely to play a bigger role. However, it should be noted only three samples were taken inside the enclosures on Site 1 compared to 31 for Site 5.

The highest average fibre concentration measured during AIB removal was 0.134 f/ml on Site 3. This is higher than the average measurement for Site 5, despite roughly three times less material being removed across a similar period. Two possible reasons for this include the enclosure on Site 3 being a more confined space and differences in working practices

between the two sites. Although work became more hurried as the job progressed on both sites, there were differences in the way this affected the work. For Site 3, this led to a reduction in the amount of wetting carried out, whereas on Site 5 this was not observed. Again, these differences in practice, and the level of control during removal, are likely to have had greater impact on the fibre concentrations.

4.4 Enclosure construction and dismantling

Removal work inside the enclosure will almost always be the highest risk activity during any given asbestos removal job, as it involves actively disturbing ACMs. However, other work will also carry a risk of disturbance of or exposure to asbestos, as all work will take place in the vicinity of ACMs or in areas where ACMs have recently been removed. All work activities on removal sites need to be considered and air monitoring carried out if necessary, in order to show that the risk controls/assessments in place do eliminate or minimise this risk of disturbance and exposure. The construction and dismantling of the temporary enclosures used in licensed removal are two activities where potential exposure is possible. Personal and static monitoring was carried out for both activities on most sites included in this study.

It was not possible to include all activities at three of the sites visited (2, 3 and 6) either because HSE scientists were not available when that activity was taking place or due to equipment failure. Charger or pump failures resulted in no personal monitoring samples taken during enclosure construction on Site 6 and no static sampling on Site 3 during enclosure dismantling. No personal samples were taken during the dismantling of the enclosure on Sites 2 and 6, as HSE scientists had to leave site before this activity took place or before it finished. However, some measurements were obtained from these sites. This data together with the complete data sets from the other sites provide sufficient information to make valid observations when comparing the differences between the fibre levels seen on different sites during these activities.

Across all sites, PCM measurements for personal sampling during these activities generally gave results below the LoQ. For enclosure construction, only 3 out of 35 (9%) samples gave results above the LoQ and for enclosure dismantling, 3 out of 19 (19%) were above the LoQ. Table 5 (in the results section) gives details of all samples where the result was above the LoQ. These results indicate that both activities do not usually result in measurable fibre concentrations but that in both cases there is a potential exposure risk present.

The average fibre concentrations across all sites, for each activity are shown in Table 11 in the results section. The personal measurements show that there was on average a higher fibre concentration during enclosure dismantling, compared to construction. However, given the small percentage of results which were above the LoQ for both activities, these average values carry a high level of uncertainty. Both activities resulted in low fibre concentrations, but did on occasion, give higher, measurable fibre concentrations. This

should be considered by LARCs when writing risk assessments and deciding what control measures to put in place for enclosure construction and dismantling, to protect their employees as well as other building occupants. LARCs also need to carry out their own personal sampling of these activities to obtain evidence about the potential risk of each activity. Static samples taken during enclosure construction and dismantling gave similar results by PCM to personal sampling results of the same activities, with the majority giving results below the LoQ. For enclosure construction, 11 out of 50 (22 %) measurements were above the LoQ and for enclosure dismantling 3 out of 14 (21%) were above the LoQ. Table 6 gives details of all samples where the result was above the LoQ.

The average PCM fibre concentrations for static samples taken during enclosure construction and enclosure dismantling (Table 11) showed less of a difference than the equivalent personal samples. However, the small number of results above the LoQ means there is high amount of uncertainty about the average values.

The TEM analysis of samples taken during enclosure construction and dismantling revealed a slightly different situation, compared with the PCM averages. TEM results from personal samples showed the average asbestos fibre concentration was significantly lower than the average PCM fibre concentration for enclosure construction samples but similar results for enclosure dismantling samples (Table 11). This suggests that the fibres detected during enclosure dismantling were more likely to be asbestos.

TEM analysis of static samples gave similar average asbestos fibre concentrations compared to the average PCM fibre concentrations for both activities. However, the TEM static construction average was raised significantly by two outlying results from Site 6 (06-021 and 06-022). The TEM average asbestos fibre concentration was 0.004 f/ml when they were included and 0.0024 f/ml when they were not. For both outlying results, the asbestos fibre concentration was higher than the PCM fibre concentration. This along with the fact there were more samples analysed by PCM than TEM, 49 compared to 15, means these samples will have had a bigger effect on the TEM static enclosure construction average than the equivalent PCM average.

The average results across all sites show potential broad patterns for activities but it is also useful to look at individual results where they show something of interest. Table 14 gives a selection of results where the PCM or TEM result gave a result above the LoQ.

Table 14. Selected samples analysed by both PCM and TEM

Sample number	Sample type	Activity	PCM fibre conc. (f/ml)	TEM asbestos fibre conc. (f/ml)
01-003	Static	Enclosure construction	0.011	<0.0047
01-012	Personal	Enclosure dismantling	<0.048	0.005
02-001	Static	Background (before work started)	0.007	<0.003
02-006	Static	Enclosure construction	0.005	<0.0062
03-054	Personal	Enclosure dismantling	0.07	0.022
04-003	Personal	Enclosure construction	<0.036	0.009
04-021	Static	Enclosure construction	0.02	<0.003
04-049	Static	Enclosure dismantling	<0.01	0.005
05-009	Static	Enclosure construction	<0.005	0.004
05-070	Personal	Enclosure dismantling	<0.019	0.008
05-076	Static	Enclosure dismantling	<0.006	0.008
06-021	Static	Enclosure construction	0.006	0.017
06-022	Static	Enclosure construction	0.008	0.011
08-004	Personal	Enclosure construction	0.02	<0.0048
08-008	Static	Enclosure construction	<0.007	0.006
08-048	Personal	Enclosure dismantling	0.03	0.009
08-049	Static	Enclosure dismantling	0.015	0.004

The TEM results presented in Table 14 show that measurable asbestos fibre concentrations were present during both enclosure construction and dismantling at six out of eight sites. Airborne asbestos fibres were measured by TEM on all sites for at least one sample taken during enclosure construction or dismantling. However, no samples gave fibre concentrations above the LoQ for Sites 2 and 7.

For several samples, the TEM results indicated a measurable asbestos fibre concentration below the LoQ of the PCM analysis. This was the case for seven of the samples presented in Table 14. Therefore, it should not always be assumed that when fibre concentrations reported by PCM are below the LoQ, that there is not a risk of exposure to asbestos fibres. The results from these air monitoring samples are used to provide evidence for risk assessments and working methods. Regulation specifies PCM analysis for asbestos air

monitoring samples. As a result, the use of scanning electron microscopy (SEM) or TEM is rare, unless it is important to determine the actual asbestos fibre concentration. Further barriers to the widespread use of SEM and TEM are that neither technique is easily performed on-site, both are more resource intensive than PCM and there are few dedicated instruments available.

Risk assessments, together with HSE guidance are used to assess whether RPE should be worn and if so, what type. HSE guidance HSG247, Asbestos: The licensed contractors' guide (HSE 2006) requires half-face RPE to be worn during the dismantling of enclosures but does not state that it should be worn during enclosure construction. However, a suitable and sufficient risk assessment is needed to ensure the correct RPE is worn for the task. This should be supported by drawing on previous air monitoring of similar tasks.

Half-face RPE was worn during enclosure construction on Sites 2 and 8, but no RPE was worn on any other sites. On Site 4, TEM analysis of a personal sample 04-003, taken during enclosure construction, showed an asbestos fibre concentration of 0.009 f/ml, whilst the PCM analysis from the same filter, gave a result of <0.036 f/ml. No RPE was worn by the worker during this task. Half-face RPE was worn by most workers during the dismantling of enclosures, witnessed by HSE scientists. However, there were a few exceptions. On Site 3, two out of three workers who dismantled the enclosure did not wear RPE. Unfortunately, due to sampling equipment failures, it was only possible to monitor the worker who wore RPE. The analysis of this sample, 03-054, showed an asbestos fibre concentration of 0.022 f/ml. All removal workers worked in close proximity to each other carrying out similar tasks and so it would be reasonable to assume the other two workers experienced a similar exposure. Figures 13 and 14 show examples where removal workers either removed RPE during enclosure dismantling work or did not wear it at all.

On all sites, examples of removal workers demonstrating bad practice were witnessed, with respect to their use of half-face RPE. No removal workers were observed carrying out a pre-use fit-check of their RPE. On several occasions they wore their RPE continuously for longer than one hour. HSG 53, Respiratory protective equipment at work (HSE 2013), says wearers of tight-fitting half face RPE need to perform a fit check before use, which involves temporarily blocking the exhaust valve to test the seal of the mask and that non-powered tight-fitting masks should not be worn continuously for more than an hour. The APF of a mask can be reduced if good practice is not followed (Howie et al., 1995). On two occasions, removal workers revealed that they did not normally wear half-face RPE for the task they were performing and were only doing so because they had been instructed to, due to the presence of HSE. On one occasion this was witnessed during enclosure construction and the other was during enclosure dismantling.

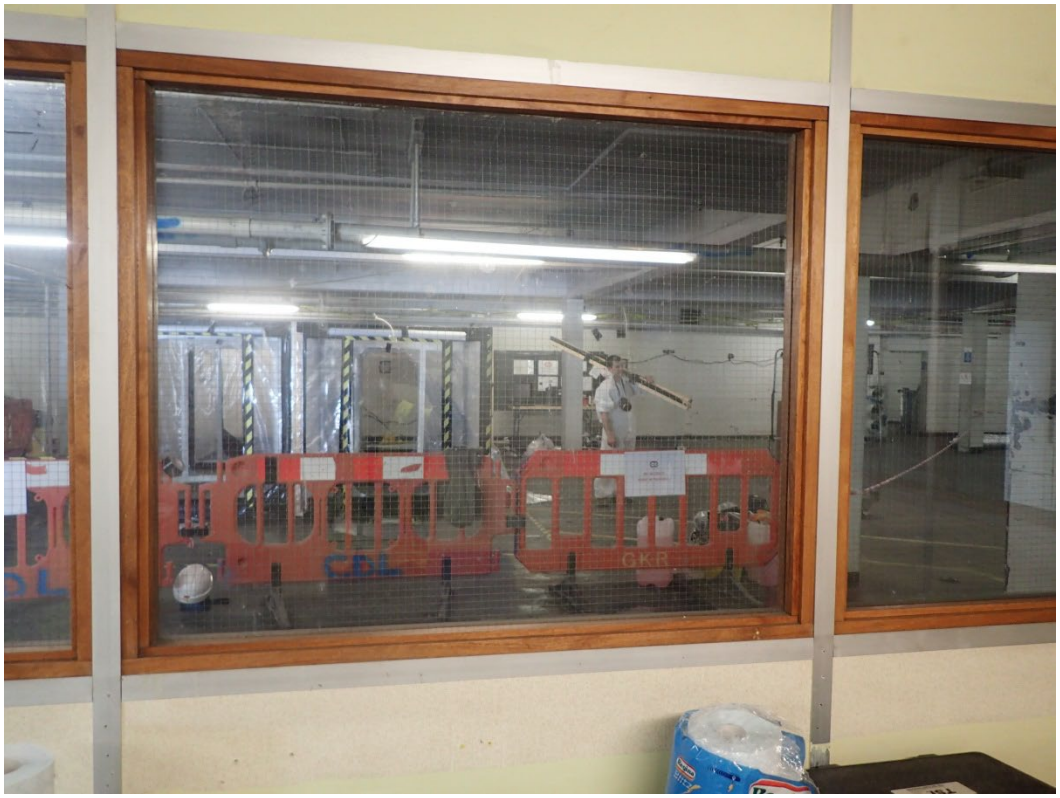

Figure 13. Removal operative on Site 5 working with half-face RPE removed during enclosure dismantling

Figure 14. Removal operative on Site 4 working with half-face RPE removed during enclosure dismantling

The two highest TEM results were static measurements on Site 6, taken during enclosure construction (06-021 and 06-022). The work on this site involved the removal of sprayed coating on steel beams, a highly friable material likely to release fibres. The static measurements indicated that higher asbestos fibre concentrations were generated during enclosure construction for this site compared to others. It is likely that a similar asbestos fibre concentration would have been measured from personal monitoring. However, this cannot be confirmed as no personal samples were taken during the construction of the enclosure on this site. HSE scientists were not able to be on site for the enclosure dismantling (although some static samples were taken the day after the dismantling). The sprayed coating on the steel beams had been encapsulated with paint and the beams were located above suspended ceiling tiles. The ceiling was removed as part of the works to construct the enclosure. Contaminated suspended ceiling tile surfaces (ie where asbestos dust and fibres have been deposited during previous disturbance activities in the void) are a recognised asbestos source when ceiling tiles are removed. There is a strong possibility that asbestos fibres previously deposited on top of the suspended ceiling could have been disturbed during this work leading to the measured elevated fibre concentrations. The monitoring inside the enclosure during removal also gave the highest individual, as well as the highest average fibre concentration of all sites. More sampling on sites where sprayed coating is present would be needed to see if there was a consistent pattern of raised asbestos fibre levels.

4.5 Waste transfer

On all sites, asbestos waste was transferred from the enclosure to a skip by transferring sealed bags out of a 3-stage baglock system to an asbestos waste skip. In most cases the bags were manually carried to the skip, although on some sites the waste was transported in wheeled containers.

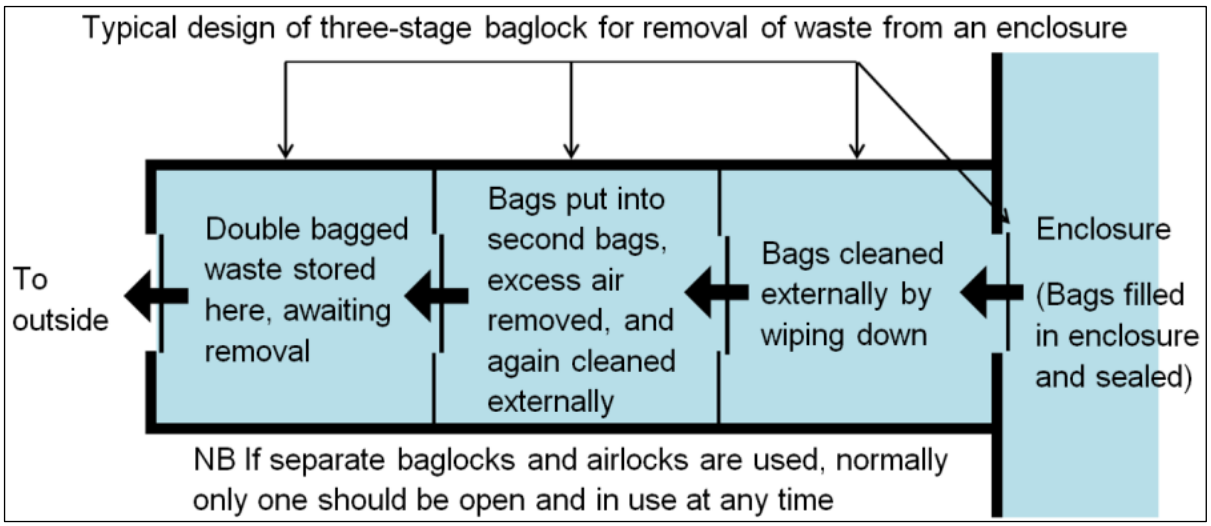

Figure 15. Baglock procedure as outlined in HSG 247 (HSE 2006)

The general procedure used to minimise spread and exposure when taking waste out of an enclosure through a baglock system is described in HSG 247 and reproduced in Figure 15. This procedure was not followed on all sites visited during this project. The outside worker was seen to enter the baglock to both receive bags and assist 'inside' workers with double bagging and bag cleaning. Guidance is written to ensure that there is minimal risk of fibres being present on the outside surface of the waste bags and therefore a lower risk of exposure to workers transporting the bags to the skip. However, there will always be a risk that cleaning has not been effective or that bags are damaged or split (eg from sharp/ragged items/materials). Therefore, guidance states that half-face RPE needs to be worn. Half-face RPE was worn by all workers who carried out this task while HSE scientists were on site, see Figure 16.

Twenty personal samples were taken on six out of eight sites whilst workers were carrying out waste transfer tasks. No samples were taken on Sites 1 or 2. Generally the PCM results were low and as expected for this low-risk activity. Only one result was above the LoQ and was significantly above it. Sample 03-040 gave a result of 0.09 f/ml which is much higher than would be expected for simply transferring waste bags if cleaning of bags had been effective.

This result, although only one measurement, suggests that waste transfer is an activity that could carry a risk of exposure and spread of asbestos outside the enclosure. It is,

however, an outlying result. The other results (all less than the LoQs) demonstrate that exposure and spread can be reduced to a minimum where good practice is followed and that this is likely to be standard procedure. The worker with the high fibre concentration was wearing half-face RPE. There was no obvious deviation from procedure with respect to how waste bags were cleaned and sealed as they were taken out of the enclosure. However, the positioning of CCTV inside the enclosure did not allow for close examination of exactly how the bags were cleaned and sealed. A static leak test sample, 03-038, taken whilst the waste was being taken out of the enclosure (and personal sample 03-040 was being taken) did not show elevated fibre levels. This could indicate that the fibre release happened inside the baglock or during the travel to/or deposition in the skip.

Six personal samples taken during waste transfer, were analysed by TEM. The results confirmed the high result for sample 03-054 and gave a higher asbestos fibre concentration, than the PCM fibre concentration (0.12 f/ml and 0.09 f/ml, respectively). Two more samples with measurable asbestos fibre concentrations by TEM were also identified. Both samples were taken on Site 6 where sprayed coating was being removed. The highest fibre concen all eight site visits were measured inside the enclosure on Site 6. The results were 0.018 f/ml and 0.005 f/ml which is significantly lower than the fibre concentration for sample 03-040 (0.09f/ml). However, it does demonstrate that waste transfer is an activity that can lead to the release and spread of asbestos fibres outside an enclosure and therefore potentially lead to exposure.

Figure 16. Removal workers on Site 5 transferring waste out of the enclosure through the baglock

4.6 Representativeness of fibre concentrations and working practices

There are usually around 400 companies that hold an asbestos removal licence issued by HSE. Over the last five years there have been on average, 35 000 notifications per year to HSE for licensed asbestos work. Therefore, the eight sites and companies included in this project, represent a very small proportion of the work carried out each year in GB. Of the eight companies monitored, seven were members of one of the trade associations (ARCA, ACAD, or NFDC), the other was not a member of any of the trade organisations (see Table 1). The eight companies represented a range of sizes from a small locally based company to a company who operated nationally. The licensing system for LARCs is designed to ensure that all companies operate to at least the same minimum standard. All LARCs have their performance monitored by regular HSE inspections and a review of their licence every 1 to 3 years. This licence review process is an appraisal of management systems and procedures which works to aid consistency in standards across the industry.

All companies that took part in this project did so on a voluntary basis and had the final say on whether a particular site could be visited by HSE scientists. It is likely that if a company volunteered to take part in this project, they considered themselves of a high enough standard to be fully compliant with statutory requirements and guidance. Companies were told in advance that the focus of the project was research and that HSE scientists did not

have any enforcement powers. Whenever poor working practices were observed, these were discussed with the site supervisor with a view to resolving them without further action being needed. However, enforcement action was highlighted as a possible outcome if issues were not properly resolved, or the infraction was considered too serious to be resolved on site. As a result, it is likely that companies that took part in this project may have been of a higher standard than the industry generally. They are also likely to have used the advance notice of the site visit to ensure standards and work practices were in line with HSE guidance, as they understood it. Workers themselves were also given project information sheets (Appendix C) in advance of the site visit and will have discussed the project with their employers and fellow employees.

Whatever the company's general standard of work and competence of its workers, under normal circumstances there is the potential for worker behaviour to change when observed. This could have affected how they worked during the site visits and consequently the fibre concentrations measured. Studies of hospital workers have shown that they increased their use of hand sanitiser when they were aware, they were being observed, compared to when they were unaware (Srigley et al., 2014, Bruchez et al., 2020). Although HSE scientists used the viewing panels only sparingly (to reduce obvious visual interference), the workers will have been aware that they were being recorded by CCTV. Asbestos removal and the working methods that workers are trained to follow are much more complex than the application of hand sanitiser which is a simple either/or scenario. It is therefore harder to predict the extent that behaviour was modified during this project. Possibilities include workers applying a higher amount of wetting agent than they normally would, workers waiting longer for a wetting agent to penetrate fully through an ACM and workers generally being more careful in how ACMs are removed from the matrix they are attached to.

The act of wearing a sampling pump itself may also change behaviour as the workers will remain aware of the sampling pump and cowl as they work. However, previous studies have not identified any significant relationship. One study, (Cherrie et al., 1994) investigated whether the wearing of sampling pumps influenced worker exposure to gases and vapours, when wearing sampling pumps compared to not wearing them (by using a less obtrusive diffusive sampler as comparison). The researchers did not report any consistent pattern (Cherrie et al., 1994). Although they would not normally wear them as frequently as they did during the site visits for this project, removal workers will be familiar with wearing sampling pumps on a regular basis.

An Italian study reviewed sampling data collected during asbestos removal and concluded that measurement results from sampling carried out by a Local Health Authority were systematically higher than those collected by the removal companies (Miscetti, Giorgio et al., 2014). This suggests that results can be affected by the organisation that collects the sampling data and under what circumstances.

Given the caveats discussed, it would be appropriate to view the fibre measurements and observations presented in this report, as the best possible practice that removal workers can achieve when they follow guidance as they understand it. It should be noted that the airborne fibre concentrations and work practices observed do not necessarily represent what would happen if HSE scientists were not present. HSE scientists did note that workers tended to change their behaviour over the course of a site visit. When they became used to the presence of HSE scientists they tended to work in a more relaxed manner and carried out tasks more quickly than at the start of the visit. Time pressures may also have played their part as workers attempted to make up time to complete the job by the required deadline after a slow start (probably because of being observed by HSE scientists).

On several occasions HSE scientists observed removal workers working in breach of guidance, which indicates that being observed, did not completely prevent bad practices from taking place. It is not possible to determine the exact reasons for this, but removal workers may have been incorrectly trained originally or have picked up bad habits since they were trained.

4.7 Comparisons with previous HSE work and industry data

4.7.1 Comparison with previous HSE research

The last time HSE scientists visited sites to monitor asbestos removal work was during a project looking at the wet stripping of ACMs. Eight site visits were carried out for this work between 1997 and 1998 (HSE, 1999).

It was not possible to directly compare all the results from the 1997/98 work with the results from this project, as different counting rules were used. In the 1997-98 study, all samples were counted by PCM using the European Reference Method (ERM), described in MDHS 39/4 (HSE 1995), the HSE approved method at the time. The main difference between the ERM and the current WHO counting rules is that the ERM ignored fibres if they were attached to particles with diameter >3µm, even if all other fibre size criteria were met (ie length >5µm, width <3µm and aspect ratio >3:1). The WHO counting rules were adopted by GB in 2006. The main impact is that counting using ERM rules may result in undercounting the number of fibres compared with WHO counts (due to fibres attached to particles being excluded by ERM but included by WHO rules). On three of the sites visited in 1997-98, some measurements were undertaken using both ERM and WHO counting rules. By comparing ERM and WHO results from the same filter, a multiplication factor of 1.55 was calculated to represent the likely difference between the different methods. Table 15 lists the range of results in enclosures on different sites, an overall TWA calculated for each site and the material being removed. WHO results have been included where available, when not available, a value has been calculated by applying the multiplication factor to the ERM result.

Table 15. Fibre concentrations during removal work at different sites during 1997/98 visits

Site number	Material removed	MDHS 39/4 TWA (f/ml)	MDHS 39/4 range (f/ml)	WHO TWA (f/ml)	WHO range (f/ml)
1	Pipe insulation (amosite)	3.05	2.07 – 4.17	4.72*	3.21 – 6.46*
2	Sprayed insulation to walls and ceiling (crocidolite)	22.16	16.2 – 34.34	37.89	27.79 – 43.41
3	Sprayed coating to steel beams (amosite)	4.26	1.99 –9.15	6.7	3.61 – 12.7
4	AIB ceiling tiles (amosite)	0.84	0.16 – 3.16	1.3*	0.25 – 4.9*
5	Asbestos cement and AIB (Amosite and chrysotile)	0.24	0.18 – 0.35	0.5	0.39 – 0.67
6	Sprayed coating to cement roof (crocidolite)	0.69	0.21 – 1.83	1.07*	0.33 – 2.84*
7	Sprayed coating to cement roof (crocidolite)	0.14	0.01 – 0.46	0.22*	0.02 – 0.71*
8	Pipe insulation (amosite)	2.18	1.36 – 4.96	3.38*	2.11 – 7.69*

*These figures have been calculated using a multiplication factor of 1.55

As can be seen from the results in Table 15, the WHO fibre concentrations measured during the 1997/98 site visits ranged from 0.02 to 43.41 f/ml. The top end of this range is significantly higher than the highest concentration measured during this project, ie 1.12 f/ml. The highest result from the 1997/98 work was taken during removal of crocidolite sprayed insulation, a material not included in this project. The amount of asbestos removed on the sites visited in 1997/98 is not included in the final report but there are four sites where potentially comparable materials were removed. These are shown in Table 16.

Table 16. Comparison between 1997/98 work and results from this report (2016-2019)

Site number and ACM (1997-98)	Average (TWA) result (f/ml)	Range of results (not weighted - f/ml)	Site number and ACM (2016-19)	Average (TWA) result (f/ml)	Range of results (not weighted – f/ml)
Site 3 Sprayed coating to steel beams (amosite)	6.7	3.61 – 12.7	**Site 6 Sprayed coating to steel beams (amosite)**	0.25	<0.018 – 1.12
Site 4 AIB ceiling tiles (amosite)	1.3*	0.25 – 4.9*	**Site 5 AIB ceiling tiles (amosite)**	0.049	<0.014 – 0.46
Site 1 Pipe insulation (amosite)	4.72*	3.21 – 6.46*	**Site 8 Pipe insulation (amosite and chrysotile)**	0.059	0.03 -0.23
Site 8 Pipe insulation (amosite)	3.38*	2.11 – 7.69*			

***These figures have been calculated using a multiplication factor of 1.55

These comparisons show that much lower fibre concentrations were measured inside enclosures for this project compared to those in 1997/98. It is possible that some of this difference is due to larger amounts of material being removed in the enclosures in 1997/98, compared with this study. However, the site visits in both studies were roughly 5 days long, apart from Sites 6 and 7 in this project, which lasted 10 or more days.

Guidance has changed substantially since the site visits in 1997/98 with the Licensed Contractors guide published in 2005 and the most recent update of the ACOP taking place in 2013. Although the removal methods still follow the same principles, ie use of a wetting agent (and in the case of sprayed coating an injection system). The change in guidance set out the method in more detail and clarified methods, although changes to the air extraction rates were also introduced in 2013 (L143, HSE 2013). These changes were made to reduce asbestos exposure and spread on removal sites. The limited data available suggest that this aim has been achieved.

The 1997/98 work did not include any personal or static monitoring of tasks undertaken outside the enclosure. However, an HSE project in 2000 (HSE, 2001), looked at potential improvements to the methods for clearance testing and included a limited amount of sampling during the dismantling of enclosures. Six personal samples were taken across three different sites and five static samples were taken across two sites. Table 17 shows a comparison between the 2000 project and this one.

Table 17. Comparison of samples taken during enclosure dismantling

Type of sample	Range for site visits in 2000	Average results for site visits in 2000 (TWA for personal)	Range for recent site visits	Average from recent site visits (TWA for personal)
Personal	<0.05 to 0.17	0.06	<0.019 to 0.063	0.004
Static	0.02 to <0.03	0.019	<0.005 to 0.015	0.005

The difference in personal sampling results between the two sets of work could be due to improvements in guidance and working practices for dismantling enclosures, which have reduced exposure and spread of asbestos in the intervening time. It could also be due to an overall reduction in fibre levels inside the enclosure during removal, together with better clearance practices, rather than any specific change to the way enclosures are dismantled. These factors should result in less fibres present on the surfaces of the enclosure by the time it is dismantled. The sample size from the project in 2000, was relatively small and may not be very representative of the levels present generally in the industry at the time. No TEM analysis was carried out for the project in 2000, so the actual asbestos fibre concentrations were not reported.

4.7.2 Comparison with available industry data

It is a regulatory requirement that LARCs undertake regular personal monitoring of their employees (CAR 2012, Reg19). This is necessary to gather evidence to support their risk assessments. Employers must keep a record of this monitoring for at least 40 years if it relates to workers under medical surveillance (licensed removal workers are required to undergo regular medical surveillance). However, this data is generally not available outside of the individual companies themselves and different companies store the data in different ways.

There are potential issues with any exercise to use this data to assess exposure levels of removal workers. The ACOP (L143, HSE 2012) requires that the following information is collected:

- the type of work undertaken and, where relevant, its exact location
- the type of sample, eg personal, static, clearance etc
- the location of any static sampler
- the date and time of sampling, the sample duration and the flow rate
- if a personal sample, the employee's name, the task being performed and the category of RPE being worn
- the length of time an individual is exposed
- the measured fibre concentration
- the fibre type, if known
- the names and organisations of the sampler and analyst and the
- sampling and analysis method used.

This minimum level of data is required to ensure that operative exposure can be appropriately assessed. However, if compared with the data collected for this project this minimum level would not be sufficient. Key bits of information would be missing including information of the LoQ, the sample volume, the enclosure size (if relevant) and the amount of material being removed as part of the work carried out. It is also likely that the sampling will have been carried out without observation of the activities being undertaken and so may not include information on the working practices and whether any wetting of the ACM was carried out. It would also be difficult to obtain and recount the original samples as these are generally not kept for longer than six months. The data itself is also not easily accessible without the consent of each individual company and may not be in an easy to process format.

One database of monitoring data is available online in an anonymised form (Assure 360, 2021). The database was created by an asbestos management consultancy who supply software to LARCs to assist them with their work. At the time of writing, this version of the database includes results of 16 000 personal samples taken across all activities carried out during asbestos removal works. The information includes sampling date, ACM type, ACM fixing (nail, screw etc.), task, anticipated fibre level, exposure duration and measured rate (reported concentration in f/ml). However, comparison of data between this project and the database has the same potential limitations as for any industry data. The database does not specify whether the fibre concentration for a given sample is above, at or below the LoQ. For example, the database includes around 600 measurements taken during enclosure construction, the majority of which would be expected to be below the LoQ and

so any averages calculated to be mainly dependant on sample volume. It is also clear that in some cases the actual concentration has been given rather than the reported concentration as should be the case according to the rules for submitting results to the database. This is probably because some of the results are well below the theoretical LoQ based on a maximum flowrate. Given the duration of the samples recorded, the reported concentration should always be the LoQ in these cases.

A limited review of the database by HSE scientists identified that the average fibre concentration recorded during AIB removal was 0.08 f/ml from 4643 samples and 0.07 f/ml from 2284 samples for removal of sprayed coating. This compares to the average measurement recorded during AIB removal in this work of 0.07 f/ml (an average of Sites 1, 3, 4 and 5) and an average of 0.27 f/ml for Site 6 where sprayed coating was removed. The difference in size between the two datasets means it is hard to draw any meaningful conclusions.

For this study, the average sprayed coating concentration from Site 6 is within the top 4% of the database results, with 87 out of 2284 (~4%) of the results in the database being higher. The work on Site 6 was the removal of 80 linear metres of sprayed coating from steel beams. A wetting agent was applied using injection and the material was scraped off the beams. This is the standard method used when removing material of this type and no issues with the removal technique were noted on site. It may be that the results added to the database are all either from work where significantly less material was removed or where only residues of sprayed coating left behind from previous removal jobs was removed.

4.7.3 Comparison with anticipated fibre concentrations in LARCs plan of works

HSE guidance states that anticipated fibre concentrations “should be considered” in their plan of works and risk assessments for the work they are undertaking. The best way to calculate anticipated concentrations would be to extrapolate from previous monitoring of similar work. Table 18 shows the anticipated fibre concentrations recorded in the LARCs plan of work (PoW) for each site visited and the levels that were measured by HSE scientists on site.

Table 18. Anticipated fibre concentrations recorded in Plan of Works

Site	ACM removed	Anticipated fibre concentration in PoW (f/ml)	Average fibre concentration measured on site (f/ml)	Highest fibre concentration measured on site (f/ml)
1	AIB (small scale)	<2	0.061	0.107
2	Low level contamination (AIB)	<0.24	0.01	0.014
3	AIB	<0.05	0.134	0.39
4	AIB (small scale)	<1	0.021	0.04
5	AIB	<0.15	0.06	0.46
6	Sprayed coating	0.27	0.27	1.12
7	Low level contamination (insulation)	<0.05	0.02	0.04
8	Pipe insulation	<0.1	0.08	0.23

The anticipated concentrations in seven of the eight PoWs prepared by LARCs indicated that they represented the maximum expected fibre concentration. In one case (Site 6), the PoW listed both the average (0.27 f/ml) and highest (<0.3 f/ml) anticipated concentrations.

On Site 3, the average measured fibre concentration was significantly higher than the anticipated concentration in the PoW. On three other sites (Sites 5, 6 and 8), the highest fibre concentration exceeded the anticipated concentration.

There was significant variation between the anticipated concentrations given by the different LARCs. This would be expected where different material types are being removed. However, there was significant variation between the sites where AIB was being removed and this could not be explained by the different amounts of AIB being removed. Sites 1 and 4, where a maximum of 5 m^2 was being removed per enclosure gave the highest anticipated concentrations of <2 f/ml and <1 f/ml respectively. Whereas Sites 3 and 5, where 16 m^2 and 50 m^2 were removed, gave much lower concentrations, as shown in Table 18.

However, it should be noted that even when the measured fibre concentrations on site exceeded the anticipated concentrations, the assessment of what RPE should be worn appeared to remain appropriate. The main reason for anticipating fibre concentrations is to assess the type of RPE that should be worn. It also indicates the LARC's assessment of

what they can reasonably achieve with respect to fibre concentrations during that job. This should be based on previous air monitoring carried out during similar types of removal work. It is likely that LARCs are not carrying out a sufficient personal sampling to make this assessment. It therefore follows that they would not be able to correctly predict a reasonable anticipated fibre concentration. During this project, most removal workers, when asked, said that they were rarely asked to wear sampling pumps for more than an hour. They also indicated that wearing sampling pumps for whole shifts, as they did for this work, was not something they were used to.

4.7.4 Comparison with other published work

A short literature search did not identify any studies that considered the exposure of asbestos removal workers in GB during the period between the last HSE study in 1997/98 and the site visits for this work in 2019.

A wider search looking at studies outside GB did identify studies that looked at the exposure of removal workers in other countries during this period. Eight studies were identified that looked at the exposure of asbestos removal workers. As these studies were carried out under different regulatory systems, it was difficult to make direct comparisons with this work. They do however offer an assessment of the potential exposure of workers generally during asbestos removal.

Many of these studies were based on data collected by either the removal companies themselves or by local authorities. This means sample collection and removal techniques were not observed by the study writers and therefore, they do not offer a useful comparison with this work.

Two studies where the removal work activities and the air sampling were observed by the study writers were Dufresne et al., 2009 and Chazelet et al., 2018.The most recent study, Chazelet et al 2018, primarily looked at in-mask sampling but also took samples outside masks for comparison. These (outside mask samples) were taken using the same personal sampling methods as used in this work. They were all analysed by TEM though, rather than PCM and so the results from the study, reproduced in Table 19, are asbestos fibre concentrations.

Table 19 Fibre concentrations measured during asbestos removal in Chazelet et al, 2018

Worksite	ACM and removal process	Number of samples	Geometric mean fibre concentration (f/ml)	Fibre concentration range (f/ml)
A	Removal of surface coatings (shot peening), soundproofing (abrasive blasting), putty (scraping)	60	1.1	0.03 – 155
B	Removal of sprayed asbestos (manual scraping)	42	32	7.6 – 85
C	Removal of sprayed asbestos (manual scraping)	36	8.5	1.8 – 36
D	Removal of asbestos-containing plaster (pneumatic scraping)	52	8.4	0.4 - 236
E	Removal of insulation (manual scraping)	47	0.08	0.006 – 0.5
F	Removal of asbestos-containing plaster (scraping; remote-controlled machinery, very high pressure)	41	6.6	0.32 – 78
G	Removal of adhesives for floor coverings and tiles by chipping and sanding	36	0.82	0.02 – 8.1
H	Removal of adhesives for floor coverings and tiles by sanding and grinding	32	0.02	0.003 – 0.6
I	Removal of asbestos-cement ducts by breaking–dismantling	17	0.06	0.006 – 0.3

The Chazelet paper describes removal work undertaken in France and includes a summary of the asbestos material removed at each site and a brief description of the removal method. Unfortunately, it does not include the asbestos types present in either the asbestos materials removed, or the air samples analysed. Wetting is only explicitly mentioned as being carried out on sites B, C, and D, but the specific wetting technique, the amount of material or the size of the enclosures was not described.

Given the lack of information on the removal technique and amount of material removed, it was not possible to make any conclusive comparisons between the results from the Chazelet et al study and the results in this report. Where there are comparable material types (sprayed coating and insulation), the Chazelet study results are significantly higher than those from this work. The descriptions of the asbestos materials removed are limited and it was not possible to determine how similar or otherwise they were to ACMs removed in this study. For Site A, this was most likely due to the mechanical blasting technique used for removal. For others (Sites B and C), the difference could have been due to the amount of material being removed or differences in wetting techniques. The type and amount of wetting during removal is not described in the Chazelet study.

The other study, (Dufresne et al., 2009), was carried out in Canada and looked at the exposure of workers on two removal sites with the aim of comparing personal sampling results to nearby static sampling. On one site, the ACM being removed was described as a friable material containing 75-90% amosite and on the other site, the ACM contained 5-10% chrysotile in a matrix of gypsum and mica. The number of personal samples taken from removal workers on each site was relatively small, with 8 taken on the first site and 18 on the second. The average fibre concentrations reported for each site were 20.3 f/ml and 6.3 f/ml, respectively. Some wetting of the ACMs took place, although the technique is not described in detail. The first material type described was similar to the sprayed coating that was removed on Site 6 in this project, but the average results reported are significantly higher (20.3 f/ml compared to 0.27 f/ml). Again, without knowing exactly how much material was removed in each instance it is hard to be certain, but this difference could also be due to different wetting and removal techniques.

While neither of these studies allow for a direct comparison with the work described in this report, they do highlight that compared with the findings of this study, higher airborne asbestos levels are possible when removing asbestos, particularly for friable materials such as sprayed coating and insulation. They also indicate what could happen if HSE guidance for wetting and removal techniques are not followed.

5. Conclusions

Results from personal air monitoring inside enclosures during removal work show that the average time weighted measurement was above the four-hour control limit on one site. This was the only site where amosite sprayed coating was being removed. Peak results were above the control limit on four out of eight sites visited.

When considering the RPE worn by workers inside the enclosure (full face powered RPE with a P3 filter with an APF of 40) the time-weighted average results for each site ranged from 0.0002 f/ml to 0.006 f/ml with a peak individual result seen in any site of 0.03 f/ml. The requirement is that suitable RPE “must reduce exposure as low as reasonably practicable” beneath the control limit when despite the use of other control measures exposure would be likely to exceed it. The average results from this work suggest that this was being achieved.

Asbestos fibres were detected on several samples taken during tasks performed outside the enclosure. These tasks included enclosure construction, enclosure dismantling and waste transfer. RPE use was observed to be less consistent for these tasks, particularly for enclosure construction, and where it was worn, best practice was not always followed. This led to instances where the asbestos exposure of removal workers during these tasks was higher than the exposures measured inside the enclosure (when RPE is considered). Guidance does not specify that removal workers are required to wear RPE during enclosure construction. However, guidance does require LARCs to gather evidence, in the form of sampling, to support risk assessments for all activities. Sampling from site visits on this project suggested that the use of RPE needs to be considered for enclosure construction under certain circumstances. This is particularly the case if the material type to be removed is very friable (such as sprayed coating) or if there is other removal work ongoing in the area where the enclosure is being constructed. This was evidenced by results on two sites in this study. On Site 4, where asbestos fibre concentrations were observed during enclosure construction, when other nearby work was being carried out and on Site 6, where asbestos fibre concentrations were measured during the construction of an enclosure for the removal of sprayed coating. The outside worker (wearing RPE and PPE) was seen to fully enter the baglock rather than lean in to retrieve the bags from outside. This poor practice is not consistent with ALARP exposure nor with HSE guidance.

Results presented in this report should be seen in overview as what licensed removal contractors are capable of when they follow guidance as they understand it. The fibre concentrations reported almost certainly do not give a representative picture of the fibre levels that will be present on licensed removal sites more generally. The eight sites visited represent a very small snapshot of asbestos removal work and there may have been a bias towards better performing contractors based on the fact only volunteers were monitored, and observation may have improved their performance.

Nevertheless, even in HSE's presence, instances of bad practice were still seen during removal work such as inadequate wetting and rushed removal leading to unnecessary disturbance of ACMs. Some of the peak results from the sites where AIB was removed for instance demonstrate the difference in fibre levels possible when care is not taken in removing this material type.

Glossary

4SC –	Four-stage clearance procedure
ACM –	Asbestos-Containing Material
AIB –	Asbestos Insulation Board
ARCA –	Asbestos Removal Contractors Association
ACAD –	Asbestos Control & Abatement Division
CAR –	Control of Asbestos Regulations 2012
DCU –	Decontamination Unit
LARC –	Licensed Asbestos Removal Contractor
LoD –	Limit of Detection- For low counts the lower confidence limit is 0, so a one-sided upper 95% confidence interval is used. For a count of 0 it is 95% probable that the true number is <3 fibres. The analytical sensitivity (based on counting one half-fibre in 200 graticule areas (the lowest count possible above zero), a sample volume of at least 480 litres and an effective diameter greater than 20 mm) is between 0.0002 and 0.0003 f/ml.
LoQ -	Limit of Quantification – By convention the LoQ for PCM counts is 0.010f/ml for a sample volume of 480 litres and 200 graticule areas counted. The LoQ can be lowered by increasing the volume or number of graticules counted
NFDC –	National Federation of Demolition Contractors
PCM –	Phase Contrast Microscopy
TEM –	Transmission Electron Microscopy
PPE –	Personal Protective Equipment
RPE –	Respiratory Protective Equipment
TWA –	Time Weighted Average

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Appendix A PCM results from all sites (landscape format)

A.1 Site 1 Results

Site - Sample number	Sample volume (litres)	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
01-001	544	68	Reassurance – Enclosure 1 setup	0.02	41.5	200
01-002	960	120	Reassurance – Enclosure 1 setup	0.01	39	205
01-003	960	120	Reassurance – Enclosure 1 setup	0.011	41.5	206
01-004	240	120	Personal - Worker 1 enclosure 1 setup	<0.020	12.5	200
01-005	240	120	Personal - Worker 2 enclosure 1 setup	<0.020	9.5	200
01-006	728	91	Leak test - outside enclosure 1	<0.007	1.5	200
01-007	73	73	Personal Worker 1 – Removal works in enclosure 1	<0.066	2	200
01-008	Void due to pump failure		Personal Worker 2 – Removal works in enclosure 1			200
01-009	480	48	Parallel clearance - test 50 cm above floor enclosure 1	0.016	29.5	202
01-010	480	48	Parallel clearance - test 105 cm above floor enclosure 1	0.02	36	201
01-011	480	48	Parallel clearance - test 155 cm above floor enclosure 1	0.015	27	200
01-012	100	50	Personal Worker 2 – Take down of enclosure 1	<0.048	8	200
01-013	480	60	Reassurance – Take down of enclosure 1	0.012	23.5	200
01-014	104	52	Personal - Worker 1 enclosure 2 setup	0.048	21	200
01-015	236	118	Personal Worker 2 - Enclosure 2 setup	<0.020	5.5	200
01-016	874	112	Reassurance – Basement sheeting up enclosure 2	0.008	34	200

Site - Sample number	Sample volume (litres)	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
01-017	976	122	Reassurance – Basement sheeting up enclosure 2	<0.005	13	200
01-018	126	63	Personal – Worker 3 construction of enclosure 2	<0.038	8	200
01-019	316	154	Personal - Worker 1 removal works in enclosure 2	0.044	53.5	201
01-020	310	148	Personal - Worker 2 removal works in enclosure 2	0.107	100.5	159
01-021	936	118	Leak test - outside enclosure 2	<0.005	1.5	200
01-022	130	65	Personal - Analyst visual inspection of enclosure 2	<0.036	4	203
01-023	480	48	Parallel clearance test - 50 cm above floor enclosure 2	0.004	8	200
01-024	480	48	Parallel clearance test - 50 cm above floor enclosure 2	<0.010	7.5	200
01-025	480	48	Parallel clearance test - 105 cm above floor enclosure 2	<0.010	11	200
01-026	480	48	Parallel clearance test - 155 cm above floor enclosure 2	<0.010	15	200
01-027	480	48	Parallel clearance test - 205 cm above floor enclosure 2	<0.010	10	200
01-028	192	64	Personal - Worker 2 take down of enclosure 2	<0.025	4	200
01-029	480	60	Reassurance – Take down of enclosure 2	<0.010	9.5	200
01-030	480	60	Reassurance - Take down of enclosure 2	<0.010	8	200

A.2 Site 2 Results

Site - Sample number	Sample volume (litres)	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
02-001	960	120	Background – LHS of delivery office - Day 1	0.007	28.5	202
02-002	960	120	Background – RHS of delivery office -Day 1	0.006	21.5	200
02-004	540	60	Reassurance - LHS of delivery office during scaffold erection - Day 1	<0.009	13.5	200
02-005	486	60	Reassurance - RHS of delivery office during scaffold erection - Day 1	<0.01	17.5	200
02-006	1025	125	Reassurance - LHS of delivery office in front of scaffold - Day 2	0.005	21.5	200
02-007	955	124	Reassurance - RHS of delivery office beneath scaffold - Day 2	0.007	26.5	200
02-009			Personal P02 - Pump failed after 13 mins - Day 2			
02-010	984	120	Reassurance - RHS of delivery office beneath scaffold - Day 2	0.008	33	200
02-011	966	120	Reassurance - LHS of delivery office in front of scaffold - Day 2	0.006	21	200
02-012	264	88	Personal P02 – Sheeting up enclosure - Day 2	<0.018	8	200
02-013	908	121	Reassurance - LHS of delivery office in front of scaffold - Day 3	<0.005	11.5	200
02-014	968	121	Reassurance - RHS of delivery office - Day 3	<0.005	12.5	200
02-017	1320	166	Leak – Beneath NPU - Day 3	<0.004	18	200
02-018	1328	167	Leak – Under scaffold next to airlock - Day 3	<0.004	11.5	200
02-021	252	84	Personal P03 – Sheeting up of windows inside enclosure - Day 3	<0.019	10.5	200
02-022	246	82	Personal P02 – Sheeting up of windows inside enclosure - Day 3	<0.020	9	200

Site - Sample number	Sample volume (litres)	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
02-023	174	58	Personal P02 – Bagging of loose waste inside enclosure - Day 3	<0.028	21.5	200
02-024	147	49	Personal P03 – Bagging of loose waste inside enclosure - Day 3	<0.033	8.5	200
02-025	222	111	Personal P01 – Removing chicken wire covering contaminated area - Day 4	<0.022	14	200
02-026	310	155	Personal P03 – Removing chicken wire covering contaminated area - Day 4	<0.015	9	200
02-029	1496	187	Leak – office room beneath enclosure - Day 4	<0.003	10.5	200
02-030	1457	188	Leak – Beneath NPU - Day 4	<0.003	6	200
02-032	174	58	Personal P02 – Vacuuming of contaminated area - Day 4	<0.028	8	200
02-033	887	113	Leak – Beneath NPU - Day 4	<0.005	6	200
02-034	150	50	P04 Personal – Visual inspection of enclosure - Day 4	<0.032	6	200
02-035	504	42	Parallel clearance – Inside enclosure NPU side of scaffold - Day 5	<0.01	7	200
02-036	492	41	Parallel clearance – Inside enclosure airlock side of scaffold - Day 5	<0.01	12	200
02-037	492	41	Parallel clearance – Inside enclosure bottom of ladder to scaffold - Day 5	<0.01	7.5	200
02-038	870	87	Reassurance - LHS of delivery office in front of scaffold - Day 5	<0.006	10	200

A.3 Site 3 Results

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
03-001	960	09:48	11:48	120	Static (reassurance) – 4th floor by door next to office space – Day 1	<0.005	10.5	200
03-002	960	09:44	11:44	120	Static (reassurance) - 3rd floor opposite lift – Day 1	Filter occluded no count recorded		
03-003	938	12:13	14:11	118	Static (reassurance) – 4th floor by door next to office space – Day 1	Filter occluded no count recorded		
03-004	552	14:57	16:06	69	Static (reassurance) - 3rd floor stairwell beneath scaffold – Day 1	<0.009	5	200
03-006	480	09:07	10:07	60	Static (reassurance) - 3rd floor stairwell– Day 2	<0.01	9	200
03-007	480	10:25	11:25	60	Static (reassurance) - 3rd floor stairwell next to lift – Day 2	<0.01	3	200
03-008	948	11:55	13:55	120	Static (reassurance) - 3rd floor stairwell next to lift – Day 2	<0.005	5	200
03-009	180	14:47	15:47	60	Personal – P02 Sheeting up enclosure – Day 2	<0.027	14	200
03-010*	369	14:55	15:40	45	Static (reassurance) - 3rd floor stairwell next to airlock – Day 2	<0.013	4	200
03-011	960	09:46	11:46	120	Static (reassurance) - 3rd floor stairwell next to airlock – Day 3	<0.005	5	200
03-013	60	12:19	12:34	15	Personal – P02 Sheeting up riser with AIB backing – Day 3	<0.080	3	200

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
03-012	372	11:55	13:55	120	Personal - P05 Removal of AIB (cowl was pulled off the coverall and dragged along the floor for a short period of time) – Day 4	0.08	100	174
03-017	984	12:07	14:10	123	Static (leak) - 3rd floor stairwell next to airlock – Day 4	<0.005	4	200
03-018	336	13:44	15:40	116	Personal – P06 Removal of AIB (removal of nails, spraying of boards, wrapping boards in waste bags, vacuuming) – Day 4	0.14	100	106
03-019	344	12:10	15:02	172	Personal – P04 Removal of AIB (removal of nails, spraying of boards, wrapping boards in waste bags, vacuuming) – Day 4	0.39	100	52
03-020†	331/92	08:56	11:30/09:39	154/43	Personal – P05 Removal of AIB (removal of nails, spraying of boards, wrapping boards in waste bags, vacuuming) – Day 5	0.08	101	196
03-021	384	09:02	12:14	192	Personal – P06 Removal of AIB (removal of nails, spraying of boards, wrapping boards in waste bags, vacuuming) – Day 5	0.13	102	100
03-022	300	09:54	12:24	150	Personal – P04 removal of AIB (removal of nails, spraying of	0.14	101	126

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
					boards, wrapping boards in waste bags, vacuuming) – Day 5			
03-025	990	08:58	11:01	123	Static (leak) - 3rd floor stairwell next to airlock – Day 5	<0.005	2.5	200
03-026	188	14:03	15:37	94	Personal – P04 removal of AIB (removal of nails, spraying of boards, wrapping boards in waste bags, vacuuming) – Day 5	0.24	110	126
03-027	185	13:53	15:28	95	Personal – P05 removal of AIB (removal of nails, spraying of boards, wrapping boards in waste bags, vacuuming) – Day 5	0.12	87	200
03-029	560	13:54	15:04	70	Static (leak) - 3rd floor stairwell next to airlock – Day 5	<0.009	6	200
03-034	1032	10:20	12:29	129	Static (leak) - 3rd floor stairwell next to airlock – Day 6	<0.005	9.5	200
03-035	324	09:44	12:26	162	Personal – P05 Removal of AIB, final clean/ drilling holes in wood– Day 6	0.16	101	98
03-036	302	10:10	12:31	151	Personal – P04 removal of AIB, final clean vacuuming – Day 6	0.1	100	166
03-037	212	14:06	15:38	92	Personal - P06 passing waste bags out of enclosure – Day 6	<0.023	3	200
03-038	720	14:15	15:45	90	Static (leak) - 3rd floor stairwell next to airlock – Day 6	<0.007	9.5	200

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
03-039	190	14:25	16:00	95	Personal – P04 passing waste bags out of enclosure – Day 6	0.03	24	200
03-040	126	14:35	15:38	63	Personal – P05 carrying waste bags to skip – Day 6	0.09	4	200
03-043	480	13:01	13:49	48	Parallel clearance test – On scaffold – Day 7	0.04	73	206
03-044	480	13:01	13:49	48	Parallel clearance test – By NPU – Day 7	0.03	63	200
03-045	480	13:01	13:49	48	Parallel clearance test – By radiator – Day 7	0.03	55	200
03-046	480	13:02	13:50	48	Parallel clearance test – Bottom of ladder – Day 7	0.03	51	200
03-047	69	12:22	12:46	23	Personal – P07 Visual inspection – Day 7	0.12	36	200
03-048	490	14:45	15:34	49	Static (leak) - 3rd floor stairwell next to airlock– Day 7	<0.010	4	200
03-049	480	15:31	16:19	48	Parallel clearance test – On scaffold – Day 7	<0.01	5	200
03-050	480	15:31	16:19	48	Parallel clearance test – By radiator – Day 7	<0.01	8	200
03-051	480	15:31	16:19	48	Parallel clearance test – By NPU – Day 7	<0.01	6	200
03-052	480	15:31	16:19	48	Parallel clearance test – Bottom of ladder – Day 7	<0.01	12	200
03-054	180	17:06	18:06	60	Personal – P05 taking down enclosure – Day 7	0.07	45	200

A.4 Site 4 Results

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
04-001	960	08:55	11:55	120	Static (reassurance) – Next to airlocks Enclosure 1 – Day 1	<0.005	3	200
04-002	924	08:55	11:55	120	Static (reassurance) – Next to NPU Enclosure 1 – Day 1	<0.005	6	200
04-003	132	14:24	15:08	44	Personal - P09 Constructing Enclosure 2 (No RPE) – Day 1	<0.036	3.5	200
04-004	127	10:28	11:22	54	Personal – P04 Constructing Enclosure 2 (No RPE) – Day 1	<0.038	2	200
04-005	942	11:08	13:08	120	Static (reassurance) – Next to Enclosure 2 – Day 1	<0.005	3.5	200
04-006	948	13:35	15:35	120	Static (leak) – Next to airlocks Enclosure 1 – Day 1	<0.005	7.5	200
04-007	207*	13:56	15:45	109	Personal – P03 Removal of AIB Enclosure 1 (Full face RPE)– Day 1	<0.023	8	200
04-009	960	13:35	15:35	120	Static (leak) – Next to Enclosure 1 – Day 1	0.008	29.5	200
04-010	960	13:36	15:36	120	Static (reassurance) – Next to Enclosure 2 – Day 1	<0.005	8	200
04-011	128	15:11	15:43	32	Personal P05 – Removing waste bags from Enclosure 1 (Half face RPE) – Day 1	<0.038	5	200
04-008	214	08:52	10:39	107	Personal – P09 Constructing Enclosure 2 (No RPE) – Day 2	<0.022	5.5	200
04-012	540	11:22	12:16	54	Parallel clearance test – Enclosure 1 floor – Day 2	<0.009	3	200

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
04-013	535	11:22	12:16	54	Parallel clearance test – Enclosure 1 floor – Day 2	<0.009	5	200
04-014	540	11:22	12:16	54	Parallel clearance test – Enclosure 1 on scaffold – Day 2	<0.009	13	200
04-015	960	08:05	10:05	120	Static (reassurance) – Next to Enclosure 1 – Day 2	<0.005	17.5	200
04-016	204	10:42	11:33	51	Personal – P08 Analyst visual Enclosure 1 – Day 2	<0.024	1.5	200
04-018	960	10:20	12:20	120	Static (reassurance) – Next to Enclosure 2 – Day 2	<0.005	4	200
04-019	624	12:50	14:08	78	Static (reassurance) – Next to Enclosure 1 – Day 2	<0.008	4	200
04-020	360	12:52	14:52	120	Personal – P04 Dismantling Enclosure 1 (Half face RPE) - Day 2	<0.013	9	200
04-021	468	14:40	15:40	60	Static (reassurance) – Next to Enclosure 3 – Day 2	0.02	43	200
04-022	252	08:16	09:40	84	Personal – P02 AIB removal Enclosure 2 (Full face RPE)– Day 3	0.02	22	200
04-023	84	08:16	09:40	84	Personal – P02 (2^{nd} pump) AIB removal Enclosure 2 (Full face RPE) – Day 3	<0.057	16	200
04-024	984	08:40	10:43	123	Static (leak) – Next to Enclosure 2 – Day 3	<0.005	12.5	200
04-025	976	08:39	10:41	122	Static (reassurance) – Next to Enclosure 3 – Day 3	<0.005	4	200
04-026	240	08:20	09:40	80	Personal – P07 AIB removal Enclosure 2 (Full face RPE) – Day 3	0.04	35	200

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
04-027	90	10:47	11:17	30	Personal – P08 Analyst visual Enclosure 2 (visual failed) – Day 3	<0.053	2	200
04-028	500	13:33	14:23	50	Parallel clearance test – Enclosure 2 floor – Day 3	<0.010	4	200
04-029	500	13:33	14:23	50	Parallel clearance test – Enclosure 2 on scaffold – Day 3	<0.010	9	200
04-030	500	13:33	14:23	50	Parallel clearance test – Enclosure 2 floor – Day 3	<0.010	5	200
04-031	1032	12:49	14:58	129	Static (reassurance) - Next to Enclosure 3 – Day 3	Filter occluded no analysis possible		200
04-032	64	13:19	13:35	16	Personal – P08 Analyst visual Enclosure 2 – Day 3	<0.075	1	200
04-033	560	15:00	15:56	56	Static (reassurance) - Next to Enclosure 2 – Day 3	Filter occluded no analysis possible		
04-034	111	15:19	15:56	37	Personal - P07 dismantling Enclosure 2 – Day 3	<0.043	6	200
04-035	468	07:58	08:58	60	Static (reassurance) – Next to Enclosure 2 – Day 4	Filter occluded no analysis possible		
04-036	465	07:59	08:59	60	Static (reassurance) – Next to Enclosure 3 – Day 4	Filter occluded no analysis possible		
04-037	492	12:25	15:09	164	Personal – P03 AIB removal Enclosure 2 (Full face RPE) – Day 4	0.02	42	200
04-038	423	12:31	14:52	141	Personal – P04 AIB removal Enclosure 2 (Full face RPE) – Day 4	0.013	22.5	200

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
04-039	528	12:50	13:56	66	Static (reassurance) – Next to Enclosure 3 – Day 4	<0.009	8	200
04-040	480	10:49	11:49	60	Static (reassurance) – Next to Enclosure 4 – Day 4	0.013	25.5	200
04-041	528	12:14	13:20	66	Static (leak) – Next to Enclosure 3 – Day 4	0.01	21	200
04-045	112	14:18	14:46	28	P05 – Personal Removal of waste from Enclosure 3 – Day 4	<0.043	2	200
04-046	430	14:04	15:04	60	Static (reassurance) – Next to Enclosure 4 – Day 4	<0.011	5	200
04-047	39	14:50	15:01	11	Personal – P08 Analyst visual Enclosure 3 – Day 4	<0.123	0.5	200
04-042	475	07:49	08:37	48	Parallel clearance test – Enclosure 3 on scaffold – Day 5	<0.01	4.5	200
04-043	475	07:49	08:37	48	Parallel clearance test – Enclosure 3 floor – Day 5	<0.01	8	200
04-044	475	07:49	08:37	48	Parallel clearance test – Enclosure 3 floor – Day 5	<0.01	6	200
04-048	474	08:59	09:59	60	Static (reassurance) – Next to Enclosure 3 – Day 5	<0.01	12.5	200
04-049	99	09:00	09:33	33	Personal – P07 Dismantling Enclosure 3 – Day 5	<0.048	7	200

A.5 Site 5 Results

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
05-001	972	08:45	10:48	123	Background – Inside former kitchen beneath AIB ceiling – Day 1	<0.005	6	200
05-002	950	08:46	10:47	121	Background – Area outside kitchen next to airlock – Day 1	<0.005	4	200
05-003	381	09:13	11:28	135	Personal P02 – Sheeting up enclosure – No RPE – Day 1	<0.013	5	200
05-004	168	09:13	11:27	134	Personal P04 – Sheeting up enclosure – No RPE – Day 1	<0.029	2	200
05-005	968	11:11	13:12	121	Background - Inside former kitchen beneath AIB ceiling – Day 1	<0.005	2	200
05-006	498	13:16	16:02	166	Personal P02 – Sheeting up enclosure – No RPE – Day 1	<0.010	5	200
05-007	483	13:16	13:57	161	Personal P04 – Sheeting up enclosure – No RPE – Day 1	<0.010	8	200
05-008	954	13:38	15:38	120	Background – Area outside kitchen next to airlock – Day 1	<0.005	7	200
05-009	980	08:23	10.57	124	Reassurance – Inside former kitchen beneath AIB ceiling – Day 2	<0.005	16	200
05-010	552*	10:30	11:39	69	Reassurance – Next to airlock – Day 2	<0.009	8	200
05-011	372	08:51	10:45	124	Personal P02 – Sheeting up enclosure – No RPE – Day 2	<0.013	5	200

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
05-012	450	13:47	16:37	180	Personal P04 – Removal of AIB ceiling – Full face RPE – Day 2	0.03	47	200
05-013	360	13:47	16:37	180	Personal P04 – Removal of AIB ceiling – Full face RPE – Day 2	0.04	61	200
05-014	336	13:42	16:30	168	Personal P03 – Removal of AIB ceiling – Full face RPE – Day 2	0.11	104	142
05-015	420	13:42	16:30	168	Personal P03 – Removal of AIB ceiling – Full face RPE – Day 2	0.07	100	180
05-016	346	13:44	16:37	173	Personal P02 – Removal of AIB ceiling – Full face RPE – Day 2	0.02	28	200
05-017	346	13:44	16:37	173	Personal P02 – Removal of AIB ceiling – Full face RPE – Day 2	0.02	33	200
05-018	1296	13:57	16:41	164	Leak – In front of airlock – Day 2	<0.004	1	200
05-019	137*	15:51	16:27	36	Personal P05 – Removing waste from enclosure – Half-face RPE – Day 2	<0.035	2	200
05-020	1304	13:58	16:41	163	Leak – Next to NPU – Day 2	<0.004	2.5	200
05-021	1097*	09:11	11:51	160	Leak – Next to NPU – Day 3	<0.004	2	200
05-022	1193	09:10	11:51	161	Leak – In front of airlock – Day 3	<0.004	4	200
05-023	350	08:45	11:40	175	Personal P03 – Removal of AIB ceiling – Full face RPE – Day 3	0.08	100	188
05-024	341	08:45	11:40	175	Personal P03 – Removal of AIB ceiling – Full face RPE – Day 3	0.06	86	200
05-025	358	08:47	11:46	179	Personal P04 – Removal of AIB ceiling – Full face RPE – Day 3	0.015	21	200
05-026	349	08:47	11:46	179	Personal P04 – Removal of AIB ceiling – Full face RPE – Day 3	<0.014	12	200

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
05-027	418	08:51	11:38	167	Personal P02 – Removal of AIB ceiling – Full face RPE – Day 3	0.09	100	142
05-028	334	08:51	11:38	167	Personal P02 – Removal of AIB ceiling – Full face RPE – Day 3	0.07	94	200
05-029	207	15:06	16:15	69	Personal P05 – Removing waste from enclosure – Half-face RPE – Day 3	<0.023	3	200
05-030	390	13:26	16:02	156	Personal P03 – Removal of AIB ceiling – Full face RPE – Day 3	0.06	102	160
05-031	312	13:26	16:02	156	Personal P03 – Removal of AIB ceiling – Full face RPE – Day 3	0.08	108	192
05-032	326	13:37	16:16	159	Personal P02 – Removal of AIB ceiling – Full face RPE – Day 3	0.02	32	200
05-033	318	13:37	16:16	159	Personal P02 – Removal of AIB ceiling – Full face RPE – Day 3	0.03	41	200
05-034	298	13:41	16:18	157	Personal P04 – Removal of AIB ceiling – Full face RPE – Day 3	0.02	27	200
05-035	306	13:41	16:18	157	Personal P04 – Removal of AIB ceiling – Full face RPE – Day 3	0.03	41	200
05-036	1240	13:51	16:30	159	Leak – Next to NPU – Day 3	<0.004	2	200
05-037	1248	13:50	16:29	159	Leak – In front of airlock – Day 3	<0.004	7	200
05-038	444	08:32	11:37	185	Personal P04 – Removal of AIB ceiling – Full face RPE – Day 4	0.011	19.5	200
05-040	322	08:45	11:30	165	Personal P03 – Removal of AIB ceiling – Full face RPE – Day 4	0.46	102	35
05-041	297	08:45	11:30	165	Personal P03 – Removal of AIB ceiling – Full face RPE – Day 4	0.13	105	140

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
05-042	N/A	08:53	11:41	N/A	Personal P02 – Removal of AIB ceiling – Full face RPE – Day 4	Pump Failed		200
05-043	N/A	08:53	11:41	N/A	Personal P02 – Removal of AIB ceiling – Full face RPE – Day 4	Pump failed		200
05-044	N/A	09:04	11:45	N/A	Leak – In front of airlock – Day 4	Pump failed		200
05-045	1288	09:04	11:47	163	Leak – Next to NPU – Day 4	<0.004	8.5	200
05-046	1170	13:58	16:53	175	Leak – In front of airlock – Day 4	<0.004	5.5	200
05-047	1509	13:39	16:50	191	Leak – Next to NPU – Day 4	<0.003	2	200
05-048	147	13:56	14:45	49	Personal P05 – Removing waste from enclosure – Half-face RPE – Day 4	<0.033	2	200
05-049	338	13:55	16:43	173	Personal P03 – Removal of AIB ceiling – Full face RPE – Day 4	0.14	100	104
05-050	338	13:55	16:43	173	Personal P03 – Removal of AIB ceiling – Full face RPE – Day 4	0.1	100	148
05-051	320	13:35	16:49	194	Personal P02 – Removal of AIB ceiling – Full face RPE – Day 4	0.05	62	200
05-052	350	13:35	16:49	194	Personal P02 – Removal of AIB ceiling – Full face RPE – Day 4	0.03	45	200
05-053	288	13:42	16:48	186	Personal P04 – Removal of AIB ceiling – Full face RPE – Day 4	0.07	78	200
05-054	124	16:03	16:45	42	Personal P05 – Removing waste from enclosure – Half-face RPE – Day 4	<0.039	3.5	200
05-055	1011	08:30	10:38	128	Leak – Next to NPU – Day 5	<0.005	4	200
05-056	941	08:30	11:38	188	Leak – In front of airlock – Day 5	<0.005	8.5	200

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
05-057	607	08:23	14:00	337	Personal P04 – Final clean – Full face RPE – Day 5	0.06	100	136
05-058	539	08:23	14:00	337	Personal P04 – Final clean – Full face RPE – Day 5	0.02	47	200
05-059	594	08:38	14:48	370	Personal P03 – Final clean – Full face RPE – Day 5	0.015	35	200
05-060	457	08:33	12:47	254	Personal P02 – Final clean – Full face RPE – Day 5	0.02	32	200
05-061	483	08:33	12:47	254	Personal P02 – Final clean – Full face RPE – Day 5	0.014	27	200
05-062	59	10:04	10:35	31	Personal P05 – Removing waste from enclosure – Half-face RPE – Day 5	<0.081	4	200
05-063	443	11:27	14:44	197	Personal Analyst – Visual Inspection – Day 5	<0.011	11.5	200
05-064	504	15:45	16:48	63	Parallel clearance test – Day 5	0.011	22	200
05-065	504	15:45	16:48	63	Parallel clearance test – Day 5	<0.010	18	200
05-066	504	15:45	16:48	63	Parallel clearance test – Day 5	<0.010	11.5	200
05-067	504	15:45	16:48	63	Parallel clearance test – Day 5	0.0098	19.5	200
05-068	504	15:45	16:48	63	Parallel clearance test – Day 5	<0.010	15.5	200
05-069					Site blank (clearance)			
05-075	601	16:33	17:34	61	Leak – To side of airlock – Day 5	<0.008	3	200
05-070	248	09:04	10:28	84	Personal P03 – Dismantling enclosure – Half-face mask - Day 6	<0.019	10	200

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
05-071	202	09:04	10:28	84	Personal P03 – Dismantling enclosure – Half-face mask - Day 6	<0.024	7	200
05-072	245	09:05	10:28	83	Personal P04– Dismantling enclosure – Half-face mask - Day 6	<0.020	4.5	200
05-073	203	09:05	10:28	83	Personal P04– Dismantling enclosure – Half-face mask - Day 6	<0.024	6	200
05-076	757	09:08	10:26	78	Reassurance – Inside enclosure – Day 6	<0.006	9.5	200
05-077	960	08:45	10:22	97	Reassurance – Between airlock and NPU – Day 6	<0.005	7	200

A.6 Site 6 Results

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-001	1056	09:30	11:30	120	Background (Enclosure 2) - 1st floor office area - 5.11.18	<0.005	3	200
06-002	936	09:30	11:30	120	Background (Enclosure 2) - 1st floor office area - 5.11.18	<0.005	4	200
06-003	286	13:16	16:56	220	Personal P05 – Removal Enclosure 1 –Full face RPE – 5.11.18	0.12	100	148
06-004	255	13:20	17:02	222	Personal P06 – Removal Enclosure 1 – Full face RPE – 5.11.18	0.29	100	68
06-005	1008	13:24	15:30	126	Leak (Enclosure 1) – Ground floor near air locks - 5.11.18	<0.005	7	200
06-006	998	13:25	15:33	128	Background (Enclosure 2) - 1st floor office area – 5.11.18	<0.005	1.5	200
06-007	-	13:26	-	-	Leak (Enclosure 1) – Ground floor near NPU - 5.11.18	Pump failed. Checked after 30 mins of sampling	-	-

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-008	557	15:55	17:05	79	Leak (Enclosure 1) – Ground floor near NPU – 5.11.18	<0.009	4	200
06-009	242	07:48	11:18	210	Personal P08 - Removal Enclosure 1- Full face RPE 6.11.18	0.16	104	132
06-010	253	07:49	11:20	211	Personal P07 - Removal Enclosure 1- Full face RPE 6.11.18	0.23	8	200
06-011	1304	07:59	10:44	165	Leak (Enclosure 1) – Ground floor near air locks - 6.11.18	<0.004	4	200
06-012	1312	08:01	10:46	165	Leak (Enclosure 1) – Ground floor near NPU - 6.11.18	<0.004	0.5	200
06-013	927	09:40	14:49	309	Background (Enclosure 2) - 1st floor office area - 5.11.19	<0.005	3	200
06-014	244	13:17	16:11	174	Personal P10 - Removal Enclosure 1- Full face RPE 6.11.18	0.12	100	180
06-015	276	13:14	17:04	230	Personal P09 - Removal Enclosure 1- Full face RPE 6.11.18	0.1	100	188

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-016	1142	13:26	16:38	192	Leak (Enclosure 1) – Ground floor near air locks - 6.11.18	<0.004	5	200
06-017	1140	13:28	16:38	190	Leak (Enclosure 1) – Ground floor near NPU - 6.11.18	<0.004	1.5	200
06-018	613	14:58	16:41	103	Background (Enclosure 2) - 1st floor office area - 6.11.18	<0.008	8.5	200
06-019	1418	08:25	16:10	465	Reassurance (Enclosure 1) - Ground floor – 15.11.18	<0.003	4	200
06-020	958	08:27	10:29	122	Reassurance (Enclosure 2) – 1st floor next to airlocks – 15.11.18	<0.005	15	200
06-021	958	08:28	10:30	122	Reassurance (Enclosure 2) – 1st floor enclosure area – 15.11.18	0.006	24	200
06-022	1193	10:31	14:13	222	Reassurance (Enclosure 2) – 1st floor enclosure area – 15.11.18	0.008	41	200
06-023	1427	07:36	15:24	468	Reassurance (Enclosure 1) - Ground floor – 16.11.18	<0.003	18	200
06-024	1203	07:38	11:46	248	Leak (Enclosure 2) – 1st floor back stairwell – 16.11.18	0.006	28	200

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-025	1208	07:40	11:49	249	Leak (Enclosure 2) – 1st floor next to airlocks – 16.11.18	<0.004	9	200
06-026	247	07:27	10:53	206	Personal P07 - Removal Enclosure 2- Full face RPE 16.11.18	0.06	57	200
06-027	252	07:27	10:57	210	Personal P09 - Removal Enclosure 2- Full face RPE 16.11.18	0.03	28	200
06-028	193	13:15	14:54	99	Personal P09 - Removal Enclosure 2- Full face RPE (in-mask TR01) 16.11.18	0.27	102	100
06-029	304	13:13	13:56	103	Personal P05- Removal Enclosure 2- Full face RPE 16.11.18	0.04	49	200
06-030	821	13:26	16:02	821	Leak (Enclosure 2) – 1st floor next to airlocks – 16.11.18	0.06	2	200
06-031	773	13:26	16:02	773	Leak (Enclosure 2) – 1st floor back stairwell – 16.11.18	0.08	1	200
06-032	266	07:32	11:14	222	Personal P08 - Removal Enclosure 2- Full face RPE (in-mask TR02) 17.11.18	0.49	104	40

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-033	268	07:34	11:17	223	Personal P09 - Removal Enclosure 2- Full face RPE (in-mask TR03) 17.11.18	0.45	100	42
06-034	960	07:50	11:53	243	Reassurance (Enclosure 1) - Ground floor – 17.11.18	<0.005	0	200
06-035	1193	07:50	11:51	241	Leak (Enclosure 2) – 1st floor back stairwell – 17.11.18	<0.004	1	200
06-036	1210	07:57	11:55	242	Leak (Enclosure 2) – 2nd floor office kitchen – 17.11.18	<0.004	5	200
06-037	1198	07:54	11:56	242	Leak (Enclosure 2) – 1st floor next to airlocks – 17.11.18	<0.004	3	200
06-038	178	10:47	11:32	45	Personal P04 – Waste run – Half-face RPE – 17.11.18	<0.027	2.5	200
06-039	226	07:31	11:17	226	Personal P09 - Removal Enclosure 2- Full face RPE (in-mask TR04) 19.11.18	0.29	100	78
06-040	275	07:28	11:17	229	Personal P08 - Removal Enclosure 2- Full face RPE (in-mask TR05) 19.11.18	0.26	100	72
06-041	2444	07:46	17:57	611	Reassurance (Enclosure 1) - Ground floor – 19.11.18	<0.002	6	200

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-042	1188	07:46	11:46	240	Leak (Enclosure 2) – 1st floor back stairwell – 19.11.18	<0.004	4	200
06-043	1205	07:49	11:50	241	Leak (Enclosure 2) – 1st floor next to airlocks – 19.11.18	<0.004	4	200
06-044	282	13:09	17:14	235	Personal P11 - Removal Enclosure 2- Full face RPE 19.11.18	0.2	100	88
06-045	305	13:24	17.38	254	Personal P05 - Removal Enclosure 2- Full face RPE 19.11.18	0.24	102	72
06-047	976	11:56	13:45	109	Reassurance (Enclosure 1) - Ground floor – 19.11.18	<0.005	0	200
06-048	300	13:25	17:35	250	Personal P06 - Removal Enclosure 2- Full face RPE (in-mask TR07) 19.11.18	0.42	100	40
06-049	295	13:21	17:27	246	Personal P09 - Removal Enclosure 2- Full face RPE (in-mask TR06) 19.11.18	0.96	112	20
06-050	1295	13:35	16:49	194	Leak (Enclosure 2) – 1st floor next to airlocks – 19.11.18	<0.004	2	200

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-051	1265	13:35	16:49	194	Leak (Enclosure 2) – 1st floor back stairwell – 19.11.18	<0.004	5	200
06-052	310	16.06	17.46	200	Personal P04 – Waste run - Half face RPE 19.11.18	<0.016	14	203
06-053	162	07:17	11:08	231	Personal P08 - Removal Enclosure 2- Full face RPE (in-mask TR09) 20.11.18	0.34	100	91
06-054	234	07:22	11:28	128	Personal P09 - Removal Enclosure 2- Full face RPE (in-mask TR08) 20.11.18	0.4	100	54
06-055	221	07:20	11:25	245	Personal P07 - Removal Enclosure 2- Full face RPE - 20.11.18	0.66	101	35
06-056	233	07:27	11:32	245	Personal P06 - Removal Enclosure 2- Full face RPE - 20.11.18	0.89	106	26
06-057	1420	07:43	13:29	284	Leak (Enclosure 2) – 1st floor next to airlocks – 20.11.18	<0.003	6	200
06-058	1470	07:41	13:38	297	Leak (Enclosure 2) – 1st floor back stairwell – 20.11.18	<0.003	4	200
06-059	2364	07:40	17:31	591	Reassurance (Enclosure 1) - Ground floor – 20.11.18	<0.002	17	200

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-060	242	13:22	17:24	242	Personal P09 - Removal Enclosure 2- Full face RPE (in-mask TR10) 20.11.18	1.12	107	20
06-061	241	13:27	17:28	241	Personal P06 - Removal Enclosure 2- Full face RPE (in-mask TR11) 20.11.18	0.5	100	42
06-062	263	13:00	17:10	250	Personal P11 - Removal Enclosure 2- Full face RPE 20.11.18	0.13	102	150
06-063	258	13:12	17:30	258	Personal P05 - Removal Enclosure 2- Full face RPE 20.11.18	0.26	101	76
06-064	1167	13:36	16:48	226	Leak (Enclosure 2) – 1st floor next to airlocks – 20.11.18	<0.004	7	200
06-065	1114	13:53	16:48	225	Leak (Enclosure 2) – 1st floor back stairwell – 20.11.18	<0.004	4	200
06-066	309	16:01	17:44	103	Personal P04 – Waste run - Half face RPE 20.11.18	<0.016	5.5	200
06-067	235	07:18	11:13	235	Personal P09 - Removal Enclosure 2- Full face RPE (in-mask TR12) 21.11.18	0.66	101	33

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-068	223	07:29	11:24	235	Personal P08 - Removal Enclosure 2- Full face RPE (in-mask TR13) 21.11.18	0.12	100	94
06-069	223	07:22	11:05	223	Personal P10 - Removal Enclosure 2- Full face RPE 21.11.18	0.08	69.5	200
06-070	220	07:24	11:36	232	Personal P07 - Removal Enclosure 2- Full face RPE 21.11.18	0.55	100	42
06-071	988	0.343055556	11:22	208	Leak (Enclosure 2) – 1st floor next to airlocks – 21.11.18	<0.005	2.5	200
06-072	2435	07:47	17:39	594	Reassurance (Enclosure 1) - Ground floor – 21.11.18			
06-073	1135	07:45	11:34	239	Leak (Enclosure 2) – 1st floor back stairwell – 21.11.18	<0.004	11	200
06-074	253	13:16	17:27	253	Personal P05 - Removal Enclosure 2- Full face RPE 21.11.18	0.2	101	103
06-075	242	13:23	17:25	242	Personal P06 - Removal Enclosure 2- Full face RPE 21.11.18	0.31	100	67

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-076	181	13:14	16:15	181	Personal P08 - Removal Enclosure 2- Full face RPE 21.11.18			
06-077	246	13:16	17:22	246	Personal P09 - Removal Enclosure 2- Full face RPE (in-mask TR15) 21.11.18	0.32	100	64
06-078	1193	13:28	17:39	241	Leak (Enclosure 2) – 1st floor back stairwell – 21.11.18	<0.004	4	200
06-079	1203	13:26	17:29	243	Leak (Enclosure 2) – 1st floor next to airlocks – 21.11.18	<0.004	4.5	200
06-080	255	16:06	17:31	85	Personal P04 – Waste run - Half face RPE 21.11.18	<0.019	8.5	200
06-081	1936	07:45	15:55	490	Reassurance (Enclosure 1) - Ground floor – 22.11.18	<0.002	15.5	200
06-082	1230	07:50	10:28	246	Leak (Enclosure 2) – 1st floor next to airlocks – 22.11.18	<0.004	2.5	200
06-083	1233	07:46	10:26	249	Leak (Enclosure 2) – 1st floor back stairwell – 22.11.18	<0.004	14.5	200
06-084	1188	07:59	11:59	240	Leak (Enclosure 2) – 2nd floor Kitchen area – 22.11.18	<0.004	20	200

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-085	235	07:30	11:25	235	Personal P09 - Removal Enclosure 2- Full face RPE (in-mask TR16) 22.11.18	0.16	103.5	142
06-086	130	07:34	11:10	216	Personal P08 - Removal Enclosure 2- Full face RPE (in-mask TR17) 22.11.18	0.12	61	200
06-087	230	07:30	11:20	230	Personal P07 - Removal Enclosure 2- Full face RPE 22.11.18	0.15	100.5	146
06-088	234	07:31	11:25	234	Personal P06 - Removal Enclosure 2- Full face RPE 22.11.18	0.25	103.5	89
06-089	1305	13:26	17:47	261	Leak (Enclosure 2) – 1st floor next to airlocks – 22.11.18	<0.004	6	200
06-090	750	13:25	15:55	150	Leak (Enclosure 2) – 1st floor back stairwell – 22.11.18	<0.006	2.5	200
06-091	1411	13:00	17:45	285	Leak (Enclosure 2) – 2nd floor Kitchen area – 22.11.18	<0.003	10.5	200
06-092	243	13:22	17:25	243	Personal P06 - Removal Enclosure 2- Full face RPE (in-mask TR18) 22.11.18	0.13	101	157

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-093	252	13:08	17:20	252	Personal P11 - Removal Enclosure 2- Full face RPE 22.11.18	0.09	92.5	200
06-094	252	13:15	17:27	252	Personal P09 - Removal Enclosure 2- Full face RPE (in-mask TR19) 22.11.18	0.41	101	49
06-095	172	13:18	10:28	172	Personal P10 - Removal Enclosure 2- Full face RPE 22.11.18	0.05	32	200
06-096	209	16:13	17:24	71	Personal P04 – Waste run - Half face RPE 22.11.18	<0.023	4.5	200
06-097	238	07:22	11:20	238	Personal P09 - Removal Enclosure 2- Full face RPE (in-mask TR20) 23.11.18	0.3	101	71
06-098	247	07:24	11:31	247	Personal P08 - Removal Enclosure 2- Full face RPE (in-mask TR21) 23.11.18	0.22	101	93
06-100	247	07:30	11:25	235	Personal P06 - Removal Enclosure 2- Full face RPE 23.11.18	0.27	104	78
06-101	1218	07:41	11:47	246	Leak (Enclosure 2) – 1st floor next to airlocks – 23.11.18	<0.004	5	200
06-102	1544	8.59	16:08	429	Reassurance (Enclosure 1) - Ground floor – 23.11.18	<0.003	7.5	200

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-103	1798	10:02	16:09	367	Leak (Enclosure 2) – 1st floor back stairwell – 23.11.18	<0.003	8	200
06-104	1025	13:20	16:09	205	Leak (Enclosure 2) – 1st floor next to airlocks – 23.11.18	<0.005	3	200
06-105	185	13:17	16:22	185	Personal P08 - Removal Enclosure 2- Full face RPE (in-mask TR22) 23.11.18	0.59	100	46
06-106	188	13:16	16:24	188	Personal P09 - Removal Enclosure 2- Full face RPE (in-mask TR23) 23.11.18	0.13	93	200
06-107	99	16:10	16:35	99	Personal P04 – Waste run - Half face RPE 23.11.18	<0.048	2	200
06-108	170	08:02	11:01	179	Personal P04 – Supervisor visual/ Fine clean Enclosure 2- Full face RPE 24.11.18	<0.028	18.5	204
06-109	895	08:09	11:08	179	Leak (Enclosure 2) – 1st floor next to airlocks – 24.11.18	<0.005	2	200
06-110	886	08:10	11:09	179	Leak (Enclosure 2) – 1st floor next to airlocks – 24.11.18	<0.005	0.5	200

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-111	850	08:17	11:07	170	Leak (Enclosure 2) – 1st floor back stairwell – 24.11.186	<0.006	3	200
06-112	239	07:19	10:28	239	Personal P09 – Fine clean Enclosure 2 - Full face RPE (in-mask TR24) 26.11.18	0.06	54.5	200
06-113	239	07:25	11:24	239	Personal P04 – Supervisor visual Enclosure 2- Full face RPE 26.11.18	0.04	34	200
06-114	1100	07:43	11:23	220	Leak (Enclosure 2) – 1st floor next to airlocks – 26.11.18	<0.004	3	200
06-115	1049	07:50	11:22	212	Reassurance (Enclosure 3) -1st floor – 26.11.18	<0.005	6.5	200
06-116	1105	07:39	11:20	221	Leak (Enclosure 2) – 1st floor back stairwell – 26.11.186	<0.004	10.5	200
06-117	2124	07:38	16:29	531	Reassurance (Enclosure 1) - Ground floor – 26.11.18	<0.002	9	200
06-118	220	13:12	17:04	232	Personal P09 – Fine clean Enclosure 2 - Full face RPE (in-mask TR25) 26.11.18	0.18	101.5	132
06-119	239	13:09	17:08	239	Personal P04 – Supervisor visual Enclosure 2- Full face RPE 26.11.18	0.03	30.5	200

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-120	1195	13:10	17:09	239	Leak (Enclosure 2) – 1st floor next to airlocks – 26.11.18	<0.004	2.5	200
06-121	1175	13:15	17:10	235	Reassurance (Enclosure 3) -1st floor – 26.11.18	<0.004	9	200
06-122	1139	13:17	17:07	230	Leak (Enclosure 2) – 1st floor back stairwell – 26.11.186	0.004	20	200
06-123	1117	08:46	12:34	228	Leak (Enclosure 2) – 1st floor next to airlocks – 27.11.18	<0.004	4.5	200
06-124	1125	08:48	12:22	225	Reassurance (Enclosure 3) -1st floor – 27.11.18	<0.004	4.5	200
06-125	1200	08:43	12:43	240	Leak (Enclosure 2) – 1st floor back stairwell – 27.11.186	<0.004	17	200
06-126	1308	08:42	14:09	327	Reassurance (Enclosure 1) - Ground floor – 27.11.18	0.005	24	200
06-127	131	14:03	15:30	87	Personal P12 – Analyst visual Enclosure 2 - Half face RPE 27.11.18	0.05	25.5	200
06-128	524	13:14	16:48	214	Personal P04 – Assisting analyst visual Enclosure 2- Full face RPE 27.11.18	0.02	49	200

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-129	1143	13:06	16:57	231	Reassurance (Enclosure 3) -1st floor – 27.11.18	<0.004	2	200
06-130	493	16:45	17:30	45	Leak (Enclosure 2) – 1st floor next to airlocks – 27.11.18	<0.010	2	200
06-131	238	07:18	11:29	251	Personal P09 – Fine clean Enclosure 2 - Full face RPE (in-mask TR29) 28.11.18	0.03	24	200
06-132	251	07:24	11:35	251	Personal P07 – Fine clean Enclosure 2 - Full face RPE (in-mask TR26) 28.11.18	0.02	19	200
06-133	1297	07:12	11:45	7273	Leak (Enclosure 2) – 1st floor next to airlocks – 28.11.18	<0.004	2	200
06-134	1318	07:15	11:44	269	Reassurance (Enclosure 3) -1st floor – 28.11.18	<0.004	2.5	200
06-135	1700	08:25	15:30	425	Reassurance (Enclosure 1) - Ground floor – 28.11.18	0.003	20.5	200
06-136	1275	08:27	11:42	255	Leak (Enclosure 2) – 1st floor back stairwell – 28.11.186	<0.004	2	200
06-137	293	13:16	17:20	244	Personal P09 –Removing ceiling tiles Enclosure 3 - Full face RPE (in-mask TR27) 28.11.18	0.08	87	201

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-138	298	13:15	17:23	248	Personal P06 – Fine clean Enclosure 2 - Full face RPE 28.11.18	0.02	26.5	200
06-139	1180	13:30	17:26	236	Leak (Enclosure 3) – 1st floor next to airlocks – 28.11.18	<0.004	9	200
06-140	1158	13:31	17:25	234	Leak (Enclosure 2) – 1st floor next to airlocks – 28.11.18	<0.004	1.5	200
06-141	1200	13:28	17:28	240	Leak (Enclosure 2) – 1st floor back stairwell – 28.11.18	<0.004	4	200
06-142	274	07:20	11:32	228	Personal P09 –Sheeting Enclosure 3 - Full face RPE (in-mask TR28) 29.11.18	0.03	28	200
06-143	272	07:16	11:03	227	Personal P10 – Fine clean Enclosure 2 - Full face RPE 29.11.18	<0.018	9	200
06-144	1122	07:22	11:11	229	Leak (Enclosure 3) – 1st floor next to airlocks – 29.11.18	<0.004	2.5	200
06-145	1129	07:23	11:15	228	Leak (Enclosure 2) – 1st floor next to airlocks – 29.11.18	<0.004	5	200

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-146	1132	07:27	11:18	231	Leak (Enclosure 2) – 1st floor back stairwell – 29.11.18	<0.004	1.5	200
06-147	932	07:26	11:19	233	Reassurance (Enclosure 1) - Ground floor – 29.11.18	<0.005	12	200
06-148	502	14:11	15:16	64	Parallel clearance test – Enclosure 2 – 11.12.18	0.03	51.5	200
06-149	506	14:11	15:16	64	Parallel clearance test – Enclosure 2 – 11.12.18	0.02	32	200
06-151	499	14:11	15:16	64	Parallel clearance test – Enclosure 2 – 11.12.18	0.02	45	200
06-152	512	14:11	15:16	64	Parallel clearance test – Enclosure 2 – 11.12.18	0.1	100	102
06-153	510	14:11	15:16	64	Parallel clearance test – Enclosure 2 – 11.12.18	0.02	49.5	200
06-154	150	14:13	14:51	38	Personal P12–Brush disturbance – Full-face mask – 11.12.18	0.03	19	200
06-155		09:46	10:43		Personal P12–Brush disturbance – Full-face mask – 12.12.18	Pump failed, filter clear		
06-156	501	10:15	11:18	63	Parallel clearance test – Enclosure 2 – 12.12.18	0.09	57	200

Site - Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
06-157	501	10:15	11:18	63	Parallel clearance test – Enclosure 2 – 12.12.18	0.13	39.5	200
06-158	501	10:15	11:18	63	Parallel clearance test – Enclosure 2 – 12.12.18	0.08	64	200
06-159	495	10:15	11:18	63	Parallel clearance test – Enclosure 2 – 12.12.18	0.11	46.5	200
06-160	499	10:16	11:18	64	Parallel clearance test – Enclosure 2 – 12.12.186	0.03	52.5	200
06-161	499	10:16	11:18	64	Parallel clearance test – Enclosure 2 – 12.12.18	0.03	59.5	200
06-162	756	12:55	13:37	42	Reassurance – Enclosure 2 - 17.12.18	<0.006	11	200

A.7 Site 7 Results

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
07-001	330	13:33	16:18	165	Personal P06 – Enclosure construction – No RPE – 23.04.19	<0.015	4	200
07-002	74	11:21	11:58	37	Personal P05 –Mobile tower construction – No RPE – 23.04.19	<0.065	3	200
07-003	316	13:34	16:16	162	Personal P08 – Enclosure construction – No RPE – 23.04.19	<0.015	1	200
07-004	76	11:21	11:59	38	Personal P06 – Mobile tower construction – No RPE – 23.04.19	<0.063	3	200
07-005	1181	11:21	16:20	299	Reassurance – Enclosure area – 23.04.19	<0.004	8	200
07-006	954	11:28	13:28	120	Reassurance – Enclosure area – 23.04.19	<0.005	4	200
07-007	1350	13:28	16:20	172	Reassurance – Enclosure area – 23.04.19	<0.004	9	200
07-008	187	14:44	16:20	96	Personal P04 – Enclosure construction – No RPE – 23.04.19	<0.026	2	200
07-009	374	08:27	11:49	202	Personal P05 – Enclosure construction – No RPE – 24.04.19	<0.013	9.5	200
07-010	1069	08:24	12:48	264	Reassurance – Enclosure area – 24.04.19	<0.004	7.5	200
07-011	1214	08:25	11:49	204	Reassurance – Enclosure area – 24.04.19	<0.004	5.5	200
07-012	302	08:27	11:48	201	Personal P03 – Enclosure construction – No RPE – 24.04.19	<0.016	4	200

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
07-013	297	08:30	11:48	198	Personal P06 – Enclosure construction – No RPE – 24.04.19	<0.016	1.5	200
07-015	780	13:10	15:46	156	Reassurance – Enclosure area – 24.04.19	<0.006	1.5	200
07-016	176	13:14	15:11	117	Personal P05 – Enclosure construction – No RPE – 24.04.19	<0.027	1	200
07-017	225	13:16	15:51	145	Personal P03 – Enclosure construction – No RPE – 24.04.19	<0.021	3.5	200
07-018	182	08:35	11:37	182	Personal P06 – Removal work in enclosure – Full Face RPE (Phantom in-mask) – 25.04.19	0.04	25	200
07-014	183	08:35	11:38	183	Personal P08 – Removal work in enclosure – Full Face RPE (Sync) – 25.04.19	<0.026	6.5	200
07-019	172	08:35	11:37	172	Personal P03 – Removal work in enclosure – Full Face RPE (Phantom in-mask) – 25.04.19	<0.028	11.5	200
07-020	177	08:41	11:38	177	Personal P05 – Removal work in enclosure – Full Face RPE (Sync) – 25.04.19	<0.027	2.5	200
07-021	1215	08:20	13:20	300	Leak – Next to enclosure – 25.04.19	<0.004	4	200
07-022	1459	08:51	13:30	286	Leak – Floor above enclosure – 25.04.19	<0.003	2	200
07-023	159	13:31	16:10	159	Personal P03 – Removal work in enclosure – Full Face RPE (Phantom in-mask) – 25.04.19	<0.03	2.5	200

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
07-024	162	13:28	16:10	162	Personal P08 – Removal work in enclosure – Full Face RPE (Sync) – 25.04.19	0.03	18.5	200
07-025	240	13:33	16:13	160	Personal P05 – Waste run – Half Face RPE – 25.04.19	<0.020	1	200
07-026	252	13:33	16:11	158	Personal P06 – Waste run – Half Face RPE – 25.04.19	<0.019	1	200
07-027	960	13:22	16:36	960	Leak – Next to enclosure by baglock – 25.04.19	<0.005	4	200
07-028	1108	08:18	12:15	277	Leak – Next to enclosure – 26.04.19	<0.004	4.5	200
07-029	972	08:33	12:36	243	Leak – Floor above enclosure – 26.04.19	<0.005	8	200
07-030	235	08:12	12:07	235	Personal P06 – Removal work in enclosure – Full Face RPE (Phantom in-mask) – 26.04.19	0.03	30.5	200
07-031	266	08:30	12:56	266	Personal P03 – Removal work in enclosure – Full Face RPE (Phantom in-mask) – 26.04.19	<0.018	8.5	200
07-032	363	08:57	12:57	242	Personal P05 – Waste run – Half Face RPE – 26.04.19	<0.013	3.5	200
07-033	192	08:38	11:50	192	Personal P08 – Removal work in enclosure – Full Face RPE (Sync) – 26.04.19	<0.025	6.5	200
07-034	146	09:41	12:00	139	Personal P04 – Removal work in enclosure – Full Face RPE (Phantom) – 29.04.19	0.04	22.5	200

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
07-035	179	08:56	11:55	179	Personal P03 – Removal work in enclosure – Full Face RPE (Phantom in-mask) – 29.04.19	<0.027	16.5	200
07-036	181	08:46	11:47	181	Personal P06 – Removal work in enclosure – Full Face RPE (Phantom in-mask) – 29.04.19	<0.027	8	200
07-037	832	08:39	12:07	208	Leak – Next to enclosure – 29.04.19	<0.006	3.5	200
07-038	2100	09:00	16:00	420	Leak – Floor above enclosure – 29.04.19	<0.002	7.5	200
07-039	133	13:36	15:49	133	Personal P05 – Removal work in enclosure – Full Face RPE (Sync) – 29.04.19	<0.036	7.5	200
07-040	129	13:41	15:50	129	Personal P06 – Removal work in enclosure – Full Face RPE (Phantom) – 29.04.19	<0.037	6.5	200
07-041	119	13:49	15:48	119	Personal P08 – Removal work in enclosure – Full Face RPE (Phantom in-mask) – 29.04.19	<0.040	13	200
07-042	116	13:57	15:51	116	Personal P04 – Removal work in enclosure – Full Face RPE (Phantom in-mask) – 29.04.19	<0.041	8.5	200
07-044	545	13:37	15:55	245	Leak – Next to enclosure by baglock – 29.04.19	<0.009	3.5	200
07-045	1770	08:33	15.5	437	Leak – Next to enclosure – 30.04.19	<0.003	2.5	200
07-046	1687	08:33	16:00	427	Leak – Floor above enclosure – 30.04.19	<0.003	6	200

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
07-048	162	08:32	11:32	180	Personal P08 – Removal work in enclosure – Full Face RPE (Sync) – 30.04.19	<0.030	10.5	200
07-049	165	08:36	11:39	183	Personal P05 – Removal work in enclosure – Full Face RPE (Sync) – 30.04.19	<0.029	5.5	200
07-050	175	08:51	11:37	194	Personal P08 – Removal work in enclosure – Full Face RPE (Phantom in-mask) – 30.04.19	<0.027	4.5	200
07-051	177	08:45	11:42	177	Personal P06 – Removal work in enclosure – Full Face RPE (Phantom in-mask) – 30.04.19	<0.027	15.5	200
07-052	128	13:20	15:42	142	Personal P04 – Removal work in enclosure – Full Face RPE (Phantom in-mask) – 30.04.19	<0.038	5	200
07-053	110	13:23	15:45	122	Personal P08 – Removal work in enclosure – Full Face RPE (Phantom in-mask) – 30.04.19	<0.044	8	200
07-054	124	13:39	15:43	124	Personal P06 – Removal work in enclosure – Full Face RPE (Phantom) – 30.04.19	<0.039	10	200
07-055	144	13:25	15:42	137	Personal P05 – Removal work in enclosure – Full Face RPE (Sync) – 30.04.19	<0.033	6	200
07-056	145	08:30	11:31	181	Personal P03 – Removal work in enclosure – Full Face RPE (Phantom in-mask) – 01.05.19	<0.033	5	200

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
07-057	132	08:35	11:20	165	Personal P04 – Removal work in enclosure – Full Face RPE (Phantom in-mask) – 01.05.19	<0.036	6.5	200
07-058	122	09:08	11:40	152	Personal P06 – Removal work in enclosure – Full Face RPE (Phantom) – 01.05.19	<0.039	11.5	200
07-059	121	09:17	11:48	151	Personal P05 – Removal work in enclosure – Full Face RPE (Sync) – 01.05.19	<0.040	5.5	200
07-060	1728	08:36	15:48	432	Leak – Next to enclosure by baglock – 01.05.19	<0.003	3	200
07-061	1736	08:39	15:53	434	Leak – Floor above enclosure – 01.05.19	<0.003	1.5	200
07-062	100	13:24	15:29	125	Personal P08 – Removal work in enclosure (fine clean) – Full Face RPE (Sync) – 01.05.19	<0.048	3.5	200
07-063	97	13:27	15:28	121	Personal P06 – Removal work in enclosure (fine clean) – Full Face RPE (Phantom in-mask) – 01.05.19	<0.049	1	200
07-064	116	13:18	16:43	145	Personal P03 – Removal work in enclosure (fine clean) – Full Face RPE (Phantom) – 01.05.19	<0.041	4	200
07-065	106	13:33	15:46	133	Personal P04 – Removal work in enclosure (fine clean) – Full Face RPE (Sync) – 01.05.19	<0.045	2.5	200
07-066	1635	08:35	15:29	414	Leak – Next to enclosure by baglock – 02.05.19	<0.003	2	

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
07-067	214	08:34	13:02	268	Personal P08 – Removal work in enclosure (fine clean) – Full Face RPE (Sync) – 02.05.19	<0.022	3.5	200
07-068	206	08:52	13:10	258	Personal P03 – Removal work in enclosure (fine clean) – Full Face RPE (Phantom) – 02.05.19	<0.023	1.5	200
07-069	160	11:31	14:51	200	Personal P04 – Supervisor visual – Full Face RPE (Sync) – 02.05.19	<0.030	2.5	200
07-070	63	11:39	12:58	79	Personal P07 – 4SC visual – Full Face RPE (Phantom) – 02.05.19	<0.076	0	200
07-071	262	10:12	14:32	262	Personal P07 – 4SC visual – Full Face RPE (Phantom) – 03.05.19	<0.018	4	200
07-072	224	09:58	13:42	224	Personal P04 – Assisting 4SC visual – Full Face RPE (Phantom) – 03.05.19	<0.021	7	200
07-073	321	08:24	13:45	321	Personal P03 – Assisting 4SC visual – Full Face RPE (Phantom) – 03.05.19	<0.015	8.5	200
07-074	1406	08:16	15:22	356	Leak – Next to enclosure by airlock – 03.05.19	<0.003	4.5	200
07-075	480	13:55	14:35	246	Parallel Clearance – Enclosure - 03.05.19	<0.01	2	200
07-076	480	13:55	14:35	241	Parallel Clearance – Enclosure - 03.05.19	<0.01	2.5	200
07-077	480	13:55	14:35	243	Parallel Clearance – Enclosure - 03.05.19	<0.01	3	200
07-078	480	13:55	14:35	243	Parallel Clearance – Enclosure - 03.05.19	<0.01	1	200

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
07-079	550	15:23	16:20	85	Reassurance – Next to enclosure by NPU– 03.05.19	<0.009	3	200
07-080	550	15:23	16:20	54	Reassurance – Next to enclosure by baglock– 03.05.19	<0.009	3.5	200
07-081	135	15:21	16:15	54	Personal P06 – Dismantling enclosure – Half Face RPE – 03.05.19	<0.036	2.5	200
07-082	133	15:22	16:15	54	Personal P05 – Dismantling enclosure – Half Face RPE – 03.05.19	<0.036	3	200
07-083	138	15:20	16:15	55	Personal P08 – Dismantling enclosure – Half Face RPE – 03.05.19	<0.035	3.5	200

A.8 Site 8 Results

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
08-002	1236	09:18	12:44	206	Reassurance – Enclosure area – 14.10.19	<0.004	11	200
08-003	1025	09:19	12:44	205	Reassurance – Enclosure area – 14.10.19	<0.005	4.5	200
08-004	340	13:11	16:01	170	Personal P05 – Enclosure construction – Half-face RPE – 14.10.19	0.02	27	200
08-005	169	13:14	16:03	169	Personal P02 – Enclosure construction – Half-face RPE – 14.10.19	0.03	22.5	200
08-006	245	13:13	16:02	169	Personal P03 – Enclosure construction – Half-face RPE – 14.10.19	<0.02	11	200
08-007	333	13:09	16:03	171	Personal P04 – Enclosure construction – Half-face RPE – 14.10.19	Filter too occluded to count		
08-008	688	13:20	15:31	131	Reassurance – Enclosure area – 14.10.19	<0.007	16	200
08-009	1103	14:31	16:20	187	Reassurance – Site Cabin – 14.10.19	<0.004	16.5	200
08-010	191	07:44	10.55	191	Personal P05 – Enclosure construction – Half-face RPE – 15.10.19	<0.025	16.5	200
08-011	182	07:46	10.58	192	Personal P02 – Enclosure construction – Half-face RPE – 15.10.19	<0.026	18	200

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
08-012	180	07:47	10.56	189	Personal P03 – Enclosure construction – Half-face RPE – 15.10.19	<0.027	4.5	200
08-014	1184	07:47	10.58	191	Reassurance - Next to airlocks - 15.10.19	<0.004	2.5	200
08-015	475	13:14	15:11	97	Leak - Next to airlocks - 15.10.19	<0.01	1.5	200
08-016	89	13:16	15:51	145	Personal P04 - Full face in-mask (NEW 11) - 15.10.19	0.10*	36	200
08-017	64	13:18	15:51	143	Personal P02 - Full face in-mask (NEW 12) - 15.10.19	0.13	32	200
08-018	No final flow reading taken	13:15	14:36	81	Personal P03 – Removal work -Full face in-mask - 15.10.19	Filter too overloaded to mount. Layer of dust and debris in cowl.		
08-019	121	08:06	11:27	201	Personal P03 - Removal work - Full face in-mask (NEW 13) - 16.10.19	0.05	25.5	200
08-020	124	08:01	11:27	206	Personal P02 - Removal work -Full face in-mask (NEW 14) - 16.10.19	0.06	30.5	200
08-021	130	07:50	11:27	217	Personal P05 - Removal work - Full face Vision - 16.10.19 AM	0.07	35	200
08-022	128	07:53	11:27	214	Personal P04 - Removal work - Full face Vision - 16.10.19	0.23	102	148
08-023	314	08:49	11:26	157	Personal P08 - Waste run - Half-face -16.10.19	<0.015	7	200
08-024	73	13:26	15:52	146	Personal P03 - Removal work - Full face in-mask (NEW 15) - 16.10.19	<0.066	18.5	200

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
08-025	76	13:33	15:54	160	Personal P04 - Removal work - Full face in-mask (NEW 16) - 16.10.19	0.13	39	200
08-026	1006	13:17	16:06	169	Leak - Next to airlocks by window - 16.10.19	<0.005	9.5	200
08-027	186	14:16	15:49	93	Personal P09 - Waste run - Half-face -16.10.19	<0.026	4.5	200
08-028	95	14:16	15:49	159	Personal P05 - Removal work - Full face Vision - 16.10.19 AM	0.12	43.5	200
08-029	87	13:17	15:52	145	Personal P04 - Removal work - Full face Vision - 16.10.19	0.08	28	200
08-030	821	07:54	11:40	166	Leak - Next to airlocks by stairwell - 16.10.19	<0.006	2.5	200
08-031	175	07:56	11:35	219	Personal P04 - Removal work - Full face Vision - 17.10.19	0.04	29.5	200
08-032	161	08:05	11:39	214	Personal P03 - Removal work - Full face In-mask (NEW 18) - 17.10.19	0.07	42	200
08-033	122	08:02	10:23	143	Personal P05 - Removal work - Full face Vision - 17.10.19	0.05	23	200
08-034	174	07:55	11:23	218	Personal P03 - Removal work - Full face In-mask (NEW 17) - 17.10.19	0.03	19	200
08-035	286	08:54	11:17	143	Personal P08 - Waste run - Half-face -17.10.19	<0.017	1.5	200
08-036	1316	11:23	15:41	181	Leak - Next to airlocks by stairwell - 17.10.19	<0.004	18.5	200
08-037	492	14:55	15:36	41	Parallel Clearance – Enclosure - 17.10.19	<0.010	10.5	200

Site Sample number	Sample volume (litres)	Time on	Time off	Sample duration (min)	Static/ Personal - Location/Activity	Fibre concentration (f/ml)	Number of fibres counted	Number of graticule areas counted
08-038	492	14:55	15:36	41	Parallel Clearance – Enclosure - 17.10.19	<0.010	14.5	200
08-039	492	14:55	15:36	41	Parallel Clearance – Enclosure - 17.10.19	<0.010	6.5	200
08-040	492	14:55	15:36	41	Parallel Clearance – Enclosure - 17.10.19	<0.010	5	200
08-041	492	14:55	15:36	41	Parallel Clearance – Enclosure - 17.10.19	<0.010	9.5	200
08-043	260	12:53	14:50	118	Personal P09 – Supervisor visual - Half-face -17.10.19	<0.018	5.5	200
08-044	248	13:32	15.36	124	Personal P07 – 4SC analyst visual - Half-face -17.10.19	<0.019	14.5	200
08-045	129	07:44	09:10	86	Personal P03 – Dismantling enclosure - Half-face -18.10.19	<0.037	8	200
08-046	132	07:45	09:10	85	Personal P10 – Dismantling enclosure - Half-face -18.10.19	<0.036	8.5	200
08-047	170	07:47	09:10	83	Personal P10 – Dismantling enclosure - Half-face -18.10.19	0.03	20	200
08-048	178	07:45	09:10	89	Personal P04 – Dismantling enclosure - Half-face -18.10.19	0.03	22.5	200
08-049	612	07:50	09:50	120	Reassurance – Enclosure area – 18.10.19	0.015	35.5	200
08-050	744	07:50	09:50	120	Reassurance – Enclosure area - 18.10.19	0.012	34	200

Appendix B Information sheets

A.9 Information sheet for employers

PH01918 Current Exposures and Work Practices in the Licensed Asbestos Removal Industry

Information for Employers
You/Your business have been approached to take part in a research project to assess the current rules and regulations governing asbestos removal and to establish the current exposures experienced by asbestos removal workers. The project is organised by the Health and Safety Laboratory (HSL) and funded by the Health and Safety Executive (HSE). Before you decide whether or not to take part it is important that you understand why the research is being done and what it will involve. Please read this information sheet and feel free to ask us if there is anything that is not clear or you would like more information about.

What is the purpose of this study?
Asbestos remains the leading cause of occupational cancers in the UK with 5000 attributable cancer registrations in 2012. HSE is committed to ensuring the respiratory heath of workers is not compromised. Due to the nature of your business (as asbestos removal contractors) you represent a group at risk of asbestos exposure.

This project aims to assess whether current practices within the industry are sufficient to reduce the risk of exposure to asbestos to as low as reasonably practicable. The information we gather will be used to update HSE guidance for the industry.

Why has my business been approached?
As your company is involved in asbestos removal we would like you to consider participating in this research. In doing so, we would seek your permission to visit your site and recruit members of your workforce to take part.

What will this research involve?
Two HSL scientists will visit a site where you are conducting asbestos removal work. Generally sites where work is taking place over three to five days will be chosen. HSL scientists will be on site for the duration of the job.

You or your site supervisor you will be the first point of contact if the researchers have any questions or issues of concern. It is expected that for the majority of site visits HSL scientists will only observe and will not need to bring issues to your attention. However, if HSL scientists see any poor practice that they think will lead to exposure to or spread of asbestos they will tell you. Through discussion with you it is envisaged that these issues would be quickly resolved.

During their time on site the HSL scientists will be observing all procedures involved with the removal process. Personal and static air monitoring will take place throughout the visit.

For the personal monitoring an effort will be made to include all roles on site but there will be a focus on those carrying out direct removal work inside the enclosure. Samples of saliva and exhaled breath condensate will also be taken from workers who enter enclosures. The process for collecting these samples will be explained during the site visits.

Prior to any sampling/survey work being undertaken, we would seek to recruit members of the asbestos removal team. An information sheet similar to this will be provided to each worker and an opportunity to ask questions will be offered. Potential participants will be asked to provide written consent to record their agreement to participate in this survey. All participants will be made aware that their participation is voluntary and that they are free to withdraw from the study at any time and that any personal information collected from them will be handled in confidence and any health results will be reported back to them in private.

Additionally, we would also like to be able to take photographs and in some cases video in order to depict work areas, processes, work practices, exposure control measures and any good practice / points of concern. This will aid the report writing and overall objectives of the research. Your consent for us to take photographs/video will be requested from you beforehand and any subsequent use of such media will only be done so ensuring identities of contractors, sites and workers are protected.

Site visits will be carried out in accordance with a HSE protocol that has been written for the project and is supplied along with this document.

Does my business have to take part?
It is up to you to decide if you want to take part. If you do take part, you will be given this information sheet and be asked sign a consent form recording your agreement for HSL to undertake survey work with you and your team. Even if you sign the consent form you can withdraw at any time and without giving a reason.

What are the benefits of taking part? The monitoring and subsequent report will provide an independent assessment of your working practices. This will provide assurances to employees and clients that work carried out by your company meets essential safety guidelines. Any constructive given in the report will allow you to improve your standards

What will be analysed in the saliva and exhaled breath condensate samples? Samples collected from consenting workers will be analysed for asbestos fibres. If they are found this may be an indication that the control measures used and RPE worn has not been effective. However, we will not be able to determine when or where the exposure took place.

WE WILL NOT ANALYSE THE SAMPLES FOR ALCOHOL, DRUGS OR ANYTHING OTHER THAN ASBESTOS.

How will the results be interpreted?
Your company will be provided with a report detailing the results from all samples taken while on site as well as an account of the observations made. The individual biological monitoring results (exhaled breath and saliva) will not be provided in this report. Results are treated as medical in confidence and will only be fed back to the participants in private.

What if the results are high?
Any air monitoring results that show exposure above the control limit after taking into account protection from RPE (for full faced respirators that would be 4 f/ml) would need to be investigated.

If asbestos fibres are found in saliva or exhaled breath condensate of consenting participants, this indicates that exposure to asbestos may not be properly controlled and some workers may have been directly exposed to asbestos fibres. However, we will not be able to determine when or where the exposure took place or whether this has any impact on the current or future health of those participants.

Participating workers will be informed that if they have concerns about their health they should discuss this with their GP. Furthermore, if they have concerns about their air monitoring results or the effectiveness of their personal protective equipment, they should discuss this with you as their employer.

You may use all results from the site visit to assess exposure controls and working practices to see how they can be improved.

If you have questions about any of the result presented, you can contact the study team (details at the end of this sheet).

How are my rights protected?
If you decide to take part in this research we need to obtain your consent beforehand. This is using a consent form, which is an agreement between you and us to ensure you understand why we are conducting this research, what will be analysed and what we will do with the results.

What will happen to the results of the project?
All information and results from the visit will be anonymised and presented in a report for HSE which will be available on their website. The results may also be presented in a peer reviewed, publicly available research paper. Your company, the worksite and individuals will not be able to be identified. We may also ask for your consent if we wish to use any photos in publications about the research findings. However, we will obscure images so that no one will be able to identify who took part in the study.

All the results of the project will be held for a minimum of 15 years with hard copy documents securely stored in locked medical cabinets and digital data on password protected and backed up computers. Both are strictly access controlled limited to the project team. Participants will be assigned a unique code reference once recruited into the study. This code will be used in place of participants name/identifiers in all subsequent

data analysis and reporting except in the instance of reporting individual personal data back to participants if they have consented for this.

Has this research been approved?
This work has been reviewed and approved to proceed by the University of Sheffield Medical School Research Ethics Committee: 0114 2261458 (medschoolethics@sheffield.ac.uk).

What do I do if I have any complaints about this work?
If you wish to complain, or have any concerns about any aspect of the way you have been approached or treated during the course of this study, then you should approach the HSL Principal Investigator or alternatively the HSL's technical lead in this research area (details below).

Contact for further information: If you have any concerns or questions about this project you can contact:

(Names and contact details were supplied here.)

Thank you for reading this information sheet

A.10 Employee information

PH01918 Current Exposures and Work Practices in the Licensed Asbestos Removal Industry

Information for participants
You have been approached to take part in a research project to assess the current rules and regulations governing asbestos removal and to establish the current exposures experienced by asbestos removal workers. The project is organised by the Health and Safety Laboratory (HSL) and funded by the Health and Safety Executive (HSE). Before you decide whether or not to take part it is important that you understand why the research is being done and what it will involve. Please read this information sheet and feel free to ask us if there is anything that is not clear or you would like more information about.

What is the purpose of this study?
Asbestos remains the leading cause of occupational cancers in the UK with 5000 cancer registrations in 2012 linked to asbestos. HSE is committed to ensuring the respiratory heath of workers is protected. Due to the nature of your work, asbestos removal contractors remain a group at risk of asbestos exposure.

This project aims to assess whether current practices within the industry are sufficient to reduce the risk of asbestos exposure. The information we gather will be used to update HSE guidance for the industry.

Why have I been chosen?
Your company has kindly agreed to assist HSL in this research and you have been chosen as you are an employee who will be working on asbestos removal on a site that has been selected for this project.

What would my participation involve?
Two HSL scientists will visit a site where you are working. Generally sites where work is taking place over three to five days will be chosen. HSL scientists will be on site for the duration of the job.

During their time on site the HSL scientists will be observing all procedures involved with the asbestos removal process. Air monitoring will take place during the visit in order to measure possible asbestos levels. For the personal air monitoring (where you may be asked to wear a sampling pump) an effort will be made to include all roles on site but there will be a focus on those carrying out direct removal work inside the enclosure.

In addition to air monitoring, samples of your saliva and exhaled breath will also be taken from workers who enter enclosures. The analysis of these samples for information about exposure to asbestos is known as biological monitoring. The process for collecting these samples is painless and very straightforward and will be explained during the site visits.

We would also like to be able to take photographs and in some cases video in order to depict work areas, processes, work practices, exposure control measures and any good

practice / points of concern. This will aid the report writing and overall objectives of the research.

Your permission for us to include you in this research, carry out personal air monitoring, collect saliva and breath samples and take photographs/video will be requested from you beforehand and recorded on a consent form.

Do I have to take part?
It is up to you to decide if you want to take part. If you do take part, you will be given this information sheet and be asked sign a consent form. Even if you sign the consent form you can withdraw at any time and without giving a reason. Your decision to not take part will not affect your employment in any way.

What will be analysed in the saliva and exhaled breath condensate samples? The samples will be analysed for asbestos fibres and this is a new method for measuring asbestos exposure that we are investigating. If asbestos fibres are found in your samples this may be an indication that the control measures used and RPE worn has not been effective. However, we will not be able to determine when or where the exposure took place.

WE WILL NOT ANALYSE THE SAMPLES FOR ALCOHOL, DRUGS OR ANYTHING OTHER THAN ASBESTOS.

How will the results be interpreted?
If you wish to receive them you will be given all personal monitoring results taken during your work during the project This includes both air monitoring and any biological sampling that takes place. Your company will also be given a report detailing the results from all samples taken while on site as well as an account of the observations made, however, your own biological monitoring results are treated in confidence and will not be made available to your company. This report should be made available to you.

What if my results are high?
Any air monitoring results that show exposure above the control limit after taking into account protection from RPE (for full faced respirators that would be 4 f/ml) would need to be investigated.

If asbestos fibres are found in saliva or exhaled breath condensate this indicates that your exposure may not be properly controlled and you have been directly exposed to asbestos fibres. However, we will not be able to determine when or where the exposure took place or whether this has any impact on your current or future health.

If you have concerns about your health you should discuss this with your GP. If you have concerns about your air monitoring results or personal protective equipment, you should discuss this with your employer.

Your employer will use all results from the site visit to assess exposure controls and working practices to see how they can be improved.

If you have questions about your results or any other aspect of this research, you can contact the HSL study team (details at the end of this sheet).

How are my rights as an individual protected?
If you decide to take part in this research we need to obtain your consent beforehand. This is recorded using a consent form, which is an agreement between you and us to ensure you understand why we are asking you to take part and your agreement to do so.

What will happen to the results of the project?
All information and results from the visit will be anonymised and presented in a report for HSE which will be available on their website. The results may also be presented in a peer reviewed, publicly available research paper. Individuals or companies will not be able to be identified. We may also ask for your consent if we wish to use any photos in publications about the research findings. However, we will obscure images so that no one will be able to identify who took part in the study. All the results of the project will be held for a minimum of 15 years with hard copy documents securely stored in locked medical cabinets and digital data on password protected and backed up computers. Both are strictly access controlled limited to the project team. Participants will be assigned a unique code reference once recruited into the study. This code will be used in place of participants name/identifiers in all subsequent data analysis and reporting except in the instance of reporting individual personal data back to participants if they have consented for this.

Has this research been approved?
This work has been reviewed and approved to proceed by the University of Sheffield Medical School Research Ethics Committee: 0114 2261458 (medschoolethics@sheffield.ac.uk).

What do I do if I have any complaints about this work?
If you wish to complain, or have any concerns about any aspect of the way you have been approached or treated during the course of this study, then you should approach the HSL Principal Investigator or alternatively the HSL's technical lead in this research area (details below).

We do not foresee any additional/added risks to participants who take part in this study as the project involves only monitoring and observing current work practices. If in the unlikely event that through taking part in this research you are harmed there are no special compensation arrangements. However, if you are harmed due to someone's negligence, then you may have grounds for a legal action but you may have to pay for it.

If you choose to take part in this project, please keep this information sheet for future reference.

Contact for further information: If you have any concerns or questions about this project you can contact:

(Names and contact details were supplied here)

In Great Britain there are around 5,000 cancer deaths a year attributed to asbestos, mainly due to past industrial exposures. The import and use of all types of asbestos was banned by 1999. However, asbestos can be present in any building built or refurbished before 2000 and continues to be removed as part of ongoing risk management. Higher-risk removal work can only be undertaken by HSE licensed contractors. Under the Control of Asbestos Regulations, exposure must be prevented or effectively controlled.

The aim of this research was to provide information on asbestos exposures to licensed removal workers in Great Britain and to assess compliance of work practices with HSE guidance. HSE scientists visited eight removal sites during 2016 to 2019. Removals included asbestos insulating board (AIB), insulation and sprayed coating. The researchers monitored airborne fibre concentrations using samplers and observed work practices. The removal contractors and workers participated on a voluntary basis. The findings are therefore likely to indicate exposure levels and working practices for contractors and workers undertaking licensed asbestos removal who are attempting to adopt good practice. The findings are not intended to be representative of the removals industry as a whole. There are three main research findings. (1) Asbestos fibres were present in the airborne fibres samples. (2) Some airborne fibre concentrations measured in the study were above the limit. (3) There is scope for further exposure reduction, for example by ensuring that workers wear respiratory protective equipment (RPE) during set up and dismantling of the enclosure used for removal activities. These findings are being used to inform HSE communication with stakeholders and updates to HSE guidance.

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