Health and Safety Executive

Further measurements of fibre concentrations in CLASP construction buildings

Prepared by the **Health and Safety Laboratory** for the Health and Safety Executive 2008

RR624
Research Report

Health and Safety
Executive

Further measurements of fibre concentrations in CLASP construction buildings

Garry Burdett
Health Improvement Group
Health and Safety Laboratory
Harpur Hill
Buxton
SK17 9JN

In late July 2006, after asbestos contractors had carried out asbestos removal work at a school, the on-site laboratory failed to obtain levels of asbestos fibre in air below 'clearance levels' when, as part of deliberate disturbance, the metal casing around the steel support columns were struck a number of times with the fist or other similar disturbance took place (sitting on and flexing the windowsills). The measured fibre concentrations inside the enclosure suggested a significant release of airborne fibres could take place from some columns. This information was reported to HSE in mid-September and an assessment of the cause, the extent of the release and the effectiveness of remediation were undertaken by HSE with substantial support and co-operation from some local education authorities and HSL. Initial advice was released to schools by HSE before the half-term holiday and a working group was set up by HSE to further assess the problem and to produce further advice from the issues arising.

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

HSE Books

First published 2008

ACKNOWLEDGEMENTS

The data in this report were collected with the help and co-operation of a number of HSE inspectors, HSL staff, schools, local education authorities and contracted asbestos laboratories. As all data has been anonymised for this report, I am unable to name them but without the extensive help and co-operation provided this report would not have been possible.

CONTENTS

EXECUTIVE SUMMARY

Objectives

This further report on CLASP 4 and 4A buildings was focussed on the following three objectives:

- To carry out a more sensitive analysis of the airborne asbestos fibre concentration in buildings under conditions of normal occupation.
- To assess the potential exposure of maintenance personnel in CLASP type buildings.
- To further assess the potential for release after remediation.

Main Findings

The first objective was met by the use of higher flow rate pumps and/or increased sampling time to give an increased volume of air sampled onto a filter and improved analytical sensitivity. Analytical transmission electron microscopy (TEM) was used to count fibres, which met the size criteria for counting by phase contrast microscopy (PCM) and to identify if they were asbestos and which type. The concentration PCM equivalent (PCME) asbestos fibres in air and the type of asbestos are the established indices for making an assessment of the asbestos risk.

Increased sampling times were used when possible to give a better estimate of the average airborne concentration over time and to increase the probability of capturing any peak release events. Sampling periods of one to seven working days were used. Improved analytical sensitivity were also achieved by extending the TEM analysis, so that instead of examining 20 grid openings (~1000 fields of view) per sample this was increased by a factor of 5 to 100 grid openings (~5,000 fields of view) for many samples.

Sampling for extended periods in occupied classrooms has many logistic problems and is also very time consuming. Therefore every effort was made to work with local education authorities and their own local sampling agencies to carry out the sampling, with HSL personnel only going on site for more specific simulation activities.

Buildings where repeated sampling was carried out enabled a profile of the fibre concentration to be built up and allowed a greater analytical sensitivity to be achieved by pooling the samples to give an overall average.

Airborne fibre concentrations in unremediated buildings during normal occupation.

In a non-remediated CLASP 4 building containing amosite asbestos insulating board (AIB) five weeks of continuous sampling was conducted at two locations, close to where the doors in frequent use were attached to the columns. The calculated pooled value of PCME asbestos fibres was 0.000007 f/ml (7 f/m^3) which had an upper 95% confidence value (limit of detection) of <0.000033 f/ml., based on a single amosite fibre being detected and a 5-day working week. This meant that the upper 95% value for PCME asbestos fibres was an order of magnitude lower than the background average value for asbestos containing materials (ACMs) in buildings (Burdett and Jaffrey, 1986; HEI, 1991) and three and two thirds orders of magnitude below the control limit. The average non-asbestos fibre concentration was calculated as 0.00063 f/ml.

It was notable that the very high winds that occurred in the third week of sampling did not lead to any detectable increase in airborne asbestos fibre concentrations in the building air.

When an normally occupied school classroom with unsealed columns was sampled (reportedly containing chrysotile board over 1 day, a single chrysotile fibre was detected. The calculated pooled result was equivalent to the analytical sensitivity of 0.00005 f/ml with a limit of detection of <0.0003 f/ml below the previously monitored average in asbestos containing buildings

Airborne asbestos concentrations in occupied remediated schools

In a previous report, the pooled TEM result from 3 samples, found one PCME amosite fibre, which gave a calculated concentration equivalent to the analytical sensitivity of 0.0001 f/ml and was below the limit of detection (0.0005 f/ml).

Further TEM results for 28 individual samples taken in seven occupied schools are given. Two of the schools had been fully remediated (seams and tops of the column casings sealed) and five partially remediated (seams only sealed). Typically samples were collected over the whole of the school day in an occupied classroom (20 samples) and using flow rates of $\geq$ 8 l/minute. Other samples were taken in communal areas (corridors, halls and cloakroom) and one sample above the ceiling.

No PCME asbestos fibres (or asbestos fibres of any size) were detected during the TEM analysis of any of these samples. Many of the individual samples had analytical sensitivities of ~0.0002 f/ml and a limit of detection of ~ 0.0006 f/ml.

Taken as a group, the further sampling had an overall analytical sensitivity of 0.000016 f/ml and a limit of detection of <0.000048 f/ml, some ten times lower than the average previously found in UK asbestos containing buildings. Taking into account the earlier combined sample, the calculated pooled value for the asbestos concentration in occupied remediated schools was <0.000014 f/ml with a limit of detection of <0.000068 f/ml based on a 95% Poisson distribution.

Non-asbestos PCME fibre concentrations gave an average concentration of 0.0024 f/ml.

Asbestos concentrations released into rooms and ceiling voids from striking columns before and after remediation.

The extent of "peak" airborne release from columns in good condition was investigated further at two unoccupied school sites. The column casings were deliberately struck hard five times with a fist, or the attached doors slammed 5 times, at the start of the sampling period. Short-term peak samples over some 30 – 60 minutes were collected and analysed by PCM and as necessary by TEM as well.

Three unsealed columns in reasonable condition were tested at the school where the original high levels were found. They gave average fibre concentration of ~0.008 f/ml for both PCM and TEM fibre counts in the nearby air. The samples taken at the same time in the ceiling void adjacent to the open top of the column, gave a slightly higher average PCM fibre concentration of 0.011 f/ml. This increase in the ceiling void average was due one sample (in the staff room ceiling void) giving around a three times higher value. These results showed that although there was release from the open tops of the columns into the ceiling void, it was similar to what was monitored close to the column in the classroom. This is an important result, as the top of the column was unsealed and the asbestos material in the column was attached to the column casing and was particularly friable.

At a second school TEM airborne asbestos concentrations in air; before and during/after testing non-remediated columns in reasonable to good condition were compared. Only a very limited release of airborne asbestos fibres (at or below the limit of detection) was found.

These results support HSE's published advice that visual inspection of the column casings in the room is a good initial guide for assessing whether fibres release into the room can take place and sealing any visible gaps will minimise releases from mechanical impacts.

Releases from simulated maintenace work activities

It is often the case in buildings containing asbestos, that peak releases occur when maintenance workers disturb the ACMs. A number of maintenance type activities were carried out involving various amounts of disturbance at two school sites.

In general, the airborne fibre concentration during activities such as removing the non-asbestos tiles to inspect the ceiling void and cable pulling activities in the ceiling void were low (0.01 f/ml) and would not exceed the control limit.

Peak disturbance activities involving sweeping areas in the ceiling void gave increased PCM fibre concentrations over short 10 minute sampling period but did not exceed the maximum level of 0.6 f/ml, at the site tested.

However, caution is necessary as it is not unusual for asbestos debris to be left in areas around the tops of the columns (e.g. off cuts of asbestos insulating board and asbestos cement sheets) from the original installation. Therefore the situation and amount of asbestos debris may vary between buildings and appropriate precautions should be taken by workers entering or disturbing the ceiling void.

Three cleaners monitored by personal sampling at one school had PCM concentrations below the limit of detection <0.015 f/ml.

Recommendations

Inspection of the column casing for gaps and holes, which will reduce the effectiveness of the enclosure around the asbestos, appears to be an effective way of determining the likelihood that a significant peak release will occur, if the column is mechanically disturbed or struck.

Release of airborne asbestos fibres into the room is effectively controlled and minimised if the column casings are sealed at room level and maintained in good condition.

The principles and guidance established for managing asbestos in buildings, if applied, will minimise airborne asbestos exposures and risks to occupants in CLASP buildings.

The occurrence of pieces of asbestos debris above some ceilings (either from the original construction or later disturbances) means that person working in, or accessing the ceiling void, will need to be aware of the potential of encountering ACM debris and should take appropriate precautions to minimise the disturbance and spread of asbestos.

A type 1 or 2 survey as described in MDHS 100, requires that the ceiling void of suspended ceilings are accessed to check for ACMs and asbestos debris, so where surveys have been carried out, the presence of ACM debris should have been found and noted.

1 INTRODUCTION

In late July 2006, after asbestos contractors had carried out asbestos removal work at a school, the on-site laboratory failed to obtain levels of asbestos fibre in air below 'clearance levels' when, as part of deliberate disturbance, the metal casing around the steel support columns were struck a number of times with the fist or other similar disturbance took place (sitting on and flexing the windowsills). The measured fibre concentrations inside the enclosure suggested a significant release of airborne fibres could take place from some columns. This information was reported to HSE in mid-September and an assessment of the cause, the extent of the release and the effectiveness of remediation were undertaken by HSE with substantial support and co-operation from some local education authorities and HSL. Initial advice was released to schools by HSE before the half-term holiday and a working group was set up by HSE to further assess the problem and to produce further advice from the issues arising.

The initial advice issued to schools was to inspect and seal any visible gaps in columns, as this prevented any direct release to the classroom and substantially reduced measured airborne fibre concentrations, in tests where the columns were struck. HSL was asked by HSE to assess the effectiveness of the proposed remediation, so the working group had an adequate scientific basis to assess the problem and the effectiveness of the remediation. A summary of the available data from schools was produced and presented at the first meeting of the CLASP working group in November 06 and later released in a more comprehensive form as HSL report HSL/2007/07.

Given the limited time available, the first report concentrated on assessing the available data from schools, which was mainly from phase contrast microscopy (PCM) analysis of air sampled through a membrane filter. A magnification of X500 is used to count all >5 µm long fibres with aspect ratio >3:1 and <3 µm width 'regulatory sized fibres' over a representative fraction of the exposed filter area (~1/500 to 1/250th). The PCM method counts all visible fibres meeting the size criteria and does not discriminate between whether they are asbestos or non-asbestos fibres.

A small number of these disturbance samples were analysed by analytical electron microscopy, which showed that the majority of the PCM fibres released during "peak" disturbance were amosite asbestos. The highest airborne fibre concentration found in a school, during the disturbance testing of an intact column casing was 0.44 f/ml on a personal sample. This showed that there was the potential for significant release into the room, should the scale of disturbance and damage to the column casing be reproduced. These releases were monitored in a sealed enclosure with no extraction and with a particularly friable deposit of asbestos attached to the casing rather than the column, giving a high level of vibration and energy input into the ACM. Although it was not known at the time how typical this construction was of other CLASP buildings, it has been subsequently found that a range of constructions were used. It appears that the friability of the material at this school and the fact that it was sometimes attached to the casing rather than the column, occurs relatively infrequently and was likely to be the "worst case" construction. Many other schools had plasterboard and asbestos cement sheet attached to the column, so it was isolated from the casing by an air gap and a few spacers. However, if the column casing was more extensively damaged, partially or fully removed the containment would be further compromised and higher airborne releases would occur.

This first report addressed a number of important questions but relied heavily on PCM data so an upper estimate of the airborne asbestos fibre release was obtained (i.e. assumes all PCM fibres were asbestos). This can be justified for close to source peak emissions such as disturbance/clearance sampling in an enclosure, where the asbestos containing material (ACM) is the main source of potential fibre release. This is unlikely to be the case in occupied buildings and classrooms, where several sources of non-asbestos fibres are present (e.g. fibres from paper, clothes, chalk etc.) Also there is unlikely to be such a direct and violent disturbance of the asbestos material. As the PCM data was based on sample volumes of <500 l and the filters have a background fibre count, the limit of quantification was an order of magnitude above the previously monitored average for the airborne asbestos fibre concentration in buildings containing asbestos materials (~0.0005 f/ml).

It was therefore recommended that future site sampling was carried out using higher volume sampling (~3000 l) and wider use of analytical transmission electron microscopy (TEM) to identify the types of fibres present.

A number of further questions were identified, for example the residual levels above the suspended ceiling, where the open tops of the columns may release fibres that could be re-dispersed during inspection and maintenance activities in the roof space.

This report summarises the further sampling and analysis carried out and discusses the results.

1.1 SAMPLING OBJECTIVES

The objectives of the further sampling were to:

1. To carry out a more sensitive analysis of the airborne asbestos fibre concentration in CLASP 4 and 4A type buildings under conditions of normal occupation.

2. To assess the exposure of maintenance personnel in CLASP type buildings.

3. To further assess the potential for release after remediation.

The ability to realise the sampling objectives were dependent on a number of practical issues and the type of access that could be obtained. Sampling in occupied schools requires various permissions and significant levels of co-operation between the local education authority, school officials, teachers, unions, school maintenance workers, cleaners, parents and pupils. Considerations such as the placing of "noisy" pumps in occupied school classrooms and maintaining the integrity of the sample / equipment are also difficult and time-consuming issues.

As notices and information to schools had already gone out to take remedial measures, the sampling was focussed on post-remedial exposures and the effectiveness of the advice given. However, as the TU representatives on the working group continued to be interested in exposures prior to and during remediation, we did follow up opportunities to sample in occupied buildings before remediation.

2 METHOD

2.1 STRATEGY

The sampling was planned and conducted as expeditiously as possible, by interfacing with local contacts and arrangements, with the sampling often being carried out through a third party, such as an accredited asbestos sampling laboratory. A sampling strategy was distributed (annex 1) and discussed with sampling laboratories and local authorities in order to achieve greater analytical sensitivity for static sampling in occupied buildings and to target particular activities (e.g. annex 2) using conventional accredited sampling, such as:

- Simulation of disturbance and cleaning activities in unoccupied rooms;
- During remediation of the column's vertical seal;
- During remediation of the top of the columns;
- Simulated disturbance of the column at the various stages of remediation;
- Maintenance activities.

Whole or half filters were sent to HSL for possible selection for TEM analysis of the asbestos fibre concentration. Often a half filter was analysed by PCM for the fibre number concentration by the sampling laboratory, prior to sending the remaining half filter to HSL.

2.2 SAMPLING METHODS

Airborne samples are collected by drawing air through a membrane filter to trap particulates. This is done at a calibrated and measured flow rate for a known time so the sampled volume can be calculated. In general, the greater the volume of air that can be sampled the lower the limit of detection (LOD). However, as sampling proceeds many other particulates are collected and once >10% of the filter area is covered with particles, accurate PCM fibre counting becomes increasingly difficult. For PCM clearance sampling (0.01 f/ml) or for assessing the exposure against the control limit (0.1 f/ml since 13/11/06) the air volumes collected on a standard 25-mm diameter membrane filter are a minimum of 480 and 240 litres of air, respectively. To monitor the background fibre concentrations in CLASP buildings, a target sample volume of ~3000 litres, on a standard 25-mm diameter membrane filter was set. As occupied schools tend to be an active environment, which can lead to overloading of the filters with particulates, the colour of the filters was monitored and sampling curtailed if it was thought the filters were becoming overloaded. Using two or more pumps at different flow rates was not used to sample in occupied areas due to the noise issue. The greater resolution of the TEM allows some of the more heavily loaded filters to be analysed.

2.3 ANALYTICAL METHODS

After sampling, sections of the filter are then cut out, chemically treated and mounted for microscopical observation. Often the sampling agency would also carry out light microscope fibre count on a half filter using a contrast enhancing method known as phase contrast microscopy (PCM). The PCM method in annex 1 of HSG248 was used for the analysis of the PCM counts in this report. The method counts all visible fibres, which are >5 µm long, < 3µm width and with an aspect ratio of >3:1 but does not discriminate between fibre types (e.g. asbestos and non-asbestos).

The same fibre size criteria can be used in the TEM analysis to count PCM equivalent fibres (PCME) as defined above, or all fibres >5 um long of any width etc. The fibres seen can be identified by energy dispersive X-ray analysis (EDXA) to determine the chemical composition of individual fibres and / or electron diffraction to measure and determine the crystal and atomic structure of the fibre/mineral.. An International Standard method ISO 10312:95 was used for the analysis with additional improvements to allow better sizing and analysis.

2.4 DATA ASSESEMENT

The capabilities of measurement methods to measure down to the airborne low levels of asbestos present in most buildings during normal use, means that an understanding of the underlying limitations of the measurement statistics and background counts are necessary.

2.4.1 Precision, limit of detection (LOD) and limit of quantification (LOQ)

Fibre counting has poor statistical precision. This means that individual results must be compared carefully to assess whether any differences are actually present. Particles sampled onto a filter at best have 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 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 it is 95% probable that the count is < 3 fibres.

The standard method for defining the limit of detection (LOD) and limit of quantification (LOQ) based on 3 and 10 standard deviations and from analysis of blank counts in the RICE[1] scheme represent a fibre count in 200 fields of view on the PCM of 5.3 and 17.6 fibres, respectively). Although individual analyses may have counts below the LOQ and LOD where many similar samples are available it is possible to get a more precise picture based on pooling the samples together and also looking at the spread of the individual data points. This is the approach taken in this report to assess much of the existing data.

[1] *Regular Interlaboratory Counting Exchanges*

2.4.2 Blank counts

Where relatively few fibres are likely to be sampled, their evaluation is made more difficult if the blank filters, even without being used for sampling, may give small number of PCM fibre counts due to imperfections in their manufacture and /or subsequent contamination. The RICE quality control program has shown that blank membrane filter counts by PCM are low and that on average <1 fibre per 100 fields was counted. This gives an upper 95% confidence limit that <5 fibres will be counted in 100 fields and similarly <6.5 fibres in 200 fields. For a sample volume of 480 litres with 200 fields counted, this corresponds to a calculated result of 0.003 f/ml for the upper 95% confidence limit and it is highly likely that above this level the fibres are from air. The average count of ~2 fibres corresponds to 0.001 f/ml.

It is now rare to find any blank filters that have asbestos fibre contamination so any asbestos fibres found by TEM are assumed to be from the sampled air.

3 RESULTS AND DISCUSSION

3.1 BACKGROUND CONCENTRATIONS IN BUILDINGS WITHOUT REMEDIATION

As HSE had acted swiftly in giving advice for schools to check and seal the column casings in schools, the opportunity to monitor an unremediated occupied school was limited. However, this was possible at one school and one former school.

Two occupied classrooms were sampled over one day in the Autumn term 2006 at the school, which was constructed using a chrysotile containing asbestos cement board as insulation for the columns. The following TEM results were obtained (Table 1) from the higher volumes of air collected. The calculated pooled result was equivalent to the analytical sensitivity of 0.00005 f/ml with a limit of detection of <0.0003 f/ml.

Table 1: TEM results for PCME fibres in an occupied school (no remediation)

HSL No.	Air volume (l)	Analytical sensitivity (f/ml)	Number of fibres found		Fibre concentration (f/ml)	
			Asbestos	Non-asbestos	Asbestos	Non-asb PCME
11908/06	3000	0.0001	0	17	<0.0005	0.0026
11909/06	3000	0.0001	1 chrys	22	<0.0007	0.0030

A Clasp 4 building that was part of a school and is now used as offices, was subject to a period of continuous monitoring over several weeks. No remediation of the columns had been carried out, which contained amosite containing insulating board attached to the columns casings. The sampling strategy was to collect weeklong samples during the day (8 am to 6 pm) to capture normal occupation and cleaning activity. Two samplers were set up one at a flow rate of 3.2 l/minute and one at 1.6 l/minute in two office rooms. Both sampling heads were positioned above radiators where there would be a good convective mixing of room air. One sampler was close to a set of doors, which vibrated the column when opened and closed. Visible gaps were present in the columns around the windows. On the third week of sampling violent gales took place subjecting the building structure to very high wind pressures and vibration – very much a worst-case situation. Even though extended counting was carried out on the samples, only 1 asbestos fibre (amosite) was found in the TEM analyses. The results are summarised in figures 1 & 2. Figure 1 shows that the airborne asbestos fibre concentrations were on average at least 1000 times lower than the control limit. Figure 2 shows that the air concentrations in the building were below the average airborne concentrations (0.0005 f/ml) of regulated asbestos fibres encountered in buildings containing asbestos materials.

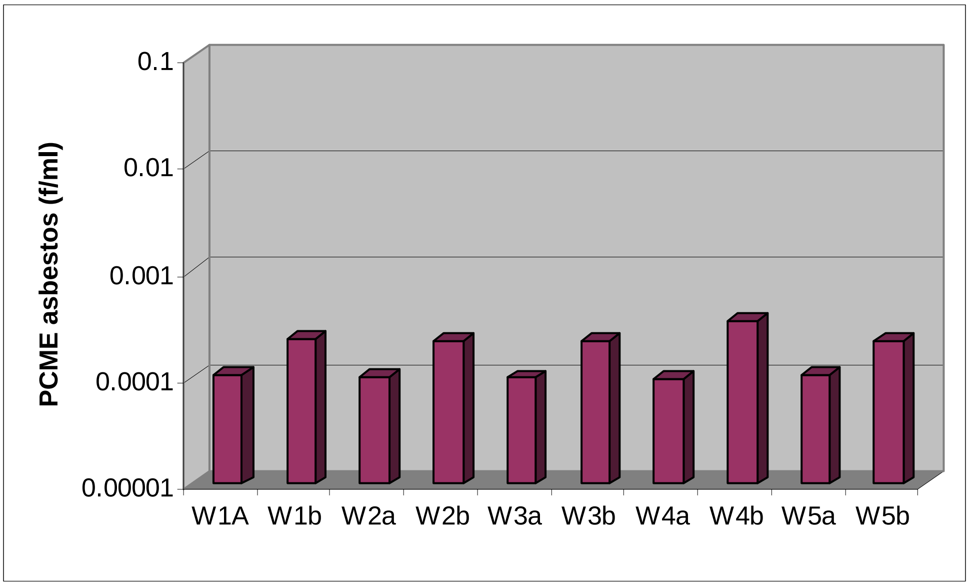

Figure 1:TEM Results of PCME asbestos fibres (1 week average) in an occupied CLASP 4 building, compared to the 0.1f/ml control limit (all values are < the upper 95% confidence limit). A logarithmic scale is used on the Y-axis for fibre concentration to show the three orders of magnitude difference.

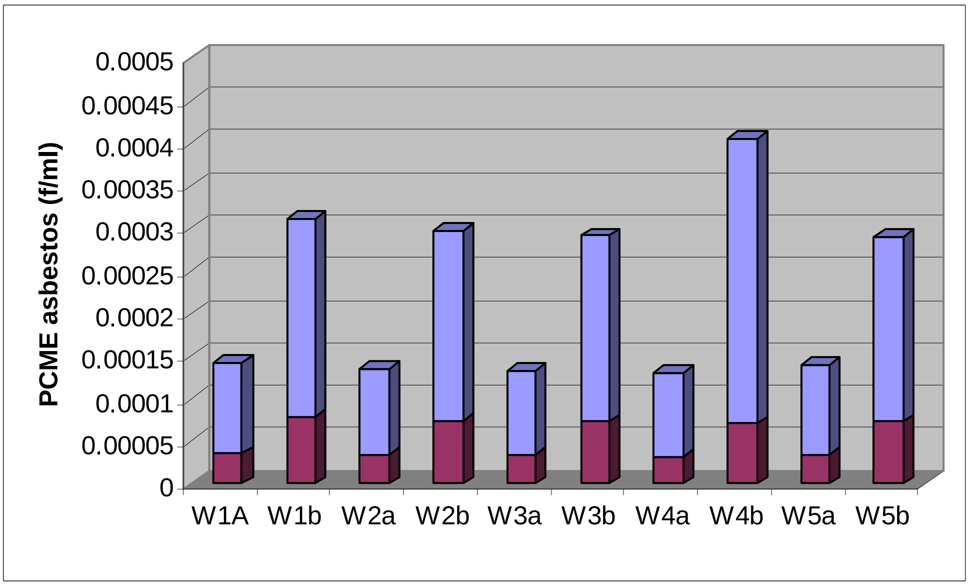

Figure 2: TEM results for PCME asbestos fibres in an occupied CLASP 4 building compared with the previous average found in asbestos containing buildings. Two samples were collected each week, over a 5-week period. The shorter/darker column heights, represents the concentration based on the analytical sensitivity (1 asbestos fibre found) and entire column represents the upper 95% confidence limit. (Note: the (b) samples had lower flow rates and collected ~42% of the air volume collected by the (a) samples, so have poorer analytical sensitivity).

As ~100 grid openings were counted in each sample, the average values for the building can be calculated from the pooled individual samples (see Table 1). This gave a calculated value of PCME asbestos fibres of 0.000005 f/ml and an upper 95% confidence value of <0.000024 f/ml for 7 days monitoring with values of 0.000007 f/ml and <0.000033 f/ml during a 5-day working week. This meant that the upper 95% value for PCME asbestos fibres was an order of magnitude lower than the background average value for asbestos containing buildings (Burdett and Jaffrey, 1986; HEI, 1991).

The average non-asbestos fibre concentrations were calculated as 0.00045 f/ml and 0.00063 f/ml for 7 and 5 days, respectively.

Table 2: Summary of the TEM results of regulatory (PCME) fibre concentrations over five x one-week period of continuous monitoring in a type 4 CLASP building used for offices.

Sample Ref	Air volume (l)	No. of asbestos fibres	Number of non-asbestos fibres	Analytical sensitivity (f/ml)	Asbestos concentration (f/ml)	Non-asbestos concentration (f/ml)
Wk1S1	9776	0	4	0.00004	<0.00011	0.00014
Wk1S2	4526	0	4	0.00008	<0.00024	0.00031
Wk2S3	12048	0	9	0.00003	<0.00011	0.00030
Wk2S4	5568	0	13	0.00007	<0.00023	0.00097
Wk3S5	12253	0	7	0.00003	<0.00010	0.00023
Wk3S6	5586	0	18	0.00007	<0.00022	0.00131
Wk4S7	12547	0	11	0.00005	<0.00016	0.00057
Wk4S8	5768	1	12	0.00009	<0.00044	0.00113
Wk5S9	11606	0	8	0.00004	<0.00011	0.00028
Wk5S10	5378	0	7	0.00007	<0.00022	0.00051

3.2 TEM AIRBORNE ASBESTOS FIBRE CONCENTRATIONS IN OCCUPIED SCHOOLS AFTER REMEDIATION.

In total, 31 individual samples taken in 8 occupied schools that had been fully or partially remediated were analysed by TEM. This includes three sequential samples from school A (see Table 3), which was reported in the previous CLASP report (HSL/2007/22). These were a set of short term samples taken in a partially remediated school corridor between two sets of double swing doors, which were mounted on the columns and were frequently opened and banged shut, causing movement and vibration to the building structure. The pooled result from 3 samples found one PCME amosite fibre. This gave a calculated concentration equivalent to the analytical sensitivity of 0.0001 f/ml and was below the limit of detection (0.0005 f/ml).

Subsequent sampling in schools was aimed at sampling over the whole school day and using higher flow rates, with short-term samples being pooled as above. A further 7 schools were sampled and the results are summarised in Tables 4 – 10 for each school, which have been coded B-H. Schools have been subject to partial remediation unless stated otherwise. In the additional samples taken after remediation and during occupation, no PCME asbestos fibres (or asbestos fibres of any size) were detected during the TEM analysis. Many individual samples had analytical sensitivities of ~0.0002 f/ml and a limit of detection of ~ 0.0006 f/ml.

Taken as a group representing CLASP schools which had under gone remediation (two had complete remediation), an overall analytical sensitivity of 0.000016 f/ml was achieved and the average level in remediated schools was below the limit of detection <0.000048, some ten times lower than the average previously found in UK asbestos containing buildings. Taking into account the earlier combined sample from school A, the calculated value for the asbestos concentration was 0.000014 f/ml with a limit of detection of <0.000068 based on a 95% Poisson distribution.

Non-asbestos PCME fibre concentrations gave an average concentration of 0.0024 f/ml.

The PCM fibre counts (where available) have also been given. These were counted on half filters retained by the sampling laboratories and generally showed higher counts of PCM fibres than recorded by the TEM analysis. The difference is due to the way organic fibres were counted: a PCM analysis will count all fibres meeting the 3:1 aspect ratio criteria but the ISO TEM method only counts fibres with approximately parallel or stepped sides which meet the aspect ratio criteria. Many organic clothing fibres have low contrast and damaged non-parallel edges and paper fibres have a distinct low contrast twisted appearance and were not included in the TEM count of non-asbestos fibres in this sample set, as their appearance was so dissimilar from asbestos fibres. Initial experience (Figure 3) showed that the air samples taken in re-occupied schools contained mostly organic clothing and paper fibres and there was little point in analysing and recording these fibres in the extended TEM analysis for asbestos fibres.

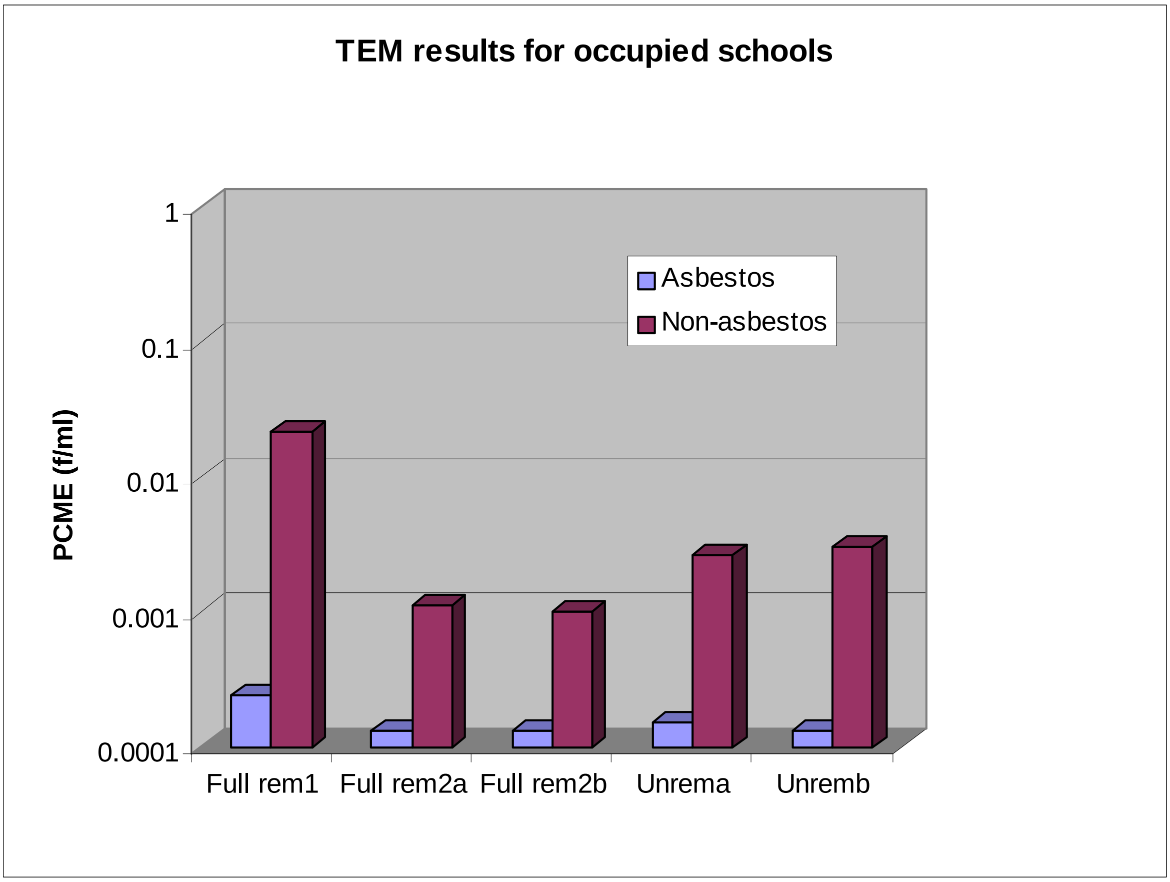

Figure 3: Examples of asbestos and non-asbestos fibre concentrations in individual TEM samples (Note: all asbestos values are given as the calculated limit of detection, no asbestos fibres were found).

Table 3: TEM results for PCME fibres and original PCM results in occupied school A

HSL No.	Location of samples	Date of sampling	Air volume (l)	Analytical sensitivity (f/ml)	Number of fibres found		Fibre concentration (f/ml)		PCM Fibres counted	Reported PCM results
					Asbestos	Non-asbestos	Asbestos	Non-asb PCME		
09451/06	Corridor	28/11/2006	2416	0.00034	0	6	<0.001	0.0021	8	0.002
09452/06	Corridor	28/11/2006	1304	0.00029	1 amosite	8	<0.0014	0.0024	8.5	0.004
09453/06	Corridor	28/11/2006	1112	0.00021	0	5	<0.0007	0.0011	5	0.003
09454/06	Corridor 3-combined	28/11/2006	4832	0.000107	1 amosite	19	<0.00052	0.0020	21.5	0.003

Table 4: TEM results for PCME fibres and original PCM results in occupied school B (Full remediation) LC (30 min samples @16 l/min)

HSL No.	Location of samples	Date of sampling	Air volume (l)	Analytical sensitivity (f/ml)	Number of fibres found		Fibre concentration (f/ml)		PCM Fibres counted	Reported results
					Asbestos	Non-asbestos	Asbestos	Non-asb PCME		
11929/06	B3 cloakroom	19/12/06	480	0.0013	0	21	<0.0040	0.0280	-	-
11930/06	B3 classroom	19/12/06	480	0.0010	0	27	<0.0031	0.0272	-	-
11931/06	B3 cloakroom	19/12/06	480	0.0009	0	16	<0.0027	0.0140	-	-
11932/06	B3 classroom	19/12/06	480	0.0008	0	24	<0.0026	0.0202	-	-
Combined	All areas		1920	0.00024	0	88	0.0007	0.0211	-	-

Table 5: TEM results for PCME fibres and original PCM results in occupied school C (Full remediation) PP

HSL No.	Location of samples	Date of sampling	Air volume (l)	Analytical sensitivity (f/ml)	Number of fibres found		Fibre concentration (f/ml)		PCM Fibres counted	Reported results
					Asbestos	Non-asbestos	Asbestos	Non-asb PCME		
11933/06	Classroom	15/12/06?	3000	0.00013	0	8	<0.0004	0.0011	-	-
11934/06	Classroom	15/12/06	3000	0.00013	0	3	<0.0004	<0.001	-	-

Table 6: TEM results for PCME fibres and original PCM results in occupied school DSS

HSL No.	Location of samples	Date of sampling	Air volume (l)	Analytical sensitivity (f/ml)	Number of fibres found		Fibre concentration (f/ml)		PCM Fibres counted	Reported results
					Asbestos	Non-asbestos	Asbestos	Non-asb PCME		
01522/07	By fire exit	16/02/07	480	8.48E-04	0	4	<0.0025	0.0034	3	<0.010
01523/07	Above ceiling	16/02/07	480	8.57E-04	0	4	<0.0026	0.0034	12	<0.010
01524/07	On work top	16/02/07	480	8.40E-04	0	3	<0.0025	<0.0065	5	<0.010

Table 7: TEM results for PCME fibres and original PCM results in occupied school E

HSL No.	Location of samples	Date of sampling	Air volume (l)	Analytical sensitivity (f/ml)	Number of fibres found		Fibre concentration (f/ml)		PCM Fibres counted	Reported results
					Asbestos	Non-asbestos	Asbestos	Non-asb PCME		
00764/07	Hall 1	18/01/07	1560	2.61E-04	0	2	<0.0008	<0.0018	2	0.0003
00765/07	Teaching 42	18/01/07	1560	2.66E-04	0	5	<0.0008	0.0013	11.5	0.002
00766/07	Hall 1	26/01/07	1560	2.66E-04	0	0	<0.0008	<0.0008	7	0.001
00767/07	Corridor 16	26/01/07	1560	2.61E-04	0	0	<0.0008	0.0008	6	0.001

Table 8: TEM results for PCME fibres and original PCM results in occupied school F

HSL No.	Location of samples	Date of sampling	Air volume (l)	Analytical sensitivity (f/ml)	Number of fibres found		Fibre concentration (f/ml)		PCM Fibres counted	Reported results
					Asbestos	Non-asbestos	Asbestos	Non-asb PCME		
01703/07	Hall	07/03/07	1920	2.16E-04	0	2	<0.0006	<0.0014	?	?
01704/07	Classroom	07/03/07	1920	2.16E-04	0	0	<0.0006	<0.0006	?	?

Table 9: TEM results for PCME fibres and original PCM results in occupied school G

HSL No.	Location of samples	Date of sampling	Air volume (l)	Analytical sensitivity (f/ml)	Number of fibres found		Fibre concentration (f/ml)		PCM Fibres counted	Reported results
					Asbestos	Non-asbestos	Asbestos	Non-asb PCME		
11906/06	Classroom	07/12/06	2520	1.63E-04	0	10	<0.0005	0.0016	29.5	0.003
11907/06	Classroom	15/12/06	2520	1.65E-04	0	5	<0.0005	0.0008	22.5	0.002
00760/07	Year 3 Class,	08/01/07	1680	2.47E-04	0	1	<0.0008	<0.0012	8.5	0.0025
00761/07	FL classroom (R)	16/01/07	2790	1.46E-04	0	1	<0.0005	<0.0007	5	0.0009
00762/07	FL classroom	23/01/07	2640	1.54E-04	0	3	<0.0005	<0.0012	18.5	0.0035
00763/07	FL classroom	01/02/07	2820	1.47E-04	0	7	<0.0005	0.0010	27	0.0048
01521/07	Year 3 class	15/02/07	2880	1.44E-04	0	0	<0.0004	<0.0004	3	0.0005
01525/07	Year 3 class	22/02/07	2760	1.45E-04	0	5	<0.0004	0.0007	14.5	0.0026
02024/07	Classroom	02/03/07	2202	1.83E-04	0	0	<0.0006	<0.0006	2.5	0.0006
02025/07	Year 3 class	16/03/07	2160	1.92E-04	0	1	<0.0006	<0.0010	42	0.0097
02026/07	Year 3 class	22/03/07	2880	1.44E-04	0	0	<0.0005	<0.0005	31	0.0054

Table 10: TEM results for PCME fibres and original PCM results in occupied school H 07-0229

HSL No.	Location of samples	Date of sampling	Air volume (l)	Analytical sensitivity (f/ml)	Number of fibres found		Fibre concentration (f/ml)		PCM Fibres counted	Reported results
					Asbestos	Non-asbestos	Asbestos	Non-asb PCME		
01701/07	0/007 CIRC	06/03/07	1920	2.16E-04	0	0	<0.0006	<0.0006	-	-
01702/07	0/027 CIRC	06/03/07	1920	2.06E-04	0	4	<0.0006	0.0008	-	-

3.3 ASBESTOS CONCENTRATIONS RELEASED FROM STRIKING COLUMNS BEFORE AND AFTER REMEDIATION.

Previous PCM data with very limited use of TEM analysis had shown that a damaged, poorly sealed column casing can release asbestos fibres into the classroom, when repeatedly struck. However, it was apparent that the columns tested had usually been chosen specifically for testing because they were the most damaged. This was a source of obvious bias and testing of columns more representative of the typical condition was undertaken. This would give a better estimate of the release and the effectiveness of the remediation.

Therefore suitable unoccupied area in schools were sought for further testing and sampling of airborne releases of fibres from columns when they were subject to impact (usually heavy striking with the fist 4-5 times). For these tests PCM analysis with a limited amount of TEM analysis was carried out, to check whether the fibre emissions occurring were due to asbestos fibres.

3.3.1 Tests at the original school where problems were found

One of the less damaged columns at the school, where the problem first came to light, was sampled both during and after partial remediation. The column had an amosite containing AIB attached to the casing, which would be mechanically disturbed by the impacts. The before and after remediation results are given in Table 11.

Table 11: PCM results before and after remediation of a column in reasonable condition (minor gaps).

Room number and sample position	Lab sample no.	Fibre concentration* PCM (f/ml)
Class 43 adjacent undamaged column during and following striking of the column.	07551/06	0.07
Class 43 teachers position (corridor end) during and following striking of the column.	07552/06	0.03
Fixed point sample while sealing up column in room 43.partial remediation	09461/06	0.006*
Fixed point sample, during and following the striking of column after partial remediation	09469/06	0.010*
* PCM count as calculated on number of fibres seen, rather than <20 fibres		

The TEM analysis of sample 09469/06 found 1 PCME amosite fibre, equivalent to an analytical sensitivity of 0.0016 f/ml and a limit of detection of <0.008 f/ml. There were however, some 12 PCME non-asbestos fibres found, giving a concentration of 0.019 f/ml. Therefore the amount of airborne asbestos release was lower than indicated by the PCM result and was well below the clearance limit, even when subjected to an intense disturbance.

At a later visit, further disturbance of columns were carried out in several areas, where there appeared to be a different construction and a sprayed material had been applied. Again "before" and "after" remediation samples were collected. Sampling times were usually just over 1 hour with the disturbance taking place at the beginning of the sampling period. Due to time constraints, only a limited time period 1.5 – 2 hours for remediation and the start of the re-sampling was allowed. Samplers were placed both in the classroom adjacent to the column (Table 12) and in the ceiling void adjacent to the top of the column (Table 13).

Table 12: Results from static samplers in classrooms adjacent to the column during disturbance: Before and after remediation.

Sample position	Lab sample no.	PCM fibre conc.* (f/ml)	TEM asbestos fibre conc. (f/ml)	TEM non-asbestos fibre conc. (f/ml)
Static samples adjacent to column before remediation.				
Corridor outside HM office	01993/07	0.005	Not done	
Staff room adjacent to windows	01994/07	0.007	0.009	0.003
Room opposite HM office	01995/07	0.012	0.007	0.017
Static samples adjacent to column after remediation.				
Corridor outside HM office	02003/07	0.008	0.007	0.008
Staff room adjacent to windows (16:19 – 17:22)	02004/07	0.025	0.044	0.010
Staff room adjacent to windows (16:50-17:25)	02004/07	0.031		
Room opposite HM office	02005/07	0.006	0.005	0.011

Table 13: Results from static samplers in the ceiling void adjacent to the column during disturbance: Before and after remediation.

Sample position	Lab sample no.	PCM fibre conc.* (f/ml)	TEM asbestos fibre conc. (f/ml)	TEM non-asbestos fibre conc. (f/ml)
Ceiling void before remediation.				
HM office	01997/07	0.005		
Room opposite HM office	01996/07	0.007		
Staff room adjacent to windows	01998/07	0.022		
Ceiling void after remediation.				
HM office	02007/07	0.013		
Room opposite HM office	02006/07	0.024		
Staff room adjacent to windows	02002/07	0.347	0.229	0.016

The results in Table 12 showed that the three unsealed columns when mechanically disturbed, gave low releases of asbestos fibres into the classroom, with an average fibre concentration of ~0.008 f/ml for both PCM and TEM fibre counts. The samples taken at the same time, in the ceiling void adjacent to the open top of the column, gave a slightly higher average PCM fibre concentration of 0.011 f/ml. This was due to the column in the staff room giving an approximate factor of three increase in the concentration above the ceiling void. The average result indicated that there did not seem to be a much greater release into the ceiling void via the open top of the column, compared with releases monitored in the classroom. This is an important result, as the asbestos material in the column was attached to the column casing and was particularly friable.

The columns were fully sealed along the exposed joins and at the tops before retesting. On retesting the room fibre concentration remained essentially unchanged except for the staffroom, which again showed about a factor of 3.5 increase in the PCM result and a factor of 5 in the TEM result. A duplicate sample started later in the period confirmed this PCM result. Samples in the ceiling void all showed an increased PCM concentration (factor of 2-3) but the staffroom sample was much higher at 0.347 f/ml. This was also found to give a concentration of PCME asbestos fibres (mainly amosite but some chrysotile) of 0.229 f/ml by TEM.

Given the short time between remediation and the start of the second test, the results after remediation will almost certainly contain a component of fibres released during the remediation and may be partly responsible for some increase but the staff room sample appears to have been biased by some additional disturbance activities between 16:33 and 16:43 that took place in another area of the staff room (see paragraph below). Therefore the sampling after remediation has been biased high due to the limited time allowed after the remedial activity for the fibres disturbed to settle out or dissipate.

A separate area of the ceiling void in the large staffroom was also subject to brushing to measure the maximum levels of asbestos that could be generate by maintenance activities. The dust raised appears to have spread out in the ceiling void and increased the air concentrations measured at the sampling position by the windows. The data after remediation is therefore not directly comparable to the before remediation data, and cannot be used to assess how effective the sealing can be in reducing the relatively low fibre emissions released, when no remediation has been carried out.

3.3.2 Disturbance tests at other schools

A suitable area for testing became available in part of another school (School A) prior to refurbishment. Several columns were tested for fibre release. One of the columns had some damage / disturbance because a fire extinguisher had been attached to it. The releases from banging individual columns and from banging the door adjacent to other columns are given in Table 14. The sampling times were up to 60 minutes. This limited the volume of air sampled and the analytical sensitivity but gave a peak measurement. These short-term disturbance samples are compared to the control limit (0.1 f/ml over 4 hours) and the clearance indicator (0.01 f/ml usually collected over 30 – 60 minutes after disturbance) in Figure 4. Only a few fibres were found and all samples were at or below the limit of detection.

This data further confirms that releases from the CLASP columns occurs when there is visible damage and only partially sealed cladding / enclosures are present and active disturbance it taking place.

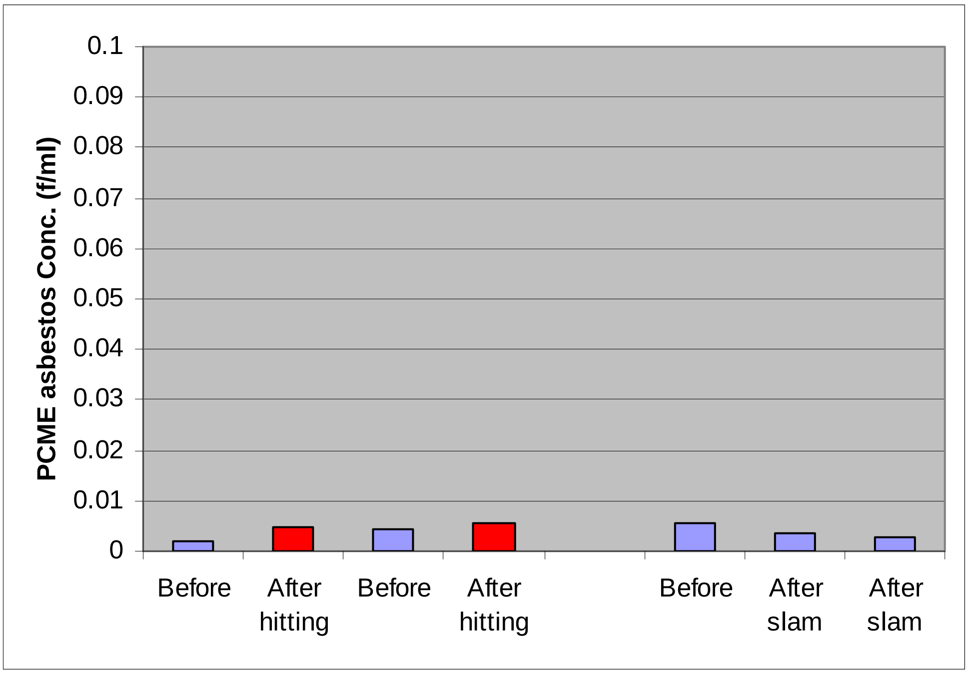

Figure 4: TEM PCME asbestos fibre concentrations in air before and after striking columns in reasonably good condition and slamming doors mounted on the column. All air concentrations given in terms of the calculated limit of detection (i.e. 95% confidence that concentrations are below this value). Red column indicates asbestos fibres detected.

Table 14: TEM results of asbestos fibre concentrations in the adjacent room area from disturbance sampling of unremediated CLASP columns in reasonable - good condition.

Sample position	Lab sample no.	PCM fibre conc.* (f/ml)	TEM asbestos fibre conc. (f/ml)	TEM non-asbestos fibre conc. (f/ml)
Striking cladding of column 1 in an unoccupied kitchen				
Before disturbance	00266/07	0.001	<0.0018	0.0079
During and after disturbance	00267/07	0.002	<0.0046 (2 asbestos)	<0.0021
Striking cladding of column 2 in an unoccupied kitchen				
Before disturbance	00268/07	0.002	<0.0044	<0.0044
During and after disturbance	00269/07	0.003	0.0054 (3 asbestos)	<0.0033
Slamming door 5 times (kitchen)				
Before disturbance	00271/07	0.001	<0.0057	<0.0057
During and after disturbance	00272/07	0.002	<0.0034	<0.0054

Slamming door 5 times (storeroom)				
Before disturbance	00271/07	0.001	<0.0057	<0.0057
During and after disturbance	00273/07	0.008	<0.0029	0.0087

The disturbance testing of unremediated columns that were judged to be in reasonable to good condition (with no obvious gaps or holes in the casing), showed that they released relatively low levels of asbestos fibres into the adjacent areas of the room, as the PCME asbestos fibre concentration did not exceed the clearance indicator (0.01 f/ml).

This supports the HSE advice that visual inspection of the condition of the column at room level is a good initial guide for assessing whether fibres can be released into the room due to mechanical impacts against the column casing.

As the tops of the columns are open, the more likely pathway for fibres to become airborne is from the open top of the column into the ceiling void. In many situations the ceiling void is separated from the occupied area by a false / suspended ceiling which would limit the amount of fibres reaching the room below. With sampling times of 30-60 minutes it may be expected that any substantial releases by this route would have influenced the room samples. However, direct sampling in the ceiling voids with PCM analysis showed that this potential release route did not appear to give rise to substantial fibre emissions and were unlikely to exceed concentrations above 0.01 f/ml in the normally occupied room areas.

3.4 RELEASES FROM SIMULATED MAINTENACE WORK ACTIVITIES

It is often the case in buildings containing asbestos, that peak releases occur when maintenance workers disturb the ACMs. A number of maintenance type activities were carried out involving various amounts of disturbance.

3.4.1 Inspection of ceiling voids and disturbing cables

Simulated inspection was carried out at two unoccupied school areas, which had been scheduled for asbestos removal. Ceiling tiles were removed adjacent to columns to gain access to the ceiling void. The tiles were handled with limited care and tilted so any dust dislodged went towards the operative. In some cases the cables in the roof were moved around and disturbed to create further airborne dust, while the operative remained in the ceiling void. The room areas treated in this way had been fully enclosed to contain the extent of any releases and had little of no air movement (air extraction was switched off) unless stated otherwise The result from personal samples and static samples in the room below during the disturbance are summarised in Table 15.

Table 15: Results from simulated maintenance activity (inspection and cable disturbance).

Sample position	Lab sample no.	PCM fibre conc.* (f/ml)	TEM asbestos fibre conc. (f/ml)	TEM non-asbestos fibre conc. (f/ml)
Ceiling void inspection 14 tiles lifted in staff room.				
Personal 11	02000/07	0.012		
Personal 12	02001/07	0.022		
In ceiling void of staff room shaking and moving cables				
	01999/07	0.023		
During both inspection and cable disturbance.				
Static in classroom by window	01991/07	0.007		
Static beneath disturbed area	01992/07	0.002	<0.001	0.002
Lifting tiles in kitchen area and disturbing cables (different school) Note: air extraction on				
Personal 9	00274/07	0.011	<0.012	<0.018
Personal 10	00275/07	0.029	<0.018	<0.026

The results in Table 15 showed that at these two sites, which contained friable ACMs in the columns, there was either not a large spread or there was only limited re-suspension of settled asbestos fibres. The concentrations obtained, suggest that asbestos PCME fibre concentrations at these two sites are around 0.01 f/ml, but caution is necessary as it is not unusual for asbestos debris to be left in areas around the tops of the columns (e.g. off cuts of asbestos insulating board and asbestos cement sheets) from the original installation. Therefore the situation and amount of asbestos debris may vary and appropriate precautions (e.g. respiratory protection, disposable overalls, mini-enclosures) should be taken by workers disturbing areas in the ceiling void.

3.4.2 Heavy disturbance in ceiling voids

A much greater level of disturbance (worst case) was imparted by using a hand brush to sweep all the reachable surfaces in the ceiling void from a small entrance (3-4 tiles removed). The test was carried out at two areas in the same school which had different conditions / histories. The staff room void has one or two visible pieces of asbestos debris, which was not brushed but had little accumulated dust and clearly the suspended ceiling was relatively new (2-6 years old) and had little settled dust. The tops of the ceiling tiles were brushed and may have released some fibres from the friable surface of the tile. The lobby area had much more accumulated dust and it was almost certain that an accumulation of dust built up since the ceiling was originally installed was being disturbed. As the ceiling tiles were made from asbestos insulating board, the brushing was confined to wooden beams, cables and ducts rather than the surface of the ceiling tiles.

The PCM counts in Table 16 show that fibre concentration during heavy disturbance gave peak 10 minute PCM fibre concentrations of ~ 0.1 – 0.2 f/ml. This is lower the allowed peak level of 0.6 f/ml allowed over 10 minutes by the approved code of Practice (L143) for CAR, 2006.

Table 16: Results from heavy disturbance activity (sweeping with a brush) inside the ceiling void of a Clasp building.

Sample position	Lab sample no.	PCM fibre conc.* (f/ml)	TEM asbestos fibre conc. (f/ml)	TEM non-asbestos fibre conc. (f/ml)
Brushing in ceiling void of staff room (5 minutes brushing) 10 minutes sampling				
Personal	02008/07	0.18	Not done	Not done
Brushing in ceiling void of lobby (1.5 minutes brushing) 10 minutes sampling				
Personal	02010/07	0.08	Not done	Not done

3.4.3 Cleaning classrooms

At school (A), which had been partially remediated, the cleaners were monitored using personal sampling while they carried out their normal cleaning activities in the classrooms (83- 91 minutes sampling time and ~ 250 l samples). The PCM results are summarised in Table 17 and Figure 5) and clearly the fibre levels are below the control limit and were below the calculated limit of detection (<0.015 f/ml) for personal samples.

Table 17: PCM results from personal; sampling of cleaners in a Clasp building.

Sample position	Lab sample no.	PCM fibre conc.* (f/ml)	TEM asbestos fibre conc. (f/ml)	TEM non-asbestos fibre conc. (f/ml)
Brushing in ceiling void of staff room (5 minutes brushing) 10 minutes sampling				
Personal 1	09458/06	0.003	Not done	Not done
Personal 2	09459/06	0.014	Not done	Not done
Personal 3	09460/06	0.011	Not done	Not done

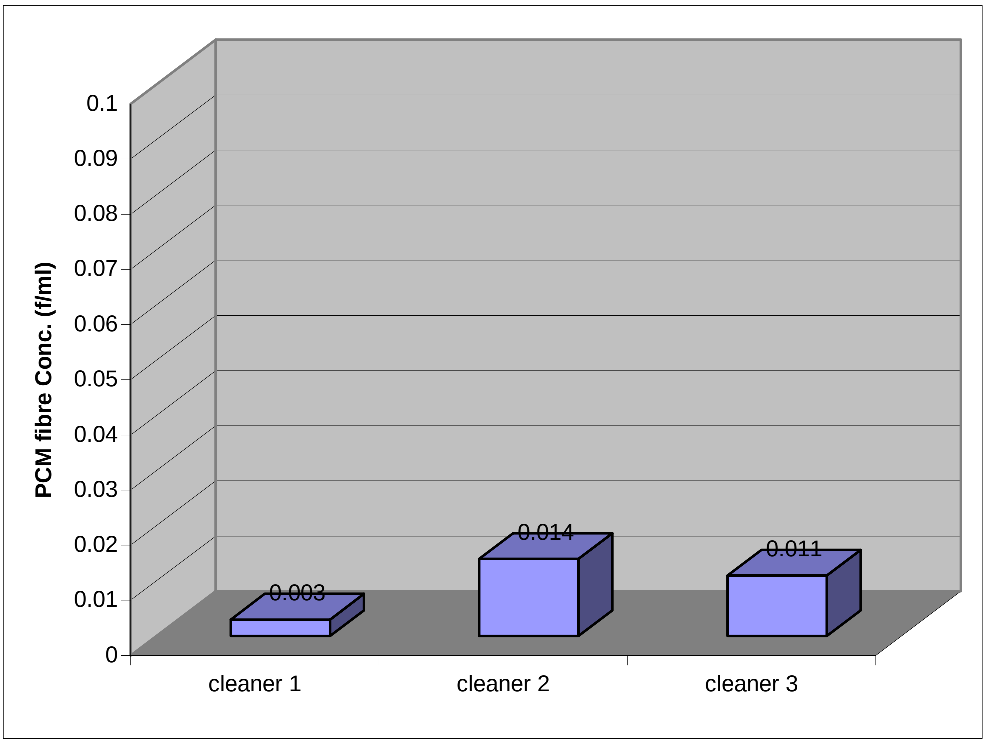

Figure 5: PCM Fibre concentration for cleaners in school C, compared with the 0.1 f/ml control limit.

3.5 ASBESTOS MANAGEMENT

A type 1 or 2 survey as described in MDHS 100, requires that the ceiling void of suspended ceilings are accessed to check for ACMs and asbestos debris. Therefore if a building survey has been carried out in accordance with HSE guidance the presence of asbestos debris from the installation or subsequent alterations should have been detected and located. If for some reason the surveyor did not access the suspended ceiling, as they should have done, the area should still have been marked as presumed to contain asbestos and work in the ceiling void should be subject to the restriction and controls in CAR, 2006, unless further assessment has been carried out by a competent person.

4 CONCLUSIONS

This second report on asbestos in CLASP buildings was focussed on the following three objectives:

- Carry out a more sensitive analysis of the airborne asbestos fibre concentration in buildings under conditions of normal occupation.
- Assess the potential exposure of maintenance personnel in CLASP type buildings.
- To further assess the potential for release after remediation.

The first objective was met by the use of higher flow rate pumps and/or increased sampling time to give an increased amount of air sampled and an improved analytical sensitivity. TEM was used to count fibres that met the size criteria for counting by phase contrast microscopy (PCM) and to identify that they were asbestos and which type. The PCM equivalent (PCME) asbestos fibres are the established index for making an assessment of the risk.

Increased sampling times were used where possible to give a better estimate of the average airborne concentration over time and sampling periods of 1 –7 working days were used. The TEM analysis was also extended and instead of counting 20 grid openings (~1000 fields of view) per sample this was increased to 100 grid openings (~5,000 fields of view) for many samples.

These longer sampling times and extended TEM counts are time consuming and costly and hence every effort was made to work with local sampling agencies and local education authorities to carry out the sampling, with HSL personnel going on site only for more specific simulation activities.

Buildings where repeated samples, were taken gave a profile of the fibre concentration and allowed a greater analytical sensitivity to be reached by pooling the samples.

4.1 AIRBORNE FIBRE CONCENTRATIONS IN UNREMEDIATED BUILDINGS DURING NORMAL OCCUPATION.

In an unremediated Clasp 4 building containing amosite asbestos insulating board (AIB) five weeks of continuous sampling was conducted in two locations where the doors were vibrating columns. The calculated pooled value of PCME asbestos fibres was 0.000007 f/ml which had an upper 95% confidence value (limit of detection) of <0.000046 f/ml., based on a single amosite fibre being detected. This meant that the upper 95% value for PCME asbestos fibres was an order of magnitude lower than the background average value for asbestos containing materials (ACMs) in buildings (Burdett and Jaffrey, 1986; HEI, 1991). The average non-asbestos fibre concentration was calculated as 0.00068 f/ml.

It was notable that very high winds that occurred in the third week of sampling did not lead to any detectable increase in airborne asbestos concentrations.

When an unremediated school containing asbestos cement board in the columns, was sampled over 1 day a single chrysotile fibre was detected. The calculated pooled result was equivalent to the analytical sensitivity of 0.00005 f/ml with a limit of detection of <0.0003 f/ml. Again this was below the previously monitored average for asbestos containing buildings.

4.2 AIRBORNE ASBESTOS CONCENTRATIONS IN OCCUPIED REMEDIATED BUILDINGS

TEM results for over 30 individual samples taken in 8 occupied schools, that had been fully or partially remediated, were reported. Some sequential lower volume short-term samples were pooled together to better represent the buildings environment. In a previous report, the pooled TEM result from 3 samples, found one PCME amosite fibre, which gave a calculated concentration equivalent to the analytical sensitivity of 0.0009 f/ml and was below the limit of detection (0.0004 f/ml).

Subsequent sampling in schools was aimed at sampling over the whole school day and using higher flow rates, with short-term samples being pooled as above. A further 7 schools were sampled and the results are summarised in Tables 4 – 10 for each school, which have been coded B-H (school A was reported in HSL/2007/22). The schools have been subject to partial remediation unless stated otherwise. In the additional samples taken after remediation and during occupation, **no PCME asbestos fibres (or asbestos fibres of any size) were detected during the TEM analysis**. Many individual samples had analytical sensitivities of ~0.0002 f/ml and a limit of detection of ~ 0.0006 f/ml.

Taken as a group representing CLASP schools, which had under gone remediation (two full remediations), an overall analytical sensitivity of 0.000016 f/ml was achieved and the average level in remediated schools was below the limit of detection <0.000048 f/ml, an order of magnitude lower than the average previously found in UK asbestos containing buildings. Taking into account the earlier combined sample from school A, the calculated value for the asbestos concentration is 0.000014 f/ml with a limit of detection of <0.000068 based on a 95% Poisson distribution.

Non-asbestos PCME fibre concentrations gave an average concentration of 0.0024 f/ml.

4.3 ASBESTOS CONCENTRATIONS RELEASED INTO ROOMS AND CEILING VOIDS FROM STRIKING COLUMNS BEFORE AND AFTER REMEDIATION.

The extent of the airborne release from columns in good condition was investigated further as two unoccupied school sites. The column casings were deliberately struck hard five times with a fist or the attached doors slammed 5 times at the start of the sampling period. Short-term peak samples over some 30 –60 minutes were collected and analysed by PCM and as necessary by TEM as well.

Three unsealed columns in reasonable condition at the school where the original high levels were tested. They gave average fibre concentrations of ~0.008 f/ml for both PCM and TEM fibre counts in the nearby air. The samples taken at the same time in the ceiling void adjacent to the open top of the column gave a slightly higher average PCM fibre concentration of 0.011

f/ml. This was due to the column in the staffroom giving an approximate factor of 3 increase in the concentration above the ceiling void. These results indicate that there did not seem to be a much greater release into the ceiling void via the open top of the column compared with releases monitored in the classroom. This is an important result as the top of the column was unsealed and the asbestos material in the column was attached to the column casing and of a particularly friable type.

At a second school TEM airborne asbestos concentrations in air before and during/after testing unremediated columns in reasonable to good condition were compared. Only a very limited release (at or below the limit of detection) was found.

These results supports the HSE advice that visual inspection of the condition of the column casing at room level is a good initial guide for assessing whether fibres can be released into the room due to mechanical impacts against the casing.

4.4 RELEASES FROM SIMULATED MAINTENACE WORK ACTIVITIES

It is often the case in buildings containing asbestos, that peak releases occur when maintenance workers disturb the ACMs. A number of maintenance type activities were carried out involving various amounts of disturbance at two school sites.

In general, activities such as removing the non-asbestos tiles to inspect the ceiling void and cable-pulling activities in the ceiling void were low and did not exceed the control limit and were around 0.01 f/ml.

Peak disturbance activities involving sweeping areas in the ceiling void gave increased PCM fibre concentrations over 10 minute sampling period but did not exceed the maximum level of 0.6 f/ml, at the site tested.

However, caution is necessary as it is not unusual for asbestos debris to be left in areas around the tops of the columns (e.g. off cuts of asbestos insulating board and asbestos cement sheets) from the original installation. Therefore the situation and amount of asbestos debris may vary between buildings and appropriate precautions should be taken by workers disturbing areas in the ceiling void.

4.5 RELEASES DURING CLEANING BUILDINGS

Three cleaners monitored by personal sampling at one school had PCM concentrations below the limit of detection <0.015 f/ml.

5 REFERENCES

Burdett-GJ; Jaffrey-SAMT (1986) Airborne asbestos concentrations in buildings, Annals of Occupational Hygiene.30, 2, 185-199.

HSL/2007/22 Burdett G. Summary of fibre concentrations In CLASP construction schools containing asbestos. HSL/2007/22 **http://www.hse.gov.uk/research/hsl_pdf/2007/hsl0722.pdf**.

CAR, Control of asbestos regulations, SI 2006/2739 The Stationary Office, ISBN 0 11 075191 4, 2006.

Health Effects Institute (HEI) - Asbestos Research, "Asbestos in public and commercial buildings: A literature review and synthesis of current knowledge." 1991.

HSG248: "Asbestos: The analyst's guide for sampling, analysis and clearance procedures"; HSE 01/05; ISBN 0-7176-2875-2, 2005.

ISO 10312: 1995. "Ambient Air - Determination of Asbestos Fibres - Direct Transfer Transmission Electron Microscopy Procedure". International Standards Organisation. Geneva. 1995.

6 ANNEXES

6.1 SAMPLING STRATEGY FOR INCREASING THE ANALYTICAL SENSITIVITY OF AIR MONITORING IN SCHOOLS AND FOR TEM ANALYSIS

6.1.1 Static sampling objectives:

- To sample a target loading of 3000 l of air on a 25 mm 0.8 µm pore size mixed ester of cellulose membrane filter.
- To collect a back up filter of ~ 1000 l of air (or lower if very dusty).
- To sample under normal conditions of occupancy over the duration of the pupils school day.

6.1.2 Introduction:

Most asbestos test laboratories that carry out air sampling are familiar with the use of larger static pumps for sampling at between 8 – 16 l/minute for clearance air sampling inside enclosures, after the asbestos removal has been completed. These are normally run only long enough to collect a total of 480 l of air to meet the minimum criteria laid down in HSG 248. Ideally, if conditions allow (not too dusty) on the standard 25 mm filter it is possible to sample between 1,000 – 3,000 l of air on the filter before it becomes too overloaded with particles for microscopical analysis.

As the amount of airborne dust cannot be gauged in advance and the filter should be inspected by the sampling personnel at regular intervals, as a guide on the amount of particulate sampled. In many circumstances if the exposed filter area turns from light to a more medium grey colour. This is often a good indicator that the particle density is high enough to obscure some 10% of the filter area (the maximum loading permitted) and that sampling should cease. As a cowl sampler is being used a torch will often be helpful to inspect the colour of the filter.

Target volume of air to be sampled is ~3000 l (3 m^3). If overloading is a concern, a second filter can be taken in parallel using a lower flow rate pump to collect about one third of the target volume (1000 l).

The sample and cassette (if disposable) can be sent with the filter still loaded to HSL for TEM analysis.

Due to the higher magnifications and superior resolution, a TEM can often work on samples that would be considered a little too dense for PCM analysis.

6.1.3 Static sampling considerations

The noise from the larger volume pumps can be a significant issue in quiet occupied spaces and either this can be partially suppressed by placing the pump in a cupboard with the filter inlet and filter head outside or running the pump at a slightly reduced flow rate.

If a flow rate of 10 l/min is used the sampling time will be 300 minutes or 5 hours to collect 3000 l. At 8 l/min. it will take 6 hours 15 minutes to collect the same volume (about the entire school day).

The site to be sampled should be an occupied classroom and if required one pump can be placed in each selected classroom.

6.1.4 Analysis

TEM Analysis will be carried out by HSL in accordance with ISO 10312:95. If the filter is cut in half the laboratory collecting the sample may be able to analyse the half filter by PCM in the normal way. The increased volume of air sampled improved the analytical sensitivity.

I anticipate we will be able to examine up to 0.5 mm^2 of filter area in the TEM, or about $1/750^{th}$ of the collected air volume (~ 4 l of air). Based on 1 asbestos fibre seen this would give an analytical sensitivity of 0.00025 f/ml on a 3000 l sample and 0.00075 f/ml on a 1000L sample.

6.1.5 Questions

Contact Garry Burdett at 01298 218000

6.2 PERSONAL SAMPLING OF CLEANING STAFF IN SCHOOLS

6.2.1 Introduction

Cleaning staff will be actively disturbing settled dust and area around the skirting and may be subject to higher airborne exposures due to the amount and types of disturbance. Sampling of this group should be done, as well as static sampling, as we are looking at more of a workplace exposure.

6.2.2 Personal sampling objectives

- To carry out personal sampling of the cleaners who are likely to be actively sweeping or dusting the classrooms.

6.2.3 Personal sampling issues

The cleaners who sweep up and disturb the asbestos dust and debris are potentially at the greatest risk. It is therefore worthwhile placing personal samplers on cleaners and running them for the entire time of their cleaning activities. This will probably give an aggregate sample over a number of rooms and or corridors but the smaller personal sampling pumps will limit the maximum flow rate to 2-4 l/min. It is suggested that the highest flow rate that can be sustained from the personal sampling pump is used, for the period that the cleaner is working. Hopefully this will be ~ 3 hours. As the personal samples are primarily to be used for worker exposure it is expected that some 300 – 1000L may be sampled, depending on the type of personal sampling pump being used and the duration of the shift. If they are sweeping up the dust produced this may also overload the sample and this may need to be checked by examining the filter colour (e.g. stop sampling once the originally white filter starts to appear that it is moving from a light grey to medium grey colour due to the amount of particulates collected.)

6.2.4 Analysis

If the filters are first cut in half, a half filter can be mounted and counted by the sampling laboratory in the normal way. If higher values are found the unmounted half filter can be carefully packaged for sending to HSL for TEM analysis to identify the asbestos fibre concentration.

TEM Analysis will be carried out by HSL in accordance with ISO 10312:95. I anticipate we will be able to examine up to 0.5 mm^2 of filter area in the TEM, or about $1/750^{th}$ of the collected air volume (~ 0.4 – 1.3 l of air). Based on 1 asbestos fibre seen this would give an analytical sensitivity of 0.0025 f/ml on a 300 l sample and 0.00075 f/ml on a 1000L sample.

6.2.5 Precision

The analytical sensitivity is based on 1 fibre and will have poor precision a minimum of 3 asbestos fibres would be required to exceed the limit of detection (i.e. that if recounted in a different area there is a 95% confidence that at least 1 asbestos fibre would be found). It is not hoped that we will find many asbestos fibres so the results will have limited precision, but aggregating a number of results together can be used to give a more precise estimate of the average airborne concentration.

6.2.6 Questions

Contact Garry Burdett at 01298 218000

Published by the Health and Safety Executive 04/08

HSE

Health and Safety Executive

Further measurements of fibre concentrations in CLASP construction buildings

In late July 2006, after asbestos contractors had carried out asbestos removal work at a school, the on-site laboratory failed to obtain levels of asbestos fibre in air below 'clearance levels' when, as part of deliberate disturbance, the metal casing around the steel support columns were struck a number of times with the fist or other similar disturbance took place (sitting on and flexing the windowsills). The measured fibre concentrations inside the enclosure suggested a significant release of airborne fibres could take place from some columns. This information was reported to HSE in mid-September and an assessment of the cause, the extent of the release and the effectiveness of remediation were undertaken by HSE with substantial support and co-operation from some local education authorities and HSL. Initial advice was released to schools by HSE before the half-term holiday and a working group was set up by HSE to further assess the problem and to produce further advice from the issues arising.

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

RR624

www.hse.gov.uk