Exposure of UK Industrial Plumbers to Asbestos, Part I: Monitoring of Exposure Using Personal Passive Samplers

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Received 27 February 2006; in final form 3 November 2006; Published online 21 December 2006

Epidemiological data suggest that there has been and may continue to be a significant risk to maintenance workers, who through their work may disturb asbestos-containing materials (ACM). The sampling and assessment of maintenance workers’ exposure is a particular problem because they may not know that they are working with ACM. A strategy to monitor their true exposure has been developed and applied to one group of workers. The asbestos exposure of industrial plumbers was measured using personal passive samplers developed at the Health and Safety Laboratory (HSL). The light-weight samplers, which collect particles by electrostatic attraction, are simple to use and do not require prior knowledge that asbestos is to be disturbed as does conventional sampling. The samplers were issued by post and analysed, after return, using transmission electron microscopy (TEM). The strategy was found to be a reasonably efficient and cost-effective way to obtain data on maintenance worker’s exposure to asbestos. The results of the TEM analysis of the passive samplers showed that the percentage of workers exposed to >5 μm long asbestos fibres was 62% in Round 1 and 58% in Round 2. For phase contrast microscopy equivalent (PCME) asbestos fibres, the values were 46 and 29%, respectively. The three samples with the highest numbers of fibres were followed up and were associated with plumbers working in areas which had supposedly been stripped of asbestos just prior to their starting work, suggesting that poor removal, clean-up and clearance practice presents a significant part of the risk to plumbers. Although flow rates will vary with conditions and time, an approximate average sampling rate from previous comparisons was used to calculate the concentration. This gave an average exposure to regulated PCME fibres of 0.009 fib/ml for amphibole asbestos and 0.049 fib/ml for chrysotile. The calculate risk based on the PCME fibre types collected and their estimated concentrations, showed that the risk from airborne amphibole fibres was ~6 times greater than from chrysotile fibres. If representative, the estimated lifetime risk of death from an asbestos related cancer for an exposure from age 20 for 40 years would be 68 per 100 000, which equates to an annual risk of death of the order of 10 per million.

Keywords: Asbestos; exposure; maintenance worker; passive sampler; risk

INTRODUCTION

There are a number of quantitative epidemiological studies, which have shown clear evidence of increased rates of diseases (e.g. asbestosis, lung cancer and mesothelioma) for workers who produced crude asbestos, or manufactured ACMs (Hodgson and Durnion, 2000). A cohort of US laggers and insulators studied by Selikoff et al. (1979), showed that the disease rates in workers who installed asbestos products was higher than those exposed in manufacturing, suggesting that either dustier conditions prevailed and/or less controls were applied. Various other industries where asbestos has been widely used for insulation have also shown significant numbers of mesotheliomas, or some other evidence of clinical effects, such as increased incidence of pleural plaques among school custodians (Oliver, 1991). Increased morbidity and/or mortality rates attributed to asbestos exposure have been reported for oil refinery workers (Gennaro et al., 1994; Finkelstein, 1996; Tsai et al., 1996a,b), chemical industry workers (Lilis et al., 1980), railway workers (Battista G et al., 1999), marine maintenance engineers (Jones et al., 1984; Selikoff et al., 1990), workers in the electrical generation...
industry (Hilt et al., 1995, Crosignani et al., 1995) and building maintenance workers (Anderson et al., 1991). There is also evidence from UK death certificates that construction workers who installed and maintained the ACMs were exposed to an increased risk (Peto et al., 1995). With the predicted continued rise of UK mesothelioma rates and its high rate of incidence (24% of the total) in construction related trades (Peto et al., 1995, 1999; Hodgson et al., 1997) there is concern for this group of workers. Data suggest that there is a significant risk to plumbers, gas fitters, carpenters, electricians, ventilation engineers, cleaners and other types of workers who maintain buildings and may through their work disturb ACMs (Matrat et al., 2004; McElvenny et al., 2005). Plumbers are one of the highest risk cohorts of workers with a proportional mortality ratio of 4.57, based on 1978–1995 mesothelioma figures. This put them in the third position i.e. behind the traditional crocidolite asbestos using industries of metal plate workers in shipbuilding and vehicle body builders (railways).

These data have in recent years, made maintenance workers a focus for Health and Safety Executive’s (HSE’s) asbestos awareness campaigns and legislation. This culminated in the introduction of a new duty to manage asbestos (Regulation 4) in the Control of Asbestos at Work Regulations (HSE, 2002), which came into effect in May 2004. The new duty requires management of the asbestos in non-domestic premises to prevent uncontrolled disturbances of ACM and releases of fibres to maintenance and nearby persons. Before the new duty came into force in 2004, an initial baseline study of exposure was planned and carried out.

Previous work by the Health and Safety Laboratory (HSL) to monitor maintenance workers using conventional pump and membrane filter sampling found that although the levels were generally below the control limits, the data represented best practice over a few hours. It was considered that a bias was introduced due to the need to know that asbestos was present and to arrange site sampling visits in advance. This meant that appropriate precautions were taken and best practice was likely to be on show. However, many maintenance workers may unknowingly disturb asbestos without taking precautions and be subject to higher exposures more frequently. To measure these unknown exposures, a passive sampling strategy was developed based on the use of a charged polypropylene electret (Brown et al., 1994).

**AIMS AND STRATEGY**

The aim of this study was to measure the asbestos exposure of one group of maintenance workers (industrial plumbers) using a passive sampling method.

The strategy was to recruit a target group of 100 industrial plumbers through the Institute of Plumbers. This group would be issued by post with a passive sampler, a set of instructions and a work activity log to monitor a working week. The samplers returned would be analysed for asbestos using analytical transmission electron microscopy (TEM). A second round of sampling for a further week was planned for those who returned the sampler.

**METHOD**

*Passive sampler*

The initial design and development of the HSL passive dust sampler has been described by Brown et al. (1994, 1996) and has been used previously in a number of studies to measure the mass of the particles or analyte collected (Brown et al., 1995). The collection medium is a single 25 mm diameter polypropylene electret, which is charged to around +1000 V, by scanning several times under a wire held at this potential. The electret must be placed in a conductive holder to create an external field and a stainless steel surround or cage that also protects it from damage or interference. A 40-mm diameter circular metal plate is placed about 1 cm in front of the electret in preference to the mesh between the two plates (Brown et al., 1994), to give a more even field over the whole electret. This plate also prevents direct impaction onto the electret by large particles. The passive sampler when worn on the upper torso is essentially two vertical parallel discs separated by 1 cm, between which (due to the characteristic flow of air currents and the bodies convective heating) respirable sized particles will move. The collection of particles depends on their electrical mobility (and polarity) assuming a minimum velocity through the sampler is achieved during use.

To overcome a number of limitations for asbestos worker surveys (including ease of use and cost), the initial HSL passive sampler developed by Brown et al. (1994, 1996) was redesigned in conductive plastic. This meant that the mesh and the front plate could be simply snapped into position on the backing plate. The actual dimensions of the holder were kept the same as before but an extra 25-mm diameter depression was made in the inside of the front plate to take an additional polypropylene electret. A slot was made near the top of the back plate to take a standard lapel clip that was used for other personal samplers. To allow the electret to be sealed inside the holder, a separate cap was designed to snap over the front plate and prevent any air circulation until removed. All the previous holder design deficiencies were addressed to produce a low cost easy to use light-weight disposable holder (Figs 1 and 2).
The sampling rate of the passive sampler will always be variable as it depends on the collection efficiency and flow rate of the sampler as well as the polarity and charge of the individual airborne particles, all of which may vary. To overcome the problem of only collecting negatively charged particles a second electret with a negative charge was placed in the front plate of the holder. This had the effect of increasing the field strength while allowing both positively and negatively charged particles to be collected. This would increase the collection efficiency, once the particles have entered the sampler but would not change the flow rate past the electrets. In practice the flow rate depends on environmental factors and the boundary layer convective flow close to the body. The performance of the initial design of the HSL passive sampler was assessed under laboratory conditions and compared to conventional pump sampling by Burdett and Revell (1998). The laboratory calibrated sampling rate of 22.5 ml/min was used for the estimation of the sampled volume and to calculate concentrations.

As dust deposit on the polypropylene electret is uneven, an indirect method of sample preparation was used to re-suspend the particles in water and filter onto 0.2 μm pore size polycarbonate filter. This indirect method also allowed the particle density of the filtered deposit to be adjusted to give an optimum sample for analysis.

The electrets and the holder were subjected to rigorous cleaning procedures. This involved repeated washing and ultrasonic treatment in a solution of ultra-pure water and detergent but ultimately this was unsuccessful in removing the background of organic polypropylene fibres, which were washed off and collected back onto the filter. During TEM analysis these appeared as very faint fibres but were easy to differentiate. The cleaned electrets were then dried in a closed cabinet over silica gel before being placed in the circular slots in the back plates ready for charging.

The polypropylene electrets were charged by passing under a corona discharge wire set at ~6 kV (just below breakdown) with a 2 kV charge on a bias grid ~1 cm above the electrets. The voltage was set to positive or negative by reversing the polarity of the voltage supplies. The electrets on the back plate were positively charged and the electrets on the front plate were negatively charged. As the front plate and mesh inlet of the holder was too large to pass under the corona charging system, all the negatively charged electrets were charged on a separate back plate and then transferred onto the front plate.

The samplers were then labelled with a unique number and left for several days covered by the airtight yellow caps, to allow the charge to stabilise. The retained voltage was measured with a charge sensor. The charges measured immediately after charging (~1000 V) were higher than the stabilised value (~800 V). As the front plate contained the moulded mesh this meant the electret was 1 cm further from the sensor and gave a lower voltage reading, ~600 V. The voltages were recorded against the sample number and after measurement the samplers recapped.

Survey design

Four-hundred of the eight-hundred plumbers registered with the UK Institute of Plumbers (with the exception of Northern-Ireland based companies) were sent a letter, outlining the survey and requesting their participation. Those who replied and indicated their willingness to participate formed the survey sample. About 1 month later, every respondent was sent a passive sampler along with an instruction sheet, a time and activity log and a further questionnaire (to be filled in by the worker using the sampler). They...
were also made aware that a second following up sampling would be carried out a few months later.

The returned samplers were analysed and the results of the TEM analysis were sent to participants, along with a new passive sampler, (including the instructions and activity log). The recipients were asked to wear the sampler during 5 working days (1 week). To begin sampling, they were asked to clip the sampler to a lapel or collar with the back plate against the clothing and to remove the yellow cap. To stop sampling, they were asked to replace the cap at the end of each day. The times when the cap was removed and replaced each day were recorded on the activity log sheet. The sampler was then capped, sealed in a polythene bag and returned with any paperwork for analysis. Further description of the method and design can be found in Burdett and Bard (2003).

**TEM analysis**

On return, the sampler was inspected to check that it was intact and the remaining charge on the electrets measured. The dust captured by each electret was recovered, re-filtered on a polycarbonate filter and prepared for analysis by transmission electron microscopy (TEM). The original method devised at the start of the work (and applied to all samples) was designed to give a high sensitivity of detection for asbestos, as low levels were expected. Both electrets were removed from the sampler and placed in a clean glass bottle with ultra-pure water and a small amount of surfactant to aid the removal and dispersion of the particles and fibres from the electrets. The bottle was capped and shaken by hand for 40 s before the solution underwent 1 min re-suspension in an ultrasonic bath.

The electron microscopy (EM) grids have ~0.0098 \( \text{mm}^2 \) grid openings and 50 grid openings or 50 fibres (on a minimum of two EM grids) were examined at 11 500 magnification in a Philips CM12 TEM. The counting, sizing and identification of fibres was carried out in accordance with the International Standards Organisation (ISO) methods for asbestos in ambient air (ISO 10374-1999). Each structure (fibre) >5 \( \mu \)m long and with an aspect ratio of >3:1 was sized, analysed and classified using a combination of electron diffraction and/or energy dispersive X-ray analysis (EDXA). The type of each asbestos fibre identified and its elemental weight percentage from quantitative analysis was noted along with the types of inorganic non-asbestos fibres present in the sample. The organic fibres present as a background on the electrets were not counted. Fibres were classified into the following groups: asbestos fibres >5 \( \mu \)m long, non-asbestos fibres >5 \( \mu \)m long, asbestos phase contrast microscopy equivalent (PCME) fibres and non-asbestos PCME fibres. PCME fibres are defined as particles which are >5 \( \mu \)m long and with an aspect ratio of >3:1 with widths between 0.2 and 3 \( \mu \)m. Each type of asbestos identified was also recorded and used to further refine the results.

To separate the two categories, the ‘>5 \( \mu \)m long fibres’ are reported in terms of structures per millilitre (s ml\(^{-1}\)) and PCME fibres are reported in terms of fibres per millilitre (f ml\(^{-1}\)), the latter being the unit used for regulatory counts by the European Reference Method (see HSE 1995, MDHS 39/4). The ISO 10374-1999 method requires that counts of <3 fibres, are reported as less than the calculated limit of quantification based on the upper 95% confidence interval (CI) from a one sided Poisson distribution. However, while both acknowledging and highlighting that low counts of fibres have very poor precision, in order to obtain an accurate estimate of a sample populations exposure, it is important to use the actual fibre counts for calculating the airborne fibre concentrations.

**RESULTS**

In Round 1 of the survey, a total of 96 passive samplers were sent to plumbers who had indicated they were willing to participate in the survey, and some 50 samplers (52%) were returned to HSL and analysed for their asbestos content. The contacts who returned a sampler in the first round were also sent a second sampler to wear and 24 (48%) of the second round samplers were returned and analysed. All respondents restricted the sampling period to a single working week.

The difference in charge on the electrets before despatch of the samplers and on their return is an important indicator on the amount of charged particles sampled and whether they were still able to efficiently sample at the end of the period of use. The average charge prior to dispatch in the first round of the survey was +950 V on the back plate electret and -687 V on the front plate electret. The average charge for the second round was +1128 V on the back plate electret and -589 V on the front plate electret. There were small differences in the charged electrets between the two rounds. One reason for the small difference might be due to the replacement of a failed high voltage power supply on the charging rig at the beginning of the second round. As Round 2 electrets had the higher charge, this would have given higher collection efficiency.

For the first round after sampling, the returned back plate electret and front plate electret had an average remaining charge of +175 V and -112 V respectively. For the second round, after sampling, the returned back plate electret and front plate electret had an average remaining charge of +162 V and -101 V respectively. This indicated that the electrets were still collecting particles at the end of the sampling period albeit at a reduced rate.
Each day, for a week, the plumbers who wore the sampler recorded the times it was worn with the cap removed and from this information, the total sampling times and volumes were calculated. In Round 1, the average time the sampler was exposed, was 2644 min (44 h) with the maximum time of 3450 min and the minimum time of 1775 min, a range of approximately ±30%. The corresponding sample volumes were calculated to be an average of 59.7 l with a range of 40.1–77.9 l. In Round 2, the average time the sampler was exposed, was 2582 min (43 h) with the maximum being 3435 min and the minimum 1775 min, a range of approximately ±33%. The corresponding sample volumes were calculated to be an average of 58.3 l with a range of 39.6–77.6 l. The duration the samplers were used was very similar for both rounds.

**Results from Round 1 for >5 \( \mu m \) long structures and PCME fibres**

A total of 873 >5 \( \mu m \) long asbestos structures were found, of which 96.7% were identified as chrysotile and 3.3% were identified as one of the regulated types of amphibole asbestos (see Table 1). Approximately 99 (11.3%) of the >5 \( \mu m \) long structures had widths between 0.2 and 3.0 \( \mu m \) and were classified as PCME asbestos fibres. Of the PCME fibres 75% were chrysotile and 25% were amphibole asbestos fibres. The higher percentage of amphibole PCME fibres, reflected the observation that most of the amphibole fibres were amosite asbestos, which tends to have a much greater proportion of PCME sized fibres than chrysotile.

The frequency that the different types of asbestos were detected on each sample is summarised in Table 1. Thirty-one (62%) of the analyses found >5 \( \mu m \) long asbestos structures, of which 30 (60%) contained chrysotile asbestos and 6 (12%) contained amphibole asbestos with 5 (10%) containing both chrysotile and amphibole asbestos. Twenty-three (46%) of the analyses detected PCME asbestos fibres, of which 21 (42%) were found to contain chrysotile asbestos, 6 (12%) were found to contain amphibole asbestos with 4 (8%) containing both chrysotile and amphibole asbestos.

The calculated average concentration for >5 \( \mu m \) long asbestos structures of 1.84 s/ml (see Table 1) was heavily influenced by a few samples that contained many fine chrysotile fibres. The corresponding average value for the concentration of PCME asbestos fibres was 0.08 f ml\(^{-1}\). A more detailed breakdown by fibre type is given in Table 2.

The average value for the non-asbestos fibres was 0.16 f ml\(^{-1}\) for both PCME and >5 \( \mu m \) long fibres, showing that there were no long thin fibres. The electrrets also had a background of organic wispy structures, which were excluded from the TEM count.

**Results from Round 2 for >5 \( \mu m \) long structures and PCME fibres**

For round 2 (see Tables 1 and 2), the total number of >5 \( \mu m \) long asbestos structures found was 61, of which 93% were chrysotile and 7% were amphibole asbestos (mainly amosite). Ten (15%) of the >5 \( \mu m \) long fibres had widths between 0.2 to 3.0 \( \mu m \) and were classified as PCME asbestos fibres. Six (60%) of the PCME fibres were chrysotile and four (40%) were amphibole asbestos fibres.

Fourteen (58%) of the 24 analyses found at least one >5 \( \mu m \) long asbestos structure, all of which, (58%) contained chrysotile asbestos with 4 (17%) containing both chrysotile and amphibole asbestos. None of the samplers only had >5 \( \mu m \) long amphibole structures.

Seven (29%) of the samplers contained PCME asbestos fibres, 4 (17%) contained chrysotile and 4 (17%) contained amosite with one sampler containing both. The values for the non-asbestos fibres were the same for both rounds (0.14 s ml\(^{-1}\)).

The asbestos concentrations in round 2 were much lower than found in round 1, with an average of 0.07 s/ml for the >5 \( \mu m \) long structures and

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<tr>
<th>Table 1. Summary of results for &gt;5 ( \mu m ) long structures and PCME asbestos fibres</th>
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<td><strong>Round 1</strong></td>
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<td>Fibre number and (%)</td>
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<td>Sample number and (%)</td>
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<td>Calculated asbestos concentration</td>
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<td><strong>Round 2</strong></td>
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<td>Calculated asbestos concentration</td>
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<td>Calculated non-asbestos concentration</td>
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Note: All concentrations are estimates based on previous comparison of passive samplers to pumped samplers in laboratory tests.
0.01 f/ml for the PCME fibres; a further breakdown by fibre type is given in Table 3.

Figures 3 and 4 give the distribution of the calculated asbestos concentrations from round 1 and round 2 for asbestos PCME fibres and for >5 μm long asbestos structures. Figure 5 gives the distribution of the calculated asbestos concentrations from Rounds 1 and 2 combined, for >5 μm long amphibole and chrysotile structures.

**DISCUSSION**

The average concentrations need careful interpretation and should also be put in context. For round 1, the average value for the analytical sensitivity of PCME fibres was 0.03 f/ml so the measured average for PCME asbestos fibres was only about three times the analytical sensitivity. Also, for round 1, no PCME asbestos fibres were found in some 55% of the samples. One sample contained many chrysotile fibres, which had a large effect on the average.

A total of eight unused electrets were analysed, five before round 1, which gave results of below the limit of detection. Three further blank electrets contained a single <5 μm long chrysotile fibril. Three funnel blanks were analysed, which contained either zero or 1 short chrysotile fibre. These analyses suggest that the occurrence of any PCME and >5 μm long asbestos structures in a sample was significant.

In any survey there is a potential for sample tampering and in an unsupervised postal survey, it is a possibility that must be considered, especially if outliers occur. Sample tampering can often be inferred by the presence of fibre clumps and large fibre bundles in the sample but this becomes much more difficult to detect when an indirect method of sample preparation is used, as in this survey. This means that the arithmetic average value, which is used for epidemiological risk assessments, is particularly vulnerable to outliers and hence sample tampering and it is a matter of judgment whether to include these values. The best judgement at present is that the outlier did not show any obvious signs of large fibre clumps and bundles and the value found, while high is not implausible if asbestos insulation was unknowingly being disturbed without precautions over a number of hours. Therefore, the average value in Round 1 was calculated using all the data collected. The average value for >5 μm long asbestos structure of 1.84 s ml⁻¹, applies to fibres which do not have a regulatory limit. The numbers of >5 μm long asbestos structure counted were substantially increased by the indirect sample preparation method, which will tend to split off loosely attached fibres from any asbestos fibre clumps and bundles. The average value for PCME fibres, in round 1, was 0.08 f ml⁻¹.

There was a clear difference in the amounts of asbestos sampled during the two rounds. There was a good possibility, that by re-sampling the same group in Round 2 of the survey, a bias was introduced as the first round results were reported back to the plumbers when the second sampler was issued and some relevant leaflets for working with asbestos were sent to those with significant amounts of >5 μm fibres on their first sampler. There is little doubt that this had the potential to influence behaviour. Also, it must be noted that, during this period, the new duty to manage asbestos in non-domestic premises was passed into legislation (although not into force) and the resultant publicity campaign may also have had an impact.
However, in such a small sample, the differences could just as well be due to whether there was or was not ACM present to be disturbed. Clearly, a few high results in Round 1 had a large influence on the averages and demonstrated that the frequency with which asbestos is knowingly or unknowingly disturbed is the key determinant of the exposures to plumbers and other maintenance workers.

The calculated average concentrations from the two rounds (see Table 2) show that regulatory PCME fibre concentrations were on average some 7.3 times as high in round 1 as in round 2. Most of this increase was due to chrysotile fibres, whose concentrations were 11.5 times as high while the amphibole fibres were only 2.8 times as high. For the >5 μm long asbestos structures, the amphibole concentration showed a similar low increase (x 2.5) but the average chrysotile concentration had increased by about 30 times. The ability of fine chrysotile fibres to separate from fibre bundles (due to the effects suspension in water and ultrasonic treatment) will be a large influence on the number and
concentration of the >5 μm long asbestos structures. The difference between the two rounds was particularly influenced by three samples with high loadings of chrysotile in round 1. If these three samples were removed, the average difference between Rounds 1 and 2 for amphiboles and chrysotile would be relatively close (between 2.7 and 4.2 times as high) (Table 2). This underlines the impact of a few higher results on the average, when dealing with a limited sample. Interestingly, the reasons for the three high results were followed up with the plumbers and it was found that the plumbers were working in an area which had supposedly being stripped of asbestos prior to their starting work and suggests that poor removal, clean-up and clearance practices are also a risk to plumbers.

Comparison with historical data

The two largest reviews of the historical exposure data for maintenance workers were carried out by CONSAD and the Health Effects Institute (HEI), but Paik et al. (1983) also gave an important summary of maintenance worker exposures in the early 1980s, and reported geometric mean phase contrast microscopy (PCM) personal fibre concentrations of 0.13 f ml\(^{-1}\) for carpenters, 0.13 f ml\(^{-1}\) for electricians, 0.03 f ml\(^{-1}\) for painters and 0.19 f ml\(^{-1}\) for sheet metal workers involved in renovation activities. Studies by CONSAD (1985) used the maintenance/renovation worker data collected previously to estimate exposure levels for US maintenance workers. It was estimated that some 130 000–740 000 US maintenance workers had average exposures of between 0.11 f ml\(^{-1}\) for repairing plumbing and 0.75 f ml\(^{-1}\) for repairing dry walling, assuming no respiratory protection was worn. Individual 8 h time weighted averages reported by CONSAD (1990) gave values of 0.01–2.8 f ml\(^{-1}\) for routine maintenance work in commercial and residential properties when asbestos materials were being disturbed.

A literature review by HEI (1991) updated the available database and provided a detailed analysis of a large unpublished database supplied to HEI by Hygenetics Ltd (HEI, 1992) and gave levels from an operations and maintenance programme at a US hospital where each task involving disturbance of asbestos was monitored for the duration of the disturbance, (93% <4 h) (Shaikh et al., 1994). Most of the work involved the disturbance of, or work close to, sprayed fireproofing on I beams or thermal pipe insulation using various control methods. A mean personal exposure of 0.11 f ml\(^{-1}\) l with a range of 0.004–0.84 f ml\(^{-1}\) was found for the 107 tasks monitored by the 203 personal samples.

Estimation of risk

An analysis of UK death certificates by Peto and Hodgson (1995) highlighted that 24% of the deaths from mesothelioma were found in maintenance worker occupations. Analysis of industrially exposed cohorts of miners and manufacturing workers by Hodgson and Darnton (2000) has allowed more focused estimates of risks to be made based on fibre type. The mesothelioma risk from exposure to asbestos was found to be much greater for amphibole asbestos exposures than for chrysotile, with the
relative risk for amosite 100 times greater and for crocidolite 500 times greater, than for chrysotile. Therefore the type of asbestos fibres to which people are exposed, is often as important as the concentration. The index of exposure is based on regulatory defined PCME fibres, which are thought to contain most of the biological potential and hence risk. Although TEM analysis allows all fibres present to be measured and identified and a subset of longer and thinner fibres may be a better measure of the biological potential. However, use of the PCME subset does not mean that these fibres are not taken account of, as they will always be present in any asbestos fibre release and would have contributed to the disease rates from previous human epidemiological experience.

A summary of the amphibole fibres found during TEM analysis, in Table 3, shows that no >5 μm long or PCME crocidolite structures were found during the analysis. One PCME tremolite fibre was found in a round 1, which was considered to have the same biological potential as amosite. Therefore for the purpose of risk estimation, all the 29 PCME amphibole fibres counted were classed as having the same risk as amosite.

The average PCME concentration calculated in Rounds 1 and round 2 (using an assumed sampling rate) for amosite and chrysotile was 0.009 and 0.049 f ml⁻¹, which equates to an estimated lifetime risk of 58 per 100 000 and 10.1 per 100 000, respectively, based on 40 years of continuous workplace exposure from the age of 20. Assuming a life expectancy of >80 years, this would equate to an estimate annual risk of death from an asbestos related cancer (mesothelioma and lung cancer) of the order of 10 per million. A risk of this level to workers is significant but would be regarded as ‘tolerable’ in published HSE guidance (HSE, 2001). It is important to stress the concentration and risk estimates are based on an assumed sampling rate, which will vary with conditions and time and many other assumptions about the long term exposures.

One important result of the risk estimates was that the risk to the plumbers in this survey was some 6 times greater from the amphibole (mainly amosite) asbestos than from chrysotile asbestos.

CONCLUSIONS

The strategy based on the use of the passive sampler in a postal survey has been shown to be a reasonably efficient and cost-effective way to obtain data on maintenance worker’s exposure to asbestos. It can measure (i) frequency of exposure; (ii) type of asbestos and relative amounts; and (iii) the estimated average level of exposure.

As the monitoring strategy does not require prior knowledge that ACMs are present or being disturbed, it can give important information on the effectiveness of current management systems and control measures, for asbestos in buildings. It also allows populations at-risk to be monitored during routine activities and the effectiveness of regulations to be assessed.

Further development of the passive sampler was successfully carried out as part of this work. First, the design and manufacture of an injection moulded three piece lightweight plastic holder has increased the availability and ease of use of the sampler and significantly reduced the unit cost for future surveys. Second, the introduction of both a positive and negative electret into the sampler has increased the collection efficiency and sensitivity of the sampler. Further field calibration of the redesigned passive sampler with the conventional pump-membrane filter method should be carried out to validate the average sampling rate and give increased confidence to any estimates of concentration.

The overall sampling efficiency and sensitivity of the sampler is primarily a function of the flow rate through the sampler and the efficiency which particles are collected once they enter the sampler. To an extent both of these are variable and any calculations of concentration are best estimates based on an assumed average flow rate (from previous calibrations) over the period the sampler was in use (as recorded by the worker on the sampling log). The results of the TEM analysis of the passive samplers showed that the percentage of workers exposed to >5 μm asbestos structures was 62% in Round 1 and 58% in Round 2, for PCME asbestos fibres the values were 46% and 29% respectively.

Chrysotile fibres were by far the most common asbestos type encountered in the TEM analysis with amosite the next most common asbestos type. No crocidolite fibres were found. The type of asbestos to which workers are exposed to has important implications for their risk.

The asbestos types present in the samples showed that the risk from amphibole asbestos fibres (mainly amosite) was about 6 times higher than from chrysotile. Using the estimated average concentration of asbestos fibres from the survey and combining with the worst case exposure to workers (40 years continuous exposure from age 20) gave a lifetime risk of death from an asbestos related cancer of 68 per 100 000.

Acknowledgement—The authors want to thank the Institute of Plumbers for their help and the many plumbers who took part in the survey.

REFERENCES


