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Asbestos monitoring

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ASBESTOS is considered by most authorities to be one of the major occupational health and safety problems in the world today. Although asbestos is no longer used in newly constructed buildings, most old buildings contain large quantities of asbestos. The first problem a building owner faces today is to determine if a potential hazard exists; in other words, whether there are asbestos-containing materials within the building. This involves bulk sample analysis by polarized light microscopy (PLM) on insulation and other building materials from all likely sources. Based on these results, decisions can be made regarding sealing of the asbestos source to prevent contamination of the building air or removal of the asbestos. If the choice is removal, that operation must be carried out with great care to avoid hazard to the workers and surrounding population and to make certain that once removal is completed, the building is "clean." Again, air filter samples and the monitoring of those filters for the presence of asbestos are required at this stage. "Aggressive" air sampling will yield filter samples that can be confidently evaluated by phase contrast microscopy (PCM).

Methods exist for the identification and quantitation of asbestos in both bulk and air samples. Staining methods, x-ray diffraction, infrared absorption, and differential thermal analysis have all been used for asbestos identification, but these nonmicroscopical methods usually require orders of magnitude larger samples than microscopical methods — micrograms versus nanograms. This may not be a problem for bulk samples, but it would be difficult for air filter samples. Thus it seems likely that most analytical chemists would agree that one of the microscopes (polarizing, scanning, or transmission electron) would be the method of choice. There are strong advocates in each of these camps and it is very difficult, especially for a building owner or removal contractor, to evaluate the claims made by each.

Personnel at McCrone Associates in Chicago and Atlanta and at McCrone Research Associates in London over the past 15–20 years have analyzed several hundred thousand samples of insulation. *Figures 1–5* show typical asbestos samples. Most of

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Figure 1 *Chrysotile fibers in bulk insulation observed dry with the stereobinocular microscope at about 30×.*

Figure 2 *Amosite fibers as in Figure 1.*

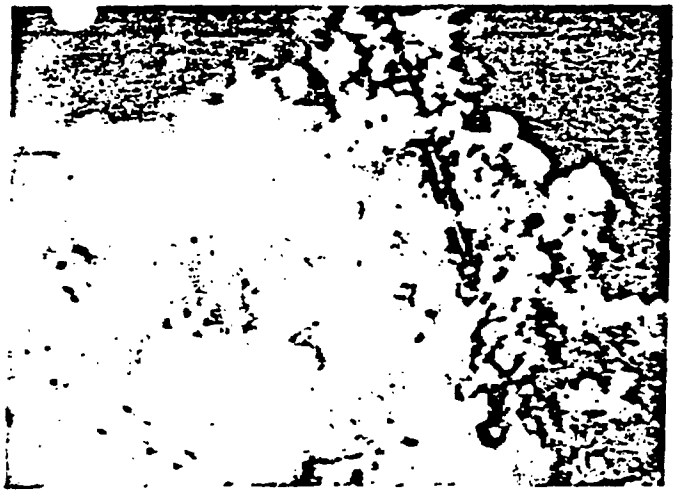

Figure 3 *Crocidolite fibers as in Figure 1.*

Figure 4 *Mineral wool fibers as in Figure 1.*

these were bulk insulation samples, though thousands of water and air samples were also analyzed. We have no question concerning the analytical method for the water samples since nearly all of the fibers in these samples are too tiny to be seen by light microscopy. The identification and quantitation of these fine fibers can only be done by transmission electron microscopy (TEM). Only that technique can routinely identify and quantitate the percentage of the different asbestos fibers in most water samples. Even the TEM, however, needs the capability for elemental analysis in order to differentiate between the various amphiboles on a routine basis. This capability is only available on analytical TEMs costing several hundred thousand dollars. On the best routine basis the cost of an analysis by TEM will be high, several hundred dollars per sample. However, since neither the light microscope nor the scanning electron microscope (SEM) has sufficient resolution to do the job, TEM is mandated for water samples.

The several hundred thousand bulk insulation samples analyzed in our laboratories have been done almost entirely by PLM. The only exceptions to this are when clients specify confirmation by a second method, and we tend in those cases to use x-ray diffraction. The identification of the individual types of asbestos in bulk insulation as well as the identification of all other fibrous components of those materials is rapid and certain by PLM, particularly when dispersion staining is used. Although we have in our laboratories several scanning electron microscopes, several transmission electron microscopes, and a number of microprobes for elemental analysis, we have elected to analyze many air samples also by PLM. The nature of the sample site determines whether we use PLM or TEM. The fibrils of asbestos are distinctive in shape and size and can be differentiated by a trained light microscopist from glass fibers, mineral wool, paper fibers, and other synthetic fibers often present in air samples. If there is any question it is a simple matter for the trained microscopist to select individual fibers from the filter and determine their identity by PLM. Any properly taken air sample in an appropriate area will show at least a few fibers large enough to be easily selected and identified. We would not, however, attempt to analyze ambient air samples for asbestos by PLM.

We acknowledge that the filter will hold many fibers too small to detect by light microscopy unless we go to ultramicroscopy or darkfield illumination. This latter technique, which, incidentally, requires little time, would detect individual fibrils as fine as any standard SEM could show, in other words, as small as about 250 Å (0.025 μm) in diameter. This is, notably, the size of the finest asbestos fibrils. We almost never go to this extreme because available evidence indicates that when such tiny fibrils are present there are reasonably well-accepted values for the percentage of finer fibers which cannot be detected by PLM. It is extremely unlikely that the polarized light microscopist would miss finding asbestos when it is present in a close-to-the-source air sample. It is extremely important however, that the sampling be performed properly and the microscopist be properly trained. The term used to describe the sampling operation is "aggressive"; in other words, the air must be actively agitated in the work area during sampling.

Proper training for the microscopist analyzing asbestos-containing dust includes knowing how to use the light microscope and skill at phase contrast, dispersion staining, and polarized light microscopy. The microscopist must be familiar with the optical crystallography and morphology of all types of asbestos and other fibers, e.g., wollastonite, brucite, fibrous talc, paper, cotton, glass, polyester, polya-

Figure 5 Paper fibers as in Figure 1.

mide, Kevlar, and other man-made fibers. He or she must be able to differentiate between fibrous and nonfibrous amphiboles and serpentines and not be confused by striations on vermiculite, talc, and mica plates. These are just a few examples of the background areas a microscopist should know to do a dependable job on asbestos samples. (Proper use of the light microscrope for the identification of asbestos and other harmless substitutes is a problem. A background in mineralogy is helpful. The McCrone Research Institute in Chicago teaches a "crash course" in asbestos identification. Other training materials are available.[1])

A microscopist with these skills will not be misled by ideas and procedures presented almost daily by nonmicroscopists (or microscopists not trained in asbestos monitoring). One recent paper presented at the American Industrial Hygiene Conference, held May 25, 1983, recommended differentiation of asbestos fibers from nonbirefringent fibers (only glass) by crossing the polars, stating that if the fibers are invisible they are not asbestos. A simple calculation based on diameter and birefringence of asbestos shows that asbestos fibers smaller than about 1.0 μm in diameter will be invisible with crossed polars. This procedure would lead to nondetection of asbestos in many air samples otherwise easily detected by a trained microscopist. Such misinformed statements are dangerously irresponsible.

Another ill-advised idea, point-counting, has been suggested for the quantitation of asbestos in bulk insulation. This is a standard and very valid procedure for well-mixed and nonfibrous component samples for which high accuracy is needed. Anyone who has examined more than a few insulation samples, however, realizes these samples are poorly mixed and very nonuniform in composition. Grab samples of 1 g each from different portions of an insulation sample will nearly always vary by 10–25% of the fibers present. Smaller samples still too large for a PLM sample often vary from 0–100% fiber. If a large enough number of PLM samples of insulation are mounted and point-counted, the analyst might, with luck, analyze 2–4 samples a day rather than the 20–50 samples now possible—and the answer would be no more accurate, significant, or useful than the 2-min method with the stereobinocular light microscope to be described.

In our asbestos courses we recommend quantitating large samples (e.g., 1 oz.) using the stereo binocular microscope at 30–40×. It is easy with that instrument to see how uniform the mixture is and to estimate in 2–4 min with more than sufficient accuracy the percentage of each individual fibrous component. Two different individuals will usually agree within about 15%, e.g., 17–23%, 34–46%, or 51–69%. This may not sound "accurate," but it is more than accurate enough and as accurate as point-counting could be without hours of counting. What would be the difference in deciding what to do if the insulation contained 60% asbestos rather than 50% or even 75% rather than 50%? Analysis based on an intelligent estimation looking at the entire sample is 20–50× faster and probably as accurate as point-counting on such samples. It is certainly the only method justified by the sample and the accuracy needed to decide how to proceed next.

Jean Prentice of our London laboratory has been very active in all areas concerning asbestos for about 20 years. She states,[2] "With respect to the analysis of insulating materials for the presence of asbestos fibres, low magnifications can be used because of the natural distribution of fibres in any bulk material. In other words, if fine fibres are present, large fibres will also be present. Similarly in the analysis of an airborne cloud (providing the air samples are taken close to source) there will be a significant number of fibres which are visible by phase contrast microscopy at 500× and an assessment of airborne contamination can be based on this. However, there are times when the optical microscope is totally inadequate, such as looking at ambient levels of fibres in the atmosphere when the source of pollution is a long way from the sampling site and the heavier fibres have dropped out." She continues: "Within the U.K., the standard method of testing for airborne respirable asbestos fibre during or after asbestos removal work is the standard phase contrast-membrane filter technique and, this has in the main been accepted. This technique has been adopted because it is relatively cheap and the results can be quickly obtained. On-site counting is often requested."

continued

The views of a number of other authorities in this field reinforce this conclusion. Most of these references are from the *Proceedings of the Fourth International Colloquium on Dust Measuring Technique and Strategy* held in Edinburgh, Scotland, in September 1982.[3] Dr. J.M.G. Davis, of the Institute of Occupational Medicine in Edinburgh[4] introduced this meeting with the fair background statement: "There is a further problem relating to the methods of fibre estimation. Up till now, all routine factory dust counts have been undertaken using light microscopy yet this cannot detect fibres below about 0.25 μm in diameter. With asbestos at least, fibres below this detection limit can still be over 10 μm in length and are, therefore, potentially very dangerous. Fibres with this small diameter can only be detected by electron microscopy. While these techniques are too costly and time-consuming for routine use it would be desirable to undertake occasional electron microscope counts to make certain that no production process produced large numbers of fine fibres but only small numbers of fibres of the sizes at present counted by light microscopy."

Hwang and Gibbs[5] show that, assuming a visibility limit of 0.2 μm using a well-set-up phase contrast microscope at 400×, the number of amosite fibers missed by an optical microscope survey would be of the order of 20% or less. If the same experiments are carried out with chrysotile asbestos, one would miss about 50% of the fibers and for crocidolite one would miss about 75% of the fibers. The significant point, however, is that one would see not less than 25% of the fibers in the worst case, crocidolite, *and* one would know, with sufficient certainty, how many fibers had been missed.

Marconi[6] of the Instituto Superiore di Sanita Laboratorio in Rome compared TEM and PCM counts on 30 samples of airborne dust from a railway repair and maintenance facility and from an auto brakeshoe and clutch operation. The PCM always found asbestos when the TEM found it. The TEM found more fibers/mm³ but only (on average) 20% more.

Cherrie[7] of the Institute of Occupational Medicine in Edinburgh found that carefully done PCM and SEM fiber counts agreed well (especially for amosite) but that the slowness of scan for the SEM to see fibers less than 0.3 μm in diameter makes the use of SEM impractical.

Middleton[8] of TBA Industrial Products Ltd. in Rockdale, England, summarizes: "the use of slow scan speeds (by SEM) gave improved visibility of fine fibers but it would not be possible to use slow scan rates during routine counting."

Robock[9] of the Asbestos Institute, in Neuss, Germany, states, "Regarding the necessity to apply the electron microscope for the occupational environment it may be stated by means of the comparative measurements conducted within the DMAP and particularly by the work of Carton/France, that this cannot be justified in view of the time consumed and the result related to the loss in counting thinner fibers (diameter below 0.2 μm) when applying the light microscope. Subsequently, (sic: consequently?) application of electron microscopy for routine measuring of work places is not essential."

Tillman,[10] from Sweden's National Board of Occupational Safety and Health, states in evaluating SEM work, "In investigating the SEM negatives it soon becomes obvious that despite the higher magnification counting was even more complex than in the phase contrast microscope. In the SEM because more details were visible, it was often more difficult for the microscopist to know how many fibres should be counted." Good indications of these difficulties are the results of comparisons of fiber counts by two different laboratories on the same series of 19 air samples (from a variety of manufacturing operations) by both SEM and PCM.[10] The two sets of SEM counts varied by factors of 0.27 to 1.86. The two sets of PCM counts varied by 0.66 to 3.30.

Tillman's actual data show that the PCM missed 15% on average of the smallest asbestos fibers in the comparison of SEM versus PCM on 30 different air samples.

A number of investigators have found that fibers shorter than 3–5 μm in length have very low, if any, carcinogenicity. The first work in this area by King et al.[11] in 1946 showed that fibers 2.5 μm long showed much less fibrosis than fibers 15 μm long. Similar results were obtained by Vorvold et al.[12] in 1951. In 1968, Klosterkötter[13] found much greater reaction with long chrysotile and long crocidolite fibers. Subsequently, studies by Hilscher et al.,[14] Davis,[15] Wright and Kuschner,[16] Timbrell and Skidmore,[17] and Webster[18] confirmed the general view that fibers shorter than about 5 μm are, at least, much less carcinogenic.

The most detailed data on the effects of fiber length were by Stanton and his colleagues.[19] They concluded that the most dangerous fibers were longer than 8 μm and less than 1.5 μm in diameter. These data have been confirmed by Pott[20] and most recently by Ferguson.[21]

These quotations yield considerable confidence in the conclusion that the light microscope, *properly used on proper samples*, is the only practical approach to the detection and identification of asbes-

tos in bulk and most air samples. We feel that the inability to detect the very finest fibrils is not a significant handicap in determining the degree of hazard represented by properly taken and properly examined air samples. Finally, the analytical (capable of elemental analysis for Mg, Na, Ca, and Fe) TEM should be used for all water samples and for all air samples except those close to the source and where aggressive sampling can ensure re-entrainment of the coarser fibers. PCM should be used to evaluate the latter air samples and PLM to identify the membrane- or Nuclepore® -filtered air samples and all bulk samples.

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