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BIOLOGICAL EFFECTS OF ASBESTOS

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able instrument, all the dust samplers available at the time have been tried and discarded for one reason or another (Holmes, 1965). Instruments based on impingement tended to break up the fibre bundles; and those based of thermal precipitation (except the long-running precipitator) appeared to be very inefficient collectors of the longer fibres. Eventually, the membrane filter method was chosen as the most likely system of sampling for asbestos fibres, and development of this method proceeded both in the UK and the USA.

The principle of the method is that the dust sample is collected on a cellulose membrane filter of fine pore size. The filter is subsequently mounted on a microscope slide and cleared (i.e., rendered transparent) with a liquid whose refractive index is such that the contrast between the fibres and the background is not impaired. The sample is then counted at a magnification of about 500 ×, and to further enhance the visibility of the fibres a phase contrast microscope is used.

For the purpose of analysis, a particle is defined as a fibre if its length is at least three times its diameter and if it is at least 5 micrometres in length. In addition, in the UK it is customary to set 3 μm as an upper limit on the diameter, on the grounds that fibres of larger diameter than this would not be respirable. The method has the great advantage that asbestos fibres are easily recognised and this is essential where mixed dust is involved. The lower length limit of 5 μm was chosen somewhat arbitrarily in the early days of the development of the method; however it is significant that fibres which are retained for long periods, either free or as the cores of asbestos bodies, in the lungs of occupationally exposed persons are generally longer than this.

The Dust Measurement Working Group of the Asbestosis Sub-Committee of the Permanent Commission has recommended the membrane filter method for acceptance as the standard method for assessing occupational exposure to asbestos, and measurements based on the method were used by the British Occupational Hygiene Society (1968) for the formulation of its hygiene standard for chrysotile asbestos dust. Government controls on asbestos dust emission in both the UK and USA are also expressed in terms of fibre counts, to be measured in the same way.

The membrane filter method possesses one important disadvantage in that the mounting and counting of the sample is a somewhat tedious operation. Means of speeding-up the work have been sought, and over the last few years the UK industry has made good use of an American instrument, the Royco Automatic Particle Counter, for routine measurements in situations such as textile factories where the dust is almost entirely asbestos. This has been made possible because, while the Royco instrument depends for its functioning on light-scattering and therefore "sees" all dust particles which pass through it, its size-discrimination facility can be adjusted to give the same numerical reading as would be obtained from a membrane filter sample taken in the same place and at the same time. It is also fitted with an automatic print-out device, thus the necessary information is provided simply and quickly without the tedium of mounting the sample and counting fibres under the microscope.

While the Royco continues to be used for routine factory monitoring and engineering controls, it is not suitable for biological studies, in which personal sampling is preferable; for this the membrane filter method is ideal, being extremely portable. Epidemiological studies already planned will involve the collection and analysis of large numbers of membrane samples, and this has led to a search for an instrument which will automatically count and size-select fibres directly from the microscope slide. Among a number of instruments already examined, the Quantimet 720 (IMANCO Ltd) is showing particular promise. Using a phase contrast microscope system with automatic focusing, the Quantimet should be able to deal with an automatically fed magazine load of microscope slides. As might be expected, the cost of such a system is likely to be considerable and could only be justified where large numbers of samples are involved.

The membrane filter method can be criticised on the grounds that very fine asbestos fibres may not be seen in the light microscope, even under the best viewing conditions. The investigation of alternative methods of analysis, usually based on mass estimation, is not being neglected, in spite of the difficulties associated with asbestos referred to above. Methods so far tried include atomic absorption spectroscopy (by which the magnesium in chrysotile can be estimated) and infra-red analysis. The most promising method explored so far, however, is based on X-ray diffraction, where even in a mixed dust sample the asbestos can be specifically identified by its crystal structure. Using an X-ray diffractometer it is possible to measure as little as 10 micrograms of chryso-

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tile asbestos in a sample where the asbestos represents perhaps only 10% of the total mass.

ENVIRONMENTAL SAMPLING OF ASBESTOS

In recent years there has been considerable speculation concerning asbestos as a public health hazard in view of its widespread usage in a variety of forms, including brake linings, in spite of the fact that for the latter application it has been shown that due to heat degradation the wear products which are generated contain little fibrous asbestos. The emission of dust from plants manufacturing asbestos products has also been mentioned as a potentially dangerous source of pollution.

The asbestos industry in the UK has therefore felt obliged to investigate the position, and it has instituted a programme of measurements in the vicinity of its factories, and in selected urban and rural situations. It was quickly demonstrated that asbestos, if it was present at all, existed in such small quantities that the standard sampling instruments and methods were completely inadequate. To obtain any measurable quantity of asbestos, it was obviously going to be necessary to sample very large volumes of air, and if this was to be collected in a reasonable time, a high speed sampling instrument would be necessary. Such an instrument is the Litton Sampler (Rickards & Badami, 1971) which works on the principle of electrostatic precipitation and is capable of sampling speeds of up to 10,000 litres of air per minute. This means that sample volumes of a million litres (1000 cubic metres) can be collected in a reasonable time.

Even in these large volume samples, estimation of the asbestos load has proved difficult. Where the total mass is above about 100 micrograms (i.e., 10^{-7} grams per cubic metre) the X-ray diffraction method has been used; but in many of the samples collected, no asbestos has been detected by this method. In these cases, it has been necessary to treat the sample by ultra-sound to disperse any asbestos present into its basic fibril form and to estimate the mass using transmission electron microscopy. This method, which is shortly to be published, can measure asbestos concentrations as low as 10^{-10} grams per cubic metre in a 1000 cubic metre sample, even in the presence of excessive amounts of other airborne solids.

To sum up, the combination of membrane filter sampling and optical microscope analysis is still considered to be the best system for monitoring asbestos dust in occupational situations. Mass estimation methods have the great advantage of rapidity, but they cannot be adopted with confidence, particularly for chrysotile, until a reliable elutriation system is available. Furthermore, because of the belief that the longer fibres may be of special significance as regards a health hazard, a technique for sizing and counting of fibres must be considered important.

On the other hand, for assessing the asbestos content of general environmental atmospheres mass estimation is the only available method. In this type of study the question of elutriation does not arise, since it can be confidently assumed that all the fibres which remain airborne in these circumstances will be respirable. The concentrations of asbestos seen under these conditions are so small that large volumes of air have to be sampled; however, here high-speed samplers can be used, which is not the case for occupational situations. The fibres collected are generally too fine to be seen under the light microscope, particularly in the presence of a high concentration of other atmospheric pollutants. Estimation of the asbestos content has therefore to be made on a mass basis using X-ray diffraction or electron microscopy, depending upon the quantity collected in the sample.

SUMMARY

The special problems associated with the sampling and analysis of fibrous dusts are discussed. The merits and disadvantages of sampling methods based on fibre counting and mass determination are reviewed in relation to sampling in both occupational and general environmental situations.

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