

PNEUMOCONIOSIS

Proceedings of the
International Conference
Johannesburg 1969

V. Timbrell, F. Pooley
and
J.C. Wagner

ALL-STATE LEGAL®
DEFENDANT'S
EXHIBIT

47

CHARACTERISTICS OF RESPIRABLE ASBESTOS FIBRES

V. TIMBRELL, F. POOLEY and J. C. WAGNER

*Pneumoconiosis Research Unit, Medical Research Council, Llandough Hospital,
Penarth, Glam., Wales*

In a study of the characteristics of respirable asbestos fibres we have examined:

- i. The UICC reference samples;
- ii. Lung sections of rats exposed to dust clouds of the UICC samples;
- iii. Industrial asbestos dusts;
- iv. Human lung sections containing asbestos.

Since some of the fibres were very slender and not visible in the optical microscope, the examinations were performed with both the electron and optical microscopes.

FIBRE SHAPE

Fig. 1 shows electron micrographs of the lung sections of rats exposed to the UICC

amosite, crocidolite, anthophyllite and Canadian chrysotile: an electron micrograph for the UICC Rhodesian chrysotile is not included as it shows features similar to the Canadian chrysotile. The fibres of the 3 amphibole dusts are straight, the observed diameter being uniform over the whole fibre length. The amosite fibres exhibit a rectangular section, crocidolite fibres an elliptical or circular cross-section, while the anthophyllite fibres are thin flakes (some in Fig. 1c are thin enough to appear semi-transparent). The chrysotile fibres present a markedly different appearance. The fibres are

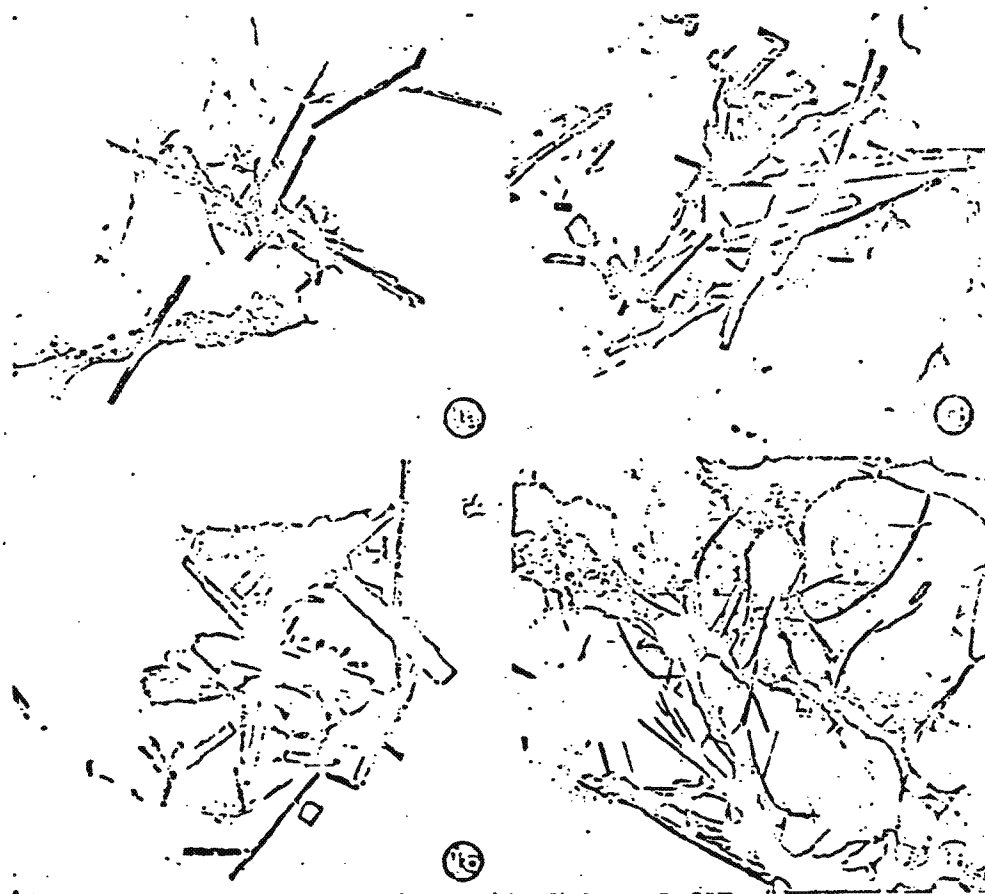


Fig. 1. Electron micrographs of lungs of rats exposed to asbestos fibres.

A: Crocidolite. B: Amosite.
C: Anthophyllite. D: Chrysotile.

curved in a wide variety of shapes. They consist of bundles of very fine fibres; the bundles are usually partially opened.

These features of the various types of fibres were reproduced in electron micrographs of the samples (ii) to (iv). The amphiboles were always straight whereas the chrysotile were almost invariably curved. The chrysotile fibres in the lung sections tended to conform to the shape of the tissue walls.

In the rat and human lung sections each type of fibre tended to occur in bunches, the longer fibres being observed in the non-ciliated regions of the smaller air ducts.

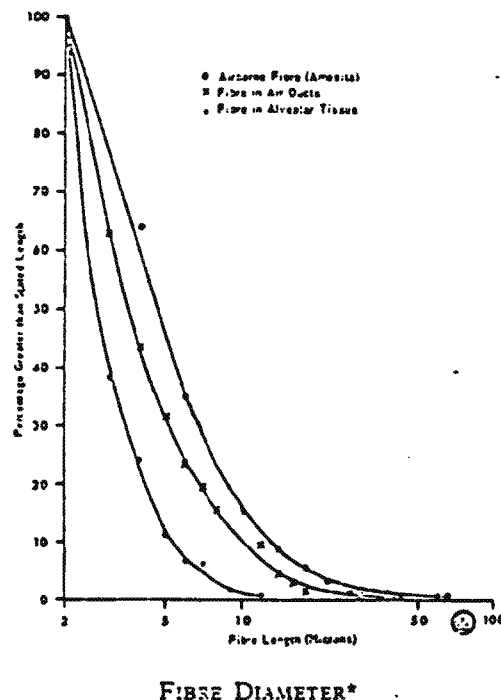
FIBRE LENGTH

A striking feature of asbestos fibres in lung sections is their considerable length, which can greatly exceed the dimensions of the particles of compact shape, such as those of coal or silica, in similar circumstances. Since some of the fibres can be longer than the field of the electron microscope, the examinations on length were performed, mainly, with the optical microscope.

A second impression obtained from examining lung sections is that the longest fibres are usually found in the respiratory bronchioles and alveolar ducts and that the fibres in the tissue are shorter. The validity of this observation has been confirmed in the present study by measurement of the length distribution of the fibres in these regions. Fig. 2 shows the length distribution of the fibres in these 2 regions in lung sections of a rat exposed to the UICC amosite dust, together with the length distribution of the dust cloud. This shows that the fibre in the terminal air sacs is generally shorter than that in the air ducts, which in turn is shorter than that in the dust cloud.

The feasibility of long fibres penetrating the lung and reaching the pulmonary air spaces, is explained by the fact that the falling speed of a fibre mainly depends on its diameter and is not very sensitive to length. A long fibre (if it is thin enough) can avoid being deposited by gravitational settlement or inertial precipitation high in the respiratory tract and may penetrate deeply into the lung. The observed concentration of long fibres in the respiratory bronchioles is explained by the fact that the probability of a fibre intercepting the wall of an airway becomes greater with increase in fibre length and with decrease in the airway diameter. Consequently, whereas interception is not important in the

trachea and larger airways, it is a very efficient deposition mechanism for long fibres in the smaller airways. The small airways progressively filter out the long fibres, so that those in the air ducts are longer than those which penetrate deeper. Comparison of the length distributions which are shown in Fig. 2 with those of fibres in lung sections from rats allowed to survive a longer period after the end of exposure indicates that, with time, the fibre in the air ducts becomes coarser, suggesting a transportation mechanism which is sensitive to fibre length.

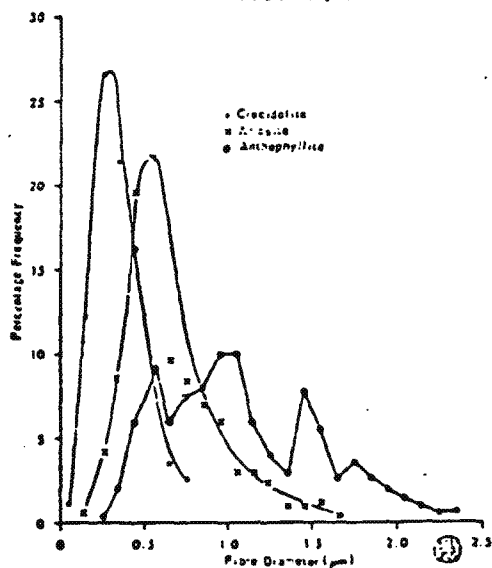
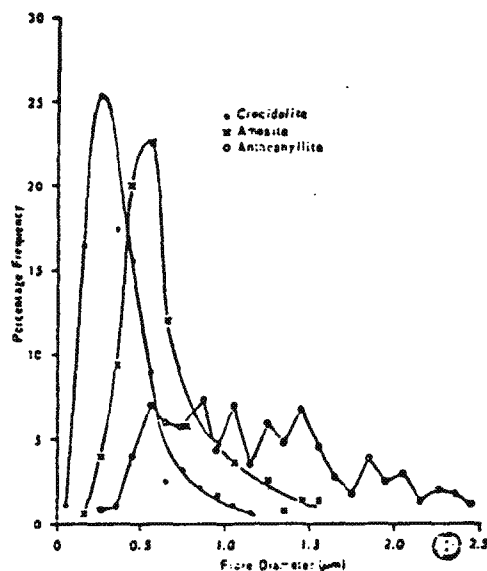


The impression is obtained from examining the electron micrographs in Fig. 1 (a-c) that the crocidolite is a more slender fibre than the amosite, which in turn is more slender than the anthophyllite. Further, the finest fibre of the anthophyllite is thicker than that of amosite and the amosite is thicker than that of crocidolite. The same impressions are obtained from the electron micrographs of the UICC dusts, and also from the industrial

*Due to a technical fault in the electron microscope, the scales of fibre diameter in Figs. 3-12 are incorrect. The scale in each Fig. should be corrected by multiplying by a factor of 0.65.

In the text, the values of fibre diameter should also be corrected by the same factor.

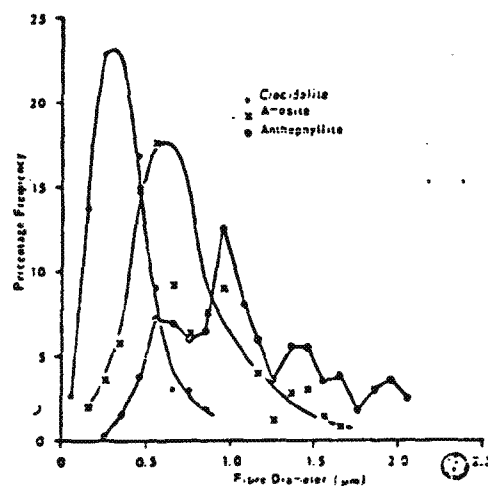
dusts and human lung sections when the exposures are pure. One also gets the impression that chrysotile follows quite a different pattern and must be treated as a separate category; as these fibres occur in bundles the diameter cannot be accurately defined.



The validity of these observations on the amphiboles has been confirmed by measurement of the diameter distribution of the fibres. Fig. 3 shows the results for the UICC dusts, Fig. 4 those for the rat lung sections, and Fig. 5 from human lung sections with pure

exposures. The agreement between the shapes of the distributions in these 3 sets of results is evident.

Another feature to note is that these fibres each have a definite minimum diameter: 0.06 μm for crocidolite; 0.15 μm for amosite; and 0.25 μm for anthophyllite. The distributions for crocidolite and amosite have peaks at 0.25

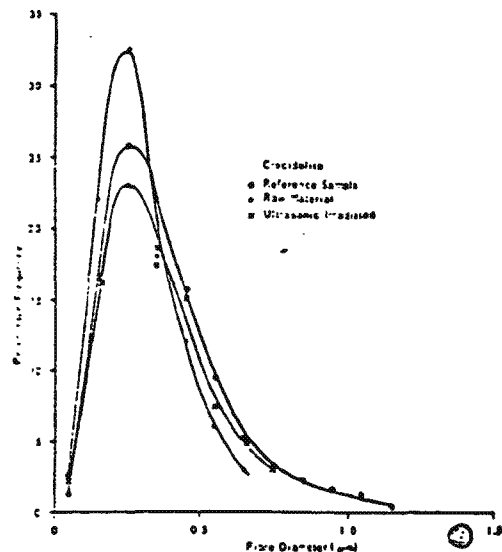


μm and 0.55 μm respectively. The points in the distribution diagrams for anthophyllite show considerable scatter and suggest a multimodal distribution.

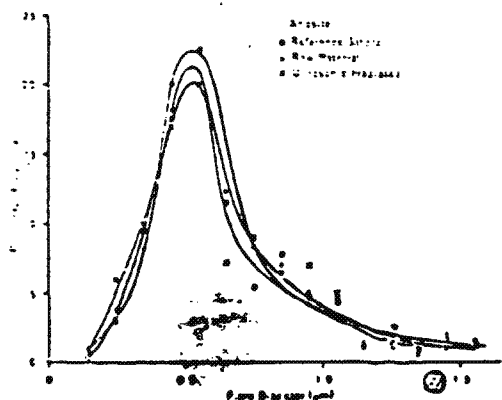
The agreement between the results for the UICC dust and those for the rat lung sections is not surprising since the UICC samples were prepared to contain in the main fine fibres of which a high proportion would be respirable. The reason for the similarity shown by the human lung sections and the other samples was not so obvious. To examine the possibility that this was due to the fibres of each type of asbestos possessing a characteristic diameter distribution, a comparison was made of the UICC dusts subjected to different mechanical actions. These included the actual UICC samples, the raw materials from which the UICC samples had been derived by grinding, and the UICC dusts which had been irradiated in an ultrasonic bath. As the larger fibres in the raw material would interfere with electron microscopy they were removed by elutriation.

The diameter distributions of these fibres are compared in Figs. 6, 7 and 8. For each type of fibre there is good agreement between the distributions. Since these are distributions by number, the removal of the

larger particles from the raw material had its greatest effect on the coarse end of the distribution, but even here it was small.



The human lung sections (for which results are shown in Fig. 5) were obtained from the same geographical locations as the UICC dusts, viz. crocidolite (Cape Province); amosite (Transvaal); anthophyllite (Paaskilla, Finland). Our results indicate that fibres from a given geographical location comminute in

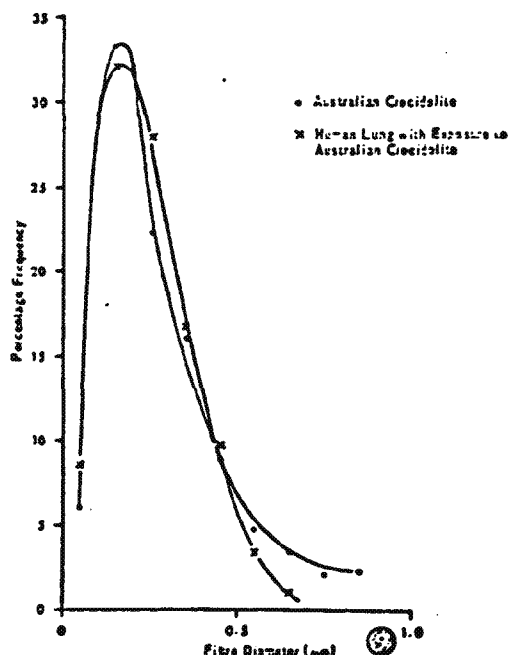
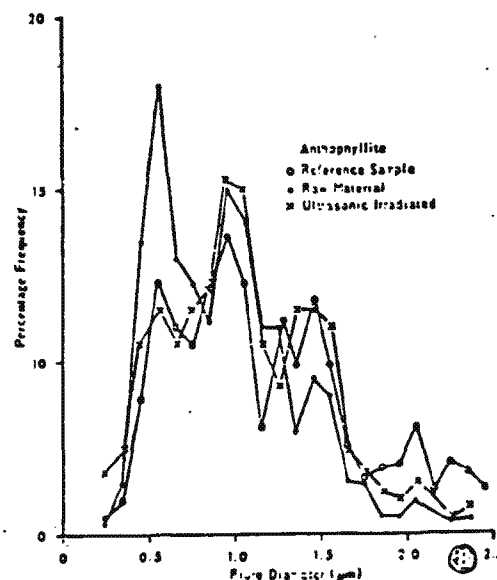


a definite fashion and even after different treatments exhibit a characteristic fibre-diameter distribution.

The diameter distributions are most stable at the lower end. This is explained by the

fact that the agents which operate to remove particles from the dust, for instance, the deposition mechanisms in the lung, show least size differential in the small diameter region.

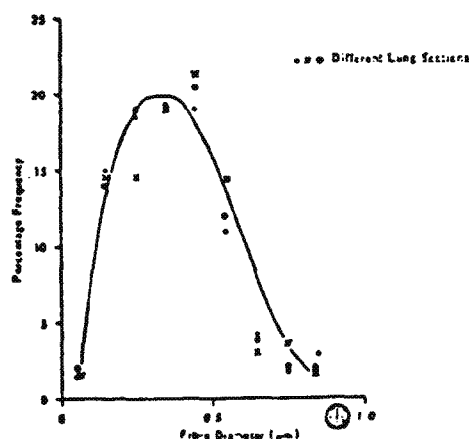
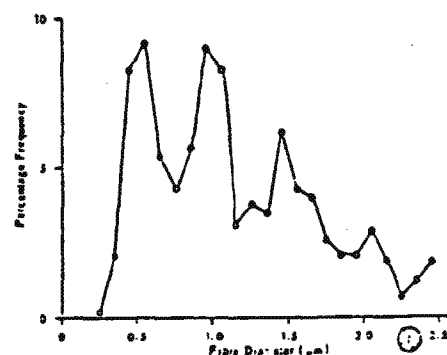
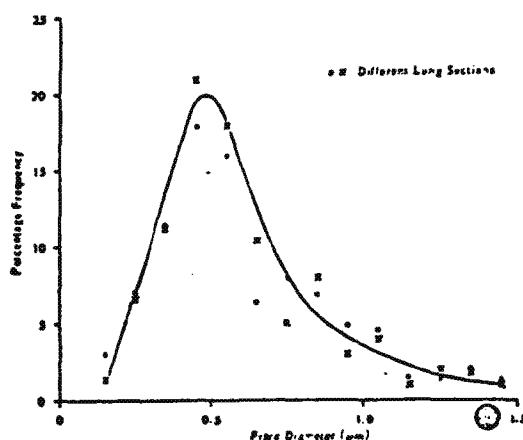
The examinations of other amphibole samples including tremolite and actinolite



have indicated that each type of fibre has a characteristic diameter distribution which depends to a limited extent on the source. For instance, Fig. 9 shows the diameter distribution of Australian crocidolite fibre. It can be seen that this is similar to that of crocidolite from Cape Province but has a higher proportion of fine fibres, and the finest fibres are of smaller diameter, $0.025 \mu\text{m}$.

IDENTIFICATION OF TYPE OF ASBESTOS FIBRES IN LUNGS

At present there is no single method which is generally applicable for the positive identification of amphibole fibres in lung residues or sections. Identification of fibre type requires the use of evidence from different methods. The possibility of using the



Examination of the frayed ends of the chrysotile fibres has shown that these consist of very fine fibrils. This structure has also been seen in the main body of a fibre. Measurement on fibrils which appear single gave for the elliptical cross-section a range of ratio of major to minor axes from 1 to 4, minimum value of minor axis $0.010 \mu\text{m}$ and maximum value of major axis $0.040 \mu\text{m}$; the mean value of the observed diameter was $0.025 \mu\text{m}$.

diameter distribution as an aid to identification has been examined in a series of blind trials and a high success rate has been achieved.

The location of the sections in the lung for this type of examination has been found to be unimportant. For example, Fig. 10 shows the results of examining 2 different sections of a human lung, one from the upper lobe and one from the base of the lower. The individual diameter distributions which could be drawn through the various sets of points would not be very different from the average distribution shown. The same conclusion applies to the results from 3 sections of a human lung shown in Fig. 11.

In examining a lung section for identification purposes, the presence of long curved asbestos fibres is a positive indication that the lung contains chrysotile. The presence of fibres of $0.025 \mu\text{m}$ diameter provides additional strong evidence.

The most useful application of the method is for the estimation of the amphiboles. Some examples are given to illustrate the method. The sections from which they were derived were examined without any previous information.

In Fig. 10, from the shape of the curve, together with the minimum diameter of

0.15 μ m and the position of the peak it was concluded that the main exposure had been to amosite. This was confirmed by the industrial history of the subject which showed he had been employed in the amosite mines of the Transvaal. Some deviation of the curve from the characteristic shape for amosite suggested exposure also to some other amphibole.

In the case of Fig. 11, the presence of fibre of 0.1 μ m diameter indicated the presence of crocidolite, while the width of the curve and the position of the peak suggested an almost equal exposure to amosite. The industrial history proved to be of a man who

had been employed on lagging with crocidolite and amosite.

The next example, shown in Fig. 12, gave a clear indication of exposure to anthophyllite. The subject proved to be a Finnish asbestos worker.

In Fig. 9, the distribution of fibre in the human lung suggested a crocidolite exposure, but with a suspicion that the source might be different from Cape Province which was until then the only geographical location examined. The subject subsequently proved to be a woman who had worked during the 1939-45 war filling the canisters of civilian respirators with a mixture of Australian crocidolite and Merino wool.