British Journal of Industrial Medicine 1983;**40**:375–379

Fibre type and concentration in the lungs of workers in an asbestos cement factory

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ABSTRACT The predominant asbestos fibre type used in the production of asbestos cement is chrysotile. The use of asbestos in relation to fibre type in a Norwegian asbestos cement plant during 1942–80 was 91·7% chrysotile, 3·1% amosite, 4·1% crocidolite, and 1·1% anthophyllite respectively. Electron microscopy and *x* ray microanalysis of lung tissue samples of asbestos cement workers who had died of malignant pleural mesothelioma or bronchogenic carcinoma showed a completely inverse ratio with regard to fibre type. The percentage of chrysotile asbestos in lung tissue varied between 0% and 9% whereas the corresponding numbers for the amphiboles were 76% and 99%. These differences are discussed with respect to the behaviour of different fibre types in the human body and to the occurrence of malignant mesothelioma in this asbestos cement factory.

Analysis of fibres in human lung tissue may be used for the verification of previous exposure to asbestos. The amount of fibres deposited in the lungs may also reflect the total dose (concentration × years of exposure) to which an individual has been exposed. Nevertheless, variations in deposition, clearance rate, and durability of different types of fibres should be borne in mind when such data are compared. The fact that chrysotile is cleared more efficiently or even dissolved in lung tissue often results in a relatively larger percentage of amphibole fibres in the lung provided that a mixed type asbestos exposure has occurred. This difference is especially important in cases of mesothelioma as it has been argued that crocidolite has the highest mesothelioma producing potential followed by amosite and chrysotile,[1] an assumption supported by the studies of Dement *et al* and Weiss who reported no mesotheliomas in two plants where only chrysotile had been used.[2,3] Contrary to these reports, Newhouse *et al* found 10 mesotheliomas in a cohort apparently exposed only to chrysotile.[4] The association between fibre type and disease has been further clarified by McDonald *et al* who showed that cases of mesothelioma and referents were similar with respect to chrysotile content in the lungs, whereas there was a substantial excess of amosite and crocidolite in the cases compared with the referents.[5]

Received 29 September 1982
Accepted 22 November 1982

Chrysotile is the predominant asbestos fibre type used in the production of asbestos cement. Crocidolite, amosite, and anthophyllite have to a far lesser extent been used, generally for special purposes.

In order to study the relation between the use of asbestos and fibre deposition we have performed an investigation in a Norwegian asbestos cement factory that started production in 1942 and closed down in 1980. The annual number of employees in the factory before 1960 was about 200. The use of asbestos from various sources with relation to fibre type was: 91·7% chrysotile, 3·1% amosite, 4·1% crocidolite, and 1·1% anthophyllite. According to factory records anthophyllite asbestos was used only from 1942 to 1945.

The object of this study was to compare the use of asbestos and exposure to asbestos in the factory with the number and type of fibres found in samples of lung tissue from four cases of malignant pleural mesothelioma and four cases of bronchogenic carcinoma.

Materials and methods

Samples of lung tissue were obtained from necropsy or lobectomy as formaline preserved tissue pieces, or as tissue embedded in paraffin blocks. In the first case the wet tissue was cut into small pieces and dried to constant weight at 60–70°C. In the latter case the paraffin was removed by xylene and the tissue was cut and dried. Twenty to 50 milligrams of dried tissue were weighed and ashed in a Tracerlab 505 low temperature plasma asher (LTA) at 60 W forward power and at an oxygen flow of 225 ml/min. The ash was suspended in a 0·5 N hydrochloric acid solution containing 10% ethanol for five minutes' treatment in an ultrasonic bath. The chemical solutions used were all filtered twice before use.

Only acid/detergent washed glass equipment was used. The ash suspensions were filtered on Nuclepore polycarbonate membranes with 47 mm diameter and 0·2 μm pore size. To avoid contamination, the membranes were kept in closed petri dishes. Pieces of the Nuclepore membranes were either coated by gold or carbon. The gold coated specimens were investigated in a Jeol JMS-35 scanning electron microscope (SEM). The number of fibres was recorded directly from the screen at 4500× magnification in the slow scanning mode. At least 200 fields or 100 fibres, whichever was completed first, were counted. The carbon coated samples were prepared for transmission electron microscopy (TEM) by dissolving the polycarbonate membrane from the carbon film with chloroform. The carbon film, with the fibres embedded, was transferred to a 150 mesh Ni-grid. These specimens were investigated in a Jeol 100 C TEM fitted with a 148 eV resolution and 30 mm² area Si (Li) detector. Using this system we could identify single chrysotile fibrils by morphology and chemistry as well as separating between very thin crocidolite and amosite fibres.

Results

USE OF ASBESTOS

Figure 1 shows the annual use of asbestos from 1942 to 1980, based on data obtained from factory records. Finnish asbestos (anthophyllite) was used only from 1942 to 1945. We identified the highest concentration of anthophyllite fibres in the lungs of three workers employed from the beginning of production. As shown, chrysotile has, however, been the major raw material during all the years of production.

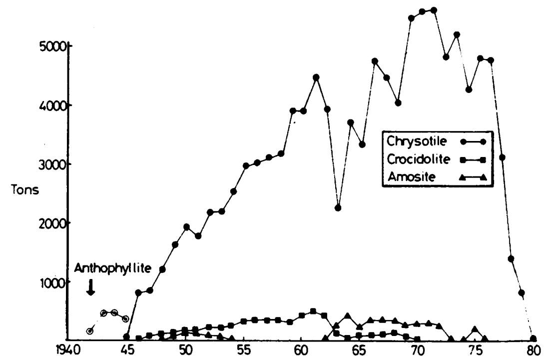

Fig 1 *Annual use in tons of different types of asbestos in a Norwegian asbestos cement factory during 1942–80.*

EXPOSURE DATA

In a report from the factory inspectorate in 1950 fibre concentrations varying from 3·6–70 mppcf were recorded. In another report in 1954 the concentrations were 3·4–15·4 mppcf. In 1964 the Institute of Occupational Health in Oslo made a survey based on gravimetric measurements and midget-impingers. The gravimetric data showed concentrations from 0·2–22·8 mg/m³ whereas the corresponding midget-impinger results were 5·2–113 mppcf. The asbestos content of the dust was 40–60%. From 1972 to 1980 fibre concentrations were regularly recorded by the company using the membrane technique. During sacking operations, fibre

Table 1 *Case information*

Case No	*Year at first exposure*	*Age at first exposure (years)*	*Duration of exposure (years)*	*Latency from first exposure until death (years)*	*Age at diagnosis (years)*	*Source of tissue*	*Diagnosis*
1	1942	39	29	33	72	Necropsy	Pleural mesothelioma. Mixed type. Asbestosis
2	1945	21	33	33	54	Necropsy	Pleural mesothelioma. Mixed type
3	1951	42	22	21	63	Necropsy	Pleural mesothelioma. Sarcomatous
4	1942	27	20	38	62	Necropsy	Pleural mesothelioma. Mixed type
5	1949	31	4	30	61	Necropsy	Bronchial cancer. Oat cell carcinoma
6	1959	51	13	20	71	Necropsy	Bronchial cancer. Squamous cell carcinoma
7	1949	33	30	31	64	Lobectomy	Bronchial cancer. Squamous cell carcinoma
8	1942	16	4	34	50	Lobectomy	Not classified

Table 2 *Concentration and type of fibres in lung tissue samples*

Date	*Fibre concentration determined by SEM (million fibres per gram dried tissue)*	*No of fibres analysed by EDS*	*Crocido-lite (%)*	*Amosite (%)*	*Antho-phyllite (%)*	*Chryso-tile (%)*	*Others* (%)*
1	112	107	56	6	28	7	4
2	490	72	68	17	3	8	4
3	83	102	74	11	8	2	6
4	206	53	60	2	34	—	4
5	6·1	28	36	14	14	—	36
6	49	22	55	32	5	9	—
7	34	61	85	11	2	—	1
8	7·5	33	6	—	70	—	24†

*Others comprise tremolite, mullite, and non-identified silicate fibres.
†10% Mullite.
SEM = Scanning electron microscopy.
EDS = Energy dispersive *x* ray microanalysis.

concentrations up to 13 fibres/cm³ were detected, but after 1973 the exposures were generally lower than 5 fibres/cm³.

LUNG TISSUE ANALYSES

Table 1 shows the data for eight cases while table 2 gives the fibre concentrations and types of asbestos found in lung tissue. Although more than 90% of all asbestos used in the factory was chrysotile, the result for the lung tissue analyses is completely reversed. The percentage of chrysotile compared with the total number of fibres varied from 0% to 9% whereas the corresponding number for the amphiboles (excluding case 5) varied between 76% and 99%. Case No 5 was not directly employed by the asbestos cement company but worked for a construction company inside the factory area. Cases 1, 4, and 8 had been employed since 1942 by the asbestos company. This is reflected in a significant number of anthophyllite fibres in their lungs, especially for case No 8 where anthophyllite constituted 70% of the fibres. Figure 2 shows a characteristic TEM-micrograph of fibres in an ashed lung sample from case No 2. Figure 3(a) and (b) shows the characteristic spectra of very thin chrysotile and crocidolite fibres. Other fibres such as tremolite (fig 3c) and mullite were found, but those were classified as "others" along with unidentified silicate fibres. In case 5, 36% of the fibres were classified as "others" due to the large amounts of other particles interfering during *x* ray microanalysis.

Discussion

Although more than 90% of the fibres used in the production of asbestos cement was chrysotile,

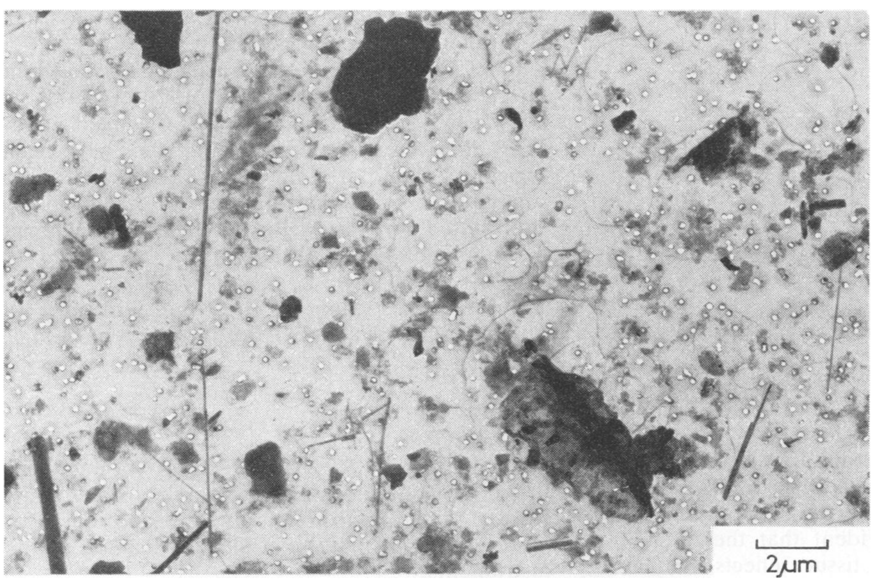

Fig 2 *Characteristic fibres found in lung tissue of case No 2 photographed in transmission electron microscope at 6250 × magnification.*

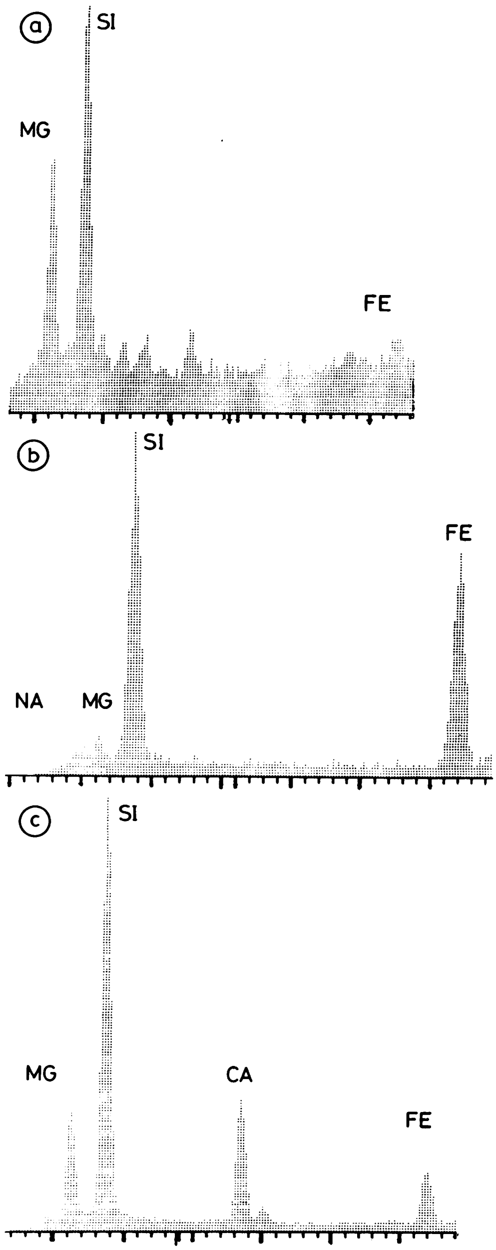

Fig 3 *Energy dispersive x ray spectra: (a) chrysotile asbestos, (b) crocidolite asbestos, (c) tremolite asbestos.*

amphibole fibres were mainly found in the samples of lung tissue. This might be due to factors such as differential clearance, penetration, and durability of the fibre types. It is evident that the number of chrysotile fibres in lung tissue reflects neither the total asbestos dose inhaled nor the exposure level to which these workers had been exposed. Walton states that crocidolite is reputedly a more dusty material than chrysotile,[6] but this alone cannot explain the large differences in the amount of fibres deposited. It is unlikely that the differences found in this study are due to the higher "dustiness" of the amphiboles.

The study further indicates that exposure to asbestos, expressed as high amounts of amphibole fibres deposited in the lungs of the workers, has been considerable for many years, especially in the cases of mesothelioma. This difference in fibre concentration between those with mesothelioma and those with bronchogenic carcinoma may be due to different exposure times or intensity of exposure; or it may be that some people deposit a higher proportion of fibres in the lung and are thus more prone to disease than others.

The anthophyllite fibres found in the lungs of the workers employed after the period when anthophyllite was used may originate from the contamination of the other asbestos types or from unknown exposure.

Recent reports from the asbestos cement industry[7-12] have indicated low frequencies of malignant mesothelioma. This may be due to the underdiagnosis of this tumour, as suggested by Weill,[7] or to the use of chrysotile as the predominant type of asbestos. A recent study by Thomas *et al* gives further evidence to the view that chrysotile is a less potent cause of mesothelioma than amphiboles.[12] In this study two cases of mesothelioma were found in a group exposed to crocidolite and chrysotile before 1936, but after 1936, when chrysotile only was used, no further mesotheliomas were detected.

In a study on the incidence of malignant mesothelioma in Norway from 1970 to 1979 six cases were recorded among asbestos cement woıkers.[13] Since then, three additional cases have been registered from the same plant. The previous consumption of crocidolite and amosite has probably contributed to the high number of malignant mesothelioma in this plant.

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We thank the Royal Norwegian Council for Scientific and Industrial Research for financial support and Electron microscopy laboratory for Bioscience, University of Oslo, for loaning us the instruments.

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sion was used to distinguish men without and with material quantities of lung dust. The groups were equally represented among the men from the several sources except for the epidemiological unit's random sample which, as might be expected, consisted predominantly of categories 0 and 1. The men who were referred from the Pneumoconiosis Medical Panel had found their way there as a result of a National Coal Board periodic *x*-ray examination; they met the same selection criteria as the other subjects. Thus while the sampling procedure was not ideal it was not obviously biased in favour of the more disabled men being those with the higher categories of pneumoconiosis. In this our sample may have been better than that cited by Cochrane and Moore; their usable data came mainly from the Staveley survey of which one of the conclusions was that men moved to those coal mines had above average respiratory health. A more definitive population might be drawn by the NCB but meanwhile our findings appear to be not unrepresentative: we hope that they will stimulate others to carry the subject further.

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Notice

Royal College of Physicians of Ireland: Faculty of Occupational Medicine

Parts I and II of the examination for the membership of the faculty will be held in May and November each year. Details may be obtained from the Examination Office, Royal College of Physicians of Ireland, 6 Kildare Street, Dublin 2.

Correction

Fibre type and concentration in the lungs of workers in an asbestos cement factory (Nov 1983)

It has been brought to my attention that the interpretation which we made (*Br J Ind Med* 1983:**40**;375–9) of results published by Newhouse and her colleagues[1] was incorrect. In our paper we stated (in the first paragraph of the paper) that these authors found ten mesotheliomas in a cohort apparently exposed only to chrysotile. In fact, eight of the ten patients with mesothelioma in that study had had a definite exposure to crocidolite during one specific job.

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