

PLAINTIFF'S
EXHIBIT
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SOME OBSERVATIONS OF THE DUST CONTENT AND COMPOSITION IN LUNGS WITH ASBESTOSIS, MADE DURING WORK ON COAL MINERS PNEUMOCONIOSIS.

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In the study of pneumoconiosis at the Safety in Mines Research Establishment (S.M.R.E.), the isolation and analysis of the dust found in lungs has been one of the major fields of research for a number of years. Studies have been made of the dust in the lungs of miners (coal, hematite, and tin), and of granite and kaolin workers, and a wide range of techniques has been developed for analysis of lung dust.

Asbestosis is not, formally, a disease with which S.M.R.E. is concerned. However, one current view of the causation of the disease is that the asbestos dust dissolves in the lung and that the dissolution product, silica, causes lung fibrosis in the same way as silica dust inhaled directly from the atmosphere (as, for instance, in mining). There was hence a possibility that a study of asbestosis might have thrown some light on coal workers' silicosis, and S.M.R.E. therefore carried out a small amount of work on the lungs of men suffering from asbestosis. More recently the work of J. C. Wagner and his colleagues on the carcinogenic effects of asbestos dust has revived interest in the disease, and S.M.R.E. has recently been able to give a limited amount of assistance to the Pneumoconiosis Research Unit, Cardiff, of the Medical Research Council, in carrying out lung analysis. Although this work has not yet led to any definite conclusions, the results obtained to date are given in the present paper.

Review of Literature

Occasional references to asbestos bodies are found in the literature from 1800 onwards, but the first detailed studies of the lung dust in asbestos come from the period 1930 to 1940. A great deal of work seems to have been done at that time on a very small number of lungs. These stemmed from what might be called the heroic period of asbestosis, before the risk of asbestos dust was clearly recognized. Ages at death were in the middle 30's, exposure periods of the order of 20 years, and the intervals between end of dust exposure and death were of the order of 1 year or less. The work of Beger and of Sundius and Bygden belongs to this period.

Beger (1935) studied sections, lung juice smears, and one piece of lung tissue of an asbestos worker who had died aged 35 years after 20 years of dust

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exposure, followed by one year out of dust. He found many asbestos bodies and fewer needles of free asbestos and identified the latter as chrysotile on the basis of their optical properties. The refractive index seemed similar to material believed to be gypsum which he found in some sections. Birefringence was low with the higher refractive index parallel to the fiber axis, and the fibers behaved similarly to fresh chrysotile in acid leaching experiments.

Beger made many measurements of the frequency and dimensions of the asbestos bodies and fibers and estimated that one cubic cm. of lung contained 0.02 mg. of asbestos. This would be equivalent to 40 mg. for a volume of 2 litres for both lungs. He gave the average dimensions of the free fibers as 50 μ long and 0.5 μ wide. Koppenhöfer (1935) examined by dark field microscopy tissue sections of the same lung embedded in bromobenzene (refractive index, 1.560) and found very large numbers of needles far smaller than those described by Beger, but these would not add much to the estimated weight. The identification of the asbestos as chrysotile and the weight estimates must both be considered unreliable by present-day standards.

Sundius and Bygdén (1938) worked on samples of the lungs of an asbestos worker who had been exposed for 21 years and died 2½ months after the end of the dust exposure. The lungs had been stored in a galvanized vessel for several years and were slightly contaminated with zinc salts. The authors used the hydrogen peroxide method, which they had developed, to destroy the lung tissue, and they also used a mechanical method; filings of the wet lung were sieved in water, the sieved suspension was centrifuged, and the residue washed successively with water, alcohol, and benzene. The residue was then fractionated with mixtures of acetylene tetrabromide and benzene. The heaviest fraction, of density above 2.37, contained free asbestos fibers and other minerals, the fraction between 2.05 and 2.37 mainly asbestos bodies.

From a quantitative study of 250 gm. wet lung, corresponding to 85 gm. of dried lung, the authors estimated that in both lungs there were about 0.3 gm. of free asbestos needles and 0.6 gm. of asbestos inside bodies, giving together 1.4 gm. of asbestos; they also estimate a similar amount of other mineral dust to have been present (quartz, rutile etc.). Total mineral dust was 2.8 gm. As figures for per cent dried lung they give — asbestos 0.6 per cent, total mineral dust 1.2 per cent.

Considerable effort was spent on the identification of the type of asbestos. By optical, chemical, and X-ray diffraction analysis this was found to be similar to amosite. There was no evidence of partial chemical attack for the X-ray diffraction lines were sharp, and the chemical composition of the asbestos similar to that of commercial samples of amosite except for a slightly higher content of Al_2O_3 . Optically, the fibers had the higher re-

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fractive index in the fiber direction, with n_y most near 1.70 but varying down to 1.63. No clear evidence was obtained for the presence, in the lung dust, of crocidolite or chrysotile.

In a later publication Beger (1949/1960) questioned the identification by Sundius and Bygdén, of the asbestos as a hornblende variety and tried to prove that they had in fact been studying a chemically altered chrysotile, but his arguments do not seem convincing.

The only later work to be mentioned here is that of Beattie and Knox (1961). These authors examined samples of lung, lymph glands, and pleura of 50 people who had been exposed to asbestos, mainly chrysotile, for prolonged periods. They distinguished four grades of asbestosis, none, minimal, moderate, and severe, and determined the amount of mineral dust obtained by ashing the tissue samples and extracting the ash with one-tenth normal (0.1 N) hydrochloric acid. They expressed these weights as mg./gm. dried tissue.

TABLE 1
LUNG DUST ANALYSES IN ASBESTOSIS, AFTER BEATTIE AND KNOX (1961)

	Grade of Asbestosis			
	None	Minimal	Moderate	Severe
Number of cases	16	14	8	11
Mineral content mg./gm. dried lung*	4.1	3.3	6.9	5.3
Dust exposure, years	16	18	27	24
Survival, years	3	7	6	10
Dust accumulation, mg./gm. per year exposed	0.27	0.34	0.25	0.21

*Five mg./gm. equals 1 gm. in a pair of lungs of 200 gm. dry weight.

We are concerned here only with the data for the lungs, which are summarized in TABLE 1. There is no clear correlation between the average lung dust concentration and the grade of asbestosis; but the lungs with the highest grade of fibrosis had the longest survival interval (period between end of dust exposure and death) and the lowest calculated dust accumulation rates.

Beattie and Knox also counted and measured the asbestos fibers in the residues, and they found that in severe asbestosis the proportion of longer fibers (above 15μ) to all fibers or particles was considerably lower than in the three other grades, but they say nothing about the nature of the

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fibers, or what proportion was recognizable as fibers.

The Lung Dust

Several years ago a Mines Research Estate of asbestosis. Most of the London Pneumoco Research Unit in Car minimal, moderate, or

terial given by Beattie. In most cases whole representative samples were minced, ground lung were as determined chemically treated with 0.1 N hydrochloric acid and a mineral residue for X-ray diffraction.

The object of the analysis was as completely as possible as little as possible. Experience from Rhodesia (previously sample), and with normal hydrochloric acid at 0.1 N was finally used as a

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Residue per cent dried

Mean

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Asbestosis

Moderate	Severe
8	11
6.9	5.2
27	24
6	10
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The Lung Dust Content of Asbestos Workers from Great Britain

Several years ago a preliminary study had been made in the Safety in
Mines Research Establishment of the dust in the lungs of some 20 cases
of asbestosis. Most of the lungs had been supplied by R. M. McGowan of
the London Pneumoconiosis Medical Panel, others by the Pneumoconiosis
Research Unit in Cardiff. The grade of asbestosis had been assessed as
minimal, moderate, or severe by the pathologists concerned, using the cri-
teria given by Beattie and Knox (1961, p. 420).

In most cases whole lungs (right, left, or both) were available, and
representative samples of one or both lungs were used for analysis. The
samples were minced, dried, and ground. Between 20 and 30 gm. of dried
ground lung were ashed at 380°C., and total silica and iron oxide were
determined chemically on part of the ash. Another sample of ash was ex-
tracted with 0.1 N hydrochloric acid, washed with water, and dried to give
a mineral residue for examination by light and electron microscopy and
X-ray diffraction.

The object of the acid treatment was to remove endogenous lung salts
as completely as possible and at the same time to attack the asbestos as
little as possible. Experiments with a fine chrysotile sample from Southern
Rhodesia (previously used by Smith et al., 1951 and referred to as 2.5 μ
sample), and with normal lung ash, were made with different buffers and
hydrochloric acid at different concentrations, and 0.1 N hydrochloric acid
was finally used as a compromise. It left about 20 per cent of the ash from

TABLE 2
AVERAGE QUANTITY OF MINERAL RESIDUE IN ASBESTOSIS
LUNGS FROM GREAT BRITAIN

	Grade of Fibrosis			All
	Minimal	Moderate	Severe	
Residue per cent dried lung				
Mean	1.4	1.7	1.8	1.6
Range	0.7-2.5	0.9-3.4	0.6-2.8	
No. of samples	1	10	10	21
Residue in grams in both lungs				
Mean	2.8	3.4	3.6	3.3
Range	1.4-5.8	1.6-7.0	1.2-8.3	
No. of samples	1	10	10	21

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TABLE 3
ASBESTOS ESTIMATES IN MINERAL RESIDUES OF
ASBESTOSIS LUNGS FROM GREAT BRITAIN

X-ray and Microscope estimate	Grade of Fibrosis			
	Minimal	Moderate	Severe	All
Much	-	2	2	4
Some	2	3	2	7
Trace or none	3	5	8	14
All	5	10	10	25

a normal lung and removed 30 per cent of the chrysotile, but the remaining chrysotile could still be identified by X-ray diffraction and polarised light microscope techniques.

Detailed results of the analyses, together with exposure and survival times, are given in TABLE 9, in which the lungs have been grouped by the increasing grades of fibrosis. Average results for the amounts of mineral residue found are given in TABLE 2. There is a slight increase in the amount of dust with increasing grade of fibrosis, but the difference between the moderate and severe groups is not significant, and the data expressed as per cent dried lung show hardly any difference.

The residues were examined by light microscopy. The amount of fiber seen ranged from nil to significant proportions in a few residues. Identification of asbestos by X-ray diffraction was based on the appearance and intensities of four lines at 9, 4.5, 3.3, and 3.1 angstrom units. Line intensities and fiber frequencies were scored roughly as "nil or trace," "some," and "much," and a reasonable concordance between both sets of scores was found. Average results for the three grades of fibrosis are set out in TABLE 3.

"Much," "some," and "nil or trace" may correspond to 10, 1, and 0.1 per cent by weight but these are rough guesses. If one assumes that the 11 residues which showed more than traces of asbestos all contained 10 per cent, then the average amount of asbestos found in these lungs would have been 0.17 per cent dried lung (range 0.06 to 0.34 per cent) or less than 0.5 gm. (range 0.17 to 0.70 gm.) in both lungs, but this is likely to be an overestimate.

The type of asbestos found was amosite rather than crocidolite, if one accepts the criterion of the larger refractive index being along the fiber axis as proof. The X-ray diffraction patterns obtained in 9 cm. diameter

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Mean Fe_2O_3

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Grams in both l

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TABLE 4
AVERAGE AMOUNTS OF SiO_2 AND Fe_2O_3 IN ASBESTOSIS LUNGS FROM
GREAT BRITAIN

	Grade of Fibrosis			
	Minimal	Moderate	Severe	All
Per cent dried lung				
Mean SiO_2 per cent	0.08	0.22	0.24	0.18
Range	0.05-0.10	0.05-0.69	0.12-0.37	
Mean Fe_2O_3 per cent	0.29	0.47	0.44	0.40
Range	0.20-0.36	0.15-0.91	0.33-0.54	
No. of samples	3	10	7	20
Grams in both lungs				
Mean SiO_2	0.16	0.52	0.76	0.48
Mean Fe_2O_3	0.58	1.06	1.30	0.98
No. of samples	3	10	7	20

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cylindrical cameras with cobalt $\text{K}\alpha$ radiation show no clear differences for the two asbestos types when these are present in small quantities. No positive identification of chrysotile could be made in any of the residues by microscopy or X-ray diffraction, but most residues showed the presence of small amounts of quartz, and unidentified lines occurred in several residues.

The average amounts of silica and iron oxide found in the lungs are given in TABLE 4. As with the mineral residues, there is no clear difference between moderate and severe fibrosis although the figures for minimal fibrosis, based on three lungs only, are lower. If all silica found by ash analysis was in the residues these would, on average, have contained 13 per cent of silica (range 4 to 33 per cent); in fact, the silica content of the residues may well have been still lower.

The iron content of the lungs is well above that found for lungs of people not exposed to dust, which according to the literature and to data obtained by us is of the order of 0.1 per cent dried lung. Much of this iron may have come from debris of asbestos bodies which was found copiously by microscopy in the mineral residues. The iron content of the lungs of miners with various X-ray categories of simple pneumoconiosis is shown in TABLE 5, together with the average amounts of dust (coal and minerals), and compared with the data for the asbestosis lungs. These

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TABLE 5
COMPARISON OF IRON AND DUST CONTENT OF
ASBESTOS WORKERS' LUNGS WITH SIMILAR DATA
FOR COAL MINERS WITH SIMPLE PNEUMOCONIOSIS

	Fe ₂ O ₃ per cent dried lung	Total dust in both lungs (grams)	No. of lungs
Coal miners			
X-ray category 0	0.38	8.4	34
1	0.45	20	28
2	0.56	27	24
3	0.64	38	19
Asbestos workers' lungs from Great Britain	0.43	4.2	20

have about as much iron as the lungs of coal miners with X-ray category 1 but contain far less dust.

The average ratio of Fe₂O₃ to SiO₂, as per cent dried lungs, for the whole series is 2.7, and it tends to rise as the fibrosis grade falls, but the scatter of values is high.

An attempt was made to relate the asbestos estimates and silica values to exposure and survival periods. There may be a slight tendency for high asbestos values, and also for high silica values as per cent dried lung, to be associated with shorter rather than with long survival periods, but the scatter is so large and the asbestos estimates are so inexact that no definite conclusions can be based on the data.

The main conclusion from this study of asbestosis lungs from Great Britain is that in over half the lungs, irrespective of grade of fibrosis, no more than traces of asbestos could be found. In other lungs fibers, probably amosite, could be identified in varying proportions. Their amount may have been of the order of 0.1 to 0.3 per cent dried lung, or less than one gram in both lungs.

Asbestos Lungs from South Africa

Asbestos workers in Great Britain usually have mixed dust exposure in the sense that they may have been exposed to chrysotile, amosite, and crocidolite dusts.

In order to be certain of the type of dust exposure one has to find men who only worked in specific mines. J. C. Wagner of the Pneumoconiosis Research Unit, Cardiff, and formerly of the Pneumoconiosis Research Unit in Johannesburg, South Africa, arranged through I. Webster of Johannesburg, for such lungs to be made available. The plan was that the lungs

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would be examined in Johannesburg, the grade of asbestosis determined, and industrial histories taken. The lungs would then be dried and ground and split into two portions for dust analysis in Johannesburg and Sheffield. Dust isolations in Johannesburg were to be made by the formamide method of Thomas and Siegemann (1954), and the residues would be examined by chemical and physical methods.

In the Sheffield laboratory we wanted to try, for dust isolation, a new method developed by I. Bergman for the isolation and determination of coal of low rank from coal miners' lungs. In this method the lung tissue is destroyed by treatment with a mixture of acetic acid and ammonium acetate, and the residues are further treated with formic acid. Tests with amosite, crocidolite, and chrysotile had shown that the former two minerals were not attacked or altered by this treatment although chrysotile was decomposed. At the time of writing analytical data and information on the lungs are incomplete. However, the numbers of the lungs so far examined, grouped according to grade of fibrosis and type of dust, are shown in TABLE 6, together with the average amounts of residue for the different grades of fibrosis. The residues averaged 2 per cent dried lung, and neither the type of asbestos nor grade of fibrosis showed any clear relationship to the amount of residue.

Microscopic inspection showed the number of fibers in the residues to vary from nil to significant proportions, and fiber frequencies were scored as "trace or nil," "some," and "much," as with the lung residues from Great Britain. Out of 22 residues four were scored as containing "much" and five "some" asbestos, while 14, over half the samples, showed only traces of fibers. Fiber frequencies were not related to grade of fibrosis but

TABLE 6
ASBESTOSIS LUNGS FROM SOUTH AFRICA
NUMBER OF LUNGS WITH DIFFERENT GRADES OF FIBROSIS AND
TYPES OF ASBESTOS, AND ACETIC ACID RESIDUE CONTENT

Type of asbestos	Grade of Fibrosis			
	Minimal	Moderate	Severe	All
Amosite	3	5	1	9
Crocidolite	6	6	2	14
All	9	11	3	23
Acetic acid residue per cent dried lung				
Mean	2.0	1.7	2.5	1.9
Range	0.8-3.8	0.8-2.7	1.9-3.4	

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TABLE 7
FIBER ESTIMATES IN ACETIC ACID RESIDUES
OF ASBESTOSIS LUNGS FROM SOUTH AFRICA

Fiber estimate	Grade of Fibrosis			
	Minimal	Moderate	Severe	All
Much	1	3	1	4
Some	2	3	0	5
Trace or none	5	6	2	13
All	8	11	3	22

markedly to type of asbestos, as shown in TABLES 7 and 8. All the large fibers seen in the residues had the larger refractive index parallel to the fiber direction and could have been amosite. No X-ray diffraction diagrams of the residues were obtained.

Some Comments on Technique

In the study of asbestosis, as of other lung dust diseases, it is probably better to start with fairly superficial work on many lungs than with very detailed work on any one particular lung, although much can be said for the latter approach.

Destruction of lung tissue. The best method of isolating asbestos, free and inside asbestos bodies, from lung tissue is not at present known. Filling of the wet lung is probably not a suitable method for quantitative studies. The hydrogen peroxide technique was first used at Sheffield when work with asbestos lungs from Great Britain started in 1955, but trouble with foaming occurred and too much working time was needed. This was the reason for adopting aniline technique, a well-established routine operation.

TABLE 8
LUNG RESIDUES OF ASBESTOSIS FROM SOUTH AFRICA:
NUMBERS OF RESIDUES WITH DIFFERENT FIBER FREQUENCIES
AFTER EXPOSURE TO AMOSITE AND CROCIDOLITE

Type of Asbestos	Microscope Fiber Estimates		
	Trace or none	Some	Much
Amosite	0	4	4
Crocidolite	13	1	0

DETAILED DATA

Case No.	Grade of Asbestosis	Dis
1	Severe	1
2		1
3		1
4		1
5		1
6		1
7		1
8		1
9		1
10		2
11	Moderate	1
12		3
13		3
14		2
15		2
16		2
17		2
18		3
19		2
20		2
21	Minimal	2
22		2
23		14
24		1
25		1

*Interval between H₂O₂ residue, a

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TABLE 9
DETAILED DATA FOR 25 ASBESTOSIS LUNGS FROM GREAT BRITAIN

Case No.	Grade of Asbestosis	Dust exposure: Years		Dried weight of both lungs (grams)	Per cent dried lung				Asbestos score of residue
		In	Out*		Ash	Mineral residue	SiO ₂	Fe ₂ O ₃	
1	Severe	5	37	121	5.9	2.0	0.12	0.47	0
2		17	15	346	5.5	2.4	0.37	0.54	0
3		43	12	307	4.3	2.0	0.25	0.34	0
4		5	33	346	8.5	2.0	0.21	0.40	1
5		16	4	336	5.0	0.8	0.20	0.33	0
6		3	14	300	4.0	0.6	0.20	0.40	2
7				362	7.5	1.7	0.32	0.58	1
8				228	8.5	2.8	—	—	2
9				266	6.4	1.4	—	—	0
10		20	17	—	8.5	2.8	—	—	0
11	Moderate	11	4	319	6.1	1.5	0.10	0.31	0
12		32	2	326	6.8	2.1	0.22	0.40	1
13		37	2	158	6.3	1.0	0.05	0.15	0
14		4	2	150	5.8	1.8	0.08	0.29	0
15		27	19	272	6.5	1.9	0.35	0.33	0
16		8	24	211	6.4	0.8	0.07	0.18	0
17		28	4	206	4.6	3.4	0.69	0.91	2
18		24	—	218	8.0	1.1	0.11	0.47	1
19		30	8	194	8.7	1.3	0.11	0.33	1
20		21	1	236	4.8	2.0	0.20	0.70	1
21	Minimal	21	5	170	4.6	1.0	0.08	0.36	1
22		20	23	154	4.1	1.2	0.05	0.20	0
23		41	2	186	7.3	1.8	0.10	0.32	0
24		37	—	—	—	0.71	—	—	1
25		18	0	—	11.9	2.5	—	—	0

*Interval between end of dust exposure and death.
H₂O₂ residue, ashed at 580°C. and extracted with 0.1 N HCl.

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in the study of coal miners' lung residues. The use of antifoaming agents (Talvitie & Brewer, 1962) has changed the situation, and it is likely that destruction of the lung tissue with hydrogen peroxide or anhydrous formamide would be better methods than ashing, although the residues would still have to be freed from carbonaceous materials and, if present, hydroxyapatite; asbestos bodies do not seem to be attacked by hydrogen peroxide.

In the study of asbestos lungs from South Africa the acetic acid method was used because we wished to avoid ashing and because this method was used as a routine, at the time, in the study of coal miners' lungs. Although not suitable for the isolation of chrysotile, it seems to be a possible method for isolating amosite and crocidolite. It seems to remove most of the material that forms asbestos bodies, but it leaves carbonaceous material intact. "Coal" is in fact determined by the loss in weight found on ashing the acetic acid residues.

The acetic acid method was used on 13 samples of the previously examined asbestosis lungs from Great Britain. The yield was, on average, about half of that given by extracting the 880° ash with 0.1 N hydrochloric acid. Although the acetic acid residues contain more carbonaceous material, they weigh less because most of the iron compounds are missing.

Separation of chrysotile. Electrophoresis of dust in 0.001 molar sodium chloride at pH 5 was used in the Sheffield laboratory in the study of silica modifications. Observations by Bergman and Langrish suggest that it may be possible by this technique to separate chrysotile, as this mineral carries a strong positive charge in contrast to amosite, crocidolite, quartz, silica, and kaolin, which are all negatively charged.

Identification of Asbestos.

In general, the more the asbestos can be concentrated in a sample the easier is its identification. Microscopy with polarized light and suitable immersion liquids and X-ray or electron diffraction are probably the most reliable methods. Samples of appropriate size (fiber length of the order of 10 μ) of the different minerals after treatment in exactly the same way as used in the preparation of lung residues, should be used as standards for determining optical and X-ray diffraction properties. Phase contrast microscopy has been recommended (Schmidt, 1960), but we do not know how well this technique works with fibers of the size found in lung residues nor have we any experience with interference microscopy.

Electron microscopy has been used to a limited extent. Strongly curved fibers seem indicative of chrysotile although Huggins (1959) has shown that crocidolite (from Bolivia) may also occur in curved form.

Conclusion

The most interesting result of this study is that in over half the lungs

from Great Britain found, irrespective of the faulty technique used, asbestos, especially chrysotile, is likely that this is real and not an artifact. Asbestos does get into the lungs. To start with a reasonable amount, which would be enough to cause a physicochemical change in the lung tissue. The most resistant residues would be the most prevalent fibrous. In most other forms of asbestosis, a theory advanced (Nagelschmidt) in the lungs, pneumoconiosis, severity of fibrosis. The amounts of advanced stages of fibrosis, as seen in the case, the are not clearly related. The most likely explanation. Similar views expressed by Bergman describes fibrosis many years after exposure. Further, research on asbestosis is probably more difficult than most of the evidence.

BEATTIE, J. & J.
Ed. Pergamon
BROOK, P. J. 1953.
BROOK, P. J. 1949.
HUGGINS, C. W.
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from Great Britain and South Africa practically no asbestos at all was found, irrespective of grade of fibrosis. It is unlikely that this was due to faulty technique although further study of the technique of recovery of asbestos, especially of chrysotile, from lungs is undoubtedly required. It is likely that this effect — the disappearance of asbestos from the lungs — is real and needs to be explained. The most likely explanation is that asbestos does get dissolved in the lungs. The process of dissolution is likely to start with a removal of the cations, magnesium, sodium, iron, and aluminum, which would leave a skeleton of hydrated silica or polysilicic acid. On physicochemical and structural reasoning one would expect chrysotile to be most easily attacked, crocidolite to be intermediate, and amosite to be the most resistant form. The finding of amosite only in some of the lung residues would be in agreement with such reasoning.

The most prevalent type of fibrosis seen in asbestosis is a diffuse interstitial fibrosis, in contrast to focal or nodular lesions found initially in most other forms of pneumoconiosis. At a later stage massive lesions may develop. A theory linking this contrast with lung dust studies has been advanced (Nagelschmidt, 1960). According to this theory the dust remaining in the lungs causes the fibrosis in coal workers' and similar forms of pneumoconiosis, and a positive correlation between amount of dust and severity of fibrosis or X-ray category of simple pneumoconiosis, is found. The amounts of dust in the lungs are large and may average 50 gm. for advanced stages of coal workers' pneumoconiosis. In diffuse interstitial fibrosis, as seen mainly in aluminosis and asbestosis, this does not seem to be the case; the amounts of asbestos found in the lung are very small and are not clearly related to grade of fibrosis; dissolution of the dust is the most likely explanation.

Similar views with regard to the action of chrysotile had already been expressed by Beger. A refinement of the same theory, by Beattie and Knox, ascribes fibrosis to the breakdown of the asbestos bodies, which may occur many years after exposure to asbestos has ceased.

Further research is obviously required before the mechanism by which asbestosis is produced can be said to be known. The study of lung residues in asbestosis will form a part of such research, but it is likely to be much more difficult than, for instance, in coal workers' pneumoconiosis because most of the evidence may have disappeared.

References

- BAKER, J. & J. F. KNOX. 1961. Inhaled Particles and Vapours. C. N. Davies, Ed. Pergamon Press, New York, N. Y.
- BEATTIE, F. J. 1933. Arch. Pathol. Anat. Physiol. 29: 280.
- BEGER, F. J. 1949. Verhandl. Dtsch. Ges. Pathol. 23: 291.
- MOORE, C. W. 1959. U. S. Bur. Mines. Rep. Invest. (No. 5551).
- LEPPENHOFER, G. F. 1935. Arch. Gewerbepathol. Gewerbehyg. 5: 88.
- NAGELSCHMIDT, G. 1960. Brit. J. Ind. Med. 17: 247.

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- SCHMIDT, K. G. 1960. Staub 26: 173.
 SMITH, J., I. D. P. WOOTON & E. J. KING. 1961. Thorax. 6: 127.
 SUNDIUS, N. & A. BYGDE. 1938. Arch. Gewerbepathol. Gewerbehyg. 8: 26.
 TALVITT, N. A. & L. W. BREWER. 1962. Am. Ind. Hyg. Assoc. J. 23: 58.
 THOMAS, K. & H. STEGEMANN. 1954. Beitr. Silikose-Forsch. (No. 28).

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