Occupational Health

THE HYGIENE STANDARD FOR CHRYSOTILE ASBESTOS*

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Summary Previous studies, including the analysis on which the current 2 fibres/cm³ hygiene standard is based, may have underestimated the risk of morbidity or mortality following exposure to low levels of asbestos dust. Accurate dose-response data at levels below 2 fibres/cm³ are unlikely to be available for the foreseeable future, and the biologically plausible assumption that excess cancer mortality is approximately proportional to dust level should be provisionally accepted. It may be reasonable, however, to postulate a safe threshold for mortality from asbestosis. If excess mortality from asbestos-related disease is proportional to dust level for each cause, approximately 10% of male asbestos workers might, under certain assumptions, eventually die of asbestos-induced disease after 50 years' exposure at 2 fibres/cm³. Peritoneal mesothelioma is usually due to crocidolite (blue asbestos) or other amphiboles, but exposure to chrysotile (white asbestos) alone may lead to a substantial risk of pleural mesothelioma. These predictions are based on rather small numbers in a single factory, and further studies in other working environments are required. Fibre counts based on optical microscopy are likely to be less relevant than total counts by electron microscopy, and excess mortality is virtually confined to men first exposed more than 20 years ago, when little or no accurate data on dust levels were collected.

THE PRESENT STANDARD

THE current hygiene standard of 2 fibres/cm³ for chrysotile asbestos dust was based on a study conducted in 1966 by the British Occupational Hygiene Society (B.O.H.S.).[1] Currently employed asbestos textile workers who had been exposed for at least 10 years were examined, and the prevalence† of crepitations (basal râles) was related to cumulative dust exposure (fibre/cm³ years). A log-normal dose-response curve fitted the data adequately and led to the prediction that the cumulative dose corresponding to a 1% lifelong risk of developing crepitations was approximately 100 fibre/cm³ years, or 2 fibres/cm³ for 50 years (fig. 1).[2] Most men with cumulative exposures of less than 100 fibres/cm³ years had been employed for between 10 and 20 years at average dust levels of less than 10 fibres/cm³, and the absence of crepitations in this group was the basis for the prediction that the effect of 50 years' exposure at 2 fibres/cm³ would be minimal.

This prediction would be reasonable if crepitations (an early sign of the effect of accumulated asbestos exposure) rarely appear or progress after exposure has ceased. However, other assumptions consistent with these data could lead to a predicted risk an order of magnitude higher than 1% following 50 years' exposure at 2 fibres/cm³. For example, suppose: (1) that pulmonary damage caused by inhaled asbestos dust is progressive, either because fibres remain in the lung or because the fibrosis they engender progresses after they have been eliminated; (2) that crepitations rarely appear less than 10 years after first exposure; (3) that men are usually removed from employment when they develop crepitations; and (4) that incidence (rate of appearance of new cases) is approximately proportional to cumulative exposure after an initial lag of 10–15 years. The B.O.H.S. study comprised all men who had started work since 1933, had completed 10 years' service, and were still employed in 1966. The proportion of men with crepitations rose from zero at exposures below 100 fibre/cm³ years to over 16% at 400 fibre/cm³ years. Under assumptions (1) to (4) the lack of cases in the lower-exposure groups might merely reflect a delay between first exposure and the appearance of crepitations, while the prevalence at 400 fibre/cm³ years would, if men were usually removed from employment within, say, 4 years of developing crepitations, suggest that the annual risk of developing crepitations after a cumulative exposure of about 400 fibre/cm³ years might be 4% per annum. (This figure depends on the average time from first detection of crepitations to early retirement, which has arbitrarily been taken to be 4 years. If employment normally continued for 8 years after the detection of crepitations the predicted incidence corresponding to 400 fibre/cm³ years would be roughly halved.) If incidence is proportional to cumulative dose the incidence at 2 fibres/cm³ might thus rise from zero during the first 10–15 years to about 1% per annum after 50 years, when the cumulative exposure would be 100 fibre/cm³ years. The risk of developing crepitations by retirement after 50 years' exposure at 2 fibres/cm³ would then be about 20%, and some further cases would appear after retirement. This figure is not presented as a useful prediction of the likely risk. It is intended only to illustrate the importance of the assumptions implicit in such extrapolation, particularly when prediction of the long-term effects of low exposure is based on initial response to relatively high exposure.

MORBIDITY AS A BASIS FOR A HYGIENE STANDARD

The B.O.H.S. analysis is significant because it is the basis of the current standard. However, the risk of developing crepitations may not be an appropriate basis for a hygiene standard. The sign itself is virtually asymptomatic and may not progress to severe breathlessness or entail a substantially increased risk of bronchial carcinoma or mesothelioma. In the absence of direct observation of the prognosis in affected workers a standard based on such early signs may thus be unreasonably restrictive. Moreover, if data on severe disability or death are sufficient to evaluate the significance of the sign they will also be sufficient to assess the serious risk directly, so there may be little advantage in considering the prevalence of such a sign in framing a hygiene standard. This is not to say that such early signs are not

*Based on a report presented to the Advisory Committee on Asbestos (Health and Safety Executive) in London on June 28, 1977.

†The *prevalence* of a sign is the proportion or percentage of workers with the sign at a particular time. This must be distinguished from *incidence*, which is the rate of appearance of new cases in previously unaffected men, and is usually expressed as a proportion or percentage per annum.

worth studying. They contribute to an understanding of the natural history of the disease process, and increased mortality in a small proportion of workers with crepitations can be detected and estimated before the overall excess approaches statistical significance.

It should also be pointed out that a 1% lifelong risk of developing such a mild condition may be too stringent a criterion.

THRESHOLD AND LINEAR MODELS FOR CANCER INDUCTION

Since the pragmatic implications of a non-linear dose-response model such as that in fig. 1 and the assumption of a threshold (absolutely safe level) are similar I shall apply the term "threshold" to both. The distinction is of scientific importance, but in the absence of biological understanding epidemiological data cannot establish whether a safe exposure level exists. Crump et al. argued on theoretical grounds that legislators should assume linear dose-response below the range of observation, even when the data suggest a quadratic model, particularly for carcinogens,[3] but for asbestos this is an academic point. The apparent threshold for crepitations could be an artefact for the reasons cited above, while for lung cancer and mesothelioma there is neither theoretical nor statistical evidence to suggest that the relation between dose and response is anything other than linear.

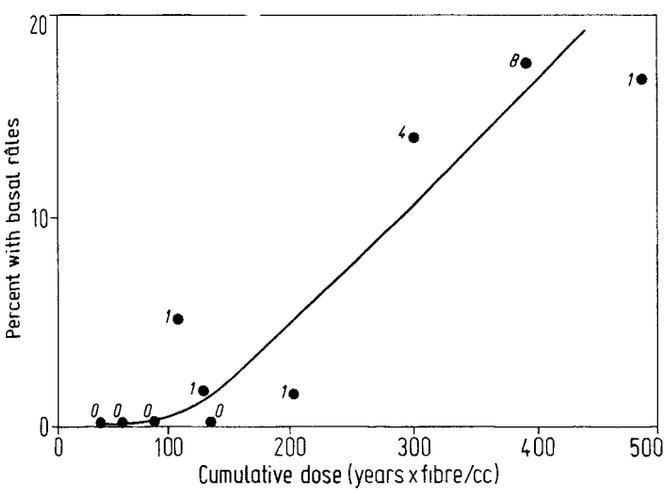

Fig. 1—Dose-response relationship for prevalence of basal râles in workers in a chrysotile asbestos factory (data from Berry[2]).
Log-normal curve. Numbers of cases in italics.

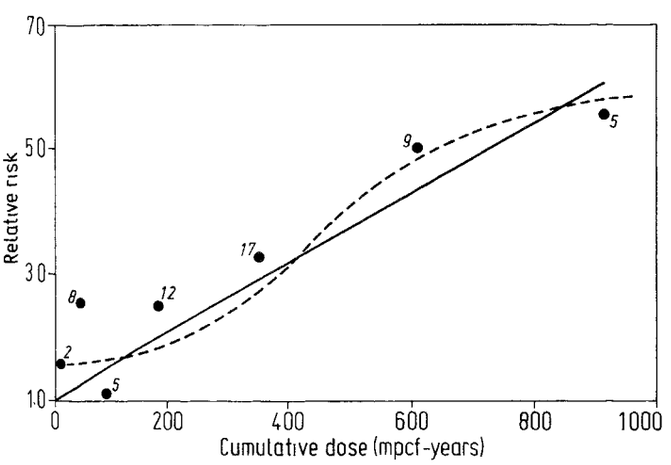

Fig. 2—Relative risk (observed/expected) for respiratory cancer in retired asbestos workers (data from Enterline et al.[5]).
– – – – – – – – Original cumulative normal curve. Numbers of deaths in italics.

PREVIOUS STUDIES RELATING CUMULATIVE EXPOSURE AND LUNG-CANCER MORTALITY

The suggestion that the eventual proportional excess (relative risk minus one) of bronchial carcinoma is approximately proportional to cumulative asbestos exposure[4] is supported by published work. Enterline's data[5] suggest such a linear relationship, but he rather arbitrarily superimposed a normal distribution (fig. 2) and concluded: "Had larger numbers been available it might have been possible to identify more precisely a T.L.V. (threshold limit value) for respiratory cancer in this type of population. The available data suggest, however, that large increments in respiratory cancer appear at a cumulative asbestos-dust exposure of somewhere between 100 and 200 mpcf-years." Similar data were reported by McDonald et al.[6] These authors inferred that "excess mortality was virtually confined to men with exposure equivalent to at least 400 mpcf-years" and concluded that "considering all facets of disease—death, roentgenographic changes, pulmonary function changes, and respiratory symptoms—the 1% risk is reached by men in our third dust exposure category (100–200 mpcf-years)". However, a straight line appears to fit their data well (fig. 3), and the corresponding proportional excess of respiratory cancer at 150 mpcf-years—about 30%—would alone constitute a lifelong risk greater than 1%, ignoring morbidity and asbestosis mortality.

A cohort briefly exposed to amosite at the beginning of the 1939–45 war has been followed up by Seidman et al.[7] This study is particularly valuable for testing models of the likely long-term effects of asbestos exposure, since the workers' cumulative doses (fibre/cm³ years or mpcf-years) have remained constant over more than 30 years, and the recorded duration of exposure, which was less than 2 years for most of the cohort, is probably closely proportional to cumulative dose. The relative risk for lung cancer rose for about 20 years and

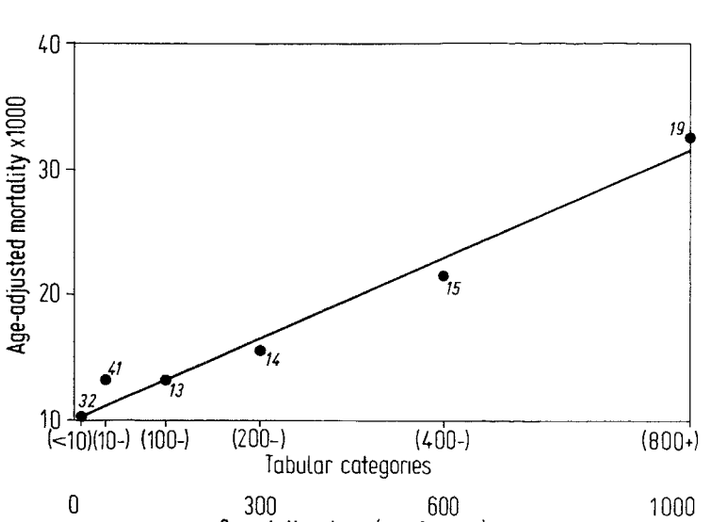

Fig. 3—Age-adjusted respiratory-cancer mortality in chrysotile mine and mill workers (data from McDonald et al.[6]).
The highest category (800 or more mpcf-years) is plotted at 1000 mpcf-years. Other categories are plotted at their mid-range. Numbers of deaths in italics.

then remained nearly constant. The assumption that proportional excess risk is proportional to cumulative dose may therefore be a useful approximation in retired workers or groups such as the asbestos textile workers described below whose exposure during recent years has been low compared with their earlier exposures, but a more sophisticated model is required to describe the slow initial rise. If the duration of brief exposure can be taken as a measure of total dose the results of this study appear to suggest that for respiratory cancer lower doses may be proportionately more dangerous, and Knox[8] inferred that the cancer risk is proportionately higher at lower dust levels or shorter exposures. However, neither these data nor the studies he reviewed are described in enough detail to confirm such a pessimistic conclusion. Such apparent non-linearity could be due to selective removal of workers who develop respiratory symptoms, saturation at very high exposures, underestimation of expected numbers, or random error in estimates of dose or duration of exposure.

A HYGIENE STANDARD BASED ON FIBRES/CM³

The studies described in the preceding section support the suggestion that dose-response is likely to be approximately linear for bronchial carcinoma, and the first two studies illustrate the common error of inferring that there is a safe threshold because mortality in the lowest-exposure groups is not significantly increased. They may be of little quantitative relevance in framing a standard based on fibres/cm³, however. The correspondence between fibres and particles is very variable,[9] and the estimates of risk shown in figs. 2 and 3 differ by a factor of more than two, perhaps reflecting differences of particle size and type in different environments. Pleural mesothelioma should be analysed separately. Excess mortality is likely to be proportional to the amount of dust that penetrates the bronchus for bronchial carcinoma or reaches the pleura for pleural mesothelioma, but the relationship with airborne concentration is not known. Different types and sizes of fibre are likely to be distributed and eliminated differently. It may be reasonable to relate excess mortality to estimated particle or fibre counts in a particular environment, but different working conditions may not affect the risk uniformly for each disease.

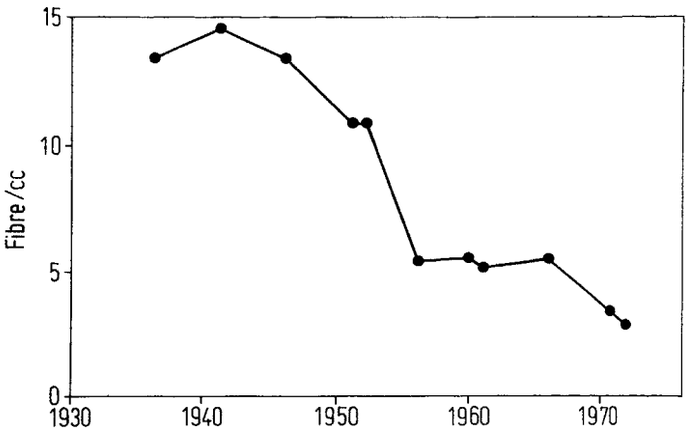

Fig. 4—Average dust levels, weighted by the number of men at each level, in an asbestos textile factory, 1936–72.

(Data from Peto et al.[10]).

MORTALITY IN ASBESTOS TEXTILE WORKERS

The 679 men in the asbestos textile factory in which the B.O.H.S. study was conducted who entered scheduled areas after Jan. 1, 1933, and had worked for at least 10 years by Dec. 31, 1972, have been followed up to the end of 1974.[10] The B.O.H.S. cohort is thus included, together with men who retired or died before June 30, 1966, and those who completed 10 years' service between June 30, 1966, and Dec. 31, 1972. Deaths from bronchial carcinoma, pleural mesothelioma, other respiratory diseases, and other causes are compared with expected numbers based on national rates in table I. This shows a substantial excess due to cancer and respiratory disease beyond 25 years after first exposure (35 observed; 15·74 expected). Mortality due to other causes has been normal, except for the "healthy worker" effect between 10 and 15 years after first exposure (14 observed; 21·63 expected). These men were still employed at the start of the period of observation and were therefore unlikely to be chronically sick during this first period.

DUST EXPOSURE

Estimated average dust levels over the period of the study are summarised in fig. 4.[10] The average (weighted by the number of men at each level) was approximately 13 fibres/cm³ up to 1950, falling to about 5 fibres/cm³ by 1955. Individual exposure histories have not yet been compiled for the whole group, but for diseases for which excess risk is approximately

TABLE I—MORTALITY IN 679 ASBESTOS TEXTILE WORKERS AFTER 10 OR MORE YEARS' EXPOSURE

Years since first exposure	Man-years	Mesothelioma		Bronchial carcinoma		Other respiratory disease		Other causes		All causes		Excess respiratory deaths* (Obs-Exp) (B)	Attributable excess mortality (B/A)
		Obs	Rate per annum	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp (A)		
10–	2727	0	0·0000	3	3·07	2	3·54	14	21·63	19	28·24	−1·61	0·00
15–	2612	0	0·0000	7	4·25	6	4·95	27	28·65	40	37·85	3·80	0·10
20–	1964	1	0·0005	5	4·50	6	5·56	35	30·03	47	40·09	1·94	0·05
25–	1188	1	0·0008	8	3·57	10	5·07	23	25·21	42	33·85	10·36	0·31
30–	630	2	0·0032	5	2·31	5	3·25	16	15·99	28	21·55	6·44	0·30
35–	189	1	0·0053	1	0·69	2	0·85	6	4·50	10	6·04	2 46	0·41
Total	9310	5	0·0005	29	18·39	31	23·22	121	126·01	186	167·62	23·39	0·14

Obs=observed, Exp=expected.

* Combined excess (observed minus expected) for mesothelioma, bronchial carcinoma, and respiratory disease.

proportional to dust level these average levels can be related to overall excess mortality, as 100 men exposed to 1 fibre/cm³ and 100 at 3 fibres/cm³ would show subsequent excess mortality similar to that of 200 men exposed to 2 fibres/cm³ over a comparable period. Such aggregation is done implicitly in any study. Measured levels vary considerably over time in each area, so even a group nominally exposed to 2 fibres/cm³ will have experienced a wide range of dust levels. The excess risk appears to be largely confined to the period beyond 25 years after first exposure (table I), when the excess mortality from respiratory disease, including bronchial carcinoma and mesothelioma, exceeded the expected mortality from all causes by 31% (19·26/61·44). The average exposure which caused this excess can be roughly summarised by total employment during the 30 years following first exposure. Table II, which is based on the 158 men followed up for at least 30 years, suggests that this exposure consisted on average of about 11·6 years before 1954 at an average dust level of about 13 fibres/cm³ followed by 9·4 years at an average of about 5 fibres/cm³—a cumulative dose close to 200 fibre/cm³ years.

Dust levels in fibres/cm³ were estimated in each area from membrane-filter measurements at fixed sampling points from 1961 onwards. Thermal-precipitator measurements in particles/ft³ taken between 1951 and 1960 were converted to fibres/cm³ using the observed ratio of parallel measurements obtained by the two methods in 1960 and 1961. Routine measurements were not made before 1951. Estimated levels in fibres/cm³ in each area of the factory are therefore based on direct observation after 1961 and conversion from particles/ft³ to fibres/cm³ between 1951 and 1960. Estimates before 1951 are based on the assumption that levels in each area fell from 1·5 times the 1951 values between 1933 and 1950. It is difficult to assess the error in this factor. Excess mortality does not appear to have been much higher in men first employed between 1933 and 1950 than among those first employed after 1950,[10] and in view of the technical continuity in many areas between 1933 and 1950 it was considered likely that dust levels did not fall substantially over this period. However, this crucial assumption is open to dispute and cannot be proved until further follow-up has provided a more accurate estimate of excess mortality in more recent employees. Exposure was predominantly to chrysotile, although a small proportion of the fibre processed was crocidolite at various times after 1933.

TABLE II—EXPOSURE (TOTAL SERVICE IN SCHEDULED AREAS) IN MALE ASBESTOS TEXTILE WORKERS IN THE 30 YEARS FOLLOWING FIRST EXPOSURE*

Year of first exposure	No. of men	% distribution of total exposure (yr)				Average exposure (yr)	
		10–	15–	20–	25–	up to 1953 (approx. 13 fibres/cm³)	from 1954 (approx. 5 fibres/cm³)
1933–34	6	17	0	67	17	14·1	7·7
1935–39	104	25	19	19	37	12·0	9·3
1940–44	48	23	19	31	27	10·5	10·0
Total	158	24	18	25	33	11·6	9·4

* Men followed up for less than 30 years are omitted.

BRONCHIAL CARCINOMA

Mortality due to lung cancers other than pleural mesothelioma in this cohort has been approximately twice the national average beyond 25 years after first exposure (14 observed; 6·57 expected). There is no evidence that the relative risk increases beyond 25 years, which perhaps reflects the relatively negligible increase in cumulative dose in recent years. Dust levels in this asbestos textile factory have been much reduced since 1955. This interpretation is supported by an earlier study. Pre-1933 workers, who were exposed to very high levels before 1933 and comparatively low levels subsequently, showed a similar lack of progression beyond 20 years for both bronchial carcinoma and asbestosis mortality.[11] If the eventual proportional increase in mortality due to bronchial carcinoma is approximately linearly related to cumulative exposure and the risk is doubled at 200 fibre/cm³ years, a level of 1 fibre/cm³ *might*, after 50 years' exposure, increase mortality due to this cause by 25% after retirement, corresponding to a lifelong risk‡ of bronchial carcinoma attributable to asbestos of about 3% in smokers.[4] The risk to non-smokers is probably very small. Asbestos and cigarette smoking appear to enhance each other's effects in causing bronchial carcinoma,[12] but mortality due to this cause is so low in asbestos workers who have never smoked that the risk due to asbestos cannot be estimated with any confidence from published work.

A MORE GENERAL LINEAR MODEL FOR BRONCHIAL CARCINOMA

This analysis is based on the assumption that the relative risk for bronchial carcinoma is increased in proportion to cumulative dose. As this is not precisely true a less restrictive assumption may be preferable. Bronchial carcinoma accounts for an approximately constant proportion of male deaths in England and Wales (12% at age 50–54, falling to 10% at age 70–74), and various studies suggest that the relative risk for this cause does not fall with the passage of time after exposure to asbestos has been substantially reduced or ceased. The observed excess mortality due to bronchial carcinoma as a proportion of total expected mortality beyond 25 years (7·43/61·44, or 12%) is therefore a reasonable estimate of the lifelong attributable risk in this cohort. It would follow, under any model which predicts that the increase in risk is approximately proportional to dust level, that a similar period of exposure at a reduced dust level would produce a proportionately lower risk. Thus a group that had on average been exposed to 1·3 fibres/cm³ rather than 13 fibres/cm³ for about 12 years followed by 0·5 fibres/cm³ rather than 5 fibres/cm³ for about 9 years would probably have a lifelong attributable excess risk due to bronchial carcinoma of about 1·2%. The conclusion that about 20 years' exposure at about 1 fibre/cm³ is likely to cause bronchial carcinoma in roughly 1 man in 100 thus follows from any linear model, but a more specific assumption is required to predict the effect of 50 years' exposure.

PLEURAL MESOTHELIOMA

As only 5 cases of pleural mesothelioma have occurred in this group, any model-fitting or extrapolation must be very speculative. These 5 cases are tabulated by man-years of observation in table I, which suggests that incidence rises sharply with increasing time since first exposure. A formal residence-time model with linear dose response for cancer incidence is given by the equation:

$$\text{Incidence at time T after first exposure} \propto \int_{t=0}^{t=T} (T-t)^k \, c(t).dt$$

where c(t) is the dust level at time t. The value k=2 fits the incidence rates in table I well and corresponds closely to Newhouse and Berry's finding that incidence rose as $(t-9)^2$ after heavy mixed exposure to chrysotile and crocidolite had ceased.[13,14] Applying the observed rates in table I, the predicted

‡Diseases for which the excess risk persists beyond retirement cannot be summarised by relative risk or cumulative prevalence at a particular age. The appropriate statistic is the proportion who will eventually die of the disease as a result of their exposure. This is described throughout as the "lifelong risk".

prevalence after 50 years' exposure at 1 fibre/cm³ corresponding to this model is 1·6%.§

The corresponding lifelong attributable risk to a man exposed to 1 fibre/cm³ from age 15 to 65 is approximately 2%. It must be emphasised that this estimate is necessarily unreliable. It is based on only 5 cases, and 2 of these were in men employed in an area where raw asbestos was handled who should perhaps be excluded from the calculation, almost halving the predicted risk.

BRIEF OR NON-OCCUPATIONAL EXPOSURE

Malignant diseases such as mesothelioma or bronchial carcinoma for which the incidence rises as the third or higher power of time since first exposure to a carcinogen cannot be understood without such formal analysis. For example, there had up to the end of 1975 been 10 cases of pleural mesothelioma among approximately 20 000 men first employed in this factory after 1933. To express this as a risk of 0·05% is meaningless. The lifelong risk to a man employed continuously since 1933 may exceed 10%. On the other hand, the suggestion that brief exposure is extremely dangerous is equally misleading. Preliminary results of a study including the entire past and present workforce support the suggested model, and only 1 case is known to have occurred in approximately 15 000 men exposed for less than 2 years since 1933. Isolated case-reports with a history of minimal exposure must be viewed against some hundreds of thousands of men and women with slight occupational exposure and several millions with casual non-occupational exposure. A recent study confirming that the risk of mesothelioma is dose-related suggests that only very high dust levels produce an appreciable risk after brief exposure.[15]

MINIMAL CROCIDOLITE EXPOSURE IN CHRYSOTILE WORKERS

It has been argued that pleural mesothelioma is due to crocidolite even when it occurs in workers whose exposure has been largely to chrysotile with minimal exposure to other fibres. Evidence from three sources appears to contradict this interpretation: (1) 9 cases¶ have occured in Canadian chrysotile miners and millers with no exposure to crocidolite;[16] (2) the incidence in our study has been comparable to that in Newhouse and Berry's[13] cohort of workers with heavy crocidolite exposure. Their data show a clear dose-response for both severity and duration of exposure. Although average exposures were longer in our cohort, total exposure to crocidolite was so much lower that the risk of mesothelioma should have been far less than that observed in the factory we studied if crocidolite were the sole cause of mesothelioma; (3) workers exposed to crocidolite show a comparable incidence of peritoneal and pleural mesothelioma. For example, 22 of the 45 mesotheliomas reported by Newhouse and Berry[13] were peritoneal in origin. None of the 34 that have occurred in workers in the factory we studied (including women and pre-1933 employees) or the 9 cases in Canadian miners and millers were peritoneal. An obvious explanation for this difference is that chrysotile causes only pleural mesothelioma, whereas crocidolite causes both pleural and peritoneal tumours.

ASBESTOSIS

The lifelong risk of death from asbestosis following exposure to 1 or 2 fibres/cm³ cannot be predicted with any confidence. There are no grounds for assuming linear dose-response for such a generalised progressive disease, and although a qualitative dose-response has been demonstrated at very high exposure levels[11] there may well be a safe or virtually safe threshold. There were 17 deaths (9·17 expected) due to non-malignant respiratory disease over 25 years after first exposure in our study, including 5 attributed to asbestosis. If it is assumed that incidence is proportional to cumulative dose, the corresponding life-long attributable risk after 50 years' exposure at 1 fibre/cm³ would exceed 1%,[4] but this model is presented for lack of another rather than because it is particularly plausible biologically. Further data on early pulmonary signs may indicate whether a threshold exists, but even if the incidence of crepitations is linearly related to dust level the prognosis in affected workers may be related to the severity of preceding exposure.

DISCUSSION

There have been too few deaths in our study to estimate the risks or evaluate the suggested models adequately for each asbestos-related disease, but the overall excess is substantial. There were 80 deaths (61·44 expected) more than 25 years after first exposure, including 14 (6·57 expected) due to bronchial carcinoma, 17 (9·17 expected) due to non-malignant respiratory disease, and 4 due to pleural mesothelioma. The excess for asbestos-related disease thus exceeds the overall expected number by about 30%. The implications of these figures are perhaps obscured by the necessarily complex statistical models presented for each separate cause. If dose-response were linear for all causes (i.e., the risk of death due to asbestos exposure were proportional to dust-level for any given period of exposure) it would follow that about 20 years' exposure at about 1 fibre/cm³ would increase total mortality by about 3% 25 years after first exposure. The trend in the right-hand column of table I suggests that this proportional excess is likely to persist with the further passage of time, so such exposure might be expected to lead to fatal asbestos-induced disease in about 3% of men. The assumption of dose-linearity is dubious for asbestosis mortality, but both epidemiological findings and contemporary knowledge of carcinogenesis suggest that excess mortality from bronchial carcinoma and pleural mesothelioma is likely to be proportional to dust level.

These predictions might be grossly inaccurate. Individual cases have not been investigated in detail, and previous employment in dusty working environments may have contributed to the excess mortality in this cohort. Employment histories are now being re-examined, but the estimates of pre-war asbestos exposure are not reliable, and the assumption that there is no safe threshold cannot be confirmed without long-term prospective observation of workers exposed to low levels. The recent I.A.R.C. monograph on asbestos,[17] which provides a comprehensive reference source and summary of recent work, concludes that "at present, it is not possible to assess whether there is a level of exposure in humans below which an increased risk of cancer would not occur." There are thus three alternatives:

1. To conclude that the economic consequences of more restrictive legislation are not justified unless a further 15 or more years' observation of workers exposed to low levels of pure chrysotile shows the current standard to be dangerous.

2. To base a decision on these analyses. Ignoring sampling error, our results suggest that about 5–10% of men exposed for 50 years to chrysotile asbestos concentrations of 1–2 fibres/cm³ are likely to die of asbestos-induced disease. Plaus-

§Assuming that k=2 and that incidence 30 years after first exposure following 11·6 years at 13 fibres/cm³ and 9·4 years at 5 fibres/cm³ (table II) is 3 per 1000 per annum (table I, col. 3). This model can be justified biologically, but for practical purposes it is irrelevant whether incidence rises roughly as t^3, as this model predicts, or as $(t-9)^2$. These factors are closely proportional for values of t between 20 and 50 years, and below 20 years the incidence is negligible.

¶A further mesothelioma occurred in a woman in this population who had previously been exposed to crocidolite.

ible alternative models might reduce or increase this range by a factor of perhaps 2 (2½–5% or 10–20%), but the data on which to base such refinements will not be available in the foreseeable future.

3. To accept that linear dose-response models are appropriate, at least for cancer, but to defer a decision until our estimates are more precise and analogous studies have been conducted in other environments. It may not always be possible to assign meaningful individual exposures, but average exposures of the sort shown in fig. 4 could be estimated in many factories. The incidence of bronchial carcinoma and mesothelioma must be studied in environments with different fibre sizes before such predictions can be generalised. It should be emphasised that such studies will not afford much information on the effect of very low doses. Their only value is to give independent estimates of the slope of the dose-response curve in other industrial settings.

The epidemiological evidence that pleural mesothelioma can be caused by chrysotile alone is supported by the observation that chrysotile is quickly eliminated from the lung parenchyma but remains in the pleura, while amphiboles are present in very much lower concentrations in the pleura than in the lung.[18] This may be because amphiboles are more penetrant and less liable to dissolution, and having left the lung are more widely distributed elsewhere but less likely to remain in the pleura. The reported excesses of peritoneal mesothelioma and other non-respiratory cancers in crocidolite workers,[14] neither of which occurred in our cohort,[10] appear to support this interpretation. The persistence of some chrysotile in the pleura but very much less in the lung perhaps reflects differential dissolution in these sites. Electron-microscope studies of the peritoneum and other organs are urgently required to confirm or refute these speculations. Total fibre counts of both air and post-mortem tissue samples, in conjunction with mortality data, would greatly increase the value of comparative studies of other working environments.

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Questionable Routines

CRITICAL EVALUATION OF ADENOIDECTOMY

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Summary In two matched groups of thirty-two children, one which had tonsillectomy alone and the other which had tonsillectomy plus adenoidectomy, the symptoms generally attributed to adenoidal hypertrophy were equally common in both groups before operation and improved with equal frequency after operation whether or not the adenoids were removed.

INTRODUCTION

TEMPORARY improvement in symptoms after adenotonsillectomy may be due to *an* operation rather than *the* operation;[1] the effects of adenotonsillectomy should thus be compared with those of another operation, to exclude the placebo effect. We have compared the improvement in the symptoms of adenoidal hypertrophy in two groups of patients, only one of which had an adenoidectomy.

PATIENTS AND METHODS

Thirty-two children listed for adenoidectomy and tonsillectomy on the waiting-list of the Liverpool Ear, Nose, and Throat Hospital were matched for age and sex with thirty-two children listed for tonsillectomy alone (table I).

The parents were interviewed and asked about the symptoms attributed to adenoidal disease (nasal obstruction, snoring, rhinorrhœa, speech problems, cough, and headache) and the children were examined for corresponding signs—mouth breathing and abnormalities on anterior rhinoscopy.[2] At the time of examination the examiner did not know what operation the children were to have.

The children were then operated on and reassessed six weeks later, again without the examiner knowing what operation they had had.

The number of positive scores for each symptom and sign in each group was analysed by a χ^2 test, with a 2×8 contingency table. The proportion of children who improved in each group (x) was calculated and a modified arc sin transformation done on the proportion $(y=\arcsin (x/n+1)^{\frac{1}{2}}+\arcsin (x+1/(n+1)^{\frac{1}{2}})$. The transformed proportions were then compared by a *t* test for paired data.

RESULTS

In the two groups, there was no significant difference in the number of children who showed signs and symptoms of adenoidal hypertrophy before operation

TABLE I—PATIENTS

	Tonsillectomy		Tonsillectomy and adenoidectomy	
Sex	No.	Age range	No.	Age range
M	16	5 yr 5 mo. to 9 yr 6 mo.	16	5 yr 6 mo. to 9 yr 6 mo.
F	16	3 yr 6 mo. to 10 yr 8 mo.	16	3 yr 9 mo. to 10 yr 5 mo.