SUMMARY AND EVALUATION

Subject: Asbestos dust control standards in Britain and the U.S. and their relationship to occupational health. Of some interest.

Evaluation: This paper is essentially identical with the one presented by the author at the Conference on "The Control of Asbestos in the Working Environment," sponsored by the British Occupational Hygiene Society and the Asbestosis Research Council, London, June 18, 1969. That paper has previously been evaluated and distributed. The author is president of the British Occupational Hygiene Society.

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Title: "Hygiene Standards for Asbestos."

Summary: Hygiene standards of the BOHS are discussed and compared with those of the ACGIH. The British standards apply only to chrysotile, and recommend a lower TLV than the latest recommended by the ACGIH.

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HYGIENE STANDARDS FOR ASBESTOS*

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AS LONG as there is any airborne asbestos dust in the work environment there may be some small risk to health. Nevertheless exposure up to certain limits can be tolerated for a lifetime without incurring undue risks.

A hygiene standard for asbestos was published in the U.K. by the Ministry of Labour in 1960 and was taken from the annual list of Threshold Limit Values of the American Conference of Governmental Industrial Hygienists (ACGIH) (Committee on Threshold Limits, Annually).

The British Occupational Hygiene Society formed a Hygiene Standards Committee in 1965 to advise on hygiene standards. This Committee recommends the use of the ACGIH list of standards and supplements this with critical examinations of ACGIH and other standards considered unsatisfactory by British workers. The Hygiene Standards Committee has expert Sub-Committees, each of which is concerned with a specific standard. There is a sub-committee on asbestos dust in air, one on trichloroethylene vapour and its urinary metabolites, one on airborne vegetable dusts in the textile industry, another on noise criteria for hearing conservation and two new ones are coming into being; on cadmium oxide fume and silica dusts in air.

It is important to take into account the economic consequences of any recommendations made as well as the benefits to health, and this is one reason why on each of these Hygiene Standards Sub-committees, scientific and medical experts from industry are included. The value of a standard rises in proportion to the number of people who become protected by it. A particular advantage of direct industrial representation on hygiene standards committees is that the industry more readily identifies itself with the standards recommended.

The Hygiene Standards Sub-committee on Asbestos, under the Chairmanship of Professor Lane, has developed new hygiene standards for airborne chrysotile dust (LANE *et al.*, 1968). These were based on the results from a medical and environmental study at an asbestos textile factory in England, in which investigations were made on 290 of the men employed at this factory in the period of 1933–1966.

The Sub-committee considered that the degree and nature of the risk associated with the standards should be specified and the method of the derivation of the standard from the data presented should be described in detail. It was also considered that the standards should give prominence to the gradually increasing risk in relation to the concentration rather than to the single figure threshold concept. Open recognition should be given to the possibility that people might be adversely affected, even

*This paper was originally presented at a Conference on Exposure to Asbestos during Brake and Clutch Maintenance, held at Brentwood, Essex, March, 1969.

when the recommended standards of air cleanliness are maintained. It was recognised that to protect the hypersusceptible workers environmental control would have to be supplemented with medical examinations.

It was evident from the data made available to the Sub-committee, and from the earlier American experience, that when concentration is held constant the prevalence of asbestosis was highest among those with the greatest duration of exposure. Over a period of time, dust accumulates in the lungs and gives rise to asbestosis. However, some of the dust is removed from the lungs, for example, by being dissolved. Consequently, if it is assumed that none is removed and exposure is limited accordingly, a safety factor is thereby incorporated. The problem of relating prevalence with concentration and with duration of exposure was resolved by assuming that the cumulative amount of asbestos remaining in the lungs from a given exposure is equally dependent on the dust concentration and on the duration of exposure to that concentration.

The asbestos dust concentration had been measured at the textile factory concerned with several different instruments, including the membrane filter method, in which the number of fibres longer than 5 μ was counted. The dust concentration to which different workers had been exposed varied from 1 fibre/cm^3 to 27 fibres/cm^3 over periods from 10 years to 33 years.

The exposure of an individual was expressed as fibre years/cm^3, that is, the product of the average concentration to which he was exposed during working hours and his years of exposure to this average. A curve was developed relating the prevalence of asbestosis to exposure expressed in this way. The principles on which this was based may be explained as follows.

An individual's response to dose of any foreign substance can be expressed by a line (Fig. 1). There is a dose which produces no response whatsoever. This is marked by the threshold A. If the individual is given progressively higher doses, the response progresses correspondingly. The least positive response may be real but merely undesirable. A higher response may have sensory manifestations. A still higher response might be associated with observable physiological changes and overt clinical effects. The highest responses of all would perhaps be signified by loss of consciousness, or even death.

The degree of response may be conceived to be measurable objectively on a continuous scale starting at zero, and the scales of dose and response could be chosen to linearise the relationship between them, as in Fig. 1. The dose-response relationship could then be described by the slope of the line and the point where the line strikes the dose axis. The slope of the line expresses the rapidity with which increases in dose produce increases in response in this individual. The steeper the slope the greater the safety factor necessary in practice to allow for the inevitable occasional excursions of dose above the maximum desirable.

Doses which give zero response are never, in fact, known with absolute certainty since the sensitivity of measurements of response is limited. A response which can just be detected in a man corresponds to another and higher dose, shown as threshold B on Fig. 1. Also, one is not normally considering just one individual. As with all other characteristics of man, the position and slope of a dose-response line varies from one individual to another. Each man's dose-response line is different with a

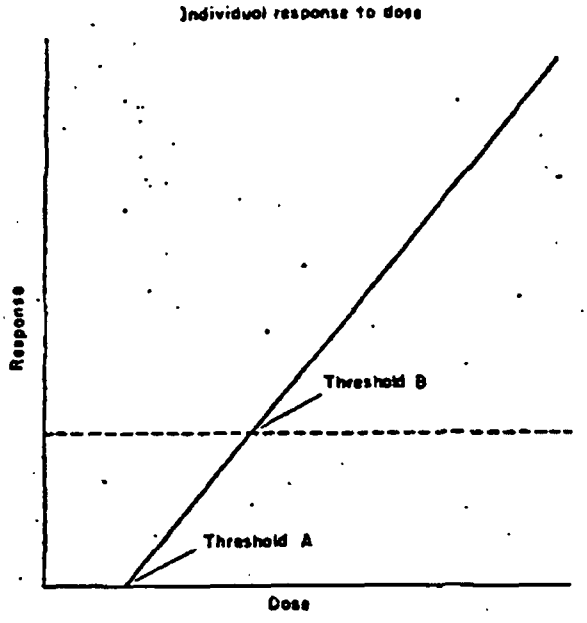


FIG. 1. Individual response to dose.

different threshold dose and a different slope. A particular population under study is represented by a family of dose–response lines centred around the line for the average man.

In a real population the threshold dose will vary from one individual to another about an average value, as in other medical norms. It is to be expected that the size frequency distribution of threshold doses would be a hump-shaped curve tailing away on either side of the central value, as shown in the Fig. 2a.

In a real field study it is established whether a man has or has not been affected. Exactly when or in what concentration he first developed the characteristic response is usually not known. A graph showing exposure against the total number of people affected by it would be a cumulative sigmoid curve, illustrated in Fig. 2b, derived from the size frequency distribution in Fig. 2a. This tails away down to zero response at zero exposure.

An air quality standard is still associated with a small but non-zero probability of men being affected by the contaminant in question. The risk of people being affected can be made as small as one wishes. Zero risk is the ultimate target and an air quality standard has to be a compromise between the costs of bearing a health risk and the costs of air contaminant control.

A curve was fitted to the data from the textile factory on asbestosis, detected clinically and the exposure in fibre years per cm³ of all the individuals under study over their years of employment up to 1966. The bottom end of the fitted curve is shown in Fig. 3. The three points relate to three of the groups of workers studied. The exposure

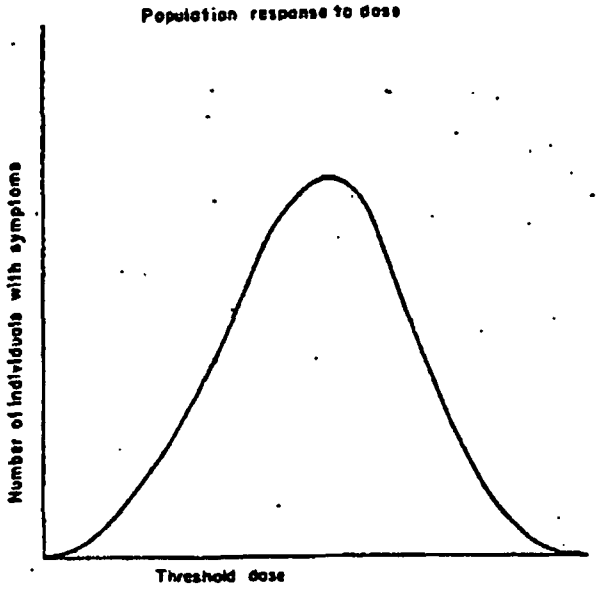


FIG. 2a. Population response to threshold dose.

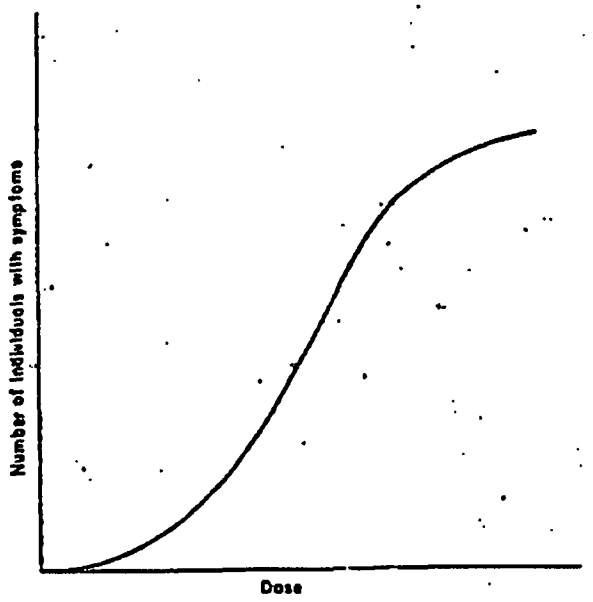


FIG. 2b. Population response to dose.

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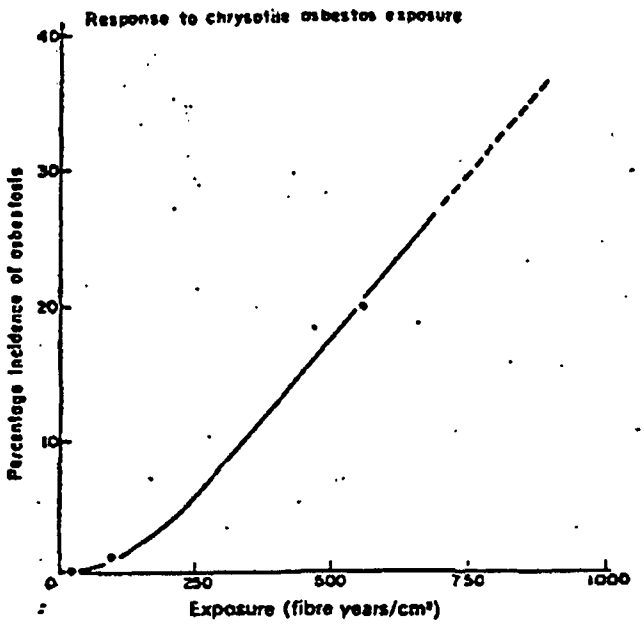


FIG. 3. Response to chrysotile asbestos exposure.

is shown on the horizontal axis, expressed in fibre years per cm³ and the corresponding prevalence is on the vertical axis, showing the proportion of people with crepitant basal rales.

Basal rales is the earliest clinically demonstrable effect on the lung due to asbestos and there is a steadily increasing prevalence of basal rales with increase in dust exposure. Only groups with near zero dust exposure show zero prevalence of basal rales.

A problem arises when it is appreciated that there is no exposure which can be said to be absolutely free of risk. There is no single threshold exposure held in common by everyone. There is, consequently, this gradually increasing risk in relation to exposure. The application of dust control to meet a TLV, an MAC, MAK value, or other similar hygiene standard will limit and control the risk but is unlikely to reduce it to zero. It has to be remembered that asbestos is very widely used and brings real benefits to the community at large. A standard could be made so stringent that the cost of dust control is prohibitive, that the production and use of asbestos ceases to be economic, production and use is discontinued and the associated benefits are lost. The benefits gained by reducing the risk of asbestosis through reducing air contaminant exposure have to be weighed against the possible loss of direct and indirect benefits to the community from the use of the material.

One conclusion from the exposure-response curve fitted to the data was that for an accumulated exposure of 100 fibre years/cm³, it is probable that the risk of being affected to the extent of having early clinical signs will be less than 1 per cent. That is, for example, a concentration of 2 fibres/cm³ for 50 years of such exposure while

at work, 4 fibres/cm³ for 25 years, or 10 fibres/cm³ for 10 years. The British Occupational Hygiene Society Hygiene Standards Sub-committee on Asbestos expressed the view that a proper and reasonable objective would be to reduce exposures to below this level and thereby reduce the risk of contracting asbestosis to less than 1 per cent of those who have a lifetime's exposure to the dust. For such workers, who may possibly work for 50 years, the long term average concentration to which they are exposed would need to be less than 2 fibres/cm³. For others, who will be exposed to asbestos dust in air for shorter periods, the long term average concentration need not be so low, as long as their exposure will amount to less than 100 fibre years/cm³.

The possibility was considered that short periods of very high concentration for a few weeks or less might be disproportionately important in determining the risk of asbestosis. However, the evidence for this was not conclusive and the committee were satisfied that the risk can be satisfactorily expressed with respect to an average concentration over 3 months and can safely be kept below 1 per cent by ensuring that a man's accumulated exposure does not rise above 100 fibre years/cm³.

The exposure measured by making fibre counts on membrane filter samples can be converted into exposure measured with an impinger, the American method, by examining the results of side-by-side comparisons of the two instruments. Such comparisons made by the United States Public Health Service in asbestos textile plants have shown that an accumulated exposure of 100 fibre years/cm³ corresponds to 15 million particle years/ft³ by standard impinger methods (AYER, LYNCH and FANNEY, 1965). The present American Threshold Limit Value is a concentration of 5 million particles/ft³ (mp/ft³) which, if it persisted, would result in an accumulated exposure of 250 million particle years/ft³ over 50 years.

These American hygiene standards, called Threshold Limit Values, are a system for summarising published information on air contaminants in a convenient form for the day-to-day practice of industrial hygiene. The present American standard for 8-hr averages is thus 17 times higher than the British standard for 3 monthly averages. However, there is a published intention to revise the American standard in view of recent knowledge.

However, the difference between the American and British standard is not primarily due to conflicting evidence on the adverse affects of asbestos. It is because of a different attitude now adopted over the degree of protection which ought to be given against asbestosis.

The American Threshold Limit Value of 5 mp/ft³ was recommended by Dreessen and his co-workers in 1938 after studying 541 employees in 4 asbestos textile plants where massive exposures to chrysotile occurred (DRESSEN *et al.*, 1938). Only 3 doubtful cases of pneumoconiosis were found at the time of the study in those exposed to dust concentrations under 5 mp/ft³, whereas numerous well-marked cases were found above 5 mp/ft³.

A conference held in 1965 on the biological effects of asbestos called attention to the very real probability that the 5 mp/ft³ limit recommended by Dreessen is inadequate to give complete working-lifetime protection against all forms of asbestos (SCHALL, 1965). Medical data on which the limits had been based were inadequate; more than half of the asbestos workers studied by Dreessen and his co-workers were under 30 years of age and thus had insufficient exposure time for much asbestosis to

develop. Of the 105 workers exposed to less than 5 mp/ft³, 82 had worked less than 5 years and only 4 had more than 10 years exposure. Moreover, it was a "point-in-time" study; many of the ill were missing, the dead uncounted, and were not considered in the over-all evaluation of the limit.

The British Hygiene Standards Committee finalised its views in November 1967 after studying the British data, and these views were immediately communicated to the ACGIH TLV committee. In May 1968 the ACGIH (Committee on Threshold Limits, 1968) proposed changes to its hygiene standard. The new asbestos limit, while taking into account the British views, had to be based on American experience and considerations applicable to the American industrial scene. Recent evaluation of the health experience in asbestos plants in the U.S.A. had, nevertheless, indicated that the 5 mp/ft³ limit was not sufficiently low to protect workers exposed for 30 years, a period rarely exceeded in America.

In accordance with these findings, the 5 mp/ft³ limit was made a ceiling value below which all concentrations should fluctuate. This corresponds to a time-weighted average concentration over a shift of 2 mp/ft³. Since the count by Impinger procedure often consists primarily of extraneous particulates, an alternative fibre count was recommended, using the membrane filter method in which fibres greater than 5 μ in length are counted as in Britain. On this basis, for a time-weighted 8-hr average limit by Impinger count of 2 mp/ft³, the corresponding limit based on the fibre count is 12 fibres/cm³. This limit is intended to reduce to an insignificant risk, the occurrence of asbestos disease among those exposed for 30 years to all forms of asbestos.

The intended changes in American TLVs give two years' notice and objections to them should be conveyed to the TLV committee of the ACGIH. All objections are given the most serious and sympathetic consideration and users are strongly advised to take advantage of this if they have reason to question the proposed changes.

The standards of the British Occupational Hygiene Society recommend that a person's accumulated exposure to chrysotile asbestos should not exceed 100 fibre years/cm³. It is probable that the risk of being affected to the extent of having early clinical signs of asbestosis will be less than 1 per cent if the conditions comply with these standards. It is believed that this is the first time a hygiene standard has been associated with such a specified degree of protection.

The standards refer essentially to an average concentration during working hours over 3 months of 2 fibres/cm³. In an environment where this 3 monthly average just equals 2 fibres/cm³, the concentration within this period will sometimes be above this value and sometimes below. The maximum 8-hr average will thus be somewhat higher than 2 fibres/cm³. The proposed change in the American TLV is to a maximum 12 fibres/cm³ 8-hr average, which if exceeded on a shift demonstrates non-compliance. Thus, there may be a rough degree of consistency between the hygiene standards from the two countries' organisations, so far as this is possible. The Factory Inspectorate in their work have often only a short time during a day to come to a judgment on conditions and are considering a development of this, applying a maximum for even shorter periods, of a few minutes, which if exceeded would indicate a probability that the Asbestos Regulations are not being complied with.

There is a growing body of information on chrysotile dust and other asbestos dusts from many countries, and it is hoped that in future the views from different

parts of the World will be sought so that standards for testing air cleanliness can, as far as possible, be held in common. Even so, the risks that may be tolerated can vary from country to country and from one situation to another within a country.

The air quality attained in industry in different countries does differ and, no doubt, will continue to differ. A wealthy country can afford to spend more money on air-contaminant control. Also, a country very conscious of the slightest risks to which its workers may be exposed through their occupation may be expected to have different standards from one which is not, where other health risks may be so much the greater.

The benefits to the community from the use of inexpensive asbestos products have in some measure to be weighed in the balance against the benefits to the health of the workers that would accrue by reducing asbestos dust exposure.

The British Occupational Hygiene Society Sub-committee on Hygiene Standards for Asbestos has not yet decided whether their chrysotile standards would be suitable for amosite or crocidolite dust, nor whether they give sufficient protection against lung cancer or mesotheliomas. The ACGIH, on the other hand, make no distinction between different types of asbestos in their standards. In this country it should be remembered that the Senior Medical Inspectors' Advisory Panel on Problems arising from the use of Asbestos considered that the evidence to date on balance indicated that a particular significance must be given to crocidolite as a cause of mesotheliomas (Ministry of Labour, 1967). That Panel recommended that other types of fibre should be substituted for crocidolite wherever possible and where this is at present impossible special precautions should be taken to reduce the risks of inhaling the material to the lowest possible level. Whatever measures may be adopted to control asbestos dust, the Panel urged that these be even more rigidly applied to crocidolite. The Factory Inspectorate is also developing procedures for testing hygiene standards in factories and is seriously considering the adoption of especially rigid requirements where crocidolite is used.

To derive hygiene standards for an air contaminant which provide a known degree of protection against a health hazard, it is necessary to have a body of data showing the amount of air contaminant to which people are exposed and the corresponding effects or lack of them in the people. It is also necessary to have a grasp of the consequences to industry and users of limiting and controlling emissions of the contaminant. Our present information is very imprecise, particularly in terms of the practical consequences of specific hygiene standards. In developing recommendations for a hygiene standard, the British Occupational Hygiene Society Sub-committee found that knowledge of the relationship between exposure and risk was not the greatest area of uncertainty. A much more difficult and contentious problem was to decide on what, in fact, was an acceptable level of dust control.

More information is needed, for example, on the expense of dust control. Where this is done by ventilation it is important to know what is the minimum amount and what kind of local exhaust ventilation and dilution ventilation is necessary to achieve a given degree of air cleanliness in a work place, since costs tend to climb as the cube of the air flow.

Research is needed to determine the balance between local and general ventilation which produces a specified degree of control at minimum cost. By setting down the capital cost, installation cost, running and maintenance costs, it becomes possible to

grasp more firmly the consequences of adopting particular hygiene standards. This kind of information is needed throughout the field of asbestos dust control so as to be able to weigh up the costs of achieving high air cleanliness.

This does not reduce the choice of an air quality standard to a mathematical equation, nor does it avoid the need to exercise wise judgment in the choice of standard. However, the judgment can become a little less arbitrary than at present.

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