C. Powell

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CRITERIA AND RECOMMENDED INTERIM STANDARD FOR PREVENTION OF ASBESTOSIS

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
Bureau of Occupational Safety and Health
Cincinnati, Ohio

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PREFACE

Industrial experience has proved the need for criteria and standards to protect the health of workers exposed to an ever increasing number of potential hazards at their workplace.

In order to provide relevant data from which valid criteria and effective standards could be deduced, the Bureau of Occupational Safety and Health has projected a formal system of research with priorities determined on the basis of specified indices.

It is intended to present successive reports as studies are completed and standards are sufficiently crystallized so as to be feasible. The first report, which follows, concerns asbestos. Other reports will follow as the research and evaluation progresses. All standards will be reviewed periodically in the light of additional data as research continues to keep protection of the worker's health as effective as the state of our technology requires.

I am pleased to acknowledge the contributions made by members of my staff, who developed this project, and the valuable constructive comments made by the Review Committee on Asbestos. A list of these contributors and reviewers appears on pages ii and iii.

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CRITERIA AND RECOMMENDED INTERIM
STANDARD FOR PREVENTION OF ASBESTOSIS

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INTRODUCTION

This report, the first in the projected series of documents, presents the criteria and recommended interim standard which were prepared to meet the need for preventing asbestosis. The necessary relevant data are also made available for use by the Secretary, Department of Health, Education, and Welfare in accordance with provisions in the proposed Occupational Safety and Health Act requiring the development of criteria by "The Secretary, Department of Health, Education, and Welfare...on the basis of such research, demonstrations, and experiments and any other information available to him..."

The Bureau of Occupational Safety and Health, after a review of all data and consultations with others, formalized a system for the development of criteria upon which standards can be established to protect the health of approximately 80 million workers from exposure to hazardous chemical and physical agents. Priorities in this system are based on five indices: (1) the number of workers potentially exposed; (2) the relative toxicity index of a particular substance or physical agent; (3) the incidence of illnesses (or death); (4) the quantity of the substance produced and used in the United States; and (5) the increase or decrease in the quantity used over a period of years.

In addition to the above system, the judgments of industrial hygienists from 10 State agencies and 20 private industries were considered in establishing a tentative priority list for over 90 chemical and two physical agents.

RECOMMENDED INTERIM STANDARD

The Public Health Service recommends that occupational exposure to asbestos dust be controlled so that no worker shall be exposed to more than 5 asbestos fibers per milliliter based on a count of fibers greater than 5 microns (μ) in length as determined by the recommended method, which is described in this report, and based on time-weighted average exposures for a 40-hour work week. (See p. 24 for definition of a fiber.) Concentrations greater than 5 fibers/ml, but not to exceed 10 fibers/ml, may be permitted for 15-minute periods each hour up to five times daily.

The interim standard recommended is based on recent investigations by the Public Health Service and the Commonwealth of Pennsylvania and on the expert opinions of the Review Committee on Asbestos. It will be subject to review in 1972 and will be revised as necessary.

This interim standard was developed to meet the following criteria:

1. It will prevent asbestosis in nearly all workers exposed over a working lifetime.
2. It utilizes techniques that are valid, reproducible and available to industry and official agencies.
3. Its attainment is feasible with existing technology.

It should be clearly understood that this interim standard is intended to prevent asbestosis. Although it would be expected to reduce the risk of neoplasms, its adequacy in this respect cannot be assured because of insufficient knowledge on dosage--response relations and the influence of different types of asbestos and co-factors. A second document dealing with criteria and standards for neoplastic effects will be forthcoming.

A second document or a revised one? Is the second document the 1972 one?
I don't see how you can have separate standards for two different effects from the same material

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REVIEW OF PROBLEM

Asbestos is a generic term that applies to a number of mineral silicates incombustible in air and separable into filaments. The most widely used in industry in the United States is chrysotile ($3MgO\ 2SiO_2\ 2H_2O$), a fibrous form of serpentine. Other types include amosite ($3MgO\ 11FeO\ 16SiO_2\ 7H_2O$); crocidolite ($Na_2O\ 3FeO\ Fe_2O_3\ 8SiO_2\ H_2O$); tremolite [$Ca\ Mg_3\ (SiO_3)_4$]; anthophyllite [$(MgFe)_7\ Si_8\ O_{22}(OH)_2$]; and actinolite [$Ca(MgFe)_3\ (SiO_3)_4$].

Uses of and Exposures to Asbestos

Almost one million tons per year of asbestos are used in the United States. In 1965, approximately 74 percent of the asbestos produced was used in the construction industry (532,300 tons) and 26 percent in non-construction industries (187,400 tons). Approximately 92 percent of the half million tons used in the construction industry is firmly bonded, i.e., the asbestos is "locked in" in such products as floor tiles, asbestos cements, and roofing felts and shingles; while the remaining 8 percent is friable or in powder form present in insulation materials, asbestos cement powders, and acoustical products.[1] As expected these latter materials generate more airborne fibers than the firmly bonded products. The 187,400 tons of asbestos used in non-construction industries in 1963 were utilized in such products as asbestos textiles, friction materials including brake linings, and clutch facings, asbestos paper, paints, plastics, roof coatings, and miscellaneous other products.

Recently the construction industry has begun the application of asbestos insulation materials by spraying. While this technique at present utilizes only a small percentage of the total asbestos produced, its use is increasing rapidly. It has been found that more asbestos fibers become airborne from this method of application than from the older conventional methods.

Mining and milling of asbestos in the U. S. is a small industry employing fewer than a thousand workers. In an unpublished Public Health Service survey of four asbestos mines and mills, mean exposure levels of 3 fibers $> 5\mu$/ml in mining and 7 fibers $> 5\mu$/ml in milling, were found. However, peak exposures were as high as 25 fibers $> 5\mu$/ml.

Recent levels of asbestos exposure in the manufacture of asbestos products are given in Table I.[2] as rounded geometric means; arithmetic means would be somewhat higher. The data represent general plant averages by operation even though some individual exposures were much higher in poorly controlled operations.

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TABLE I

Asbestos Concentrations by Operation[2]

(Fibers > 5 μ per ml)
Geometric Means

Operation	Highest*	Second Highest*	Second Lowest*	Lowest*
Textile				
Fiber Prep.	11.37	10.26	0.75	1.02
Carding	9.28	9.17	2.55	0.77
Spinning	11.22	7.74	1.40	1.02
Twisting	14.03	4.52	2.47	0.55
Weaving	11.97	2.96	1.69	0.65
Friction				
Mixing, Coating, Extruding	3.37	3.32	0.50	-
Forming	6.70	3.11	0.65	-
Hot Pressing	8.39	2.65	0.40	0.10
Grinding & Sanding	6.40	4.57	0.73	0.32
Cutting & Drilling	10.04	3.20	0.47	-
Inspecting & Packing	4.09	4.63	1.26	0.65
Cement Pipe				
Warehousing & Mixing	4.29	5.50	1.22	1.22
Pipe Forming	2.11	1.48	0.63	0.63
Pipe Finishing	4.09	4.06	0.58	0.56
Coupling Finishing	2.92	9.53	1.23	0.92
Shingle, Mill Board, Gasket				
Warehousing	8.11	-	-	3.20
Forming	0.92	-	-	0.90
Finishing	2.61	-	-	2.96
Insulation				
Mixing	77.96	46.96	9.54	1.05
Forming	20.05	21.82	2.57	0.44
Finishing	49.52	27.9[illegible]	5.42	0.57
Inspecting & Packing	13.10	19.21	2.73	0.41

* As determined by overall plant average concentrations.

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Recent (1963-65) data from Pennsylvania[4] in two asbestos textile plants show average dust concentrations in <u>carding</u> of 3.5 mppcf and <u>weaving</u> of 0.68 mppcf, which are approximately equivalent to 17.5 and 3.4 fibers/ml respectively. In one plant, in <u>twisting</u> the average concentration was 2.3 mppcf or 11.5 fibers/ml; in the other plant <u>spinning</u> was 1.6 mppcf or 8 fibers/ml. These concentrations are in general agreement with the results for textile operations presented in Table I.

Little data are available on the exposure of insulation workers, other asbestos product users, or other workers with secondary exposures such as construction workers. Balzer and Cooper[3] reported mean exposure levels of 3 - 9 fibers > 5 u/ml with peak exposures greater than 25 fibers > 5 u/ml for various operations in the handling of asbestos insulation. These workers, however, did not spend all of their time working with asbestos insulation, and, consequently, time-weighted average exposures were lower.

There are approximately 40,000 insulation workers in the United States who are exposed to asbestos dust. The activities of these workers cause secondary exposures to an estimated three to five million other building construction and ship insulation workers.[5] The dust exposure of the individual worker is extremely variable. Because of this variation and the small number of asbestos workers at any one location, the asbestos dust exposures of these workers have never been satisfactorily estimated.

An estimated 50,000 workers are involved in the manufacture of asbestos-containing products. This figure does not include secondary manufacture of products which contain asbestos, as electrical or thermal insulation, or products which include previously manufactured components containing asbestos.[5]

The following information, furnished by the Pennsylvania Division of Occupational Health, shows the number of plants using asbestos in which potential exposures can occur. These figures are based on a total of 18,439 manufacturing plants in that State as of August 22, 1969, and represent about 1.4 percent of all manufacturing operations in Pennsylvania. Service facilities such as garages are not included.

Insulation, including cutting, drilling, and tape manufacture	75
Manufacturing and processing	16
Brakes and friction	10
Cement, clay	18
Miscellaneous*	146
	265

*Gaskets
Signs
Safety Equipment
Laminated Material
Paint and Roofing Materials
Shipbuilding and Shipbreaking
Impregnating Resin and Urethane
Textile
Undercoating Material
Ironing Board Covers
Flooring

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Indications of Extent of Hazard

The widespread use of asbestos fibers did not begin until the last quarter of the nineteenth century.[6] As a result of the increasing use of asbestos minerals, there has been an undercurrent of concern over their role as factors in human disease. To interpret accurately the biologic actions of asbestos, it is imperative that the character of the exposure as to concentration, size, and type of fiber must be known. Data of this nature are scanty or often non-existent at present with respect to human exposure.[6] The first record of a case of asbestosis was made by Montague Murray in 1906.[7] The first complete description of asbestosis and of the "curious bodies" seen in lung tissue appeared in 1927 when Cooke[8] and McDonald[9] each reported on the same case of asbestosis and McDonald's report included another case. Each author gave reasons for believing that asbestos bodies originate from asbestos fibers that reach the lungs. A majority of people exposed to asbestos dust develop the disease "asbestosis" if the dust concentration they have been exposed to is high and the duration of their exposure is long. This has been documented by the following studies: Merewether and Price, 1930; Fulton et al., 1935; and Dreessen et al., 1938. In 1918 Hoffman[10] reported that it was the practice of American and Canadian insurance companies not to insure asbestos workers on account of the assumed health-injurious conditions of that industry. About the same time

Pancoast, Miller, and Landis[11] reported on x-ray appearances of pneumoconiosis in 15 individuals exposed to asbestos. Mills' publication[12] was the first report on asbestosis published in the United States, and in that same year, 1930, Lynch and Smith[13] reported on asbestosis bodies* found in the sputum of asbestos workers. In Merewether's review of asbestosis,[14] emphasis was placed on the relation of asbestosis to dusty working conditions. The clinical aspects of asbestosis are well documented. Gloyne[15] discussed the pathology of asbestosis and methods for diagnosing asbestos bodies and asbestosis. Selikoff and Hammond[16] analyzed 1,975 autopsies in three large New York City hospitals and found asbestos bodies in 942 (47.7%). Broadly considered, 40 percent of housewives, 50 percent of "white collar" males, and 50 percent of "blue collar" males showed asbestos bodies; while males who had a history of shipyard or construction work had a higher incidence of asbestos bodies, e.g., 90 of 129 cases or 70 percent. Selikoff's observations also suggest that asbestos bodies were as frequently present 35 years ago as now. The Annals of the New York Academy of Sciences presents an excellent and lengthy documentation on the "Biological Effects of Asbestosis."[1] The Public Health Service, with the assistance

* "Ferruginous bodies" is a more descriptive term.

of asbestos producers and manufacturers, is examining its findings with populations exposed occupationally during the past 30 years. This information should provide more definitive epidemiological knowledge as to the conditions necessary for the prevention and ultimate reduction of significant pulmonary fibrosis in workers exposed to airborne asbestos fibers.

Medical Aspects of Asbestosis

The occupational disease, asbestosis, is characterized by:

1. A pattern of x-ray changes consistent with diffuse interstitial fibrosis of variable degree and, at times, pleural changes of fibrosis and calcification.

2. Clinical changes including fine rales and finger clubbing. These may be present or absent in any individual case.

3. Physiological changes consistent with a restrictive lung disorder.

The diagnosis of asbestosis is further predicated upon a known history of occupational exposure to airborne asbestos dust. In general, considerable time must elapse between inhalation of the dust and appearance of x-ray changes.

Several clinical abnormalities appear to occur with unusual frequency in those environments where airborne asbestos fibers, often in association with other substances, exist. Of these, diffuse

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chronic inflammation and scarring of the lung, historically referred to as "asbestosis," was recognized early in this century. Based upon the premise that a reduction in the number of fibers inhaled and retained in the lungs would lessen the severity or prevent the occurrence of "asbestosis," efforts to decrease the "dustiness" of the worker's environment in some, though not all, asbestos milling or using processes began in the middle 1930's and early 1940's. The fact that a reduction in frequency and severity of asbestosis has been demonstrated in those working places where such a program of dust reduction has been established, confirms the view that asbestosis is "dose-related" to fibers of asbestos.[17] Some, though meager and incomplete, numerical data relating clinical manifestations of asbestosis to dose of asbestos fibers are now available.

An abnormality, occurring with unusually greater frequency in populations exposed to inhalation of asbestos fiber, is that of localized thickening of the pleura with or without calcification of these plaques. The failure to find these plaques, as a result of some studies of certain design in certain areas, in some persons known to have sustained substantial exposure to asbestos fiber; the seeming absence of a dose relationship; the occurrence of the plaques on a rather striking geographic basis; and their association with other exposures such as to talc and mica make the role of the asbestos fiber in this manifestation difficult to understand.

In the late 1940's, a frequency of bronchogenic cancer greater than that occurring in the general population was observed in persons suffering from asbestos derived from manufacturing of asbestos products. In 1964, this greater frequency was also reported in a group of insulation installers who were exposed to several materials including airborne asbestos fibers. In contrast to populations exposed to these kinds of mixed environments, examination of populations exposed to a less complex array of materials other than asbestos, as exemplified by the mining and milling of asbestos fiber, has shown either no greater or a lesser order of augmentation of frequency of bronchogenic cancer. Although the question remains debatable, there is evidence to suggest that a dose-relationship exists between the inhaled asbestos fibers and their role in bronchial carcinoma. The possibility that other co-existing agents (co-carcinogens) such as cigaret smoking and metallic cations, play a role in this overall carcinogenic relationship is strong.

An increased rate of occurrence of mesothelioma of the pleura or peritoneum was reported in some populations in 1959 and in subsequent years. The possibility that asbestos may play a role in this distribution has been raised. The failure to find, thus far, an augmented frequency of this particular tumor in some other populations exposed for similar periods to substantial concentrations of airborne asbestos fiber, raises a doubt that asbestos per se is of necessity the responsible agent.

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Thus, while present data are not adequate to define completely the problem, it can be stated without hesitation that asbestosis, bronchogenic cancer, and mesothelioma constitute abnormalities that pose a threat to life and well-being and hence are to be prevented. Of these three conditions, our current knowledge is most substantial with respect to the relationship, both etiologically and quantitatively, between asbestos fiber inhalation and the subsequent development of asbestosis. Our knowledge is quite meager with respect to these specific relationships regarding bronchogenic cancer and mesothelioma.

Evidence in hand indicates that past and current standards for fiber concentration in the working places where asbestos fibers occur, though undoubtedly contributing to reduction of the severity and frequency of the disease, have not prevented completely the development of asbestosis. The role of asbestos in mesothelioma is uncertain, and information as to its etiological and quantitative relationship to asbestos fibers are so lacking, that criteria for setting a standard at this time which would prevent mesothelioma are virtually non-existent. With respect to asbestos and bronchogenic cancer, while scant pertinent data do exist and more will be available in the near future, usable and meaningful criteria upon which to base a standard for asbestos in the environment do not now exist.

Granted the need for a new standard, if it is to be based upon meaningful data and criteria, the standard must be based upon those

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criteria related to asbestos (pulmonary fibrosis) with the conviction that this will be a step in the direction of lessening whatever carcinogenic influence asbestos fibers in the environment of the working place may ultimately be shown to have.

Of necessity, the criteria for the recognition of asbestosis during life are those of a clinical nature. While the histological alterations associated with asbestosis are known, no body of data now exists relating these anatomical changes in a reliable epidemiological manner to various environmental concentrations of respirable-sized fibers of asbestos. The clinical findings that have been related to patterns of exposure are: (1) changes to be observed in the chest roentgenograms and (2) physical signs of rales, rhonchi and clubbing of fingers. The influence of asbestosis upon pulmonary and circulatory functions has been studied, but only now are the effects of such influences in the process of being related epidemiologically to patterns of exposure to asbestos fiber. Until the epidemiological relation is established, the criteria for prevention of asbestosis must be clinical.

DEVELOPMENT OF STANDARDS

Various criteria have been used for categorizing the environment in terms of its dustiness in past years. Recent developments have made it clear that, with respect to establishing a standard for prevention of asbestosis in those working places where asbestos fibers exist in the environment, a method utilizing the capture and direct estimation of fibers of asbestos be utilized. In the past in the United States, the impinger method was utilized for evaluating the dustiness of environments by counting particles as well as asbestos fibers. Even so, it may be possible to extrapolate, with some degree of utility, current estimations of direct fiber count in a retrospective manner based upon previous counts by the midget impinger technique.

While there still exists the question of whether or not different varieties of asbestos fiber may have varying biological effects, there is at this time insufficient information to justify treating one variety in a different manner than another with respect to setting a standard. The question has also been raised as to whether or not fibers less than 5 microns in length have any or equivalent biological activity in comparison to asbestos fibers longer than 5 microns. Current evidence suggests that it is the fibers longer than 5 microns that are biologically active or that the fibers longer than 5 microns faithfully mirror the numbers of those fibers shorter than 5 microns in terms of biological activity; therefore it is appropriate to use a count of fibers longer than 5 microns as a criterion for characterizing the environment.

Thus, the interim standard developed is based upon the above criteria, recent environmental data and the available, though scant, epidemiological information.

Basis for Previous Standards

The first standard for controlling exposure to asbestos dust was recommended by Dreessen et al.[12] in 1938 following a study of 541 employees in four asbestos textile plants where massive exposures occurred. A tentative threshold limit for asbestos dust of 5 million particles per cubic foot (mppcf), determined by the impinger technique, was recommended. They found numerous well-marked cases of pneumoconiosis where concentrations exceeded 5 mppcf, but only three doubtful cases where concentrations were under 5 mppcf. However, only five persons were exposed over ten years to concentrations from 0 to 4.9 mppcf. None of the 39 persons exposed to concentrations below 2.5 mppcf showed evidence of asbestosis; but only six of these had been employed more than five years.

The study by Dreessen et al. had unavoidable limitations such as the fact that 333 of the 541 employees studied had worked less than five years in these textile mills, only 66 were employed as long as 10 years, and only 2 for over 20 years. Furthermore, the average age of these asbestos textile workers was 32.1 years and only one of the four plants studied had been in operation for at least 15 years.

Thus, the first standard established was based upon limited data, a condition recognized by the authors who stated that..."5 mppcf may be regarded tentatively as the threshold value for asbestos-dust exposure until better data are available."

For several years, the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Value (TLV) for asbestos dust was 5 mppcf. This limit was based on the study by Dreessen et al.[16] and subsequent investigations by others. However, in 1968 ACGIH proposed a lower TLV of 12 fibers/ml > 5 μ in length or 2 mppcf and, ~~[illegible]~~.[19] a still lower limit of 5 fibers/ml > 5 μ in length ~~will be~~ was proposed in 1970.[19].

Believing that the 5 mppcf tentative limit recommended by Dreessen et al., which the ACGIH TLV subsequently adopted in 1946, was out of date, the Committee on Hygienic Standards of the British Occupational Hygiene Society reviewed medical evidence, results of recent studies made by the asbestos industry in the United Kingdom, and epidemiological data from the United States. In 1968, this Committee published Hygiene Standards for Chrysotile Asbestos Dust.[17] The following is a summary and the recommendation contained in the report:

"1. As long as there is any airborne chrysotile dust in the work environment there may be some small risk to health Nevertheless, it should be realized that exposure up to certain limits can be tolerated for a lifetime without incurring undue risks.

"2. The committee believes that a proper and reasonable objective would be to reduce the risk of contracting asbestosis to 1 percent of those who have a lifetime's exposure to the dust. By "asbestosis" this committee means the earliest demonstrable effects on the lungs due to asbestos.

"It is probable that the risk of being affected to the extent of having such early clinical signs will be less than 1 percent for an accumulated exposure of 100 fibre years per cm^3. That is, for example, a concentration of 2 fibres per cm^3 for 50 years, 4 fibres per cm^3 for 25 years or 10 fibres per cm^3 for 10 years.

"3. It is recommended that exposures which lie in certain ranges of dustiness be designated by categories according to the following scheme:

DUST CATEGORY	CONCENTRATION AVERAGED OVER 3 MONTHS (FIBRES/CM^3)
Negligible	0-0.4
Low	0.5-1.9
Medium	2.0-10.0
High	Over 10.0

"4. The levels are expressed in terms of the number of fibres per cm^3 greater than 5 μ in length as determined with the standard membrane filter method. Any other method can be used provided it is accompanied by appropriate evidence relating its results to those which would have been obtained with the standard membrane filter method.

"5. When it is necessary to work intermittently in a "high dust" area an approved mask should be worn, provided that the concentration is no more than 50 fibres per cm³ and the mask has been shown by test to be a good fit prior to entering the area. Should the concentration exceed 50 fibres per cm³ a higher standard of respiratory protection should be provided, such as a pressure-fed breathing apparatus.

"Additional recommendations

"1. It is recommended that where practicable an up-to-date employment record card be kept of every person which indicates, every calendar quarter, the category or categories in which he or she has been employed and in which he or she is recommended to work.

"2. All employees exposed to risk should be medically examined before employment. Periodic examinations should be made thereafter, annually.

"Notes

"These hygienic standards are subject to review in the light of new evidence and improved methods of measurement.

"The standards are, in our opinion, the best that can be drawn from the existing data. These data are scanty and based on factory experience of continuous exposure during working hours. Due caution should be exercised in applying these standards to other patterns of exposure. As far as possible the dust exposures have been estimated conservatively and, in particular, in the period 1933-1950 the average hours of work were substantially greater than 40 per week.

"It is hoped to supplement the existing data in due course, when the standards will, if necessary, be modified. These standards will be formally reviewed in three years."

It should be emphasized that the environmental data upon which the British standard was based, according to Holmes, were related to "fixe samples taken as near as possible to the breathing zone of the worker."[20] In other words, these were not breathing zone samples collected by personal samplers as recommended in this document or as practiced generally in the United States. For this reason, the British standard is lower by a factor of about 1.5 than it would be had breathing zone samples been collected. This statement is based on studies made by the Bureau of Occupational Safety and Health and referred to in more detail in the section, Principles of Sampling. For these and other reasons it is not possible to compare the British standard with that recommended here or with the ~~proposed~~ ACGIH TLV.

In 1968, Balzer and Cooper[3] reported asbestosis among insulation workers exposed at levels not exceeding the time-weighted average of 5 mppcf.

In a recent unpublished paper, Williams, Baier and Thomas[4] compiled data from the Pennsylvania Department of Health files on exposure levels at various textile processing operations in two plants. The data presented include results of dust concentrations from 1930 through 1967 in one plant and from 1945 through 1965 in the second plant. Even though controlled exposures were for the most part below 5 mppcf and in many cases below the 1968 ACGIH proposed limit of 2 mppcf, 64 cases of asbestosis were reported from these two asbestos textile plants. The authors conclude that: "If asbestosis is to be prevented, airborne asbestos dust must be stringently controlled in the working environment. From these data a TLV of 3 mppcf 19 fibers/ml would provide inadequate protection and the proposed 2 mppcf 10 fibers/ml may not be substantiated." (It should be noted that 10 fibers/ml corresponds to less than 2 mppcf and that the interim standard recommended--5 fibers/ml would be less than 1 mppcf.)

Thus, considerable evidence exists indicating that prevention or reduction of the occurrence of asbestosis among workers, the concentration of asbestos fibers to which they are exposed must be reduced.

There is at this time, however, only scant epidemiological data correlated with results of environmental exposures upon which a definitive standard can be established. In 1964, the Bureau of Occupational Safety and Health initiated a study, scheduled for completion in 1972, to relate dust levels to which workers are exposed to the incidence of asbestosis. Exposures to trace metals, as well as to carcinogenic oils in asbestos dust, ~~will~~ are also be studied because these may be important in the mechanism of causation of asbestosis and cancer.

Basis for Proposed Standard

The proposed standard of 5 asbestos fibers/ml, > 5 μ in length, is based on the best available information to date and includes a consideration of the British standard, which states that the probable risk

5720 = 100

of developing asbestosis (from exposure to chrysotile) will be less than 1 percent for an accumulated exposure of 100 fiber years per ml (150 fiber years per ml based on breathing zone samples). This equals 3 fibers/ml for 50 years, 6 fibers/ml for 25 years, or 15 fibers/ml for 10 years--based on breathing zone samples. Thus, even though it is not possible to compare the British data (based upon exposures to chrysotile) with data collected in the United States[3,4] where workers were exposed to various types of asbestos, it is believed that this limit will reduce to an insignificant risk the occurrence of asbestosis among workers, even those who may be exposed to asbestos dust for as long as 25 to 30 years. It must be emphasized, however, that this standard may not necessarily prevent neoplasms. Additional research is needed before a second document, covering this subject, can be prepared because of the many other variables and factors involved.

Furthermore, until additional epidemiological and environmental data become available, it is recommended that exposures to asbestos dust be maintained as much lower as practicable than the proposed recommended standard.

METHODOLOGY

Air Sampling Methods

In the study of asbestosis conducted by Dreessen et al.[16] midget impinger count data were used as an estimate of dust exposure. All of the dust particles seen, both grains and fibers, were counted since too few fibers were seen to give an accurate measurement. The

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resulting count concentration was a measure of overall dust levels rather than a specific measurement of the asbestos concentration. This method was satisfactory at that time since exposures were massive and the control measures installed to reduce overall dust levels also reduced the asbestos dust levels.

As dust levels were reduced, it became necessary to measure the biologically appropriate attribute of the dust cloud. At equal levels of overall dustiness, the concentration of asbestos could vary considerably from textile manufacture (75-85% asbestos) to insulation (5-15% asbestos). Furthermore, if the limit were lowered below the 5 mppcf used previously and dust counts taken by the impinger technique, it would be necessary to consider the effect of background dust, which could be as high as 1 mppcf.

A number of methods for measurement of asbestos dust concentrations have been used in the Public Health Service's epidemiological study of the asbestos products industry.[21, 22, 23, 24] Based on the data, the preferred index of asbestos exposure is the concentration of fibers longer than 5 μ counted on membrane filters at 430X with phase contrast illumination.[25, 26] Fibers longer than 5 μ in length are counted in preference to counting all fibers seen in order to minimize observer/

microscope resolving power variability. Furthermore, the British define a "fibre" as a particle longer than 5 μ and having a ratio of length to breadth greater than 3:1.[17] This method has been adopted as the standard field sampling method by the Public Health Service.

Based on results of samples collected simultaneously by the impinger and membrane filter methods in the asbestos textile industry, a concentration of 6 fibers/ml longer than 5 μ is approximately equivalent to 1 mppcf. If this relationship is used, the intended change in the Threshold Limit Values (TLV) adopted by the American Conference of Governmental Industrial Hygienists (ACGIH) of 2 mppcf based on the impinger methods is equivalent to 12 fibers/ml longer than 5 μ.[27] Although the British have refrained from standardizing on a single method of measurement, recent measurements have been performed by a method essentially identical to the fiber count method described in detail below, and the British interim standards for chrysotile asbestos dust are stated in these terms.

When exposures are measured in industries other than asbestos textiles, the asbestos fiber concentration is generally lower than 12 fibers/ml when the impinger concentration is at 2 mppcf. Since the ACGIH TLV is concerned with asbestos exposure, it should be considered exceeded only when the fiber concentration is over 12 fibers/ml as the dust being counted in the impinger may include cement, resin, and other non-asbestos materials.

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Principles of Sampling

A dust sampling procedure must be designed so that samples of actual dust concentrations are collected accurately and consistently. The results of the analysis of these samples will reflect realistically the concentrations of dust at the place and time of sampling.

In order to collect a sample representative of airborne dust, which is likely to enter the subject's respiratory system, it is necessary to position a collection apparatus near the nose and mouth of the subject or in his "breathing zone."

The concentration of dust in the air will vary, depending upon the nature of the operation and upon the type of work performed by the operator and the position of the operator relative to the source of the dust. The amount of dust inhaled by an individual can vary daily, seasonally, and with the weather. In order to obtain representative samples of workers' exposures, it is necessary to collect samples under varying conditions of weather, on different days, and at different times during a shift.

The percentage of working time spent on different tasks will affect the concentration of dust the worker inhales since the different tasks usually result in different concentrations associated with them. The percentage can be determined from work schedules and by observation of work routines.

The daily average weighted exposure can be determined by using the following formula:

$$\frac{(\text{hours X conc. task A}) + (\text{hours X conc. task B}) + \text{Etc.}}{\text{8 hours (or actual hours worked)}}$$

The concentration of any air contaminant resulting from an industrial operation also varies with time. Therefore, a longer sampling time will better approximate the actual average.

With the following recommended sampling procedure, it is possible to collect samples at the workers' breathing zones for periods of from 1 to 8 hours thus permitting the evaluation of average exposures for a half or full 8-hour shift--a desirable and recommended procedure. Furthermore, dust exposures of a more normal work pattern result from the use of personal samplers. Studies conducted by the Bureau of Occupational Safety and Health in several industries showed that results of dust counts from personal samples exceeded those collected at fixed positions by a median factor of 4. In the asbestos industry this factor was 1.5. This emphasizes that samples should be collected as near as possible to workers' breathing zones in order to evaluate their daily exposures.

Collecting Sample

The standard recommended in this report was based on a modification of the membrane filter method described by Edwards and Lynch.[25]

Breathing zone samples for count are collected on Millipore* type AA filters in personal samplers operated by battery powered pumps and worn by the employees. The filters are contained in plastic filter holders and are supported on pads which also aid in controlling the distribution of air through the filter. To yield a more uniform sample deposit the filter holder face caps should be removed.

Mounting Sample

The mounting medium used in this method is prepared by dissolving 0.05 g of membrane filter per ml of 1:1 solution of dimethyl phthalate and diethyl oxalate. The index of refraction of the medium thus prepared is $N_D = 1.47$.

To prepare a sample for microscopic examination, a drop of the mounting medium is placed on a freshly cleaned standard (25 mm x 75 mm) microscopic slide. A wedge-shaped piece about 1 cm x 2 cm is excised from the filter with a scalpel and forceps and placed dust side up on the drop of mounting solution. A No. 1-1/2 coverslip, carefully cleaned with lens tissue, is placed over the filter wedge. Slight pressure on the coverslip achieves contact between it and the mounting medium. The

* Mention of commercial products does not constitute endorsement by the Public Health Service or U. S. Department of Health, Education, and Welfare.

sample may be examined as soon as the mount is transparent. The optical homogeneity of the resulting mount is nearly perfect, with only a slight background granularity under phase contrast, which disappears within one day. The sample should be counted within two days after mounting.

Evaluation

The filter samples mounted in the manner previously described are evaluated in terms of the concentration of asbestos fibers greater than 5 μ in length. A microscope equipped with phase contrast optics and a 4-mm "high-dry" achromatic objective is suitable for this determination. 10X eyepieces, one of which contains a Porton or other suitable reticle at the level of the field-limiting diaphragm, should be used. The left half of the Porton reticle field serves to define the counting area of the field. Twenty fields located at random on the sample are counted and total asbestos fibers longer than 5 μ are recorded. Any particle having an aspect ratio of three or greater is considered a fiber.

The following formulae are used to determine the number of fibers/ml:

$$(1)\quad \frac{\text{Filter area (mm}^2\text{)}}{\text{Field area (mm}^2\text{)}} = K$$

$$(2)\quad \frac{\text{Average net count} \times K}{\text{Air volume sampled (ml)}} = \text{fibers/ml}$$

For example, assume the following: area of the filter used was 855 mm^2, counting area of one field under the Porton reticle was 0.005 mm^2; average net count per field of 20 fields was 10 fibers; and sample was collected at 2 liters per minute for 90 minutes. Then:

$$\frac{855\ mm^2}{.005\ mm^2} = 171,000\ (K)$$

$$\frac{10\ \text{fibers} \times 171,000}{2,000\ \text{ml/min} \times 90\ \text{min}} = 9.5\ \text{fibers/ml}$$

Analytical Methods

The recommended interim standard, as noted earlier, is based on the number of asbestos fibers/ml $> 5\ \mu$ in length to which workers are exposed. In many operations involving the use of asbestos, fibers other than or in addition to asbestos may be present in the sample collected. Thus, situations will arise where the airborne fibers must be identified. Furthermore, circumstances may require the identification or differentiation of various types of asbestos fibers present in the sample.

An experienced microscopist can easily distinguish asbestos fibers in the presence of rock wool, glass wool, and many organic fibers. However, it may be necessary at times to determine qualitatively or quantitatively the types of asbestos present. Several methods for this purpose are given in the Appendix and others, such as electron microprobe analysis, may be found in the literature. It must be emphasized, however, that the analytical procedures described in the Appendix are not recommended procedures because they have not been refereed by other agencies. Additional research is needed to develop analytical techniques which are capable of differentiating between the massive and fibrous forms. Also, there is need for more sensitive procedures to identify single fibers that are encountered in biological samples.

CONCLUSION

The criteria, the interim standard, and the method for the collection and evaluation of dust exposures to asbestos recommended in this report are based on the latest data available and on the opinions of experts in this field.

On the basis of these data and opinions, an interim standard is recommended to control workers' exposures to asbestos fibers at no more than 5 fibers per milliliter, as determined by the recommended method of counting only those fibers greater than 5 microns in length and based on time-weighted average exposures for a 40-hour work week.

The criteria do not include desirable data apt to be developed; e.g., all of the facts that should be known about asbestosis, the relationship between exposure to the various forms of asbestos and the increased incidence of cancer associated with workers exposed to asbestos, the relationship between asbestos dust levels, and minimal health effects. Nor is there a recommended analytical technique to differentiate massive forms of asbestos from the fibrous forms although several techniques are described in the Appendix of this report.

Research in these and other areas will continue and the criteria and interim standard for asbestos will be reviewed no later than two years following the adoption of this interim standard. Revisions of the standard will be issued as necessary. It should be emphasized that exposures should be kept as far below this interim standard as possible until additional data become available on the dose-response relationship.

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APPENDIX: ANALYTICAL METHODS

Modern analytical methods and instrumentation used in the identification and characterization of asbestos minerals include x-ray diffraction, atomic absorption spectrophotometry, emission spectroscopy, electron microscopy, electron microprobe, thermoanalysis plus the necessary sample preparation procedures [1]

Internal Standard Technique for Chrysotile

Chrysotile may be determined by the x-ray diffraction and internal standard technique.[2]

Sample Preparation. The substances to be analyzed may be classified as settled dust samples or as bulk samples of process materials. Settled dust samples analyzed for non-fibrous minerals by x-ray diffraction are usually passed through a 325-mesh sieve in the preparatory procedure. Fibrous structures, such as asbestos, do not have the aerodynamic properties associated with approximately spherical airborne particles; hence the preparation of asbestos-containing settled dusts consists only in a preliminary screening of gross particles followed by grinding to less than 3.5 microns. This is accomplished by dry grinding in a mixer mill for ten minutes.

Bulk samples may be obtained from the materials used in an industrial process. An alumina-ceramic vial and mixer mill are used in preparing this type of sample for analysis. A representative portion of the bulk sample is pulverized in the mixer mill, as described for settled dusts.

Procedure. The ground dust or bulk sample is first scanned with the diffractometer to establish a qualitative diffraction pattern. This preliminary analysis will verify the presence or absence of chrysotile and will demonstrate the presence of possible interfering substances, which are discussed in a subsequent section. Chrysotile is confirmed as present by comparison of the sample's qualitative pattern with that of the pure mineral. If the pattern is found, a rough estimation of the percentage of chrysotile is then made.

A mixture of the dried sample and the aquamarine, each weighed separately, is prepared: The combined weights should be approximately 1 g. The percentage of aquamarine in the mixture should be approximately the estimated percentage of chrysotile in the sample. The mixture is then wetted with isopropanol and ground in a mechanically driven boron carbide mortar for 15 minutes. After this final grinding the mixture is dried at 110°C. and packed in the sample holder of the diffractometer for analysis.

The ratio of the area under the aquamarine 3.25-A peak to the area under the chrysotile 3.65-A peak is computed from the digital print-out record. Background corrections are applied to determine the net area of a given peak. The average background count, calculated from the values provided over a fixed interval extending on each side of the diffraction peak, is used to calculate the total integrated background correction under the diffraction peak.

With the standard curve taken as a reference, the ratio of the weight of aquamarine to the weight of chrysotile is determined. The percentage of chrysotile is computed from the ratio of aquamarine to chrysotile, the weight of the dust sample, and the weight of the added aquamarine as follows:

$$(A \times 100)/(S \times R) = \%\ \text{Chrysotile}$$

Where: A = weight of aquamarine
S = weight of sample
R = ratio of aquamarine to chrysotile (by weight) as read from the calibration curve

Standardization. A Brazilian aquamarine is used as the internal standard. The clearest portion of this mineral is selected for milling, and the ground material which passes through a 325-mesh sieve serves as the source of internal standard. In our laboratory the sieved fraction of the aquamarine was sized by electron microscopy; 99% of its particles

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measured 3.0 μ or less. The ground chrysotile used in the preparation of the standard samples was also sized by electron microscopy; 99% of its fiber lengths measured 2.5 μ or less.

The standard curve is obtained by application of the procedure to a series of mixtures of aquamarine and chrysotile. This series includes weight ratios of aquamarine to chrysotile of 0.5:1, 1:1, 2:1, 3:1, 4:1, and 5:1. Each mixture, in approximately 1-g samples, is mixed in the mill and finally ground in a mortar, as described under Procedure. The ratios of the intensities of the aquamarine 3.25-A peak to the chrysotile 3.63-A peak (each corrected for background) are plotted against the weight ratios to obtain the standard curve. Each plotted ratio is the average of three to five replicate packings and scannings of each mixture of sample and internal standard.

External Standard Technique for Chrysotile, Amosite and Crocidolite

These types of asbestos may be determined by an x-ray diffraction and external technique.[3]

Procedure. The substances to be analyzed are classified as settled dust, bulk samples of process materials, or airborne dust samples. The preparation of asbestos-containing settled dusts consists of a preliminary screening of gross particles followed by grinding to fiber lengths of less than 3.5 microns. This is accomplished by dry-grinding in a mixer mill for ten minutes.

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Bulk samples may be derived from the starting materials, intermediates or finished products encountered in industrial processes. A representative portion of a bulk sample is pulverized in the mixer mill as described for settled dusts.

The technique of mounting representative portions of dust samples on a molecular membrane filter has been described by Talvitie and Brewer.[4] For this purpose, a known weight of the finely comminuted sample is suspended in 250 ml of water in an MCA volumetric flask. Proper distribution of the material in water is insured by use of a wetting agent. Then the samplr, which may include agglomerations, is dispersed with the aid of a small ultrasonic bath. An aliquot of the thoroughly agitated suspension, containing a known amount of the sample, is filtered using a molecular membrane filter. This method provides a sample of known weight on the filter. This technique has proved to be applicable to dust samples containing asbestos fibers whose sizes are of the magnitude described in this paper.

In-plant samples of airborne asbestos collected on membrane filters are analyzed without size reduction. From fiber size measurements made at this facility, the range and the mean values have been determined to be of the same order of magnitude as those of the asbestos standards used to calibrate the method.

In-plant samples of airborne asbestos fibers collected on membrane filters may not be uniformly distributed on the filters. As a uniform distribution of the fibers is required for this procedure, an even distribution of the collected fibers is obtained by removing the sample from its original filter and redepositing it on a second filter. This is accomplished by placing the original filter sample in a test tube containing a few drops of a suitable wetting agent and sufficient water to cover the filter. The test tube is then immersed in an ultrasonic bath for five minutes to remove the dust deposit from the filter. The original filter is then removed from the test tube and the suspended dust is redeposited on a second filter using the technique described above. This is also a convenient point to aliquot heavy dust samples.

The membrane filter with the aliquot of dust adhering to its surface is mounted in the x-ray diffractometer. A qualitative scan, usually at 1°/min, is run on the sample to establish the presence or absence of asbestos minerals and of possible interferences.

The area under the major diffraction peak of each asbestos mineral present in the dust sample is determined in order to calculate the weight of that particular form of asbestos. If the major diffraction peak is affected by that of another mineral present in the dust, then the second most intense peak of the asbestos mineral is used for a quantitative determination. For determining the area of a peak, the diffractometer is operated at a low scanning speed (0.2°/min) and a slit combination of 1° beam slit, medium Soller slit, and 0.2° detector slit. The area under the peak is computed from the digital printout record. Background corrections are applied to determine the net area of a given peak. The average background count calculated from a fixed interval extending on each side of the diffraction peak is used to calculate the total integrated background correction under the diffraction peak.

The net area of a given peak, computed from the printout data, is referred to a standard curve relating peak area, expressed in counts, to the weight of the appropriate asbestos mineral, expressed in milligrams. The latter quantity is the amount of the mineral represented in the aliquot portion of the analyzed sample.

Standardization. Pure asbestos minerals are used as the external standards. Because some composition differences do occur in asbestos minerals of a given class, the standards should be obtained from the same or a similar source as that of the asbestos present in the dust samples.

The minerals used in establishing the standard curves are treated as described in the Procedure. In our laboratory these prepared minerals had fiber lengths less than 3.5 μ for 99% of the amosite and

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crocidolite fibers and less than 2.5 μ for 99% of the chrysotile fibers, as determined by an electron microscopic sizing procedure.

A 50-mg quantity of each of the pulverized asbestos minerals is placed in an individual 250-ml, MCA volumetric flask. The suspensions are prepared as described for the dust samples. Aliquots containing one to ten mg of a given asbestos standard are removed and transferred to individual membrane filters. A separate series of these standards is prepared for each mineral.

The major (or primary) diffraction peak is counted to determine the area. The net area, after correcting for background, is reported in counts. The relationship of the weight on the filter to the area under a given diffraction peak is a linear function. The plotting of counts and mg of mineral provides the standard curve. These standardization data are obtained from replicate analyses of the filter-mounted standards. A set of three filters is prepared for each concentration level of each mineral. The total number of analyses performed for the standardization of the method involved two to three determinations per filter. These absolute deviations, represented as milligrams (mg) of a specific mineral, were uniform over most of the usable range of the method. The relative standard deviations were as follows: 1.8 to 5% for 1 to 10 mg of chrysotile, 2 to 5% for 1 to 8 mg of crocidolite, and 2 to 5.5% for 1 to 8 mg of amosite.

On the basis of these data, the working ranges of the quantitative method are 1 to 10 mg of chrysotile and 1 to 8 mg of crocidolite or amosite if the deviations are to be held within the indicated limits.

Infrared Spectroscopy

Infrared (IR) spectroscopy involves mixing a dust sample with potassium bromide to make a pellet which is inserted into the IR spectrometer to obtain a spectrum of the sample components. From this spectrum one can identify the major dust components.

Method (Qualitative). A 0.3-mg dust sample (ground so that greater than 90% of the particles are less than 5 μ in diameter) is mulled for 5 minutes with 300 mg IR quality potassium bromide until thoroughly mixed. This mixture is pressed in a 13-mm die for five minutes at 25 tons pressure after an initial five minutes of evacuation. A clear pellet about 0.79 to 0.83 mm will result. This pellet is then placed in the instrument and scanned from 8 to 30 microns. From the resulting spectrum one can identify the asbestos constituents.[5]

Method (Quantitative). Although this method has not been used for the quantitative determination of asbestos components, experiments have shown that 10 micrograms of quartz can be detected to ≈3x scale expansion. In a 10 mg sample this is 0.1% sensitivity. Only under certain conditions could asbestos minerals be quantified.

The IR spectrophotometric method must be used with great care for the identification of specific forms of asbestos occurring in mixtures. The spectra of various mineral components may overlap and make individual identification very difficult or impossible. This method is not preferred for quantitative analysis.

Differential Thermal Analysis of Chrysotile

The implication of chrysotile as a causative agent in certain types of pneumoconiosis has resulted in the appearance of numerous methods of analysis (both quantitative and qualitative) for chrysotile. One of these methods is differential thermal analysis (DTA).

The relatively simple DTA experiment measures temperature difference between a sample and an inert reference material as both are heated or cooled at a uniform rate. By indicating the gain or loss of heat from a system, DTA signifies when a component undergoes a physical change such as fusion, sublimation, or vaporization. Since these physical changes generally occur at different temperatures, a unique thermogram can be obtained for most thermally active materials.

While the principle behind DTA has been known for a long time, it has only been recently that acceptable thermal analysis equipment has become commercially available.

Consequently, the DTA technique will undoubtedly improve with time. A large number of chrysotile samples from various locations throughout the world have already been characterized by DTA.[6-9] This technique has also been used to detect the presence of chrysotile in filled resins.[10]

DTA is a relatively simple technique especially applicable to samples containing a single mineral. However, difficulties arise when multi-component samples are to be analyzed, since the unique thermograms of individual components may not be differentiated.

Atomic Absorption Spectrophotometry

An indirect estimation of chrysotile may be made by utilizing the determination of magnesium in chrysotile-bearing samples by means of atomic absorption spectrophotometry.

Chrysotile asbestos, a hydrated magnesium silicate, is readily broken down by mineral acids. On acid treatment the combined magnesium is dissolved out and can be determined by atomic absorption.

If the general formula ($3MgO\ 2SiO_2\ 2H_2O$) is used for chrysotile, the theoretical magnesium content is about 26%. With this information and the magnesium content of a given sample, it is possible to calculate the approximate amount of chrysotile in the sample. The assumption would have to be made that the sample contained no other magnesium-

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Dr. Powell —

In case your TWA tickets do not come in time for your Jpn. Trip, I have your complete TR in your Travel folder (grey) behind my desk on the 3rd shelf of the book case. [illegible]

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bearing compounds other than chrysotile. Most of the samples analyzed to date have been airborne particulates collected on membrane filters.

Sample Treatment. To the membrane filter sample in an acid-cleaned Phillips beaker is added 10 ml of 6N HCl. The sample is then heated on a hotplate (130°C.) for 20 to 30 minutes to totally break down the chrysotile. The resulting solution is transferred to suitable volumetric glassware and adjusted to a known volume.

Analysis. The magnesium content of the sample is determined by atomic absorption spectrophotometry. Both single element and multi-element hollow cathode devices have been used to produce the Mg 2852Å resonance line which is used for the analysis. The percent absorption at this line is used to calculate the magnesium content of the samples.

Aqueous standards are prepared from a stock solution made from a pure magnesium compound and a standardization curve is run. The range of the method as used is 0 to 2 µg of Mg per ml of solution. Each standard is 0.3N in HCl.

The absorption for unknown samples is referred to the standard curve. The magnesium content in µg per ml is determined, and a final value for total magnesium in the samples is calculated by using the total volume figure for each sample.

This method has been used primarily for small samples (0.20 μg) obtained by using personal samplers. Large samples require such dilution that considerable error may be introduced by dilution factors alone.

It must be emphasized that this method will only determine the magnesium content of the sample. It does not determine the parent compound that contains the magnesium, whether it be magnesium carbonate or one of the types of magnesium silicate. In the analysis of an unknown sample, the dubious assumption would have to be made that chrysotile was the only magnesium compound present. At best, this method provides only an indirect estimation of chrysotile.

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May 1, 1970

Recommended Criteria and Interim Standard for Prevention of Asbestosis

Director, BOSH

1. Enclosed for your review, consideration, and disposition is a document on the above subject, which was approved by all but one member of the Review Committee on Asbestos.

2. This document was prepared according to the procedures as outlined to you previously and included the following steps:

a. A rough draft was prepared by the "working committee," composed of several Bureau personnel.

b. The rough draft was reviewed by the "internal review committee" in July 1969. Extensive revisions were made and it was re-reviewed during August.

c. Copies of the first draft of the proposed criteria and recommended interim standard were sent to the Review Committee on Asbestos, September 5, 1969.

d. The Review Committee met all day, September 16, 1969, at 1014 Broadway and reviewed this draft. (Seven members of the Review Committee -- Mr. Lumsden and Dr. Moore were not present -- and 14 BOSH personnel attended.) Many changes were suggested in the write-up, additional data were promised, but there was general agreement on a limit of 12 fibers/ml as the standard. Three members of the Committee agreed to supply additional material.

e. Additional material was received in January 1970, the document was retyped, reviewed internally, and sent to members of the Review Committee on February 5.

f. The Review Committee met at 1014 Broadway on March 6 to review the second draft. All but one member agreed to a standard of 5 fibers/ml based on a time-weighted exposure with a ceiling of 10 fibers/ml not to exceed 15 minutes in any hour for 5 such periods per day. Baier, Lee and Moore were not present. A few changes in the second draft were suggested.

Page 2 - Director, BOSH

g. Based on letters and/or telephone calls up to April 17 to settle any further differences, a third draft was prepared. All but one member of the committee reaffirmed their earlier agreement on the criteria and recommended interim standard of 5 fibers/ml $> 5 \mu$ in length, based on a time-weighted average exposure and a ceiling not to exceed 10 fibers/ml for a 15-minute period during any one hour not to exceed 5 such periods per day.

3. It is recommended that the criteria and interim standard (third revised draft) be forwarded through proper channels for adoption.

Andrew D. Hosey, Director
Division of Criteria and Standards Development
Bureau of Occupational Safety and Health

Enclosure

cc: Review Committee members

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