STATE OF CALIFORNIA—HEALTH AND WELFARE AGENCY RONALD REAGAN, Governor

DEPARTMENT OF HEALTH
2151 BERKELEY WAY
BERKELEY 94704

June 20, 1974

RECEIVED JUN 25 1974

Dear Colleague:

Enclosed is a copy of a draft of an overview paper on asbestos prepared at the request of the Department of Health. It is meant as a starting point for further discussion by Department staff and other interested persons in order to further elucidate this environmental problem. Therefore the comments concerned therein should not be considered Department policy at this time.

We are sending it to you for information and for any comments or criticisms you may have.

Sincerely,

Jerome J. Wesolowski, Ph.D., Chief
Air and Industrial Hygiene Laboratory

Enclosure

A 17987

DRAFT

ASBESTOS IN THE CALIFORNIA ENVIRONMENT

AIHL REPORT NO. 164

Prepared by:

Jerome J. Wesolowski, PhD
Chief

Air and Industrial Hygiene Laboratory
Laboratory Services Program
California State Department of Health
2151 Berkeley Way, Berkeley, CA
94704

May 1974

TABLE OF CONTENTS

ASBESTOS IN THE CALIFORNIA ENVIRONMENT

I INTRODUCTION

The purpose of this report is to bring together into one document the most up-to-date information on the ubiquitous and dangerous pollutant asbestos, so that those in the California Department of Health who are involved in the decision-making processes with respect to health effects, environmental quality standards, monitoring, emissions control, and methodology development will have easy access to the information they require.

II DESCRIPTION OF THE PROBLEM

A. Background

"Asbestos" is a generic term for a group of hydrated silicates that, when processed, separate into flexible fibers made up of smaller fibrils.* The asbestos minerals are divided into two classes of crystal structures: serpentine and amphibole. Chrysotile, representing 95% of the asbestos produced today, is the only member of the serpentine class. The members of the amphibole class of commercial importance are amosite, crocidolite, anthophyllite, tremolite and actinolite.

Asbestos was formed several billion years ago by the re-crystallization of the constituents of rock by water at a high temperature and pressure–chrysotile in the cracks of the mineral serpentine, and the amphiboles in sedimentary ironstones.

The utility of the mineral comes from its flexibility, tensile strength, and resistance to heat and chemicals. The various types of asbestos differ in their physical and chemical properties. These properties determine the industrial uses and perhaps the respirability, deposition, retention, translocation and biologic reactivity.

The use of asbestos was first recorded in 450 B.C. when Herodotus described enshrouding corpses with asbestos cloth before cremation to permit easy collection of the ashes for burial (1). Pliny in 50 A.D. refers to the use of respirators to avoid inhalation of asbestos dust (1). Legend also has it that Charlemagne attempted to impress the "Henry Kissingers" who visited his court with his magical powers by throwing an asbestos tablecloth into the fire and then withdrawing it unscathed and clean (1,2). Since then its uses have increased and its "magical" properties have been exploited for profit rather than for impressing visiting dignitaries with the court's powers.

B. The Environmental Burden

Asbestos is an ubiquitous pollutant, being found in air, water, soil, food, drugs, and beverages. Evidence has been presented in the literature of extensive contamination of intravenous injectables (3) and beverages (4) by asbestos filters which were ostensibly used to remove contamination. Asbestos contamination from natural sources such as wind and water erosion of

*The large fibers may be reduced to fibrils by solvents or abrasion. Thus a large fiber in an environmental medium may in time fracture longitudinally into smaller fibrils. The word fiber will be used throughout this report, but with the understanding that it encompasses fibrils.

asbestos-containing rock formations, may be appreciable. This is particularly true in California which has some of the richest serpentine deposits in the country (cf. Figure 1). However, there are not sufficient reliable data to attempt to quantify the natural contribution.

Table I gives some measured values of asbestos concentrations in various environmental media. Although the accuracy of these measurements is poorly defined, as will be discussed later, the table does clearly point out the ubiquitous nature of the pollutant.

Since there are around 4,000 uses of asbestos, the anthropogenic contribution is also difficult to ascertain, although some rough engineering estimates have been made for emissions from mining and milling operations, processing operations, and selective consumptive uses. Tables II, III, and IV are reproduced from an Environmental Protection Agency document "Emission Factors for Trace Substances" (5). The 1970 world production of asbestos was 4 million short tons per year (6). The emisssion factor for controlled mining and milling is 25 lbs/ton, so we can estimate the total emission to the environment is approximately 50 thousand tons per year, an amount that cannot be considered negligible. Further, the emissions are localized, i.e., occur in those regions carrying out mining and milling operations. Statistics for 1966 show that California produced 130 thousand tons, giving an emission of 1500 tons that year. By way of reference, consider that in 1970, 500 tons of DDT were used in California and far less since then (7).

The emission factors for the consumptive uses of asbestos are also quite large (cf. Table IV), especially for the insulation and construction industries. However, there are so many uses of asbestos, that any attempt to estimate emissions based solely on the four uses listed in the table would be inadequate. Essentially every vehicle, home, factory and building in the United States contains asbestos products. The emission of fibers during use of such products depends on the ease with which the application of energy can dislodge the fibers and the degree to which the application of energy destroys the fibers, i.e., makes them amorphous, during product use. The fibers in asbestos cement products such as shingles and floor tiles are usually tightly bound but this is not the case for such products as asbestos paper, cloth, and spray fireproofing materials. The heat generated by application of pressure on brakelinings, is so intense that many of the fibers are made amorphous. Nevertheless it has been estimated that 1-3% remain fibrous (8).

Asbestos cement pipes are often used to transport drinking water. Although there is some evidence of an increase of the total number of fibers from source to distribution, it is not known whether the increase is due to the breaking of larger fibers originating at the source, the erosion of the pipe, or is a result of field repairs on the pipe (9).

In many cases the asbestos product per se is not an emission source but becomes one when the asbestos product is destroyed. This is particularly true in demolition of industrial and commercial buildings that have been fireproofed with asbestos-containing material.

Although many specific examples of possible sources of asbestos emission can be cited, there is no way at present to assess accurately the total environmental burden.

C. The Health Hazard

1. Occupational Groups

The health hazards of asbestos were first noted by the Roman naturalist Pliny the Elder and the Greek geographer Strabo who recorded a lung sickness in slaves who wove asbestos into cloth (2). Further documentation did not occur until the early 1900's. At present the

inhalation of the fibers is associated with three diseases: asbestosis, lung cancer and mesothelioma. These diseases have latency periods measured in decades.

Asbestosis was the first demonstrable adverse effect of asbestos in man. The first case was reported in London in 1907, and involved a man who had worked for 10 years in an asbestos factory (10). A detailed description was provided by Cooke in 1927 and that is when the term "asbestosis" was coined (11). Sufficient epidemiological evidence has since been accumulated and standards for occupational exposures have been established in the United States and 10 other countries.

Lynch and Smith first suggested in 1935 that asbestos inhalation might be related to cancer of the lung (12). Numerous other studies since then have confirmed an association between occupational exposure and an increase in lung cancer incidence.

The first serious consideration of a possible causal relationship between asbestos and mesothelioma was outlined by Wagner et al in 1960 when they reported 33 cases of pleural mesothelioma in a part of South Africa noted for crocidolite mining (13). Most of those afflicted did not have direct occupational exposures but merely lived near the mines or had household contacts with asbestos workers. Since 1960 additional studies have tended to support the relation between asbestos and mesothelioma, particularly the work in 1965 by Selikoff et al (14). One of the difficulties in obtaining information on the association is the long period, around 30 years, between the first exposure and the appearance of a tumor.

There is evidence that insulation workers, chronically exposed to high levels of airborne asbestos, suffer a disproportionate incidence of gastro-intestinal cancer and abdominal mesothelioma. This possibly is due to the ingestion of asbestos fibers during occupational exposure (15).

2. Non-Occupational Groups

There is strong evidence that most human lungs contain thousands or millions of fibers (16,17,18,19). Pleural calcification, regarded as almost diagnostic of asbestos-related disease, shows an association with non-occupational exposure to asbestos (20,21). Much of the evidence comes from studies of groups living near asbestos sources. In the study of Wagner et al, cited earlier (14), most of those afflicted with mesothelioma did not have direct occupational exposure but only lived near the mines or had household contacts with asbestos workers. According to Wagner "a particularly striking case was that of a woman who was born in a town on the asbestos fields, left the region at the age of five, and died of a pleural mesothelioma at the age of fifty-seven". Detailed investigation of her childhood revealed that she and her playmates (two of whom also died of mesothelioma) used to enjoy sliding down the asbestos dump on their way home from school.

Thus there can be little doubt that asbestos fibers can be hazardous to both occupational and non-occupational groups. Unfortunately, the two crucial pieces of data needed to complete the picture, namely the role of cofactors, and the dose-response relationship have not been established at this time.

III IMPORTANCE OF THE PROBLEM

The significance of a pollutant is judged by its effects on human beings, by the number of people so affected, and by trends in the environmental burden.

Since the effect of sufficient exposure to asbestos is death, the importance of the problem must be judged with the same yardsticks that are used to judge other highly toxic pollutants such as the carcinogens. Thus it should not be compared to many other pollutants which affect only esthetics or morbidity rates.

It is customary when talking of trends in environmental burden or the number of people exposed to a pollutant to address both the future and the present problem. Because of the long latency period of asbestos-related diseases, such an artificial division can be misleading. The lack of appropriate action by responsible agencies and industries in regulating asbestos 30 years ago is the cause of members of our society dying today from asbestos-related diseases. Similarly, lack of appropriate judgment on the part of responsible agencies in the year 1974 will result in the death of people from asbestos-related disease in the year 2004. Figure 2 gives a comparison of trends in the world production and U.S. consumption of asbestos, from the 1940's to the 1970's (22). The curves clearly indicate that from the viewpoint of both production and consumption, the magnitude of the problem has been increasing over the past 30 years. It should also be clear from the sharp rate of increase that, unless recently established control strategies are very effective, the maximum death rate from asbestos-related diseases is still to come.

There are about 40,000 field insulation workers in the United States who are exposed to asbestos, and the activities of these workers in turn cause secondary exposures to an estimated 3 to 5 million other building construction and shipyard workers (23). In addition an estimated 50,000 workers are involved in the manufacture of asbestos-containing products, not including fabrication of products such as electrical or thermal insulation or products which involve previously manufactured asbestos components. The effect of today's exposures in the working place will not be known before the year 2,000, but according to projections made in 1971 by Dr. I. Selikoff of Mt. Sinai Hospital, N.Y. that unless working conditions in the insulation industry are significantly altered, asbestos exposure will lead to 17,000 excess deaths from lung cancer, 10,000 from cancer of the pleura and peritoneum, and 10,000 from asbestosis over the next 30 years (24). Since 1971 conditions in this particular industry have been improved. This improvement may lessen the projected number of excess deaths.

It is impossible to make projections of the number of deaths possible in the non-occupationally exposed population. Since the pollutant is so ubiquitous, all members of the population will be affected.

The seriousness of the problem has not been neglected by responsible agencies. The National Academy of Sciences states "Asbestos is too important in our technology and economy for its essential use to be stopped. But because of the known serious effects of uncontrolled inhalation of asbestos minerals in industry and uncertainty as to the shape and character of the dose-response curve in man, it would be highly imprudent to permit additional contamination of the public environment with asbestos. Continued use at minimal risk to the public requires that the major sources of man-made asbestos emissions to the atmosphere be defined and controlled. In the absence of such controls, local fiber concentrations might at times approach those in occupational sites. Analytic methods and epidemiological data are not yet adequate for the development of an ambient air standard but emission controls are needed and appear to be feasible."(8)

The National Institute of Occupational Safety and Health (NIOSH) states "It is recognized that additional data would be desirable to support an asbestos standard. But because of the immediate need for worker protection it is necessary to make a recommendation based on available studies and data." As a result NIOSH has established criteria for a recommended standard for occupational exposure to asbestos (23).

The administrator of the Environmental Protection Agency has made a judgment that in order to provide an ample margin of safety to protect the public health from asbestos it is necessary to control emissions from major man-made sources of asbestos emissions into the atmosphere, but that it is not necessary to prohibit all emissions (25). An important consideration in the promulgation of this emission control regulation was the lack of satisfactory methods for sampling and identifying and measuring airborne asbestos. As a result, it was determined not to be practical to establish allowable numerical concentrations or mass emission limits for asbestos. Instead the standard was expressed in terms of required control practices that limit asbestos emissions to an "acceptable" level.

Although EPA did not promulgate a numerical ambient air standard, at least one state is considering such a standard. The Department of Environmental Protection of the State of Connecticut has proposed an asbestos ambient air quality standard of 30 nanograms per cubic meter based on a 24-hour average sample (26). Connecticut selected the criterion of mesothelioma as the basis for developing this standard.

The question has now been raised as to the possibility of a hazard to individuals who ingest food and water which contain asbestos. Recently the Reserve Mining Company, which produces 15% of the iron ore used in this country, was ordered closed by a Federal judge on the grounds that there was sufficient evidence to show that asbestos fibers which were discharged into Lake Superior by Reserve constituted a public health hazard to those who depend on the lake for drinking water.

Considering the effects, the trends, the number of people involved and the responses of federal and state agencies and the courts to the possible health effects of asbestos, it would be highly imprudent for the State of California with its large deposits of asbestos-bearing rocks, its large mining and milling operations and its extensive shipyard facilities to simply neglect this important pollutant.

IV TECHNOLOGY AVAILABLE FOR MEASURING ASBESTOS

It should be clear from the above sections that prudence would dictate that numerical standards be established for asbestos in environmental media. The unfortunate lack of dose-response information has caused responsible agencies to adopt non-numerical standards or no standards at all. Such information can be available only when appropriate epidemiological studies are carried out, and such studies are in turn completely dependent on accurate monitoring data. The latter data are sparse and inaccurate because of the lack of technology to accurately determine asbestos in environmental media.

This section briefly describes the methodology available and some of its limitations. However, the limitations are not so severe as to preclude initiation of a limited State monitoring program in air and water. Although such measurements may be somewhat inaccurate at first, they will still be of value if accuracy limitations are taken into consideration in their interpretation. Further, improvements in the methodology will occur faster if the development work carried out in the laboratory is coupled with an actual monitoring program.

According to the National Academy of Science report on asbestos, "when considering the influence of type of asbestos, fiber size, and cofactors on biologic effects, it is necessary to emphasize that a given attribute may influence respirability, deposition, retention, clearance, translocation, and biologic reactivity in different ways" (8). There is very little documentation on the detailed influence of these parameters on biologic effects. This includes the movement of fibers within the human body, particularly their potential for entry through the gastrointestinal tract. The aerodynamic properties of fibers depend largely on their diameter, with fibers below 3.5 μm in diameter being respirable (27). Thus it is important for any monitoring program whose ultimate goal is obtaining a dose-response relationship that fiber type and size be measured.

At the present time the only tools available for measuring size are the optical microscope and the electron microscope. However, the optical microscope can distinguish only those fibers of diameter greater than 0.5 μm. In most environmental samples the majority of fibers is much smaller. This is clearly illustrated in Figure 3 which is a three-dimensional plot of the numbers of asbestos fibers by length and diameter near a chrysotile asbestos mill located south of King City, California. The number of fibers per liter is indicated by the height of the column plotted over the appropriate cell in the length-by-diameter matrix (28). The plot demonstrates that the large majority of fibers are both thin and short (less than 0.5 μm in diameter by less than 2.5 μm long). AIHL has also carried out similar asbestos characterizations for other ambient air locations in California and for water samples collected from rivers, and drinking water taps. Although there are variations in the size distributions and in the concentration of fibers present, all samples demonstrate that the large majority of the fibers are too small to be detected light microscopy. It is for this reason that much of the discussion to follow will focus on electron microscopy.

A. Measurements of Asbestos in Air

There are three important distinctions between occupational air and ambient air with respect to asbestos. First, there are far more fibers in occupational air. Second, it is easier to obtain a useful standard for identification purposes in an occupational situation since the source of the asbestos is known. Third, the standard for occupational exposure refers to only those fibers greater than five micrometers in length. For these reasons occupational and ambient air measurements are discussed separately.

1. Ambient Air

The methodology of asbestos quantification in environmental samples falls into these interrelated areas: sampling, preparation of the sample for subsequent analysis, identification, and determination of the concentration of asbestos.

To collect the sample, air is moved through a membrane filter at a specified flow rate for a length of time determined by the expected concentration of asbestos in the air. For ambient air monitoring, the Air and Industrial Hygiene Laboratory method employs 0.8 μm pore size Nuclepore filters of 47 mm diameter, at a flow rate of ten liters per minute, for 2 to 24 hours. If caution is taken to use proper aerosol sampling procedures the collection error is small compared to those associated with the preparation of the sample and the identification and counting of the fibers.

Since the vast majority of the fibers in ambient air and water are too small to be resolved by light microscopy, sophisticated, time-consuming, and expensive electron microscopic techniques must be used. Two general classes of sample preparation utilized to obtain size distributions by electron microscopy are the direct-clearing technique and the separation

technique. The direct method presents the microscopist with a sample on which a minimum of manipulation has been carried out but which contains both asbestos particles and all other particles which were present in the environmental medium when the sample was collected. The separation technique presents a sample which contains a minimum of interfering particles, but which was prepared with much manipulation.

In many air samples and in some water samples, it is possible to use the direct-clearing method to size and count asbestos fibers among the other materials present. In this method the sample filter is coated with a layer of silicon monoxide or carbon to hold the fibers in place. The filter itself is then dissolved by vapors of a solvent such as acetone or chloroform. The film with embedded fibers and other particles is then examined by electron microscopy. However, urban air containing 100 micrograms of particles per cubic meter will probably contain on the the average only 0.01 microgram asbestos per cubic meter. Thus the sample filter contains 10,000 times as much non-asbestos as asbestos material by weight. The number ratio of particles may vary, but for average conditions encountered in urban air will range from 10,000 to 100,000 non-asbestos particles for every asbestos fiber. The ratio is even larger in water samples. Under such circumstances, quantitation by the direct-clearing technique is difficult.

In the separation technique, the filter is ashed to destroy organic particles and fibers, carbon, and the filter material itself. The ashed sample is then mixed with a solution of 0.5% Parlodion in amyl acetate. An aliquot of the suspension is dropped on a water surface within a confined area of known size. Electron microscope grids are then drawn through the asbestos-containing Parlodion film for subsequent counting and sizing (29).

The preparation techniques could be the source of large errors, particularly with respect to the alteration of the size distribution of the sample. More research is needed to delineate the magnitude of errors in the various preparation techniques.

After sample preparation, the grid is scanned in an electron microscope at 1000X to determine uniformity of sample deposition. The search for fibers is conducted at 8000X. Each fiber detected is identified at 20,000X morphologically and by electron diffraction if necessary (30). The length and diameter are then measured.

Although chrysotile may be presumptively identifed by recognition of a central longitudinal canal in the fibril (cf. Figure 4), positive identification requires electron diffraction. In this technique a selected area of an individual fiber is bombarded by the electron beam of the microscope and the resulting diffraction pattern is recorded. Figure 5 is an example of a diffraction pattern obtained from tremolite asbestos fibers. Crystal lattice parameters are computed from such spot and ring patterns and compared with those of standards (31).

This technique allows differentiation of asbestos from non-asbestos materials and of chrysotile from amphibole asbestos. It does not, however, normally allow the identification of the specific type of amphibole present. Fibrils smaller than 0.05 μm in diameter seldom produce diffraction patterns suitable for identification.

Since electron diffraction identification is slow and expensive, in most cases only 5% of the morphologically-identified asbestos fibers have their identifications confirmed by electron diffraction.

After examining a minimum of 20 grid holes in each of three grids for each sample, the total number of fibers in each size category is calculated, producing the size distribution.

One of the largest sources of error is in the morphological identification. First, there are man-made and natural fibers that resemble asbestos. Second, it is difficult to obtain suitable standards to make morphological comparisons with the fibers found in the environmental sample. Although standard asbestos samples prepared by the Union Internationale Contre Cancer (UICC) are accepted throughout the world as standards for mined asbestos, they are not universally applicable as standards for asbestos in environmental media. In fact the chemical and physical forces of environmental media may in time cause a change in the properties of the fibers. This is particularly true for water, where, for example, magnesium may be leached from chrysotile asbestos during prolonged immersion.

Although, at present no one knows the accuracy or even precision of the various methods, one would be hard pressed to claim that data obtained thus far for any environmental medium are better than an order of magnitude estimate.

A large error which is often overlooked is the error associated with the non-representativeness of the sample. One sample can hardly characterize the air or water of a city. Thus any program which attempts to measure average concentration of asbestos and to characterize the size distributions in any environmental medium must provide for the collection of sufficient number of samples by location and time. However present analytical techniques are expensive and time consuming. Thus at the present time only a few dozen California air samples have been analyzed and even fewer for water, food, drugs, and beverages.

Research is needed to develop screening procedures which will reduce the 6 to 8 hours presently needed to analyze one sample. An example of a technique currently under feasibility study at AIHL is the electron microscopic dark-field screening technique. This technique is an application of the optical microscopic principle that dark-field images of amorphous particles are generally different from those produced by crystalline substances. Thus crystalline fibers can be readily distinguished from non-crystalline fibers. This procedure is advantageous in detecting asbestos fibers which often constitute only a small fraction of the total fibers present. Some samples contain only one asbestos fiber per 100 non-crystalline fibers. The screening method eliminates the effort spent diffracting the non-crystalline fibers to ascertain that they are not asbestos, resulting in a proportionate savings in time.

Although the transmission electron microscope will continue to be the basic tool necessary for the identification of asbestos fibers, a recently developed instrument called EMMA which is a combination transmission electron microscope and electron microprobe analyzer may in time become the ideal instrument for the detection and identification of very fine asbestos particles. The electron microprobe enables the microscopist to obtain an elemental analysis of a specific fiber for which morphological and selected area diffraction have been made, thus enhancing the certainty of identification (32).

Another technique called the rubout technique, measures the weight of asbestos present. This is done by grinding all asbestos fibers into fibrils of fairly uniform size. These fibrils are then mounted on electron microscope grids for identification, sizing and counting. The

weight of asbestos is estimated by calculating the total volume of asbestos fibrils and multiplying by the density of the asbestos type present. Since one large fiber can account for 99% of the weight present in an environmental sample, this method has limited value in assessing health problems.

2. Occupational Air

In the recommended National Institute for Occupational Safety and Health (NIOSH) method for the measurement of asbestos, air is moved through a membrane filter, at the normal breathing rate for a specified length of time. The asbestos particles, as well as the other aerosols in the air, are thus collected on the filter. A portion of the filter is then rendered transparent by suitable application of a clearing agent and the transparent filter is then placed under a phase contrast optical microscope. The small difference between the refractive indices of asbestos and the cleared filter requires the use of phase contrast microscopy to detect the asbestos present. The microscope magnification is 430 and only those fibers that are larger than five microns in length are counted. The statistical error resulting from the non-random distribution of the fibers is kept to an acceptably low level by appropriate counting procedures. The method described by NIOSH is adequate to determine compliance with the NIOSH standard, but it is important to note that the standard was developed around the existing analytical methodology and the sole criterion used was the control of pleural calcification and asbestosis.

However, the presumption is made that the number of fibers greater than five micrometers inhaled by workers is an index of the total number of fibers inhaled and therefore the total amount of asbestos deposited in the lungs. This has never been verified, and in fact one would anticipate that the size distribution of particles would vary greatly from operation to operation, and to a lesser extent, from time to time within a given operation.

The methodology discussed above directly measures the number of fibers in occupational air that could be inhaled by workers. There is a second type of methodology dealing with bulk samples which addresses the question of possible sources of asbestos. Here one is asking such questions as: "could the material in a ceiling which is slowly deteriorating be a possible source of airborne asbestos?" or "could the fireproof material in the return air plenums between floors of modern buildings be a source of airborne asbestos?" The resolution to these questions requires the identification and quantification of asbestos present in the bulk materials. This is done by use of x-ray diffraction techniques. The bulk sample is made uniform by ultrasonification, or by grinding, and then exposed to x-rays. The identification and quantification is made by comparison of the diffraction pattern and intensity to that from a known amount of reference material. At the present time, this method can measure as little as one percent by weight of asbestos.

An example which highlights the importance of this technique for seeking out possible sources of airborne asbestos occurred recently in Riverside County, California. Teachers in a high school demanded that a ceiling which was slowly deteriorating be analyzed for asbestos. Samples of the ceiling were sent to AIHL for analysis. It was found that about 20% of the material which was slowly falling into the classroom environment was asbestos. Unfortunately, no air samples were taken in the rooms to determine if indeed asbestos levels were higher than in rooms not having such an obvious source.

B. Measurements of Asbestos in Water

For water samples, a suitable amount, usually about one liter, is collected in a clean bottle or flask. The water is then passed through a filter, such as Nuclepore, which collects the asbestos particles. Although the filter collection efficiency for small asbestos particles remains to be determined, clearly the smaller the pore size, the higher the collection efficiency. Unfortunately, filtration of water through a small pore filter is a slow process and if, as is usually the case, the water contains many other kinds of particles, the filter may clog before all the water has gone through. It has been estimated that losses of the order of 50% may occur as a result of inefficient filtration through 0.8 micrometer and larger pore size filters.

Methods for the preparation of the filter for microscopy and the subsequent identification and sizing of the fibers are similar to those used for air samples. Sources of error are also similar, but the change of characteristics in water over a time period and the great abundance of organic material present in most water samples make identification of asbestos in water more difficult than in air. The research needs are similar to those outlined in the section on air.

C. Measurements of Asbestos in Foods, Drugs, Beverages and Talc

The collection procedures necessary to assure representation of samples are well established for this category. However, sample preparation techniques, especially for vegetable and animal food solids and tissue have not yet been developed.

The major requirement for isolation of asbestos from such samples is the destruction of organic matter without the concurrent destruction of asbestos. In view of chrysotile's partial solubility in acid, hot and/or concentrated acid digestions must be avoided. Therefore this category of samples requires more development in sample preparation than that needed for air and water.

D. Measurements of Asbestos in Human Lung Tissue

The most important information needed is the dose-response curve. An approximation of the dose inhaled by a human over a lifetime may be made by measuring the amount of asbestos present in autopsy lung tissue. Much work has been done on the methodology necessary to identify asbestos in lung tissue and there is strong evidence that most human lungs contain thousands or millions of fibers (16,17,18). However, very little effort has been made in developing methods to quantify the amount of asbestos in autopsy samples. Therefore, methods for identifying and quantitating asbestos in biologic tissue need development and application.

V ROLE OF THE DEPARTMENT OF HEALTH

A. Standards Setting

The Department of Health has an advisory role in standard setting. Through research and consultation, the Department helps develop the necessary criteria upon which appropriate agencies base standards. This section will discuss the present status of asbestos standards.

1. Occupational Air Standards

Present National Institute for Occupational Safety and Health (NIOSH) recommended standards obviate the necessity for the Department of Health considering occupational

standards for the control of asbestosis. However the NIOSH numerical standard, designed around valid, reproducible and inexpensive optical microscopic techniques available at the time of its recommendation, refers only to those asbestos fibers longer than 5 μm. Yet fibers longer than 5 μm account for less than 5% of the total fibers present in an occupational environment, and for some operations, notably textile processing and friction material and pipe manufacturing, only 2% of the total (33).

Since these smaller fibers are respirable and since the dose-response relationship of lung cancer and mesothelioma may be dependent on fiber size, fibers monitored in industrial settings (i.e., longer than 5 μm) must be related to the size distribution of fibers present. There is very little information on this relation, and it is believed to vary with type of manufacturing process and even with individual companies within a given industry. At present, the CAL/OSHA program routinely collects air samples in California asbestos industries for counting of fibers longer than 5 μm by the optical method. It is recommended that a statistically significant set of these samples for various types of asbestos industries be analyzed by electron as well as optical microscopy in order to determine the relation of the NIOSH method to the size distribution. The role of the Department of Health is to encourage OSHA to carry out such a program in California. Should OSHA not respond adequately to these needs, the Department should then assume responsibility for such a program.

2. Ambient Air Standards

The administrator of EPA, under provisions of the National Emissions Standards for Hazardous Air Pollutants (NESHAP), has declared asbestos to be a hazardous pollutant and has attempted to control ambient asbestos levels by promulgating emission controls and by reducing the amount of asbestos in certain products to less than 1%. EPA does not control emissions from mines and mills, since according to the Administrator, they are adequately controlled by the U.S. Bureau of Mines (25). EPA encourages delegation of NESHAP enforcement to the states, provided state regulations are equivalent to or more stringent than the federal regulations.

There are no numerical ambient air standards for California at the present time.

In January 1973, Director Hodges of the State Department of Public Health wrote in a memo to the California Air Resources Board: "The possibility of general increase in malignant mesothelioma and the likelihood that several decades would have to pass before we could detect this effect makes it incumbent upon us to restrict unnecessary asbestos exposure as much as possible. It is to that end that it is proposed that air quality standards be set. The possible role of community asbestos in cancer of the lung gives added importance to this proposal" (34).

He further stated: "It is appropriate and reasonable to require upwind and downwind monitoring by any user whose activities are likely to lead to appreciable (4x to 10x) increases in community asbestos exposure."

Dr. Hodges concluded: "It would be appropriate and reasonable for the State Department of Public Health with assistance of an advisory group to review the health implications of asbestos exposure and to make further recommendations for air quality standards and for control."

The role of the Department of Health in 1974 is to promote vigorously the recommendations made by Dr. Hodges in January 1973.

3. Water Standards

The lack of sufficient data to establish a causal relationship between ingested asbestos and gastrointestinal cancer makes it difficult to support a numerical asbestos standard for water at this time. However, prudence demands that reasonable steps be taken to minimize the dispersal of asbestos in waters ultimately used for drinking and that filtration of drinking water be made more efficient for removal of asbestos fibers. The Department of Health should establish an advisory committee, including members of industry and other state and federal agencies, to delineate the sources of asbestos in California drinking water and to make recommendations for minimizing the possible health hazard.

4. Food, Drug and Cosmetic Standards

Foods, drugs and cosmetics are controlled by federal and state laws which prohibit the presence of toxic substances. The federal Delaney Amendment prohibits the presence of any carcinogenic substance in foods, no matter how small the concentration. Ingested asbestos has not yet been established as a carcinogen, however, its carcinogenicity is unquestioned when inhaled in sufficient concentrations in the work place. No prohibition of asbestos in foods, drugs or cosmetics has yet been made and no enforcement action on asbestos in foods, drugs and cosmetics is currently underway in California.

However state and federal food and drug officials discourage the use of asbestos filters in the processing of foods, drugs and cosmetics.

The Department, through an advisory committee, should participate with the Federal Food and Drug Administration in determining whether asbestos should be banned in foods, drugs and cosmetics.

B. Methodology Development

There is need for vast improvement in the methods used to identify and quantitate the number of asbestos fibers in various size ranges in environmental media. Of particular concern are methods of sample preparation and identification. Since present techniques are costly, there is a need for faster screening techniques as discussed earlier. There is a great deal of overlap between the methods for air, water, foods, drugs and beverages, and cosmetics, but also sufficient differences, especially in the area of sample preparation, to make it improbable that any one method will be universally applicable. Various agencies, such as the Federal Food and Drug Administration and the U.S. Environmental Protection Agency are funding or planning to fund some development efforts. Improvements in the methodology probably will occur in a step-wise fashion over many years.

The California Department of Health should not be involved in funding methods development per se. However, it is of crucial importance that the Department maintain a microscopy laboratory of sufficient expertise to:

1. Study those aspects of the methodological problems which are unique to California, such as establishing reference materials applicable to the California environment. For example, the reference materials which were used to determine the source of asbestos in the Duluth case discussed earlier would be of little value in determining the source of asbestos in San Francisco drinking water.

2. Keep well informed of current advances in methodology so that they can be rapidly applied to California monitoring and epidemiological studies.

3. Carry out method development in those areas neglected by federal agencies.

C. Monitoring

1. Occupational Air

The Department, through the CAL/OSHA program is fully involved in the "monitoring" of occupational air for asbestos fibers longer than 5 μm. However, as discussed earlier, the Department should encourage OSHA to carry out a program in California to determine the relation between the number of fibers longer than 5 μm and the size distribution in various California asbestos industries. Should OSHA not respond adequately to this need, the Department should assume the responsibility for such a program.

2. Ambient Air

The Air and Industrial Hygiene Laboratory under contract with the research section of the California Air Resources Board, will make measurements this year of the concentration of asbestos fibers in ambient air near a California mine and mill. Other than this rather limited project, there is no monitoring effort in California at this time. Because of the problems associated with the methodology available for identifying and quantifying asbestos and the cost involved, it would be inappropriate at this time to establish a large-scale air monitoring program in California. However, it is crucial that a limited program be started now to obtain a rough measure of the atmospheric burden and the relative changes with season and location.

The Environmental Protection Agency is in the process of funding a national program for monitoring asbestos in air and water but the funding expected to be allocated for California is, in our opinion, far too small, even to reach these limited objectives. Therefore the Department of Health, working in cooperation with the Air Resources Board, should establish a limited air monitoring program.

3. Water

There are no monitoring activities in the State at this time. The total number of California water samples analyzed for asbestos to date is probably around one dozen. For the same reasons cited in the above section, it would be inappropriate at this time to establish a large-scale water monitoring program. However, the expected large burden to California drinking water due to erosion of serpentine rock formations necessitates that a limited monitoring program be established. Again, in our opinion, the planned Environmental Protection Agency program is not sufficient. Therefore, the Department of Health, in cooperation with the Water Resources Board, should establish such a program.

4. Foods, Drugs, Beverages, and Cosmetics

The methodological problems associated with sample preparation are even greater for this general category of samples than for air and water. Therefore even a limited monitoring program would be inappropriate at this time. An exception would be liquid samples where sample preparation can in many cases be similar to that used for water. In those cases, it is appropriate that a small program be started to estimate the asbestos concentration in products consumed by the California population with special emphasis on those products consumed regularly by the young. If such a program cannot be established by other agencies the Department should assume the responsibility.

D. Epidemiological Studies

Since the ultimate goal should be the establishment of the dose-response curve, there is no doubt of the need for more epidemiological studies, particularly with respect to air and water. For air, according to the National Academy of Sciences, "Populations in several different exposure ranges should be studied, including occupational, household, and neighborhood exposures. Special studies of mesothelioma are needed to determine whether the incidence has been increasing and to determine the current pattern of distribution. A large series of routine autopsies should be studied to determine whether causes of death can be related to amounts of asbestos in the lungs and other organs. All the above are urgent if a range of safe exposure is to be established with confidence." (8) For water, it is important to estimate drinking water asbestos exposures in areas of California where epidemiological data on gastrointestinal cancer incidence are available.

The role of the Department of Health is to carry out such programs, in cooperation with federal agencies when possible.

VI CONCLUDING REMARKS

The above report has summarized the environmental asbestos problem and has indicated possible roles of the Department of Health. It is meant as a starting point for future discussions by Department staff and other interested persons in order to further elucidate both areas, and lead to a comprehensive program to assure adequate health protection for the California population.

Since lack of action or of appropriate judgment on the part of the Department in the year 1974 may result in the death of Californians in the year 2004, it is imperative that such a program be implemented expeditiously and yet with great technical care. It is hoped that the above report will serve as a catalyst to such a dual approach.

REFERENCES

1. Hunter, Donald. The Diseases of Occupations, 4th Edition. Little, Brown and Co. 1969 p. 1009.

2. Brodeur, Paul. Asbestos and Enzymes. Ballantine Books, N.Y. 1972 p. 10.

3. Nicholson WJ, Maggiore CJ, Selikoff IJ: Asbestos contamination of parenteral drugs. Science 177, 171-173, July 14, 1972.

4. Cunningham HM, Pontefract R: Asbestos fibres in beverages and drinking water. Nature 232, 332-333, July 30, 1971.

5. Emission factors for trace substances. Environmental Protection Agency 450/2-73-001, 1973.

6. Control Techniques for Asbestos Air Pollutants. Environmental Protection Agency, AP-117, 1973.

7. Pesticide Use Report 1970. California Department of Agriculture, Sacramento, CA. (1971).

8. Asbestos: The need for and feasibility of air pollution control. National Academy of Sciences (1971).

9. Sargent H: Paper presented at a New England Water Works Association Meeting, Northfield, Vermont, May 17, 1973.

10. Murray HM: Statement before the committee in the minutes of evidence in report of the departmental committee on compensation for industrial disease. London, H.M. Stationery Office, 1907, pp. 127-128.

11. Cooke WE: Pulmonary asbestosis. Brit. Med. J. 2:1024-1025, 1927.

12. Lynch RM, Smith WA: Pulmonary asbestosis III. Carcinoma of lung in asbesto-silicosis. Amer. J. Cancer 24:56-64, 1935.

13. Wagner JC, Sleggs CA, Marchand P: Diffuse pleural mesothelioma and asbestos exposure in the northwestern cape province. Brit. J. Ind. Med. 17:260-271, 1960.

14. Selikoff IJ, Churg J, Hammond EC: Relation between exposure to asbestos and mesothelioma. New England J. Med. 272:560-565, 1965.

15. Kahn, E, State Dept. of Health, Berkeley, CA. Private communication. 1974.

16. Langer AM, Baden V, Hammond EC, Selikoff IJ: Inorganic fibers, including chrysotile, in lungs at autopsy: preliminary report. Presented at Third International Symposium on Inhaled Particles, London, September 22, 1970.

17. Langer AM, Selikoff IJ, Sastre A: Chrysotile asbestos in the lungs of persons in New York City. Arch Envir. Health 22:348-361, 1971.

18. Pooley FD, Oldham PD, Um, CH, Wagner JC: The detection of asbestos in tissues. H.A. Shapiro, Ed. Pneumoconiosis. Proceedings of the International Conference 1969, Capetown, Oxford University Press, 1970, pp. 108-116.

19. Selikoff IJ, Hammond EC: Asbestos bodies in New York population in two periods of time. H.A. Shapiro, Ed. Pneumoconiosis. Proceedings of the International Converence, Johannesburg, 1969, Capetown, Oxford University Press, 1970, pp. 99-105.

20. Kiviluoto R: Pleural calcification as a roentgenologic sign of non-occupational endemic anthophyllite-asbestosis. Acta Radiol. Suppl. 194:1-67, 1960.

21. Raunio V: Occurance of unusual pleural calcification in Finland: Studies on atmospheric pollution caused by asbestos. Ann. Med. Int. Tenn. 55 (Suppl. 49) 1-61, 1966.

22. Sullivan RJ, Athanassiadis YC: Preliminary air pollution survey of asbestos. U.S. Department of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service (October 1969).

23. Criteria for a recommended standard... occupational exposure to asbestos. U.S. Department of Health, Education, and Welfare, HSM 72-10267 (1972).

24. Selikoff, IJ Mt. Sinai Hospital, N.Y. Letter to United States Secretary of Labor, J.D. Hodgson (1971).

25. Background information on development of National Emission Standards for Hazardous Air Pollutants: Asbestos, beryllium and mercury. U.S. Environmental Protection Agency APTD 1503 (March 1973).

26. Bruckman L: The environmental impact of asbestos in Connecticut. Report issued by State of Connecticut, Department of Environmental Protection, 1973.

27. Timbrell V: The inhalation of fibrous dusts. Ann. N.Y. Acad. Sci., 132, 255 (1965).

28. Wesolowski JJ, Stanley R, Smith G, Carpenter L, and Berner A: Asbestos measurements in the California environment. Prepared for publication in the Proceedings of the International Symposium on Recent Advances in the Assessment of the Health Effects of Environmental Pollution, World Health Organization Conference, Paris, June 1974.

29. Smith G: Parlodion film method for the determination of asbestos in ambient atmospheres, AIHL Method 38-A, State Department of Health, Berkeley, CA 94704 (1973).

30. Seshan K: Morphological identification of chrysotile asbestos by transmission electron microscopy, AIHL Report No. 149, State Department of Health, Berkeley, CA 94704 (1974).

31. Skikne M, Talbot J, Rendall R: Electron diffraction patterns of U.I.C.C. asbestos samples. Env. Rsch. 4:2, 141-145 (1971).

32. McCrone W, Stewart IM: Asbestos. American Laboratory, April 1974.

33. Lynch JR, Ayer HE, Johnson DL: The interrelationships of selected asbestos exposure indices. Amer. Ind. Hyg. J., 31:598-604, 1970.

34. Hodges, FB. State Dept. Public Health, Berkeley, CA. Letter to AJ Haagen–Smit. Chairman State Air Resources Board. Jan. 8, 1973.

TABLE I

ASBESTOS CONCENTRATIONS FOUND IN VARIOUS SAMPLES AND LOCATIONS

Sample	Location	Asbestos Conc.	Reference
Ambient Air	Upwind of asbestos plant, CA	16×10^6 fibrils/m^3	2
" "	Downwind " " "	100×10^6 fibrils/m^3	"
" "	San Lucas, CA 5/15/72	1×10^6 fibrils/m^3	"
" "	San Lucas, CA 9/25/72	2×10^6 fibrils/m^3	3
" "	King City, CA 9/25/72	1×10^6 fibrils/m^3	"
" "	Berkeley, CA 2/10/72	0.7×10^6 fibrils/m^3	2
" "	Berkeley, CA 11/30/72	0.3×10^6 fibrils/m^3	3

Recalculation of the above data on a mass basis gives the following:

Ambient Air	Upwind of asbestos plant, CA	*Approx 57 ng/m^3	3
" "	Downwind " " " "	11,000 ng/m^3	"
" "	San Lucas, CA 5/15/72	" 6 ng/m^3	3
" "	San Lucas, CA 9/25/72	" 110 ng/m^3	"
" "	King City, CA 9/25/72	" 175 ng/m^3	"
" "	Berkeley, CA 2/10/72	" 73 ng/m^3	"
" "	Berkeley, CA 11/30/72	" 22 ng/m^3	"
Ambient Air	8 Burroughs of NY	11 to 60 ng/m^3	1
" "	Philadelphia, PA	45 to 100 ng/m^3	"
" "	Ridgewood, NJ	20 ng/m^3	"
" "	Port Allegany, PA	10 to 30 ng/m^3	"
" "	Dayton, Ohio	0.4 to 11 ng/m^3	4
" "	Houston, Texas	4 to 6 ng/m^3	"
" "	Pittsburgh, PA	2 to 8 ng/m^3	"

*Order of magnitude only

TABLE I (continued)

Sample	Location	Asbestos Conc.	Reference
Ambient Air	San Francisco, CA	1.5 to 40 ng/m^3	4
" "	Washington, DC	1.6 to 40 ng/m^3	"
" "	Cincinnati, OH	< 20 to 60 ng/m^3	"
Remote	Frankfort, KY	0.024 to 0.147 ng/m^3	"
Asbestos workers lungs		0.001 to 0.6% asbestos by weight	1
General population lungs		48% to 100% of cases showed presence of chrysotile asbestos	"
Beer	Canada	4.3 to 6.6 x 10^6 fibrils/l	5
Beer	USA	1.1 to 2.0 x 10^6 fibrils/l	"
Sherry	Canada, Spain, South Africa	2.6 to 4.1 x 10^6 fibrils/l	"
Port	Canada	2.1 x 10^6 fibrils/l	"
Vermouth	France, Italy	1.8 to 11.7 x 10^6 fibrils/l	"
Carbonated beverages	Canada	1.7 to 12.2 x 10^6 fibrils/l	"
Tap water	Canadian major cities	2.0 to 4.4 x 10^6 fibrils/l	"
Filtered tap water	Canadian asbestos mine area	2.9 to 9.5 x 10^6 fibrils/l	"
Unfiltered tap water	" " " "	173 x 10^6 fibrils/l	"
Melted snow	Ottowa, Canada (top 30 cm)	33.5 x 10^6 fibrils/l	"
River water	Ottowa River at Ottowa	9.5 x 10^6 fibrils/l	"
Parenteral Drugs		1,700 to 1,100,000 ng/l	6
Water control for parenteral drugs		500 ng/l	"

TABLE I (continued)

References

1. Selikoff IJ, Nicholson WJ, Langer AM: Asbestos air pollution. Arch Environ Health 25:13, 1972.

2. Smith GR, Carpenter LM, Stanley RL, Mueller PK: Determination of the concentration of asbestos fibers in ambient air near an asbestos processing plant. AIHL Report No. 128, Revision No. 1, Air and Industrial Hygiene Laboratory, California State Department of Public Health, March 1973.

3. Smith GR: Private communication, Air and Industrial Hygiene Laboratory, California State Department of Public Health, Berkeley, March 1973.

4. Henry WM, Heffelfinger RE, Melton CW, Kiefer DL: Development of a rapid survey method of sampling and analysis for asbestos in ambient air. Battelle Laboratories, Columbus, Ohio.

5. Cunnighaham HM and Pontefract R: Asbestos fibers in beverages and drinking water. Nature 232:332-333, July 30, 1971.

6. Nicholson WJ, Maggiore CJ, Selikoff IJ: Asbestos contamination of parenteral drugs. Science 177:171-173, July 14, 1972.

Table II

EMISSION FACTORS FOR ASBESTOS
FROM MINING AND MILLING[a]

Source[b]	Emission factor, $kg/10^3 kg$ (lb/ton) of asbestos produced
Mining, total	5 (9 to 10)
Mining	2 (3)
Loading	1 (2)
Hauling	1 (2)
Unloading	1 (2)
Mining, total, 50% control	3 (5)
Milling	50 (100)
Milling, 50% control	40 (80)
Milling, 80% control	10 (20)

[a]The emission factors are based on engineering estimates and no source sampling. These factors cannot be used to quantify asbestos emissions.

[b]Uncontrolled unless otherwise specified.

Source: Emission Factors for Trace Substances
U.S. Environmental Protection Agency
EPA-450/ 2-73-001

A 18009

Table III

EMISSION FACTORS FOR
PROCESSING OF ASBESTOS[a]

Source[b]	Emission factor, kg/10^3kg (lb/ton) of asbestos processed
Friction material, controlled	3 (6)
Asbestos cement products, controlled	0.5 (1)
Textiles	20 (40)
Textiles, controlled	1 (2)
Asbestos paper	2 (4)
Asbestos paper, controlled	0.5 (1)
Floor tile	2 (4)
Floor tile, controlled	0.5 (1)

[a]The emission factors are based on engineering estimates and no source sampling. These factors cannot be used to quantify asbestos emissions.

[b]Uncontrolled unless otherwise specified.

Source: Emission Factors for Trace Substances
U.S. Environmental Protection Agency
EPA-450/ 2-73-001

A18010

Table IV

EMISSION FACTORS FOR
CONSUMPTIVE USES OF ASBESTOS[a]

Source[b]	Emission factor, $kg/10^3 kg$ (lb/ton) of asbestos applied
Brake linings	5 (10)
Steel fireproofing, controlled	5 (10)
Insulating cement, controlled	13 (25)
Construction industry	13 (25)

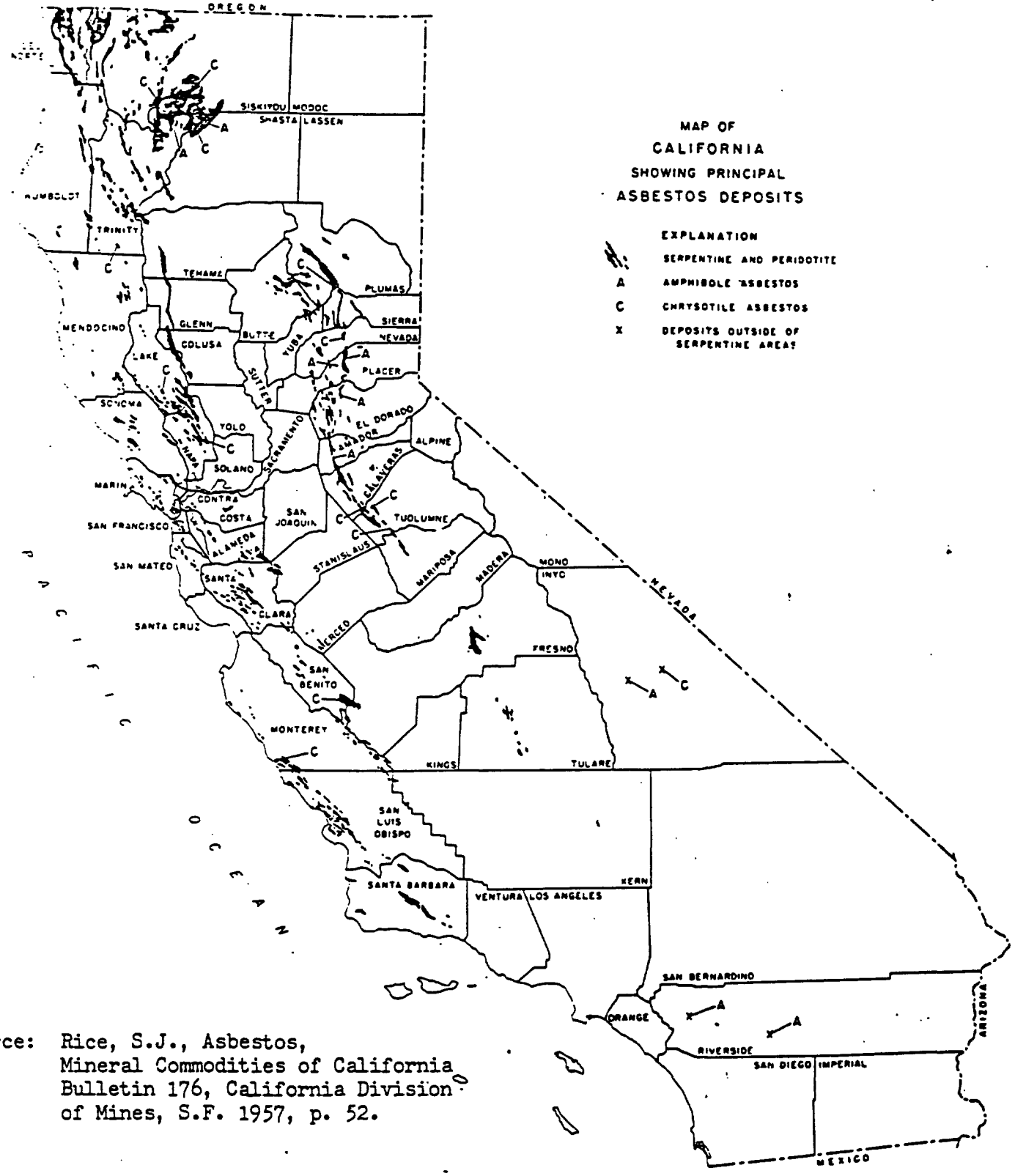
[a]The emission factors are based on engineering estimates and no source sampling. These factors cannot be used to quantify asbestos emissions.

[b]Uncontrolled unless otherwise specified.

[c]A factor of 0.0005 pound per 10^3 vehicle miles can also be used.

Source: Emission Factors for Trace Substances
U.S. Environmental Protection Agency
EPA-450/ 2-73-001

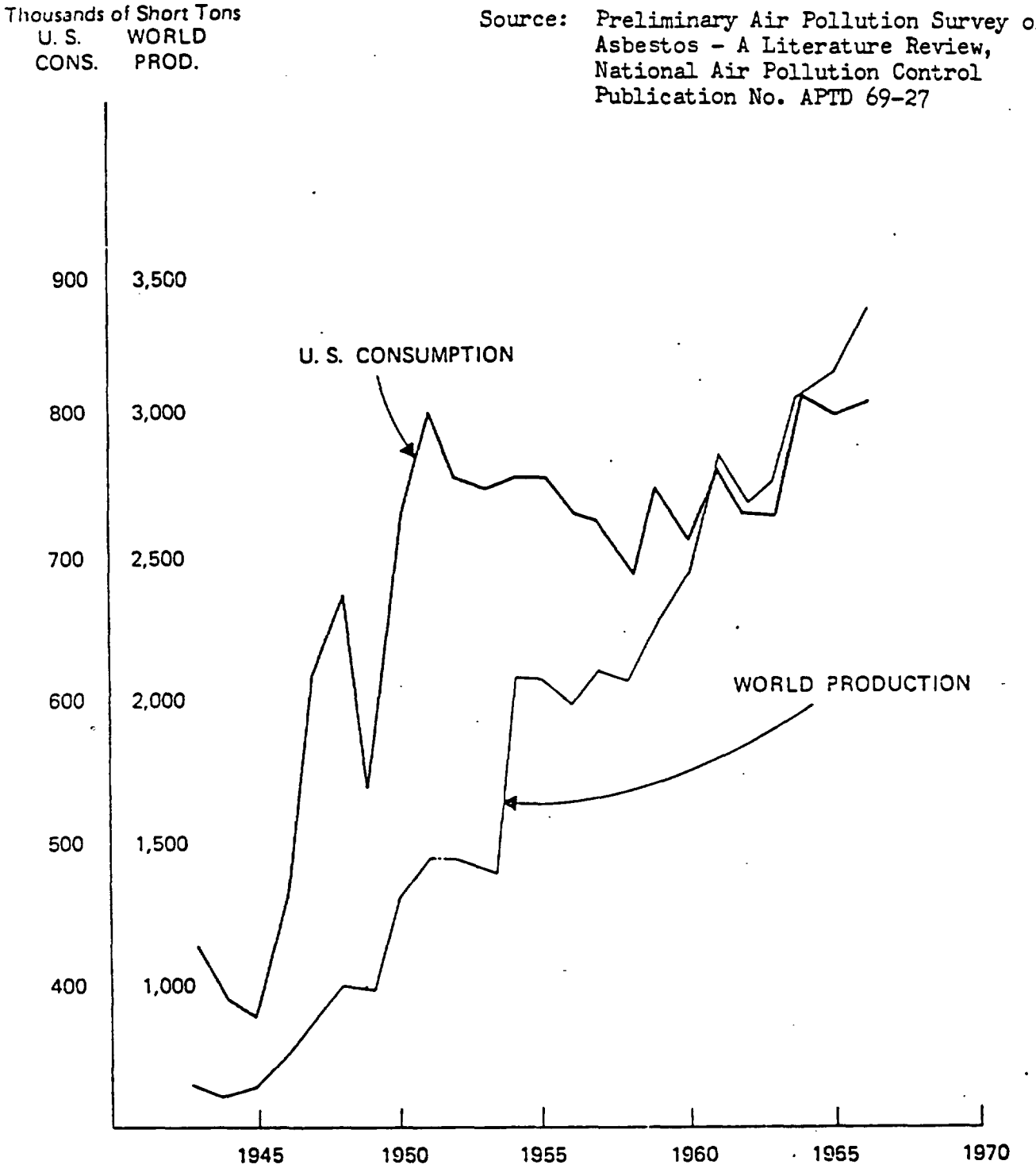
Figure 1



Source: Rice, S.J., Asbestos, Mineral Commodities of California Bulletin 176, California Division of Mines, S.F. 1957, p. 52.

A 18012

Figure 2



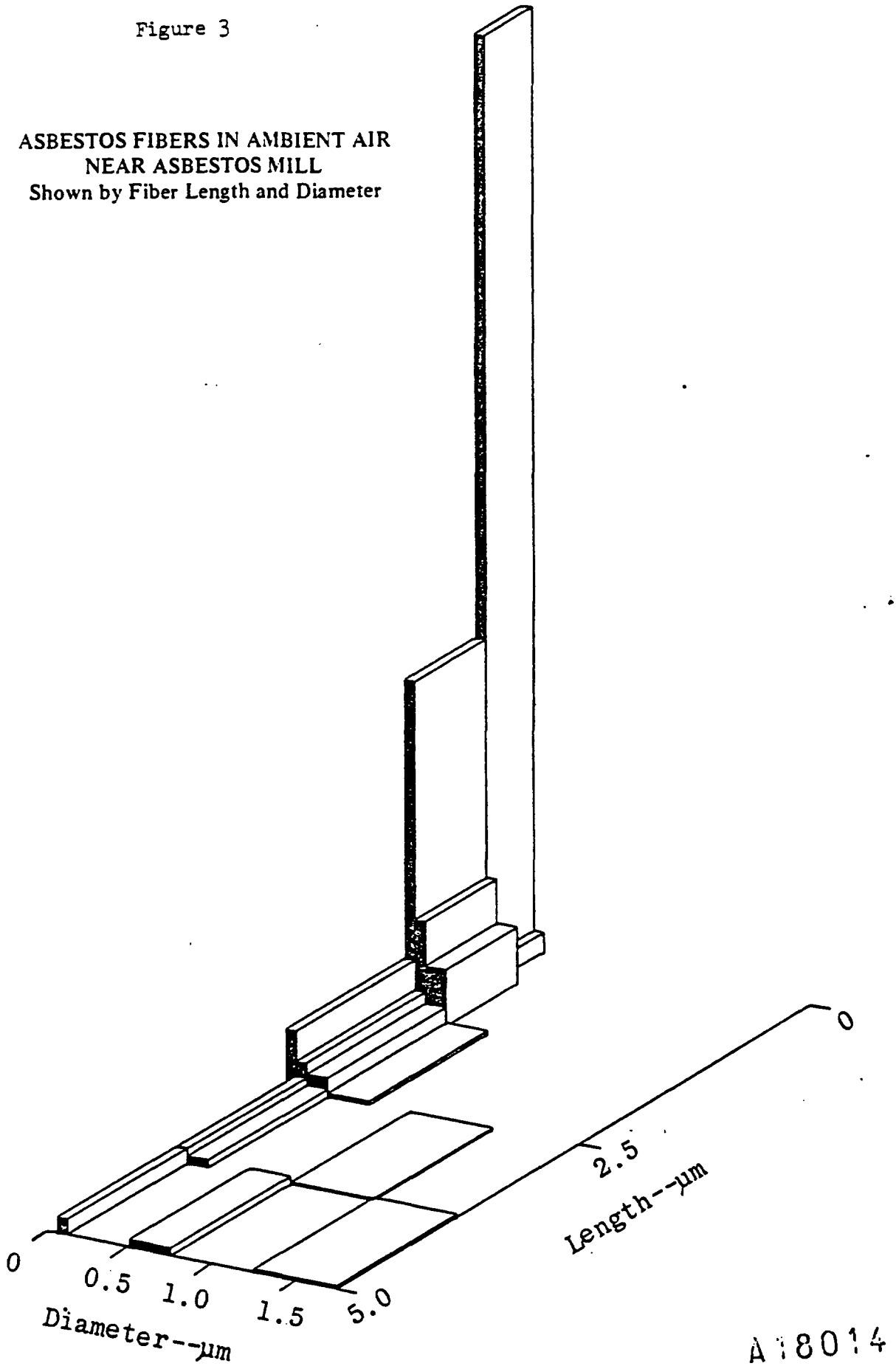
Source: Preliminary Air Pollution Survey of Asbestos - A Literature Review, National Air Pollution Control Publication No. APTD 69-27

Comparison of Trends in World Production and U.S. Consumption of Unmanufactured Asbestos

A18013

Figure 3

ASBESTOS FIBERS IN AMBIENT AIR
NEAR ASBESTOS MILL
Shown by Fiber Length and Diameter



Source: Air and Industrial Hygiene Laboratory, Berkeley, CA

Figure 4

Chrysotile asbestos fibrils taken from an ambient air sample, San Lucas, California. Grid preparation: direct clearing of the Millipore filter with acetone. The long fibril is 1.2 microns in length and 0.029 microns in diameter.

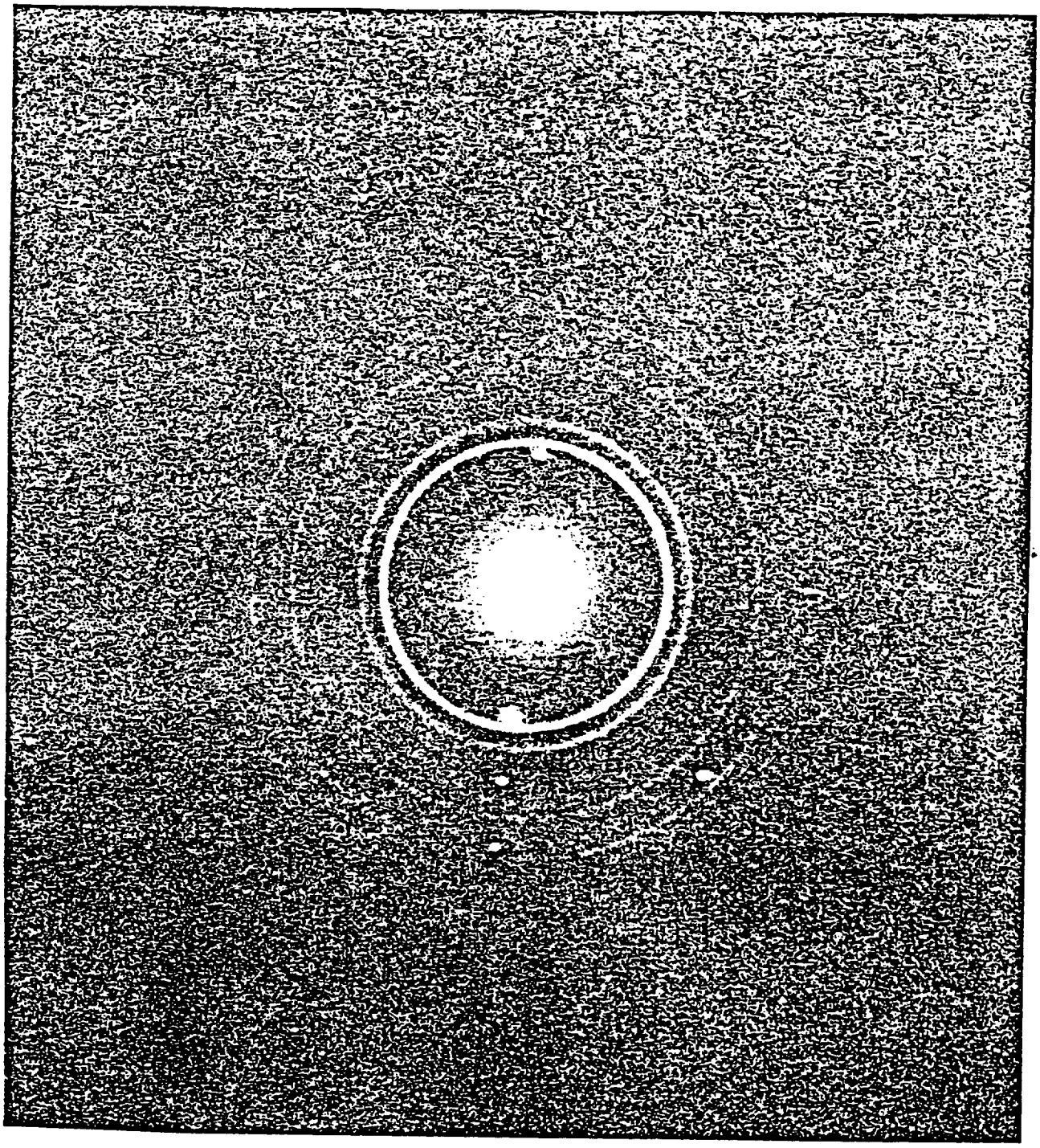
120,000X

0.25 μm

A 18015

Source: Air and Industrial Hygiene Laboratory
Berkeley, CA

Figure 5



Selected Area Electron Diffraction Pattern
From Tremolite Asbestos Fibers

Source: Air and Industrial Hygiene Laboratory
Berkeley, CA