

March-April, 1968

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Source and Identification of Respirable Fibers

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☉ Fibrous bodies with an iron-containing coating have been found in the lungs of persons coming to autopsy in a number of urban hospitals, the number of fibrous bodies varying greatly with approximately 4 to 6% of the persons examined showing numerous bodies. Because these findings raise questions with regard to the possibility that asbestos is a factor in increased lung cancer, questions concerning the nature, source, and significance of these bodies are discussed in the light of research needed to find answers.

Introduction

INVESTIGATORS, during the past several years, have reported the occurrence of fibrous bodies in the lungs of persons coming to autopsy in urban hospitals. These bodies are characterized by an iron-containing structure coating the fibers and exhibit a golden yellow appearance. Although the techniques of the investigators varied somewhat, the data provide evidence that the occurrence of these bodies in the lungs of urban residents is not restricted to isolated localities and is not a chance observation.

Thomson *et al.*, 1963, reported finding fibrous bodies in the lungs in 26.4% of the autopsies in a series of examinations in Cape Town;¹ Thomson and Graves, 1965, reported 27.2% in Miami;² Cauna *et al.*, 1965, 41.0% in Pittsburgh;³ Webster, 1965, 39.2% in Johannesburg;⁴ Meurman, 1966, 57.6% in Finland;⁵ Anjilvel and Thurlbeck, 1966, 48.0% in Montreal;⁶ and Cooper and Tabershaw, 1966, 42.0% in San Francisco.⁷ In these investigations the percentage of lungs having numerous fibrous bodies varied from around 4.0% to 6.0%. It is not known how many of this group may have been occupationally exposed to fibrous materials or may have lived in residences adjacent to manufacturing establishments processing fibrous materials.

In carrying out these studies, the investigators examined smears taken from lungs of persons coming to autopsy for the presence of fibrous bodies. All coated fibers that resembled the well-known golden-yellow fibrous bodies seen in the lungs of asbestos workers were termed "asbestos bodies" even though the nature of the fibers in the different studies was never identified.

A considerable difference of opinion exists concerning the identity, source, and meaning of pulmonary fibers and their associated fibrous bodies. On the premise that the fibrous bodies observed in the lungs of persons at autopsy are all "asbestos bodies" and that coated fibrous bodies are a specific reaction to asbestos fibers, some investigators have concluded that asbestos fibers are significant air contaminants and suggested that this may have an effect on community mortality patterns. Others believe that asbestos is only one of many types of fibers that produce similar fibrous bodies in the lungs.

The presence of golden-yellow fibrous bodies in the sputum and lungs of asbestos workers was first reported by Marchand, 1906,⁸ and by Fahr and Feigel, 1914.⁹ These bodies were studied in more detail and further described by Cooke, 1927.¹⁰ He recommended that they be called "curious bodies" and speculated that

TABLE I
Examples of Minerals with Fibrous-like Structure

Ortho- and Ring Silicates*
Epidote Group (epidote)
Sillimanite, Kyanite, Mullite
Chain Silicates
Pyroxene Group (diopside, hedenbergite, jadeite)
Wollastonite
Amphibole Group (anthophyllite, tremolite, hornblende, riebeckite, amosite, grunerite, actinolite, crocidolite)
Sheet Silicates
Mica Group (Muscovite)
Pyrophyllite
Talc
Serpentine (chrysotile)
Clay Minerals (vermiculite)
Prehnite
Framework Silicates
Zeolite Group (natrolite, scolecite, thomsonite, stilbite, mordenite, ferrierite)
Non-silicates
Oxides (cassiterite, limonite, rutile)
Hydroxides (brucite)
Sulphates (gypsum, celestite, anhydrite, morenosite, alums)
Carbonates (calcite, siderite, magnesite)
Phosphates (apatite, vivianite)

*Classification taken from—Deer, W. A., R. A. Howie, and J. Zussman: *An Introduction to the Rock Forming Minerals*. John Wiley and Sons, Inc., New York, N. Y. (1966).

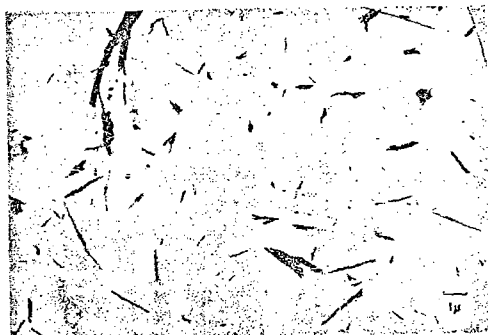


FIGURE 1. Electronmicrograph showing sub-micron chrysotile fibers.



FIGURE 2. Electronmicrograph of attapulgite particles.



FIGURE 3. Electronmicrograph of diatomaceous earth.



FIGURE 4. Electronmicrograph of sillimanite.

any fine spicule of mineral could effect a similar response. Subsequently, coated fibrous bodies have been found in the lungs of workers in a number of non-asbestos industries.⁵

Vorwald *et al.*, 1951,¹¹ and Gross *et al.*, 1966,¹² reported that fibrous minerals, other than asbestos, are capable of producing pseudo-asbestos bodies in animals. There is increasing evidence that the coating of inhaled fibers in the lungs with an iron-containing material is a general protective mechanism and, therefore, a non-specific response.¹³ The morphology of these pulmonary bodies in many instances may be very similar, although different fibers are involved. Gross *et al.*¹² recommended that such coated fibers be termed "ferruginous bodies" where the fibers have not been specifically identified.

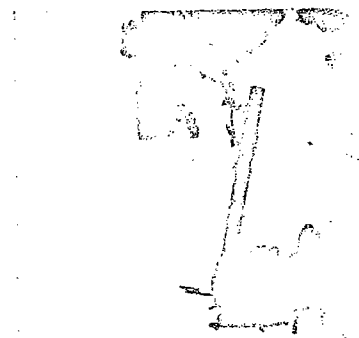


FIGURE 5. Electronmicrograph of ground, uncoated fibrous glass.

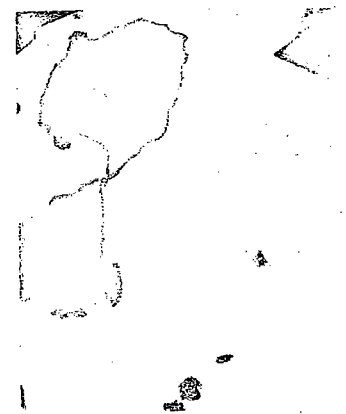
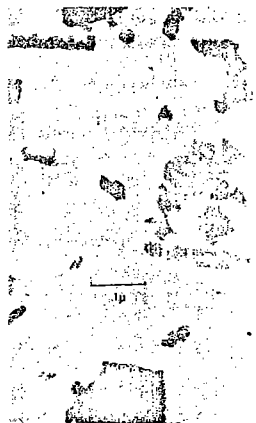


FIGURE 6. Electronmicrograph of insulating powder.

Enterline and Kendrick,¹⁴ in their study of the effects of asbestos on mortality in workers in products manufacturing industry, found a low level of overall mortality and a modest increase of lung cancer in workers in plants manufacturing asbestos building products and friction products. They concluded that exposures to asbestos at levels considerably below those found in types of industries (levels of exposure experienced in urban populations) would not be important from a health standpoint.

Anjilvel and Thurlbeck¹⁵ in their study of the relation between malignancy and asbestos bodies and concluded from the autopsy cases that the exposure to asbestos is not a significant factor in the development of malignancy in the lung.



icrograph of diatomaceous



crograph of sillimanite.

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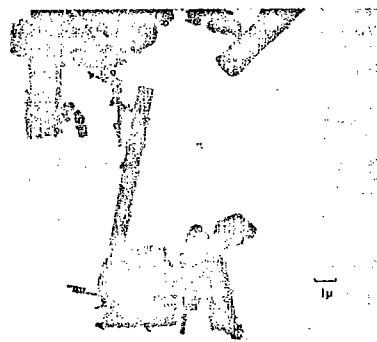


FIGURE 5. Electronmicrograph of a special grade, ground, uncoated fibrous glass.



FIGURE 6. Electronmicrograph of a kitchen scouring powder.

Enterline and Kendrick,¹⁴ in studying the effects of asbestos on mortality in the asbestos products manufacturing industry, reported a low level of overall mortality with only a modest increase of lung cancer rate among workers in plants manufacturing asbestos building products and friction materials. They concluded that exposures to asbestos dust at levels considerably below those in these two types of industries (levels that might be experienced in urban populations) are unlikely to be important from a health standpoint.

Anjilvel and Thurlbeck⁶ found no association between malignancy and the presence of asbestos bodies and concluded from limited data on the autopsy cases studied that casual exposure to asbestos is not an important cause of malignancy in the general population.

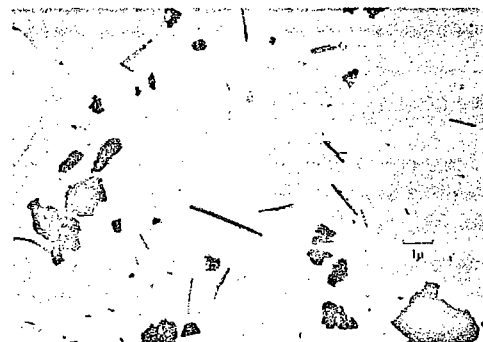


FIGURE 7. Electronmicrograph of an animal insecticide dusting powder.



FIGURE 8. Electronmicrograph of a plant insecticide dusting powder.

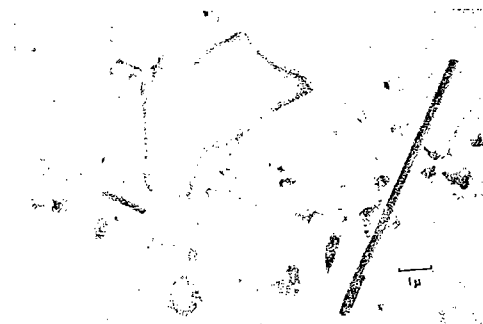


FIGURE 9. Electronmicrograph of a common yard fertilizer.

They are extending their study to include a larger number of cases.

Elmes *et al.*,¹⁵ in reporting on 100 cases of bronchial carcinoma, found no significant difference between the presence of asbestos

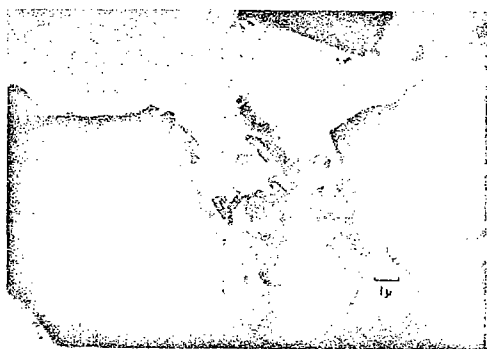


FIGURE 10. Electronmicrograph of a grade of vermiculite for use on lawns.

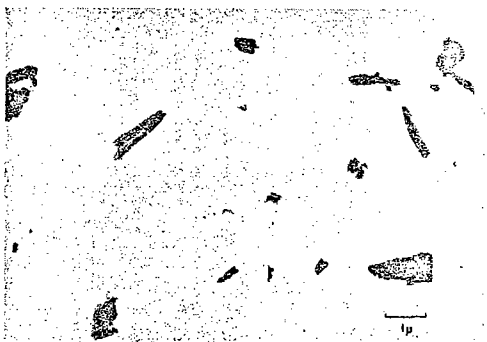


FIGURE 11. Electronmicrograph of common household grade of plaster of Paris.

bodies in this group and that in a non-malignant control group. They did find a significant increase in asbestos bodies in mesothelioma cases as compared with the control group.

A supportive approach in establishing the meaning of the presence of these pulmonary fibers and their associated ferruginous bodies is to define the nature and source of the more common respirable fibers and, through laboratory research, the biological response to these different fibers.

Identification of Fibrous Materials

The lack of analytical techniques sufficiently sensitive to identify individual fibers in the lower micron and sub-micron diameter range has been a major problem in the past in studying the health effects of inhaled fibers. More precise analytical techniques and equipment have increased considerably the poten-

tial for the identification of these fibers.

The electron microprobe is especially useful in identifying major elements of individual fibers of up to one micron in diameter. These elements may be individually focused on an oscilloscope, and the resulting fiber image photographed to provide permanent records of the analyses.¹⁶

A second technique employs a laser microprobe in conjunction with a time-of-flight mass spectrometer. The laser beam is focused on a 6- to 8-micron spot containing the fiber. The laser vaporizes the constituents of the materials in the spot, and an elemental analysis is made with the mass spectrometer.¹⁷ The laser assembly may also be mounted on the optical bench of an emission spectrograph and used as a source of energy to vaporize elements for spectrographic analysis.¹⁸

Techniques are now available for removing organic material from a sample without altering the inorganic compounds. In a commercial instrument available for low-temperature dry ashing, incineration proceeds in an oxygen atmosphere at a pressure of 1 to 2 mm of Hg. A radio frequency source produces excited monatomic oxygen for the oxidative process.¹⁹

Improvements have also been made in optical and electron microscopy for studying the morphology of sub-micron fibers in greater detail.

Nature and Source of Fibrous Materials

Respirable fibers may be mineral, vegetable, or animal in origin and may come from both natural and synthetic sources. There are well over a hundred different natural minerals with some degree of fibrous structure. They are of widely contrasting chemical composition and may exist as ores of commercial value or may be disseminated generally in the earth, in fossil and other fuels, and in other commercial minerals. Examples of minerals with some degree of fibrous-like structure are shown in Table I.

Respirable fibers of vegetable origin may be from both live and dead plant tissues and include plant hairs, fragments of leaves, stalk, bark, flowering parts, ash from burning vegetation, and the like. Both silica and silicates, as well as other mineral constituents, may be



FIGURE 12. Electronmicrograph of dust vacuum cleaner bag after sweeping a carpet.



FIGURE 13. Electronmicrograph of dust from a lawn after mowing.

incorporated into the cellulose structure of the fiber.

Animal fibrous materials include hair and scale, insect hair, and fragments of insect appendages.

Synthetic fibers include the newer fibers, metal whiskers, glass fibers, slabs, etc., as well as a wide range of established and emerging organic types used in fillers, containers, filaments, structural materials, etc.

The accompanying figures present data from a limited survey of respirable materials associated with industrial, commercial, and domestic products to which they are found in industrial, urban, and residential areas.

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Another technique employs a laser microprobe in conjunction with a time-of-flight mass spectrometer. The laser beam is focused on a spot containing the fiber. The laser vaporizes the constituents of the fiber in the spot, and an elemental analysis is made with the mass spectrometer.¹⁷ The fiber assembly may also be mounted on the anode of an emission spectrograph and used as a source of energy to vaporize elements for spectrographic analysis.¹⁸

Techniques are now available for removing material from a sample without altering its inorganic compounds. In a commercial procedure available for low-temperature incineration, incineration proceeds in an oxygen atmosphere at a pressure of 1 to 2 mm of Hg. A radio frequency source produces excited microwave oxygen for the oxidative process.¹⁹ Experiments have also been made in electron microscopy for studying the morphology of sub-micron fibers in great detail.

Origin and Source of Fibrous Materials

Respirable fibers may be mineral, vegetable, or animal in origin and may come from both natural and synthetic sources. There are well over a hundred different natural minerals with a wide degree of fibrous structure. They have widely contrasting chemical compositions and may exist as ores of commercial value or may be disseminated generally in the earth as fossil and other fuels, and in other natural minerals. Examples of minerals with a degree of fibrous-like structure are listed in Table I.

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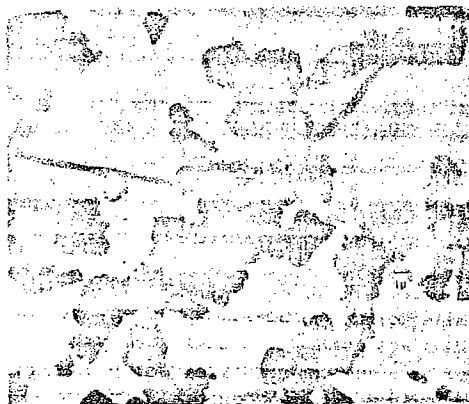


FIGURE 12. Electronmicrograph of dust from a vacuum cleaner bag after sweeping a carpet of synthetic fiber.

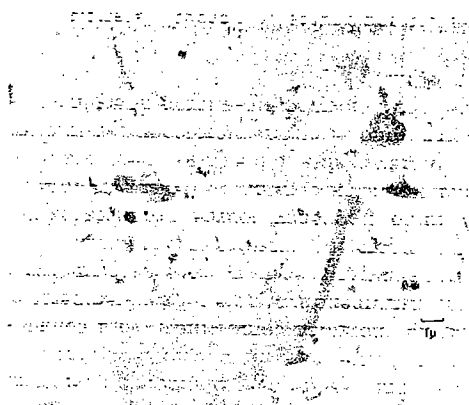


FIGURE 13. Electronmicrograph of sweepings from a lawn after mowing.

incorporated into the cellulose structure of the fiber.

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The accompanying figures present data from a limited survey of respirable fibrous materials associated with industrial, commercial, and domestic products to which persons are exposed in industrial, urban, and residential environ-

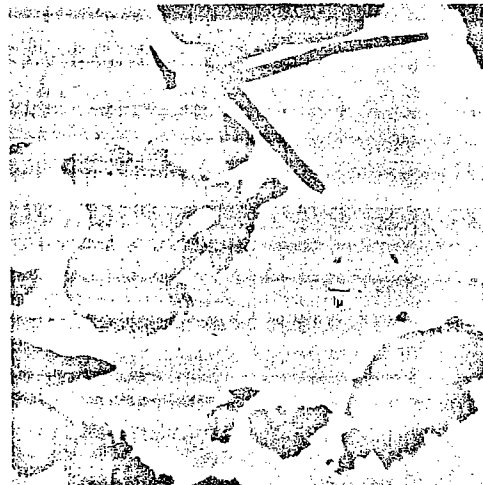


FIGURE 14. Electronmicrograph of cosmetic grade talcum powder.

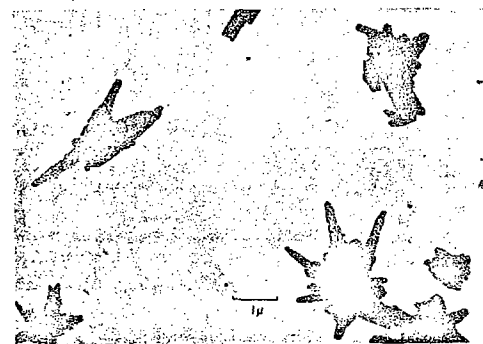


FIGURE 15. Electronmicrograph of a toothpaste.

ments may be exposed.

The illustrations were taken from electron micrographs of samples collected during the current study on membrane filters or bulk material samples prepared by viscous shear. The specimens were transferred to formvar films on copper grids and were left uncoated. The illustrations are typical of the fibers seen throughout the samples.

Figures 1-5 show submicron fibers of a number of basic fibrous materials often encountered in industry and in some types of commercial and domestic products: chrysotile, attapulgite, diatomaceous earth, sillimanite, and glass fiber. The morphologic differences distinguishable in the electron photomicro-

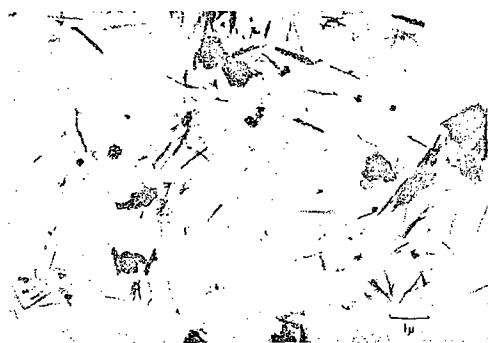


FIGURE 16. Electronmicrograph of an anti-diarrheal compound available without prescription through retail drug outlets.

graphs would not be apparent in the lower magnification of the optical microscope.

Figures 6-11 show fibrous materials contained in products commonly encountered in the home environment: scouring cleaners, animal and plant insecticide dusts, yard fertilizers, vermiculite, and plaster of Paris.

Figure 12-16 show fibrous materials in a variety of common sources including vacuum sweepings from a synthetic carpet, lawn sweepings after mowing, cosmetic talcum powder, toothpaste, and an anti-diarrheal compound available through retail outlets and without prescription.

Figure 17 shows fibrous materials from Cincinnati rainwater following a dust storm originating in the Texas panhandle-Oklahoma area. Wind velocities up to 60 miles per hour prevailed during the storm.

Summary

Recent investigations have shown the presence of fibers, coated with an iron-containing material, in the lungs of persons coming to autopsy in a number of urban hospitals. The number of fibrous bodies observed on the slide smears from individual lungs varied greatly with around 4.0% to 6.0% showing numerous bodies. It is not known how many of the latter group have had appreciable exposure to fibrous materials through their work or by living in residences adjacent to manufacturing plants processing fibrous materials. The nature of the fibers from which the coated bodies were derived, has not been established.



FIGURE 17. Electronmicrograph showing fibers found in rainwater collected at Cincinnati, Ohio, several days after a severe dust storm in Texas.

It is probable, with the application of improved research techniques that fibrous bodies as well as uncoated fibers, will be found in varying amounts in the lungs of a vast percentage of all persons.

Environmental investigations have shown that respirable fibers are ubiquitous. Although they have probably always been present in man's environment, our modern technology and way of life have undoubtedly increased considerably their nature and extent. They arise from industrial processing, community and personal activities, and the action of natural forces. These fibers may be mineral, vegetable, or animal in origin and may come from natural and synthetic sources. Little is known on the pulmonary response to these different fibers or to the pattern of their distribution among urban, rural, and industrial population groups. Definitive information must be obtained on their identification, source, and biological response before perspective assessment can be made of the meaning of their presence in the lung.

Acknowledgments

The authors gratefully acknowledge the very valuable work of Mr. George W. Edwards, who assisted with the mineralogical aspects, and Mr. Thomas A. Brown, who prepared the electron micrographs.

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Journal

In the above photograph, Clifford New Jersey Section, and Mr. J. A. copy of the A.I.H.A. Journal to Mr. of Engineering. The New Jersey Section in New Jersey to receive subscription local section. The Section further and discussions on industrial hygiene.

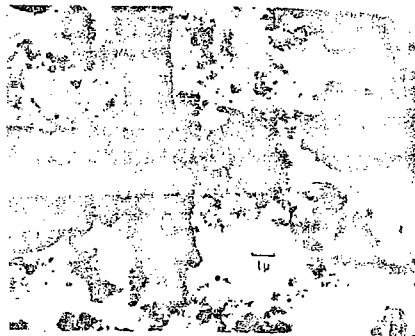


FIGURE 17. Electronmicrograph showing fibrous bodies in rainwater collected at Cincinnati, Ohio, 1 day after a severe dust storm in Texas.

probable, with the application of modern research techniques that fibrous bodies, all as uncoated fibers, will be found in large amounts in the lungs of a vast percentage of all persons.

Environmental investigations have shown that respirable fibers are ubiquitous. Although they have probably always been present in the environment, our modern technological way of life have undoubtedly increased considerably their nature and extent. They come from industrial processing, community personal activities, and the action of natural forces. These fibers may be mineral, vegetable, or animal in origin and may come from natural and synthetic sources. Little is known on the pulmonary response to different fibers or to the pattern of their deposition among urban, rural, and industrialization groups. Definitive information can be obtained on their identification and biological response before proper assessment can be made of the meaning of their presence in the lung.

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Journal Presentation

In the above photograph, Clifford S. Hellings, President of the A.I.H.A. New Jersey Section, and Mr. J. McVeigh, Director, are shown presenting a copy of the A.I.H.A. Journal to Mr. Morton Snowwhite at the Newark College of Engineering. The New Jersey Section of A.I.H.A. has selected seven colleges in New Jersey to receive subscriptions to the A.I.H.A. Journal as gifts of the local section. The Section further plans to offer services by supplying speakers and discussions on industrial hygiene topics.