DISCUSSION PAPER: ASBESTOS FIBER EXPOSURES IN A HARD ROCK GOLD MINE *

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INTRODUCTION

The study reported by Gillam *et al.*[1] demonstrated a significantly increased risk of both malignant and nonmalignant respiratory disease among a cohort of miners at a hard rock gold mine in Lead, South Dakota. That study also reported data that showed low-level exposures to fibrous grunerite (amosite) in the mine. The following paragraphs describe in further detail the laboratory analyses undertaken by the National Institute for Occupational Safety and Health (NIOSH) to determine the fiber exposures reported by Gillam *et al.*

METHODS AND MATERIALS

In 1974, during the industrial hygiene survey conducted at the subject mine by the U.S. Bureau of Mines' Mining Enforcement and Safety Administration (MESA), approximately 200 air samples were taken to determine 8-hr time-weighted average fiber exposures, as analyzed by the NIOSH phase-contrast optical microscope counting technique.[2] The average fiber concentration was found to be 0.25 fibers greater than 5 μm in length per cubic centimeter of air, and the highest single concentration was 2.8 fibers/cm^3. No fiber identification was done in that study, however.

To further characterize the fiber exposures in the subject mine, portions of all of the 200 air samples collected by MESA during its survey were made available to NIOSH. Twenty-five of the underground personnel personal air samples with the highest fiber concentrations, as determined by MESA by phase-contrast optical microscopy, were chosen for detailed analysis by analytic electron microscopy. The membrane (Millipore type AA) filter samples were mounted on formvar and carbon-coated copper electron microscope grids (200 mesh) by means of the direct clearing method, as described by Fraser.[3] Samples for scanning electron microscope analysis were further coated with a thin (100–150 Å) gold layer by vacuum evaporation.

A JEOL, JEM 100B transmission/scanning electron microscope equipped with an EDAX energy-dispersive x-ray spectrometer (specimen to detector distance of approximately 10 mm) was used for all analyses. This instrument allowed for simultaneous observation of single-fiber electron diffraction patterns

* Mention of commercial products does not constitute endorsement by NIOSH.

and fiber chemical composition by x-ray microanalysis. An acceleration voltage of 100 kV was used for transmission electron microscopy, and 20 kV was used for scanning electron microscopy.

Two criteria were used as necessary and sufficient data to classify fibers in these air samples: observation of the single-fiber electron diffraction pattern and observation of semiquantitative elemental analysis spectra with x-ray microanalysis techniques.[5]

Typical fibers, electron diffraction patterns, and x-ray spectra for fibers in the air samples and appropriate amphibole fiber standards were photographed; integrated x-ray counts from the x-ray spectra were recorded for further analysis. Cleavage patterns for typical fibers in mine-settled dust samples were observed and then photographed with scanning electron microscopy. Approximately 250 separate fiber analyses were conducted.

Airborne fiber concentrations and size distributions were determined by counting and sizing fibers directly on the microscope's viewing screen at a magnification of 10,000×. Fiber diameter and length were simultaneously determined by comparison with calibration marks engraved on the screen. Counting-field areas were defined by means of the electron grid openings, the areas of which were calibrated. A total of 2111 fibers were counted and sized.

Results

Figure 1 shows a typical micrograph of fibers seen in a grunerite standard, obtained from the Smithsonian Institution, along with the single-fiber amphibole electron diffraction pattern and x-ray spectra for the same fiber. Figure 2 shows the same data for a typical fibrous grunerite (amosite) fiber seen in the air samples collected in the hard rock gold mine. This fiber demonstrates a chemical composition (x-ray spectrum) identical to UICC amosite and a definite amphibole diffraction pattern. These data demonstrate the presence of amosite asbestos in the mine's work atmosphere.

Other fibers, defined as particles with an aspect ratio of at least three to one, identified in these samples include cummingtonite and hornblends. Table 1 shows the relative proportion of the various fibers observed. As can be seen, 80–90% of the airborne fibers demonstrated an amphibole electron diffraction pattern. Of these amphiboles, 60–70% had chemical compositions identical to that of fibrous grunerite (amosite), 1–2% were fibrous cummingtonite, and 10–15% had compositions of common hornblends, that is, aluminum in the fiber structure.

Table 1

Results of Microscopic Identification of Airborne Fibers by Electron Diffraction and X-Ray Spectrometry, Hard Rock Gold Mine, South Dakota

Amphibole by Electron Diffraction (%)	Unidentified by Electron Diffraction (%)	Percentage of Amphibole Fibers in Each Category		
		Grunerite	Cummingtonite	Hornblends
80–90	≈20	60–70	1–2	10–15

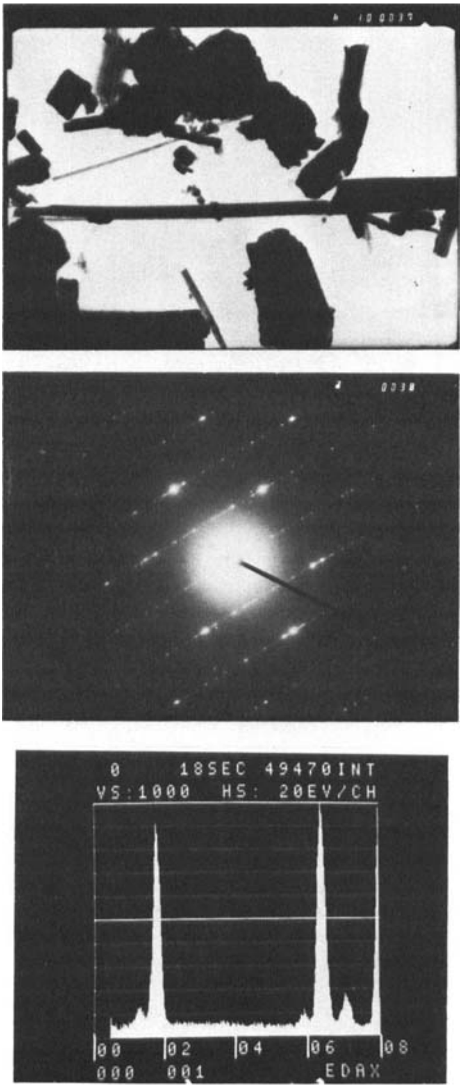

FIGURE 1. Grunerite standard. *Top,* electron micrograph (×10,000); *middle,* amphibole diffraction pattern; *bottom,* x-ray spectrum.

Approximately 20% of the airborne fibers were either too thick or too thin to give identifiable diffraction patterns and were, therefore, not classified. However, many of these fibers also had chemical compositions identical to that of amosite asbestos.

The fibrous nature of the amphibole particles was also demonstrated by using scanning electron microscopy. FIGURE 3 shows scanning micrographs of a settled dust sample that possesses fibers with amphibole cleavage patterns, namely, cleavage parallel to length.

Results of the fiber concentration measurements are shown in TABLE 2. By

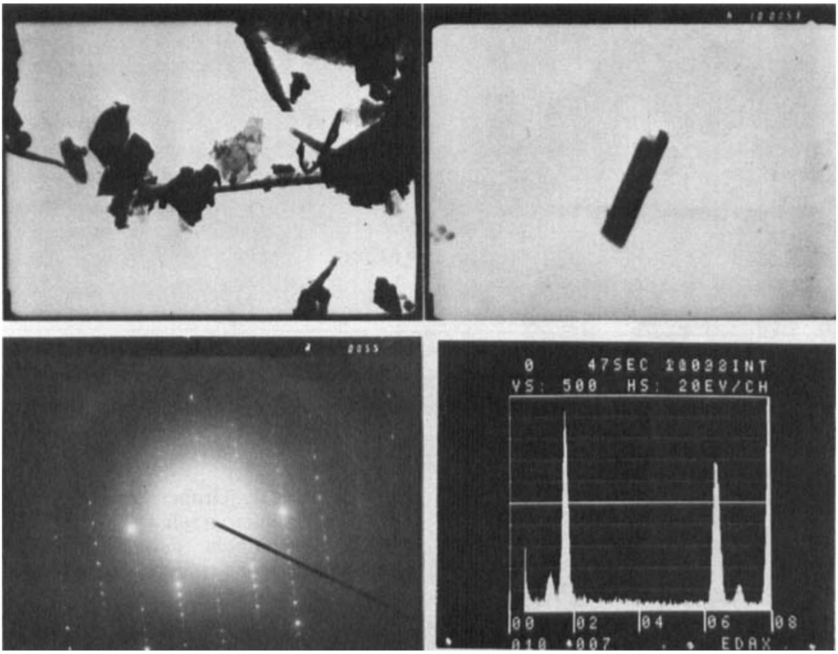

FIGURE 2. Fibrous grunerite (amosite) present in air sample. *Top,* electron micrographs (×10,000); *bottom left,* amphibole diffraction pattern; *bottom right,* x-ray spectrum.

use of electron microscopy, fiber concentrations were seen to be low, with an *average* concentration of 0.36 fibers/cm^3 *greater than 5 μm in length.* The average *total fiber* concentration was found to be 4.82 fibers/cm^3. Airborne fiber length and diameter data, as determined by electron microscopy, are shown in TABLE 3. *Median* fiber diameter and length were found to be 0.13 and 1.1 μm, respectively; 94% of the fibers were less than 5 μm in length.

DISCUSSION

Fibrous grunerite (amosite) has been shown to be present at low concentrations in this hard rock gold mine; most fibers are shorter than 5 μm in length. TABLE 4 compares fiber length distributions of fibers from this mine to those from other asbestos-using industrial operations. As can be seen, the proportion of fibers longer than 5 μm in length ranges from 1 to 51%, depending on the operation and on the type fiber present. It is now well recognized that the NIOSH phase-contrast fiber-counting method for asbestos, in which only fibers longer than 5 μm in length are counted, represents only an "index" of the true

FIGURE 3. Scanning electron micrographs of amphibole fibers in settled dust samples (×3000).

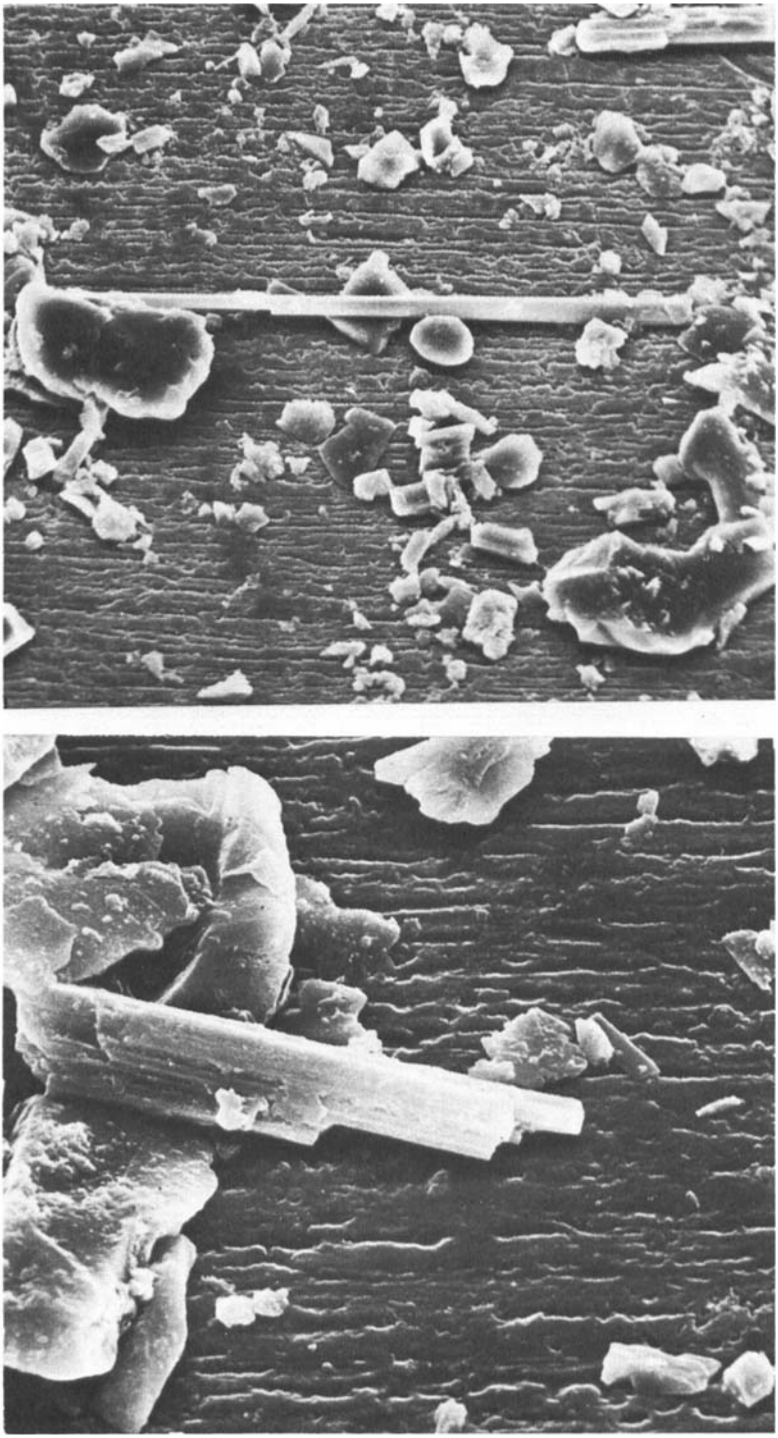

TABLE 2

AIRBORNE FIBER CONCENTRATIONS AS DETERMINED BY ELECTRON MICROSCOPIC FIBER COUNTS AT 10,000× MAGNIFICATION, HARD ROCK GOLD MINE, SOUTH DAKOTA *

Measure	Total Fibers	Fibers > 5 μm
Mean ± SE	4.82±0.68	0.36±0.08
Range	0.66–11.79	0.07–1.29

* Fiber concentrations in mine, average of 22 samples (fibers/cm³).

TABLE 3

SUMMARY OF AIRBORNE FIBER SIZE DISTRIBUTIONS AS DETERMINED BY ELECTRON MICROSCOPY, HARD ROCK GOLD MINE, SOUTH DAKOTA

Summary Statistic	Diameter	Length
Count median size, N=2111, (μm)	0.13	1.10
Geometric standard deviation	3.13	2.70
95% confidence interval for count median size (μm)	0.128–0.141	1.07–1.15

TABLE 4

COMPARISON OF AIRBORNE FIBER LENGTH DISTRIBUTIONS IN VARIOUS ASBESTOS OPERATIONS

Operation	Fiber Type	Median Length	% >5 μm
Textile *	chrysotile		
Fiber preparation and carding		1.4	4
Spinning, twisting, weaving		1.0	2
Friction *	chrysotile		
Mixing		0.9	2
Finishing		0.8	2
Asbestos-cement pipe *	chrysotile		
Mixing		0.9	2
Finishing		0.7	1
Pipe insulation †	amosite		
Pipe forming		4.9	51
Gold mining	amosite		
Miners		1.1	7

* From Reference 6.
† Unpublished NIOSH study.

fiber exposures. This is due to two factors: most airborne asbestos fibers are shorter than 5 μm in length and are, therefore, not counted, and many fibers, although longer than 5 μm, may be too small in diameter to be detected by optical microscopy due to resolution limitations. Phase-contrast fiber counts represent at best, therefore, a crude method of *true total fiber exposure.*

Anderson *et al.*[4] presented data that demonstrated the occurrence of mesothelioma and asbestosis among household contacts of amosite asbestos workers. Such "take home" exposures would be expected to be of low concentration. Moreover, the lifetime cumulative dust exposures among such household contacts would certainly be far below that experienced by a typical asbestos worker exposed at concentrations at the OSHA 1976 standard of 2.0 fibers greater than 5 μm in length per cubic centimeter. The results of Anderson *et al.*[4] and of the NIOSH study of hard rock gold miners thus point to the inadequacy of the OSHA 1976 asbestos occupational exposure standard to protect against asbestos-related malignant and nonmalignant diseases.

Summary and Conclusions

Amosite asbestos fibers of short length have been identified in the study mine at concentrations far below the 1976 OSHA standard of 2.0 fibers greater than 5 μm in length per cubic centimeter. Moreover, the mortality study presented by Gillam *et al.*[1] has shown significantly increased risks of both cancerous and noncancerous respiratory disease in that mining population, findings that are consistent with an asbestos-related etiology.

Three specific conclusions can be drawn when the results of the present study are considered in combination with the data presented at this conference[1, 4]:

The OSHA 1976 asbestos standard of 2.0 fibers greater than 5 μm in length per cubic centimeter may not be adequate to protect against asbestos-induced respiratory neoplasia.

The adverse health implications of asbestos fibers shorter than 5 μm in length in asbestos disease etiology must be paid greater attention in the development and setting of asbestos exposure standards. A routine sampling method that more adequately accounts for such fibers must be developed.

Noncommercial asbestos fibers, namely, asbestos fibers present as contaminants in other products, are capable of producing disease. This finding is of paramount importance in regard to several occupational and environmental issues, such as air pollution by asbestiform fibers in many areas of the United States and of other countries and asbestos contamination of commercial talc products, in which fibrous anthophyllite and tremolite asbestos are frequently found.

References

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