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Mortality Among Asbestos Products Workers in the United States

Tables presented at the Conference on the Biological Effects of Asbestos

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by

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Table 1

Number of white males working in selected asbestos products and cotton textile plants at some time during the period 1948-51, by age in 1950

Age in 1950	Number of Workers	
	Asbestos Products Plants	Cotton Textile Plants
All ages 15-64	2,833	6,242
15-24	425	1,447
25-34	888	1,703
35-44	795	1,553
45-54	464	973
55-64	261	566

Asbestos (Textiles) 9 1 fraction

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Table 2

Person years experience by age group and calendar period, white males working in selected asbestos products and cotton textile plants at some time during the period 1948-51

Age in Calendar Period	Asbestos Products Plants			Cotton Textile Plants		
	1948-52	1953-57	1958-63	1948-52	1953-57	1958-63
All ages 15-64	11,120	13,148	13,159	25,123	29,081	29,451
15-24	1,250	544	4	4,839	2,249	71
25-34	3,423	3,702	2,206	7,030	9,303	7,366
35-44	3,275	4,382	4,737	6,308	7,796	9,242
45-54	2,028	2,968	4,114	4,364	6,353	7,862
55-64	1,144	1,552	2,098	2,582	3,380	4,910

Table 3

Observed and expected*number of deaths through June 30, 1963, showing SMR's for selected causes, white males, 15-64, working in selected asbestos products and cotton textile plants at some time during 1948-51

	Asbestos Products Plants			Cotton Textile Plants		
Cause of Death	Obs.	Exp.	SMR	Obs.	Exp.	SMR
All causes	277	254.4	108.9	473	549.6	86.1
Tuberculosis (001-019)	3	5.7	--	13	12.1	107.4
Cancer (140-205)	57	42.9	132.9	56	92.3	60.7
Digestive System (150-159)	21	13.9	151.1	24	29.8	80.5
Respiratory System (160-165)	23	11.9	193.3	7	25.6	--
All other cancer (residual)	13	17.1	76.0	25	36.9	67.8
Stroke (330-334)	9	13.3	--	35	28.9	121.1
Heart Disease (400-443)	116	102.4	113.3	188	219.3	85.7
Coronary Heart Disease (420)	84	83.5	100.6	157	178.6	87.9
Hypertensive Heart Disease (440-443)	14	5.8	241.4	9	13.0	--
All Other Heart Disease (Residual)	18	13.1	137.4	22	27.7	79.4
Hypertension Without Mention of Heart Disease (444-447)	4	1.2	--	5	2.5	--
Diseases of the Respiratory System (470-527)	25	9.4	266.0	12	20.1	59.7
Influenza and Pneumonia (480-493)	2	5.0	--	8	10.7	--
All other Diseases of the Respiratory System (Residual)	23	4.4	522.7	4	9.4	--
Asbestosis (523.2)	17	--	--	-	--	--

Table 3 con't

Cause of Death	Asbestos Products Plants			Cotton Textile Plants		
	Obs.	Exp.	SMR	Obs.	Exp.	SMR
Accidents (800-962)	22	27.8	79.1	70	63.1	110.9
Suicides and Homicides (963-964, 970-985)	13	11.1	117.1	28	23.7	118.1
All other causes (Residual)	28	40.6	69.0	66	87.6	75.3

* Age-cause specific death rates for U.S. white males, 1950, 1955, and 1960 applied person years experience shown in table 2.

Table 4

Observed and expected* number of deaths through June 30, 1963, showing SMR's by calendar period and selected causes, white males, 15-64, working in selected asbestos products and cotton textile plants at some time during 1948-51

Cause of Death	Asbestos Products Workers			Cotton Textile Workers		
	1948-1952	1953-1957	1958-1963	1948-1952	1953-1957	1958-1963
All Causes						
Observed	63	90	124	122	140	211
Expected	67.1	82.8	104.5	146.9	177.3	225.4
SMR	93.9	108.7	118.7	83.0	79.0	93.6
Cancer (140-205)						
Observed	10	19	28	18	16	22
Expected	10.0	14.0	18.9	21.7	29.9	40.7
SMR	100.0	135.7	148.1	82.9	53.5	54.1
Digestive System (150-159)						
Observed	3	10	8	7	7	10
Expected	3.7	4.5	5.7	7.9	9.6	12.3
SMR	81.1	222.2	140.4	88.6	72.9	81.3
Respiratory System (160-165)						
Observed	3	6	14	4	1	2
Expected	2.2	3.9	5.8	4.8	8.1	12.7
SMR	136.4	153.8	241.4	83.3	12.3	15.7
All Other Cancer (Residual)						
Observed	4	3	6	7	8	10
Expected	4.1	5.6	7.4	9.0	12.2	15.7
SMR	97.6	53.6	81.1	77.8	65.6	63.7
All Causes Excluding Cancer and Asbestosis (Residual)						
Observed	49	66	88	104	124	189
Expected	57.1	68.8	85.6	125.2	147.4	184.7
SMR	85.8	95.9	102.8	83.1	84.1	102.3

* Age-cause specific death rates for U.S. white males, 1950, 1955, and 1960 applied to person years experience shown in table 2.

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Table 5

Observed and expected* number of deaths through June 30, 1963, showing SMR's for selected causes, white males, 15-64, working in selected ..asbestos products plants at some time during 1948-51

Cause of Death	Observed Number of Deaths	Expected Number of Deaths	SMR
All Causes	277	218.6	126.7
All Cancer (140-205)	57	26.4	215.9
Cardio-Vascular Diseases (400-468)	133	110.4	120.5
Diseases of the Respiratory System (470-527)	25	5.7	438.6
Violence (800-964, 970-985)	35	45.3	77.3
All other causes (Residual)	27	30.8	87.7

* Age-cause specific death rates for white male cotton textile workers applied to person years experience for asbestos products plants shown in table 2.

RELATIONSHIP OF IMPINGER COUNTS TO FIBER CONCENTRATIONS BY MEMBRANE FILTER IN ASBESTOS TEXTILE PLANTS

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ABSTRACT

In the United States the recommended standard for asbestos exposure to any type of asbestos is the ACGIH Threshold Limit of 5 million particles per cubic foot of air as determined by the impinger collection, light field counting method. More than 90% of the particles counted by this method are grains associated with asbestos, rather than asbestos fibers. The asbestos textile industry in Great Britain uses an unofficial guideline in terms of fibers per milliliter of air, counting only those fibers longer than 5 microns and using the thermal precipitator or membrane filters for collection.

The Division of Occupational Health, U. S. Public Health Service, is engaged in a study of health hazards in the asbestos processing industries. Environmental studies have been made in eight asbestos textile plants. Samples have been taken by the impinger method for total particle count, and by the membrane filter for fiber count and size distribution.

Results of simultaneous midget impinger and membrane filter samples have been compared. Ratios between counts by the two methods vary

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considerably from plant to plant and operation to operation, but over-all tentative fiber concentrations counted with a 4 mm phase contrast objective equivalent to one million particles per cubic foot by impinger are:

Fiber Length	Concentration Fibers per cc
Total fibers	10
Longer than 5 μ	6
Longer than 10 μ	3

Particle and fiber size distributions have been made from electron micrographs of membrane filter samples. Typical median fiber lengths are one to two microns; geometric standard deviations range about 3; and a typical filter sample has one-fifth to one-third of the fibers longer than three microns.

Fiber counts from electron micrographs compared with optical counts on the same filters reveal that only 1/2 to 1/4 of the fibers longer than 3 μ are counted with a 4 mm phase contrast objective.

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INTRODUCTION

The Division of Occupational Health, Public Health Service is presently engaged in a study of health hazards in asbestos processing. Objectives, methods and preliminary results of this study have been presented elsewhere.[1,2,3] The Engineering Section of the Research and Technical Services Branch, Division of Occupational Health, has, as part of the study, conducted environmental surveys at asbestos textile manufacturing operations. Sampling methods have been selected to give data comparable to past studies and also to give the best characterization of each exposure compatible with the scale of the study.

Both impinger and membrane filter sampling methods have been used for evaluation of asbestos exposure in the past. U. S. studies and the ACGIH TLV are based on impinger counts, and the informal standards used by the British are based on fiber counts from thermal precipitator or membrane filter samples. Counts obtained by the two methods are not directly comparable, as the impinger count is made using a 16 mm (10X) objective, and over 90% of the particles counted are regularly shaped

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grains, while the British use a 4 mm (43X) objective and count only fibers longer than 5 microns. To enable comparison of results by the two methods, with the limitations which will be discussed subsequently, simultaneous, adjacent samples have been taken by impinger and membrane filter in each plant surveyed. These comparisons were presented in detail in a previous paper[2] and are summarized here with some additional data.

Personal samples, using membrane filters, were taken for periods of 1 to 2 hours, using the type of samplers shown in Figure 1, worn as shown in Figure 2. These samples included enough dust so that size distributions could be obtained from electron micrographs. (The 10 to 20 minute "breathing zone" samples for comparison with impinger counts usually contained too few particles per electron microscope field.) These electron micrographs enabled us to determine length and diameter of fibers and particle diameter down to 0.2 μ; and fibers and particles to less than 0.1 μ diameter were clearly visible. The electron micrographs were made from filter samples on which an optical fiber count had already been determined, so direct comparison of numbers of fibers visible by the two methods was possible. From other samples it was possible to make indirect comparisons of impinger counts with fiber concentration from the electron microscope. These comparisons are reported in this paper.

No effort is made here to report average atmospheric dust concentrations in the U. S. asbestos textile industry, as the samples

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selected for comparison of methods do not necessarily represent average situations for a particular plant or operation. Preliminary average results have been presented by Lynch.[3]

METHODS

Impinger counts were made by the NCGIH standard method of 1942[4] with the following modifications:

(1) Kohler illumination was used, with a research type illuminator, and

(2) a calibrated Porton reticle was used rather than a reticle giving a projected area of 0.25 mm^2.

Membrane filter counts were made on filters transparentized with a 50-50 mixture of dimethyl phthalate and diethyl oxalate, using a 4 mm phase contrast objective, and a 10X eyepiece with a Porton reticle for delineating field area and judging fiber length.

The membrane filters were prepared for electron microscopy using the method of Fraser.[5] Particles and fibers on enlarged electron photomicrographs were sized and counted by means of a particle size analyzer which records the size of a light spot adjusted to just cover the particle (or fiber), at the same time marking with a pinhole the particle which has been sized.

RESULTS

Ratios of fibers per cc as seen on membrane filter at 430X to million particles per cubic foot from impinger counts at the usual 100X in four asbestos textile plants have been reported previously.[2] In

comparing counts by two methods, each of which has a rather high variance, it is difficult to draw firm conclusions from individual sample pairs. considering ~~Given~~ the hundreds of comparisons which have been made, however, the ratios presented in the previous paper give average figures from which valid comparisons can be made. Additional sampling in more asbestos textile plants has not substantially changed these average ratios. Rounded off, they are shown in Table I.

TABLE I

FIBER CONCENTRATIONS EQUIVALENT TO
ONE MILLION PARTICLES PER CUBIC FOOT

Fiber Length	Concentration Fibers/~~cc~~ cc of air
Total fibers	10
Longer than 5 μ	6
Longer than 10 μ	3

These ratios were obtained by: (1) comparison of individual sample pairs taken by the two methods and (2) comparison of the number of samples below a given concentration. The first method demonstrates that there is a considerable difference in particle-fiber ratios between operations and also between plants. Table II gives ratios of fibers per ~~milliliter~~ cubic centimeter (f/cc) to mppcf by plant and operation, as well as the ratio of the over-all counts by plant and operation. The over-all average ratios of total f/cc to mppcf range from about 5 to 14 by plant,

TABLE II

TOTAL FIBER CONCENTRATIONS EQUIVALENT TO ONE MPPCF
BY PLANT AND OPERATION

PLANT / OPERATION	A	B	C	D	Ratio of Average Concentration by Operation
Fiber Preparation	11	8	4	11	8.6
Carding	9	14	6	27	12.7
Spinning	6	6	3	13	8.3
Twisting	6	2	7	14	6.5
Weaving	6	20	4	15	12.5
Ratio of Average Concentrations by Plant	8.0	8.6	5.2	15.5	Ratio of grand means 9.4

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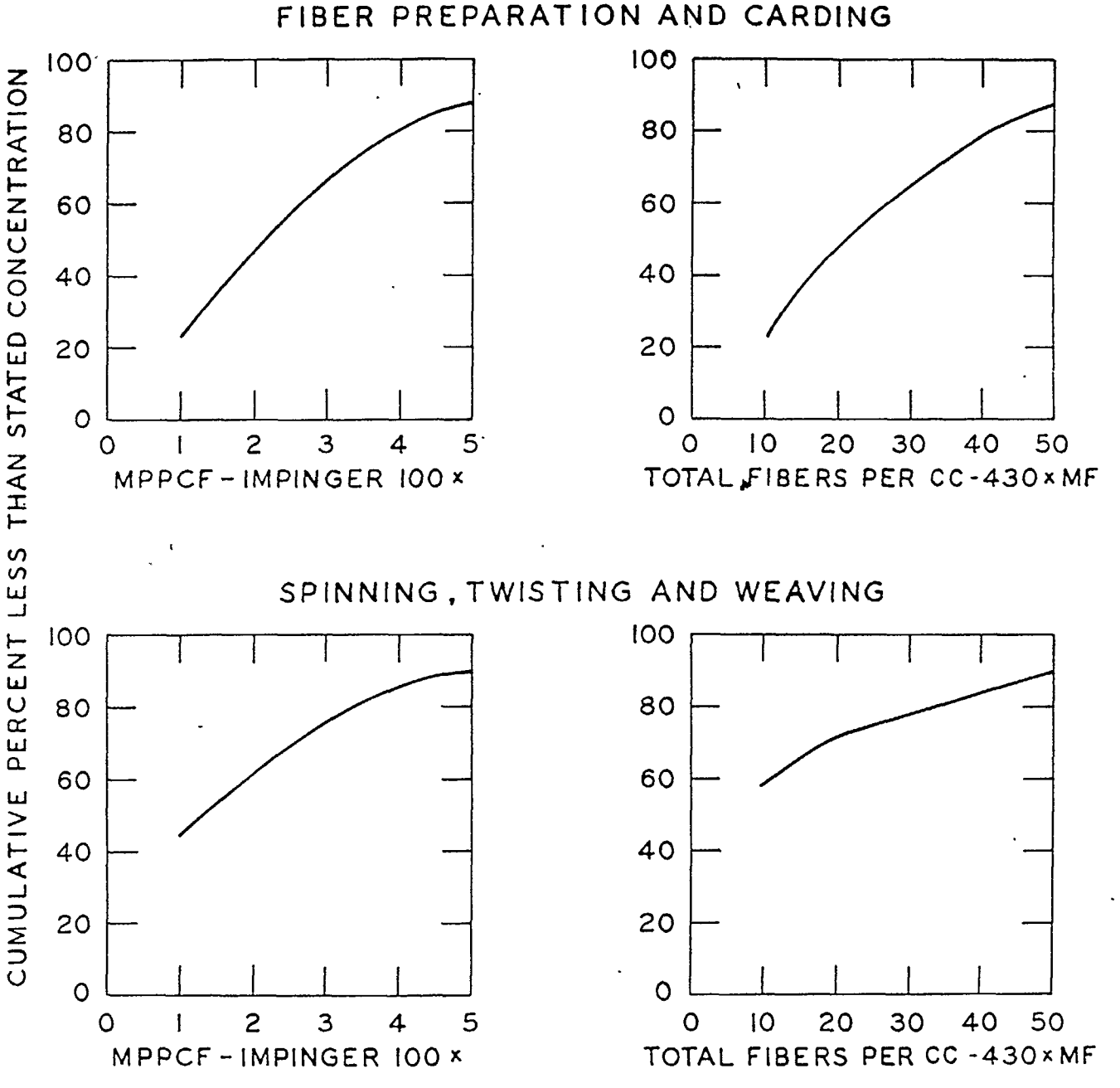
and from about 7 to 13 by operation. Individual plant-operation averages vary by considerably more. The second method, comparing the cumulative curves of concentration by the two methods, is shown in Figure 1. This shows 90% of the impinger samples below 5 mppcf, and 90% of the membrane filter samples below 50 fibers/cc. The cumulative concentration curves tend to reduce variations in individual determinations, and the fact that comparison of these curves gives essentially the same ratios as the averages from sample pairs increases confidence in the results.

It was recognized that, although examining the membrane filters with a 4 mm objective would reveal more fibers than shown by impinger samples, many fibers were too small to be seen even with the 4 mm objective. Therefore, electron micrographs were made on membrane filter samples which appeared to have a density of dust suitable for this treatment. Size distributions have been determined from ~~46 of the~~ of 46 of the samples electron micrographs. Median fiber lengths on these samples ranged from 0.4 to 4.5 μ with three-fourths having medians between 0.9 and 1.9 μ. The geometric standard deviations, as determined graphically, ranged from 2.1 to 4.3, with a typical value of 2.8. Maximum fiber lengths could not be readily determined, as the long fibers cross the boundaries of the electron microscope viewing field. Although the diameter of some fibers is greater than 1 μ, the majority of fibers were less than 1/2 μ in diameter. There was no obvious difference in fiber length or diameter by plant or operation.

FIGURE 3

Cumulative Impinger Mat Concentration Curves - Impinger Sampler and Membrane Filter Fiber Curves



The size distributions automatically provided a count of fibers longer than a given size. In order to consider only fibers which might be visible by optical microscopy, the concentration of long fibers was used. For the electron micrographs as sized by our particle size analyzer, 3 microns in length proved to be a convenient cutoff since this was the largest size within the range of the analyzer at all magnifications. From the size distribution data, concentrations of fibers longer than 3 microns were determined. These were compared with optical microscope counts made on the same filters. The results of 46 such comparisons are given in Figure 4. The ratios of electron microscope counts to optical counts center about a value of 4, with three-fourths of the ratios between 2 and 8. There was no apparent difference in the ratios by plant or operator. From this it appears that about one-fourth of the fibers longer than 3 μ are counted by the optical method employed for membrane filters. The ratio of total fibers by electron microscope to fibers counted by the 4 mm objective is about 13.

In sizing fibers on the electron micrograph it is necessary to judge whether fibrils are individual, or part of a larger fiber. In general, where there was the least possibility that a fiber was individual, it was counted as such. The numbers of fibers from electron micrographs given here thus represent maxima, ~~and the actual number of discrete fibers may be less by as much as a factor of two~~. Further size determinations, using other criteria, are planned.

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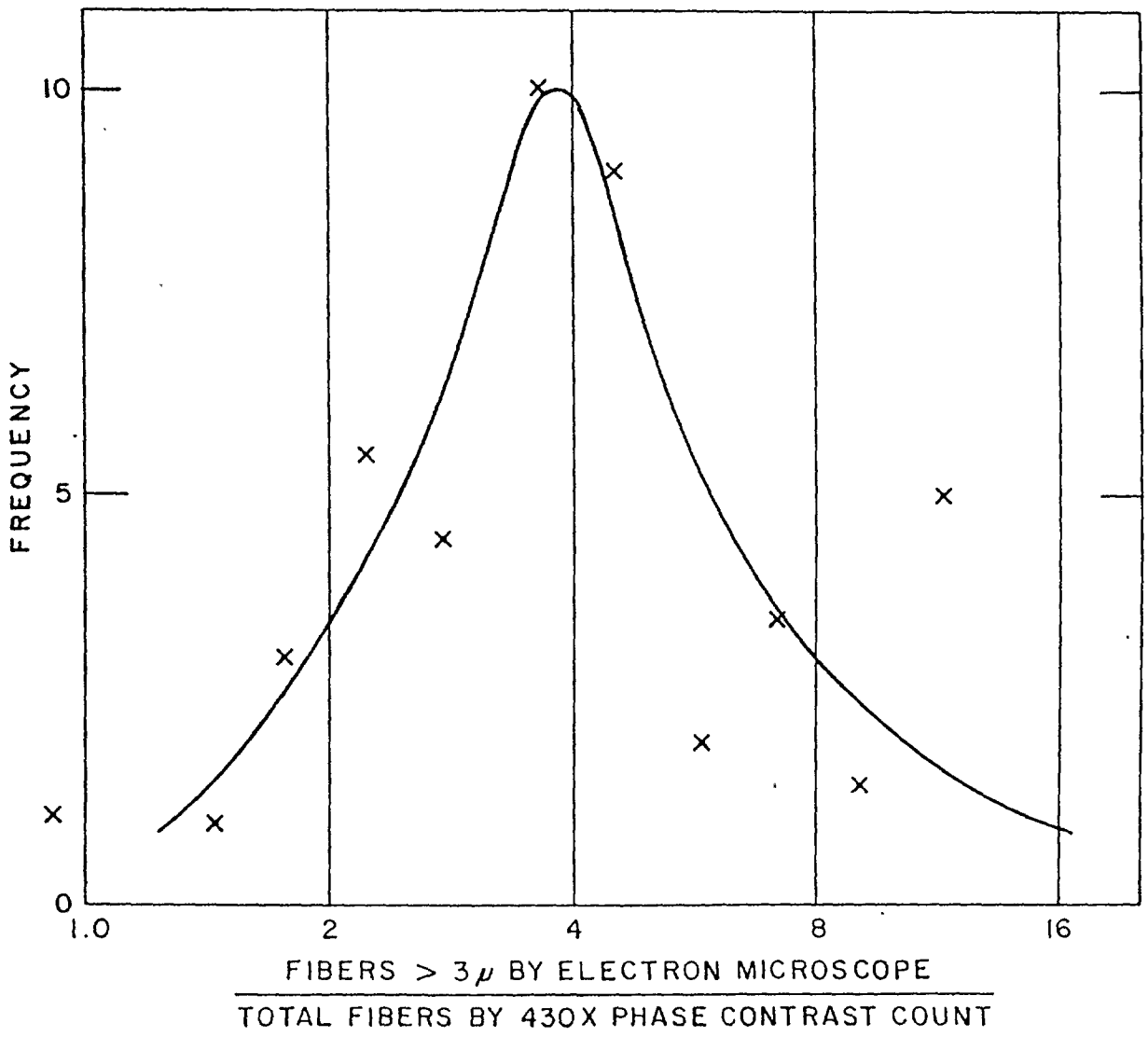
Figure 4

DISTRIBUTION OF ASBESTOS FIBER COUNT RATIOS



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The regular shaped particles (grains) on the filter were also sized. It was considered useful to compare the relative fraction of grains or fibers counted by the two methods to the total number presumably visible as determined by electron microscopy. The ratio of grains larger than 0.8 μ diameter to fibers longer than 3 μ on the same filters was compared with ratios of impinger counts to membrane filter total fiber counts in Tables III and IV.

TABLE III

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RATIO OF PARTICLES TO FIBERS BY DIFFERENT METHODS

PLANT	A	B	C	D	Overall
Electron Microscope					
No. of Samples	13	14	14	5	46
Grains > 0.8 μ / Fibers > 3 μ	2.2	2.9	1.6	1.0	2.1
Optical Counts					
No. of Samples	38	92	54	46	230
Impinger Grains / MF Total Fibers	4.4	4.1	6.8	2.4	3.8

TABLE IV

RATIO OF PARTICLES TO FIBERS BY OPERATION

Operation	Number of Samples	EM Ratio Grains > 0.8 μ / Fibers > 3 μ	Number of Sample Pairs	OPTICAL Ratio Impinger Grains / MF Total Fibers (Opt.)
Fiber Prep.	12	2	39	4.1
Carding	16	2	59	2.8
Spinning	8	2	50	4.2
Twisting	4	2	42	5.4
Weaving	3	4	50	2.8
Over-all	43	2	230	3.8

The ratios given in Tables III and IV indicate that the impinger 10X light field count system is relatively more efficient for grains larger than 0.8 μ than the membrane filter 43X phase contrast is for fibers longer than 3 μ. Since most of the fibers are less than 0.5 μ in diameter, many of the fibers which are over 3 μ or even 5 μ in length are not visible by the optical system used for MF counts. Optical visibility, as well as aerodynamic behavior[6] are functions of fiber diameter.

DISCUSSION

Any comparison of counts made by different methods is imprecise, reflecting the imprecision of the count methods employed. Bianconi,[7] for example, has reported a coefficient of variation for impinger counts of 22% and a coefficient of variation for membrane filter counts of 15%. At two conferences on dust assessment in 1964 and 1965[8] larger coefficients of variation were observed on impinger counts by different dust counters each using his own equipment. Edwards, et al.[9] have reported similar variation in a carefully controlled laboratory experiment, with greater variation in fiber counting than in particle counting. It is to be expected, therefore, that there will be a wide variation in ratios of counts of asbestos dust made by two methods. Some of the variation will reflect systematic differences between observers. In sizing of electron micrographs, there is some difficulty in distinguishing the finest fibers from irregularities in the base film, and with longer fibers there are many judgments to be made as to whether fibers are independent and crossing or a part of and attached to other fibers.

Results, therefore, indicate a larger variance in electron micrograph counts than would be predicted from the assumption of a random distribution on the filter. Some typical electron micrographs are shown in Figures 5, 6 and 7.

An ideal method for assessing exposure to asbestos would give a direct measure of the particulate hazard. Inasmuch as the fraction of material which may create a hazard has not yet been determined, it is not possible to select such a method for asbestos at the present time. Assuming, however, that it is the fibrous material which causes disease, the method chosen should at least provide an index of the concentration of fibers.

While the data presented indicate that either the impinger count or a membrane filter fiber count at a higher magnification could give such an index, the fibers by MF would be a more direct measure and therefore less subject to the systematic variation caused by differences in plant and operation which has been observed with the impinger.

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Figure 1 - Personal Sampler

Figure 2 - Worker Wearing Personal Sampler

Figures 5, 6, & 7 - Electron micrographs of air [illegible] asbestos dust