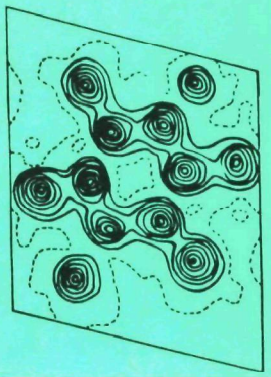
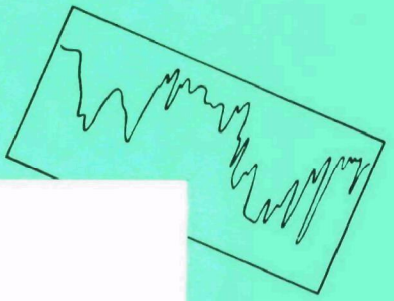
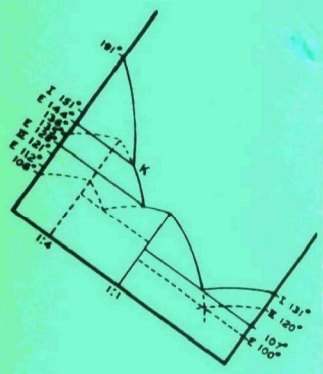
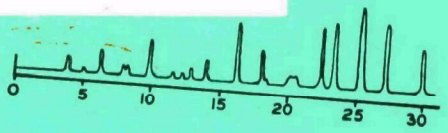
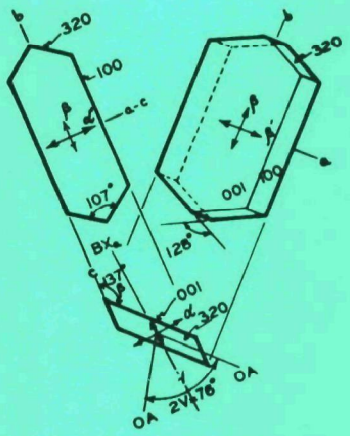


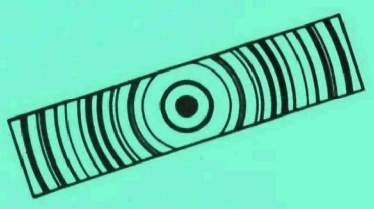




Asbestos in the Water Supplies of the Ten Regional Cities







walter c. mc crone associates, inc.

Dr. R.J. Carton
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Office of Toxic Substances
Washington, D.C. 20460

Contract 68-01-2690

Asbestos in the Water Supplies of the Ten Regional Cities

Date: 22 April 1976

MA Number: MA 4200

Copy 19 of 44

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Asbestos in the Water Supplies of the Ten Regional Cities

City of Boston

The Boston water supply originates from two main sources - the Quabbin watershed and the Wachusett watershed - located in Central Massachusetts and is fed to the city by a series of aqueducts. The city was visited on two occasions, 25 July 1975 and 17 October 1975 when samples were collected at Norumbego treatment station situated on the Hultman aqueduct. In March 1976 additional samples were received from the city of Boston water department. These samples were two raw samples taken at the outlets of Quabbin and Wachusett Reservoirs, a raw sample taken at the Norumbego treatment station and a chlorinated sample taken at Newton pumping station.

The results of the analyses for asbestiform minerals are tabulated. The data for Norumbego on 7/25/75 at first seem anomalous. The detection of amphibole in the chlorinated water only is not at present understood. The amphibole type present could be amosite or crocidolite. (Na is not readily detectable by the EDXRA (energy dispersive x-ray analysis) system and some crocidolite standards have failed to give a detectable peak.) The possibility of amphibole contamination, such as from a gasket or insulation cannot be entirely ruled out. In connection with a different contract in which considerable amounts of chrysotile were detected in a sample the source of this asbestos was traced to a deteriorating gasket in a pump in the treatment plant of that city.

City of Boston

Sample location and type		Date	F.p.l.[1] ($\times 10^6$)	µg/litre
Norumbego station				
	Raw	7 25 75	BDL (0.28)	
			6.7 (C)R	0.069
	Chlorinated	7 25 75	1.4 (A)[2]	25.2
			4.4 (C)R	35.7
Norumbego station				
	Raw	10 17 75	7.5 (C)	1.43
	Chlorinated	10 17 75	10 (C)	33.8
			8.1 (C)R	22.6
			BDL R (0.126)	
Quabbin	Raw	March 76	BDL (0.126)	
Wachusett	Raw	March 76	BDL (0.126)	
Norumbego	Raw	March 76	BDL (0.126)	
Newton	Chlorinated	March 76	BDL (0.126)	

1) F.p.l. = fibers per litre
2) C = Chrysotile; A = Amphibole; R = Replicate analysis
3) BDL = Below detection limit; number in parentheses = detection limit
4) n.d. = none detected
5) Less than 5 fibers detected

City of Philadelphia

Sample location and type		Date	F.p.l.[1] ($\times 10^6$)	µg/litre
Queen Lane	Raw	5 14 75	70 (C)[2]	3.89
			BDL[3] R^2 (1.0)	
Queen Lane	Finished	5 14 75	BDL[3] (0.13)	
			11 (C) R^2	0.227
Belmont	Raw	5 14 75	24 $(C)^2$	31.9
			84 (C) R^2	12.9
			6.7 (A) R^2	0.322
Belmont	Finished	5 14 75	0.75 $(C)^2$	0.007
Torresdale	Raw	5 14 75	BDL[3] (2.5)	
			200 $(C)^2$ R	1.233
Torresdale	Finished	5 14 75	17 $(C)^2$	0.581
			4 $(C)^2$ R	0.301

1) F.p.l. = fibers per litre
2) C = Chrysotile; A = Amphibole; R = Relicate analysis
3) BDL = Below detection limit; number inparentheses = detection limit
4) n.d. = none detected
5) Less than 5 fibers detected

City of Denver

Sample location and type		Date	F.p.l.[1] ($\times 10^6$)	µg/litre
Marston Conduit 20				
	Raw	2 26 75	BDL (0.25) 0.22(A) R(5)	.491
Marston Conduit 30				
	Finished	2 26 75	BDL (0.25) 0.056(A) R(5)	.333
Moffat	Raw	2 26 75	BDL (0.25) BDL R (0.1)	
Moffat	Finished	2 26 75	BDL (0.25) BDL R (0.05)	
Marston	Raw	9 15 75	1.5(5) (C)	.648
Marston	Finished blend	9 15 75	BDL (0.52)	
Moffat	Raw	9 15 75	BDL (0.50)	
Moffat	Finished No. 2	9 15 75	BDL (0.50)	
Moffat	Finished No. 3	9 15 75	BDL (0.50)	

1) F.p.l. = fibers per litre
2) C = Chrysotile; A = Amphibole; R = Replicate analysis
3) BDL = Below detection limit; number in parentheses = detection limit
4) n.d. = none detected
5) Less than 5 fibers detected

Standard Chrysotile Dispersion

Run No.	No. of observations	Fibers/litre ($x10^6$)	Relative Std. dev. (%)
1 a	39	33.5	9.88
1 b	9	34.3	19.08
1 c	5	31.7	38
1 d	15	25.7	8.96
1 e	15	27.4	6.85
1 f	5	2.38	11.09
1 g	5	0.36	48.6

Notes

Runs 1a - 1c freshly prepared dispersion, results of 3 different observers.

1a = 39 observations, 3 grid squares on each of 13 different grids

1b = 9 observations, 9 grid squares from 5 different grids

1c = 5 observations, 5 grid squares from 1 grid

1d and 1e = 2nd and 3rd preparation from standard after manual agitation to redisperse, 3 grid squares from 5 grids, observer of 1a

1f = suspension of 1a - 1e, diluted 10:1, 1 grid square from 5 grids, observer of 1 a

1g = as 1f, but diluted 100:1

Asbestos in the Water Supplies of the Ten Regional Cities

Summary

As part of a program to determine the impact of point and non-point sources on waterborne levels of asbestos, samples of raw and finished water from the ten cities housing regional headquarters of the Environmental Protection Agency have been examined. These cities are Boston, New York, Philadelphia, Atlanta, Chicago, Dallas, Kansas City, Denver, San Francisco and Seattle.

The results of this examination show that while New York, Chicago, Dallas, Kansas City and Denver are essentially free of asbestos, asbestiform fibers have been detected at Boston, Philadelphia, Atlanta and Seattle and the potential exists for asbestos contamination in the water supply of San Francisco.

Introduction

The Office of Toxic Substances of the Environmental Protection Agency has sponsored a nationwide survey to determine the impact of point and non-point sources on waterborne levels of asbestos. This survey covers both natural sites, in which asbestos bearing rocks are prevalent, and man-made sources. Additionally, it provides for sampling water supplies in a number of cities and towns. A listing of these sites is given in Appendix 11 accompanying this report.

This report records the results of the analysis of water from the ten major regional cities, headquarters of the EPA regional offices.

Sampling and Analysis Methods (See Appendix 12)

Aliquots of the water were vacuum filtered through 47 mm dia Millipore 0.45 μm pore size filters. This filter was then prepared for examination on the transmission electron microscope by the direct transfer method. Nylon support grids were used to minimize background signals during X-ray analysis in EMMA-4, the combined electron microscope microanalyzer. Wherever practicable samples for analysis were filtered directly on site. Exceptions to this were the cities of Chicago, Denver and Seattle.

Results

Appendices 1 -10, numbered to correspond to the EPA region number, each describe the sampling locations and conditions, tabulate the results obtained and briefly discuss the results.

General Discussion

Although asbestos fibers have been detected in the water sources and supplies of some major cities, in almost all cases the fiber sizes have been extremely small. Indeed in most cases the mean fiber length noted is of the order of 1.5 to 2 micrometers with some instances of submicrometer mean lengths observed. The most marked exceptions to this generality occur in samples from Boston with mean lengths of 5.4 μm and 9.6 μm but here, other

anomalies in the data have led to the postulation of a proximal source for the asbestos, such as a deteriorating gasket or damaged transite pipe.

The role of climatic changes appears to have been demonstrated in Atlanta and Philadelphia where samples associated with high river flow rates have shown an increased asbestos count. Climate might also be expected to influence possible asbestos levels in the San Francisco area since the reservoirs of that city which showed an asbestos content (principally Calaveras and Lower Crystal Springs) receive water from the Hetch-Hetchy aqueduct during periods of low precipitation in their neighboring watersheds and thus are not contributing to the water supply at that time.

In all instances where asbestos has been detected the predominant asbestos type has been chrysotile and, again with the exception of one analysis from one Boston sample asbestiform amphibole has not been observed other than associated with chrysotile.

It is necessary to inject a note of caution on the significance of the mass per litre data. This data is derived mathematically from the dimensions of the individual fibers, assuming a density of 2.3 g/cc for chrysotile and 3.3 g/cc for amphibole and a square cross section. Apart from the geometric limitations referred to in Appendix 12 it should be borne in mind that the occurrence of a single large, or, more particularly, wide fiber will severely skew the data to an unrealistically high figure.

Conclusions

Although asbestos fibers have been detected in the water supplies and sources of five of the ten regional cities — Boston, Philadelphia, Atlanta, San Francisco and Seattle — the fiber size observed is generally very small, averaging approximately 1-3 μm long. The remaining five cities, New York, Chicago, Dallas, Kansas City and Denver showed no asbestos levels above background.

Some evidence exists for seasonal variations in the observed levels. It has not been established whether these levels are attributable to natural or point sources.

Appendix 1 Boston

City of Boston

The Boston water supply originates from two main sources - the Quabbin watershed and the Wachusett watershed - located in Central Massachusetts and is fed to the city by a series of aqueducts. The city was visited on two occasions, 25 July 1975 and 17 October 1975 when samples were collected at Weston reservoir, one of the small overflow reservoirs on the aqueduct system. In March 1976 additional samples were received from the city of Boston water department. These samples were two raw samples taken at the outlets of Quabbin and Wachusett Reservoirs, a raw sample taken at Norumbega reservoir (similar to Weston reservoir but situated on the Hultman aqueduct) and a chlorinated (presumably finished) sample taken at Newton pumping station.

The results of the analyses for asbestiform minerals are tabulated. The data for Weston on 7/25/75 at first seem anomalous. The detection of amphibole in the finished water only is not at present understood. The amphibole type present could be amosite or crocidolite. (Na is not readily detectable by the EDXRA (energy dispersive x-ray analysis) system and some crocidolite standards have failed to give a detectable peak.) The possibility of amphibole contamination, such as from a gasket or insulation cannot be entirely ruled out. In connection with a different contract in which considerable amounts of chrysotile were detected in a sample the source of this asbestos was traced to a deteriorating gasket in a pump in the treatment plant of that city.

It should be noted that the March 1976 samples do not duplicate the 1975 samples in that Norumbego reservoir is not located on the same aqueduct as Weston and the advisability of additional sampling on both aqueducts should be considered.

City of Boston

Sample location and type		Date	F.p.l.[1] ($\times 10^6$)	µg/litre
Weston Reservoir				
	Raw	7 25 75	BDL (0.28)	
			6.7 (C)R	0.069
	Finished	7 25 75	1.4 (A)[2]	25.2
			4.4 (C)R	35.7
Weston Reservoir				
	Raw	10 17 75	7.5 (C)	1.43
	Finished	10 17 75	10 (C)	33.8
			8.1 (C)R	22.6
			BDL R (0.126)	
Quabbin	Finished	March 76	BDL (0.126)	
Wachusett	Finished	March 76	BDL (0.126)	
Norumbego	Finished	March 76	BDL (0.126)	
Newton	Finished	March 76	BDL (0.126)	

1) F.p.l. = fibers per litre
2) C = Chrysotile; A = Amphibole; R = Replicate analysis
3) BDL = Below detection limit; number in parentheses = detection limit
4) n.d. = none detected
5) Less than 5 fibers detected

Appendix 2 New York

City of New York

The city of New York water supply is derived from two main systems - the Catskill-Delaware system which is fed to the Hillview Reservoir in Yonkers and the lower level Croton system. The water is treated with $CuSO_4$ for algae control, chlorinated to maintain a level of 0.8-1.0 ppm free chlorine and fluorinated. pH is adjusted to 6.9-7.0 by the addition of NaOH.

The water was grab sampled at 3 reservoirs on 2 separate occasions, 11 August and 22 October 1975. Raw water was sampled at the Hillview, Jerome Park and Central Park reservoirs and finished water at the Hillview and Central Park reservoirs. At Hillview, both the Catskill source and Delaware source raw waters were sampled.

No asbestiform minerals were detected in any New York City water samples, either in the raw water or in the finished product.

City of New York

Sample location and type		Date	F.p.l.[1] ($\times 10^6$)		μg/litre
Jerome Park Reservoir					
	Raw	8 11 75	BDL	(0.18)	
Central Park Reservoir					
	Raw	8 11 75	BDL	(0.21)	
	Finished	8 11 75	BDL	(0.13)	
Hillview Reservoir					
	Raw	8 11 75	BDL	(0.36)	
	Finished	8 11 75	BDL	(0.18)	
Jerome Park Reservoir					
	Raw	10 22 75	BDL	(0.25)	
	Finished	10 22 75	BDL	(0.25)	
Central Park Reservoir					
	Raw	10 22 75	BDL	(0.25)	
	Finished	10 22 75	BDL	(0.25)	
Hillview Res (Catskill source)	Raw	10 22 75	BDL	(0.25)	
Hillview Res (Delaware source)	Raw	10 22 75	BDL	(0.25)	
Hillview Res	Finished	10 22 75	BDL	(0.25)	

1) F.p.l. = fibers per litre
2) C = Chrysotile; A = Amphibole
3) BDL = Below detection limit; number in parentheses = detection limit, f.p.l. x 10^6
4) n.d. = none detected
5) Less than 5 fibers detected

Appendix 3 Philadelphia

City of Philadelphia

The city of Philadelphia draws its water supply from two main sources, the Schuylkill River and the Delaware River via 3 plants - Queen Lane and Belmont on the Schuylkill and Torresdale on the Delaware. The city was visited on 3 occasions - 14 May 1975, 27 October 1975 and 1 and 2 April 1976. On the first two occasions grab samples were taken at all 3 plants. On the third visit both grab and integrated samples were taken. Grab samples were also collected at points on the Schuylkill River and Wissahickon Creek - a principal tributary of the Schuylkill having its confluence with the Schuylkill just above the Queen Lane intake. Samples which had been collected on the Delaware during boat surveys by the Philadelphia water department were also received on the third visit. Only the data for the water supply samples are presented in this report. Data for the river samples will be presented in a later report.

The results of the analyses are presented in the table following this report. It will be noted that some wide variations occur between replicate samples. One explanation for this lies in the appearance of the asbestos observed which both analysts described as occurring in clumps. Such clumping generally makes quantitation more difficult and less objective e.g. it is difficult on occasion to decide whether a clumped fiber is truly one fiber or an aggregate of several; additionally, other adhering particulates may obscure fibers or portions of fibers.

Despite these difficulties there is no doubt that asbestos fibers are present in the raw water intakes of Queen Lane and Belmont and that a portion of these can pass through the Belmont filtration and be released into the water supply. The situation at Torresdale is less clear. We believe the high counts observed at Torresdale may well represent isolated events which are not reflected in the later, integrated samples.

Another confusing factor in the Philadelphia situation is the weather effect. On both the 1975 visits the rivers were running above their long term monthly averages as shown in the following table.

Daily Average Flow (cfs)

Date	Delaware River at Trenton	Schuylkill River at Philadelphia
5 10 75	21,400	3,860
5 11 75	18,800	3,570
5 12 75	17,000	3,360
5 13 75	17,900	4,310
5 14 75	24,700	4,720
5 15 75	26,800	3,830
5 16 75	25,900	4,510
Long term May avg.	14,600	23,390
10 24 75	26,400	4,860
10 25 75	22,600	4,370
10 26 75	20,100	4,030
10 27 75	18,000	3,670
10 28 75	16,100	3,280
10 29 75	15,100	3,000
10 30 75	13,700	2,770
Long term Oct avg	4,200	1,425

The April 1976 visit was marked by severe thunderstorms and very heavy rain on the night before sampling. The decision was therefore made to integrate the samples over two 12 hour periods instead of one 24 hour period in order to determine whether any weather effects could be detected, and indeed we do see an increase at all three intakes during the second 12 hour session. This is believed to indicate transport of material from upstream shore line asbestos

deposits which are more severely eroded during adverse weather conditions. The exact location of these deposits is not at present identified.

City of Philadelphia

Sample location and type		Date	F.p.l.[1] ($\times 10^6$)	µg/litre
Queen Lane	Raw	5 14 75	70 (C)[2]	3.89
			BDL[3]R[2] (1.0)	
Queen Lane	Finished	5 14 75	BDL[3] (0.13)	
			11 (C) R[2]	0.227
Belmont	Raw	5 14 75	24 (C)[2]	31.9
			84 (C) R[2]	12.9
			6.7 (A) R[2]	0.322
Belmont	Finished	5 14 75	0.75 (C)[2]	0.007
Torresdale	Raw	5 14 75	BDL[3] (2.5)	
			200 (C)[2]	1.233
Torresdale	Finished	5 14 75	17	0.581
			4 (C)[2]	0.301

1) F.p.l. = fibers per litre
2) C = Chrysotile; A = Amphibole; R = Relicate analysis
3) BDL = Below detection limit; number inparentheses = detection limit
4) n.d. = none detected
5) Less than 5 fibers detected

City of Philadelphia

Sample location and type		Date	F.p.l.[1] ($\times 10^6$)	µg/litre
Queen Lane	Raw	10 27 75	BDL[3] (0.13)	
			100 (C) R[2]	210.54
Queen Lane	Finished	10 27 75	BDL[3]	
Belmont	Raw	10 27 75	230 (C)[2]	2.6
Belmont	Finished	10 27 75	130 (C)[2]	
			26 (C) R[2]	0.588
Torresdale	Raw	10 27 75	160 (C)[2]	3.63
Torresdale	Finished	10 27 75	16 (C)[2]	0.259
			60 (C) R[2]	0.016

1) F.p.l. = fibers per litre
2) C = Chrysotile; A = Amphibole; R = Replicate analysis
3) BDL = Below detection limit; number in parentheses = detection limit
4) n.d. = none detected
5) Less than 5 fibers detected

Philadelphia Integrated samples

Sample location and type		Date	F.p.l.[1] ($\times 10^6$)	µg/litre
Queen Lane	Raw	4 1 76	24 (C)[2]	0.501
Queen Lane	Finished	4 1 76	BDL[3] (0.13)	
Belmont	Raw	4 1 76	7.7 (C)[2]	0.016
Belmont	Finished	4 1 76	1.1 (C)[2]	0.075
Torresdale	Raw	4 1 76	BDL[3] (0.25)	
Torresdale	Finished	4 1 76	BDL[3] (0.13)	
Queen Lane	Raw	4 2 76	120 (C)[2]	22.423
Queen Lane	Finished	4 2 76	BDL[3] (0.13)	
Belmont	Raw	4 2 76	50 (C)[2]	1.391
Belmont	Finished	4 2 76	4.3 (C)[2]	0.213
Torresdale	Raw	4 2 76	0.74[5] (C)[2]	0.012
Torresdale	Finished	4 2 76	1.0 (C)[2]	0.02

1) F.p.l. = fibers per litre
2) C = Chrysotile; A = Amphibole; R = Replicate analysis
3) BDL = Below detection limit; number inparentheses = detection limit
4) n.d. = none detected
5) Less than 5 fibers detected

Appendix 4 Atlanta

City of Atlanta

Atlanta draws its water from the Chattahoochee River which rises in the hills of White County and flows south to join the Apalachicola and from thence into the Gulf of Mexico.

The city of Atlanta water supply was sampled on two occasions, 3 April 1975 and 28 November 1975. On each visit a sample of the raw water and a sample of the finished water was obtained from the Atlanta water works quality control control center located in Northwest Atlanta. Two additional samples taken by the Atlanta water department in March 1976 were also obtained.

The results of the analysis for asbestiform minerals are presented in the accompanying table. The presence of chrysotile asbestos during the April sample, its absence in November and its recurrence in March of 1976 may reflect seasonal variations. It was noted during the April 1975 visit that sampling had followed a violent thunderstorm with tornado watch the previous evening and that the Chattahoochee River was rising due to torrential rains: indeed the flow rate, recorded at 11,300 c.f.s. was almost 2-1/2 times the 1974 average of 4800 c.f.s.

At the time of sampling in March 1976 the river was again reported as running at a high level.

At such periods of high flow rate natural erosion processes are accelerated and settled detritus may be reentrained. Additionally shore line deposits, either natural or industrial may become submerged and eroded which normally are unaffected by the river flow. We believe, therefore, that the asbestos content of Atlanta raw water may be related to climatological conditions.

City of Atlanta

Sample location and type	Date	F.p.l.[1] (x10[6])	µg/litre
Water Quality Control Center			
Raw	4 3 75	8.4 (C)[5]	0.119
Water Quality Control Center			
Finished	4 3 75	12 (C)	0.574
Finished	4 3 75	11 (C) R	0.193
Water Quality Control Center			
Raw	11 28 75	BDL (0.5)	
Finished	11 28 75	BDL (0.12)	
Water Quality Control Center			
Raw	March 76	36 (C)	0.256
Finished	March 76	BDL (0.12)	

1) F.p.l. = fibers per litre
2) C = Chrysotile; A = Amphibole; R = Replicate analysis
3) BDL = Below detection limit; number in parentheses = detection limit
4) n.d. = none detected
5) Less than 5 fibers detected

Appendix 5 Chicago

City of Chicago

The city of Chicago draws its water supply from Lake Michigan via a series of offshore cribs located approximately 1 mile out in the lake. The water supply was sampled by Chicago water department personnel on March 27, 1975, and two samples, identified as "Raw Crib" and "Outlets" were brought the same day to the Chicago laboratory of Walter C. McCrone Associates, Inc., where they were immediately filtered.

No asbestiform minerals were detected in either the raw or the finished water.

City of Chicago

Sample location and type	Date	F.p.l.[1] ($\times 10^6$)	µg/litre
Raw Crib	3 27 75	BDL (0.25)	
Outlets	3 27 75	BDL (0.25)	

1) F.p.l. = fibers per litre
2) C = Chrysotile; A = Amphibole
3) BDL = Below detection limit; number in parentheses = detection limit
4) n.d. = none detected
5) Less than 5 fibers detected

Appendix 6 Dallas

City of Dallas

Samples of the city of Dallas water supply were obtained from EPA Region 6 personnel (F. Warren Norris, Jr., Water Division), and were filtered at McCrone Associates on receipt during March 1975. The samples were identified by EPA codes as 10841-Raw water; and 10842-Finished water.

No asbestiform minerals were detected in either sample.

City of Dallas

Sample location and type		Date	F.p.l.[1] ($x10^6$)		µg/litre
10841	Raw	March 1975	BDL	(0.25)	
10842	Finished	March 1975	BDL	(0.25)	

1) F.p.l. = fibers per litre
2) C = Chrysotile; A = Amphibole
3) BDL = Below detection limit; number in parentheses = detection limit
4) n.d. = none detected
5) Less than 5 fibers detected

Appendix 7 Kansas City

Kansas City

Metropolitan Kansas City has three water treatment plants serving Kansas City, Kansas; Johnson County, Kansas; and Kansas City, Missouri. All three water treatment plants were visited on September 17, 1975.

The Johnson County plant supplies water to purchasers in the communities neighboring Kansas City, Kansas on the south. Water from the Kansas River seeps into 21 wells located along the shore. It is pumped from these wells into the water treatment plant for processing. Samples were obtained from the Kansas River at the wells and also from the treated water tap at the plant.

Both Kansas City, Kansas and Kansas City, Missouri draw water from the Missouri River near treatment plants just a few miles from each other. Raw and finished water were obtained from each of these plants.

No asbestiform minerals were detected in either the raw or the finished water from any of the three Kansas City water treatment plants.

Kansas City

Sample location and type	Date	F.p.l.[1] ($\times 10^6$)	µg/litre
Johnson County Raw	9 17 75	BDL (2.1)	
Finished	9 17 75	BDL (0.48)	
Kansas City, Missouri			
Raw	9 17 75	BDL (5.7)	
Finished	9 17 75	BDL (0.41)	
Kansas City, Kansas			
Raw	9 17 75	BDL (2.1)	
Finished	9 17 75	BDL (0.55)	

1) F.p.l. = fibers per litre
2) C = Chrysotile; A = Amphibole
3) BDL = Below detection limit; number in parentheses = detection limit
4) n.d. = none detected
5) Less than 5 fibers detected

Appendix 8 Denver

City of Denver

The city of Denver has two water treatment plants deriving their water from reservoirs in the mountains. The plants are located at Marston, in S.W. Denver and Moffat in N.W. Denver. Samples were obtained at these plants on February 26, 1975, and September 1975.

Reference to the analysis results in the accompanying table shows that low levels of fibrous amphibole were detected by one analyst in both the raw and the finished water of Marston plant sampled on February 2. To put this into perspective, however, it should be noted that these data correspond to only 2 fibers observed in the raw water sample and 1 fiber in the finished sample in 10 electron microscope grid squares - a level which could be background contamination. Similarly the chrysotile reported for Marston Raw on September 15th corresponds to the observation of 3 fibers in 40 grid squares.

We believe, therefore, that the Denver water supply system is free of asbestos.

City of Denver

Sample location and type		Date	F.p.l.[1] ($\times 10^6$)	µg/litre
Marston Conduit 20				
	Raw	2 26 75	BDL (0.25) 0.22(A) R(5)	.491
Marston Conduit 30				
	Finished	2 26 75	BDL (0.25) 0.056(A) R(5)	.333
Moffat	Raw	2 26 75	BDL (0.25) BDL R (0.1)	
Moffat	Finished	2 26 75	BDL (0.25) BDL R (0.05)	
Marston	Raw	9 15 75	1.5(5)	.648
Marston	Finished blend	9 15 75	BDL (0.52)	
Moffat	Raw	9 15 75	BDL (0.50)	
Moffat	Finished No. 2	9 15 75	BDL (0.50)	
Moffat	Finished No. 3	9 15 75	BDL (0.50)	

1) F.p.l. = fibers per litre
2) C = Chrysotile; A = Amphibole; R = Replicate analysis
3) BDL = Below detection limit; number in parentheses = detection limit
4) n.d. = none detected
5) Less than 5 fibers detected

Appendix 9 San Francisco

City of San Francisco

The San Francisco Water System is extremely complex, deriving its main feed from the Yosemite Mountains some 100-150 miles east of the city. From the Yosemites the water is fed via tunnels and pipes (The Hetch-Hetchy aqueduct) to a number of holding reservoirs which are also fed by local run off. The map accompanying this report shows, in part, the complexity of the system. A "short narrative" (some 22 pages and 16 pages of Appendices) describing the San Francisco water suppling system is available from the San Francisco Water Department.

The water system was sampled on two occasions, 5 March 1975 and September 10 and 12, 1975 when the following samples were taken.

March 5

Alameda East Portal ("Terminus" of the Hetch-Hetchy aqueduct.)
This water has been chlorinated and is regarded as "finished" water. No treatment other than chlorination is applied.

Calaveras Reservoir
Surface water sampled approximately 50 yards from boathouse

San Antonio Reservoir
Surface water sampled at boathouse

Lower Crystal Springs Reservoir
Surface water sampled at shore line - rock samples also collected - bedrock extremely friable

San Andreas Reservoir
Faucet on side of chlorination plant -"raw water"

San Andreas filtration plant, outlet no. 1, "finished water"

Pilarcitos Reservoir
Surface water

September 10 Alameda East Portal ("Terminus" of the Hetch-Hetchy aqueduct.)
This water has been chlorinated and is regarded as "finished" water. No treatment other than chlorination is applied.

Calaveras Reservoir

San Antonio Reservoir

Sunol filtration
San Antonio treated

Crystal Springs
"Raw water"

Crystal Springs
"Finished" - chlorination only

San Andreas Reservoir

San Andreas filtration plant, outlet no. 1
"Finished" water

San Francisco tap water - Airport Holiday Inn

September 12 Mocassin Reservoir - about 100 miles east of San Francisco

During analysis of the first batch of samples it became apparent that sample preparation problems were being experienced. The data reported for these samples, therefore, is generally that obtained by Murchio.

Sampling during the second visit was carried out by a different sampling team and also under a different guide, thus there are some differences in location at the reservoirs sampled. The most noticeable difference in results between the two samplings is in the Lower Crystal Springs Reservoir samples where 620×10^6 chrysotile fibers were found on the first visit and

none on the second visit. We believe this may be explained by the different locations at which the samples were taken. It was noted in the trip report for the first visit that the bedrock adjacent to the sampling location is extremely friable and samples of this rock were taken. These samples did indeed turn out to have a large serpentine content (determined by light microscopy) and the rock could be powdered between the fingers. It is therefore not surprising that the chrysotile content of the first sample is high. It might also not be unexpected that a sampling point some miles distant from the first should show a completely different picture. This highlights the problem of trying to characterize a system as complex as that of San Francisco which could well merit a major study of its own. An additional explanation of differences between the March and September samples may be found in the San Francisco Water Department booklet which, in talking of the Crystal Springs, San Andreas, Pilarcitos section says ...."Historically this has been a problem water due to high turbidity during the winter months ..." thus seasonal variation may also be a factor.

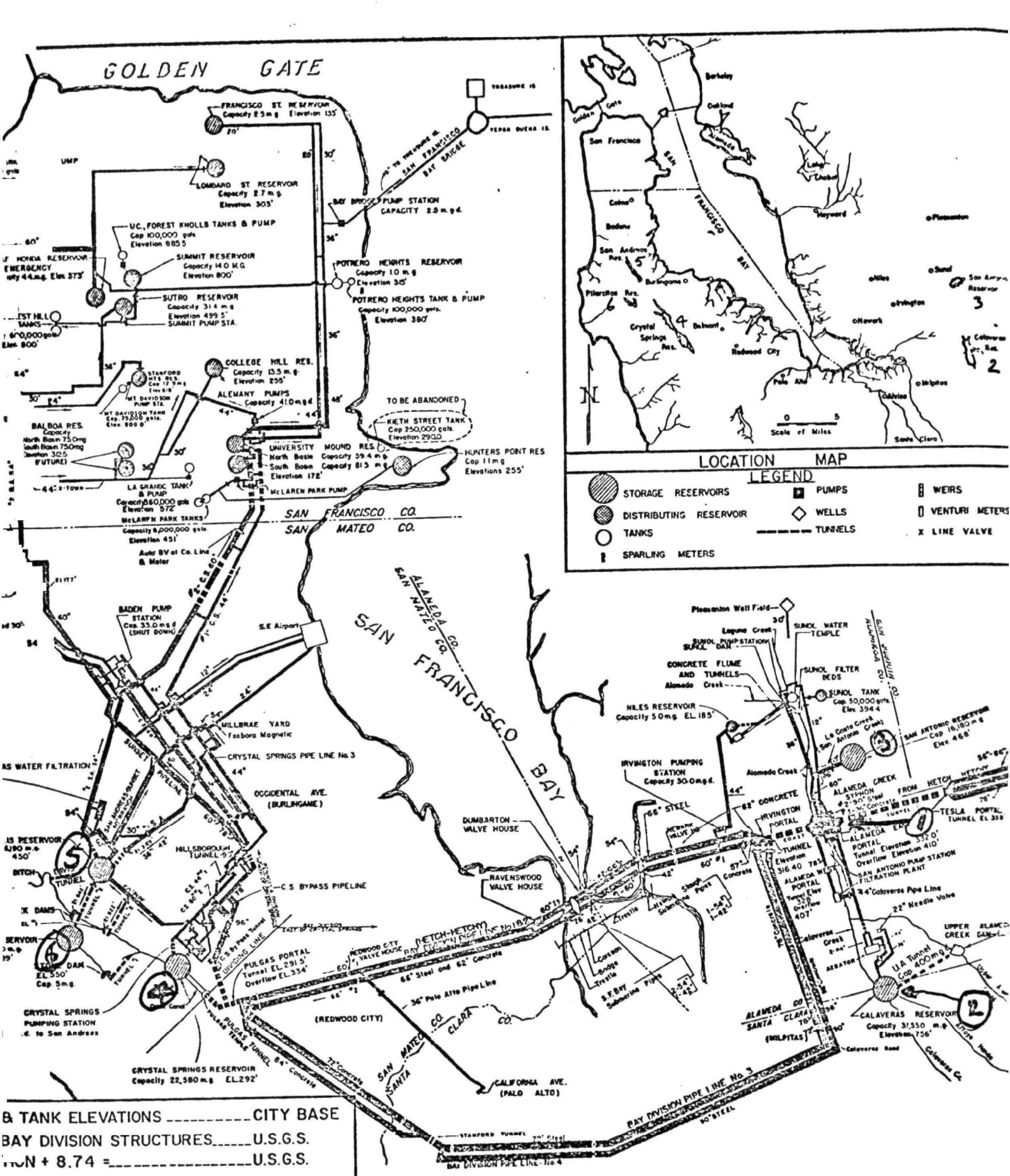
We believe the San Francisco situation may best be summarized as follows:

1) Water from the Hetch-Hetchy aqueduct entering the San Francisco water system (at Alameda East Portal) is free of asbestos.

2) The potential for contamination of the San Francisco water system by asbestos - both serpentine and amphibole - exists due to natural sources in certain of the holding reservoirs, principally Crystal Springs and Calaveras and to a lesser extent San Antonio and San Andreas.

3) These natural sources may be isolated rock outcrops whose total impact on a large reservoir (e.g. Crystal Springs holds $22,580 \times 10^6$ gallons) may not be significant.

4) No evidence has been found of asbestos in any of the finished waters examined.



B TANK ELEVATIONS _____ CITY BASE
BAY DIVISION STRUCTURES _____ U.S.G.S.
TION + 8.74 = _____ U.S.G.S.

DIAGRAM OF SYSTEM

SUPERSEDES: X-838-B
ORIGINAL: January 1949
REVISED: JULY 1973

SAN FRANCISCO WATER DEPARTMENT

X-838-C

Engineer

City of San Francisco

Sample location and type	Date	F.p.l.[1] ($\times 10^6$)	µg/litre
Alameda East Portal			
Finished	3 5 75	BDL (0.22)	
Calaveras Reservoir			
Raw	3 5 75	45(A)[5], 240(C)	39.019 A, 1.405 C
San Antonio Reservoir			
Raw	3 5 75	0.56(A)[5], 0.56(C)[5]	0.33A, 0.13 C
Crystal Springs Reservoir			
Raw	3 5 75	4.3(A), 180(C)	0.14 A, 141 C
		1.7(A)[5], 71(C) R	0.341 A, 1.385 C
San Andreas Reservoir			
Raw	3 5 75	4.1(A)	6.74 A
San Andreas Outlet No. 1			
Finished	3 5 75	BDL (0.05)	
Pilarcitos Reservoir			
Raw	3 5 75	BDL (2.5)	

1) F.p.l. = fibers per litre
2) C = Chrysotile; A = Amphibole; R = Replicate analysis
3) BDL = Below detection limit; number inparentheses = detection limit
4) n.d. = none detected
5) Less than 5 fibers detected

City of San Francisco

Sample location and type	Date	F.p.l.[1] ($\times 10^6$)	µg/litre
Alameda East Portal			
Finished	9 10 75	BDL (0.43)	
Calaveras Reservoir			
Raw	9 10 75	2.6 (C)[5]	0.214
		15 (C) R	0.143
San Antonio Reservoir			
Raw	9 10 75	BDL (0.55)	
Sunol Filtration (San Antonio finished)	9 10 75	BDL (0.31)	
Crystal Springs Reservoir			
Raw	9 10 75	BDL (0.48)	
Crystal Springs Reservoir			
Finished	9 10 75	BDL (0.52)	
San Andreas Reservoir			
Raw	9 10 75	BDL (0.52)	
San Adnreas Outlet No. 1			
Finished	9 10 75	BDL (0.55)	
San Francisco tap water			
Finished	9 10 75	BDL (0.32)	
Mocassin Reservoir			
Raw	9 12 75	1.6 (C)[5]	0.04

1) F.p.l. = fibers per litre
2) C = Chrysotile; A = Amphibole; R = Replicate analysis
3) BDL = Below detection limit; number inparentheses = detection limit
4) n.d. = none detected
5) Less than 5 fibers detected

Appendix 10 Seattle

City of Seattle

Only 1 sample from the city of Seattle has been examined. This sample came from the Tolt Reservoir and is therefore raw water. The only further treatment to which this water is subjected prior to passing into the distribution system is chlorination. The sample should therefore be representative also of the finished product.

The "pedigree" of the sample is as follows:

EPA Region 10 Drinking Water Programs Branch is actively conducting a survey program in their region which includes the Seattle water supply. Jack Murchio, a consultant on this project is also associated with the Seattle project and permission was received from EPA region 10 for the transfer of this sample from their project. The sample is part of a limited "round robin" series and had been analyzed by two other laboratories as well as by Murchio.

The data presented herein is that of both McCrone Associates and of Murchio, the latter identified by the final letter 'M'. The samples designated DM are duplicates run at McCrone Associates on the actual filter analyzed by Murchio. It will be noted that Murchio reports both amphibole and chrysotile fibers present at levels of 1.9×10^6 and 1.5×10^6, respectively, whereas McCrone finds both below the limit of detection. Attention is drawn, however, to the McCrone descriptions which mention poorly diffracting fibers resembling chrysotile but with elemental compositions rich in Al, Si, Ca, Fe and some Mg. A positive identification of these fibers has not been made and the possibility that they are a fine amphibole in the Tremolite-Actinolite series cannot be ruled out. We have examined Murchio's data and consider that his identification of the chrysotile is valid. We therefore believe that both chrysotile and amphibole asbestos are present in Tolt reservoir water.

For further information on the EPA Region 10 program

contact: Roy Jones, U.S.E.P.A.
Drinking Water Programs Branch
1200 6th Avenue
M/S 429
Seattle, Washington 98101 Phone: 206 442 1223

City of Seattle

Sample location and type	Date	F.p.l.[1] ($\times 10^6$)	µg/litre
Tolt reservoir	9 8 75	BDL (0.25)	
		1.9 (A) M	1.21
		1.5 (C) M	0.008
		BDL (0.25) DM	

1) F.p.l. = fibers per litre
2) C = Chrysotile; A = Amphibole; M = Murchio date; DM = Duplicate run at McCrone Associates on Murchio sample (see text)
3) BDL = Below detection limit; number in parentheses = detection limit
4) n.d. = none detected
5) Less than 5 fibers detected

Appendix 11 List of Sample Sites

Appendix 11 - Sampling areas and expected source types

Source type	Sampling area
Natural	Montana - Red/Beaverhead Rivers
	California - Trinity River and various reservoirs in Northern California
	Vermont - Connecticut River
	Tennessee-Georgia - Hiwasee, Little Tennessee and Upper Savannah Rivers
Mining	G.A.F. - Vermont
Milling	Union Carbide - King City, California
AC Pipe	J.M.* - Dennison, Texas
	CAPCO - Ragland, Alabama
	CAPCO - Van Buren, Arkansas
	Certain Teed - St. Louis, Missouri
	Flintkote - Ravenna, Ohio
AC Sheet	National Gypsum - New Orleans, Louisiana
	G.A.F. - St. Louis, Missouri
	J.M.- Nashua, New Hampshire
	Nicolet - Ambler, Pennsylvania
Asbestos paper	J.M. - Tilton, N.H.
	J.M. - Pittsburg, California
	Armstrong - Fulton, New York
	G.A.F. - Erie, Pennsylvania

* J.M. = Johns Manville

Asbestos paper, con't.	G.A.F. - Whitehall, Pennsylvania
	Hollingsworth and Vose - East Walpole, Massachusetts
Millboard	J.M. - Billerica, Massachusetts
Roofing	G.A.F. - Erie, Pennsylvania
Tile	Armstrong - Kankakee, Illinois
Misc. (friction materials, textiles etc.)	Raybestos Manhattan - Stratford, Connecticut
	Raybestos Manhattan - North Charleston, S.C.
	Raybestos Manhattan - Marshville, N.C.
Multi product	J.M. - Manville, New Jersey
Accessory minerals	Morenci Mine - Arizona
	Homestake Mine - South Dakota
	W.R. Grace - Montana
	International Talc Company - New York
Water supplies	10 regional cities
	Boston
	New York
	Philadelphia
	Atlanta
	Chicago
	Dallas
	Kansas City

Water supplies con't.

Denver

San Francisco

Seattle

The following 7 are associated with potential natural sources

Lima, Montana

Dillon, Montana

Weaverville, California

Redding, California

Chattanooga, Tennessee

Anderson, South Carolina

Greenville, South Carolina

The following 13 are finished water at plants where city water is used in processing

St. Louis, Missouri

New Orleans, Louisiana

Erie, Pennsylvania

Pittsburg, California

Lead, South Dakota

Billerica, Massachusetts

Manville, New Jersey

Nashua, New Hampshire

Stratford, Connecticut

North Charleston, South Carolina

Marshville, North Carolina

Kankakee, Illinois

Van Buren, Arkansas

Appendix 12 Analytical Methodology

Appendix 12 Method for Determination of Asbestos

Samples are filtered onto 0.45 μm pore size membrane filters. Sections of the filter approximately 2-3 mm square are placed face-down on previously carbon-coated electron microscope grids and the membrane filter is dissolved, using acetone, in a Soxhlet extractor. Previous work has shown us that there is very little risk of contamination in transferring the filter on the electron microscope grid to the Soxhlet extractor. Furthermore, by dissolving the filter in situ on the grid, the risk of losing portions of the sample is minimal. Techniques involving transfer of a liquid suspension directly to the electron microscope grid are more subject to error since there is frequently a size separation as the meniscus of the drying drop recedes.

The sample grids are examined on the electron microscope (JEM 200 or EMMA 4) using a magnification such that the intermediate lens aperture is in focus in the specimen plane. It is thus possible, by inserting the aperture and switching to the diffraction position, to obtain a selected area electron diffraction (SAED) pattern of the fiber with no other adjustments to the microscope. In this way it is possible to spot check the diffraction pattern of individual fibers very rapidly.

The length and width of each asbestos fiber is recorded. Interpolation from intervals scribed on the screen allows an accuracy of measurement on the screen of approximately ±0.05 cm. This corresponds to an accuracy in size measurement of about 0.02-0.03 μm. Measurements of the individual fibers are computer processed to give listings of the length and width of the fibers, together with a computed mass of each fiber computed on the basis of density, D, and dimensions, L and W ($D \times L \times W^2$). A value of 3.40 is taken as the mean density of grunerite amphibole fibers. Densities of 2.3 and 3.0 are used for chrysotile and tremolite, respectively. Because many of the amphiboles are lath-shaped rather than square in cross section, this figure may well be slightly high, since the laths will, in general, tend to lie flat rather than on edge. There is, however, a finite possi-

bility that some laths will be on edge and, due to the very small size of many of the fibers of interest, the approximation to a square fiber will not give more than a slightly high bias to the mass readings. The program automatically assigns the longest dimension to the fiber length and excludes all fibers with an aspect ratio below three.

Also presented in the computer printout are the calculated number of fibers per unit volume, the calculated mass of fiber per unit volume, the size distribution of the fibers based on length and width, and the distribution of fibers by aspect ratio together with the relevant statistical information on these parameters.

A sample computer printout is attached.

As mentioned in the first paragraph, losses in a correctly operated Soxhlet extractor are minimal, but careful control of both heating rate and cooling rate of the cold finger are required. When these conditions are obtained, and maintained, estimated losses (based on filtration and examination of the solvent after several weeks use) are less than 1 fiber per grid processed. Additional evidence that losses are minimal is provided by examining filter segments which do not fully cover the grid. These show a clean junction between membrane and non-membrane area with no evidence of "bleed-off" of particulates.

The reproducibility of the method is clearly of prime importance. A report is currently being prepared describing tests performed to assess the reproducibility,accuracy and statistical validity of the method. The accompanying table presents part of this data and shows that, for a standard chrysotile dispersion, the filtration technique, and the electron microscope preparation method yield uniform dispersions over the entire filter area and grid area within a standard deviation of less than 10%. This standard deviation, however, also includes the variation in the operator's objectivity in deciding whether fiber bundles are one fiber or a composite of fibers, thus the S.D. of the dispersion

is probably better than 10%. The standard deviation deteriorates to approximately 20% when 3 operators (using 2 different Soxhlet extractors in different laboratories) are involved.

The data also show exceptionally good agreement between expected and observed values when successive dilutions of 10:1 and 100:1 are analyzed, although with low loadings the standard deviation again increases, as might be expected - at extreme dilutions clearly one enters the realm of probability statistics and the chance of finding a fiber in any given grid square predominates.

Errors in estimating the fiber content of real samples generally err on the low side because of practical difficulties such as fiber overlap - either with other fibers or with non-fibrous particulates in the sample. Furthermore, the philosophy has been adopted of only counting fibers which can be positively identified as asbestos during examination of the sample - it is impractical to photograph each fiber together with its diffraction pattern for later analysis and measurement. The possibility exists, therefore, that fibers in the grey area between positive acceptance and positive rejection as asbestos will be excluded although they might be asbestiform.

Standard Chrysotile Dispersion

Run No.	No. of observations	Fibers/litre ($x10^6$)	Relative Std. dev. (%)
1 a	39	33.5	9.88
1 b	9	34.3	19.08
1 c	5	31.7	38
1 d	15	25.7	8.96
1 e	15	27.4	6.85
1 f	5	2.38	11.09
1 g	5	0.36	48.6

Notes

Runs 1a - 1c freshly prepared dispersion, results of 3 different observers.

1a = 39 observations, 3 grid squares on each of 13 different grids

1b = 9 observations, 9 grid squares from 5 different grids

1c = 5 observations, 5 grid squares from 1 grid

1d and 1e = 2nd and 3rd preparation from standard after manual agitation to redisperse, 3 grid squares from 5 grids, observer of 1a

1f = suspension of 1a - 1e, diluted 10:1, 1 grid square from 5 grids, observer of 1 a

1g = as 1f, but diluted 100:1

SAMPLE (AMPHIBOLE)

FIBER CONCENTRATION BY NUMBER, PER LITER : 0.14E+09
FIBER CONCENTRATION BY MASS, PER LITER : 1272.500 GRAMS*10**-6
VOLUME FILTERED : 2.7 ML
GRID SQUARES COUNTED . . 10
TOTAL SUSPENDED SOLIDS: 44.000 MG PER LITER
PH = 7.4

DESCRIPTIVE STATISTICS

NO. OBS. = 34

	VARIABLE	MEAN	VARIANCE	STANDARD DEVIATION	STANDARD ERROR
1	LENGTH	0.32971E+01	0.54009E+01	0.23240E+01	0.39856E+00
2	WIDTH	0.45912E+00	0.22026E+00	0.46932E+00	0.80487E-01
3	ASPECT RATIO	0.10909E+02	0.56126E+02	0.74917E+01	0.12848E+01
4	MASS	0.90250E+01	0.42518E+03	0.20717E+02	0.35529E+01

	SKEWNESS	KURTOSIS	MAX	MIN	RANGE
1	0.14010E+01	0.79931E+00	0.90000E+01	0.60000E+00	0.84000E+01
2	0.15926E+01	0.16288E+01	0.18000E+01	0.50000E-01	0.17500E+01
3	0.15959E+01	0.20858E+01	0.36000E+02	0.33333E+01	0.32667E+02
4	0.28274E+01	0.78963E+01	0.96228E+02	0.12700E-01	0.96215E+02

SAMPLE (AMPHIBOLE)

	LENGTH	WIDTH	ASPECT RATIO	MASS
1	1.8000	0.1000	18.0000	0.0594
2	2.2000	0.2000	11.0000	0.2904
3	3.4000	0.4000	8.5000	1.7952
4	3.0000	0.3000	10.0000	0.8910
5	9.0000	0.7000	12.8571	14.5530
6	1.4000	0.2000	7.0000	0.1848
7	2.0000	0.3000	6.6667	0.5940
8	2.0000	0.3000	6.6667	0.5940
9	2.4000	0.4000	6.0000	1.2672
10	4.0000	1.2000	3.3333	19.0080
11	4.0000	0.5000	8.0000	3.3000
12	2.0000	0.3000	6.6667	0.5940
13	2.8000	0.3000	9 3333	0.8316
14	3.5000	0.3000	11.6667	1.0395
15	6.0000	1.8000	3.3333	64.1520
16	0.6000	0.1000	6.0000	0.0198
17	2.4000	0.2000	12.0000	0.3168
18	3.0000	0.3000	10.0000	0.8910
19	2.5000	0 3000	8.3333	0.7425
20	1.8000	0.0500	36.0000	0.0148
21	2.4000	0.1000	24.0000	0.0792
22	7.0000	1.0000	7.0000	23.1000
23	7.0000	1.3000	5.3846	39.0390
24	2.2000	0.0800	27.5000	0.0465
25	9.0000	1.8000	5.0000	96.2280
26	2.2000	0.1000	22.0000	0.0726
27	1.8000	0.2000	9.0000	0.2376
28	1.8000	0 3000	6 0000	0 5346
29	0.6000	0.0600	7.5000	0.0127
30	3.5000	0.6000	5.8333	4.1580
31	9.0000	1.0000	9.0000	29.7000
32	2.0000	0.6000	3.3333	2.3760
33	2.0000	0.1000	20.0000	0.0660
34	1.8000	0.1000	18.0000	0.0594

SAMPLE

DISTRIBUTION BY LENGTH

LENGTH		NUMBER	PERCENT	CUMULATIVE PERCENT
0.0	0.5	0	0.00	0.00
0.5	1.0	2	5.88	5.88
1.0	1.5	1	2.94	8.82
1.5	2.0	10	29.41	38.24
2.0	2.5	7	20.59	58.82
2.5	3.0	3	8.82	67.65
3.0	3.5	3	8.82	76.47
3.5	4.0	2	5.88	82.35
4.0	4.5	0	0.00	82.35
4.5	5.0	0	0.00	82.35
5.0	5.5	0	0.00	82.35
5.5	6.0	1	2.94	85.29
6.0	6.5	0	0.00	85.29
6.5	7.0	2	5.88	91.18
7.0	7.5	0	0.00	91.18
7.5	8.0	0	0.00	91.18
8.0	8.5	0	0.00	91.18
8.5	9.0	3	8.82	100.00
9.0	9.5	0	0.00	100.00

DISTRIBUTION BY WIDTH

WIDTH		NUMBER	PERCENT	CUMULATIVE PERCENT
0.0	0.1	9	26.47	26.47
0.1	0.2	4	11.76	38.24
0.2	0.3	9	26.47	64.71
0.3	0.4	2	5.88	70.59
0.4	0.5	1	2.94	73.53
0.5	0.6	3	8.82	82.35
0.6	0.7	0	0.00	82.35
0.7	0.8	1	2.94	85.29
0.8	0.9	0	0.00	85.29
0.9	1.0	0	0.00	85.29
1.0	1.1	2	5.88	91.18
1.1	1.2	0	0.00	91.18
1.2	1.3	1	2.94	94.12
1.3	1.4	1	2.94	97.06
1.4	1.5	0	0.00	97.06
1.5	1.6	0	0.00	97.06
1.6	1.7	0	0.00	97.06
1.7	1.8	0	0.00	97.06
1.8	1.9	2	5.88	102.94

DISTRIBUTION BY ASPECT RATIO

ASPECT RATIO		NUMBER	PERCENT	CUMULATIVE PERCENT
3	10	23	67.65	67.65
10	20	7	20.59	88 24
20	30	3	8.82	97.06
30	40	1	2.94	100 00
40	50	0	0.00	100.00
50	60	0	0.00	100.00
60	70	0	0.00	100.00
70	80	0	0.00	100.00
80	90	0	0.00	100.00
90	100	0	0.00	100.00
100	110	0	0.00	100.00
110	120	0	0.00	100.00
120	130	0	0.00	100.00
130	140	0	0.00	100 00
140	150	0	0.00	100.00
150	160	0	0.00	100.00
160	170	0	0.00	100.00
170	180	0	0.00	100.00
180	190	0	0.00	100.00
190	200	0	0.00	100.00
* OVER 200		0	0.00	100.00