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Is Chrysotile Asbestos Released From Asbestos-Cement Pipe Into Drinking Water?

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To investigate the possibility that asbestos-cement pipe does, as has been suggested, release asbestos as a contaminant in drinking water, a study was made of water samples from fifteen public water-supply systems before and after their flow through asbestos-cement pipes of various ages, lengths, and diameters.

More than 200 000 miles of asbestos-cement water distribution pipe have been placed into service in the United States since its introduction in 1929. One-third of all water distribution pipe currently being sold in the US is made of asbestos-cement. Its principal attributes are resistance to corrosion and scaling, light weight, and low cost.[1]

A question has arisen concerning the possible release of asbestos fibers from asbestos-cement pipe into drinking water. Occupational epidemiology studies indicate that there may be a human health hazard associated with the ingestion of asbestos because death rates due to cancer of the digestive system are elevated in asbestos workers.[2] This finding may be related to the swallowing of asbestos that was inhaled and cleared from the respiratory system via the respiratory clearance mechanism.[3]

Asbestos is a generic term for a number of fibrous silicate minerals and represents 16-18 per cent (by weight) of the composition of asbestos-cement potable-water pipe.[1] Chrysotile refers to the serpentine $[Mg_6Si_4O_{10}(OH)_8]$ variety of asbestos[4] and comprises 80 per cent or more of the asbestos used in asbestos-cement pipe. The remaining asbestos is of the crocidolite variety.[5]

The Johns-Manville Corp. has studied two asbestos-cement pipes in two different municipal water systems in order to determine if chrysotile was released. These pipes of unspecified ages were studied over a period of about one year. Paired water samples were taken two to three times a month from water before and after it flowed through the pipes. It was concluded that chrysotile release from both pipes was on the order of nanograms per liter at the 10 per cent level of significance.[5]

Since the effect of pipe age on the release of chrysotile was unknown, the

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TABLE 1

General Characteristics of Selected Asbestos-Cement Field Pipes

Water Systems	Pipe Age *years*	Length *ft*	Diameter *in*
Groundwater systems			
Westmont	0 5	200	12
Lisle	1	3000	6
Hoffman Estates	18	3700	8
Rolling Meadows	20	4400	12
York Center	27	1100	6
Lake Michigan systems			
Bannockburn	1	1300	10
Bradley Road	14	1000	6
Zion-Benton	18	10 000	8
Waukegan	19	800	6
Zion	26	1150	6
Midlothian	27	1500	6
Blue Island	30	3248	8
Brookfield	35	40 000	20
Glenview	37	1500	6
Highland Park	40	275	6

Fig. 1. Chrysotile asbestos fibril in a field sample (length = 1.8 μm, diameter = 0.04 μm)

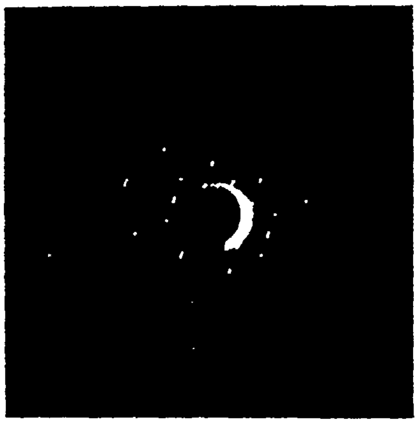

Fig. 2. Selected area electron diffraction pattern (SAED) of a chrysotile asbestos fibril

TABLE 2

*Saturation Index and Data Pertinent to its Calculation**

Water Systems	$H \times 10^{-3}$ moles/l	$A \times 10^{-3}$ eq/l	$Ca^{++} \times 10^{-3}$ moles/l	T C	log K	pH	pH_s	Saturation Index (I)
PGroundwater systems								
Westmont	0 75	7 12	0 35	10	2 34	7.1	7 9	−0 8
Lisle	4 56	5 76	2.40	10	2.34	7 7	7 4	0 3
Hoffman Estates	4 45	3 00	2 23	10	2.34	8 2	7 7	0 5
Rolling Meadows	3 06	5 68	1 95	10	2 34	7 5	7 4	0 1
York Center	5 26	7 28	3 13	10	2.34	7.7	7 2	0 5
Lake Michigan systems								
Bannockburn	1 42	2 16	0 93	5	2 47	8 4	8.3	0.1
Bradley Road	1 42	2.16	0 93	5	2.47	8.4	8.3	0.1
Zion-Benton	1 35	2.16	0.90	10	2 34	6.1	8.2	−0.1
Waukegan	1 80	2.80	0 95	5	2 47	†	8 2	†
Zion	1 35	2.16	0 90	10	2 34	8.1	8.2	−0.1
Midlothian	1 23	2.16	0.83	15	2.21	8 2	8.1	0 1
Blue Island	1 23	2.16	0 83	15	2.21	8.2	8.1	0.1
Brookfield	1 23	2.16	0 83	15	2 21	8 2	8.1	0.1
Glenview	1.28	1.96	0.83	10	2.34	7.6	8 2	−0.6
Highland Park	1.30	2 00	0.85	5	2.47	7.9	8.3	−0 4

*Abbreviations:

H = total hardness ($CaCO_3$)

A = total alkalinity ($CaCO_3$)

Ca^{++} = calcium

I = pH − pH_s

†Data not available

K = $(Ca^{++})(HCO_3)/H^+$

T = temperature

pH = − log H^+

$$pH_s = \log K + \frac{2.5\,(4H\text{-}A)^{1/2}}{1 + 5.3\,(4H\text{-}A)^{1/2} + 5.5\,(4H\text{-}A)} + pCa^{++} + pA,\ \text{for pH} < 8.5$$

TABLE 3

Aggressiveness Index and Data Pertinent to its Calculation

Water Systems	pH	Total Alkalinity mg/l $CaCO_3$	Calcium Hardness mg/l $CaCO_3$	Aggressiveness Index pH + log (xy)*	Aggressiveness
Groundwater systems					
Westmont	7 1	356	35	11 2	moderate
Lisle	7.7	288	240	12 5	none
Hoffman Estates	8 2	150	223	12.7	none
Rolling Meadows	7 5	284	195	12 2	none
York Center	7 7	364	313	12 8	none
Lake Michigan systems					
Bannockburn	8 4	108	93	12.4	none
Bradley Road	8 4	108	93	12.4	none
Zion-Benton	8.1	108	90	12.1	none
Waukegan	†	140	95	†	†
Zion	8.1	108	90	12.1	none
Midlothian	8 2	108	83	12.2	none
Blue Island	8 2	108	83	12.2	none
Brookfield	8 2	108	83	12 2	none
Glenview	7.6	98	83	11.5	moderate
Highland Park	7 9	100	85	11 8	moderate

*x = total alkalinity in mg/l $CaCO_3$, y = calcium hardness in mg/l $CaCO_3$

†Data not available

TABLE 4

*Number of Grid Squares Scanned, Average Number of Fibers Per Grid Square, and Standard Deviation**

Water Systems	Before Pipe		After Pipe	
	Number of Grid Squares Scanned	Average Number of Fibers† Per Grid Square	Number of Grid Squares Scanned	Average Number of Fibers Per Grid Square
Groundwater systems				
Westmont	20	0 15 (0 49)	20	0.10 (0 31)
Lisle	10	0 10 (0 32)	10	0 60 (1.90)
Hoffman Estates	20	0 25 (0.72)	20	0 ‡
Rolling Meadows	20	0.40 (0 60)	20	0 ‡
York Center	20	0 05 (0 22)	20	0 25 (0.72)
Lake Michigan systems				
Bannockburn	20	0.10 (0 31)	20	0.30 (0 57)
Bradley Road	20	0.10 (0 31)	20	0 65 (0 88)
Zion-Benton	10	0.10 (0 32)	10	0.30 (0 67)
Waukegan	20	0 20 (0.70)	20	0.10 (0 31)
Zion	10	0 10 (0 32)	10	0.10 (0 32)
Midlothian	20	0.40 (1.35)	20	0 45 (0 94)
Blue Island	20	1.15 (1.57)	20	0 95 (1.23)
Brookfield	10	0 70 (0 82)	10	0 30 (0.48)
Glenview	20	0.05 (0.2	[illegible]	0 25 (0 64)
Highland Park	20	0.15 (0.[illegible]		0 20 (0 52)

*In parentheses

†Fiber designates either a fibril or bundle of fibrils.

‡Standard deviation not applicable when count is zero.

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may be broken down during transit and thus create the appearance of chrysotile release, in terms of fiber count, from asbestos-cement pipe. Some evidence was found to support this hypothesis from the following analysis of Lake Michigan systems. All the fiber lengths from the before samples were compared to all the fiber lengths in the after samples by using the Mann-Whitney test. The lengths of the after fibers were found to be somewhat shorter ($P = 0.063$) than those of the before samples. The same analysis of groundwater systems did not reveal a significant difference between before and after fiber lengths ($P = 0.382$). Because of the possibility that fibers may be broken down during transit through the pipe, a before-after increase was considered significant only if a statistically significant increase was demonstrated by both fiber count and mass data. Referring to Table 6, it can be seen that these two criteria were not satisfied at the 5 per cent level of significance.

Table 7 contains the distribution of chrysotile fiber lengths. Eighty-seven per cent of the chrysotile fibers were in the form of single fibrils and 13 per cent were composed of bundles of fibrils. The length of the longest fibril in a bundle was taken as the length of the bundle. The mean and median lengths of Lake Michigan fibers (2.2 μm and 0.4 μm, respectively) were somewhat greater than those encountered in groundwater systems (0.5 μm and 0.2 μm, respectively).

The diameters of chrysotile fibrils in groundwater and Lake Michigan systems were distributed over a narrow range from 0.02 μm to 0.1 μm; mean and median diameters were both 0.05 μm for both types of water. Bundles of fibrils were not included in the analysis of diameters because, in general, they do not have circular cross-sections nor uniform widths.

The central question addressed in the present study was whether an increase of chrysotile could be detected in water passing through asbestos-cement pipe and, if so, how much of an increase. Because the before sample served as the reference or control for the after sample, there was no need to analyze samples specifically for the purpose of determining laboratory contamination. The problem of laboratory contamination is widely recognized by asbestos researchers and may result from the presence of chrysotile in the air, membrane filters, or grid coatings. When data are presented in an absolute sense as in Table 8 (Fiber and Mass Concentrations of Chrysotile), it is important to control for contamination. Since appropriate control samples were not analyzed for laboratory contamination, the data in Table 8 must be considered preliminary in nature.

TABLE 7
Distribution of Chrysotile Fiber Lengths

Length of Fiber μm	Groundwater Systems: Absolute Frequency number	Groundwater Systems: Cumulative Frequency per cent	Lake Michigan Systems: Absolute Frequency number	Lake Michigan Systems: Cumulative Frequency per cent
0.1	2	6.5	2	2.6
0.2	14	51.6	15	22.1
0.3	6	71.0	15	41.6
0.4	2	77.4	9	53.2
0.5	3	87.1	5	59.7
0.6	2	93.5	6	67.5
0.7	1	96.8	2	70.1
0.8	0	96.8	1	71.4
1.0	0	96.8	2	74.0
1.1-2.5	0	96.8	8	84.4
2.6-5.0	0	96.8	3	88.3
5.1-10.0	1	100.0	4	93.5
10.1-15.0	0		1	94.5
15.1-20.0	0		2	97.4
20.1-25.0	0		2	100.0
Total	31		77	

TABLE 8
*Fiber and Mass Concentrations of Chrysotile**

Water Systems	Before Pipe: fibers/l	Before Pipe: pg/l	After Pipe: fibers/l	After Pipe: pg/l
Groundwater systems				
Westmont	1.2×10^{5}	120	8.0×10^{4}	740
Lisle	8.0×10^{4}	100	4.8×10^{5}	350
Hoffman Estates	2.0×10^{4}	220	†	†
Rolling Meadows	3.2×10^{5}	850	†	†
York Center	4.0×10^{4}	24	2.0×10^{5}	220
Lake Michigan systems				
Bannockburn	5.8×10^{4}	31	1.8×10^{5}	2200
Bradley Road	5.8×10^{4}	3500	3.8×10^{4}	240
Zion-Benton	5.8×10^{4}	240	1.8×10	730
Waukegan	1.2×10^{5}	10 100	5.8×10^{4}	2800
Zion	5.8×10^{4}	160	5.8×10^{4}	200
Midlothian	2.3×10^{5}	740	2.6×10^{4}	600
Blue Island	6.7×10^{5}	17 500	5.5×10^{5}	3900
Brookfield	4.1×10^{5}	540	1.8×10^{5}	160
Glenview	2.9×10^{4}	230	1.5×10^{5}	480
Highland Park	8.8×10^{4}	140	1.2×10^{5}	58

*These are preliminary data; see text for details.
†Below detection

In conclusion, fifteen asbestos-cement pipes of various ages, lengths, and diameters were studied for possible release of chrysotile asbestos. Although several water systems contained moderately aggressive water, no statistically significant release of chrysotile was observed. It may be possible, however, that chrysotile is released from pipes at levels below the detection limits used in this study or at levels that were obscured by laboratory contamination or by chrysotile already present in the water.

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