Environmental Health Perspectives
Vol. 53, pp. 45–48, 1983

PLAINTIFF'S EXHIBIT
DOW-1401

Asbestos in Water Supplies of the United States

by James R. Millette,* Patrick J. Clark,* Judy Stober* and Montiel Rosenthal*

The review of available data on the concentrations of asbestos in U.S. water supplies suggests that the majority of water consumers are not exposed to asbestos concentrations over 1 million fibers/Liter. A few populations, however, may be exposed to concentrations over 1 billion fibers/L. Of the 538 water supplies for which waterborne asbestos data are available, 8% have concentrations of fibers over 10 million fibers/L.

The vast majority of asbestos fibers found in U.S. water supplies are under 5 μm in length.

Fiber Concentrations in Water

In 1980, two publications summarized the data on asbestos in drinking water that had been gathered from literature and other U.S. Environmental Protection Agency analytical records (*1,2*). The data are summarized in Table 1. Since that report, a number of studies have provided additional data on asbestos counts in drinking water.

McGuire and Bowers (*3*) have reported billions of chrysotile asbestos fibers in the California Aqueduct system. The reservoirs at the southern end of the State Water Project provide an opportunity for some of the asbestos particles to coagulate with other particles and settle to the bottom. However, concentrations as high as 1.3 billion fibers/L were reported at one water plant intake, and the maximum asbestos concentration in the effluent of one plant (i.e., in the drinking water) was 200 million fibers/L. The authors also reported variable asbestos concentrations up to 13 million fibers/L in the Colorado River water delivered to southern California. No evidence of amphibole fibers was found in either source of supply. Other data from the California Health Department indicate that some small water supplies in northern California have asbestos concentrations over 100 billion fibers/L (S. Hayward, Calif. Dept. of Health personal communication).

Table 1. Distribution of reported asbestos concentrations in drinking water from 406 cities in 47 states, Puerto Rico, and the District of Columbia.

Highest asbestos concentration, 10^6 fibers/L	Number of cities	Percentage
Below detectable limits	117	28.8
< 1	216	53.2
1–10	33	8.1
> 10	40	9.9
Total	406	100

The source is apparently natural erosion of serpentive minerals in the watershed. The water has very little turbidity, and no filtration treatment is employed for these northern California systems.

Data from both Canadian and U.S. sources (*4*) show concentrations of fibers as high as 100 billion fibers/L in the Sumas River, which flows into Canada from the State of Washington. The Yukon River, which is shared by Alaska and Canada, has been reported to have asbestos concentrations as high as 1 billion fibers/L for amphibole and 100 million fibers/L for chrysotile (*5*).

A report of asbestos in the groundwater of northern New Jersey was published by Germaine and Puffer (*6*) in 1981. They found 4.7 million fibers/L of crocidolite in the well water of the Mendham Borough water supply. Similar crocidolite fibers were found in samples of the local bedrock. In general, there are few reports of asbestos in groundwater sources. Earlier work showed groundwater asbestos concentrations as

*Toxicology and Microbiology Division, Health Effects Research Laboratory, U.S. EPA, Cincinnati, OH 45268.

ST0096982

ST0096983

high as 1 billion fibers/L in wells in New Mexico (*7*), but our laboratory could not confirm these results even though we used a more generally accepted technique of analysis.

EPA Region II has contracted to have 100 water supplies in New York and New Jersey analyzed for asbestos. The contractor's results are not yet available, but at least one supply has an asbestos concentration over 10 million fibers/L based on counts in Cincinnati for a portion of split samples used for quality control checking.

The cities of Chicago, Illinois, and Duluth, Minnesota, have continued to monitor their drinking water for asbestos as it comes from filtration plants. Neither reports any real variation from the values reported 4 yr ago. Both have asbestos concentrations under a million fibers per liter.

Cisterns receiving rainwater off asbestos-cement (AC) roofs have been found to contain levels of chrysotile asbestos as high as 500 million fibers/L (*8*). Asphalt shingles containing asbestos as a binder and used on roofs in the collection of rainwater were not found to contribute significant numbers of asbestos fibers to the cistern waters.

Discharges from asbestos processing and manufacturing plants can have very high asbestos concentrations as are being found in a new survey by the EPA Effluent Guidelines Division. There is no evidence, however, that any of these plants is directly contaminating drinking water supplies.

The study of the aggressive index (AI) as an indicator of a water's corrosivity toward AC pipe has continued. The AI is based on calcium carbonate saturation conditions and is derived from the sample pH, calcium hardness and total alkalinity according to the equation: $AI = pH + \log(AH)$, where A is the total alkalinity (expressed in mg/L $CaCO_3$) and H is the calcium hardness (expressed in mg/L $CaCO_3$). Values of AI below 10 are considered very aggressive, while values above 12 are considered nonaggressive. Analysis of water from AC pipe systems in Wisconsin where the water was aggressive showed fiber counts between 1 and 10 million fibers/L. Analyses of waters from towns in Virginia and Delaware with AC pipe and moderately aggressive waters did not show consistent fiber counts over 1 million fibers/L. In a paper published in 1981, Kanarek, Conforti, and Jackson (*9*) reported concentrations of asbestos as high as 34 million fibers/L in an AC distribution system with essentially nonaggressive water. The condition of the pipe surface was not investigated. In-house work by Schock and Buelow (*10*) has indicated some theoretical reasons why the AI will not always correctly predict fiber release from AC pipe. Other in-house research has suggested that iron, which is not considered in the AI, can, in concentrations at about 0.3 mg/L, coat the surface of a pipe in some way, even in the presence of an aggressive water. This coating does not necessarily prevent calcium from being depleted by the action of the aggressive water on the cement, but binds the fibers and prevents them from being eroded off the pipe. These data are consistent with an early Norwegian study (*11*) and some recent data from Germany (*12*) that showed protective iron-containing coats even in some aggressive water situations.

In response to a National Academy of Sciences recommendation that data were needed on the particulate concentration in typical U.S. drinking water, a survey was designed to obtain a representative picture of the particulates in U.S. water systems. Because of the time, cost and effort involved with the asbestos and other analyses, the survey was designed to sample only 100 U.S. water supplies. In order to get a representative sampling with only 100 collections, a stratified random sampling was done from the Community Water Systems Survey Database (*13*). This database list of 984 systems was originally obtained by a stratified random sampling of a list of over 40,000 utilities compiled by the USEPA Office of Drinking Water. A sample of 2139 utilities was randomly selected from the list, which was stratified geographically by EPA regions and demographically by seven population classifications of systems serving between 25 and 100,000 persons. Added to the sample was a list of all 232 utilities serving over 100,000 persons. Questionnaires were sent to these systems and the respondents, 948 systems, make up the Community Water Systems Survey Database.

From the database list stratified according to regions and three population groups, two groups of 100 systems were drawn as shown in Table 2. The second set of 100 acted as a reserve in the

Table 2. Distribution of systems by size and regions for 100 utility samples.[a]

U.S. EPA regions	Population 25–999	Population 1000–99,999	Population >100,000	Total
I and II	9 (88)	6 (60)	4 (41)	19 (189)
III and IV	10 (104)	6 (59)	7 (68)	23 (231)
V and VI	9 (87)	7 (70)	5 (44)	21 (201)
VII and VIII	10 (100)	6 (64)	3 (18)	19 (182)
IX and X	9 (96)	5 (53)	4 (32)	18 (181)
Total	49 (475)	30 (306)	23 (203)	100 (964)

[a]The number of water systems for each size and region in the Community Water Systems Database is given in parentheses.

event a utility in the first group could not be sampled. Table 2 shows that the distribution by cell of the 100 utility sample stratified for population size and geographic area, and the original database distribution by cell, represent about the same percentage of the total.

The water samples from residential drinking water taps were collected in the distribution systems of the utilities by EPA regional personnel, State health personnel, or local utility officials. The results of the asbestos analyses for these 100 utilities are shown in Table 3. When compared with the results from all asbestos analysis data available in 1982 (Table 4), the data from the representative sampling show a slightly lower percentage in the > 10 million fibers/L group. This may reflect the emphasis in the overall data on collecting more water samples from areas thought to have problems with asbestos. A survey of asbestos fibers in Canadian water supplies concluded that 5% of the public receive water with fiber concentrations exceeding 10×10^6 fibers/L (*14*). Consideration of the population served by the U.S. water supplies shown in Table 4 suggests that the percentage of U.S. population receiving water with fiber concentrations exceeding 10 million fibers/L is similar but somewhat less than the 5% figure determined for the Canadian population.

Sizes of Fibers

The length of a vast majority of asbestos fibers found in water supplies was less than 5 μm. Large numbers of waterborne chrysotile fibers have been sized in conjunction with an epidemiology study in California (*15*) and one in Puget Sound (Washington) (*16*). A comparison of the fiber size data in Table 5 shows that the San Francisco Bay Area water has a slightly higher percentage of longer fibers than that of the Puget Sound area.

Some caution is suggested when comparing these data, however, because the analytical methods used for sizing asbestos fibers in the Puget Sound area study (*17*) were more refined and perhaps more sensitive to small fibers than the methods used to characterize the asbestos fiber sizes of the Bay Area waters, which were studied at an earlier time (*18*).

Table 3. 100-City survey: asbestos analysis.

Highest concentration, 10^6 fibers/L	Number of cities
Below detectable limits	61
< 1	27
1–10	7
> 10	5

Table 4. Asbestos in U.S. water, 538 cities.

Highest concentration, 10^6 fibers/L	Number of cities	%
Below detectable limits	187	34.8
< 1	264	49.1
1–10	41	7.6
> 10	46	8.6
Total	538	100.1

Nonasbestos Fibers

For the survey of consumers' tapwater from 100 water utilities chosen to represent the size of population served and U.S. geographic area, data show a range in turbidity from 0.1 to 19 nephelometric turbidity units (NTU). The mean value for the set was 1.9 NTU. Particle counts from the same set of samples using a HIAC particle counter showed a range of 14,000 to 10,700,000 particles/L. The particles measured ranged in diameter from 2.5 to > 150 μm. The median particle size was 4 μm. Two nonasbestos mineral fibers, palygorskite and halloysite, have been found in concentrations over 1 million fibers/L in drinking water (*19*), but the occurrence of these forms of fibers is not widespread in water systems. Silicate algal scales, a biologically produced rigid fiber, can be found in a number of water systems (*20*). Glass fibers have not been identified in any water systems.

Conclusions

Additional data have not suggested that a change is necessary in the earlier conclusion (*1*) that the majority of U.S. water consumers are not exposed to constant concentrations of asbestos fibers over 1 million fibers/L. In some areas, however, people are exposed to concentrations of asbestos fibers over 1 billion fibers/L.

Table 5. Comparison of asbestos fiber lengths.

	California (Bay Area)	Washington (Puget Sound area)
N, fibers	7,375	6,977
Mean length, μm	1.35	0.6
Std. dev.	1.99	0.52
Median length, μm	1.0	0.5
Range, μm	0.1–59.0	0.1–9.5
Distribution		
90% <	2.2 μm	1.1 μm
75% <	1.5 μm	0.7 μm
25% <	0.6 μm	0.3 μm
Percentage ≥ 5 μm	2.3%	0.2%

ST0096984

The sizes of asbestos fibers in drinking waters vary depending on the source of the fibers. Generally, asbestos fibers found in drinking waters are less than 5 μm in length.

The research described in this paper has been peer and administratively reviewed by the U.S. Environmental Protection Agency and approved for presentation and publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

REFERENCES

1. Millette, J. R., Clark, P. J., and Pansing, M. F. Exposure to asbestos from drinking water in the United States. Environmental Health Effects Research Report, Office of Research and Development, EPA-600/1-79-028, 1979.
2. Millette, J. R., Clark, P. J., Pansing, M. F., and Twyman, J. D. Concentration and size of asbestos in water supplies. Environ. Health Perspect. 34: 13–25 (1980).
3. McGuire, M. J., Bowers, A. E., and Bowers, D. A. Asbestos analysis case history: surface water supplies in Southern California. J. Am. Water Works Assoc. 74: 470–477 (1982).
4. Schreier, H., and Taylor, J. Asbestos Fibers in Receiving Waters. Technical Bulletin 117, Inland Waters Directorate, Environment Canada, Vancouver, British Columbia, Canada, 1980.
5. Marklund, D. R. Mineral Fiber Analysis of Yukon River Samples. Technical Report, U.S. Department of Interior, Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, Alaska, 1981.
6. Germaine, M., and Puffer, J. H. Distribution of asbestos in the bedrock of the northern New Jersey area. Environ. Geol. 3: 337–351 (1981).
7. Oliver T., and Murr, L. E. An electron microscopic study of asbestiform fiber concentrations in Rio Grande Valley water supplies. J. Am. Water Works Assoc. 69: 428–431 (1976).
8. Millette, J. R., Boone, R., and Rosenthal, M. Asbestos in Cistern Water. Environ. Res. Brief, USEPA, Health Effects Research Laboratory, Cincinnati, 1980.
9. Kanarek, M. S., Conforti, P. M., and Jackson, L. A. Chrysotile asbestos fibers in drinking water from asbestos-cement pipe. Environ. Sci. Technol. 15: 923–925 (1981).
10. Schock, M. R., and Buelow, R. W. The behavior of asbestos-cement pipe under various water quality conditions: Part 2, theoretical considerations. J. Am. Water Works Assoc. 73: 636–661 (1981).
11. Kristiansen, H. Corrosion on asbestos-cement pipes. Vatten 33: 53–61 (1977).
12. Meyer, E. Untersuchungen zum Vorkommen von Asbestfasern in Trinkwasser in der Bundesrepublik Deutschland und gesundheitliche Bewertung der Ergebnisse (Studies of the presence of asbestos fibers in drinking water in the Federal Republics of Germany and a health evaluation of the results). GWF-Wasser/Abwasser 123: 85–96 (1982).
13. Herschell, C. Survey of Operating and Financial Characteristics of Commercial Water Systems. EPA Report #570-9-77-003, 1977.
14. Chatfield, E. J., and Dillon, M. J. A National Survey for Asbestos Fibers in Canadian Drinking Water Supplies. Department of National Health and Welfare, 79-EHD-34, Ottawa, Canada, 1979.
15. Kanarek, M. S., Conforti, P. M., Jackson, L. A., Cooper, R. C., and Murchio, J. C. Asbestos in drinking water and cancer incidence in the San Francisco Bay Area. Am J. Epidemiol. 112: 54–72 (1980).
16. Polissar, L., Severson, R. K., Boatman, E. S., and Thomas D. B. Cancer incidence in relation to asbestos in drinking water in the Puget Sound region. Am. J. Epidemiol. 116: 314–328 (1982).
17. Boatman, E. S. Analyzing asbestos fibers in water by means of transmission electron microscopy. J. Am. Water Works Assoc. 74: 533–536 (1982).
18. Cooper, R. C., and Murchio, J. C. Preliminary Studies of Asbestiform Fiber Concentrations in Domestic Water Supplies. Final Report to the Aerospace Medical Research Laboratory, Wright Patterson Air Force Base, Ohio. Available from NTIS, U.S. Department of Commerce #AD-A011-855, 1976.
19. Millette, J. R., Twyman, J. D., Hansen, E. C., Clark, P. J., and Pansing, M. F. Chrysotile, palygorskite, and halloysite in drinking water. Scan. Elec. Microsc. 1: 579–586 (1979).
20. Millette, J. R., Rosenthal, M. T., and Feldman, R S. Asbestos analytical technique. In: Proceedings, American Water Works Association Water Quality Technical Conference, Miami, FL, December 1980.

ST0096985