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ANALYZING FOR ASBESTOS IN DRINKING WATER

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Detecting, identifying, and counting asbestos fibers in drinking water supplies have been the concern for some time of scientists at the Water Supply Research Division (WSRD), a part of the newly formed Municipal Environmental Research Laboratory (MERL) in Cincinnati. During the past year and a half, they have subjected drinking water samples from over 70 cities throughout the United States to this type of analysis. In addition, they have examined samples collected at pilot plants where techniques for removing asbestos from drinking water are being applied. Currently, several water systems that use asbestos-cement distribution lines are being monitored on a bimonthly basis to determine how much, if any, asbestos is released into the drinking water. In conjunction with this study, a 100-foot recirculating asbestos-cement pipeloop was constructed at the laboratory to study the influence that pH, hardness, and alkalinity have on the release of the fibers.

ASBESTOS

Asbestos is the general name for a family of silica rock crystals that form long, flexible fibers (Figure 1). Naturally occurring in many rock formations, asbestos is mined commercially in several places in the United States. Among other applications, it is

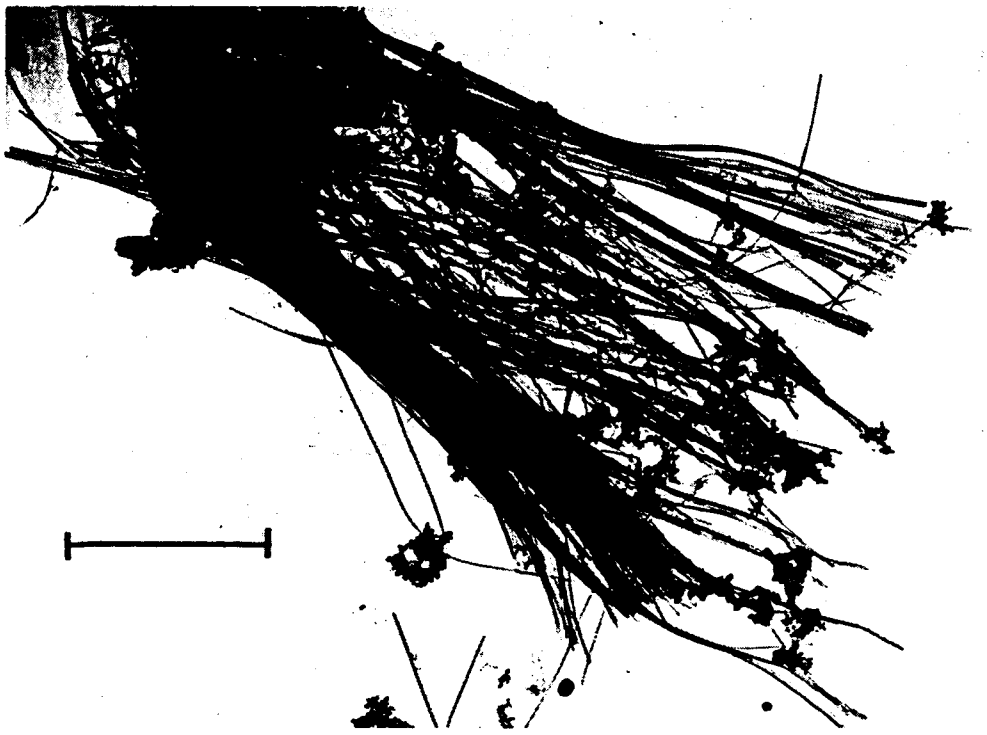


Figure 1. Electron micrograph of a bundle of chrysotile asbestos fibers found in water that had flowed through asbestos-cement pipe. Bar represents 3 micrometers.

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used in the making of floor tiles, pipewrappings, brakelinings, and plastic reinforcements, and it is added to cement to make asbestos-cement products. There are two classes of asbestos based on crystal structure. The serpentine class, which has only one asbestos member (chrysotile), accounts for 93% of the asbestos fibers used commercially. The amphibole class has several varieties, including amosite, anthophyllite, crocidolite, actinolite, and tremolite.

Serious health hazards can exist if asbestos fibers are inhaled, and levels to which a person may be occupationally exposed have been set. Ingesting such material may also be dangerous, as evidenced by increased rates of gastrointestinal cancer among asbestos workers and the results of research done on animals. Although there is no proof that drinking water containing asbestos will cause cancer, the long-term health effects of swallowing small doses of asbestos are uncertain. The long, sharp form of the fibers is thought to be the important factor in the mechanism by which asbestos causes cancer, and it is, therefore, necessary to determine how many fibers per liter are present in drinking water.

ANALYZING FOR ASBESTOS

Since asbestos fibers found in drinking water are generally too small to be seen through a conventional light microscope, an electron microscope (EM) is needed. The EM used by the WSRD is in a central EM facility where it can be used by associated environmental research laboratories in Cincinnati. The laboratories provide the personnel trained in their particular area of interest.

Analyzing a drinking water sample for asbestos is a lengthy, somewhat tedious process — preparing it, for example, requires between 6 and 8 hours. The suspended material in a 500-milliliter volume of the water sample is collected on a membrane filter with a 0.45-micrometer pore size. After the filter is dried in an asbestos-free oven, a small disc is cut from it and placed upside down on an EM carbon-coated specimen grid. The filter is gently dissolved in a condenser washer, leaving the asbestos and other suspended material on the grid. The grid is then placed in the EM and magnified 17,000 times. Before a fiber can be counted, it must be identified as being asbestos, preferably by type. The identification is based on three factors: morphology (size, shape, and appearance), crystal structure, and elemental composition.

Asbestos fibers generally appear to have sharp edges and often ragged or broken ends. When viewed at a high magnification, they can be readily distinguished from most biological and many inorganic fibers. Chrysotile asbestos has a distinctive central channel running the length of the fiber, whereas the amphiboles are more solid (Figure 2).

Identifying fibers by their crystal structure is done in the EM using selected area electron diffraction. An intense beam of electrons penetrates a section of a suspected fiber, and if a diffraction spot pattern appears on the microscope screen, the substance is crystalline. The arrangement of the spots depends on the atom layers in the crystal and is, therefore, a sort of identifying fingerprint. Diffraction spots from the amphibole asbestos fibers form rows of uniformly spaced dots, while the distinctive 3 double dot diffraction pattern is an important way to identify chrysotile asbestos (Figure 3).

The elemental composition is determined by the x-ray energy dispersive analysis system (EDS) attached to the EM. The electron beam is focused on the fiber of interest, and x-rays are produced as a result of the interaction between the electrons and atoms on the surface of the fiber. A lithium drifted silicon (Si(Li)) crystal detector converts the x-rays into voltage pulses proportional to their x-ray energies. After accumulating x-rays for a preset period of time, the EDS unit displays the data graphically as spectra of peaks (Figure 4). Since atoms of different elements produce x-rays having different energies, the positions of the peaks show which elements are present in the fiber. The height of the peaks gives an indication as to the amount of each element present. Since all types of asbestos fibers have a basic silicon structure but differ in the amount of magnesium, iron, calcium, and sodium they contain, the EDS unit can differentiate among the types of asbestos present.

Identifying and counting the fibers on a significant portion of the sample grid requires between 1 and 4 hours. The number of fibers per liter present in the sample is determined by multiplying the average number of fibers per grid opening by a factor that contains the ratio of the area of the grid opening to the filter area and the sample volume used.

RESULTS

Of the over 70 drinking water samples collected all over the United States, only 4 had asbestos concentrations of over a million fibers per liter. The samples from Duluth, Minnesota, contained relatively high amounts of amphibole asbestos whereas those from San Francisco and North Troy, Vermont, contained chrysotile fibers only. The samples from the Tolt River system in Seattle contained about equal quantities of both types of fibers. Chrysotile fibers exceeded half a million per liter in samples from four other cities.

Untreated water from Lake Superior contained between 1 and 4.8 million amphibole fibers per liter, but the number dropped below detectable levels after the water was subjected to various filtering techniques.

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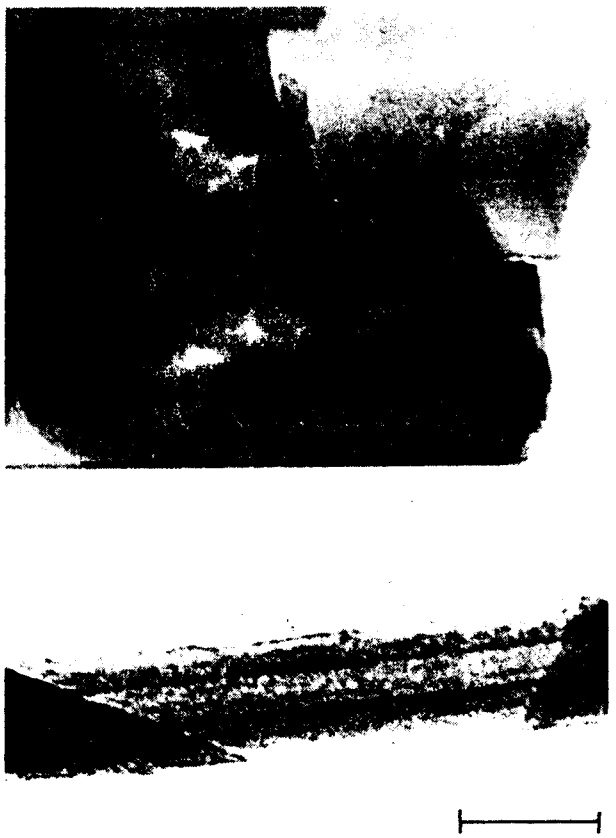


Figure 2. Electron micrographs showing the morphological differences between the amphibole (crocidolite) and the serpentine (chrysotile) types of asbestos. Bar represents 0.05 micrometer.

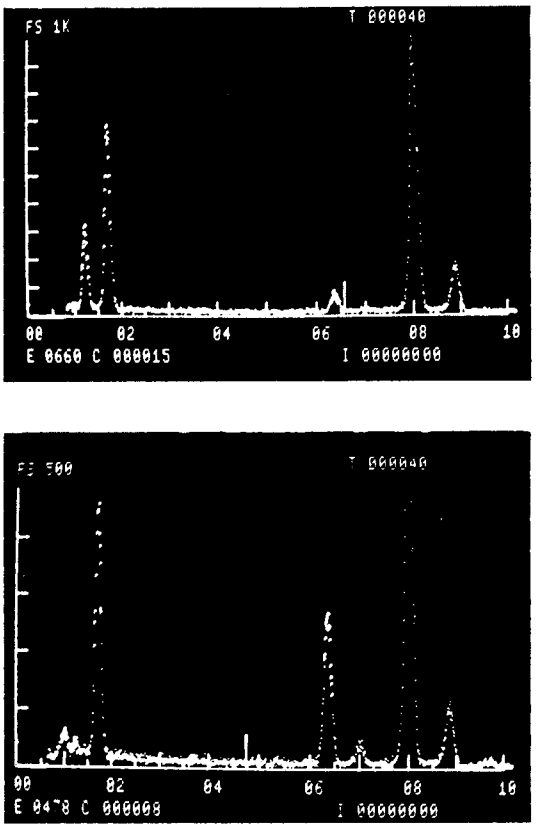


Figure 4. Energy dispersive x-ray spectra of anthophyllite (top) and crocidolite (bottom); the x-axis is in keV. From left to right, the peaks reflect the presence of sodium, magnesium, silicon, iron; the two copper peaks were produced by the supporting EM grid.

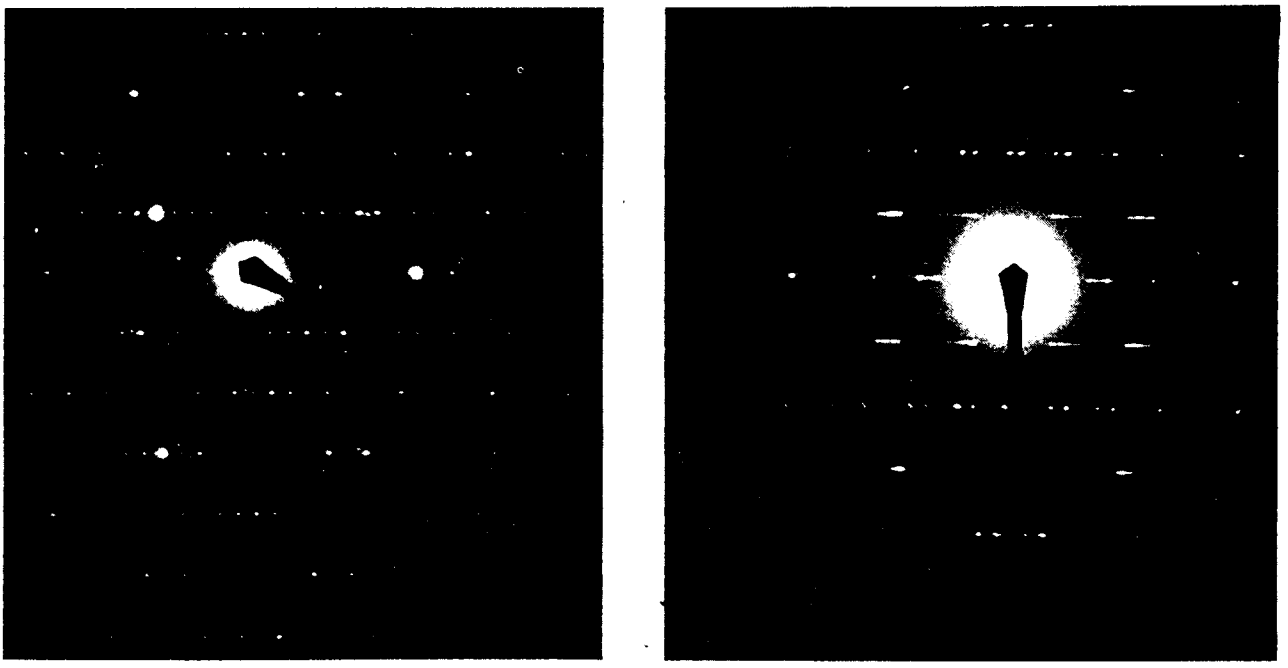


Figure 3. Selected area diffraction patterns of amosite (left) and chrysotile (right).

Erosion of asbestos fibers from the walls of asbestos-cement (A/C) pipe used in a water distribution system may be a source of asbestos in drinking water supplies. Investigations of this possibility involved a controlled experiment in which water of a known chemical quality was circulated through two 100-foot lengths of A/C pipe. During a 4-month period, the number of chrysotile fibers found in water taken from the 4-inch pipe ranged from 14 to 1,950 per liter and from 360 to 2,570 in samples obtained from the 6-inch pipe. Average counts were 475 and 1,350, respectively. The water being used was "mildly aggressive"; its pH was 7.5 and total hardness was 20 milligrams per liter.

In another phase of this project, samples have been collected from six systems in which water that has a low asbestos content flows for some distance through A/C pipe before use. Limited preliminary data indicate that only the two "more aggressive" waters (low in pH, hardness, and alkalinity) contain any significant numbers of fibers — Seattle, 0.4 to 1.5 $\times 10^6$ fibers per liter and Pensacola, Montclair system, 0.7 to 32.0 $\times 10^6$ fibers per liter.

SUMMARY

Although the health implications of asbestos fibers being present in drinking water are not known at this time, sufficient concern exists to warrant that the levels be investigated. The routine analysis of asbestos requires that an electron microscope be used because it can identify fibers by their morphology, crystal structure, and elemental composition. Analyses of samples collected all over the country indicate that a few city water supplies contain relatively high amounts of asbestos and that water having certain chemical characteristics may cause asbestos fibers to be released from A/C pipe into a water system.

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