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PLAINTIFF'S EXHIBIT
CT-273

FROM: Roman P. Korobij

SUBJECT: UNIVERSITY OF CALIFORNIA - KANAREK STUDY

"Asbestos in Drinking Water and Cancer Incidence" - University of California - EPA Study

This flare-up of the asbestos and health issue began when the EPA made a grant to Dr. Robert Cooper of the School of Public Health at the University of California. The purpose of this grant was to finance a study of the San Francisco Bay Area water supply to test the hypothesis that there is a positive association between the presence of chrysotile asbestos in drinking water supplies and cancer incidence in the human populations served by those water supplies. The San Francisco Bay Area was selected because it is known that there are varying degrees of asbestos content in the water supplies.

The study was conducted by Marty Stevens Kanarek and was the subject for his thesis for a doctorate degree from the University of California. In his thesis, Kanarek reported that statistically significant results were found for cancer of the peritoneum for both sexes, lung cancer for males and gall bladder and pancreatic cancers for females.

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Although Dr. Cooper had not issued his report, the thesis nonetheless was forwarded to EPA and at the direction of the EPA an abstract of the thesis was sent to utilities involved in the study. Shortly thereafter front page headlines in the San Francisco and Oakland newspapers proclaimed that the drinking of Bay Area potable water supply had been linked to cancer. Naturally, this tended to create a mini panic with lots of press and T.V. coverage paid to the news. However, public interest soon died down. The reason was in part due to the rational approach by the California State Public Health officials. The California Public Health Department issued a position that the University of California doctoral thesis contained no new or original evidence of a medical nature about cancer and asbestos. Nor did it establish any causatal link between asbestos in the Bay Area drinking water and the incidence of cancer. It simply requested that water utilities should develop plans to reduce the asbestos content in their water supplies and to adjust water quality if necessary so that there would be no pickup of asbestos from A/C pipe.

The EPA has issued several position papers on this study. The most significant part of their position papers is the statement that the results of this new study in California are not definite enough to justify extensive modifications in water supply treatment and distribution, but it would be prudent to operate water systems to minimize fiber counts. This would include optimal operation of filtration to remove fibers from raw water when present and actions to stabilize distributed water so that it does not erode the A/C pipe and then add fiber to drinking waters.

The industry's position on the Kanarek study is that although the data do support a statistical association, they are clearly inadequate even for speculation in establishing a cause and effect relationship. Determining causality involves a number of indispensable factors, none of which is considered in this study. For example, the multifactorial etiology of cancer is well known, particularly in relation to cancer of the lung, yet this factor is not adequately discussed in the Kanarek thesis. With respect to cancer of the gall bladder and pancreas, there is a complete absence of data indicating an increased risk to those cancers among those highly exposed occupationally in the past to asbestos, so any potential association in the general population would have to be examined more critically than is done in this study. In the case of cancer of the peritoneum, peritoneal involvement is a most common occurrence even though the primary site of the cancer may be another organ of the abdomen; therefore, it is critical that cancers of the peritoneum be studied to determine whether they are primary or secondary tumors, Again, the Kanarek thesis does not take this factor into account.

In summary, cancer causation is a highly complex process and the superficial biological observations of the Kanarek study do not support asbestos in drinking water as being causally related to the cancer incidence noted in the report.

NEWS RELEASE

Department of Health Services
714 P Street, Sacramento, CA. 95814

NUMBER: 52-78
FOR RELEASE: IMMEDIATE

DATE: 22 September 1978
CONTACT: Pete Weisser
(916) 445-1967

The UC doctoral thesis abstract (entitled: Asbestos in Drinking Water and Cancer Incidence) contains no new or original evidence of a medical nature about cancer or asbestos, nor does it establish any causal link between asbestos in Bay Area drinking water and the incidence of cancer.

It does suggest an apparent statistical correlation between water supplies high in naturally occuring asbestos and higher-than-expected cancer of some body sites, including the stomach.

The department agrees with the student's conclusion (recited on pages 155 and 156 of the complete thesis) that:

"The results of this study can only be judged as suggestive of needed further research into the question of the carcinogenic effects of asbestos fibers in drinking water.

"The study design was the indirect approach; census tracts were compared. Indirect epidemiological studies such as this one can only specify associations, and cannot pinpoint causation."

As the student also noted in his conclusion the sample was limited and potentially important variables such as cigarette smoking, alcohol consumption and other dietary factors were not included in his research.

Accordingly, it would be unscientific to conclude from the relatively narrow scope of research of this study that Bay Area water users need to change in any way their habitual and customary use and consumption of water.

However, the research path explored here merits further study.

(more)

The department plans to consult with the water utilities involved in the study and stands ready to perform further research and consultation with local health officers, the university, the Federal Environmental Protection Agency, and other agencies and individuals with an interest in safeguarding California water supplies.

We suggest that persons interested in the water aspects of this study contact the Sanitary Engineering Section of the State Department of Health Services at (415) 843-7900. Persons interested in the cancer epidemiological aspects of the study, which is now being reviewed by the Environmental Protection Agency, may contact Dr. Donald Austin, Chief of the Department's Resource for Cancer Epidemiology through the same telephone number in Berkeley.

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ASSIGNMENT EDITOR'S NOTE: The Department Health Services meeting with water utility representatives is scheduled for Tuesday at 10 am at the Department of Health Services offices at 2151 Berkeley Way in Berkeley. The meeting is scheduled for Room 123.

Water Quality Deterioration in the Distribution System

by

Earl F. McFarren, Ralph W. Buelow, Robert C. Thurnau,
Marvin Gardels, R. Kent Sorrell, Patricia Snyder and Ronald C. Dressman

For

Presentation at Water Quality Technology
Conference, Kansas City, Missouri
December 5th and 6th, 1977

Water Supply Research Division
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Water Quality Deterioration in the Distribution System

Introduction

Everyone in the water industry probably is aware that lead plumbing was used in ancient Rome and has read or heard speculations concerning the possible relationship between the use of lead pipe and the downfall of Rome. Because of the high toxicity of lead, other materials like copper and galvanized iron have largely replaced lead as distribution piping material during the last one hundred years. However, many older systems, like Boston, Massachusetts and Bennington, Vermont still contain lead service lines that were installed many years ago.

Not only metals, but also organic materials and particulates may be released from the distribution system when piping materials such as polyvinyl chloride, asbestos-cement, or coal tar lined pipes are used. These compounds also have health significance.

In the case of metal and asbestos-cement piping the release of substances from the piping materials is the result of corrosion, depending mostly upon the quality of the water. Important water quality parameters related to corrosion, are pH, alkalinity, hardness, temperature, dissolved oxygen and dissolved carbon dioxide. In the case of coal-tar-lined or plastic pipe, the quality of the water is of minor importance, and the concern becomes simply a matter of leaching of material from the pipe or lining by the water.

This report will attempt not only to present some data to illustrate the nature or extent of the problem encountered with each kind of pipe but will also discuss methods for the control and measurement of each parameter. Deterioration of water quality in metal pipes will be discussed first, followed by asbestos-cement pipe, then plastic pipe and finally coated pipes.

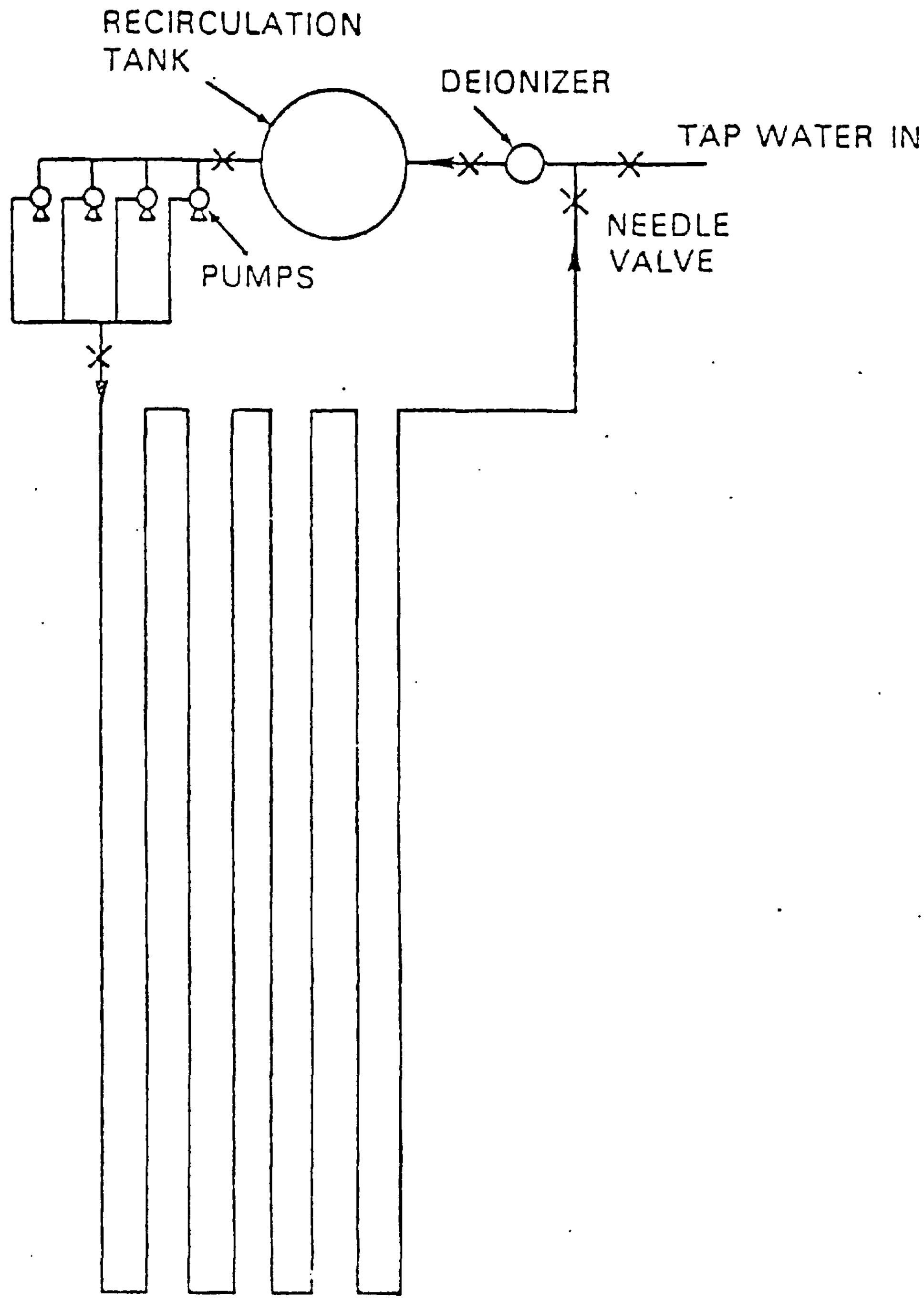
Galvanized Iron Pipe Loop

A galvanized iron pipe loop study was initiated because of a continuing question as to whether cadmium (an impurity) was leaching from the zinc coating of galvanized pipe and thereby getting into domestic water supplies. A pipe loop was fabricated from 1/2-inch pipe, and connected to a system of pumps and timers that simulated household usage (see Figure 1). Based on the analysis of the galvanized pipe coating, concentrations of 0.054 μg/ℓ of cadmium and 9.1 μg/ℓ of lead were calculated to be expected if the pipe was exposed to corrosive water. To check this conclusion and to simulate the worst possible condition, deionized water was circulated through 160 ft. of pipe at the rate of 200 gallons per day, with intermittent flow to simulate household usage, and only samples of the water that had been standing in the pipe overnight were collected for chemical analysis. After four weeks of operation, analysis of the data showed that the lead concentration in the water varied from 3.2 to 24.1 μg/ℓ and the cadmium from < 0.04 to 0.2 μg/ℓ. Zinc, as expected, was the only metal found in quantity; namely, 280 to 1400 μg/ℓ. From this experiment cadmium impurities in galvanized pipe was concluded not to be a problem, but that lead might be.

Lead in Distributed Water

Distribution studies conducted several years ago in Seattle[1] and Boston[2] illustrate the effect of corrosive water on tap-water quality.

FIGURE 1. SCHEMATIC OF GALVINIZED PIPE LOOP.



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Both Boston and Seattle use impounded surface water and provide chlorination as the only treatment. Seattle also fluoridates. The hardness and alkalinity of these waters are low, and the pH is on the acid side. In Seattle that part of the distribution system served by the Tolt River was sampled. Samples were collected from 31 points in the distribution system, primarily household taps. Two types of samples were collected early in the morning for comparison - a standing and a running sample. Standing samples were the first to run out of the faucet in the morning, representing water with a long residence time in the household plumbing and service line. Running samples were collected afterward, ensuring that the house lines were well flushed and represented water from the mains.

This same procedure was followed in Boston, and running and standing samples were collected at 54 households in the Beacon Hill area. The difference in metal pickup between these systems (see Table I) is most likely related to the type of plumbing material and service lines in use. In Boston a high percentage of homes sampled had lead service pipes; in Seattle copper and galvanized iron were more commonly used. No lead pipes were reported in Seattle and the source of the lead was assumed to be from the solder used to join the copper piping.[1] In light of the galvanized loop studies reported above, the source of the lead more probably was the galvanized pipe because all the houses but one had galvanized iron pipe plumbing, although a number (about half) did have copper service lines.

Recently, in a class action suit brought by a private individual against EPA, the distributed water of Bennington, Vermont also was shown to contain high levels of lead (See Table II). In this

Table I. Boston and Seattle

Water Quality Parameters

Parameter	Boston	Seattle
pH	6.7	5.5
Hardness - mg/ℓ	14.0	6.0
Alkalinity - mg/ℓ	8	2
Chlorides - mg/ℓ	12	2.1
Sulfates - mg/ℓ	10*	2
Lead** - running - mg/ℓ	0.241	0.022
standing - mg/ℓ	0.321	0.170

* 0.008 correction for lead determination required
** maximum values

case, the interior results indicate the first water collected from the household plumbing in the morning, the service results represent the water sample collected after allowing the water to run until it became cool, and the main results are the water samples collected after allowing the water to run for an additional one or two minutes.

A lead pipe loop has also been constructed by the Water Supply Research Division. Our experimental apparatus consists of 100 ft of 3/4 inch diameter lead pipe, a 350 gallon reservoir and a series of pumps and timers. The reservoir allows the chemistry of the water entering the loop to be closely controlled and permits several days operation from a single batch of water. In this case, the water from the loop goes to waste rather than returning to the reservoir. The pumps and timers simulate daily usage with 100 gallons being selected as the daily volume. The first series of tests were designed to simulate the effect of Boston

Table II. Lead* in Bennington, Vt. Water Samples

Residence	Water from Interior plumbing	Water from Service Line	Water from Street Main
A	.165	.440	.096
B	.112	.096	.047
C	.155	.180	.110
C	.124	.144	.056
E	.165	.540	.072
F	.145	.448	.200
G	.150	.132	.450
H	.185	.860	.156
I	.328	.600	.592
J	.165	.460	.145

Raw Water - pH 5.5, alkalinity 1.0, sodium 0.7, lead < .005
* all values in mg/l.

water upon new lead pipe and to observe the effect of increasing the pH (A possible control procedure) of the water upon the lead concentration. A simulated Boston water was achieved by mixing Cincinnati tap water with deionized water in a ratio of 1 to 10, the pH being adjusted with sodium hydroxide.

The lead data that are reported (Table III) were obtained by analysis of water that had resided in the pipe overnight and is assumed to be the worst condition. Adjustment of the pH was not expected to significantly lower the lead values and the data shows that adjustment of the pH did not (see Table III). At present, it is not understood why the pH of the water in the pipe (see Table III) increased. The next test will be to observe

Table III. Lead Concentration as a Function of pH

Test No.	Number of Days	pH Intended	pH Reservoir	pH Loop	Avg. Lead Conc., mg/ℓ	Langelier Index Reservoir	Langelier Index Pipe
1	8	7.5	7.6	9.61	0.167	-2.11	-0.16
2	9	8.5	7.9	9.24	0.169	-1.89	-0.49
3	6	9.5	9.1	9.60	0.187	+ 0.54	-0.13

Alkalinity 10.2 to 11.3
Hardness 18.1 to 21.4

the effect of the addition of sodium bicarbonate to increase the alkalinity upon the lead levels. The Church and Dwight Co., Inc.[3] suggest that with such treatment the lead levels can be reduced to as low as 0.016 mg/ℓ. The Virginia Chemical Co. also suggests that the addition of zinc ortho phosphate[4] with the pH controlled to between 7.0 to 7.3 should be effective. Supposedly the zinc phosphate (which has a lower solubility than either calcium or zinc carbonate) causes a film to be formed on the pipe which protects the pipe and prevents corrosion. This possibility will be investigated later.

In analysis of the samples for lead, the so-called "flameless atomic adsorption spectrophotometric" or graphite furnace technique was used. With this technique, however, caution does need to be observed because sulfate[5] in the water sample will suppress the signal and produce erroneous results. One can either add lanthanum to the sample and standards to overcome this effect or measure the concentration of sulfate in the water and apply a correction to the lead results. The Boston lead values cited above have been corrected in the latter manner by adding a factor of 0.008 mg/ℓ to the lead results to compensate for the presence of 10 mg per liter of sulfate.

Asbestos Cement Pipe

The AWWA Standard C400-77 establishes criteria for determining the quality of water that can be transported through A/C pipe without any adverse effects. These criteria are:

(a) Use either Type I or Type II pipe where pH + log (AH) ≥ 12

(b) Use Type II where pH + log(AH) ≥ 10

Where:

Type II A/C pipe is autoclaved and Type I (no longer manufactured in this country) is not.

pH = index of acidity or alkalinity of the water in standard pH units

A = the total alkalinity in mg/ℓ as $CaCO_3$

H = the calcium hardness in mg/ℓ as $CaCO_3$.

Because (according to the above) pH, alkalinity and calcium hardness of the water are the main factors that determine whether water is aggressive or corrosive to A/C pipe, a range of water qualities from the aggressive to the non-aggressive were selected for field evaluation. Six public water supply systems that used A/C pipe and whose water had combinations of pH, alkalinity, and calcium hardness to produce aggressive indices (A.I. from the equation above) ranging from 5.34 to 12.85 were finally selected for a year long study. Water samples were collected by the local water utility or water supply regulator personnel on the average of at least once every two months. The samples were collected in 1 qt (946 mℓ) cubitainers and shipped to EPA Water Supply Research Laboratory, Cincinnati, Ohio for analyses. To determine the possible release

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of asbestos fibers from the pipe walls, samples of water as it entered

. . . .

microscope. Samples for asbestos analysis were preserved with mercuric chloride, while other samples collected at the same time and place for pH, alkalinity and calcium hardnes were non-preserved. Table V lists the six systems studied, their water quality characteristics and their asbestos fiber counts. As can be seen, consistently quantifiable fiber counts were found only in the two systems with very aggressive waters.

Table V. Water Quality Parameters

Name of System	pH	Alkalinity mg/ℓ $CaCO_3$	Calcium Hardness mg/ℓ $CaCO_3$	Aggressiveness Index (A.I.)*	Avg. Chrysotile Fiber Count Fibers/liter
Pensacola, Fla.	5.2	1.0	1.4	5.34	5.52×10^6
King County Water Dist. No. 58 Seattle, Wash.	7.2	14	14.5	9.51	0.66×10^6
Grant Hill Assoc., Bloomfield, Conn.	7.5	88	82	11.56	NSS
Clark County Utilities, Northridge, OH	7.8	220	250	12.54	BDL
Lockhart, Texas	9.4	50	44	12.74	BDL
Cleburne, Texas	9.7	36	39	12.85	BDL

*As water entered pipe

NSS - not statistically significant[7]
BDL - Below the Detection Limit[7]

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For asbestos analysis, from 100 to 500 mℓ (depending upon the amount of other debris present) of a well mixed sample was filtered with suction through a 0.45 um pore diameter millipore filter. The filter was removed, dried in an oven at 45°C for 2 hours, a 3 mm circle cut out of the filter and placed upside down on a carbon-coated (200 mesh) copper grid. The grid is then placed on the coldfinger of a side arm condenser washer that has been charged with acetone. The acetone is then refluxed for four hours to dissolve away the filter and leave the residue deposited on the carbon-coated grid. The grid was then placed in a transmission electron microscope mounted in a special carbon specimen holder and viewed at 17,000 X. At least 10 grid holes on each of two grids were viewed. Every time a fiber was found, an electron diffraction pattern was attempted. A fiber was then counted, provided a diffraction pattern was obtained which was characteristic of either chrysotile or one of the amphiboles. If any doubt existed concerning the identity of a fiber an energy dispersive xray spectrum was also obtained. The microscopist used a tally sheet to note the number of fibers found in each grid hole and to note the size of each. When 20 grid holes had been counted, an average of the number of fibers found per hole was calculated, and this used to calculate the number of fibers per liter of sample. This procedure is the same as that presented at an earlier meeting of this association in Dallas and is published in the proceedings of that meeting.[7] It is also, for all practical purposes, identical to an "Interim Method for Asbestos Analysis" recently adopted by EPA.[8]

Although not indicated in Table V, the pH, alkalinity, and calcium hardness increased as the water passed through the pipe, presumably as a result of the water reacting with the cement in the pipe, and thus causing the water to become less aggressive to the pipe.

This is evident also from SEM (scanning electron micrographs) of an inside section of unused a/c pipe (Figure 2A) and a piece of the interior surface (Figure 2B) of the pipe from the King County Water District. As can be seen in Figure 2B, the interior surface of the pipe is significantly changed.

Although no known or proven methods for controlling corrosion of A/C pipe exist, the above observations would indicate that simply adjusting the pH upward and adding calcium might solve the problem. This seems, however, too obvious and some people might object to an increase in the hardness of their water. Currently, two other procedures that have proven successful with cast iron pipe are being tested. The Water Supply Research Division has a reserach a grant with Greenwood, South Carolina to try pH adjustment and coating of the pipe with zinc ortho phosphate[4] and also has a research contract with the Corner Water Company in Shippenville, Pennsylvania for rehabilitation of their badly deteriorated asbestos-cement pipe by cleaning of the pipe and then coating it in place by using controlled calcite-cement deposition (McCauley Process).[9,10]

Polyvinyl Chloride Pipe Studies

Polyvinyl chloride (PVC) pipe has been in use to varying degrees in some water distribution systems in the United States for the past 18 years. Recently, however, concern has been raised that unpolymerized vinyl chloride remaining in the pipe could migrate into the water flowing through it. To investigate this theory existing methodology[11] for vinyl chloride was improved[12] to permit the detection and measurement of vinyl chloride at very low concentrations in water, and five water systems that used PVC pipe were studied. In a paper submitted to the Journal of the American Water Works Association in May 1976 concentrations between 0.03 and 1.4 μg of vinyl chloride per liter of water were reported[13] in the distributed water, although none was found in the source. The lesser concentration was found to persist in a system containing pipe that was nine years old and the higher concentration was found in the newest system (pipe about 1 year old). These levels are well below those that have been associated with adverse effects in experimental animals, and should decline as lower residual monomer pipe (the only known means of control) is put into use.

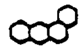
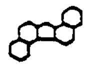
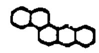
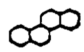
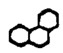
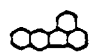
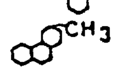
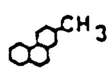
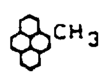
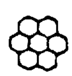
To achieve greater sensitivity than can be provided by purging a 5 mℓ sample,[11] a modification was developed to enable the contents of a 40 mℓ bottle to be purged onto a silica gel trap.[12] The vinyl chloride is then desorbed onto a column composed of one third Chromosorb 101, and two-thirds Chromosorb 102, rather than all Chromosorb 101 in order to resolve vinyl chloride and cyanogen chloride, an interference in some samples. The gas chromatograph is initially set at 50°C, but is programmed to rise by 10°C per minute to 160°C. Nitrogen carrier gas flow was 80 mℓ per min. and desorb (inlet) temperature was 150°C. Detection was achieved by using the halogen specific microcoulometric detector, and the limit of detection was 0.1 μg/ℓ.

Asphalt Coated Pipes

To prevent corrosion of cast iron or steel pipes and to aid in the curing of cement lined pipes, the innerside of such pipes may be lined with asphalt or coal-tar coatings. Depending upon conditions, temperature, thickness and age, during the production of these coatings, polynuclear aromatic hydrocarbons (PAH's) may be released. The solubility of most PAH's in water is relatively low; however, a number of representatives of the PAH's are known carcinogens and the World Health Organization has recommended a limit of 200 ng/ℓ for the total of six representative P.A.H.'s (a value well below their solubility). Table VI lists some of the PAH's that have been found in water,[14] and indicates their relative carcinogenicity.

TABLE VI

SOME PAH'S FOUND IN WATER

NAME	STRUCTURE	CARCINOGENICITY
BENZO (a) ANTHRACENE		•
BENZO (b) FLUORANTHENE		••
BENZO (j) FLUORANTHENE		••
BENZO (a) PYRENE		•••
BENZO (e) PYRENE		•
CHRYSENE		•
INDENO (1,2,3 cd) PYRENE		•
ANTHRACENE		?
PENANTHRENE		?
BENZO (k) FLUORANTHENE		–
BENZO (ghi) PERYLENE		–
FLUORANTHENE		–
PERYLENE		–
PYRENE		–
1–METHYL PHENANTHRENE		?
2–METHYL PHENANTHRENE		?
1–METHYL PYRENE		?
CORONENE		?

••• STRONG
•• MODERATE
• WEAK
– INACTIVE
? UNKNOWN

A high pressure liquid chromatographic procedure (HPLC) for the determination of PAH's[15, 16, 17] in distributed water is presently under development. Because the details of this procedure will be discussed at another session of this meeting, (see paper by Sorrell, K., McFarren, E.F., and Dressman, R., High Pressure Liquid Chromatography for Measurement of Polynuclear Aromatic Hydrocarbons in Distributed Waters, in the proceedings of the meeting), they will not be discussed here.

The next step will be to select various cities around the United States where there are asphalt lined pipes in place, and attempt to determine whether during passage of water through the system any increase in PAH content occurs. If any PAH's are found, an attempt will be made to correlate the PAH content of the water to the age and length of pipe, and the type of coating (bituminous or petroleum base), etc.

No methods for the control or for the prevention of PAH's getting into the water are known or have been investigated.

Summary

An attempt has been made to identify the problems that may be encountered when different kinds of pipe (galvanized, lead, poly vinyl chloride, asbestos-cement, and asphalt coated) are used to distribute waters of various quality. The methods of analysis developed to identify these problems as well as ideas for controlling or preventing the deterioration of the water quality during distribution are discussed.

EXPOSURE TO ASBESTOS FIBERS IN WATER DISTRIBUTION SYSTEMS

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Pre-Publication Copy

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American Water Works Association
Anaheim, California
May 8 - 13, 1977

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Serious health hazards can exist if asbestos fibers are inhaled. Asbestos-related lung cancer, mesothelioma, and fibrotic pulmonary disease have been documented in occupationally exposed populations (1-4). Ingesting such material may also be dangerous, as indicated by increased rates of gastrointestinal cancer among some asbestos worker groups (5,6,7). Animal studies in which asbestos fibers have been injected or implanted (8,9,10) indicate that the fibers may penetrate the mucosa of the stomach and intestine. Although there is no proof that drinking water containing asbestos will cause cancer, the long term health effects of ingesting asbestos fibers are uncertain.

Several surveys of domestic water supplies have noted the presence of asbestos fibers in drinking water (11,12,13). Contamination of surface water occurs because of industrial activity or from the erosion and weathering of fiber bearing rocks. Asbestos fibers can also be found in wells where the ground water originates in serpentine rock. Asbestos-cement pipe used as water mains may also contribute fibers to the drinking water if the asbestos is leached from the interior walls of the pipe. Samples collected from 64 water systems in the U.S. prior to distribution through water mains showed 29 of the systems with asbestos fiber concentrations above 50,000 fibers per liter. Systems in San Francisco, Seattle and Duluth had concentrations over 1 million fibers per liter (14). The chrysotile fibers found in the surface water sources used by Seattle and San Francisco were attributed to erosion of asbestos-bearing rock in the water shed. Duluth also uses surface water, Lake Superior, and the source of amphibole asbestiform fibers here has been related to industrial contamination. Considerable amounts of asbestos-cement pipe convey potable water in North America, Europe and other parts of the world. According to a recent survey by the Asbestos-Cement Pipe Industry, of U. S. cities with a population of 1,000 or more, 38% (65 million people) specify, purchase or have in service A/C pipe. Over 200,000 miles of

A/C pipe are now in use in the U.S. (15). Chrysotile comprises 80% or more of the asbestos used in asbestos-cement pipe manufactured in the U.S. (16). These facts have raised a question with respect to the possible health hazard that may be associated with drinking water which has flowed through this type of pipe.

In 1974, a committee on asbestos in water chaired by George M. Wright, M.D. prepared a report for the American Water Works Association (16) which summarized the information available on asbestos in water from A/C pipe and recommended several study areas where research was needed to answer the health questions raised by the use of such pipe. Included in the research suggestions were:

a. the need for data on fiber quantities and sizes as found in A/C pipe water systems.

b. the need to conduct epidemiology studies of human population groups exposed to asbestos-cement distribution systems.

An investigation of the use of asbestos-cement pipe for public water supplies and the incidence of gastrointestinal cancer in Connecticut was initiated in 1974 by the Health Effects Research Laboratory (HERL) in response to these needs. A multidisciplinary team of water supply officials, public health engineers, epidemiologists, scientists, and statisticians from HERL, The Connecticut Tumor Registry, and the Center for Disease Control collaborated in the design, field work, and analysis of data in this study. This report is primarily to define the methodology used to determine the extent of exposure of Connecticut's population to A/C pipe and to serve as a progress report of the initial findings of the epidemiologic study which will be described in detail elsewhere (17). Selected water samples collected in conjunction with this study were analyzed by electron microscopy techniques (18). These provided some data as to fiber quantities and sizes as found in a number of different water distribution systems containing A/C pipe. The size of asbestos fibers leached from the interior of asbestos-cement pipe may differ from those found in source waters.

The State of Connecticut was chosen as the site of the study because of the reliable cancer incidence data over a 38 year period available through the Connecticut Tumor Registry. Registration of cases during life now exceeds 98% and histological confirmation approaches 100% (19). Preliminary surveys of the use of A/C pipe in Connecticut showed that some A/C pipe had been in use for a number of years but that a major effort would have to be undertaken to document this usage by town so it would be compatible with the tumor registry data which is recorded by township.

The Connecticut Study

Public water supplies, available in 148 of Connecticut's 169 towns, provided water to 82% of the state's population in 1975. The total population served by public water supplies in each town varied from 10% or less in 36 towns to 95% or more in 30 towns. Because asbestos-cement pipe is unlikely to be used in individual water systems, only public water supplies were included in this study.

A list of public water supplies using asbestos-cement pipe was compiled after surveying each public water supply and cross referencing the data with information available from the Public Utilities Commission and the Water Supplies Section, State Department of Health. Public water supplies are not developed according to town boundaries. Some towns are served by several different water supplies and a single water supply may serve areas in several towns. Because the Tumor Registry collects data on a town basis, it was necessary to compile the asbestos-cement pipe data in a similar manner. Each public water supply using asbestos-cement pipe was then contacted in order to document the location of the pipe and collect the following data felt to be of epidemiologic importance: (a) date(s) of installation of the asbestos-cement pipe, (b) length of asbestos-cement pipe compared to other types of pipe, and (c) population served by asbestos-cement pipe compared to other types of pipe. The data were then grouped by town.

Asbestos-cement pipe is used totally or partially by 149 public water supplies in 82 towns. Approximately 576,800 people in Connecticut received water which has passed through asbestos-cement pipe. This compares to a total population of 1,724,000 for the 82 towns in which 1,488,500 people are served by public water supplies. In assessing the exposure to asbestos fibers from the pipe, several factors were considered.

Factor: Age of Pipe

Some public water supplies reported asbestos-cement pipe that was 45 years old in 1975; some reported newly installed pipe less than 5 years old. The majority (66%) of the population receiving water through asbestos-cement pipe used pipe at least 25 years old in 1975. The majority of the towns had asbestos-cement pipe that was at least 25 years old in 1975: (a) 34% had asbestos-cement pipe 30 years old or greater, (b) 16%; 25-29 years old, (c) 16%; 20-24 years old, (d) 22%; 15-19 years old and (e) 12%; less than 15 years old. In a few instances asbestos-cement pipe had been used for a period of time but replaced in recent years. These were included as asbestos-cement pipe systems only for their period of usage.

Factor: Length of Pipe

Approximately 900 miles (1450 KM) of asbestos-cement pipe were found to be in use in Connecticut. The majority of the towns had at least 3 miles (4.8 KM) of A/C pipe in their distribution lines: 28% had between 10 (16 KM) and 101 (160 KM) miles of A/C pipe, (b) 46% had between 1 (1.6 KM) and 10 (16 KM) miles, and (c) the remaining 26% had less than 1 mile (1.6 KM) A/C pipe.

Factor: Population Served by A/C Pipe

The percentage of the town population that received water which had flowed through A/C pipe was determined after investigating the distribution systems of each of the 149 water utilities. If the utility had a section of A/C pipe at the beginning of the distribution line, the entire population served by that utility was considered as being served by A/C pipe. In towns served by more than one utility the populations served by A/C pipe in each utility were added. Where a utility served two towns, the distribution system was divided according to town boundaries.

Factor: Aggressiveness of Transported Water

The quality of the water transported by the pipe is known to be a critical parameter in the release of fibers from the pipe. In 1973 Webster (20) presented pictures of the A/C pipe which had been carrying brine (water with a high saturation index) for a number of years. The pictures showed a well marked deposition of calcium salts lining the inside of the pipe which would protect the pipe from corrosion. He also presented pictures of the A/C pipe that had been subjected to acid conditions while carrying sewage. These had very rough inner surfaces which presumably could release fibers through erosion.

The corrosive effects of certain waters on A/C pipe have been studied closely by the Asbestos Cement Pipe Industry and a definition of aggressive water derived from the Langlier Index is given in the AWWA Standards C400-75 for A/C transmission and pressure pipe (21). The aggressiveness of water transported through a pipe, within the temperature range of 40-80°F, is determined by the formula:

$$\text{aggressiveness index (A.I.)} = \text{pH} + \log (A \times H)$$

where: pH = index of acidity or alkalinity of the water in standard pH units

A = total alkalinity in mg/l as $CaCO_3$

H = calcium hardness in mg/l as $CaCO_3$

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Higher values of this aggressiveness index are less corrosive than lower values. Waters with an A.I. less than 10 are considered very aggressive while A.I.'s greater than 12 are considered essentially non-aggressive. The criteria established by AWWA Standard C400-75 are:

(a) use either Type I (not autoclaved) or Type II (autoclaved) pipe where A.I. > 12.0

(b) use Type II where A.I. > 10.0

The correllation between fiber release and water aggressiveness has been confirmed by studies recently completed by the EPA (Municipal Environmental Research Laboratory) on asbestos-cement pipe distribution systems in the field (22). These investigations showed that fibers were present in water sampled over a year period from two systems which had source A.I.'s under 10.0, but few, if any, fibers could be found in water samples from 3 systems with source A.I. > 12.0. In the 1974 AWWA Asbestos in Water Committee Report (16), analyses of two similar A/C pipe distribution systems were reported in terms of asbestos fiber mass/unit volume of water. The data showed that a greater amount of asbestos (0.28 μg/l) was found to be coming from the pipe in the Malvern system which had a source A.I. of 11.2 than from the A/C pipe in the Glendale system with a source A.I. of 11.8. Glendale A/C pipe was found to have contributed 0.015 μg/l.

Water samples were collected from each public water supply in Connecticut with asbestos-cement pipe, analyzed for the appropriate chemical parameters, and an A.I. was calculated for each supply. A population weighted A.I. was calculated for each town according to the number of public water supplies with asbestos-cement pipe in the town. The majority of towns had an aggressiveness index under 9.8: (a) 56% had A.I.'s under 10.0, (b) 43% had A.I.'s between 10.0 and 12.0, (c) 1 town (1%) had an A.I. above 12.0.

FACTORS COMBINED FOR ASSESSMENT OF EXPOSURE:

While current exposure to asbestos fibers leached from A/C pipe could best be described by direct measurement of the fibers in the distribution system, this might not provide an accurate assessment of exposure to fibers over the entire time the pipe was used. An assessment of exposure value or risk factor was developed from the factors described in the preceeding paragraphs which were felt to be of epidemiologic importance and important in the release of fibers from the interior of the A/C pipe. To prevent a possible bias in data analysis, the assessment of exposure (AOE) values were developed independently of the tumor registry data. None of those calculating the AOE's had knowledge of cancer incidence by town within Connecticut and thus were not influenced in the selection of parameters used to calculate the exposure to asbestos-cement pipe in each town.

A list of towns was prepared according to the percent of population served by public water supplies and towns were subdivided into those with and those without asbestos-cement pipe. The towns were further subdivided according to urban and non-urban criteria, an urban town being defined as having an estimated 1975 population of > 2500 and > 50% of the town's population served by public water supplies. The towns were than ranked according to the following parameters to show a relative risk of exposure to asbestos from asbestos-cement pipe.

(1) maximum age of asbestos-cement pipe

(2) population-weighted A.I.

(3) Assessment of Exposure (AOE) as defined by:

$$AOE = (L) \times (P) \times (\frac{Z}{25}) \times \text{A.I. Factor}$$

where: L = length of asbestos-cement pipe in miles
P = population served by asbestos-cement pipe
Z = age of pipe in years
A.I. Factor: use 1.0 if A.I. = ≥12.0; 1.3 if A.I. = 11.1-12.0; 1.6 if A.I. = 10.1-11.0; 2.0 if A.I. = ≥10.0.

(4) Risk Factor (RF) as defined by RF = AOE/(P)

The AOE and RF were developed to combine epidemiologically important parameters and factors influencing the release of fibers from pipes. Since risk was felt to be independent of the population using asbestos-cement pipe, the RF was calculated omitting this parameter. However, rank correlations calculated for towns ranked by AOE and RF showed the town ranks to be similar (Spearman .88*, $p<.0001$; Kendall .713, $p<.0001$) and only the AOE was used in further analysis. Since age of pipe and corrosiveness of water (A.I.) were felt to be most important in assessing total fiber release from pipes, these parameters were to be analyzed separately with Tumor Registry Data.

To determine current exposure to asbestos in drinking water and confirm the importance of the aggressiveness index and the other factors used to establish the relative exposure to asbestos by the towns, a study of asbestos in source water and tapwater samples from each township has been undertaken using electron microscopy techniques (13,18). Electron diffraction and energy dispersive x-ray analysis are being used to classify fibers as chrysotile, amphibole, or nonasbestos. Information on the length, diameter, and age of A/C pipe between the source and sampling point and the aggressiveness indexes of the water at both sites are also being recorded.

To evaluate if populations not served by asbestos-cement pipe were exposed to naturally occurring asbestos in water sources, thirty-one samples were collected at water sources prior to entering the distribution system.

Sampling sites were selected based on the type of water source, size of system and geographic location. All major water supplies were sampled including the Metropolitan District Commission, New Haven Water Company, and Bridgeport Hydraulic Company. All samples except three were either below detectable limits, which means no chrysotile or amphibole asbestos fibers were found, or not statistically significantly, which means that less than five asbestos fibers were found in the portion of the sample examined. The three source water samples containing asbestos were:

(1) A drilled rock well serving 100 customers contained 100,000 chrysotile fibers per liter.

(2) A surface water source serving 3,000 customers contained 500,000 chrysotile fibers per liter. Resampling is now in progress.

(3) A gravel well was found to contain 300,000 chrysotile fibers per liter but this could not be confirmed upon resampling.

RESULTS

Based on these sampling results it was concluded that the population served by public water systems not using asbestos-cement pipe were not exposed to significant amounts of naturally occurring asbestos in water.

Thus far, 19 water samples have been analyzed from the distribution system after water had passed through various lengths of asbestos-cement pipe. Chrysotile fiber counts ranged from below detectable limits (10,000 fibers/liter) to 700,000 fibers per liter. Some amphiboles were detected; concentrations were below 50,000 F/ℓ.

Seven of the samples had chrysotile fiber counts over 100,000 fibers per liter. In general, the fiber counts were low when compared to counts reported for water in some other situations. In Duluth where the source of amphibole fibers in the water is considered to be related to mineral processing operations, fiber counts as high as 600 million fibers per liter have been found (23). Two hundred million chrysotile fibers per liter were found in water from a lake in Marin County, California which receives runoff from areas of serpentine rock (24). In some non-Connecticut asbestos-cement pipe systems which transport highly aggressive water, chrysotile fiber counts as high as 32 million fibers per liter have been found (22).

In the Connecticut samples where chrysotile fibers were found, their lengths ranged from 0.2 to 60 µm with widths from 0.02 - 0.5 µm. Aspect ratios (length/width) ranged from 3 to 2000. Figure 1 presents a comparison between the fiber lengths found in the Conn. A/C pipe distribution systems and fibers found in a sample from a San Francisco Reservoir in California which has a natural source of chrysotile fiber from surrounding rock formations. It is apparent that the pipe distribution samples have a higher percentage of fibers over 1 μm in length than does the sample with a natural source of fibers. The median value of the San Francisco fiber length range was 0.7 um while the median value of the fiber length range from the Conn. A/C pipe distribution samples was 2.0 um. The data is also compared with amphibole fiber lengths as found in Duluth, Minnesota tap water 1975 (23).

The age adjusted sex specific incidence data for stomach, colon, and rectum cancer for Connecticut townships for the period 1935 to 1973 was used to investigate whether asbestos cement pipe usage in public water systems could be associated with gastrointestinal cancer. Observed versus expected ratios for the occurrence of each cancer, by sex, time period, and estimated exposure to asbestos cement pipe were calculated within each of three categories of population density. In addition, townships within each of the three categories of population density were ranked for age-adjusted rates of each cancer site, by sex and time period and compared to townships ranked for exposure to asbestos-cement pipe. These correlations revealed no obvious trends or patterns of association with the use of asbestos-cement pipe (17).

These negative findings seem to indicate that the use of A/C pipe has probably not been responsible for excess gastrointestinal cancers, but there are inherent uncertainities associated with epidemiologic studies of this type. Prior migration, occupational history, and personal habits regarding other asbestos exposure and smoking could not be obtained in this type of study. Because the study area was selected to take advantage of reliable cancer data available in the long standing State Tumor Registry, another limitation which could not be avoided was the small population served by A/C pipe. An additional factor which may be important is the relatively low dose asbestos exposure found after sampling a limited number of water systems using A/C pipe.

It seems justified, however, to report these initial, negative findings to allay fears that a large, obvious epidemic of gastrointestinal cancer attributable to the use of A/C pipe has been overlooked. It is accurate to state that if asbestos in water has influenced gastrointestinal cancer rates in Connecticut, the effects are not obvious (17).

Additional studies are now in progress to provide more substantial data on fibers in Connecticut water supplies. When the present work is completed, all 82 towns identified as using asbestos-cement pipes will have been sampled. Supplies in thirty towns not using

A/C pipe will also have been sampled. All the major sources in each town are to be analyzed for natural asbestos content. Analysis of data from at least 82 pairs of samples, before A/C pipe and from the distribution system after a known length of A/C pipe, will be compared with aggressiveness index changes of the water in the system.

It is possible that a re-evaluation of our exposure assessment will be necessary if fiber counts do not confirm the Assessment of Exposure equation as a reliable predictor of fiber exposure. Closed loop studies and field sampling are currently underway to determine if one of the three parameters used to determine the aggressiveness index (A.I.) is more important than the others. Data on corrosion control practices, such as, the addition of polyphosphates is being collected to determine their influence on preventing fibers from being released from the pipe. A situation in which iron in the water can apparently coat the interior of the pipe preventing fiber release is also being investigated. Further studies will be conducted investigating the relationship between incidence of gastrointestinal cancer and the following: 1) current asbestos counts, 2) town aggressiveness indexes, 3) age of pipe data, 4) revised AOE calculations, if indicated by the current sampling program.

An investigation of pleural and peritoneal mesothelioma using data from the Connecticut Tumor Registry is currently being conducted in conjunction with the Connecticut Cancer Epidemiology Program, Yale University School of Medicine. If sufficient numbers of cases of peritoneal mesothelioma are found which are not associated with occupational exposure, a case-control study will be conducted to determine if these are related to drinking water that has passed through asbestos-cement pipe.

The Health Effects Research Laboratory is currently sponsoring another epidemiologic study in an area of California where chrysotile asbestos occurs in the source water. This study will look at cancer incidence in counties which maintain tumor registries. Although the fiber concentrations and sizes may be somewhat different than those found in the Connecticut A/C pipe systems, the California study will provide additional data as to the health effects of ingested asbestos. Further information will also be provided by the results of a large scale animal feeding study supported by the Food and Drug Administration, EPA, and the National Institute of Environmental Health. Results of this study will not be available for several years.

SUMMARY

A study of the asbestos-cement pipe distribution systems in Connecticut water supplies was performed as background for an epidemiology investigation designed to determine whether there were differences in cancer experience between population groups exposed to asbestos-cement pipe distribution systems and those exposed to distribution systems of other materials.

Connecticut townships were ranked according to the population served by A/C pipe, the age and length of the pipe, and the aggressiveness of the water transported. Towns studied contained from less than 1 to over 100 miles of A/C pipe. The majority had A/C pipe that was at least 25 years old and most had water which would be considered aggressive based on the chemical parameters of pH, alkalinity, and calcium hardness.

The preliminary findings of the epidemiology study did not show any excess in cancer incidence for stomach, colon, or rectum in Connecticut townships during 1935-1973 that could be related to the use of asbestos-cement pipe for drinking water.

Since the safety of asbestos in drinking water cannot be proven or disproven at this time, current public health recommendations about the use of A/C pipe for potable water systems should be based primarily on the aggressiveness of the water. Closed pipeloop studies and field sampling currently in progress are expected to provide data on which water quality parameters have the most affect on the release of fibers from the interior of A/C pipe.

On the basis of the analytical results from thirty-one samples collected at the water sources prior to entering the distribution system, it was concluded that the population served by public water systems not using asbestos-cement pipe were not exposed to significant amounts of naturally occurring asbestos in water. Chrysotile fiber counts from 19 samples collected after water had passed through various lengths of asbestos-cement pipe ranged from below detectable limits (10,000 fibers/liter) to 700,000 fibers per liter. The lengths of the chrysotile fibers found ranged from 0.2 to 60 micrometers in length; 0.02 to 0.5 micrometers in width.

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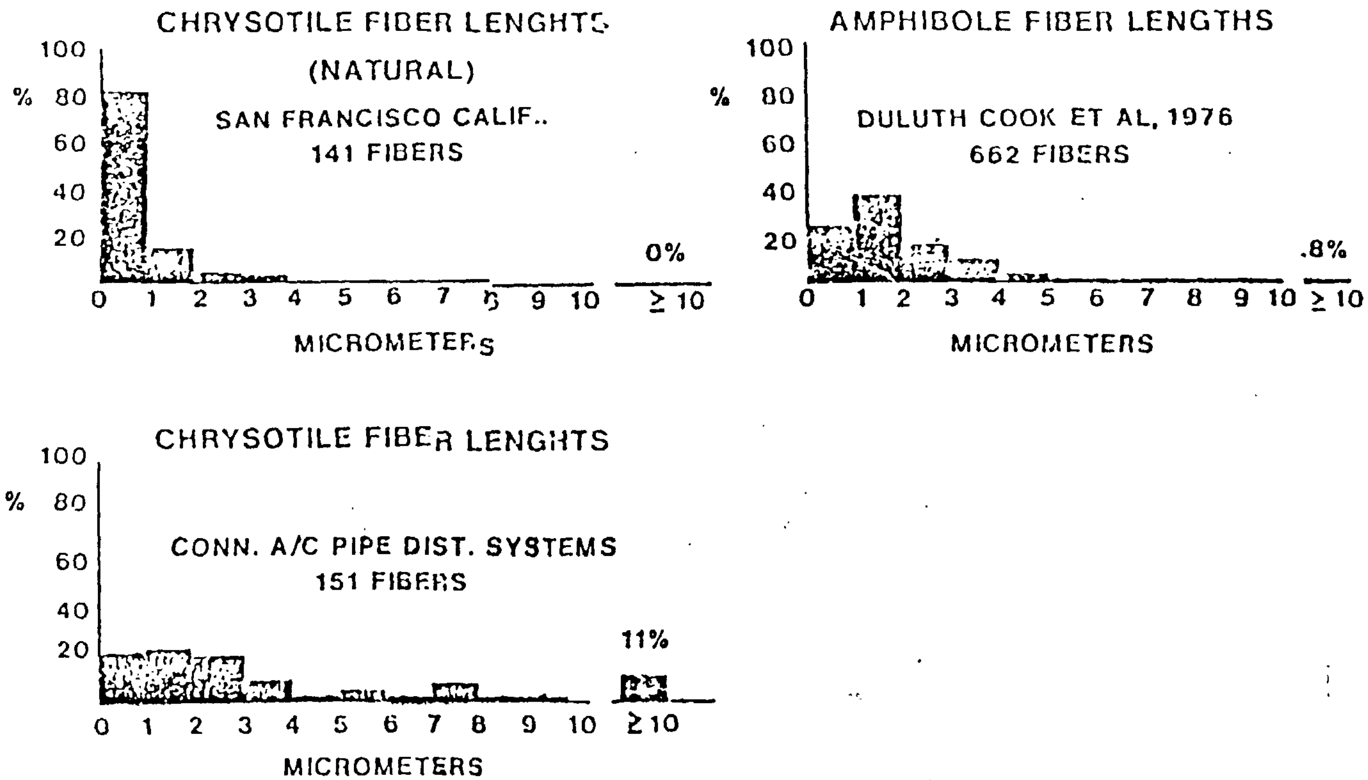
FIGURE 1



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