PLAINTIFF'S EXHIBIT

CAP-771

A/C Pipe
Producers Association

Internal Correspondence

TO Executive Committee
International Affairs Committee

J.F. Welch

FROM J.F. Welch, Vice President

DATE August 30, 1982

SUBJECT U.S. Environmental Protection Agency (EPA) - Office of Drinking Water

REF: (1) JFW correspondence, same title, July 16, 1982
(2) JFW correspondence, U.S. Environmental Protection Agency (EPA) - Corrosion Control Manual, May 21, 1982

Enclosed is a presentation made by the Chief, Science and Technology Branch, Office of Drinking Water to the Pennsylvania Water Works Operators Association Annual Conference, August 2-4, 1982. It is our understanding that the presentation will be peer reviewed within EPA and published in the Conference proceedings.

Attention is directed to "Note to Readers" and its listing of a mid-1983 deadline for review of all aspects of the asbestos drinking water issue. The note also includes a disclaimer that the presentation/paper "...should not be considered to be agency policy." Staff believes that the disclaimer resulted from its letters to EPA about such speeches being misconstrued as formal statements of policy.

Certain portions of this document will be used in the EPA corrosion control manual mentioned in Reference (2). Pages 10 through 14, excluding the summary, will be edited and appear in the manual. At AACPP request, the statement, "In general, the AI should be adjusted to around 12," (page 11) will be deleted. Staff will review a final draft of the manual in mid-September. For reference, the contractor for the corrosion control manual is:

ESE
Bevin (Bo) Beaudet, P.E.
Department Manager
Water/Waste Treatment Technology
P.O. Box ESE
Gainesville, FL 32602
Telephone: (904) 372-3318

If you have any questions, please do not hesitate to call.

JFW/ccw

Enclosure

cc: A. Kahn, Esq.

Copies:

Executive Committee	International Affairs Committee
L. Ambler	E. van der Rest
J. Cran	R. Dorner
L. Taylor	L. Giannitrapani
	P. Hart
	A. Saoulis
	V. Pattabhi
	R. Jalan
	H. Hudson
	C. Barton
	S. Al-Tarkait
	M. Delcourt
	J. Cuvelier
	B. Giboin
	J. Rodrigues Dubuc
	G. Zaviezo
	J. Schmaus
	Dimatit

0172083001
Chrono

DRAFT

OPERATIONAL CONCERNS IN THE USE
OF ASBESTOS CEMENT PIPE FOR
POTABLE WATER TRANSMISSION

Prepared for:

Pennsylvania Water Works Operators's
Association Annual Conference

August 2-4, 1982

Hugh F. Hanson, P.E.
Chief, Science & Technology Branch
Office of Drinking Water
United States Environmental Protection Agency
Washington, D.C.

NOTE TO READERS

The Office of Drinking Water and other Offices within the United States Environmental Protection Agency are in the process of developing and analyzing data on all aspects of the asbestos issue and the concerns about Asbestos Cement Pipe (AC) in particular. It is not anticipated that this review will be completed until mid 1983. Therefore, the information presented should be considered preliminary and must be interpreted with care when applied to any specific situation. When, and if, it becomes appropriate for the Agency to make a specific determination concerning the use of AC pipe, that determination will be made formally with adequate opportunity for public review and comment of the proposed actions of the Agency. This paper serves as a review of the issues as they are presently perceived by the Office of Drinking Water, but has not been peer reviewed and therefore should not be considered to be Agency policy.

Operational Concerns in the Use of Asbestos Cement Pipe for Potable Water Transmission

by

Hugh F. Hanson, P.E.
Office of Drinking Water
August 1982

Introduction

Asbestos is a generic term representing a number of fibrous silicate minerals. These minerals vary in their metallic content, fiber diameter, flexibility, tensile strength, and surface properties. Six asbestos minerals have been identified for their commercial importance and are chrysotile, amosite, crocidolite, anthophyllite, amphiboles, and actinolete. Chrysotile refers to the serpentine ($Mg_6Si_4O_{10}(OH)_8$) variety of asbestos and comprises 80 percent or more of the asbestos used in asbestos-cement pipe. Chrysotile accounts for approximately 95 percent of the world's asbestos production and is mined and quarried primarily in Quebec and Vermont. It is identified physically as a tubular or hollow fibrous material. The remaining type of asbestos used for manufacture of potable water pipe is the crocidolite variety. This mineral is a fibrous blue or bluish green silicate of iron and sodium.

Asbestos is ubiquitous and asbestos fibers of one variety or another are present in soils throughout the U.S. The most frequent occurrences of near surface asbestos fibers in soils are found in the western and Atlantic seaboard states. These asbestos fibers are present in our nation's water supply sources as they are leached from the soils by runoff and recharge water. Natural wind erosion and earth disturbances will also act to transport asbestos fibers into water ways. Thesefore, it can be anticipated that appreciable amounts of asbestos fiber may exist in potable water as it enters distribution systems. Lastly, Asbestos Cement (AC) pipe can release asbestos fibers into a distribution system when the piping material is attacked by corrosive water or by improper installation of the pipe or appurtenances.

Numerous investigations have been initiated to determine if asbestos minerals are released from asbestos-cement pipe into potable water. In general, these investigations have attempted to correlate various water quality conditions and pipe ages with asbestos fiber releases or occurrences in potable waters after passing through a specified length of asbestos-cement pipe. The results of these investigations will be discussed subsequently. However, it is important to note the difficulty in conducting these investigations and obtaining meaningful results.

Release of Asbestos Fiber From AC Pipe

Asbestos-cement pipe is composed of 15 to 20 percent asbestos fiber, 48 to 51 percent cement, and 32 to 34 percent silica. The cement portion is either Portland cement, Portland blast furnace slag, cement, or Portland pozzolena cement.

Asbestos-cement pipe was first manufactured in Europe in 1913 and was introduced in the U.S. in 1929. Approximately one-third of all water distribution pipe currently being sold in the U.S. is manufactured of asbestos-cement. Since its introduction approximately 200,000 miles of asbestos-cement pipe has been placed into service for transporting potable waters.

To determine if asbestos fibers are released from asbestos-cement pipe in potable water distribution systems, it is necessary to quantify incremental changes in asbestos concentrations or fiber counts as the water enters and passes through the pipe. Observed incremental changes in asbestos concentrations or counts, however, do not necessarily indicate a release from the asbestos-cement pipe. Increases in fibers or fiber concentrations may result by contamination from the surrounding serpentine soil which remains in the pipe following construction or repairs.

In one study, conducted by the Vermont Department of Health, Sargent reported that asbestos fibers can appear in potable water distribution systems which do not use asbestos-cement pipe. The objective of their study was to compare various sources and to determine if asbestos fibers were picked up in distribution systems. To eliminate the effect of the ubiquitous nature of asbestos and its possible presence in source water, the investigators took samples of both the source and the distribution system and compared the results of the analysis. The results showed that in 17 out of 23 systems initially sampled, the number of asbestos fibers increased from source to distribution, while in six systems it actually decreased.

Incremental increases may also result from drilling and tapping operations when the interior surface of the pipe is disturbed. Although the release of asbestos fibers via drilling and tapping is directly associated with the use of asbestos-cement pipe, measured incremental increases observed during field or laboratory studies should not be construed as normal release of asbestos fibers from the smooth interior surface. Therefore, during such investigations, any drilling and tapping or other pipe disturbances must be identified.

Several investigations have been conducted to ascertain that asbestos-cement pipe does undergo deterioration resulting in the release of asbestos-cement fibers in potable water systems. Other more recent investigations have been initiated in an attempt to identify and quantify the various characteristics which affect asbestos-cement pipe performance. The results of most studies reported to date indicate that structural deterioration is usually negligible even with apparently high asbestos fiber counts, although a measurable decrease in pipe thickness may occur. Primary characteristics identified for examination include water quality, detention or pipe-water exposure time, pipe age, and installation practices.

Hallenbeck et al investigated the effects of pipe age on the release of asbestos fibers. For this study, paired samples were taken from 15 public water systems in Northeast Illinois. The transmission electron microscope analysis technique was used to detect and count chrysotile fibers. Paired samples were collected for comparison and were representative of before and after passing through asbestos-cement pipe.

A wide variety of water quality characteristics were investigated. Consequently, the authors performed statistical tests on the before and after sample pairs. Although some increases occurred, the authors concluded that no statistical significant release of chrysotile fibers was observed. In some analyses, it was found that the fiber counts increased. From fiber length measurements, it was determined that this increase was probably due to breakage in fiber as the fibers were generally shorter in the after exposure samples.

Tracy also investigated the effects of pipe aging on the release of asbestos fibers from asbestos-cement pipe. In this investigation, water quality samples for pH, hardness, and alkalinity were collected from various locations in the distribution systems and changes were observed. Asbestos-cement pipe sections of various ages were selected for this study from three communities in

Vermont which were Brattleboro, South Shaftsbury, and South Burlington. Water quality observations were continued over nearly a four-year period to identify any effects of pipe aging.

It was shown that significant increases in pH, alkalinity, and hardness were observed from samples which were approximately five years old. Samples collected from these same facilities after they had been in service for approximately nine years showed less significant changes. Additionally, Tracy observed from the results of samples taken from the nine-year-old South Burlington system that only slight changes in water quality occurred in portions of the distribution system where circulation was good as compared to dead-end sections where circulation is minimal. From the results of this study, Tracy concluded the asbestos-cement pipe may stabilize with age and become more resistant to water quality characteristics.

Buelow et al investigated the behavior of asbestos-cement pipe under various water quality conditions. The specific objective of their study was to determine if asbestos-cement pipe would be attacked and asbestos fibers released under the various conditions. Their approach was to select ten water supply systems throughout the U.S. which utilized asbestos-cement pipe and which had various water quality characteristics with respect to pH, calcium hardness, and alkalinity. Pipe sections from most of the systems were visually inspected and the samples were analyzed using the electron microscope technique. The results of their study were reported as a correlation between a water quality aggressive index, calculated from the value of the water quality parameters listed above, and the incremental increase in asbestos fibers observed from samples selected.

The aggressive index used for the Buelow et al study follows that procedure identified by AWWA Standard C400-77 which establishes criteria for determining the quality of water that can be transported through asbestos-cement pipe without any adverse structural effects. Although this parameter is often presented in asbestos-cement studies, it is not always accurate in predicting a tendency to release fibers or to allow $Ca(OH)_2$ leaching. The aggresive index (AI) is calculated as:

$$\text{Aggressive Index} = pH + \log (AH)$$

where,

pH = index of acidity or alkalinity in standard pH units
A = total alkalinity in mg/l as $CaCO_3$
H = calcium hardness in mg/l as $CaCO_3$

Values greater than 12.0 identify non-aggressive water; values between 10.0 and 11.9 identify moderately aggressive water; and values less than 10.0 identify highly aggressive waters.

Three of the systems investigated had a water quality aggressive index in excess of 12.0 and are, therefore, considered non-aggressive. Samples collected from these systems were, in general, free of asbestos fibers. Only two samples collected from the three systems which had passed through asbestos-cement pipe had asbestos fiber counts which were statistically significant. The highest value reported was 0.3 million fibers per liter (MFL). In this analysis, a fiber count of 0.2 MFL was also identified in the water source or at the treatment facility.

Two of the water systems investigated had a water quality aggressive index between 10.0 and 11.9 and are considered moderately aggressive. The first system reported had an aggressive index of 11.56 and the second had an aggressive index of 10.48. Only two samples collected from the first system had fiber counts which were statistically significant. Both values were 0.2 MFL. A third sample taken from the well pump had an asbestos fiber count of 0.1 MFL.

In the second system which had a moderately aggressive water (aggressive index = 10.43), changes in water quality with respect to pH, calcium hardness, and alkalinity were also monitored at two sampling locations. It was observed that pH and calcium concentrations increased as the water passed through the asbestos-cement pipe. This increase indicates that calcium hydroxide or other calcium products in the cement binder were being dissolved resulting in an increase in pH and calcium concentrations in the water, and demonstrates that water aggressive to asbestos-cement pipe will continue to increase in pH and calcium with time of exposure as the water seeks its calcium saturation level. In this system significant asbestos fiber counts ranging up to 4.6 MFL were observed. However, because of the large fluctuations in the number of fibers found in various samples, the authors explained the high fiber counts as originating from pipe tapping in the sample collection area.

Five of the ten systems investigated had a water quality aggressive index less than 10.0 and are considered highly aggressive to asbestos-cement pipes. For these five systems surveyed, the aggressive index ranged from

5.34 to 9.51. From the results of this investigation, several important observations were made. In general, water samples taken from the system showed that pH and the aggressive index increased as the aggressive water passed through the asbestos-cement pipe indicating that the asbestos-cement pipe serves a source of pH adjustment. With only one exception, high fiber counts were measured in these water systems having highly aggressive waters as was anticipated. In these tests pipe sections were removed for inspection and pipe deterioration and lossened fibers were apparent where high fiber counts were observed. In one test where asbestos-cement pipe was exposed to a water having an aggressive index of 8.74, the pipe inspection showed that the cement binder had been dissolved to a depth of 1/8 inch.

In another test by Buelow et al, asbestos-cement pipe was exposed to a water having an aggressive index of 6.0 to 7.5 and a pH ranging from 4.5 to 6.0. Although a high asbestos fiber count was expected, very few were actually observed. Additionally, a visual inspection showed little deterioration, but instead the prescence of an iron rust-like coating. It is suspected that this iron rust-like coating actually provides a protective coating against pipe deterioration from aggressive water. Subsequent laboratory testing confirmed this speculation.

The Environmental Protection Agency Drinking Water Research Division also conducted laboratory studies to investigate the performance of asbestos-cement pipe under various water quality conditions. In the initial testing, full lengths of four-inch and six-inch diameter pipes were used in an effort to simulate actual conditions and minimize problems associated with laboratory scale down. However, during the testing, water quality conditions were difficult to maintain as a drift in pH and alkalinity concentrations were observed owing to the exposure of the water supply source to carbon dioxide in the atmosphere. Despite the problems encountered, some interesting qualitative results were observed. For example, it was observed that iron, dissolved in the water from some of the experimental equipment, precipitated and provided a protective coating on the asbestos-cement pipe and halted calcium leaching. From this initial experimental test it was also verified that drilling and tapping of asbestos-cement pipe will generally result in increased fiber counts in water and this increase can be significant.

Because of the difficulties in controlling water quality conditions in this initial experimental test, a laboratory scale coupon test experiment was performed. The objective of this study was to investigate the effects of controllable water quality conditions on asbestos-cement pipe deterioration. This study included the use of chemical additives as a corrosion control strategy.

The results indicated that the use of zinc orthosphoshate at a lower pH or aggressive index was not as effective for preventing asbestos-cement pipe deterioration. It does, however, appear to offer some protection.

Other experiments were performed to demonstrate the performance of $CaCO_3$ as a protection mechanism under conditions of saturation and unsaturation. For these experiments, pH was used as the controlling variable for $CaCO_3$ saturation. It was shown that the asbestos-cement pipe was attached by a water which was unsaturated or unstable with respect to $CaCO_3$, although the aggressive index was high. Alternatively, a water which was saturated with respect to $CaCO_3$ did not attack the asbestos-cement pipe.

Analytical Method

Analytical procedures used to quantify the existence of asbestos minerals in water are severely limited and are subject to produce erroneous results. Primary reasons for the extreme difficulty in determining asbestos fiber concentrations in water include 1) asbestos fiber concentration in potable water is generally very low, 2) chemical analytical methods are not applicable because elements present are common to all rock-forming minerals, 3) asbestos fibers cannot be concentrated or separated from other inorganic solids present in the water, and 4) fiber sizes are often below the resolution of the optical microscope. Also, a knowledge of field operations is necessary to determine the possibility of fiber release resulting from drilling and tapping as opposed to regular deterioration.

One technique employed to analyze asbestos fiber concentrations or counts in water utilizes the electron microscope. Using this technique, solids are removed from the water sample by filtration on a membrance filter and the entire sample is ashed to destroy the filter and any organic and oxidizable inorganic solids that may be present. The inorganic residue is then rubbed out in a dilute solution of nitrocellulose to reduce the particle sizes and transferred to a standard electron-microscope grid. This sample is examined under an electron microscope and the presence of chrysotile fibers is quantified by measuring the length and diameter of each fiber, calculating the total mass and finally relating this mass to the original amount of water sampled. This technique is specific to chrysotile fibers because of their recognizable hollow-tube structure.

The accuracy and precision of this analysis is very poor because only an extremely small fraction of the sample can be examined and this sample generally contains only a small amount of asbestos. Analysis of samples using the electron microscope technique cannot be duplicated by better than a factor of three, and it is estimated that the measured value is accurate to within a factor of ten of the true value. Therefore, measured values should be considered indicators or indices of the relative amount of fiber present. Another limitation of this technique is that the analysis is specific to the structurally recognizable chrysotile fibers. Several other varieties of asbestos materials may be present in water such as crocidolite which is also a component of most asbestos-cement pipe.

Health Concerns

Concerns regarding the health effects caused by ingested asbestos in the mid-1970's due to the discovery of as much as 600 million asbestos like fibers per liter in the drinking water supplies in Duluth, Minnesota. The source of contamination was from taconite tailing wastes dumped into Lake Superior by a mining company since 1955. Recently, additional concerns have been raised regarding the contribution of asbestos fibers to drinking water from the use of AC pipe.

Much of these concerns are based on the fact that in addition to peritoneal mesothelioma, higher than expected incidence rates of gastric, kidney and colon cancers among workers exposed to airborne asbestos were found by some investigators. These findings suggested that inhaled asbestos found their way into the gastro-intestinal tract when cleared from the respiratory tract and swallowed.

EPA is concerned with the potential health implications associated with the ingestion of waterborne asbestos fibers. A number of research studies have investigated the possible adverse health effects caused by ingesting asbestos. The following list summarizes the results of studies in the major areas of toxicology and epidemiology. The summaries were drawn from the abstract or results section of the papers. The full reports are being reviewed for their scientific usefulness in determining whether or not to regulate asbestos in drinking water.

Toxicology

1) Bonser and Clayson (1967) - no intestinal tumors in rats fed crocidolite asbestos.

2) Smith et al. (1965) - no effect of ingested asbestos in rats and hamsters.

3) Gross (1974) - no effect of ingested asbestos in three animal studies.

4) Gibel (1976) - increased tumor occurrence in rats fed asbestos containing filter material.

5) Cunningham et al. (1977) - inconclusive results on whether or not ingested asbestos causes cancer due to the small number of animals tested.

6) Donham et al (1980) - no increase in tumors in rats fed chrysotile asbestos. Other conclusions included evidence of increased probability of asbestos-fed animals to develop colon lesions in general.

7) Hilding et al. (1981) - no significant increase in the incidence of malignant tumors in any experimental group (Duluth tap water, taconite plant tailings, amosite asbestos) compared with that in the control group.

8) Smith et al (1980) - no deleterious health effects and no tumors related to treatment were found in hamsters exposed to milled taconite ore. Tumors found in hamsters exposed to a preparation of amosite asbestos could not be specifically attributed to asbestos.

9) Ward et al (1980) - experimental evidence suggested but did not prove that oral chrysotile asbestos exposure in rats may have increased the incidence of intestinal tumors occurring naturally. No control group maintained.

10) McConnel, E (1982) - no evidence of increased tumor risk among hamsters eating chrysotile and amosite as 1% of their diets throughout their life-span.

11) Studies still underway at NIEHS and in Europe.

Epidemiology

1) Masson et al. (1974) and Sigurdson et al (1980) found no increase in gastrointestinal cancer incidence in Duluth, MN.

2) Harrington et al. (1978) and Miegs et al. (1980) found no association between cancer risk and use of asbestos-cement pipe in Connecticut.

3) Kanarek et al. (1980), Conforti et al. (1981), and Tarter (1981) found an association between incidence and asbestos in the drinking water of the San Francisco Bay Area.

4) Wigle (1977) and Toft et al. (1981) found no relationship between cancer mortality and asbestos in municipal water supplies in Quebec, Canada.

5) Severson (1979) and Polissar (1982) found no effects of asbestos in drinking water on cancer incidence in the Puget Sound region of the State of Washington.

The studies completed to date have yet to demonstrate a consistent significant elevation in cancer incidence among populations ingesting asbestos when compared to populations lacking such exposure. However, as a precautionary measure, EPA is recommending that exposure to asbestos should be minimized where it is possible.

Treatment of Water to Prevent the Deterioration of Asbestos Cement Pipe

Attack of corrosive waters on AC pipe may be prevented by initiating an appropriate corrosion control program with sufficient monitoring. Such a program will have an added benefit of protecting other piping materials in the distribution system such as lead, galvanized steel and copper. An effective corrosion control program is not only beneficial from the health effects point of view, but also makes good economic sense. It has been estimated that the annual loss from the water corrosiveness is about $375 million. In addition to the deterioration of materials used to convey water, water leakage from deteriorated distribution system can be substantial. In some instances, as much as 25 percent of the water leaving a treatment plant is lost before reaching the consumer.

Tuberculation of the interior surfaces of metal pipes caused by corrosion will cause a loss of the carrying capacity of the water through the distribution system. Resistance to the flow is caused by the roughening of the interior surfaces of the pipes by the tubercules and by the reduction of the inner diameter of the pipe due to the deposition of the corrosion products. In order to overcome the loss of the carrying capacity, higher pressures have to be maintained at the pumping stations, which in turn requires additional energy.

One of the best methods to prevent the attack of aggressive waters on AC pipe is to stabilize the water with respect to calcium carbonate saturation. This may be achieved by a number of methods including pH adjustment, addition of lime to increase hardness, or in some cases, increasing the alkalinity. All of these methods are suitable to adjust the Aggressive Index above the non-corrosive range. In general, the AI should be adjusted to around 12. The treatment method to stabilize the water should be evaluated on a case-by-case basis depending on the quality of the water being dealt with. The pH of the water plays an important role in the effectiveness of corrosion control by calcium carbonate saturation. Sufficient amount of calcium has to be present in the water to provide adequate protection. It has been shown that better protection is attained by achieving saturation at lower pH levels at higher calcium concentrations than at high pH levels with low calcium concentration in the water. Laboratory tests at the EPA Cincinnati laboratories (MERL) indicate that the use of inhibitors containing zinc and silicates may be used to prevent the deterioration of AC pipe. Protection is achieved by the formation of a protective layer of zinc-hydroxycarbonate on the AC pipe surface when inhibitors containing zinc are used. When using these types of inhibitors, dosages should be kept sufficiently high to maintain zinc hydroxycarbonate supersaturation throughout the distribution system in order to provide effective pipe coating. Results of tests indicate that a zinc concentration of 0.3 mg/l is needed while maintining pH levels above 8.2. The role of silica in protecting AC pipe surfaces have not been thoroughly investigated yet, however, preliminary results indicate that it may be beneficial in preventing deterioration of AC pipe.

Recommendations

In order to minimize the presence of asbestos fibers in the drinking waters from AC pipe and prevent the deterioration of AC pipe, the following is recommended:

1. First, it should be determined whether the water is aggressive and it attacks the AC pipe. In order to accomplish this, the following approach should be taken:

a. When it is possible, samples from AC pipe from the field should be collected and preserved by the crew who is doing the maintenance and repair work. The location and age and the condition of the samples should provide a realistic indication as to how well the AC pipe performs in the distribution system.

2. A number of representative water samples should be taken from locations of the distribution system where the flow is sufficient to maintain the pipe free from debris and where drilling or tapping of the pipe have not been performed near or during the time of the sampling. The samples should be analyzed for pH, hardness, alkalinity and the presence of asbestos fibers. In addition, the AI should be determined. On the basis of experience in the laboratory and in the field, the MERL Cincinnati laboratory recommended the following interpretation of the analytical results which may be used as a basis to determine whether the water is aggressive or not to AC pipe.

The water is not corrosive to AC pipe if:

a. An initial Aggressive Index above 11, and

b. No significant change in the pH or the concentration of calcium occurring as the water flows through the pipe, and

c. No asbestos fibers consistently found in representative water samples, or

d. Significant asbestos fiber counts being found in representative water samples at one time, but not another at a location where water flow is sufficient to clean the pipe of tapping debris (recent tapping can cause high fiber counts not related to pipe attack), or

e. Significant asbestos fiber counts only being found in water samples collected from low-flow deadends or from fire hydrants (non-representatative samples) and nowhere else in the system.

The water will be corrosive to AC pipe if:

a. An initial Aggressive Index is below 11, and

b. A significant increase in pH and the concentration of calcium occurs as the water flows through the pipe, and

c. Water does not contain iron or manganese, or possibly similar metals, and

d. Significant asbestos fiber counts are consistently found in representative water samples collected from locations where: 1) the flow is sufficient to clean the pipe of debris, and 2) drilling and tapping of the pipe has not been performed near the sampling location during the sampling period, and

e. Inlet water screens at coin operated laundries, etc. become plugged with fibers.

Determination of the corrosivity of the water should not solely rely on the calculation of AI. The presence of natural inhibitors such as iron and mangenese will protect AC pipe from deterioration in aggressive waters. In other instances due to the lack of calcium carbonate in the water, the AC pipe may not be protected even though the AI indicates non-corrosive conditions.

3. If the water is found to be aggressive toward AC pipe, the utility should initiate a corrosion control program either by stabilizing the water or by adding an inhibitor. Select one which is compatible with other materials. Monitoring for corrosion should continue in order to assure that the treatment initiated is effective.

4. Another way to minimize the presence of fibers is proper installation and maintenance procedures. Tapping and drilling of AC pipe should be avoided if possible. Use of factory pre-tapped couplings on new AC systems will reduce the need for field tapping. If field tapping is necessary, a sharp tapping tool and saddle type connection should

be used. The AC industry recommends, that when tapping AC pipe while under pressure, that equipment with a positive purge be used. This ejects 99 percent of the asbestos-cement chips.

The system should be thoroughly flushed to eliminate the presence of soil contamination in the following instances:

a. After installing a new system.

b. After field tapping AC pipe. If the connection is to a house, remove all strainers and flush the house plumbing following connection to the main.

c. Flush the entire system every six months to remove sediment and asbestos fibers.

5. When installing new AC pipe and where the water is moderately aggressive, AI 10.0-11.9, use Type II AC pipe as recommended by AWWA Standard C400-77.

SUMMARY

AC pipe performs in distribution systems as one would predict. While there are other sources of asbestos fibers, AC pipe will contribute fibers to drinking water when the distributed water is corrosive. Corrosivity for AC pipe can be predicted by the Aggressive Index and is particularly affected by calcium carbonate saturation. The health implications of elevated levels of asbestos fibers in drinking water are not clear and the Agency is making a concerted effort to clarify all of the questions that still exist. A decision is expected next year. In the interim, irregardless of the health issue, it does not make good economic sense to allow the deterioration of any piping material and methods are available to treat finished water so that the release of fibers will not occur. Lastly, a high quality corrosion control program will reduce the release of fibers and other corrosion related products and give the system operator the ability to speak with confidence about any and all corrosion related issues.

GENERAL REFERENCES

AWWA Standard for Asbestos-Cement Pressure Pipe, 4 in. through 24 in. for Water and Other Liquids. AWWA C400-77 Revision of C400-75, AWWA, Denver, Colorado.

Buelow, Ralph W., Millette, James R., McFarren, Earl F. Field Investigation of Asbestos Cement Pipe Under Various Water Quality Conditions. EPA, Municipal Environmental Research Laboratory, Cincinnati, Ohio.

Buelow, R. W., Millette, J., McFarren, E. and J. M. Symons, "The Behavior of Asbestos-Cement Pipe Under Various Water Quality Conditions," A Progress Report, Presented at the American Water Works Association, 1979 Annual Conference, San Francisco, June 27, 1979.

Direct Filtration of Lake Superior Water for Asbestiform Fiber Removal. EPA-670/2-75-050a

Hallenbeck, W. H., et al, "Is Chrysotile Asbestos Released from Asbestos-Cement Pipe into Drinking Water?," Journal-American Water Works Association, Vol. 70, No. 2, 1978, pp. 97-102.

Hudson, H. E., Jr. and F. W. Gilcreas, 1976. "Health and Economic Aspects of Water Hardness and Corrosiveness". Journal of the American Water Works Association, 68:201-204.

Kirmeyer, Gregory J. Seattle Tolt Water Supply Mixed Asbestiform Removal Study. EPA-600/2-79-125.

Millette, James R., Clark, Patrick J., Pansing, Michael F. "Exposure to Asbestos from Drinking Water in the United States" Health Effects Research Laboratory, ORD, U.S. EPA, Cincinnati, Ohio

Sargent, H. E., "Asbestos in Drinking Water," Journal-New England Water Works Association, Vol. 88, No. 1, 1974, pp. 44-57.

Symons, G. E., Ph.D., "Water Systems, Pipes and Piping, Part 1/Piping Systems Design," Water and Wastes Engineering/Manual of Practice Number Two, Vol. 4, No. 5, May 1976, pp. M3-M50.

Tracy, E. L., "Observations on Water Samples from Cement-Asbestos Pipe Systems in Vermont," Journal-New England Water Works Association, Vol. 64, 1950, pp. 164-178.

Wright, G. W. (Chairman), et al, Committee Report, "Does the Use of Asbestos-Cement Pipe for Potable Watere Systems Constitute a Health Hazard?" JAWWA. September 1974, pp. 4-21.

EPIDEMIOLOGY REFERENCES

Duluth, MN

Levy, B. S., E. Sigurdson, J. Mandel, E. Landon, J. Pearson (1976) Investigating possible effects of asbestos in city water: Surveillance of gastrointestinal cancer incidence in Duluth, MN. Amer. J. Epi., 103:362-368.

Masson, T.J., F.W. McKay, R.W. Miller (1974) Asbestos-like fibers in Duluth water supply. JAMA, 228(8):1019-1020.

Sigurdson, E. E., B. S. Levy, J. Mandel, R. McHugh, L. Michienze, H. Jagger, J. Pearson (1981) Cancer morbidity investigations: Lessions from the Duluth study of possible effects of asbestos in drinking water. Envir. Res., 25:50-61.

Connecticut

Harrington, J. M., G. Craun, J. W. Miegs, P. Landrigan, J. Flannery, R. Woodhill (1978). An investigation of the use of asbestos cement pipe for public water supply and the incidence of gastrointestinal cancer in Connecticut, 1935-1973. Amer. J. Epi., 107(2):96-103.

Meigs, J. W., S. Walter, J. Heston, J. Millette, G. Craun, R. Woodhill, J. Flannery (1980) Asbestos-cement pipe and cancer in Connecticut, 1955-1974. J. Envir. Health, 42:187-191.

Bay Area, CA

Conforti, P.M., M. Kanerk, L. Jackson, R. Cooper, J. Murchio (1981) Asbestos in drinking water and cancer in the San Francisco Bay area: 1969-1974 incidence. J. Chron. Dis., 34:211-224.

Kanarek, M. S., P. Conforti, L. Jackson, R. Cooper, J. Murchio (1980) Asbestos in drinking water and cancer incidence in the San Francisco Bay Area. Amer. J. Epi., 112:54-72.

Tarter, M. E. (1981) Pattern recognition in the context of an asbestos cancer threshold study. Preprint: Proc. of the Thirteenth Annual Symposium on the Interface: Computer Science and Statistics.

Quebec, Canada

Polissar (1982) Asbestos in Drinking Water and Cancer Incidence in the Puget Sound Area. Amer. J. Epi. (In Press).

Severson, R. 91979 A study of the effects of asbestos in drinking water and cancer incidence in the Puget Sound region. M. S. Thesis, Univ. Of Wash., Seattle, Wash., p. 110.

TOXICOLOGY REFERENCES

Bonser, G. M. and Clayson, D. B. Feeding of blue asbestos to rats. In: 45th Annual Reports of the British Empire Cancer Campaign, 1967, p. 242.

Cunninghand, H. M., Moodie, C. A., Laurence, G. A. and Pontefract, R. D. Chronic effects of ingested asbestos in rats. Arch. Environ. Contam. Toxicol. 6:507-13 (1977).

Donham, K.J., Berg, J.W., Will, L.A., Leininger, J.R. The effects of long-term ingestion of asbestos on the colon of F344 rats. Cancer 45:1073-1084 (1980).

Gibel, W., Lohs, K., Horn, K. H., Wilner, G. P., and Hoffman, F. Tierexperimentelle Untersuchungen uber eine Kanserogene Wirkung von Asbestfiltermaterial nach Oraler Aufnahme (Experimental study on cacerogenic activity of asbestos filters following oral ingestion). Arch Geschwulst-forsch Band 46 Heft 6; 437-42 (1976).

Gross, P. Is short-fibered asbestos dust a biological hazard? Arch. Environ. Health 29:115-117 (1974).

Hilding, A. C., Hilding, D. A. and Larson, D. M. Biological effects of ingested amosite asbestos, m taconite tailings, diatomaceous earth and L. Superior water in rats. Arch. Environ. Health 36(6):293-303 (1981).

McConnel, E. (1982) NIEHS Feeding Study - Hamster Data (In Review).

Smith, W. E., Miller, L., Eleasser, R. E. and Hubert, D. D. Tests for carcinogenicity of asbestos. Ann. New York Acad. Sci. 132 Part 1(456-488 91965).

Smith, W. E., Hubert, D. C., Sobel, H. J., Peters, E. t. and Doerfler, T. E. Health of experimental animals drinking water with and without amosite asbestos and other mineral particles. J. Environ. Path. Tox. 3:277-300 (1980).

Ward, J.M., Frank, A.L., Wenk, M., Devor, D. and Tarone, R. E. Ingested asbestos and intestinal carcinogenesis in F344 rats. J. Environ. Pathoo. Toxicol 3:301-12 (1980).

Will, L. A., Berg, J., Stevens, R., Donham, K., Leininger, J. Asbestos ingestion and 1,2-dimethyl-hyrazine injection effect on colon tumor development. In: Proc. 2nd Intern. Workshop on the In Vitro Effects of Mineral Dusts, Degray, AR, Apr. 28, 1982. (In Press).