United States
Environmental Protection
Agency

Water Engineering
Research Laboratory
Cincinnati OH 45268

Research and Development

EPA/600/S2-85/042 Sept. 1985

EPA

# Project Summary

# Controlling Asbestos Loss from Asbestos-Cement Pipe in Aggressive Waters

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**A project was undertaken to evaluate measures for controlling the loss of asbestos fibers from asbestos-cement (A/C) water distribution pipe under aggressive water conditions. The project was divided into two phases: (1) data collection and pilot tests of alternative control strategies, and (2) field testing of the most effective control strategy.**

**During Phase 1, water quality data were analyzed for the existing distribution system of the City of Bellevue, Washington, which receives its drinking water from Seattle Water Department's Tolt and Cedar River systems. Samples were collected at monthly intervals for 1 year from both sources before and after exposure to A/C pipe. Both sources were shown to be aggressive to A/C pipe, as evidenced by higher asbestos fiber counts, pH, calcium and alkalinity after exposure to the pipe. The Tolt supply was the more agressive of the two sources and was therefore studied further.**

**The pilot tests in Phase 1 evaluated eight alternative control strategies for curtailing pipe deterioration, including pH adjustment and addition of zinc chloride, sodium metasilicate, or ferric chloride. The zinc chloride/pH adjustment strategy performed best and was chosen for the Phase 2 field test.**

**Phase 1 testing also involved the selection of quantitative measures to determine the hardness of A/C pipe before and after exposure to aggressive water, both in the pilot tests and in the distribution system. The Shore D and Rockwell L hardness tests were found useful in quantifying pipe hardness.**

**Selection of control measures was complicated by the fact that the Seattle Water Department had recently completed a corrosion study and was planning to institute its own corrosion control program of pH adjustment for both the Tolt and Cedar supplies. The pilot tests, therefore, assumed the proposed Seattle Corrosion Control Program as a baseline.**

**In Phase 2, a test and a control loop were established in the distribution system, with samples collected before and after exposure to A/C pipe at monthly intervals for 1 year. The test strategy was to add 0.6 mg/L zinc chloride at a point in Clyde Hill, an isolated pressure zone within Bellevue. The control section was in the northeastern portion of the Bellevue 520 zone. Both locations received water from the Tolt system. Immediately before the Phase 2 field test, the Seattle Water Department began its full-scale corrosion control program, so both sections received water that had been adjusted upward in pH and alkalinity, complicating the ability to separate the effects of zinc from the effects of pH and alkalinity adjustment.**

**The field test in Phase 2 did not show conclusively whether the zinc chloride addition effectively prevented pipe deterioration and fiber loss. Results over time from the test section with zinc chloride and the control section were similar, suggesting that the alkalinity and pH increases in effect at the time of the field test may have acted to protect the pipe from deterioration. Further testing of 6 to 12 months appears to be necessary to reach a**

**firmer conclusion about the effect of the zinc addition.**

***This Project Summary was developed by EPA's Water Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).***

## Introduction

The City of Bellevue, Washington, located near the Metropolitan Seattle area, began using asbestos cement (A/C) pipe for its water distribution system in the 1940's. A/C pipe makes up approximately 90 percent, or about 483 km (300 miles), of the city's distribution system. Bellevue receives its water from the City of Seattle. Because of its location, Bellevue generally receives primarily Tolt River water in the northern portion of the city and primarily Cedar water in the south.

Both water supplies are low in mineral content, with total dissolved solids (TDS) values typically lower than 30 mg/L, and alkalinity values of about 16 mg/L for the Cedar River supply and 5 mg/L for the Tolt supply. Cedar River pH averages about 7.4, and Tolt River pH averages about 5.7. As a consequence of this low mineral content and pH, the Langelier Index is as low as -5 for Tolt River water and -2 for Cedar River water.

This study was instituted to evaluate different methods of controlling asbestos fiber loss. Both pilot plant and field tests were conducted. Phase 1 involved the study of a distribution system and pilot plant testing, and Phase 2 consisted of a field test to evaluate the most promising control strategy found in the pilot test.

Between Phases 1 and 2 of the Bellevue study, the City of Seattle implemented a corrosion control program consisting of pH adjustment for Tolt and Cedar waters and alkalinity adjustment for Tolt water.

## Methods

### *Methods of Analysis*

Whenever possible, standard methods of analysis were used. The interim method (counting asbestos fibers under a transmission electron microscope) was used to determine the asbestos fiber concentrations in water. The detection limits are variable and depend on the amount of total particulate matter in the sample as well as the contamination level in the laboratory environment. Under favorable circumstances, detection limits of 0.01 million fibers per liter (MFL) can be obtained.

### *Sampling Methods*

Asbestos samples were taken in clean, 1-L polyethylene bottles. Except for two locations, the sampling sites were set up for continuous flow to assure representative samples. The exceptions were two sites at the inlet to the Clyde Hill system in Phase 2 of this study. In those instances, the port was opened and allowed to run before sampling. The sample bottles were filled about one quarter full and rinsed with the sample water. This rinsing step was repeated before a sample was taken. Finally, the bottle was filled, allowing 2 in. of air space in the bottle for shaking. No preservatives were used.

### *Hardness Tests*

Hardness tests borrowed from the material science field were used to provide reproducible and objective measures of the conditions of the inner surfaces of the A/C pipe. Hardness was measured as the resistance to indentation by a hard ball or cone under a given static load. Since the release of asbestos fibers and the general deterioration of A/C pipe in water is related to the deterioration of the cement matrix, the hardness or sponginess of the remaining A/C pipe material should be a measure of its condition. Two tests were found suitable for use on A/C pipe. The first was the Shore D test, a member of a class of durometer tests normally used for hard rubbers or plastics. The second, the Rockwell L test, is generally used on harder materials such as metals. The Shore D tests consist of a calibrated spring that forces a sharp point into the material. The Shore D range goes from 100 (which is the hardest) to 0 (which is the softest) and corresponds to a 0.25-cm (0.1-in.) maximum indentation. The Rockwell L test is one of a series of Rockwell tests that use a steel ball or a diamond cone to penetrate the material. For the Rockwell L test, a minor load of 10 kg is first used to set an initial indentation, after which an additional major load of 60 kg is applied to make the final indentation. A 0.64-cm (0.25-in.) steel ball is used in this test. As with the Shore D test, the range in hardness is from 100 (indicating a very hard material) to 0 (indicating a very soft material). The Shore D and Rockwell L test results do not necessarily correspond or correlate with each other. In both tests, three separate readings are taken on a single sample and then averaged into a single result for that sample.

To test the appropriateness of the Shore D and Rockwell L hardness tests, coupons of A/C pipe measuring 5 by 5 cm (2 by 2in.) were analyzed. The results of these tests are shown in Table 1. Both test procedures yielded the same relative order, from softest to hardest, for all three pipe samples. In addition, the spread of values obtained for each pipe section was relatively narrow. Thus it could be expected that results may be reproducible and show good relative hardness results from one sample to the next.

One other concern that needed to be satisfied was the effect of moisture on the hardness tests for the A/C test coupons. Hardness tests were run on A/C pipe coupons after removal from water, after drying for 24 hr, 36 hr, 4 days, and 8 days, and after 8 hours of drying plus 48 hr in an oven at 100°F. Test results indicated that the hardness changed only 5 to 10 percent despite the variation of drying times and procedures. Therefore it was concluded that either air-dried or oven-dried A/C pipe coupons could be subjected to hardness testing.

Scanning electron microscope analyses were also applied to the A/C pipe coupons to determine (1) the surface composition of the A/C pipe, and (2) the degree to which calcium had leached from the pipe matrix.

## Phase 1A: Characterization of the Distribution System

In anticipation of the field test using a corrosion control strategy from the pilot test, it was necessary to characterize the Bellevue distribution system to (1) document the changes in the water quality throughout the distribution system, and (2) assess the A/C pipe condition after 30 to 40 years of exposure to both Tolt and Cedar River waters. Samples taken in this phase of the study were taken before the Seattle Corrosion Control Program went into effect.

The most notable aspects of Tolt water are its low pH (generally averaging about 5.7) and its low mineral content (with calcium at 7.4 mg/L, alkalinity at 5.1 mg/L, silica at 5.5 mg/L, and an overall TDS of about 14 mg/L). Changes in water quality conditions generally supporting the deterioration of A/C pipe and found to be significant at the 5 percent level using T-test analysis were chrysotile concentrations, alkalinity, Langelier Index, pH, TDS, and silica. Also, a notable decrease was found in the Tolt water zinc level, which possibly indicates protective action on A/C pipe.

*Table 1. Initial Hardness Test Results for A/C Coupons (3/25/81)**

| Sample Number | Description | Shore "D" Hardness | Rockwell "L" Hardness Scale |
|---|---|---|---|
| A-1 | 6" A/C Pipe | 67 | 7 |
| A-2 | 9200 NE 34th | 65 | 10 |
| A-3 | | 66 | 5 |
| A-4 | | 64 | 14 |
| Average | | 65.5 | 9.0 |
| Std. Dev. | | 1.29 | 3.92 |
| B-1 | 6" A/C Pipe | 68 | 64 |
| B-2 | Unknown | 74 | 60 |
| B-3 | Location | 67 | 65 |
| B-4 | | 73 | 56 |
| Average | | 70.5 | 61.5 |
| Std. Dev. | | 3.51 | 4.11 |
| C-1 | 8" A/C Pipe | 79 | 99 |
| C-2 | New, Uninstalled | 81 | 100 |
| C-3 | Pipe | 82 | 98 |
| C-4 | | 78 | 98 |
| Average | | 80.0 | 98.7 |
| Std. Dev. | | 1.83 | 0.96 |

**Tests performed by Northwest Laboratories of Seattle, Inc.*

The mineral content of Cedar River water is generally higher but nevertheless low compared with that of other water supplies. TDS levels were 35 mg/L, with calcium at 6.99 mg/L, alkalinity at 16.5 mg/L, silica at 9.74 mg/L, and a Langelier Index ranging from -0.53 to -3.14. Again, statistically significant increases were found in the chrysotile concentration, Langelier Index, alkalinity, pH, and calcium and silica concentrations. These increases support the conclusion that Cedar River water is also aggressive with respect to A/C pipe. The decrease in zinc concentration in the Cedar portion of the system was not found to be statistically significant. The differences found between the Tolt and Cedar River water supplies were consistent throughout the year of monitoring. Water entering the Seattle and Bellevue distribution systems from the Tolt River was higher in chrysotile concentration and lower in pH, alkalinity, calcium, and silica. The Tolt water supply was also more negative in Langelier Index.

Samples of A/C pipe were also taken for conducting the Shore D and the Rockwell L hardness tests. The results for these tests are summarized in Table 2. Samples designated 300 and 400 were new, unused A/C pipe and served as a reference point for used A/C pipe. Samples designated 500 through 510 were taken from the distribution system. The results indicate that, on the average, the Shore D hardness changed approximately 0.5 point per year, whereas the Rockwell hardness changed approximately 2 points per year. All pipes showed evidence of softening throughout their 30- to 40-year service periods.

## Phase 1B: Recirculation Experiments

Six corrosion control strategies were tested on a pilot scale in this part of Phase 1. The tests lasted 48 weeks and were conducted in eight separate 378-L (100 gal) systems. Two of the systems were used as controls. A/C coupons were placed in special holders and placed in line with the recirculation loop. Control strategies and results are presented in Table 3.

All tanks showed an increase in chrysotile fibers as would be expected, but the zinc strategies showed the best inhibition of fiber release.

All coupons showed some signs of softening. Although differences in hardness were small, the zinc strategies appeared to be the best for preventing deterioration.

Calcium loss analyses were conducted by the U.S. Environmental Protection Agency (EPA) using a scanning electron microscope with an energy-dispersive X-ray (EDX) device. This analysis measured the depth to which calcium had been leached from the cement matrix of the pipe; results ranged from undetected levels to 0.3 mm. The zinc strategies showed the least amount of calcium leaching.

Based on all of the results put together, zinc was concluded to be the best corrosion inhibition strategy, so the field test added zinc chloride to the water supply.

## Phase 2: Field Test

The field tests of zinc chloride began immediately after the startup period ended for the Seattle corrosion control program. The field test site was chosen in an area receiving exclusively Tolt River water. After the startup of the Seattle corrosion control program, lime addition for the Tolt supply was set to maintain a pH of 8.2, and soda ash addition was set to add 7 mg/L of alkalinity to that existing in the Tolt water.

Site selection involved six basic criteria for the actual test site:

1. The site must receive Tolt water exclusively.
2. The area must be isolated to avoid affecting surrounding areas.
3. The area must be small enough to minimize chemical costs.
4. The test area must provide a detention time of approximately 15 to 20 hr between the chemical addition point and the final sampling point to match the detention times used in Phase 1A.
5. A control area with the same water supply and a similar detention time must be available.
6. The site must have a structure available for housing the chemical feed system and must also have a flow metering system that can be used to pace the chemical feed into the water supply lines.

The test area chosen was the Clyde Hill zone directly northwest of the Bellevue Civic Center. Sampling points on the Clyde Hill distribution network were then assigned (Figure 1). A sampling site just upstream of the chemical addition point was labeled CH1, and a point near the end of the system and representing 16 to 18 hr of detention time was labeled CH2. A sampling point just after the chemical addition, labeled CH1A, was used to verify the zinc dose. Two dead-end points on the system, labeled CH3 and CH4, were used to detect any buildup of particulate zinc. Finally, two sewage sampling points that drain the Clyde Hill system were designated S1 and S2. These two points were used to estimate the amount of zinc leaving the system.

The control area chosen was the same as that used in Phase 1A for the Tolt water and is located directly east of the Clyde Hill area. The original sampling location designations, D3 and D4, were kept during the field test. The detention time in the control system was approximately 15 to 25 hr under average conditions.

Water quality sampling was scheduled on a monthly basis for asbestos fibers

**Table 2.** *Hardness Testing Results for Coupons Removed from the Distribution System*

| Sample Number | Location | Shore "D" Hardness | Rockwell "L" Hardness Scale | Remarks |
|---|---|---|---|---|
| 300 | ---- | 89 | 108 | new pipe (unused) |
| 400 | ---- | 91 | 104 | new pipe (unused) |
| 500 | 16240 SE 9th | 57 | 37 | rust-red deposits, smooth interior |
| 501 | NE 2nd at Overlake Dr. | 55 | 51 | installed 1948, reddish-brown, rough |
| 502 | 166th at DW 35th | 68 | 39 | some brown deposits, smooth interior |
| 503 | 3440 NE 78th | 66 | 45 | some red deposits, smooth interior |
| 504 | 8015 NE 28th | 69 | 41 | installed 1943, dark brown |
| 505 | 4315 SE 134th | 76 | 65 | light tan, some roughness |
| 506 | 92 Ave NE at NE 34th | 77 | -10† | brown, smooth |
| 507 | 91st NE 10 | 70 | 22 | dark brown |
| 508 | Overlake Dr. at Upland | 68 | 61 | very dark brown, smooth |
| 509 | 2515-86 Ave NE | 72 | 64 | rough, white interior |
| 510 | 3104-124th SE | 79 | 85 | rough, white interior |

* All analyses performed by Northwest Laboratories of Seattle. All results are average of 3 readings.
† Tapered end of pipe interfered with test.

**Table 3.** *Selected Water Quality and Hardness Test Results for Recirculation Tank Corrosion Control Experiments*

| | | | Water Quality Results | | | Hardness Results | | |
|---|---|---|---|---|---|---|---|---|
| Tank | Conditions | Exposure Time (Wks) | Chrysotile Concentration MFL | Calcium Increase mg/L | Silica Increase mg/L | Coupon No. | Shore "D" | Rockwell "L" |
| 1 | Cedar Control | 0 | 5.1 | -- | -- | -- | -- | -- |
| | | 12 | -- | -- | -- | T1-1 | 88 | 102 |
| | | 24 | 50.9 | -- | -- | T1-2 | 88 | 97 |
| | | 36 | -- | -- | -- | T1-3 | 80 | 98 |
| | | 48 | 60.9 | 4 | 4 | T1-4 | 84 | 93 |
| 2 | Tolt Control | 0 | 24.6 | -- | -- | -- | -- | -- |
| | | 12 | -- | -- | -- | T2-1 | 88 | 101 |
| | | 24 | 54.5 | -- | -- | T2-2 | 88 | 100 |
| | | 36 | -- | -- | -- | T2-3 | 81 | 98 |
| | | 48 | 69.3 | 4 | 4 | T2-4 | 87 | 91 |
| 3 | Tolt; Seattle Corrosion | 0 | 10.7 | -- | -- | -- | -- | -- |
| | Control Program (SCCP); | 48 | 82 | 2 | 2 | T3-1 | 85 | 89 |
| | pH = 8.0 | 48 | -- | -- | -- | T3-2 | 82 | 93 |
| 4 | Tolt; SCCP; Add'l lime; | 0 | 17.3 | -- | -- | -- | -- | -- |
| | pH = 9.0 | 48 | 166 | 2 | 2 | T4-1 | 85 | 97 |
| | | 48 | -- | -- | -- | T4-2 | 85 | 92 |
| 5 | Tolt; SCCP; 0.3 mg/L Zn; | 0 | 9.7 | -- | -- | -- | -- | -- |
| | pH = 8.5 | 48 | 23.7 | 1.5 | 1 | T5-1 | 87 | 92 |
| | | 48 | -- | -- | -- | T5-2 | 86 | 95 |
| 6 | Tolt; SCCP; 0.6 mg/L Zn; | 0 | 8.4 | -- | -- | -- | -- | -- |
| | pH = 8.0 | 48 | 34.9 | 1.5 | 1 | T6-1 | 86 | 95 |
| | | 48 | -- | -- | -- | T6-2 | 85 | 98 |
| 7 | Tolt; SCCP; 12.7 mg/L $SiO_2$; | 0 | 12.5 | -- | -- | -- | -- | -- |
| | pH = 8.0 | 48 | 39.7 | 2 | 1 | T7-1 | 83 | 90 |
| | | 48 | -- | -- | -- | T7-2 | 82 | 90 |
| 8 | Tolt; SCCP; 0.2 mg/L Fe; | 0 | 3.1 | -- | -- | -- | -- | -- |
| | pH = 8.0 | 48 | 170 | 2 | 1 | T8-1 | 82 | 91 |
| | | 48 | -- | -- | -- | T8-2 | 82 | 92 |

* All samples were oven dried.

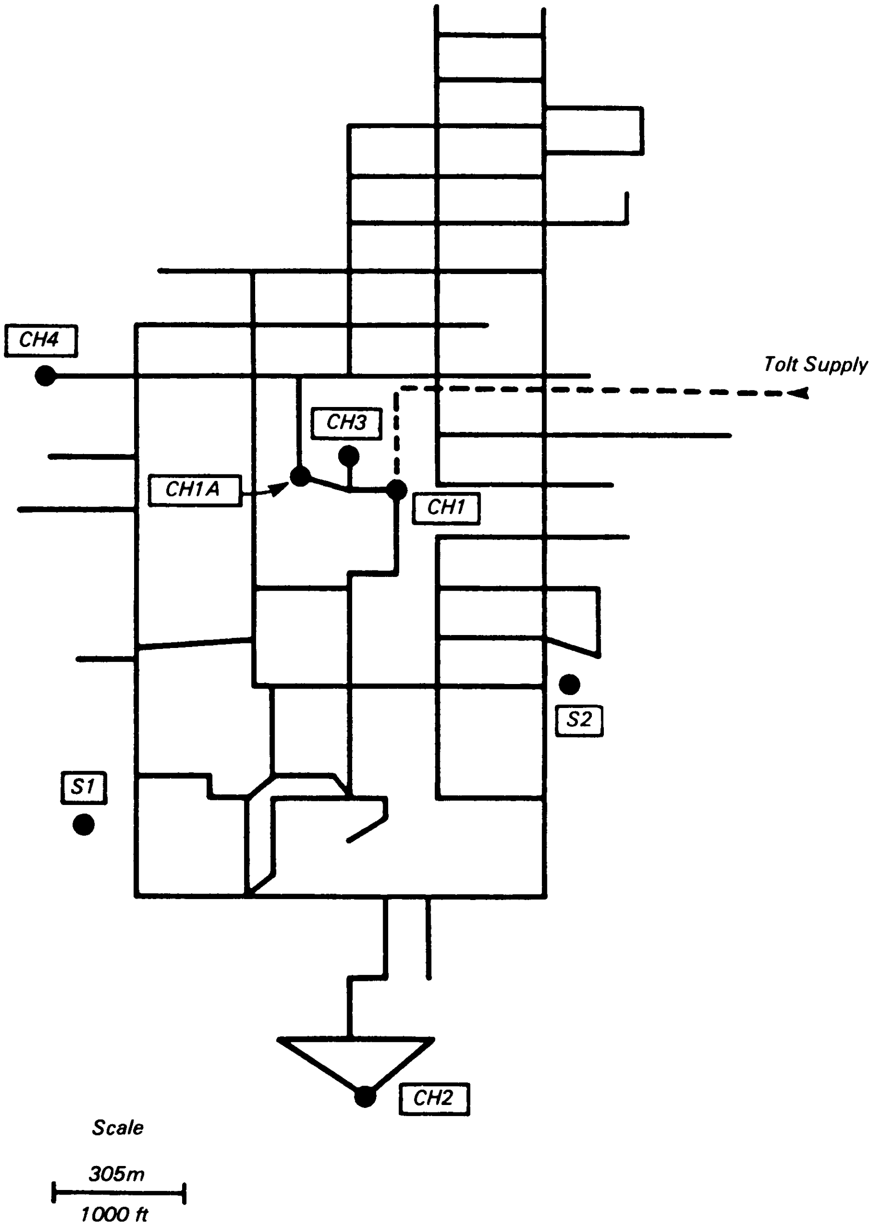


*Figure 1.* Clyde Hill 465 Zone pipe network.

and 20 other water quality parameters especially those associated with the deterioration of A/C pipes, such as calcium and silica. In addition, particulate and total zinc samples were taken at the deadends (CH3 and CH4) on a quarterly basis. The zinc chloride dose was chosen to be 0.6 mg/L as zinc. The recirculation tests of Phase 1B showed that the zinc solubility at pH 8 was nearly the same as that at pH 8.5—that is, approximately 0.1 mg/L as zinc. The goal of adding zinc at a concentration of 0.6 mg/L was to exceed the soluble amount and precipitate zinc onto the A/C pipes to form a protective coating. Another concern was to maintain the zinc concentrations throughout the test area, a procedure very much analogous to maintaining a chlorine residual in the distribution system.

Zinc chloride was added to the distribution system through a metering pump that was fed by a 65-percent zinc chloride stock solution. A special control system paced the metering pump speed with the water flows into the Clyde Hill system.

In addition to the chemical feed system, 0.9-m (3 ft) lengths of A/C pipe sections were installed at locations CH1A, CH2, D3, and D4. Mortar-lined A/C pipe sections of the same length were installed at locations CH1A, CH2, and D3. All of these test sections were placed directly in-line (that is, no special side loops were created). The purpose for these special sections of pipe was to remove them at the end of the study and test them for hardness.

Test results showed that in the first few months of the field tests fewer asbestos fibers were released from the zinc chloride test section than from the control. However, later behavior of the control section (D3 to D4) indicates that the Seattle corrosion control program may be providing some protection for the A/C pipes. This effect can be seen in the asbestos results some 7 months into the field test.

Because a reduction in asbestos fiber counts occurred in both the control and test sections of the field test, the affect of the zinc chloride treatment is uncertain. The control area experienced conditions similar to those in the recirculation tests of Tanks 3 and 4. Both of these tanks experienced a reduction in calcium and silica pickup relative to the untreated control. Thus it may be reasonable to assume that the Seattle corrosion control program is protecting the A/C pipe.

After 12 months of field testing, the short sections of A/C pipe and mortar-lined A/C pipe were removed. Coupons were cut from these pipes and subjected to the calcium loss analysis and physical hardness testing. The calcium loss analysis was conducted by EPA as in Phase 1B of this study. With a precision of approximately 0.1 mm, no appreciable calcium loss could be detected on either the coupons subjected to zinc chloride or the coupons in the control area. In contrast, the recirculation tests of Phase 1B showed no appreciable loss of calcium only in the zinc chloride addition tanks (Tanks 5 and 6). The range of calcium loss in the other tanks was between 0.2 and 0.3 mm. These results further suggest that the water quality changes resulting from the Seattle corrosion control program may be protecting the A/C pipe by virtue of the increase in the Langelier Index.

Hardness testing using the Shore D and Rockwell L tests on the pipe sections removed from the test and control areas failed to produce any differences between them.

Another question posed by this project was whether or not the added zinc was deposited inside the Clyde Hill pipe network. Zinc concentration at the end of the network was approximately 50 percent of the original dose, which indicates some accumulation in the system.

Evidence exists that both precipitation and deposition were occurring in the Clyde Hill network, but the actual proportion of zinc going to one or the other process could not be established. Analysis for total and soluble zinc at the deadends of the system (CH3 and CH4) indicated that particulate zinc was forming at these locations. This result indicates that if zinc is to be added to the Bellevue system, flushing of deadends would be necessary at various intervals. Evidence that zinc may form a coating on A/C pipe comes from X-ray analysis that detected zinc on the surfaces of the A/C pipe sections removed from the field test sites. Zinc deposition was also evident on the mortar-lined A/C pipe sections.

A brief cost comparison was conducted to gain perspective on how zinc chloride treatment compares with other options available to the City of Bellevue. The capital cost estimate included eight separate chemical feed stations determined on the simplifying assumption that Bellevue could be conveniently divided up as such. Other items included were buildings to house the equipment, labor to build it, water meters, and metering pumps. The buildings were assumed to be built on land owned by the City of Bellevue. Annual costs were divided into chemical costs for zinc chloride (approximately $12.50/100 lb) and operating and maintenance costs, which included labor, power, and replacement parts. Converting the annual costs to an equivalent present value gives a total value of nearly $1 million.

Pipe replacement and pipe relining work were the only alternatives to chemical treatment considered, since they represent the conventional ways of dealing with pipe deterioration problems. Replacing the A/C pipe with steel or ductile iron pipe costs similar amounts, each totaling about $35.6 million. Both steel and ductile iron pipe were assumed to be mortar-lined and mortar-coated. Replacement with PVC Class 150 pipe costs approximately 10 percent less than steel or ductile iron, but PVC pipe is only available in diameters up to 30 cm (12 in.). For larger diameters, steel pipe was used. All replacement costs assumed (6-ft) cover and no allowance for service connections.

Relining consists of scraping the inside surface of existing A/C pipe and then coating it with a mortar lining. Mortar lining can be accomplished in place on pipes having diameters of 10 cm (4 in.) and larger. The total cost of relining is nearly $20 million, or approximately 60 percent of the cost of replacing the A/C pipe.

## Conclusions

1. Monitoring presents strong evidence that portions of the A/C pipe matrix were dissolving into the supply water. This condition was indicated by increased water concentrations of components most associated with pipe dissolution: calcium, silica, chrysotile fibers, pH, and alkalinity. Water from the Tolt supply (before alkalinity and pH control was initiated) was more aggressive toward the pipe matrix than was the Cedar supply.
2. Although a natural background of chrysotile fibers exists in the water supply, monitoring results and pilot studies indicated that the A/C pipes do release these fibers into the water.
3. Hardness tests such as the Shore D and the Rockwell L are useful for determining the condition of A/C pipe; however, the natural variability in the samples and method results suggests that time periods greater than 1 year are required for determining statistically whether any changes in hardness have occurred. The Shore D test can be conducted in the field with a small, handheld durometer.
4. Older A/C pipes removed from the Bellevue network show softening as measured by the Shore D and Rockwell L. tests. These tests might be used to determine a priority system for a planned replacement program.
5. Though zinc chloride was found to be effective in controlling A/C pipe corrosion in the pilot test, it could not be determined whether the zinc chloride was effective under field test conditions. This uncertainty may have been the result of the alkalinity and pH control recently initiated by the Seattle Water Department for the source water supply.
6. The alkalinity and pH control may be protecting the A/C pipe or at least slowing down the deterioration. Evidence of this is seen in the chrysotile data for the field test. Both the control area and the test area (with zinc chloride added) behaved the same, showing a decrease in fiber pickup over the course of the field test.
7. Evidence from the field test suggests that the zinc accumulated in the test area as both particulate and deposited zinc.

The full report was submitted in fulfillment of Cooperative Agreement No. CR807789010 by James M. Montgomery Consulting Engineers, Inc. under the sponsorship of the U.S. Environmental Protection Agency.



☆U. S. GOVERNMENT PRINTING OFFICE:1985/559-111/20682

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*The complete report, entitled "Controlling Asbestos Loss from Asbestos-Cement Pipe in Aggressive Waters," (Order No. PB 85-191 690/AS; Cost: $20.50, subject to change) will be available only from:*
*National Technical Information Service*
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