Environmental impact of cured-in-place pipe renewal on an asbestos cement water main

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ABSTRACT

According to the US Environmental Protection Agency's (USEPA) estimation, asbestos cement (AC) pipe accounts for approximately 15% of the total length of pipe networks for water distribution systems in North America; and just as other pipe materials, the AC mains are deteriorating and are in need of attention/renewal. However, there are concerns surrounding the environmental impact of AC pipe renewal that are leading to confusion among the utility managers. The prevailing apprehensions led to the commission of a project to examine the concerns associated with the current pipe renewal practices. While the first phase of the project examined available pipe renewal practices and the data required to determine the practice's safety, the second phase of the project focused on demonstrating and evaluating two renewal practices (namely, pipe bursting and cured-in-place pipe (CIPP) renewal methods). The findings from the CIPP demonstration conducted on a 400-mm (16-in) AC water main are presented herein, which point out the CIPP's applicability to transmission sized AC water mains (i.e. 300-mm or 12-in and larger) and its negligible environmental impact based upon air, soil, and water samples collected on site.

Key words | asbestos cement (AC) pipe, cured-in-place pipe (CIPP), pipeline renewal, transmission mains, trenchless technology

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INTRODUCTION

Asbestos cement (AC) pipe accounts for approximately 15% of the total length of pipe networks for water distribution systems in North America (US Environmental Protection Agency (USEPA) 2007). Renewal activities are needed to maintain these pipes as they deteriorate, however, concerns over the environmental impact of AC pipe renewal technologies and the associated regulations are an area of confusion for water utility managers (Griffin 2009).

The Water Research Foundation (WRF) commissioned project #4093, Long-Term Performance of AC Pipe, which included a study of renewal approaches (Hu *et al.* 2013). This study identified a need for environmental assessments of various renewal approaches. After the project, the industry was still struggling with regulations and practices for renewing AC pipes, and required help establishing reasonable regulations based on actual data (Salvo *et al.* 2012).

The concerns are primarily related to the release of asbestos fibers in the debris or at the site created from the renewal process. This led WRF to commission a second project to examine the concerns associated with the current renewal practices. The first phase of the project examined the kinds of renewal practices that are commonly allowed and the data required to determine the safety of a renewal practice (Matthews & Stowe 2015).

Subsequently, the second phase of the project focused on demonstrating and evaluating two renewal methods (namely, pipe bursting and cured-in-place pipe (CIPP)). The observations from the CIPP renewal project are laid

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out in the following sections. The CIPP technique was applied to a 940-m (3,100-ft) section of a 50-year-old 400-mm (16-in) AC water main. In order to evaluate the impact to the environment, air, soil, and water, samples were collected from the site during and after the CIPP demonstration and were analyzed by a certified laboratory for asbestos fiber content.

TECHNOLOGY DESCRIPTION

A glass-fiber reinforced CIPP liner product designed for use on pressurized water mains was chosen by the utility for the renewal of the 400-mm (16-in) AC water main. The liner is an American Water Works Association (AWWA) Class IV fully structural liner (AWWA 2014) that is National Sanitation Foundation 61 approved for potable water systems. The liner can be manufactured in lengths up to 300-m (1,000-ft) and can be applied to pipes ranging from 150 to 1,200-mm (6–48-in) in diameter. In the lining process, the glass-fiber reinforced liner is installed by inverting it through the host pipe and expanding it in place with the aid of pressurized air and steam. The internal pressure ensures the liner is pressed against the host pipe, and the steam cures the liner that is impregnated with thermosetting epoxy resin. The thickness of the liner ranges from 5.5 to 20-mm (0.22–0.79-in) based upon the number of felt and glass-fiber reinforcement layers, and the needed design strength. The design strength is calculated such that the pipe liner has self-supporting properties and is able to withstand all internal and external loads independent of the host pipe (i.e. AWWA Class IV). The liner design selected for this project consisted of two layers of glass-fiber reinforcement and one layer of felt. The final installed thickness of the liner was 7.3-mm (0.29-in) with a nominal operating pressure rating of 1.31 MPa (190 psi).

SITE AND PIPELINE PREPARATION

To gain access to the main, 20 pits were excavated. A 250-mm (10-in), high-density polyethylene (HDPE) bypass was installed that had 31 service connections and 14 fire hydrant connections. Following the installation of the bypass, the host pipe was drained and the sections of pipe exposed in the pits were removed using a wet-cutting technique to prevent the release of asbestos fibers.

Prior to lining, the host pipe was inspected via closed-circuit television (CCTV) to determine condition and locate all services. After the inspection, the pipe was cleaned using a water jet and any remaining water was removed using a squeegee. Once the pipe was dry, the services were plugged to prevent blockage during liner installation (Figure 1). Services up to 50-mm (2-in) were plugged using the CCTV robot.

INSTALLATION OF CIPP LINER

The liner was prepared off-site where it was impregnated with a thermosetting epoxy resin. The installation procedure used was inversion, which is a common method for CIPP insertion that has been around for more than 40 years. The pit where the liner was inserted into the pipe from the inversion truck was designated Station A. Once in position, a short length of liner was pulled through the opening of the pressure vessel, inverted, and attached to the sidewalls (Figure 2).

To begin installation, the pressure vessel was filled with air to maintain a pressure of 69 kPa (10 psi), which led the liner to invert through the opening. The liner exposed the impregnated resin to make contact with the internal host

Figure 1 | Assembled service connection plug.

Figure 2 | Inverted liner end attached to pressure vessel opening.

Figure 3 | Liner punctured by stingers at Station B.

pipe wall. The inverting rate of the liner was regulated using a rope connected to the spool. Regulating the speed of liner travel helps to preventing unnecessary liner stretching. The liner was fully inserted once a nylon rope is exposed at the exiting end (Station B) of the host pipe.

CURING OF CIPP LINER AND INSTALLATION OF END SEALS

The liner was thermally cured using steam. The pressure vessel located at Station A regulated the steam into the liner at a pressure of 69 kPa (10 psi). The temperature of the steam at Station A was between 82 °C (180 °F) and 99 °C (210 °F). The steam exited the liner at Station B through two hoses that served as vents. Each vent hose was connected to a sharpened, metal pipe called a 'stinger', which was used to puncture the protruding liner (Figure 3) as a means to regulate the liner's internal pressure and temperature.

Curing of the liner was accomplished by maintaining the set temperature, which lasted around 3 hours after reaching an even temperature. Following curing, the liner was allowed to cool to ambient temperature for 1 hour. Once the liner had cooled, the stingers were removed and the liner was cut flush with the end of the pipe. End seals were installed at each end to prevent water from getting behind the liner once the pipe was back in service (Figure 4).

Figure 4 | Finished end seal.

PRESSURE TEST

Following the installation of the end seals, each lined section of pipe was pressure tested to ensure that no leaks were present in the liner or seals. Water from a tanker truck was pumped into each segment at approximately 350 kPa (50 psi). An electric pump connected to the pipe supplied the deficient water to bring the pressure to 1 MPa (150 psi). Then the electric pump was turned off and the pressure was monitored for 1 hour. If no loss in pressure was observed after 1 hour, the liner was deemed leak free.

POST-LINING ACTIVITIES

Post-lining included service reinstatements, disinfection, reconnection of the water main, and the removal of the bypass. Services were reinstated robotically with a cutting tool that allowed it to cut out the plugs. Of the 31 services, only one did not allow for robotic reinstatement and had to be excavated. The lined sections of AC were joined using C905 polyvinyl chloride (PVC) pipe (Figure 5). Finally, the entire length of pipe was disinfected, the bypass was removed, and the site was restored.

ENVIRONMENTAL SAMPLING RESULTS

A major focus of this demonstration project was to evaluate the environmental impact the project had on the air, soil, and water, where possible. The following subsections describe the sampling and testing results for the air, soil, and water.

Air sampling

Nine air samples were collected on three separate days, including three field blanks, by placing air pumps on workers inside and around the access pit locations for 4-hour periods during CIPP lining preparation and lining activities. This is the only area where the AC pipe was exposed and therefore the only reasonable place where asbestos may be measured in the air. Due to an inadequate volume of air sampled on the first day, only six samples, including two field blanks, were analyzed. Air samples were collected using a personal air sampling pump with an approximate flow rate of 2 liters per minute (LPM). The pumps were calibrated in the field prior to sample collection using a flow calibrator. Table 1 summarizes the readings of air samples collected.

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Figure 5 | Lined AC pipe sections connected by PVC pipe.

Table 1 | Summary of collected air samples

Sample no.	Lining run no.	Average flow rate (LPM)	Run time (min)	Volume collected (L)
3	#5	1.9847	259	514
4	#6	1.9822	244	484
5	#6	2.0352	280	570
6	#6	2.0427	252	515
Field Blank-2	#5	NA	NA	NA
Field Blank-3	#6	NA	NA	NA

NA, not available.

The air samples were analyzed using transmission electron microscopy (TEM) following the International Organization for Standardization (ISO) method 10312 (1995). As shown in the air sample analyses (Table 2), the asbestos concentration of all but one sample (i.e. Sample 5) was below the analytical sensitivity for the 8-hr time-weighted average (TWA)-permissible exposure limit (PEL) of 0.1 s/cc set by the Occupation Safety and Health Administration (OSHA). The asbestos concentration of sample 5

Table 2 | Air sample asbestos results summary

Sample no.	Number of asbestos structures detected	Analytical sensitivity (s/cc)	Asbestos concentration (s/cc)[a]
3	ND	0.0050	BAS
4	ND	0.0050	BAS
5	1	0.0048	0.0048
6	ND	0.0050	BAS
Field Blank-2	ND	NA	BAS
Field Blank-3	ND	NA	BAS

s/cc, structures per cm^3; ND, none detected; NA, not available; BAS, below analytical sensitivity.

[a] OSHA TWA-PEL = 0.1 s/cc.

(i.e. 0.0048 s/cc) was measurable, but also below the OSHA TWA-PEL.

The air sample results are representative of all activities that occurred on site on the specific day of sampling, except for pit excavation and removal of AC pipe sections. While air samples during cutting of the AC were not collected, this is not expected to cause a negative impact when proper wet cutting practices are used, as were in this case (Matthews *et al.* 2015). Wet cutting is an AWWA- and OSHA-approved practice for working with AC pipe. The air samples were collected on the surface at the edge of the pits, due to space restrictions and worker safety air sampling personnel were not allowed inside the pit. During the lining operation, the air sampling personnel traveled between the insertion pit (Station A) and the end pit (Station B) in an attempt to collect representative samples. These results are comparable with another air sampling study conducted on an AC pipe renewal project (Jonsson 2011), which also used wet cutting.

Soil sampling

Six pre-lining soil samples were collected from three different excavation pits over 2 days. Each soil sample was collected from the pit walls at two locations around the host pipe (i.e. one near the pipe crown and one near to the pavement surface). Post-renewal soil samples could not be collected due to the paving of access pits after lining, but a change in the soil asbestos content would not be expected since the host pipe is not disturbed during lining. Samples were analyzed using polarized light microscopy in accordance with USEPA Method 600/R-93/116 (USEPA 1993). Samples 1, 2, and 3 also underwent a 400-point count (soil sample analyses in Table 3).

No asbestos was detected in soil samples 4, 5, and 6. Samples 1, 2, and 3 each contained trace amounts of Chrysotile and the point count further narrowed the trace amount of Chrysotile as being less than 0.25% visual estimate. The results essentially suggest that asbestos has not leached from the pipe to the surrounding soil since its installation nearly 50 years ago. These results are comparable with the soil sampling from the other demonstration site that used the pipe bursting method (Matthews *et al.* 2015).

Water sampling

Baseline water samples were collected from services immediately downstream of the lining operation also connected to AC mains. Both samples were collected from backflow preventers located above ground in 1-liter HDPE bottles. The samples were analyzed using TEM following USEPA method 100.2 (USEPA 1994) and the results are presented in Table 4. Both samples were found to be non-detected (i.e. asbestos concentration was below analytical sensitivity of 0.03 million structures per liter). The USEPA maximum contaminate level for asbestos in drinking water is 7 million structures per liter.

Following the completion of the lining project and reinstatement of the main, two additional water samples were collected from the sample locations (Table 5). Both post-renewal water samples were also found to be non-detected. These results are comparable with the water sampling from the other demonstration site that used the pipe bursting method (Matthews *et al.* 2015).

Table 3 | Soil sample asbestos results summary

		Asbestos content			
Sample no.	**Sample location**	**Mineral**	**Visual estimate (%)**	**Non-asbestos fibrous component (%)**	**Non-fibrous components (%)**
1	Pipe crown	Chrysotile point count:	TR < 0.25	TR	100
2	Above pipe crown	Chrysotile point count:	TR < 0.25	TR	100
3	Pipe crown	Chrysotile point count:	TR < 0.25	TR	100
4	3 o'clock position	NA	ND	TR	100
5	Pipe crown	NA	ND	TR	100
6	3 o'clock position	NA	ND	TR	100

ND, none detected; TR, trace, <1% visual estimate.

Table 4 | Pre-renewal water sample asbestos results summary

Sample no.	Total no. of asbestos structure detected	Analytical sensitivity (million structures/liter)	Total asbestos concentration (million structure/liter)
1	ND	0.03	BAS
2	ND	0.03	BAS

ND, none detected; BAS, below analytical sensitivity.

Table 5 | Post-renewal water sample asbestos results summary

Sample no.	Total no. of asbestos structure detected	Analytical sensitivity (million structures/liter)	Total asbestos concentration (million structure/liter)
1	ND	0.03	BAS
2	ND	0.03	BAS

ND, none detected; BAS, below analytical sensitivity.

CONCLUSIONS

This project resulted in the successful installation and evaluation of a glass fiber reinforced CIPP liner used to rehabilitate a 50-year-old AC transmission main. From the air, soil, and water sampling and test results, it may be concluded that no negative impacts to the environment were observed that could be directly attributed to the lining technology. The air and water sampling and testing showed no negative impact on the surrounding environment. The soil sampling and testing indicated only trace amounts of asbestos in the soil surrounding the pipe, with no increase in asbestos following the completion of the renewal activities.

It should be noted that this is the only known CIPP lining project of an AC pipe where environmental impact data has been collected and published. While that means this is a unique project, it also is a limitation of the study and the authors recommend similar data be collected on future AC CIPP projects. It should also be noted that data from multiple pipe bursting projects (e.g. a technology that is expected to be more disruptive than CIPP) has been collected and show no negative impacts (Matthews *et al.* 2015). It is recommended that more environmental impact studies be conducted to validate these two results.

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