Evaluation of Cured-in-Place and Other Plastic Pipe Suitability for Potable Water Applications

Project Progress and Findings

Cambridge Water Department

December 11, 2018

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Presentation Contents

- Introduction
- Need and Purpose of using CIPP/HDPE
- Materials of Composition of CIPP/HDPE
- Where and Who uses CIPP/HDPE
- Review of Available Information on CIPP/HDPE
- Calculated Health Risk Estimates
- Next Steps

Introduction

Why and How We Replace or Rehabilitate Potable Water Pipes

- Why?
  - Water Quality Improvement
  - Hydraulic Improvement
  - Structural Improvement
- How?
  - Open trench dig & replace construction
  - Rehabilitation through trenchless technology

Example of open trench construction. Photo obtained at https://wedigportland.com/work-in-progress-flavel-watermain-improvement/

Why and How to Rehabilitate Pipes through Trenchless Technology

- Why?
  - Very difficult location to excavate
  - Trenching would cause severe disruption to the area
- How?

HDPE

  - Pipe bursting
  - Sliplining
  - Pipe Jacking/Microtunneling
  - Directional Drilling

CIPP

  - Pipe lining

Example of trenchless rehabilitation with HDPE. Photo obtained at https://wedigportland.com/work-in-progress-flavel-watermain-improvement/

Example of trenchless rehabilitation with CIPP. Photo obtained by CDM Smith in Foxboro, MA

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Plastic Pipes in this Study

- **High Density Polyethylene (HDPE)**
  - Polyethylene pipe use started in 1950s
  - HDPE is High molecular weight polyethylene
  - It is a homogeneous material
  - Different formulations are used for drinking water vs wastewater or drains
  - Potable water application is NSF/ANSI 61* approved

**NSF/ANSI 61: Drinking Water System Components – Health Effects*
NSF = National Sanitation Foundation
ANSI = American National Standards Institute

Plastic Pipes in this Study *(continued)*

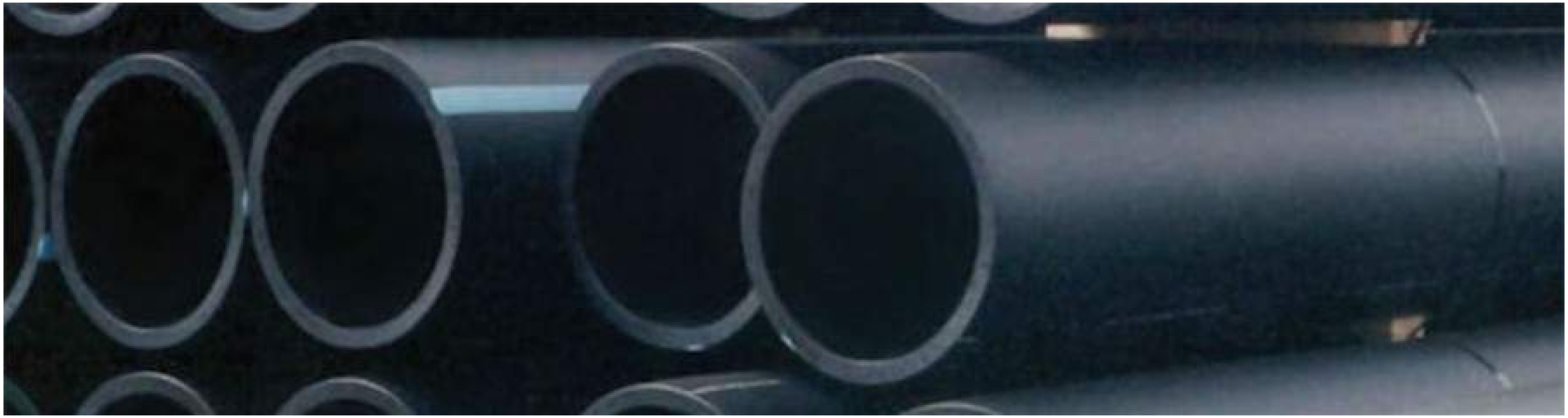
- **Cured-in-Place Pipe (CIPP)**
  - CIPP use in drinking water applications dates back to the 1990s
  - It is a composite material consisting of multiple layers
    - Outer layer is felt or polyester fabric impregnated with epoxy
    - Inner protective layers in contact with potable water are polyurethane, polyethylene, or polypropylene
  - A different formulation with styrene is used in wastewater and drains
  - Potable water application is NSF/ANSI 61 approved

Need and Purpose of Using CIPP/HDPE

What is an HDPE Pipe?

- Thermoplastic
  - Can be manufactured to meet drinking water materials standards
- Flexibility and toughness of material makes it an option for trenchless installations
- Also corrosion resistant and hydraulically smooth

Example of HDPE drinking water pipe. Photo courtesy of Performance Pipe



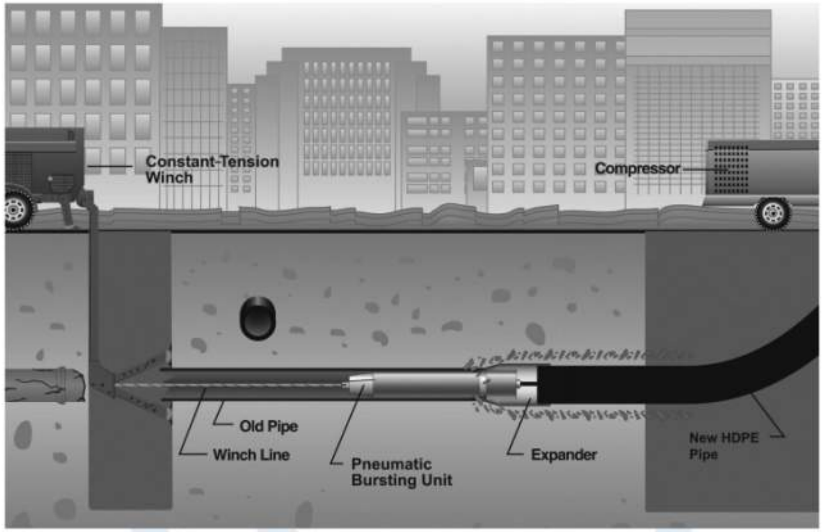
What is an HDPE Pipe *(continued)*

- NSF/ANSI 61 approved for potable water pipe
- Additives are used to protect pipe from disinfectant oxidation effects
- Can be continuously heat fused together
- Can be used for rehabilitation if host pipe diameter can be reduced

How is HDPE Used to Rehabilitate Pipes

- Sliplining
  - Smaller pipe pulled into larger host pipe
  - Void between new liner and host pipe is grouted
  - Reduces pipe diameter
- Pipe Bursting
  - Bursting tool breaks existing host pipe
  - New pipe is pulled into place behind the bursting tool
  - Used in cement and iron pipe; can be used in steel with a special cutter

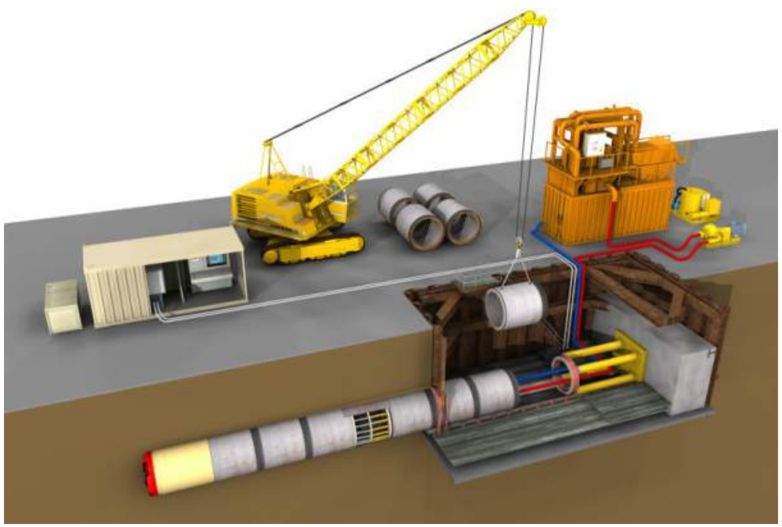
Insertion of slipliner from AWWA M28.



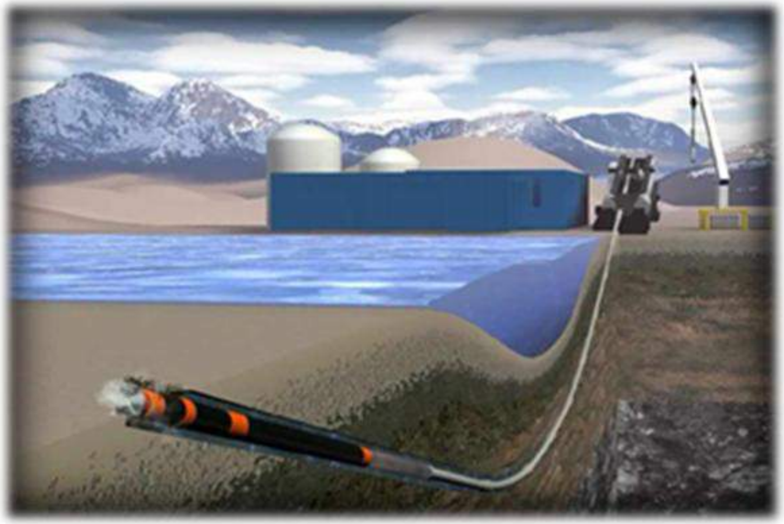
Pipe bursting schematic from AWWA M28.

How is HDPE Used to Rehabilitate Pipes *(continued)*

- Pipe Jacking/ Microtunneling
  - Sleeve is hydraulically pushed into ground
  - Liner is installed inside sleeve
  - Typically used for large diameter pipes
- Directional Drilling
  - A drill rig drills a pilot hole and then a reamer is pulled through the hole
  - Flexible pipe is pulled into the hole



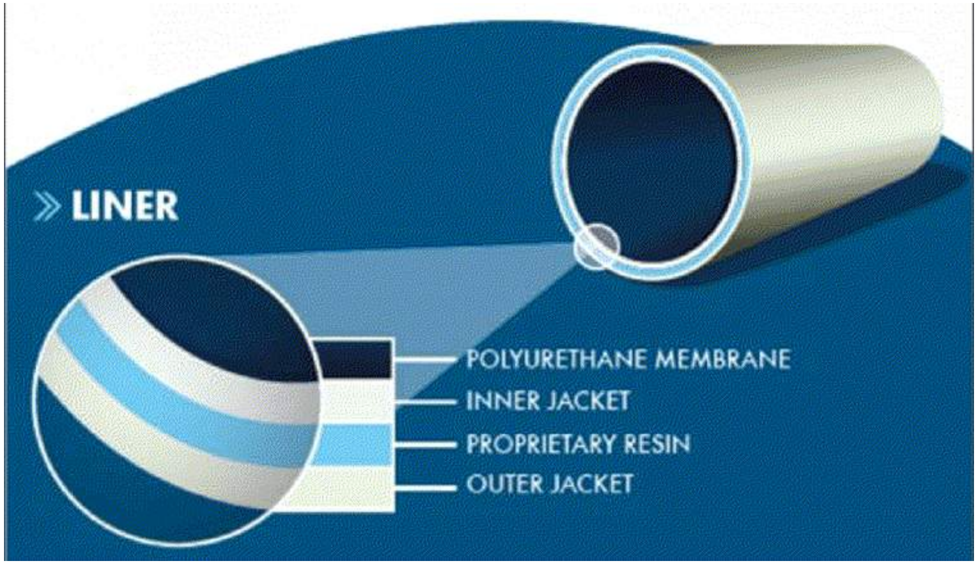
Pipe jacking schematic courtesy of Victoria Trenchless Solutions.



Directional drilling schematic courtesy of Safety Dig.

What is CIPP?

- Cured-in-Place Pipe
  - Polymer fiber reinforced tube or hose
  - Tube is coated or impregnated with NSF/ANSI 61 drinking water approved resin to cure in the host pipe
  - NSF/ANSI 61 approved membrane barrier in contact with drinking water
  - Often used if internal pipe diameter must be maximized



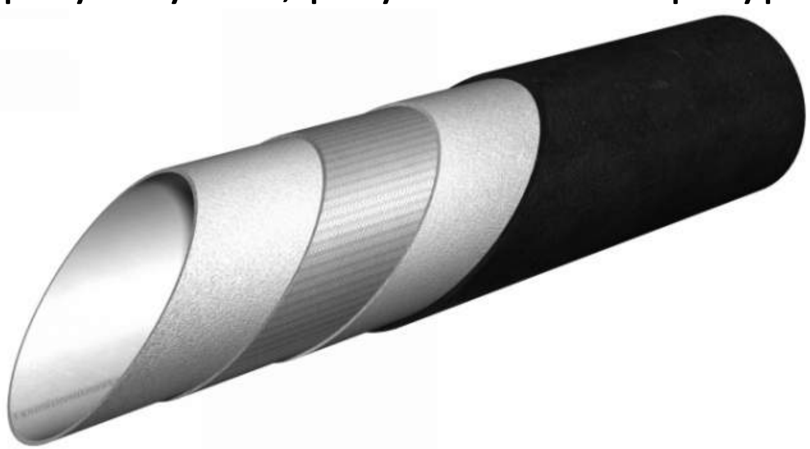
Example of woven hose type CIPP liner for drinking water. Photo courtesy of AquaPipe.

What is CIPP? *(continued)*

- Material is “thermosetting” requiring heat or energy to cure the material to form a solid pipe
- Used exclusively for lining mains, its shape conforms to the host pipe
- No AWWA manufacturing standard
- Flexible before curing – Strong when cured
- Corrosion resistant and hydraulically smooth

How is CIPP Used to Rehabilitate Pipes

- Non- or semi-structural
  - Typically membrane only systems to provide corrosion protection and bridge small pinholes and joint gaps
- Structural
  - Woven hose or polyester felt-based systems impregnated with epoxy and with internal membrane in contact with potable water (polyethylene, polyurethane or polypropylene)

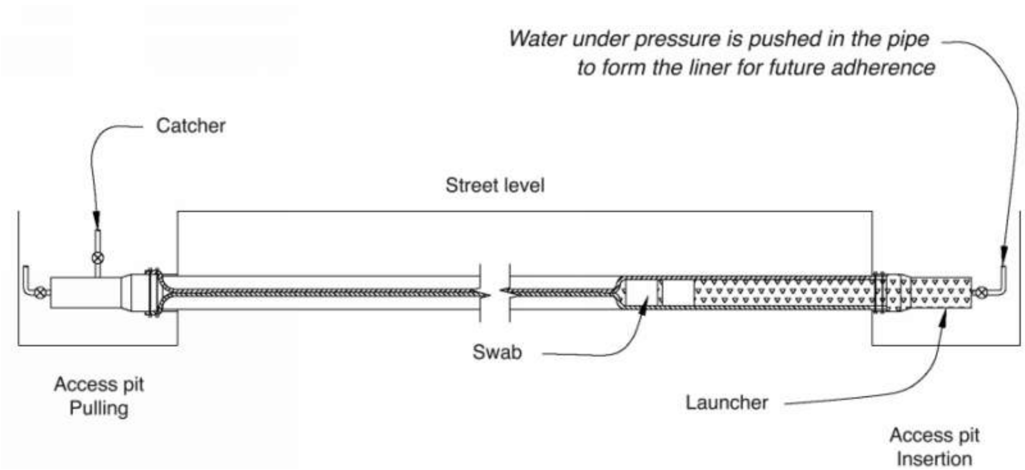


Example of felt-based CIPP liner for drinking water. Photo courtesy of InsituForm.

How is CIPP Used to Rehabilitate Pipes *(continued)*

- Installation
  - Inversion process or
  - Pull into place process
- Curing
  - Heat curing, typically hot water or steam (in some cases UV light)

CIPP installation using inversion. Photo courtesy of InsituForm.



CIPP installation using pull into place method. Photo courtesy of Sanexen.

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Potential CIPP/HDPE Applications in Cambridge

- Ductile iron considered preferred material for renewal/ replacement for the City
- Applications when trenchless rehabilitation may be considered
  - High traffic areas/major arteries
  - Bridge crossings or canal crossings
  - Railroad/MBTA tunnel/track crossings
  - Areas with many utility crossings and very high utility density

Materials of Composition of CIPP/HDPE

HDPE Materials of Composition – Progress

- Obtained information from three major HDPE manufacturers
  - Materials of composition
  - What product warranties exist
  - How repairs could be made to the pipe

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HDPE Materials of Composition – Key Findings

- JM Eagle
  - PE4710
  - 50 year warranty
  - Repairs: replace with new section of pipe connected with either a coupling or fused
- WL Plastics
  - High Performance PE4710, PE4710/PE100
  - 1 year warranty
  - Repairs: replace with new section of pipe connected with either a coupling or fused
- Georg Fischer – GF Piping
  - PE4710/PE100
  - 6 month warranty
  - Repairs: replace with new section of pipe connected with either a coupling or fused

CIPP Materials of Composition – Progress

- Obtained information from four major CIPP manufacturers
  - Materials of composition for liners
  - What product warranties exist
  - How repairs could be made to the liners
  - How many miles have been installed to date

CIPP Materials of Composition – Key Findings

- AquaPipe
  - Polyurethane fiber jacket on the interior in contact with potable water
  - Cured using an 100% solids epoxy resin – proprietary
  - 1 year product warranty is standard
  - Repairs can be done by replacing damaged liner with new piece of pipe with couplings
  - Approx. 1,000 miles installed to date
- NordiPipe
  - Polyethylene coating on the interior in contact with potable water
  - Cured using a potable water approved epoxy resin - proprietary
  - 1 year product warranty is standard
  - Spot repairs can be completed using an internal rubber seal and tension band
  - Approx. 130 miles installed to date

CIPP Materials of Composition – Key Findings *(continued)*

- InsituMain
  - Polypropylene on the interior in contact with potable water
  - Cured using an epoxy resin
  - 1 year product warranty is standard
  - Approx. 7 miles installed to date
  - Repairs can be done by replacing damaged liner with new piece of pipe with couplings
- Saertex
  - Polyethylene and polyamide blend barrier on the interior in contact with potable water
  - Cured using a styrene-free resin
  - Approx. 3 miles installed to date, primarily in Europe
  - Repairs can be done by replacing damaged liner with new piece of pipe with couplings

CIPP Materials of Composition – Key Findings *(continued)*

- In the US, there are more than 1 million miles of buried potable water mains*
- In AWWA's "Buried No Longer" a survey of potable water pipe materials does not even consider HDPE or CIPP
- For CIPP, based on data from the four major companies contacted, 1140 miles of CIPP has been installed to date
- Therefore, CIPP installation accounts for about 1/10 of 1% of the total miles of pipe in service in the US
- HDPE use is much greater than CIPP, but the total miles of HDPE installed is indeterminate

*American Water Works Association: "Buried No Longer: Confronting America's Water Infrastructure Challenge" (2012)

Standards Review – HDPE

Vendor	Model	Materials	Reference Standards: AWWA	Reference Standards: ASTM	Reference Standards: Plastics Pipe Institute (PPI)	Approvals: NSF/ ANSI	Approvals: MassDEP
Georg Fischer Central Plastics	Continuum DGDA-2490 BK	Bimodal polyethylene resin	-	D 3350	PE 4710 TR-4	NSF 61 and 14	Unknown
	Continuum DGDA-2492 BK	Bimodal polyethylene resin	-	D 3350	PE 4710 TR-4	NSF 61 and 14	Unknown
	Alathon L4904	Bimodal high density polyethylene resin	-	D 2513 D 3350	PE 4710 TR-4	NSF 61 and 14	Unknown
	TUB 121	High density bimodal polethylene copolymer	-	D 3350	PE 4710	NSF61	Unknown
WL Plastics	WL125	High density polyethylene (PEX)	C901 C906	-	-	NSF 61 and 14	Yes
JM Eagle	Water/Sewer DIPS	High density polyethylene	C901 C906	F714 D3035	PE 4710 TR-4	NSF61	Yes

Standards Review – CIPP

		Reference Standards		Approvals		
Vendor	Materials	AWWA	ASTM	NSF/ ANSI	MassDEP	Other
InsituMain	Composite polyester fiber, fiberglass and epoxy resin system. Polypropylene on the inside surface.	-	F 1216	NSF61	Yes	Great Britain, Canada
AquaPipe	Two circular polyester jackets with a watertight polymeric membrane (polyurethane) fused to the inner jacket, impregnated with a two part epoxy system	-	F 1216 F 1743	NSF61	Yes	Great Britain, Canada, Germany
Saertex-Liner H2O	Inner coating, GRP-liner (ECR-glass, styrene free polyester or vinylester resin), outer coating of reinforced light protection foil and inner PE/polyamide barrier	-	-	NSF61	Yes	Germany, Poland, Slovak, Spain, Czech Republic, Russia, Brazil
NordiPipe	Felt impregnated with resin, glass-fiber reinforcement, and PE coating	-	F 1216 D 638 D 2990	NSF61	Yes	None

Where and Who Uses CIPP/HDPE

HDPE Installations for Potable Water/ References

Location	Length	Installation Method	Why HDPE?
Tampa, FL	1650 feet	Pipe bursting	High traffic area
Utah	28 miles	Cut and cover, jack and bore plus horizontal directional drilling.	High pressure and corrosion resistance requirements
San Clemente, CA	255 feet and Water Storage Tank Liner	Hand fusion technique	Time and space-sensitive project.
Colorado Springs, CO	20,000 feet	Horizontal directional drilling	Area sensitive to disruption
Chesapeake and Delaware	5,000 feet	Directional drilling	Canal crossing
Taos, NM	16,500 feet	Pipe bursting	High traffic area
Greeley, CO	8,000 feet	Swagelining	High utility density
Fairfield, NJ	8,250 feet	Pipe bursting	Mitigate hazardous waste requirements of asbestos cement
California	10 miles	Open trench installation	Superior performance under high velocity flows
Cambridge, MA	890 feet	Sliplining	Crossings at MBTA/AMTRAK yard and the Little River

Potable Water CIPP Installations/Reference Checks

Water Supplier	Reference Checked	CIPP Products Used				Total Length Lined (ft)	Type of Project Completed		Additional Information	
		AquaPipe	InsituMain	NordiPipe	Saertex		General Maintenance	Specialty Crossing	Independent Research Completed	Water Quality Testing After Installation
Foxboro DPW Foxboro, MA	X	X				20,200	X			
NJ American Water Cherry Hill, NJ	X	X		X		61,025	X	X		
Middlesex Water Woodbridge, NJ	X	X				1,800	X			Standard Bacteria Test Passed
Monroe County Water Authority Rochester, NY	X	X		X		150	X	X	VOC test prior to installation Passed	
City of Westminster Westminster, CO	X			X		1,800	X			Standard Tests (Chlorine, Bacteria & Clean Water) Passed
Acton Water District Acton, MA	X	X				10,000	X			
Bristol County Water Authority Warren, RI	X	X				1,000	X			
Suez Water Toms River, NJ	X	X				1,500	X			

Potable Water CIPP Installations/Reference Checks

Continued

Water Supplier	Reference Checked	CIPP Products Used				Total Length Lined (ft)	Type of Project Completed		Additional Information	
		AquaPipe	InsituMain	NordiPipe	Saertex		General Maintenance	Specialty Crossing	Independent Research Completed	Water Quality Testing After Installation
City of New York Manhattan		X				230’		X		
Montclair Township Montclair, NJ				X		164’		X		
Arlington County Arlington, VA				X		475’		X		
Santa Ana Watershed Project Authority, CA			X							
Chester Water Authority, PA				X		2,100’	X			
Las Vegas Valley Water District, Las Vegas, NV				X		4,830’	X			
Madison Water Utility, WI				X		11,180’	X			
BWSC, Boston MA		X		X		4,889’*		X		
Cambridge, MA		X				900		X		

*BWSC total includes total length CIPP and HDPE installations combined

Literature Review on CIPP/HDPE in Potable Water Systems

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Review of Available Reports, Studies, & Standards

Literature Review Search Terms
Safety, installation, chemical exposure – CIPP, Potable Water
Formulations – CIPP or HDPE, Potable Water
Contaminants, leaching – CIPP or HDPE, Potable Water
Chlorine, disinfectants – CIPP or HDPE, Potable Water
NSF/ANSI, procedures
Curing times (or periods), chemical, leach out – CIPP, Potable Water
Installation conditions, chemical, leach out CIPP, Potable Water
Stability, after (or post) installation – CIPP, Potable Water
Odor, taste, aesthetics – CIPP or HDPE, Potable Water

Review of Available Reports, Studies, and Standards: Literature Review Resources

- CDM Smith Subscribed Resources
  - Engineering Village
  - EBSCO Discover Database
  - ASCE Research Library
  - AWWA WATERNET Database
  - Knovel Online Library
  - Science Direct
  - ASTM Standards
- Other Resources
  - General web searches and Google Scholar
  - North American Society of Trenchless Technology: No-Dig Conference papers, 1991-present
  - EPA online publications and EPA library
  - University Research: Purdue research; Trenchless Technology Center at Louisiana Tech.
  - National Research Council of Canada
  - Various US and Canadian lining and pipe manufacturer webpages for white papers, article, presentations.

Review of Available Reports, Studies, and Standards: Literature Review Resources *(continued)*

- Member Associations/ Organization Resources
  - American Water Works Association (AWWA)
  - Water Research Foundation (WRF)
  - International Water Association (IWA)
  - Water Environment & Reuse Foundation (WE&RF)
  - Water Environment Federation (WEF)
  - American Water Resources Association (AWRA)
  - Association of Metropolitan Water Agencies (AMWA)
  - National Association of Clean Water Agencies (NACWA)

Review of Available Reports, Studies, and Standards: Literature Review Resources *(continued)*

- CDM Smith InfoCenter Library Consortium Memberships (shared resources)
  - Lyrasis
  - OCLC
  - LVIS (Libraries Very Interested in Sharing)
  - MIT Library Privileges
  - Social Law Library
  - SLA (Special Library Association)

HDPE Literature Review – Progress

- A literature review was conducted to examine recent publications related to HDPE pipe suitability for use in potable water mains, either as a standalone pipe or as a slipliner.
- A total of 30 documents of interest were obtained and reviewed
- 22 of those documents were selected for use based on the relevance of their content

HDPE Literature Review – Key Findings

- Field studies identifying and quantifying chemical leach out over time
  - In the 2008 Stern and Lagos study, “Are There Health Risks from the Migration of Chemical Substance from Plastic Pipes into Drinking Water?”, 7 different brands of HDPE pipe were tested for chemicals known to leach from polymeric pipes that are classified as liver, kidney, or nervous system toxicants.
  - In the 2018 Pizzirro study, “Characterization of Leachable Chemical Substances from Common Drinking Water Piping Materials”, 37 chemicals leached out of HDPE pipe, 17 of which did not have an established drinking water standard
  - In the 2016 Connell study, “PEX and PP Water Pipes: Assimilable Organic Carbon (AOC), Chemical, and Odors”, AOC increased 58% in a 28-day period. The concentration was still under the microbial growth threshold

HDPE Review – Key Findings *(continued)*

- Field studies analyzing the effects of chlorine and other disinfectants
  - A field study demonstrated that oxidized pipe reduced pipe flexibility over time
  - NSF/ANSI 61 approved stabilizers can help mitigate the effects on pipe due to oxidized chlorine
  - A 160-day field study indicated that carbonyl intensities increased and antioxidants on the surface decreased over time.

HDPE Literature Review – Key Findings *(continued)*

- Peer reviewed studies on how installation conditions may affect chemical leach out
  - Permeability can be an issue for HDPE, particularly in ground contamination with hydrocarbon compounds
- Field studies on HDPE stability or problems after installation
  - HDPE without additives can become more brittle when exposed to chlorine
  - Small diameter HDPE can experience permeation when buried in contaminated soils

HDPE Literature Review – Key Findings *(continued)*

- Field studies on taste and odor
  - PE fittings can cause odors
  - In the 2006 Heim study, “Impact of Polymeric Plumbing Materials on Drinking Water Quality and Aesthetics”, it was noted that when HDPE was exposed to chloramines, the odor was described as “waxy-crayon/plastic”
  - Multiple studies described odor of water from HDPE pipes as “waxy/plastic/citrus”
  - In the 2003 Skjevrak study, “Volatile organic components migrating from plastic pipes into drinking water”, VOCs were proportional to threshold odor number

CIPP Literature Review – Progress

- A literature review was conducted to examine recent publications related to CIPP suitability as a lining method for potable water.
- A total of 21 documents of interest were obtained and reviewed
- 10 of those documents were selected for use based on the relevance of their content

CIPP Literature Review – Key Findings

- Worker and public safety during handling and installation of CIPP
  - In a 2015 WRF study, trace amounts of asbestos were found in the air after installing a CIPP liner on an asbestos concrete pipe
- Effects of chlorine or other disinfectants
  - Multiple studies showed, biofilms were less likely to form on CIPP liners than DICP
- Field studies on CIPP stability or problems during installation
  - In some instances, small services had to be dug instead of robotically cut

CIPP Literature Review – Key Findings *(continued)*

- Field and peer reviewed studies to indicate curing periods prior to the introduction of potable water into the pipes to mitigate leach out
  - In a 2012 EPA case study on CIPP installation for potable water, entitled, "Performance Evaluation of Innovative Water Main Rehabilitation Cured-in-Place Pipe Lining Product in Cleveland, Ohio," several contaminants of concern were detected in the water only after the liner was installed, but none above their MCLs
  - In the 2012 Matthews study, "Demonstration and evaluation of an innovative water main rehabilitation technology: Cured-in-Place Pipe lining", BPA was detected in water prior to CIPP installation, but after was tested at below reaction limit

The Intent of NSF/ANSI 61 Certification

- Developed to establish “minimum requirements for the control of potential adverse human health effects from products that contact drinking water”
- Designed to cover “all indirect additives products and materials”

Review of NSF/ANSI 61 Procedures

- NSF/ANSI 61 prescribes:
  - Minimum testing requirements: metals, VOCs etc.
  - Exposure water make-up: free chlorine is only required in exposure water for metals analysis
    - pH = 5 with 2 mg/L free available chlorine and 100 mg/L hardness (for metal analytes)
    - pH = 10 with 2 mg/L free available chlorine (for metal analytes)
    - pH = 8 with 0 mg/L free available chlorine and 100 mg/L hardness (for organic analytes)
  - Conditioning/pre-exposure requirements
  - Exposure duration specified
  - Calculation for scaling up from laboratory results to field results, and correcting to field exposure conditions (16 hr for HDPE and 24 hr for CIPP)

NSF/ANSI 61 Minimum Testing Requirements

Testing Requirements	HDPE (NSF/ANSI 61 Section 3)	CIPP (NSF/ANSI 61 Section 5)
VOCs (EPA 524.2)	✓	✓
Acid-, base-, and neutral-extractable organics (EPA 625)	✓	✓
Regulated metals	✓	
Bisphenol A and related compounds		✓
Bisphenol F and related compounds		✓
Epichlorohydrin		✓
Additives specific to product formulation		✓

Review of NSF/ANSI 61 Procedures *(continued)*

- HDPE governed by Section 3 and CIPP by Section 5; most rigorous evaluation conditions apply if product falls under more than one category
- Product passes if testing results show it meets water criteria listed in Annex D of the standard: based on US EPA and Health Canada drinking water criteria + criteria for non-regulated contaminants
- NSF/ANSI 61 provides Short Term Exposure Levels (STEL) values for the compounds considered during NSF/ANSI 61 testing, as well as any relevant drinking water standards or single-product allowable concentration (SPAC) values.
- None of the above levels were exceeded for the compounds detected during NSF/ANSI 61 testing, as discussed below

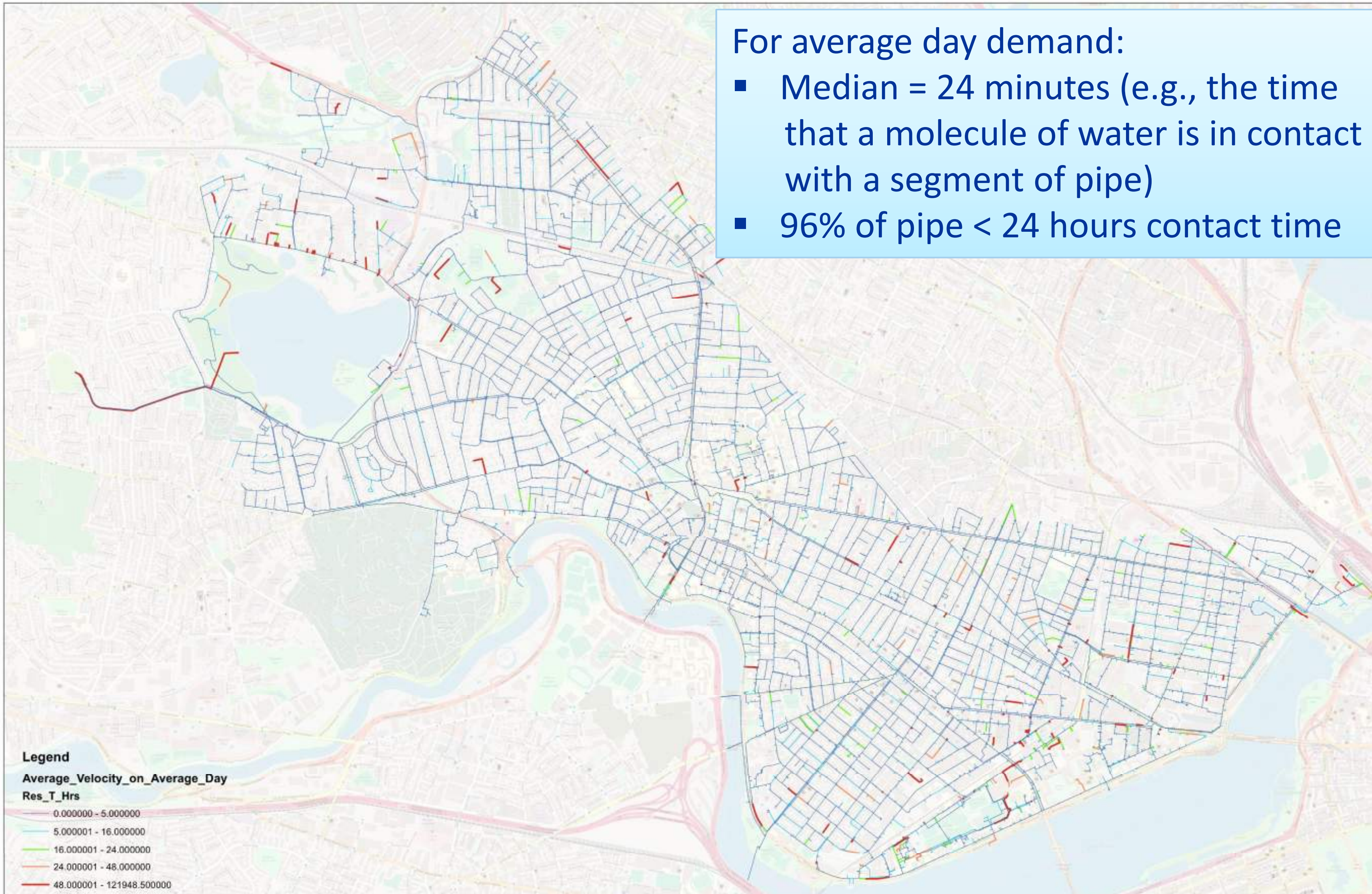
Other Research/Findings

- Cambridge Water Dept. reached out to Dr. Andrew Whelton on Nov. 2, 2018 to see if he could provide some assistance with the evaluation of the byproducts of CIPP and HDPE used in potable water applications.
- Dr. Whelton replied on Nov. 4, 2018. He stated,
  - "To my knowledge, there has been only 1 drinking water CIPP leaching study conducted to date [EPA Cleveland Study discussed above], and based on my review of it, I would not put too much faith behind it."
- Dr. Whelton also provided references to past publications and presentations all of which were related to CIPP products used in wastewater and stormwater and not potable water.

Water Residence Time in Cambridge Water System

For average day demand:

- Median = 24 minutes (e.g., the time that a molecule of water is in contact with a segment of pipe)
- 96% of pipe < 24 hours contact time



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Other Research/Findings

- To Date, Literature Search Has Not Found:
  - Publicly available field studies on the safety of various CIPP formulations and the conditions required for safe use.
  - Longitudinal field studies that identify which contaminants and the quantity that may leach out of various CIPP formulations over 5, 10, 20, or 50 years, as available and how it interacts with drinking water as it ages.
  - Field studies to indicate curing periods prior to the introduction of water into the pipes to mitigate chemical leach out.
  - Peer review studies identifying how installation conditions may affect chemical leach out from CIPP.
  - Field studies on CIPP stability or problems after installation.
  - Field studies related to the impact of CIPP on the taste of water.

Evaluation of Potential Health Risks Associated with CIPP/HDPE

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Identification of Potential Contaminants of Concern – Sources of Information

- CIPP
  - NSF/ANSI 61 certification data for drinking water system components
    - 16 to 24 hour laboratory analysis of leaching from CIPP
    - Results are normalized to flowing conditions in a water supply system
  - EPA performance evaluation of a CIPP lining product in Cleveland
    - Samples collected from two locations along a 2,000 foot CIPP project
    - Three sampling events – baseline and two post-rehabilitation events
  - Literature search
- HDPE
  - Literature search
  - Very limited quantitative data are available

Identification of Potential Contaminants of Concern – Key Findings

- CIPP
  - NSF/ANSI 61 testing identified metals and organic compounds
    - Metals – Aluminum, Barium, Tin
    - Organic compounds – Bisphenol A diglycidyl ether, Chloroform, Dibutyl phthalate, Dodecanol, 2-Ethylhexyl glycidyl ether, Toluene, Xylenes
  - EPA Cleveland evaluation identified Di(2-ethylhexyl)adipate
  - Bisphenol A not detected in NSF/ANSI 61 testing or the post-rehabilitation samples from the EPA Cleveland evaluation

- HDPE
  - Numerous potential contaminants of concern identified qualitatively via literature search
  - Limited quantitative data in laboratory studies identified for Antioxidants/By-products, Esters, Aldehydes, Ketones, Terpenoids, and Aromatic Hydrocarbons

Development of Estimated Worst-Case Concentrations of Contaminants – Key Findings

- CIPP
  - Maximum NSF/ANSI 61 concentrations normalized to the flowing condition in a water supply system
  - Maximum detected concentration of Di(2-ethylhexyl)adipate from the EPA Cleveland evaluation
- HDPE
  - Limited quantitative data are available
  - Skjevrak *et al.* 2003 study "Volatile organic compounds migrating from plastic pipes (HDPE, PEX and PVC) into drinking water" quantifies classes of chemicals leaching to water based on laboratory studies but provides little information on individual chemicals
  - Skjevrak data could be adjusted based on assumptions about a future Cambridge application

Contaminant Level Terms – Chronic Health Risk Based

- MCLs – Maximum Contaminant Levels. MCLs are legal thresholds set by EPA representing the amount of a substance that is permitted in public water systems under the Safe Drinking Water Act.
- MAC – Maximum Acceptable Concentrations. MACs are the Canadian equivalent of MCLs.
- TAC – Total Allowable Concentration. The maximum concentration of a nonregulated contaminant allowed in drinking water as calculated by the NSF 61 standard based on available toxicity information.

Contaminant Level Terms – Short Term Health Risk Based

- STEL – Short Term Exposure Levels. STELs are calculated from short-term no observed adverse effects levels (NOAELs) in human or animal studies of exposure to contaminants of concern. The NOAELs are adjusted for body weight and uncertainty factors to ensure the calculated STELs are health protective. For contaminants measured over time in NSF 61 testing, concentrations on the first day must not exceed STELs.
- SPAC – Single Product Allowable Concentrations. SPACs are developed to address the possibility that multiple sources may contribute a contaminant to drinking water and are calculated from regulatory drinking water values (such as MCLs) divided by the number of possible sources of the contaminant. If the number of potential sources is not known, the SPAC is 10% of the regulatory value. Normalized flowing contaminant concentrations in NSF 61 testing must meet SPACs.
- GW-1 Standards – These groundwater standards were developed by the Massachusetts Department of Environmental Protection for use at contaminated sites and represent concentrations of contaminants in water intended for consumption that pose no significant risk to human health.

Potential Contaminants of Concern - CIPP

Contaminant	Maximum Concentration Detected (µg/l)	Detection Limit (if known; µg/L	MCL/MAC or TAC (µg/l)	SPAC (µg/l)	STEL (µg/l)	GW-1 Standard (µg/l)
Metals						
Aluminum	<10	6.4	9000	2000	9000	NA
Barium	<4	0.6	2000	200	NA	2000
Tin	<35	0.3	4000	400	NA	NA
Organic Compounds						
Bisphenol A diglycidyl ether	<40	13	1000	100	5000	NA
Chloroform	1	0.3	80	80	NA	70
Dibutyl phthalate	<5	2	700	70	NA	NA
Di(2-ethylhexyl)adipate*	<2		400	40	NA	NA
Dodecanol	<5	1	NA	NA	NA	NA
2-Ethylhexyl glycidyl ether	1	1	3	0.3**	10	NA
Toluene	<3	0.3	1000	100	NA	1000
m-,p-Xylenes	<1	0.3	10000	1000	NA	10000
Total Xylenes	<1	0.6	10000	1000	NA	10000

*Di(2-ethylhexyl)adipate detected in EPA Cleveland Study. All other contaminants are from NSF Testing.

**SPAC limit was exceeded on one test. Repeated tests were below SPAC limit

Potential Contaminants of Concern – HDPE

Component Class	Chemicals	Concentration range (sum of class) (ng/l)	Source/Notes	MCL/ MAC Or TAC (ng/l)	SPAC (ng/l)	STEL (ng/l)	GW-1 (ng/l)
Antioxidants /By-products	2,6-Di-tert-butyl-benzoquinone	400-5180	Skjevrak et al., 2003	3000	300	10000	
	2,4-Di-tert-butyl phenol		Based on three successive 72 hour tests on seven different pipe brands designed to identify and quantify VOCs leaching into water in unused HDPE pipe segments. Tested pipes were 1 m long and 51.4 mm in inner diameter. Concentrations are total concentrations by component class. 2,4-Di-tert-butyl phenol ranged from 20 to 5000 ng/l. 2,6-Di-tert-butyl-benzoquinone ranged from 60 to 600 ng/l. Butyl hexanoate maximum concentration approximately 300 ng/l.	100000	10000	2000000	
	4-Methyl-2-6-di-tert-butyl-phenol						
Esters	Butyl acetate	10-710		1000000	100000	20000000	
	Ethyl hexanoate						
	Hexyl acetate						
	Propyl hexanoate						
	Butyl hexanoate						
	Ethyl octanoate						
	Hexamethyl butanoate						
	Isobornyl acetate						
	Hexyl hexanoate						
	Ethyl decadienoate						
	2,2,4-Trimethyl-1,3-pentanediol diisobutyrate (2,2,4-TPD)			400000	40000	5000000	
Aldehydes	Nonanal	40-950		3000	300	10000	
	Decanal						
Ketones	2-Decanone	50-300					
	2-Undecanone			3000	300	10000	
	2-Dodecanone						

Potential Contaminants of Concern - HDPE

Component Class	Chemicals	Concentration range (sum of class) (ng/l)	Source/Notes	MCL/ MAC Or TAC (ng/l)	SPAC (ng/l)	STEL (ng/l)	GW-1 (ng/l)
	Alpha pinene		Skjevrak et al., 2003				
	Limonene						
Terpenoids	Alpha terpinolene	10-80					
	Delta carene		Based on three successive 72 hour tests on seven different pipe brands designed to identify and quantify VOCs leaching into water in unused HDPE pipe segments.				
	Alpha farnesene						
	Benzene			5000	500		5000
	Toluene			1000000	100000		1000000
	Ethylbenzene			700000	70000		700000
	Xylene			10000000	1000000		10000000
	Styrene		Tested pipes were 1 m long and 51.4 mm in inner diameter.	100000	10000		100000
	Isopropyl benzene			700000	70000		
Aromatic hydrocarbons	n-Propyl benzene	220-1390					
	Ethyl methyl benzene						
	1,3,5-Trimethylbenzene						
	1,2,4-Trimethylbenzene		Concentrations are total concentrations by component class.		50000		
	p-Isopropyl toluene			3000	300	10000	
	Naphthalene		Benzene ranged from non detect to 1,000 ng/l.	100000	10000		140000
	1-(3-Ethyl-4-(hydroxymethyl)phenyl)ethanone						
Acetophenone derivatives	1,1'-(Phenylene)bisethanone	Not reported					
	Acetophenone		Pizzirro et al., 2018				
	2,5-Dimethyl-2,5-hexanediol						
Alcohols	Methanol	Not reported					
	tert-Butyl alcohol						

Potential Contaminants of Concern - HDPE

Component Class	Chemicals	Concentration range (sum of class) (ng/l)	Source/Notes	MCL/ MAC Or TAC (ng/l)	SPAC (ng/l)	STEL (ng/l)	GW-1 (ng/l)
Aldehydes	3-Methyl-2-butenal	Not reported	Pizzirro et al., 2018				
	Aldehydes (generic)						
	Decanal						
	Nonanal						
Alkyl phenol	Butylated hydroxytoluene	Not reported					
Alkyl phenol acids/esters	Methyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate	Not reported					
Alkyl phenols	2,4-Di-tert-butylphenol	Not reported					
	2,6-Di-tert-butyl-4-ethylphenol						
	2-t-Butyl-4-methylphenol						
	Phenolics (generic)						
Amides	Dizadiketo-cyclo-tetradecane	Not reported					
Aromatic hydrocarbons	1,4-Di-tert-butylbenzene	Not reported					
	Alkyl naphthalene						
	Benzene						
	Ethylbenzene						
	Methylstyrene						
	Naphthalene						
	Toluene						
	C3- and C4-alkylated benzenes						
	Xylenes						
	Styrene						
Bisphenol compounds	Bisphenol A	Not reported					
Epoxides	Oxirane,((2-propenyloxy)methyl)-	Not reported					

Potential Contaminants of Concern - HDPE

Component Class	Chemicals	Concentration range (sum of class) (ng/l)	Source/Notes	MCL/ MAC Or TAC (ng/l)	SPAC (ng/l)	STEL (ng/l)	GW-1 (ng/l)
Esters	1,3-Diol diisobutyrate	Not reported	Pizzirro et al., 2018				
	2,2,4-Trimethyl-1,3-pentanediol diisobutyrate (2,2,4-TPD)						
	Butyl acetate						
	Butyl hexanoate						
	Ethyl decadienoate						
	Ethyl hexanoate						
	Ethyl octanoate						
	Hexyl acetate						
	Hexyl butanoate						
	Hexyl hexanoate						
	Isopropyl acetate						
	Propyl hexanoate						
Ethers	Methyl tert-butyl ether	Not reported					
Halogenated hydrocarbons	Trichloroethylene	Not reported					
Heterocycles	1,3-Diphenylguanidine	Not reported					
	Benzothiazole						
	Tetrahydrofuran						
Hydrocarbons	Nonylcyclopropane	Not reported					
Inorganic	Carbon disulfide	Not reported					

Calculated Health Risk Estimates: CIPP Key Findings

- Quantitative NSF/ANSI 61 concentrations normalized to the flowing condition in a water supply system and post-rehabilitation measurements from the EPA Cleveland study compared to drinking water standards
  - MCL – Maximum Contaminant Level
  - MAC – Maximum Acceptable Concentrations
  - TAC – Total Allowable Concentrations
  - Massachusetts GW-1 Standards
  - STEL – Short Term Exposure Levels
  - SPAC – Single Product Allowable Concentrations
- Drinking water standards are health-based and consider cancer and non-cancer health effects including endocrine disruption
- No contaminants were identified at levels that pose a significant risk to human health

Calculated Health Risk Estimates: HDPE Key Findings

- Limited quantitative data are available for HDPE pipe
- Maximum laboratory concentrations of a small number of contaminants (2,6-di-tert-butyl-benzoquinone and benzene) exceeded SPACs but were less than MCLs and STELs
- More Industry research is needed to characterize how laboratory measurements correspond to conditions in the field

Future Industry Research Needs

- Characterization of water quality in CIPP and HDPE installations under field conditions
  - Consider CIPP/HDPE formulations, length of pipe, residence time of water in the system, temperature, pH, disinfection technology and other factors
- Long-term evaluation of drinking water quality following installation of CIPP and HDPE pipe
  - Very limited information is available on potential leaching from aged CIPP and HDPE pipe installations

Next Steps

- CDM Smith
  - ✓ Follow-up on reference call backs
  - ✓ Present information at Water Board on December 11, 2018
  - ✓ Provide Information to Cambridge Public Health Department
  - ✓ Summarize findings, prepare a draft technical memorandum
  - ✓ Present findings at a future meeting with the Water Board.
- Cambridge Public Health Department
  - ✓ Confer with a risk assessor and then will work with the Water Board members to understand the nature and scale of the potential risk posed by these materials, if used
  - ✓ Conduct an informal evaluation of relative risk between basic scenarios
  - ✓ Examine risk mitigation strategies if CIPP/HDPE should be used
  - ✓ Summarize findings and develop a draft technical memorandum.

Next Steps – CPHD Potential Risk Mitigation Strategies

- Testing program for major breakdown products of CIPP/HDPE material exposure to treated water in the one or more locations where CIPP has previously been used,
- Continued tracking of peer-reviewed literature relevant to materials of concern, as determined by prior exposure assessment (item 5 above).
- Identify opportunities for the Cambridge Water Department to participate in field research in collaboration with other drinking water systems to improve and deepen available dataset and literature on possible exposures associated with this type of CIPP/HDPE used in treated water delivery systems
- Water Department will evaluate future removal or mitigation options available in the event that major concerns emerge about the safety of the CIPP/HDPE materials and methods currently being proposed, and
- Consider alternate approaches and materials if new technologies that are deemed safer are available in the future.

Questions/Discussion