Drinking Water Pipe Repairs with Coatings and Liners: Experience and Knowledge-Gaps

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Aging Drinking Water Pipes

Repair or Replace?

- Improve water pressure
- Decrease water age
- Improve water quality
  - Increase disinfectant residual
  - Decrease biofilm
  - Decrease metal contaminants
  - Improve color/clarity
  - Improve taste/odor

Univ. Alaska Fairbanks
Plastics are being used for water pipe repairs because of their low cost, corrosion resistance, ease of installation, and estimated long service-lives.

Non-structural = Coatings
Semi-structural = Pressure transferred to host pipe
Fully-structural = Independent of host pipe, pipe within pipe

Common approach: Chemically manufacture plastics inside the field, in damaged pipes

Education: Plastic Technology is Not Common Education for Water Utility, Consulting Engineers, and Construction Professionals

Typical Civil / Environmental / Construction Courses
- Water and wastewater treatment
- Water distribution modeling
- Water chemistry
- Environmental science
- Hydraulics
- Timber, concrete, asphalt, steel
- Statics, Dynamics, Deforms
- Construction management
- Soil mechanics
- Corrosion science

What we are Providing
- Polymer Chemistry
- Polymer Engineering
- Surface Science
History has Proven Product Testing Standards for Plastic Water Infrastructure Technologies have been Deficient

<table>
<thead>
<tr>
<th>PB pipe failures (1980s-Pres)</th>
<th>HDPE pipe failures (2002-Pres)</th>
<th>Epoxy coating failures (ongoing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![PB pipe failure image]</td>
<td>![HDPE pipe failure image]</td>
<td>![Epoxy coating failure image]</td>
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Cured-in-Place-Pipe (CIPP): Chemical Manufacture of a New Plastic Pipe Inside an Existing Pipe

Today, about 50% of all water pipes in the U.S. are repaired by CIPP
- Resin impregnated tube hardened inside a broken pipe
- Curing methods: Hot water, Steam, UV light
- Deliberate curing time: Hours to many days

![CIPP installation image]
Chemical Plumes Generated by CIPP can Escape the Pipe Being Repaired and Enter Nearby Buildings

For a drinking water pipe, the epoxy resin tube is inserted, steam is injected at 10 psi, 180 to 210°F to facilitate chemical reactions (curing). *(other curing methods are available)*
Our National Science Foundation Study is Designed to Determine the Materials Emitted into the Air from Cured-in-Place-Pipe (CIPP) Installation Activities, 2016-Present

Objectives

1) Conduct air sampling and analysis for Indiana and California CIPP pipe repair sites
2) Examine the resin’s chemical composition
3) Characterize materials emitted and their magnitudes
4) Identify any worksite safety issues

Our Stormwater Culvert Repair Technology Study is Investigating Cured-in-Place-Pipe (CIPP) Water Impacts and Material Longevity

Contaminant Release from Storm Water Culvert Rehabilitation Technologies: Environmental & Long-Term Material Integrity Impacts, 2016-2019

(1) Determine the problem scope across departments of transportation (DOTs) (i.e., the extent of use of these technologies and the scale of their impacts to water quality);
(2) Identify the effectiveness of existing construction specifications at minimizing contaminant release from rehabilitated culverts
(3) Determine the degree structural integrity and longevity of rehabilitated culverts are compromised by chemical leaching.
Today, Plastics Can be Chemically Manufactured Inside Drinking Water Pipes

- BPA (Bisphenol A)
- Epichlorohydrin
- BADGE
- BFDGE
- Ethylenediamine (EDA)
- Diethylenetriamine (DETA)
- Triethylenetetramine (TETA)
- Tetraethylenepentamine (TEPA)
- Pentaethylenehexamine (PEHA)

What we Know from Plastic-Drinking Water Studies

What is Typical in Drinking Water
- Total organic carbon (TOC): 1 – 6 mg/L
- pH 6.5 – 8.5
- Disinfectant residual to limit microbial growth (i.e., chlorine, chloramine, etc.)
- Individual contaminants
- Disinfectant byproducts (DBP)
- Drinking water odor: < 3 TON

New Plastic
- Organic Chemicals
- Organic chemicals + disinfectant → DBPs
- Organic chemicals + water → CO₂, [pH↓]
- Biofilm

New Plastic
- Organic Chemicals
BIG Misconceptions
EPA tests plumbing products to determine if they are safe – No they do not
EPA transferred product testing authority to NSFI – No they did not

NSF(I) Standard 61 – Pipe “Health Effects” Testing

For plastic coatings...
No water testing during the first 4 days of product use
No water testing for total organic carbon (TOC)
No water testing for generated disinfectant byproducts (DBP)
Water pH effect not evaluated for plastic pipe leaching
All drinking water disinfectant chemicals not considered
No organism growth impacts considered
No taste or odor impacts considered
No test results are made public even for ‘approved’ products

NOT A REGULATORY BODY, NO ENFORCEMENT CAPABILITY
Testing lab with 2,100 employees globally; all sectors, all continents except Antarctica

For U.S. and Canada Epoxy Drinking Water Applications, Only a Few Studies have been Conducted

<table>
<thead>
<tr>
<th>Year</th>
<th>Epoxy Test Condition</th>
<th>Water Quality Impacts</th>
</tr>
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<tbody>
<tr>
<td>2017</td>
<td>1 NSFI approved formulation; pH 8, 6.5; Free chlorine, Monochloramine</td>
<td>1. BADGE, BFDGE hydrolyzed and decayed 2. BPA, BPF did not decay 3. BPA, BPF, and triethylenetetramine (TETA) reacted with both disinfectants 4. BADGE did not react with disinfectants</td>
</tr>
<tr>
<td>2007</td>
<td>1 NSFI approved formulation; pH 8; Free chlorine, Monochloramine</td>
<td>1. TOC 6.3 mg/L (new), 1.7 mg/L (day 30) 2. BPA, phenol, 4-nonylphenol (4-NP), styrene, toluene, benzaldehyde 3. Odor caused “plastic/solvent-like/glue” 4. Disinfectant loss occurred 5. DBPs were produced (THM &amp; HAA5)</td>
</tr>
<tr>
<td>2002</td>
<td>5 NSFI approved formulations; 2 coatings</td>
<td>1. Total BTEX ranged from 0.2 to 48 mg/L 2. TOC ranged from 34 to 345 mg/L</td>
</tr>
<tr>
<td>1989</td>
<td>1 formulation in lab; 3 field storage tanks</td>
<td>1. MIBK, o-,m-,p-xylene; ethoxy ethyl acetate; methyl benzaldehyde 2. Disinfectant loss occurred 3. DBPs were produced (THM) 4. Water soaking caused more rapid leaching than air drying 5. MIBK and xylenes detected in storage tanks</td>
</tr>
</tbody>
</table>
Studies from Outside the US and Canada

In Summary: Epoxy Created Inside Water Infrastructure

In the USA and Canada
- There has been wide variability in chemical leaching from across NSF Standard 61 products
- Many chemicals that are released have no US drinking water standard
- TOC level found as high as 345 mg/L
- Free chlorine and monochloramine react with chemicals that are released
- Regulated DBPs can be formed by leached chemicals
- Odors can be caused

Outside the US and Canada
- There has been wide variability in chemical leaching from across products
- BPA leaching expected to be greater in summer (warmer) months
- Found 250 µg/L BPA in cold water and 23,500 µg/L BPA in hot water
- Chemical leaching can occur for months, years
- Epoxy leaching increased during the first 5 months of a 6 month study
- Microorganisms can grow because of epoxy leaching
- Odor and bad flavor can be caused
Conclusions

There is very little information available about chemical leaching from epoxy materials used for drinking water pipes and tanks

*Much less information for polyurea and polyurethane coatings*

Dr. Stephen Randtke et al. (2017), Leader of recent water pipe lining study

“Since epoxy formulations, application methods, curing times, and other factors vary among manufacturers...the results are not necessarily representative of those that would be obtained using other applications or epoxy formulations”

Looking Ahead...

- Require products to pass a more representative leaching test in addition to NSFI Standard 61
- Determine your pass/fail thresholds: Contaminants and surrogate indicators (i.e., TOC, odor, etc.)
- Contractors create plates which are leached Compare results to your predetermined acceptability criteria
- Request for BIDs, Select qualified contractors based on their material’s compliance with your performance criteria
- Require water testing (and plastic testing) for actual field installations to validate performance or nonconformance
Thank you.

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Right Sizing Tomorrow’s Water Systems for Efficiency, Sustainability and Public Health, 2016-2019

Funded 2016: $1,989,000 EPA + $1,100,000 Industry

OUR PROJECT GOAL: To better understand and predict building drinking water quality and health risks posed by declining water usage and low flows.

- Educational Institutions
- Architecture and Building Design Firms
- Water Utilities
- Construction, Water, Health, and Environmental Associations and Networks
- Technology Companies
- Government Agencies

VISIT US ONLINE
www.PlumbingSafety.org