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

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PURDUE UNIVERSITY

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## Aging Drinking Water Pipes

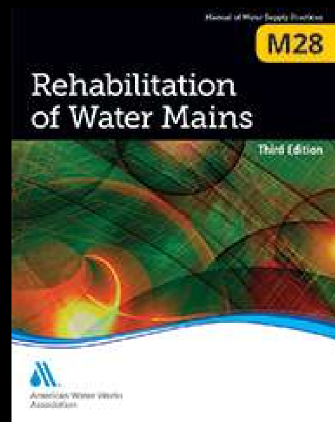
Univ. Alaska Fairbanks

**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

***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*

## <u>Education:</u> Plastic Technology is Not Common Education for Water Utility, Consulting Engineers, and Construction Professionals

**<u>Typical Civil / Environmental / Construction Courses</u>**

Water and wastewater treatment
Water distribution modeling
Water chemistry
Environmental science
Hydraulics
Timber, concrete, asphault, steel
Statics, Dynamics, Deforms
Construction management
Soil mechanics
Corrosion science

**<u>What we are Providing</u>**

Polymer Chemistry
Polymer Engineering
Surface Science


## History has Proven Product Testing Standards for Plastic Water Infrastructure Technologies have been Deficient

**PB pipe failures (1980s-Pres)**

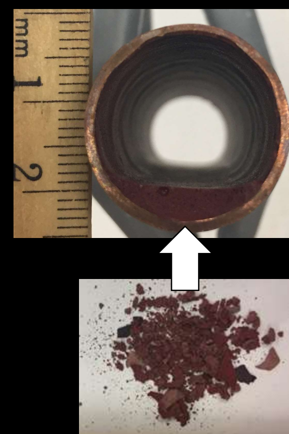
**HDPE pipe failures (2002-Pres)**

Water Only Exposed

Free Chlorine

Chlorine Dioxide

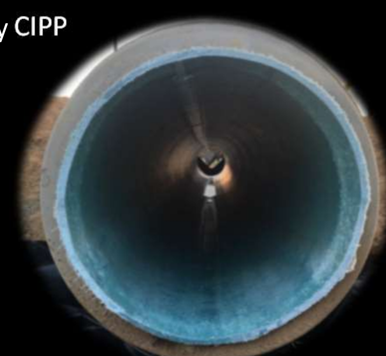
**Epoxy coating failures (ongoing)**

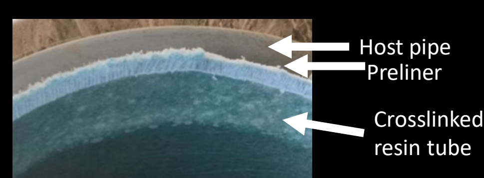


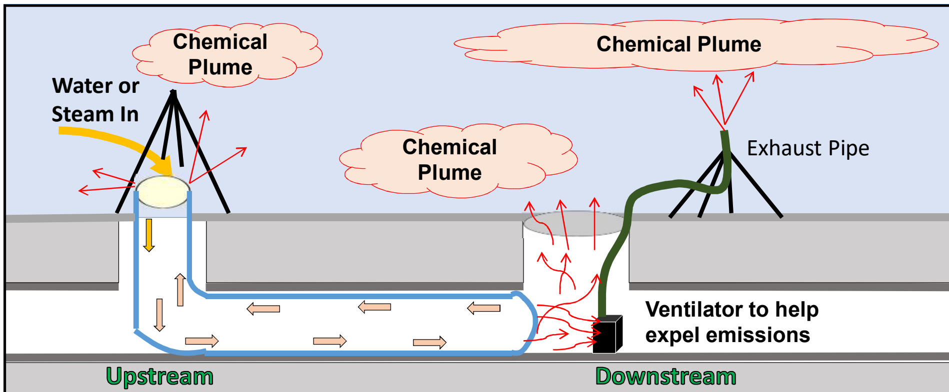

## Cured-in-Place-Pipe (CIPP): Chemical Manufacture of a New Plastic Pipe Inside an Existing Pipe

Today, about 50% of all water pipes in the U.S. are repaired by CIPP

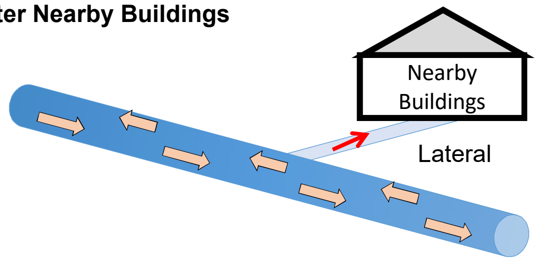
- Resin impregnated tube hardened inside a broken pipe
  - Curing methods: Hot water, Steam, UV light
    - Deliberate curing time: Hours to many days








**Chemical Plumes Generated by CIPP can Escape the Pipe Being Repaired and Enter Nearby Buildings**




Discharge into air (sewer pipe example)


Matthews et al. (2015)

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

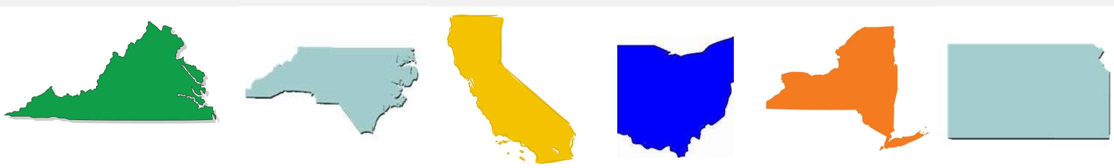
1) Conduct air sampling and analysis for Indiana and California CIPP pipe repair sites
2) Examine the resin's chemical composition
3) Characterize materials emitted and their magnitudes
4) Identify any worksite safety issues

NSF PURDUE UNIVERSITY Crowdfunding

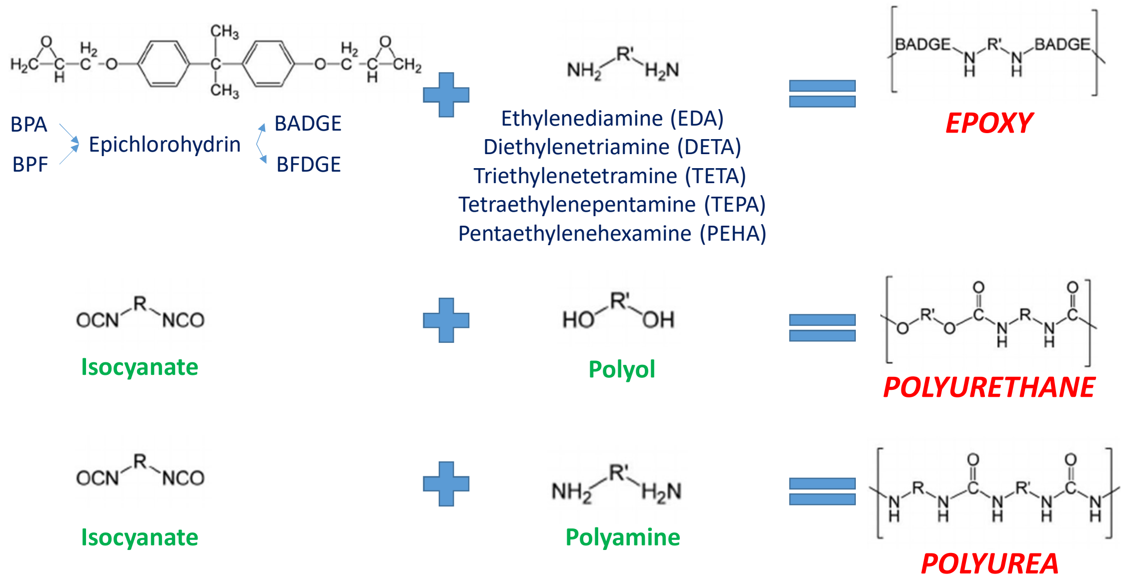
## Our Stormwater Culvert Repair Technology Study is Investigating Cured-in-Place-Pipe (CIPP) Water Impacts and Material Longevity

**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




## What is Typical in Drinking Water

Total organic carbon (TOC): 1 – 6 mg/L

pH 6.5 – 8.5

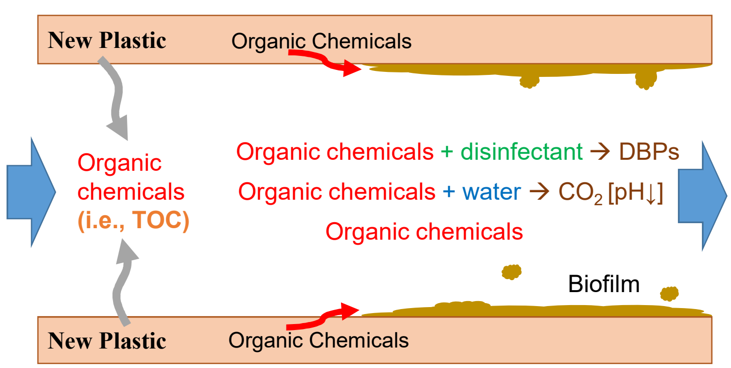
Disinfectant residual to limit microbial growth (i.e., chlorine, chloramine, etc.)

Individual contaminants

Disinfectant byproducts (DBP)

Drinking water odor: < 3 TON

## What we Know from Plastic-Drinking Water Studies



**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

we've got mail

American Water Works Association

Letters to the Editor

**ARTICLE REPORTING ON LEAD CONTAMINATION FROM BRASS PLUMBING DEVICES IN NEW BUILDINGS SPARKS DISCUSSION**

The University of North Carolina at Chapel Hill (UNC) campus experienced an unfortunate and signifi- … certified to NSF 61, which has been repeatedly alleged in studies published in JOURNAL AWWA. In fact, if current proposed amendments are made to the SDWA to reduce the definition of "lead free" from 8% to 0.25%, then NSF 61 …

AWWA is the authoritative resource for knowledge, information, and advocacy to improve the quality and supply of drinking water in North America and beyond. AWWA is the largest organization of water professionals in the world. AWWA advanc- …

Letters to the Editor

**COMMENTS ON "PEX AND PP WATER PIPES: ASSIMILABLE CARBON, CHEMICALS, AND ODORS"**

I found the expanded summary of "PEX and PP Water Pipes: Assimilable Carbon, Chemicals, and Odors" by Connell et al., which appeared in the April 2016 *Journal AWWA* (Vol. 108, No. 4, p. 69), to be misleading when compared with the content of the complete manuscript that appears on the *Journal AWWA* website. The paper contains some pretty strong allegations, including the following: "Certified products are causing homeowners to refuse to use their drinking water out of safety concerns."

The summary states that data showed PEX pipes were the source of drinking water odor, yet the full paper reports that two of three systems tested in the field exhibited threshold odor numbers (TONs) that were "not statistically different from TON values of the tap water before it entered the PEX system." … incidents of abnormal T&O in any new plumbing products, while possible, is simply not the case in the vast majority of new piping installations.

Manufacturers and end users of water contact products that are tested and certified to NSF/ANSI 61 can be confident that their products are safe concerning the health effects of the general public. The discussion in the expanded summary does not seem to be supported by the data contained in the complete paper. *Journal AWWA* should take better care in reviewing these expanded summaries to see whether the data truly support the conclusions.

*Dave Purkiss*
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Plumbing Products Division
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Ann Arbor, Mich.

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

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

| Year | Epoxy Test Condition | Water Quality Impacts – Studies from Outside the US and Canada |
|---|---|---|
| 2016 (Finland) | Six old coatings were tested in the field | 1. BPF, 4-NP, 4-t-octylphenol rarely found; trace concentrations<br>2. BPA was detected in majority of samples; Maximum (cold water) 250 µg/L and (hot water) 23,500 µg/L<br>3. **Older epoxy leached 4-20x more BPA than newer epoxy** |
| 2014 (France) | 3 coatings | 1. **Epoxy #3 showed increasing leaching during 5 months**<br>2. **BPA only found in absence of disinfectant, no BPF found at all**<br>3. 2,4,6-trichlorophenol (TCP), a BPA chlorination by-product sporadically observed in the chlorinated water |
| 2014 (France) | 27 old coated water tanks<br>200 old coated pipe sections | 1. TANKS: No BPA, BPF or TCP<br>2. PIPES: High frequency of BPA and BPF detection, sometimes with maximum values around 1 µg/L |
| 2009 (France) | 1 coating, 1 hr after installation | 1. Benzyl alcohol (345 µg/L), monoglycidyle ether of butane diol (12 µg/L), diglycidyl ether of butane diol (386 µg/L), diaminodiphenylmethane (72 µg/L)<br>2. Total flavor number: **6 "glue and bitter almond" to 2.5 "bitter flavor"** |
| 2007 (France) | Five 1-10 year old coatings were tested | 1. No detectable TOC<br>2. GC-MS analysis found no epoxy specific compounds resulting from 4 epoxies<br>3. 1 epoxy showed evidence of leaching of 4-t-butyl phenol (4-TBP), and the presence of halogenated 4-TBP products, with a max. 2.2 µg/L |
| 2004 (Spain) | 5 coatings | 1. BPA of 0.02-0.03 µg/cm$^2$, benzyl alcohol of up to 180 µg/cm$^2$; phthalates of 0.04-0.3 µg/cm$^2$, benzaldehyde, 4-NP, etc. |
| 2002 (Korea) | 3 coatings | 1. BPA from unit area of epoxy resin coating was in the range of 1.68 to 1,734 µg/m$^2$<br>2. Higher risk of BPA leaching to drinking water during a summer season<br>3. **Microbial growth was higher** with epoxy than in a stainless steel tank |

# In Summary: Epoxy Created Inside Water Infrastructure

**In the USA and Canada**

- There has been wide variability in chemical leaching from across NSFI 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

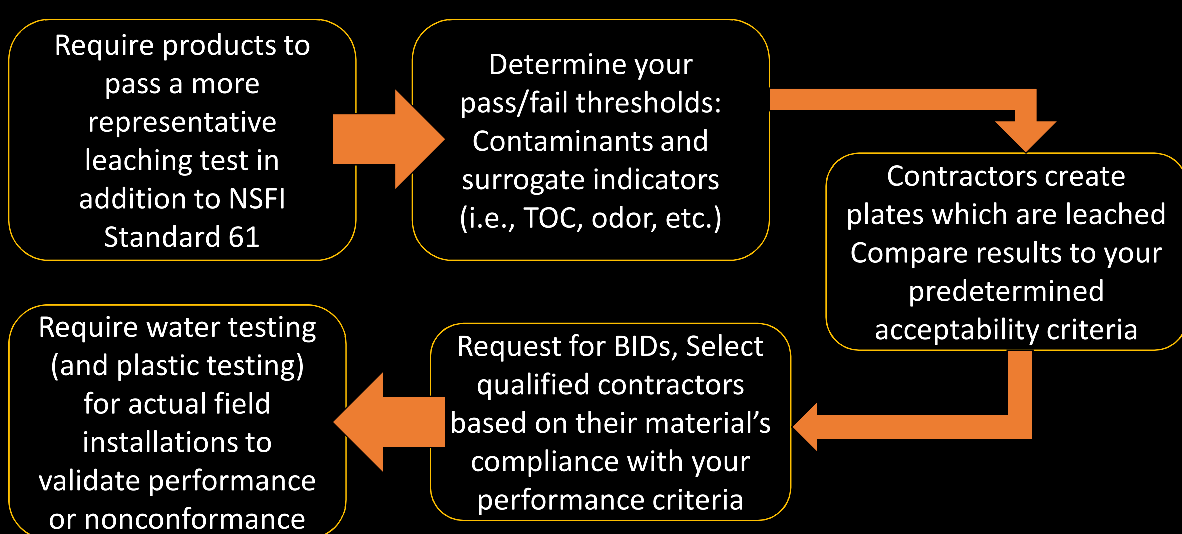
There is very little information available about chemical leaching from epoxy materials used for drinking water pipes and tanks

*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…



# Thank you.

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