Drinking Water Quality Impacts of Cured in Place Pipe (CIPP) Lining

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What?

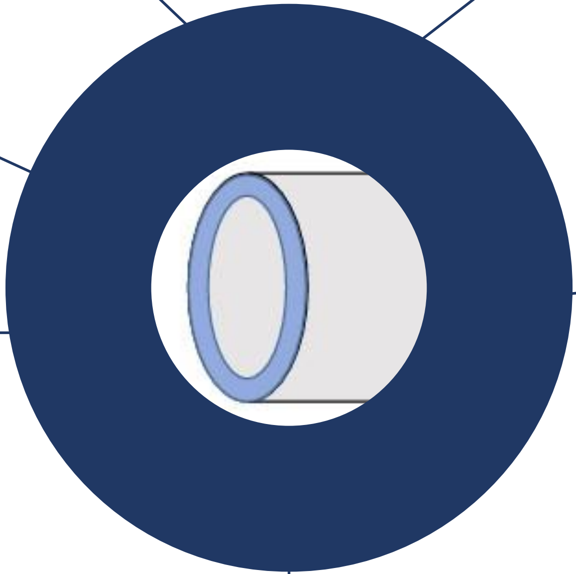
Trenchless pipe rehabilitation

How?

Insert a resin soaked felt liner into the pipe and cure using steam, heat, UV, or ambient conditions

Why?

Less disruption, Efficient, & Lower cost



Applications?

Typically used in sewer and stormwater pipes. **Epoxy resin-based CIPP** mostly used for **potable water.**

Guidelines?

AWWA Mfg. Std. C623-21

AWWA Manual M28

Market Overview:

$2.8 B market globally; 5% CAGR; Est. 2028 forecast to be $3.8 B

Epoxy resin < 1% of the CIPP projects

A Utility Case Study: Epoxy CIPP for Water Mains

Followed AWWA standard C651

Flushed water was milky white foamy

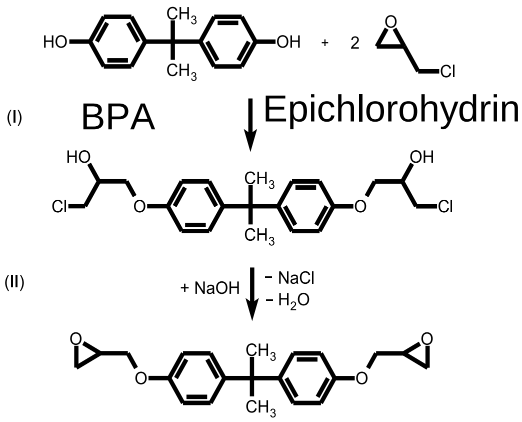
Four epoxy CIPPs installed; CAN/ANSI/NSF/ NSF-61 certified

Many flushing’s required

The wastewater utility <u>would not</u> accept the flushed water

Laboratory testing found chemicals present like **acetone, 2-butanone, styrene, and more**

Most Common Epoxy Resin

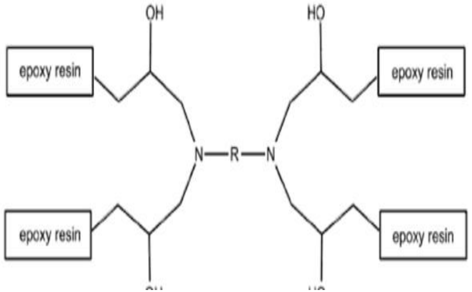


BADGE (MONOMER)

Two Ways of Polymerization

1. Homo-polymerization
   linear chain of same monomer

2. Forming co-polymer w/ hardeners (**Crosslink**)
   Phenol, triethylenetetramine, isophorone diamine, etc.



Polymerization with a diamine

Chemicals expected in the epoxy resins:

1. BPA (=SVOC)
2. Epichlorohydrin (=SVOC)
3. BADGE (=SVOC)
4. VOCs?

Manufacturer's 2023 Claim

Direct use possible after manufacture without flushing

Select Drinking Water Regulations:

Minnesota BPA limit: 20 ppb /100 ppb (chronic/short term)

EPA Epichlorohydrin: MCLG =0; MCL =TT

& More

Our review of SDSs for epoxy CIPP raw materials revealed a diversity of chemicals reported

Listed Ingredient	CASRN	Products reported on SDS documents, % unless shown otherwise									
		A	B	C	D	E	F	G	H	I	J
Polyamides	63428-83-1				>80						
Bisphenol A reaction product	25085-99-8			<85							
Epoxy resin	25068-38-6						50-80	40-70	50-80	10-30	10-30
4,4’-Isopropylidenediphenol-epichlorohydrin copolymers	25068-38-6	55-90									
Fatty acids, C18-Unsatd., dimers, reaction products with polyethylenepolyamines	68410-23-1		30-65								
Teta, reaction products with phenol and formaldehyde	32610-77-8					40-70					
Triethylenetetramine	112-24-3		30-50			15-40					
Phenol	108-95-2					15-40					
Benzyl alcohol	100-51-6				<15						
Polyglycol diglycidyl ether modifier	74398-71-3							5-15			
Polyfunctional glycidyl ether modifier	26142-30-3									5-15	5-10
Polyglycol diglycidyl ether	26142-30-3						5-15		5-15		
2-Ethyl hexyl glycidyl ether (EHGE)	2461-15-6			>10							
Xylene	1330-20-7									<7	7-13
Isophoronediamine	2855-13-2				>5						
Epichlorohydrin	106-89-8	3-4ppm									
Carbon black	1333-86-4						<2		<2		
Acetone	67-64-1									<1	
Petroleum distillates	64742-47-8			<1							
Adhesion promoter	Not reported									<1	

Our study goal: To better understand the chemicals used and released from drinking water CIPPs

Questions:

1. What chemicals are found in and leach out from new epoxy CIPPs?
2. How do manufacturing conditions impact CIPP drinking water impacts?
3. Do “VOC-free” epoxy resin and hardeners contain VOCs?

Material Type	Resin: Hardener Ratio	Rec. Cure Time	Rec. Cure Temp.	Total List of SDS Ingredients
Resin	-	-	-	75-80% Bisphenol-A Epichlorohydrin Epoxy Resin 10-20% [[(2-ethylhexyl)oxy]methyl]oxirane 1-5% Silicon dioxide, chemically prepared
Hardener 1 (Normal Drying)	4:1	3.5 hours (3-4)	130°F	>80% Polyamides <15% Benzyl alcohol >5% Isophorone diamine
Hardener 2 (Quick Drying)	2:1	2 hours	130°F	55-65% reaction products with phenol and formaldehyde 15-20% Triethylenetetramine 15-20% Phenol

We created CIPP composites under 3 conditions:

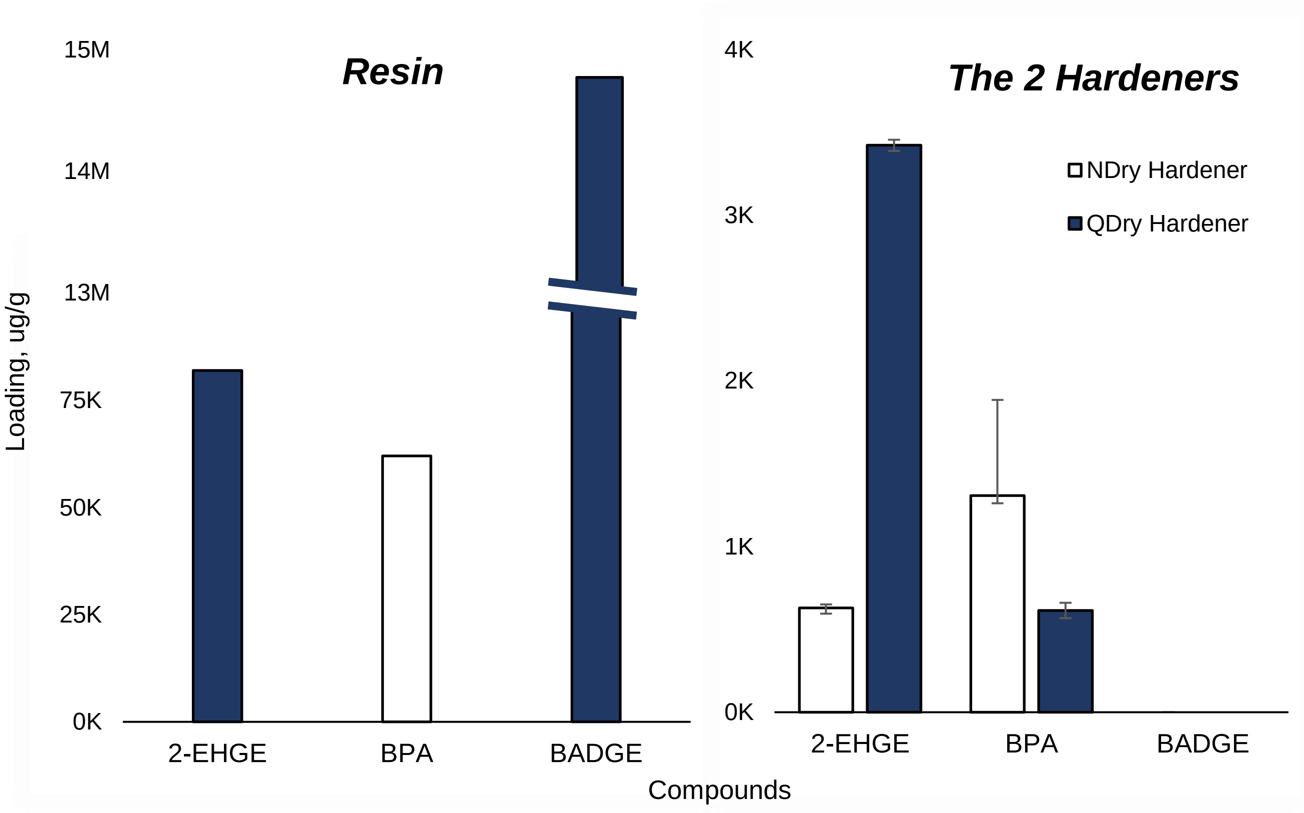
Standard Mfg | 10% Less Time | 5% Less Hardener

CIPPs were exposed to drinking water for 24 hr → 24 hr → 24 hr → 72 hr

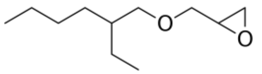
The CIPPs and drinking water were characterized using a variety of methods

1. GCMS (Gas Chromatography Mass Spectrometry)
2. TOC (Total Organic Carbon) analyzer for water analysis
3. TGA (Thermogravimetric Analysis) for CIPP characterization
4. PID (Photoionization Detector) for air monitoring

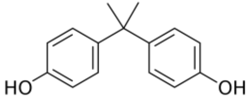
As expected BADGE was present at a high loading in the resin, but BPA and 2-EHGE were present too



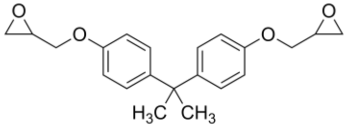
2-EHGE = Viscosity reducer



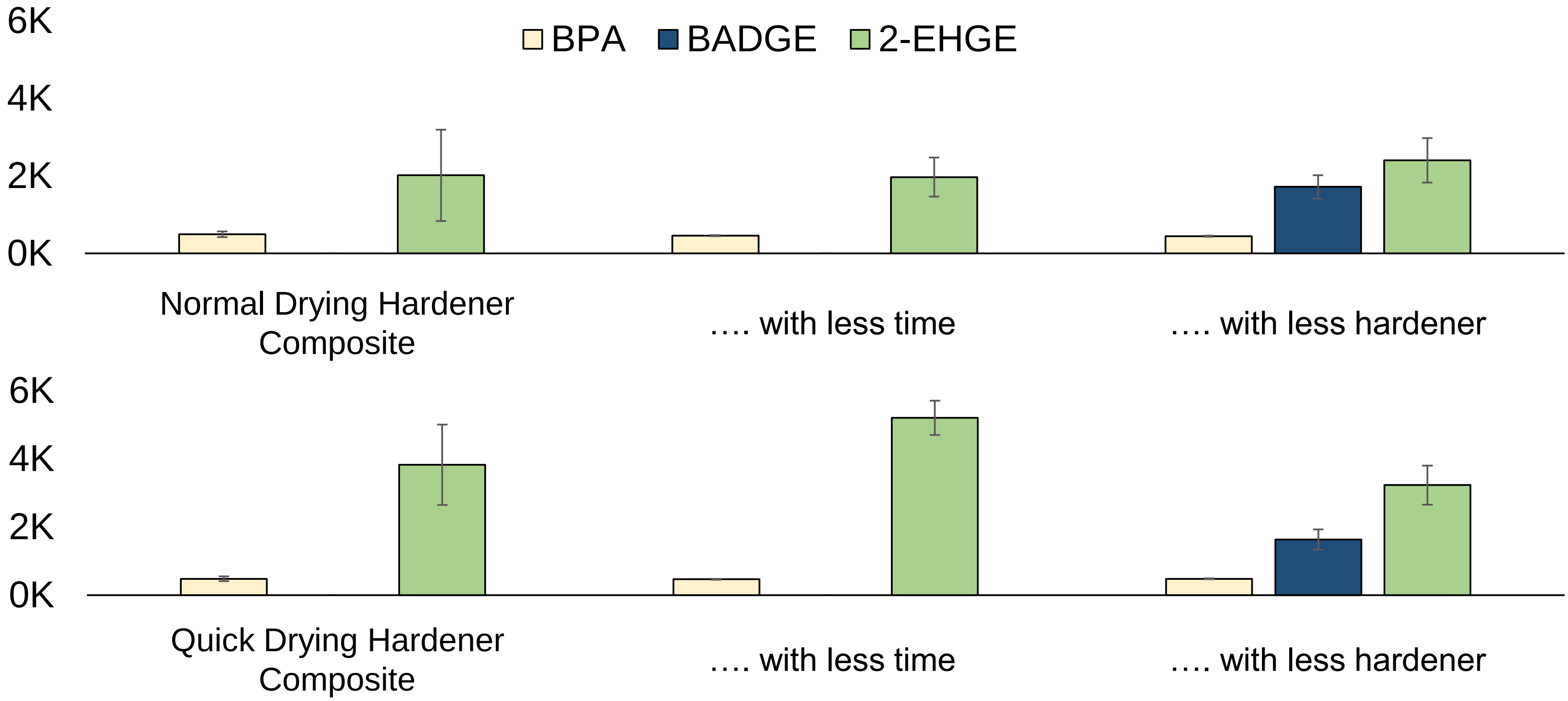
BPA = Reactant to create monomer



BADGE = Monomer



The quick dry CIPPs (with less time) had a much greater 2-EHGE loading than normal dry CIPPs. BADGE remained when hardener amount was not adequate.



Several tentatively identified compounds (TICs) were found in the raw materials and CIPPs. Fewer TICs were found in the CIPPs

Area	Uncured Materials			Epoxy CIPP Composites	
	Resin	Standard Dry Hardener	Quick Dry Hardener	Standard Dry Hardener	Quick Dry Hardener
>100K	14	33	27	9	17
>300K	8	24	19	3	9
>500K	6	16	18	2	5
>1M	3	11	15	2	5
>5M	2	7	10	1	2
>10M	2	3	6	1	1

TICs include, but are not limited to:

Heptane

Pentadecane

1-Butanol

2 Ethyl hexanol

Phenol

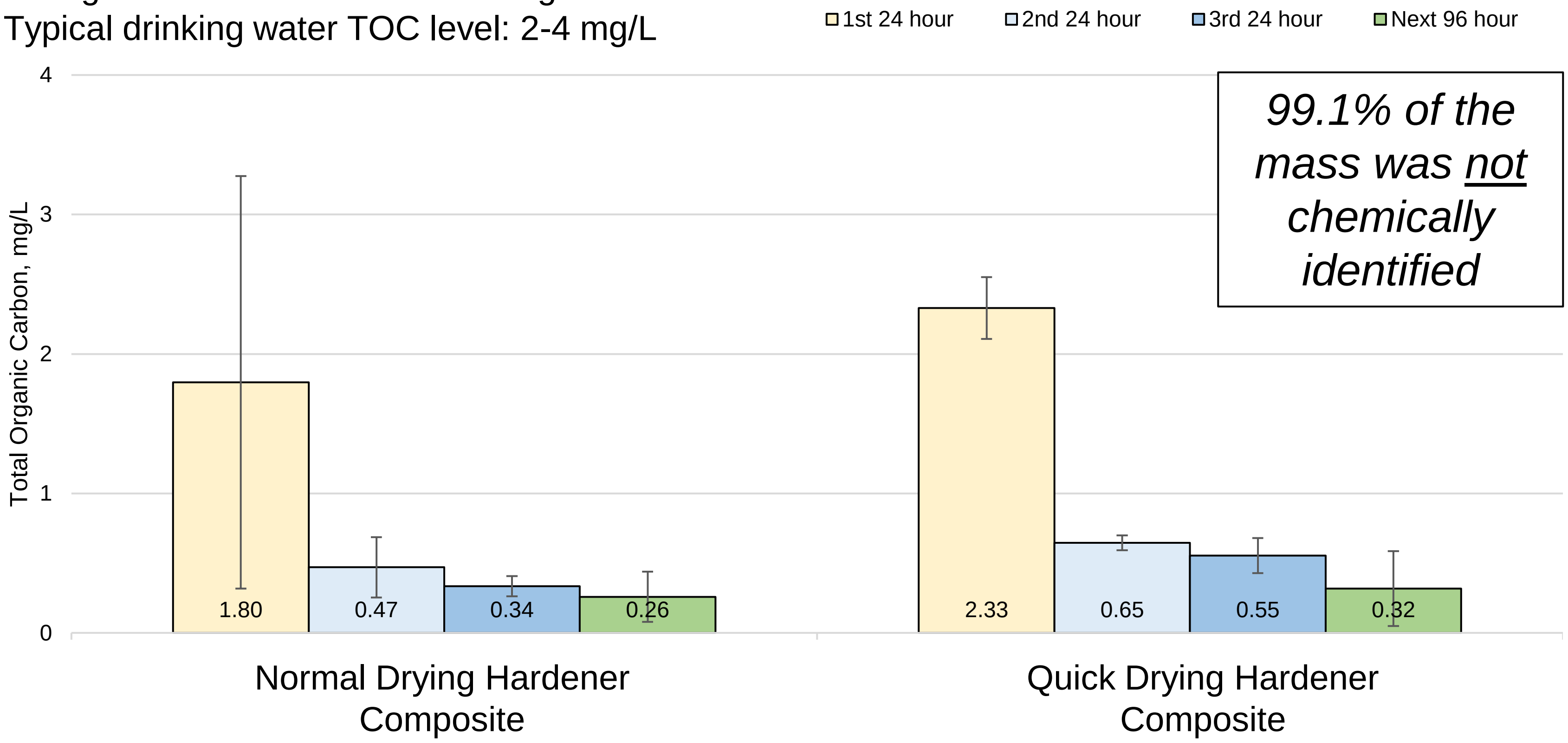
o-Cresol

p-Cresol

& More

The CIPPs released a notable amount of carbonaceous material into drinking water

Background TOC level was 0.09 mg/L
Typical drinking water TOC level: 2-4 mg/L

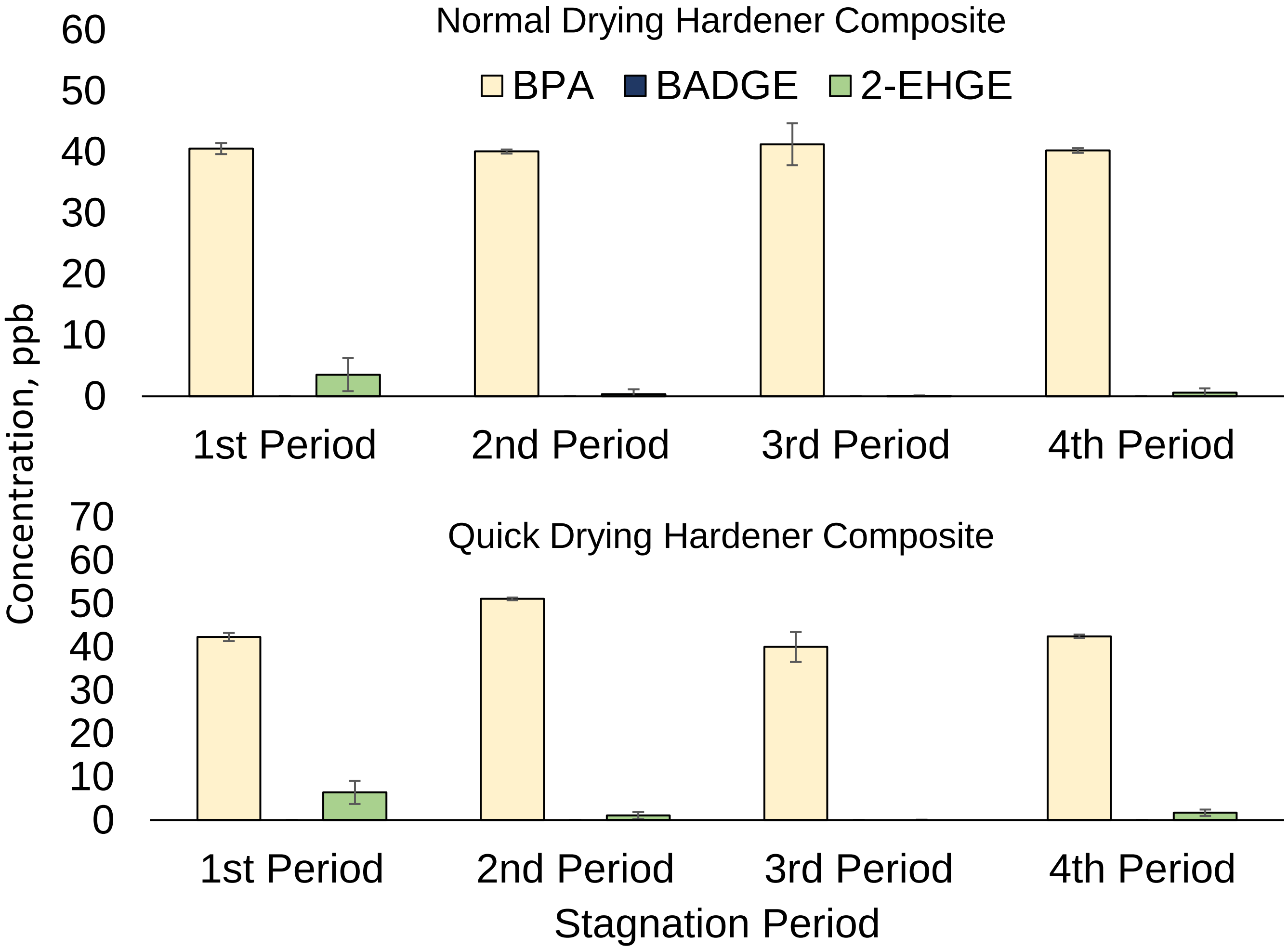


99.1% of the mass was not chemically identified

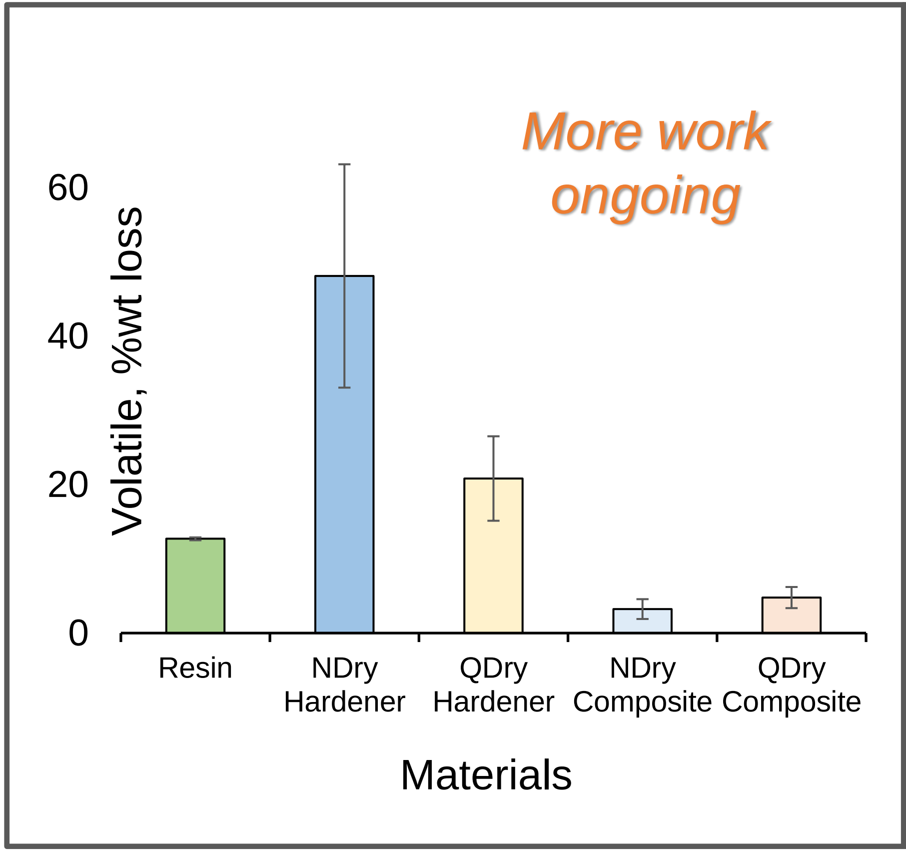
CIPPs leached BPA and 2-EHGE into drinking water during stagnation

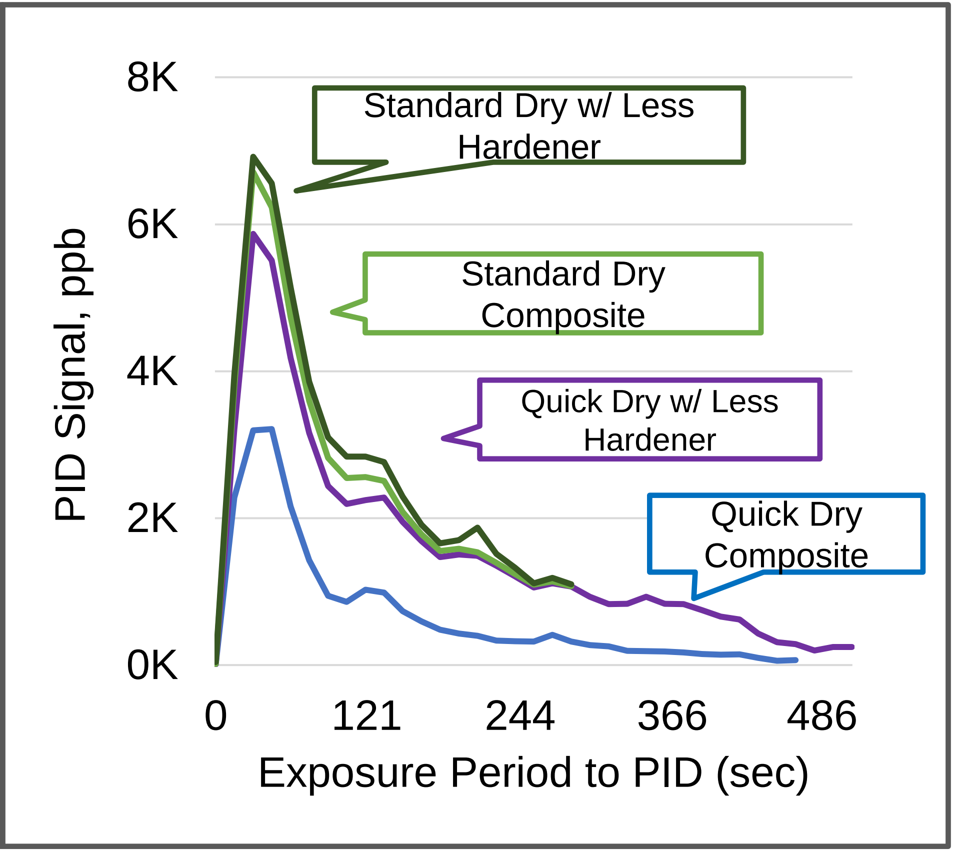
No apparent aqueous concentration differences found across CIPPs

BADGE was not detected



TGA and PID data indicated that CIPPs contained VOCs and VOCs were released into air





When leaching results were scaled, smaller diameter CIPPs were found to exceed drinking water exposure limits, ppb

Compound and CIPP Type		Concentration for the 1st (3rd) and 4th Stagnation Period and Water Main Pipe Diameter, Inches					Drinking Water Health-Based Exposure Limits			
		36	24	12	6	4	WHO	EU	Minnesota (Long-term, Short-term)	NSFI 61 (SPAC/TAC/STEL)
BPA	NDry	3 -3- 3	5 -5- 5	10 -10- 10	20 -20- 20	30 -30- 30	1	2.5	20/ 100	10/ 100/ 200
	QDry	3 -3- 3	5 -5- 5	10 -10- 10	21 -20- 21	31 -29- 31				
2-EHGE	NDry	0 -0- 0	0 -0- 0	1 -0- 0	2 -0- 0	3 -0- 0	-	-	-/-	0.3/ 3/ 10
	QDry	1 -0- 0	1 -0- 0	2 -0- 0	3 -0- 1	5 -0- 1				
TOC	NDry	0 -0- 0	0 -0- 0	0 -0- 0	1 -0- 0	1 -0- 0	-	-	-	-
	QDry	1 -0- 0	1 -0- 0	2 -0- 0	3 -0- 0	5 -0- 0				

Observations and Conclusions

The SDSs did not list all chemicals in the resin and hardeners

- Resin contained 2-EHGE (VOC, not listed), BPA (SVOC, not listed), and BADGE (SVOC)
- There were many TICs in the raw materials: Resin (14), Standard Hardener (27), Quick Dry Hardener (33)

New CIPPs contained a variety of extractable organic compounds, and their loading was sometimes influenced by manufacturing conditions

- 2-EHGE, BPA, and TICs were extracted from the CIPPs
- Less curing time and less hardener conditions prompted different residuals in the new CIPPs

Chemicals in the CIPPs leached into drinking water

- 2-EHGE and BPA were leached by both CIPP types, but concentrations were not different.
- TOC monitoring had limited usefulness. >99.1% of carbon mass was not identified

Implications and Recommendations

-VOCs- were in the CIPPs and were released into air

- ❑ Resin is marketed as 100% solids but *does contain* VOCs
- ❑ Some consultants advertised epoxy CIPP as VOC free to utilities (Whelton experience)
- ❑ Epoxy CIPPs are created with VOCs, that remain in the CIPPs and can leach out

Info available underscores the need for careful consideration

- ❑ Potential impact of CIPPs on drinking water quality increases with smaller pipe diameters
- ❑ Repeated stagnation and flushing cycles can remove leachable chemicals
- ❑ Unclear how the diversity of resins, hardeners, and manufacturing differences influence SHORT- and LONG-term drinking water quality performance (microbial, DBPs, etc.)
- ❑ Standard USEPA methods will not detect many of the CIPP leached chemicals
- ❑ Testing recommended for all new CIPP installations. Formal studies recommended too.
- ❑ The toxicity of waste from steam epoxy CIPPs has gone unstudied.

Thank you

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www.PlumbingSafety.org
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