Lessons Learned from a 3 Year DOT Study for Cured-in-Place-Pipe (CIPP) for Storm Water Applications: Safety and Environmental Protection





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Visit www.CIPPSafety.org for more information

SESSION OUTLINE

1. Plastic composites 101
2. CIPP materials, process, wastes
3. Best CIPP construction practice

Wednesday February 5, 2020

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What are fiber reinforced polymer composites (FRPCs)?

- Composites materials are made by combining two materials where:
  - ❖ One of the materials is a reinforcement (fiber)
  - ❖ The other material is a matrix (resin).
- Fibers: glass fiber (fiberglass), carbon fiber, aramid, and polyester.
  - The fibers come in veil mat, short fiber mat, woven cloth, unidirectional tape, biaxial cloth or triaxial cloth.
- Resins: Typically thermoset resins such as polyester, vinyl ester, epoxy, polyurethane and phenolic.
  - The resins start as a liquid and polymerize during the cure process and harden.

FRPCs are high performance materials that are much higher cost than other structural materials

However, in construction, FRPCs have been considered as substitute for traditional civil engineering materials, namely concrete and steel.

This because FRPCs are:

- Lightweight and non-corroding (polymer based)
- Exhibit high specific strength and specific stiffness (due to fibers)
- High durability (due to matrix)
- Can be tailored to satisfy performance requirements
- Are easily constructed, therefore cheap for low run size

Formula cars vs production cars!

Properties of CIPP are dependent upon many factors

Fiber type

Glass Fiber

- Advantages: Low cost, High strength, Moderate stiffness,
- Disadvantage: High density, Low fatigue resistance, Stress corrosion, brittle

Staple Polymer

- Advantages: Extremely low cost, High toughness, Low density
- Disadvantages: Low stiffness, Low strength, low temp, poor solvent

Fiberglass represents > 90% of the reinforcements used in infrastructure applications

Resin type

Unsaturated Polyester

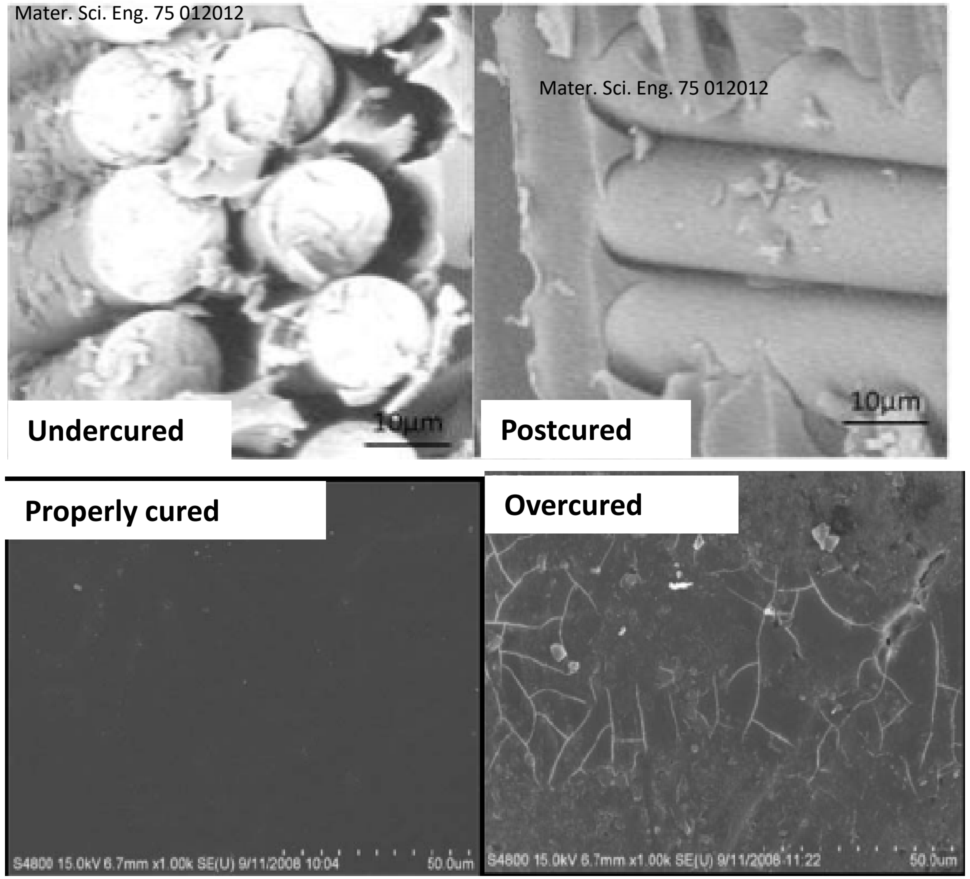
- Cheapest resin
- Multiple types (Ortho- vs Iso-)
- Thermal (peroxide), Redox (MEKP), or UV (Irgacure) radical cure
- Good water performance
- Safety Issues:
  - Diluted 30-60% in reactive solvent (styrene)
  - Some initiators are explosive
  - Can be composed of Phthalates

Epoxy

- Most expensive
- Best performance
- No reactive solvent
- Many types (BPA, BPF, CA)
- Can have poor water performance
- Safety Issues:
  - Has BPA
  - Can contain amines (hardeners)

Curing issues in FRPC

- The curing process plays a major role in achieving the final mechanical properties
- Aerospace industry has complicated time/temperature/pressure profile to reduce porosity and improve cure
  - Increases crosslink density, so T_g and strength increases
  - Can post-cure to improve properties
- Many possible issues with curing
  - Undercuring: Lack of complete reaction. Lowers Tg and strength and leaves residual monomer
  - Overcuring: Causes chain-scissioning, matrix cracking and debonding at fiber/matrix interface. Lowers Tg and strength. Similar to UV exposure.
  - “Overtemp” (not a real term): can heat too high
    - Thermal runaway
    - Flash off monomer (styrene)
    - Cause too fast initiator (catalyst) decomposition



http://etd.fcla.edu/CF/CFE0002406/Tipton_Bradford_R_200812_MSME.pdf

Trying to speed up curing, or “force” complete cure will cause issues – If hot is good, hotter is not better!

There are “free” small molecules in FRPCs after curing

- Impossible to achieve 100% cure in a thermoset
  - Highly dependent upon cure temperature, schedule and type
- Residual organic compounds will be leached out over time and may change mechanical properties of the composites.
  - Monomers such as amines (for epoxy resin), and styrene (for unsaturated polyester or vinyl ester resin) remain unreacted due to diffusion limitations
    - Composites will change properties over time and pick up water as monomer leaves.
  - Plasticizers and additives such as butylated hydroxytoluene, 1-tetradecanol, diethyl phthalate are used to impart specific properties of the composites.
    - Composites will become embrittled over time as additives are depleted.
  - Oxidation and degradation products of monomers, polymers, and initiators/catalysts remain.
- Commonly 1-6% residual monomer in UPR/VE
  - Quick calculation: L=10m, D=1m, T= 10cm, 50% resin, 1% residual monomer = ~14Kg
  - However, after initial burst from surface, monomer comes out over years.

CFRP production can pose issues to fabricators

- Three main areas of concern: fiber handling, cutting/sanding, and resin use
- Fiber handling: mostly fiber skin penetration
- CFRP cutting: breathable dust, eye irritation.
  - 2016:   "OSHA Issues $47k in Penalties to Manufacturer of Fiberglass Boats For Exposing Georgia Employees to Serious Hazards" (Hansford Lawfirm)
- Resin Use:
  - Exposure to monomers (styrene from vinyl ester and polyester)
  - Environmental emissions (VOC)
  - Flammability concerns (redox initiators and brass/steel fittings, etc)

Styrene emissions were a huge issue for bathtub and boat manufacturers

- Large scale FG manufacturers were forced to change procedures due to lawsuits and regulations
  - OSHA, EPA, DHHS all issued reports regarding styrene release
- Possible solutions:
  - Industrially, proper ventilation, such as a push/pull ventilation system is necessary to remove styrene from the work area
    - Lasco Bathware $2M investment 2008 to meet clean air standards (reduced emission by ~250,000 tons/year)
  - High transfer efficiency spray guns for gel coating applications
  - Reduced styrene content in resin
  - Styrene substitution with a less volatile monomer, such as p-methyl styrene
  - Vapor suppressant
- Controls reduce exposure below threshold limits, still concerns about chronic exposure

1. Industrially, ventilation/emissions control is necessary
2. Proper PPE are needed (especially for small fabricators)

What about Performance?

- There is a difference between manufacturing defects and aging (not discussing physical assaults such as earthquakes, etc)
  - Manufacturing defects are typically related to curing but can also be too much resin bleed, porosity, pinholes and poor interlaminar adhesion.
    - Poor curing will weaken material, but even if fully cured, poor interlaminar shear strength can cause failure under load.
  - Aging is also possible – polymers (such as composites) gradually lose properties in the environment.
    - Chemical attack- solvents but also water.
    - Oxidative – thermooxidative (ie time) and photooxidative (light)

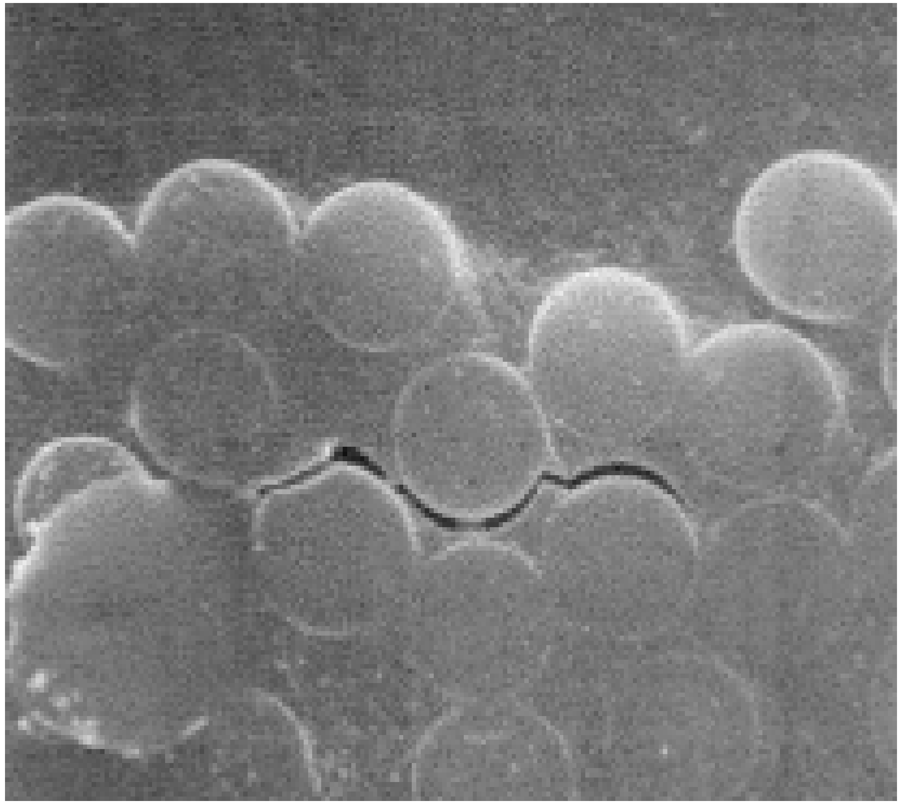
Oxidative aging is typically seen in “old” materials

- Rubber “dry rot”, cracking of vinyl, breakage of plastic in light fixtures, yellowing of finishes near windows, etc, are all examples of oxidative aging.
- Oxidation causes chemical changes, chain scissioning, and cross-linking leading to weakening, embrittlement and discoloration.
- Highly time dependent but accelerated by heat, oxidants and light
  - In typical exterior environments, photoxidation is main culprit
  - Photooxidation depth is dependent on transparency of material
  - Most resins use a complex package of antioxidants/photostabilizers to extend lifetime

Photo of a Nylon bag under a deck for ½ summer showing light induced aging

In CIPP, chemical attack is most likely by Water

- Hygrothermal aging of composites can be important in wet environments
  - Water molecules diffuse into composite
    - Depends on hydrophobicity of resin and residual monomer that is leached out
  - Moisture can
    - increase creep and relaxation
    - induce stresses causing interlaminar failure
    - degrade polymers, fibers, and fiber/matrix interfaces
    - Moisture can accelerate fatigue degradation of composites,
    - Moisture can initiate localized cracking of matrix.
  - pH and Salinity can have an effect
    - Acid, Base and Salt tend to accelerate degradation
    - Contact with decaying organic matter, concrete pore solution and deicing salts may be a problem over the long term



Construction and Building Materials 48 (2013) 360–370

Main take-homes for Aging

1. Time always wins!
   - Not a question of <u>if</u> aging failure will happen, but <u>when</u>.
2. Aging can be long process (years to decades) so it is hard to test for
   - So we use <u>Accelerated Aging</u>
3. Accelerated Aging is highly system dependent (depends on material, application (conditions), time-scale, and model used.
   - There are <u>>2000 ASTM</u> standards for Accelerated Aging in polymers!
4. Vini, Vidi, Validation.
   - Need validation against real world/real time performance.

Overall, there is a general lack of peer-reviewed public aging studies on CIPP

Manufacturing CIPP Plastic Outdoors: Materials, Processes, and Wastes

Yoorae Noh
Purdue University

02.06.2020

Indiana LTAP Stormwater Drainage Conference

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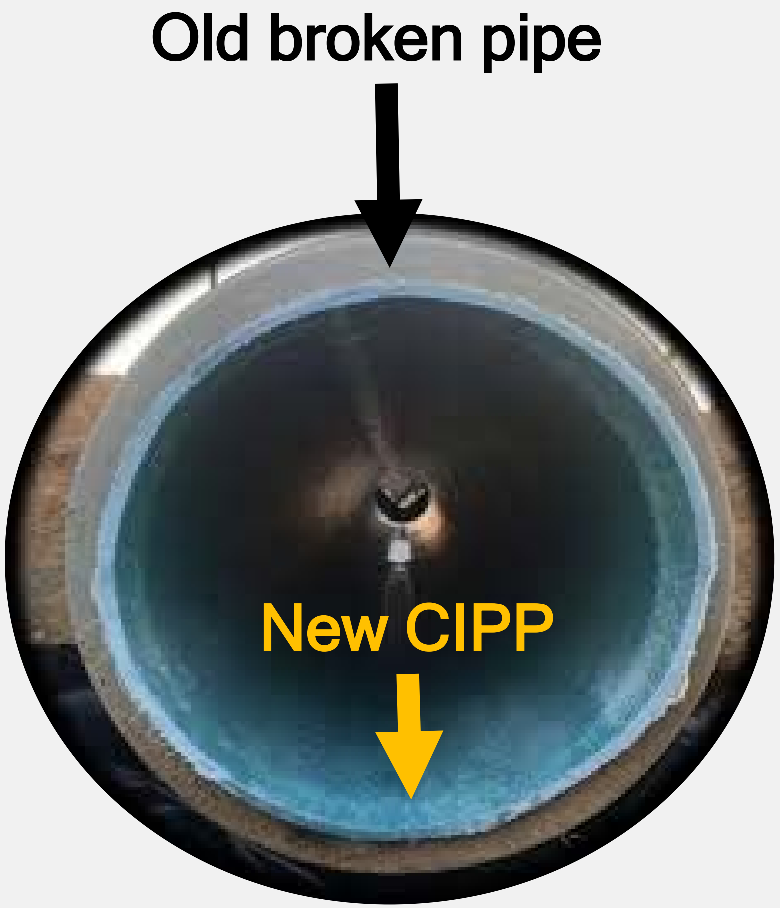
WHAT are Cured-In-Place-Pipes (CIPPs) ?

- The process chemically manufactures a new plastic pipe inside an existing damaged pipe
- Advantages: Do not dig up existing pipe, little to no traffic shutdowns, can be less expensive than other repair alternatives
- Raw chemicals and materials are brought onsite to manufacture the plastic outdoors



WHERE is CIPP manufacturing applied?

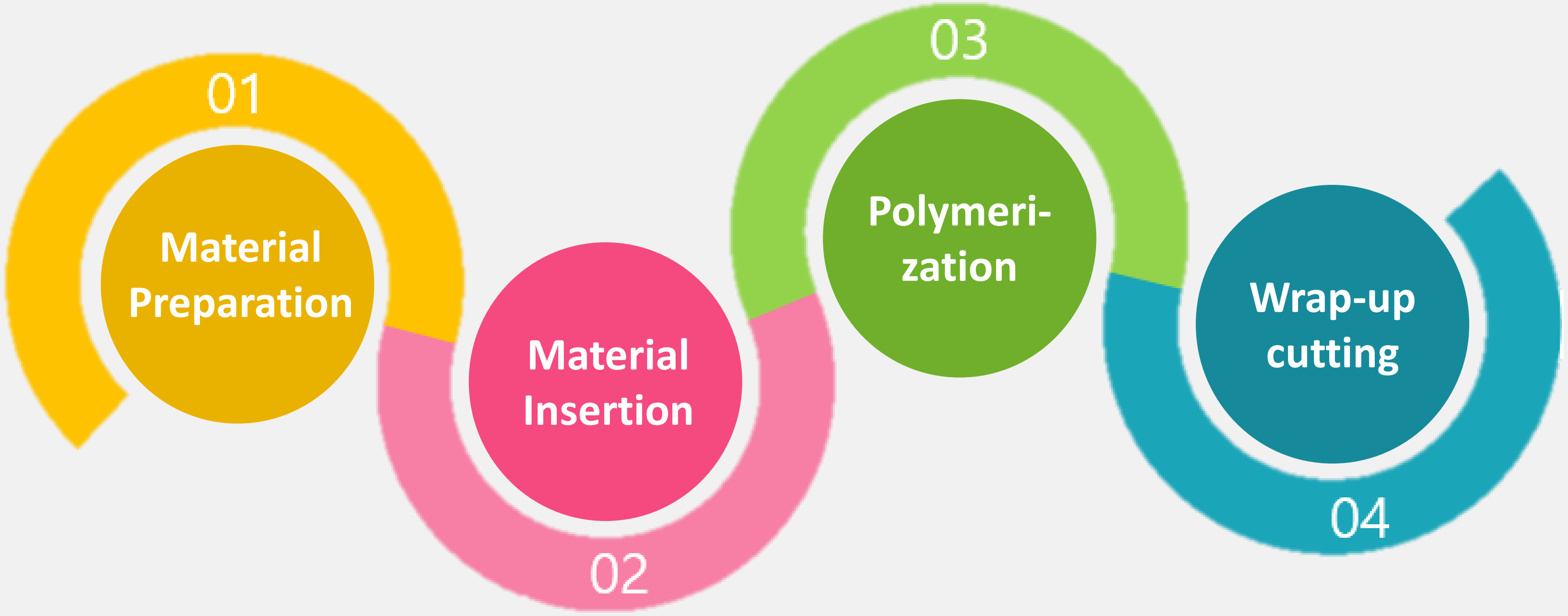
- Sanitary sewer, storm sewer, potable water, industrial water
- A new plastic CIPP has a suspected 50 year design life
- Common Practice: Wastes are discharged to the environment

Within neighborhoods

Next to roadways

Purdue research at CIPP worksite

HOW is a CIPP created onsite?



Step 1. Prepare Materials

- Uncured resin
- Initiators, felt, plastic films and coatings, filters, and reinforcements

* Styrene-based resins, such as polyester and vinyl ester, are the most popular

Step 2. Material Insertion

- Flexible tube containing raw chemicals is inserted into the damaged culvert.

Step 3. Polymerization

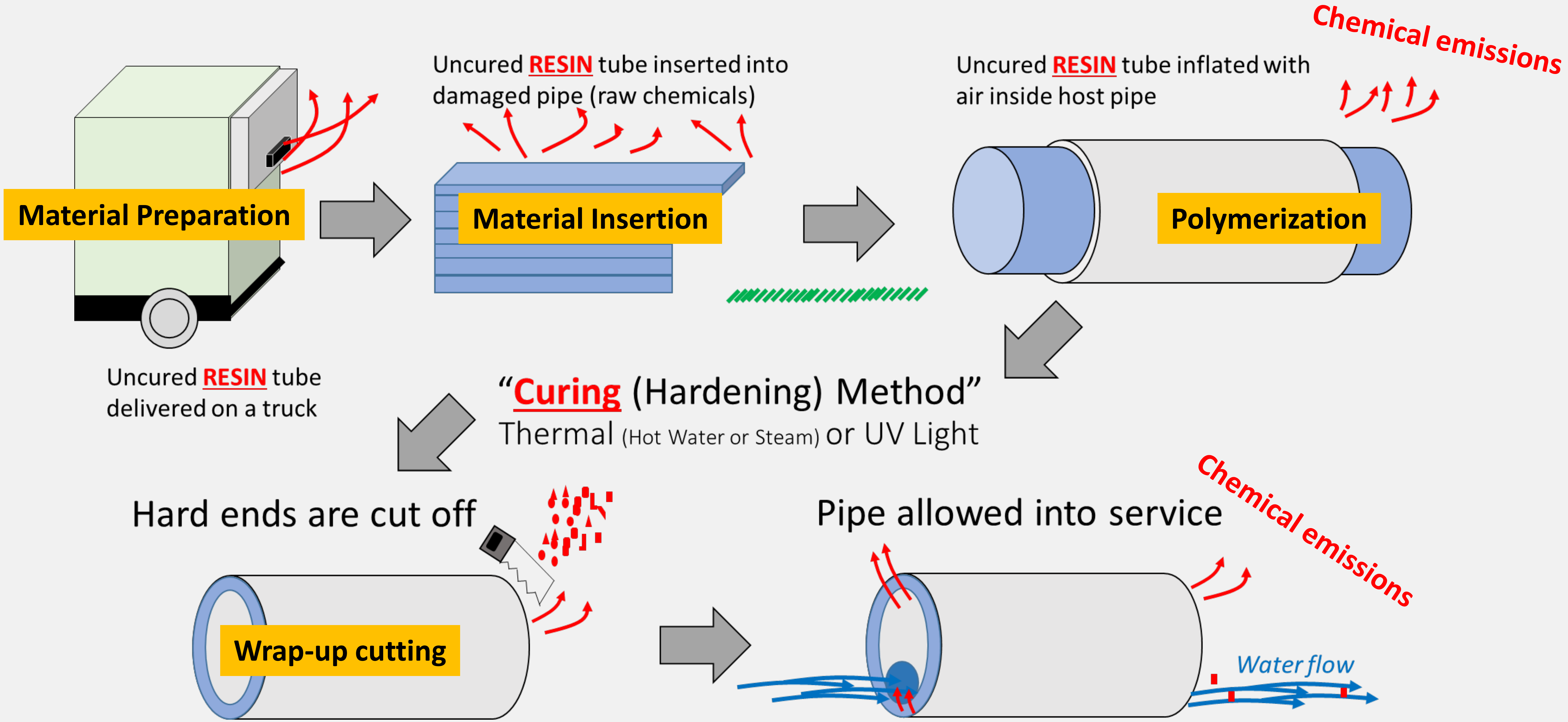
- Thermal (hot water, steam) or photo (UV light) curing

* Steam method is the most popular U.S.

Step 4. Physically cuts

- The ends of the hardened plastic are mechanically removed
- The new CIPP pipe is placed into service

Here's WHAT CIPP manufacture it looks like



WHAT actual chemicals are used?

Real SDS of the Resin for storm water culvert repair in NY site
(Safety Data Sheets)

- Styrene
- Irgacure ® 819
- Irgacure ® 651

Actual chemical composition of a resin

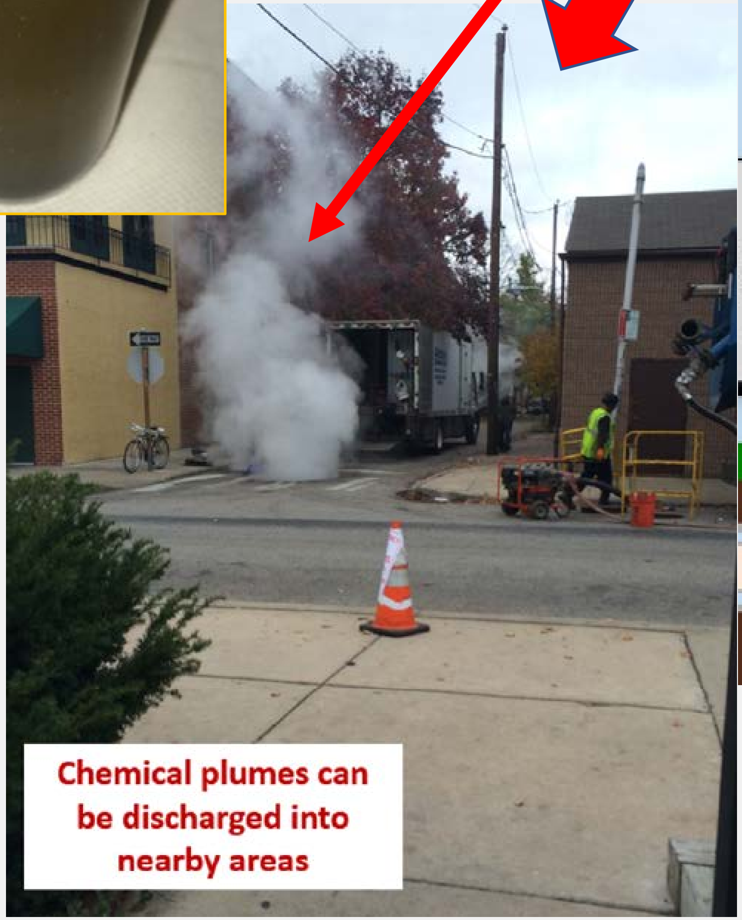
Li et al., 2019

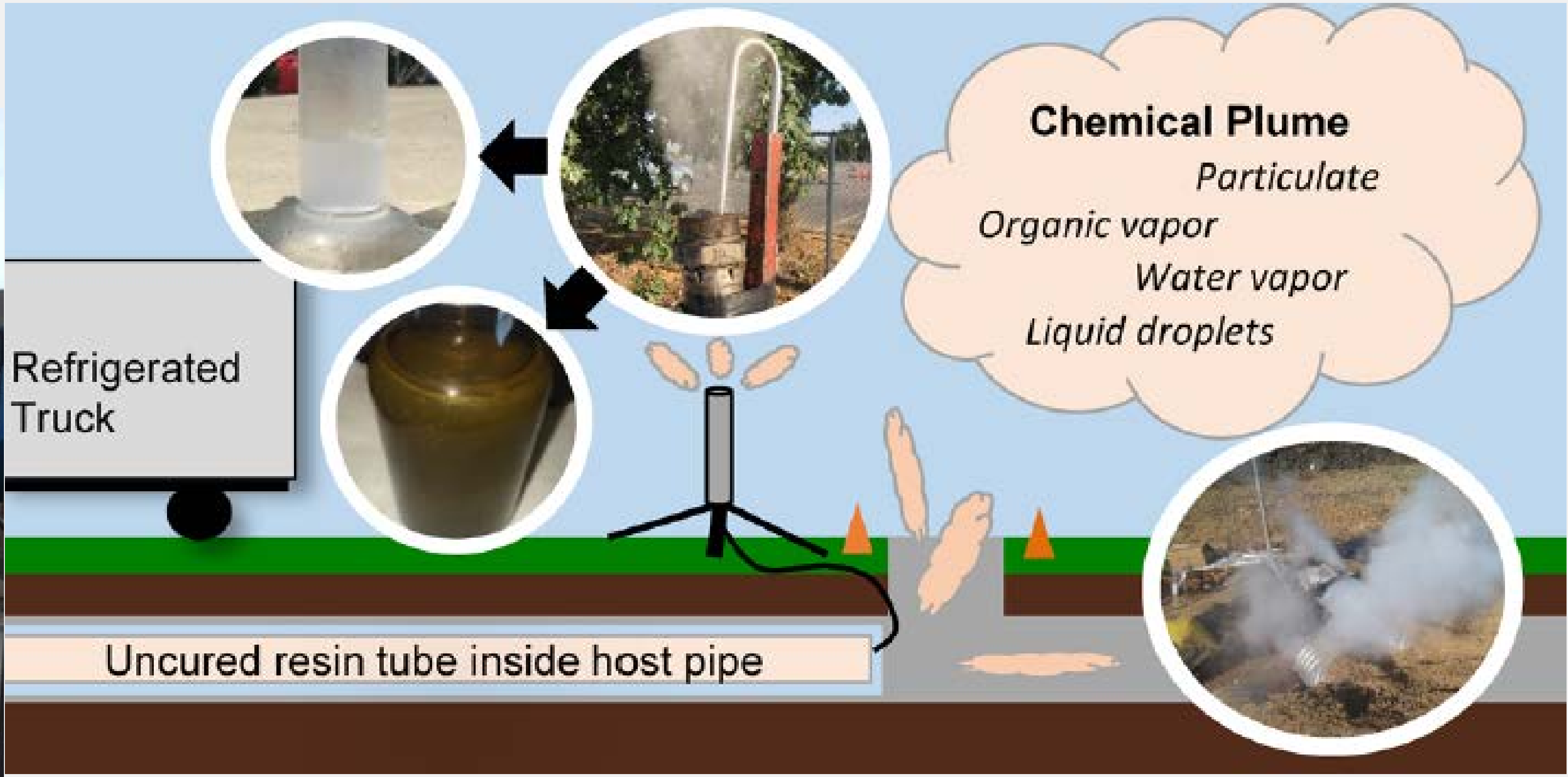
Chemical compounds	Note
Irgacure ® 184	Photo-initiator
BADGE (bisphenol a diglycidyl ether)	Common oligomer; endocrine disruptor
Maleic anhydride	HAP (Hazardous air pollutant)
Phthalic anhydride	HAP
Benzaldehyde	-
Styrene oxide	HAP; human carcinogen
Isopropylbenzene	Human carcinogen
Styrene	HAP; human carcinogen
Xylenes	HAP
… and + 70 other chemicals	-

Not all chemicals onsite listed on MSDS,
yet some have environmental and human health risks

WHAT materials are discharged into air?

This is a Multiphase Chemical Mixture, NOT Steam
(particulates, droplets, partially cured resin, etc.)

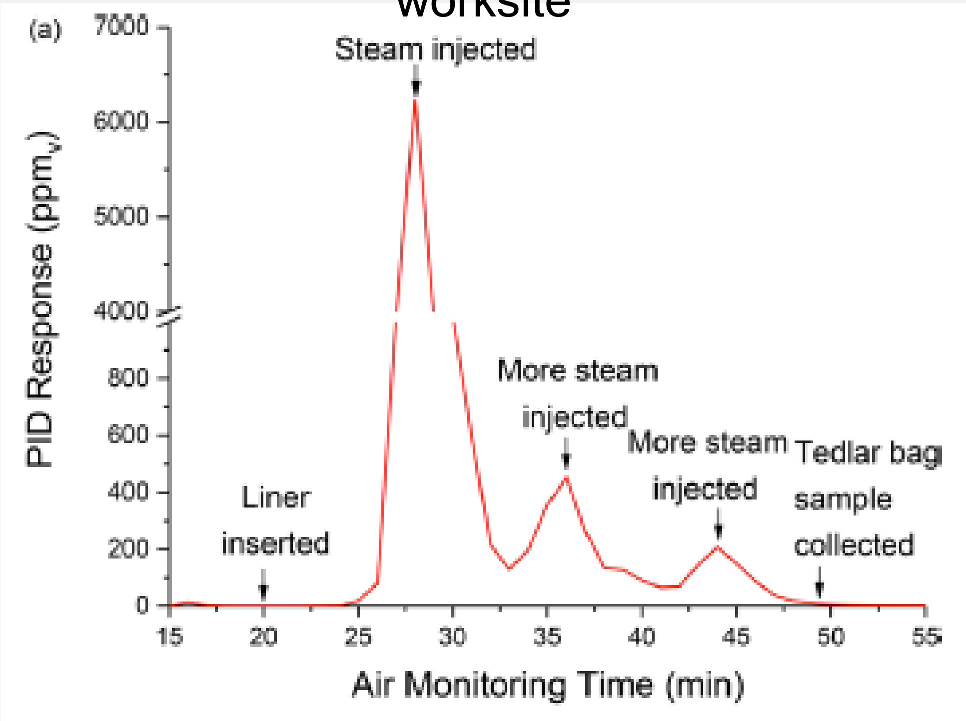




Seyedeh Mahboobeh et al., 2017

WHAT materials are discharged into air?

PID air monitoring result in IN CIPP worksite



Seyedeh Mahboobeh et al., 2017

*Investigators speculated that styrene caused the PID response

In addition to **Styrene** [a,b,c], other chemical compounds were detected

Acetone	4-(1,1-Dimethyl) cyclohexanol
Acetophenone	4-(1,1-Dimethyl) cyclohexanone
Benzaldehyde	1-Dodecanol
Benzene	Ethylbenzene
Benzoic acid	3-Heptanol
BHT	Isopropylbenzene
tert-Butyl alcohol	*p*-Isopropyltoluene
tert-Butyl benzene	Methylene chloride
4-*tert*-Butylcyclohexanone	*N*-Propylbenzene
4-tert-Butylcyclohexanol	Phenol
Chloroform	1-Tetradecanol
o-Chlorotoluene	Toluene
Diallyl phthalate (DAP)	1,2,4-Trimethylbenzene
Dibutyl phthalate (DBP)	1,3,5-Trimethylbenzene
Diethyl phthalate (DEP)	Xylene (total)
Di(2-ethylhexyl) phthalate (DEHP)	And more…

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WHAT materials are discharged into air during the manufacturing?

In addition to **Styrene** [a,b,c], other chemical compounds were detected

~~Acetone~~	~~4-(1,1-Dimethyl) cyclohexanol~~
~~Acetophenone~~	~~4-(1,1-Dimethyl) cyclohexanone~~
Benzaldehyde	~~1-Dodecanol~~
~~Benzene~~	~~Ethylbenzene~~
~~Benzoic acid~~	~~3-Heptanol~~
BHT	~~Isopropylbenzene~~
~~tert-Butyl alcohol~~	~~*p*-Isopropyltoluene~~
~~tert-Butyl benzene~~	~~Methylene chloride~~
~~4-*tert*-Butylcyclohexanone~~	~~*N*-Propylbenzene~~
~~4-tert-Butylcyclohexanol~~	~~Phenol~~
~~Chloroform~~	~~1-Tetradecanol~~
~~o-Chlorotoluene~~	~~Toluene~~
~~Diallyl phthalate (DAP)~~	~~1,2,4-Trimethylbenzene~~
~~Dibutyl phthalate (DBP)~~	~~1,3,5-Trimethylbenzene~~
~~Diethyl phthalate (DEP)~~	Xylene (total)
~~Di(2-ethylhexyl) phthalate (DEHP)~~	~~And more…~~

Only Styrene, benzaldehyde, BHT, and xylene were detected in the uncured resin tubes

Non-styrene compounds were likely created during curing and other manufacturing process

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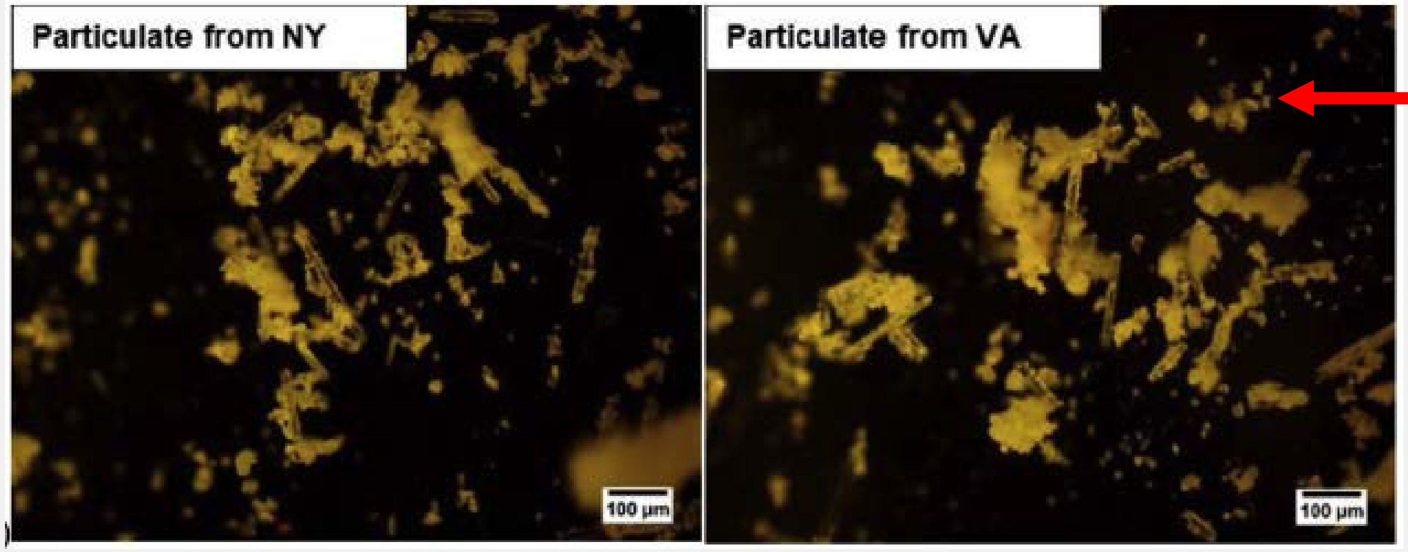
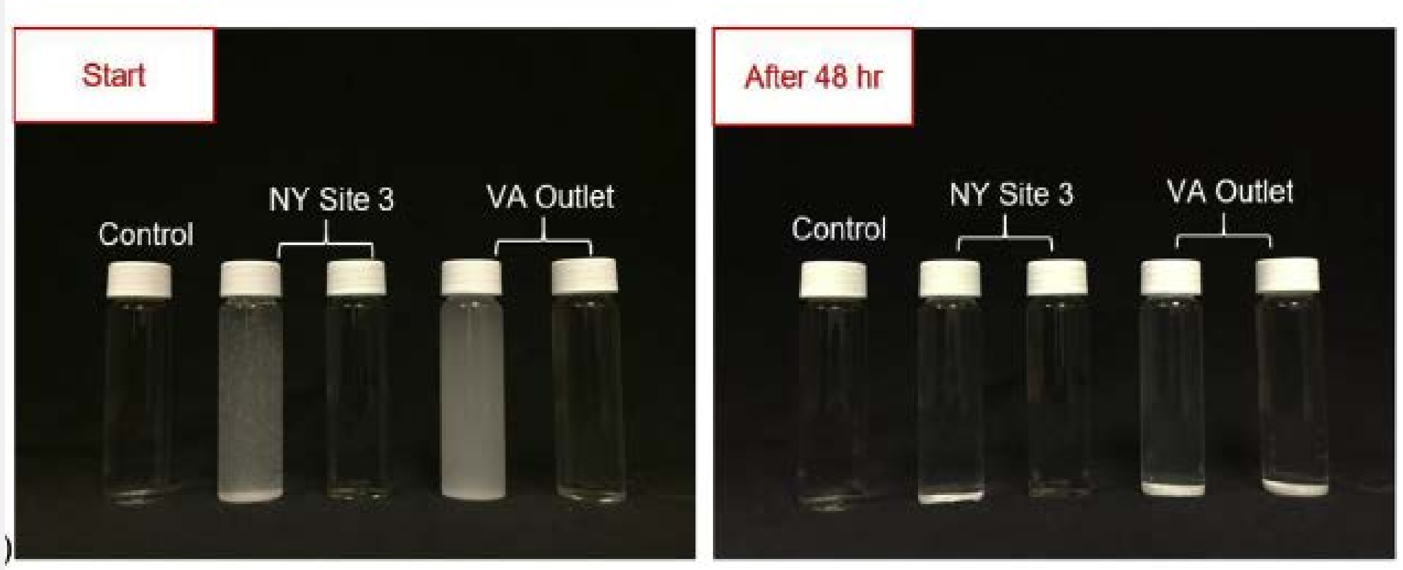
WHAT materials are discharged into air during CIPP cutting?



Cutting particles after CIPP lining

Particulate behavior in water



Li et al., 2019

CIPP cutting

White-greyish material generated

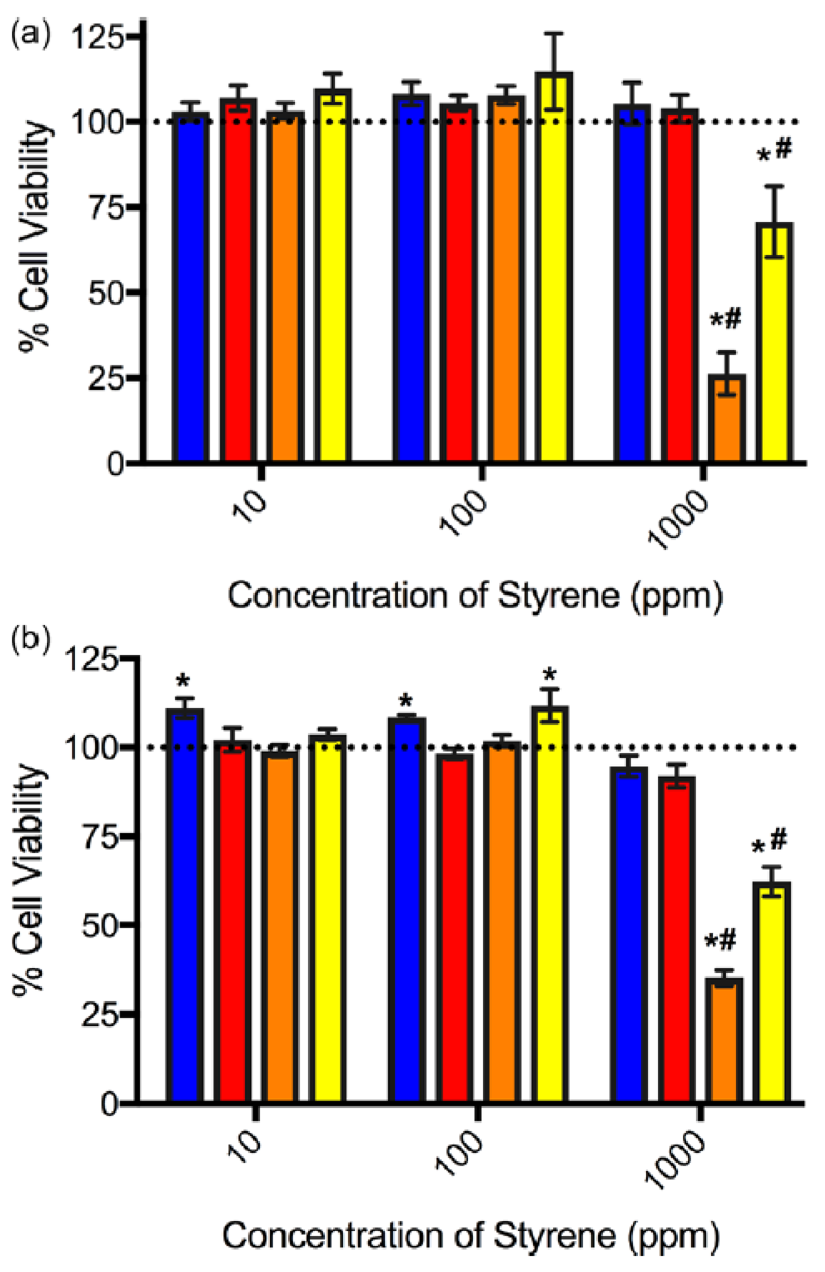
Particles emitted in to the air

Deposited on soil and water

Settle down on the inner CIPP surface

Particles loaded with chemicals that leach

HOW toxic the emitted CIPP condensate?



Seyedeh Mahboobeh et al., 2017

Toxicity study (MTT assay) for CIPP condensate

(a) Mouse alveolar type II epithelial cells
(b) macrophages

CIPP condensate-exposed cells for 24 h at a styrene concentration of 10, 100, or 1,000 ppm

Styrene conc. in CIPP condensate is about **1800 ~ 4300 ppm**

Kobos et al., 2019

WHAT is possible emission and exposure standard for styrene?

Max concentration of styrene in most of CIPP worksite exceeded the current safety limits

Units: ppm

Limits for residential and building occupants		Limits for workers			
EPA Acute	Odor threshold	OSHA PEL (TWA)	OSHA Peak	ACGIH TLV	NIOSH IDLH
4.9	0.016	100	600	20	700

Max. conc. reported in studies			
Purdue [Field_condensate]	**NASSCO LATECH [Field_vapor]**	**LAX [Field_vapor]**	**NIOSH [lab-scale_vapor]**
4,300	**1,820**	**1,070**	**5,160**

[Terms]
PEL: Permissible Exposure Limit
TLV: Threshold Limit Values
IDLH: Immediately Dangerous To Life or Health
Peak: Allowable level for a single time period up to 5 mins for any 3 hrs

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WHAT other air-contamination risks are included?

More than 9 chemical compounds are included in EPA 189 Hazardous Air Pollutants

Units: ppm

	Odor threshold *	OSHA PEL (TWA)	NIOSH IDLH
Acetophenone	0.00024	[ACGIH TLV] 10	-
Benzene	0.47	1	500
Chloroform	0.102	[ceiling] 50	500
Dibutyl phthalate (DBP)	0.023	0.43	345
Ethylbenzene	< 0.002	100	800
Methylene chloride	1.2	25	2300
Phenol	0.0045	5	250
Toluene	0.021	200	500
Xylene (total)	0.012	100	900

Odor threshold reference *
American Industrial Hygiene Association (AIHA), 2013

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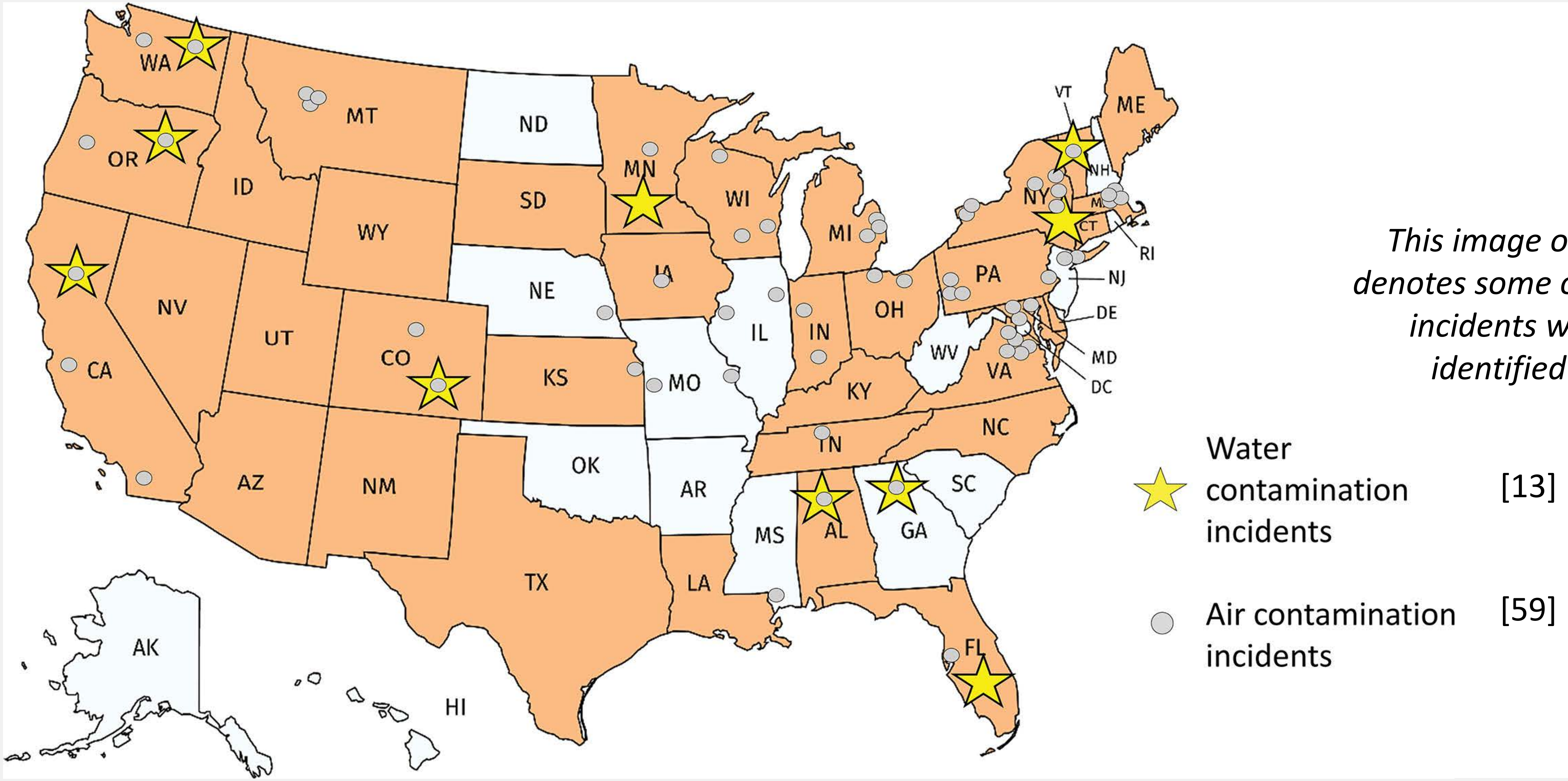
<u>HOW</u> many incidents were occurred?

As CIPP Lining Use was Widespread, the contamination events were also numerous



This image only denotes some of the incidents we identified

Ra et al., 2017

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WHAT do CIPP stormwater incidents look like?

CIPP contractors released uncured resin, chemicals or wastewater into a water or storm sewer during/ after installation

Location	Environmental Contamination	Odor Report	Chemical compounds detected
Pennsylvania (2019)	More than 300 fish killed	YES	Max. concentration of styrene: 28.7 ug/L
Georgia (2016)	Contaminate water	YES	Styrene and a variety of other CIPP associated compounds in water
California (2013)	Contamination of soil and the tributary to Wolf Creek	YES	Styrene leak
Vermont (2013)	Contaminate water even 225 ft below the culvert; Complained from residents	YES	Max. concentration of styrene: 5,160 mg/L Styrene level remained up to 0.08 mg/L 70 days after the installation; Detected other chemical compounds
Minnesota (2011)	Complained from residents due to odor	YES	Residual odor remained for five months in residential building
Alabama (2010)	Contaminate water; Complained from residents due to odor and vapor intrusion; Causes residents ill	YES	Styrene in water: 143 mg/L; Styrene at building faucets: 4 mg/L (EPA MCL: 0.1 mg/L)
Canada (2007)	Contaminate water; Fish kill found	YES	Styrene in water: 2 ~ 85 mg/L
Unknown (2007)	More than 5,500 fish killed	YES	Styrene in downstream: 100 mg/L

15+ Incidents are reported in our FHWA report (11 states in the USA and Canada)

What could people expect may happen?

Whelton et al., 2019

WHY do CIPP stormwater incidents occur?

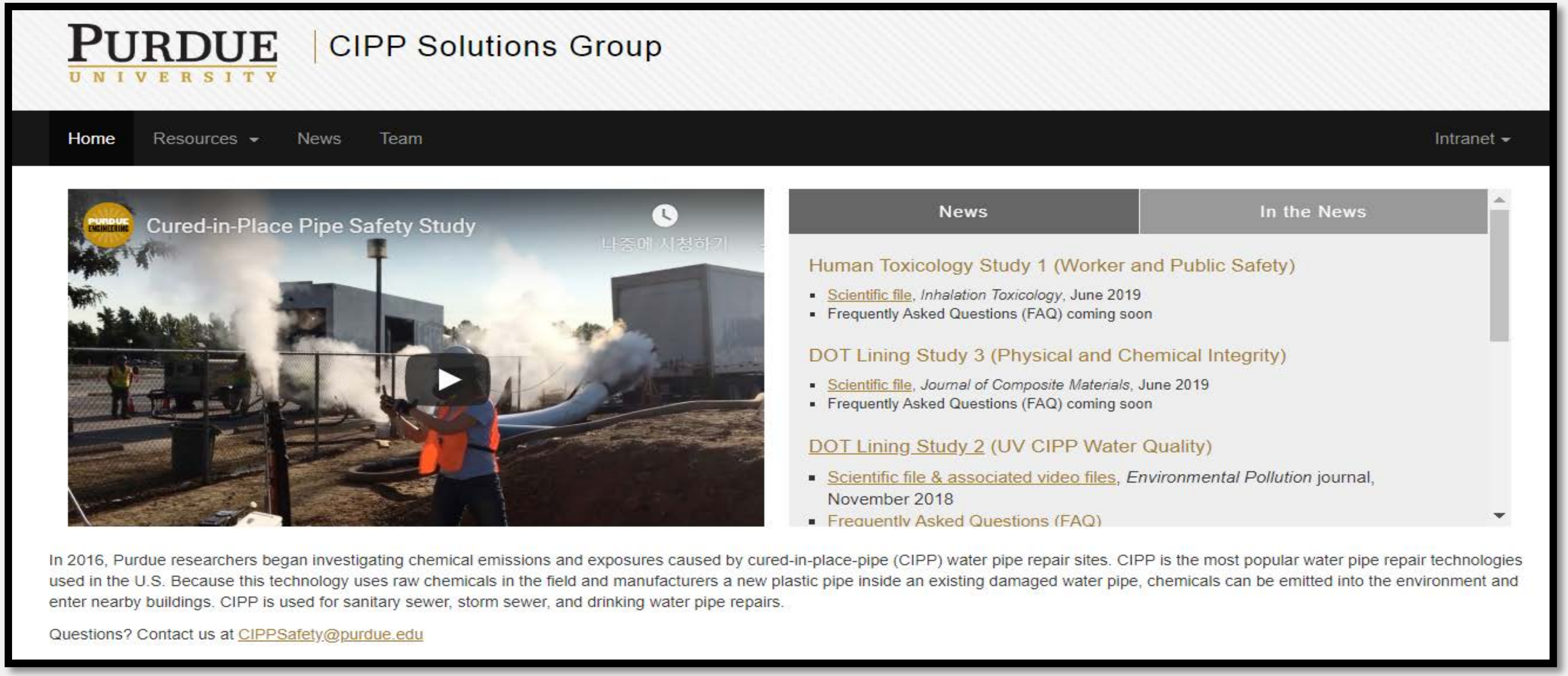
Reasons for environmental contamination and other Incidents

- ❑ Construction specifications do not require waste capture and disposal
- ❑ Construction inspector not onsite or trained on plastic manufacture waste handling and risks.
- ❑ CIPP industry for years encouraged waste disposal in “streams and ditches”.
- ❑ And others….

Thank you, Next….Best Practices

Contact: Yoorae Noh, noh18@purdue.edu

For More information visit www.CIPPSafety.org



New: Evidence-Based CIPP Best Construction Practices for Sewer Lining Projects

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Visit www.CIPPSafety.org for more information

Wednesday February 5, 2020

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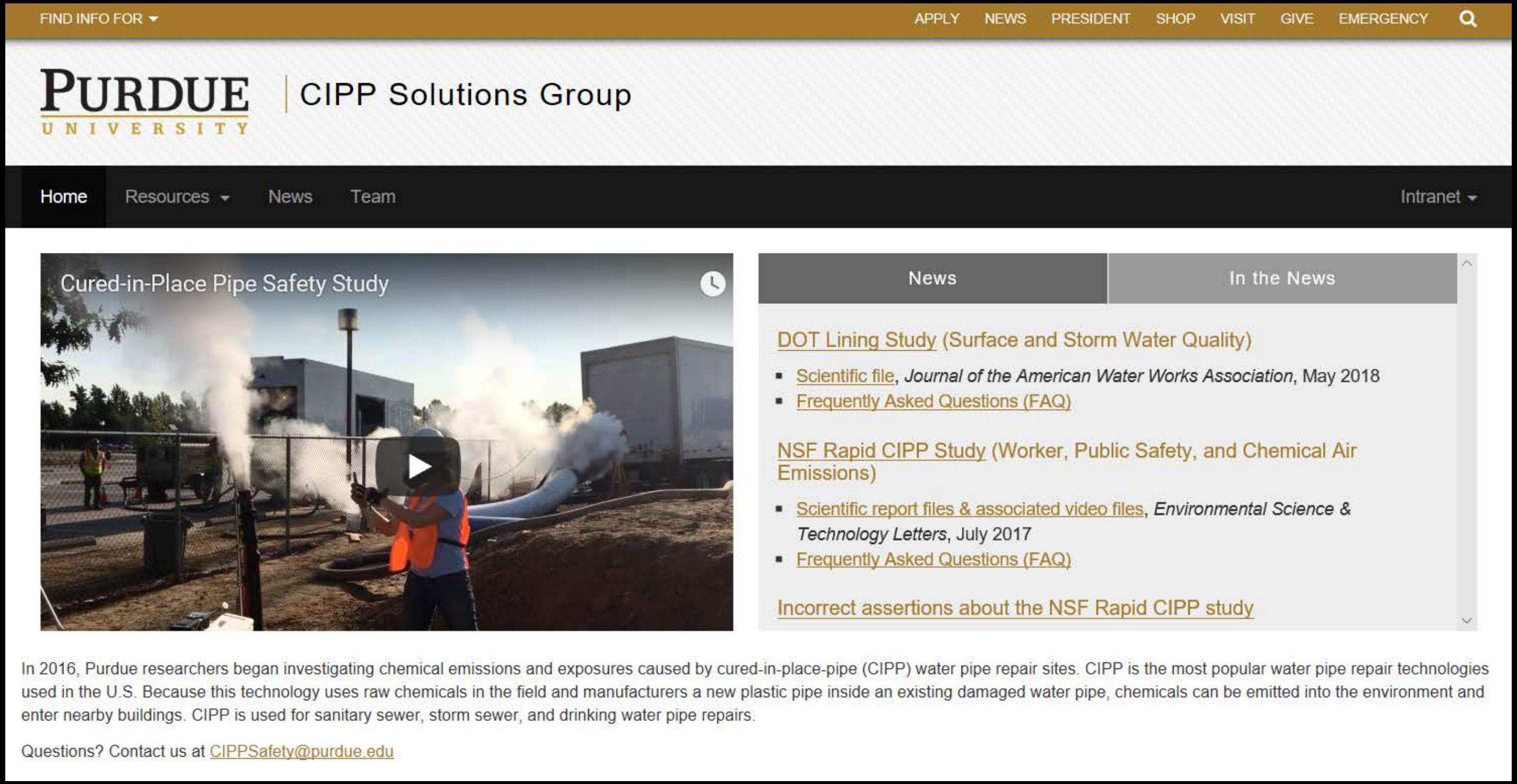
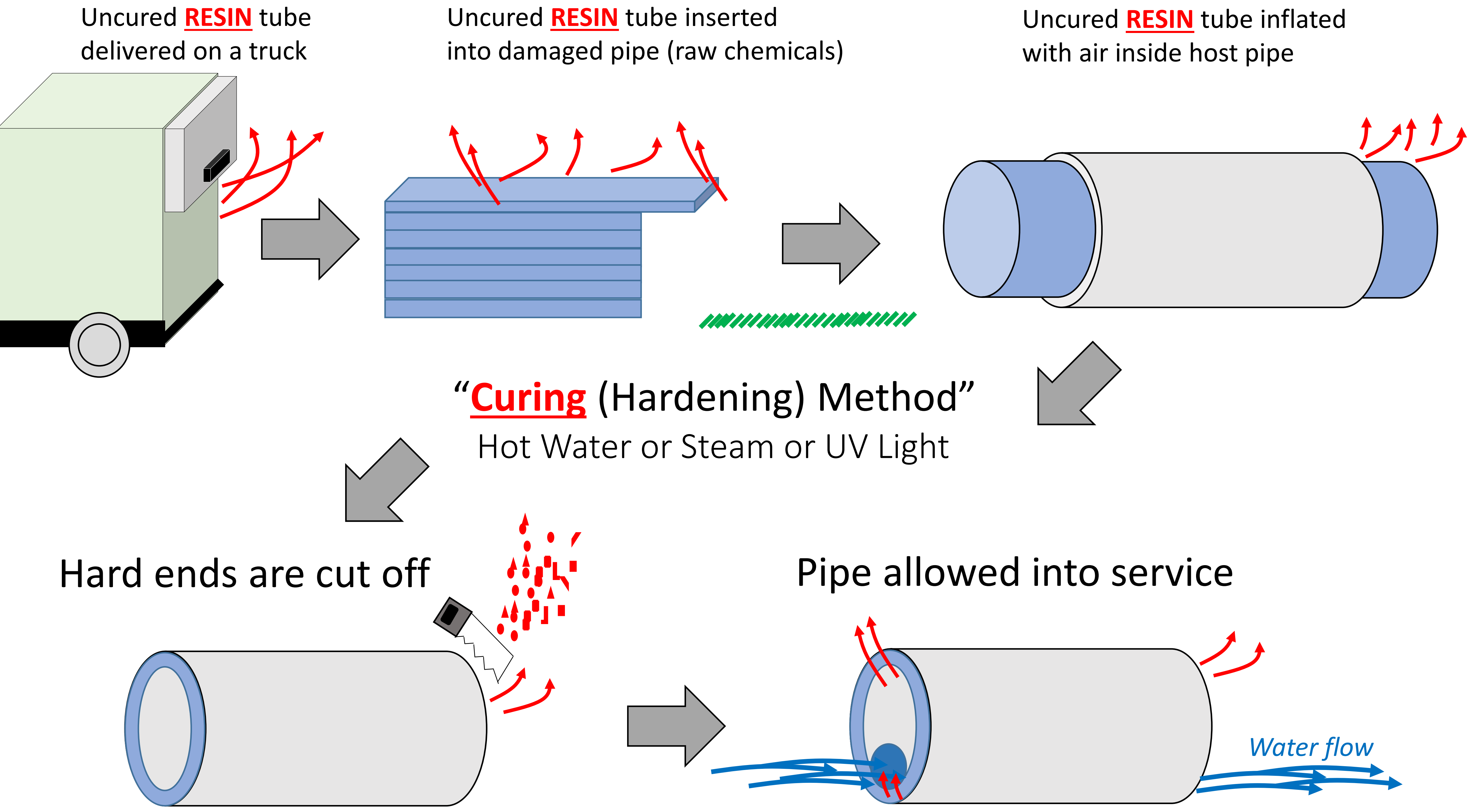
Learn More. Freely downloadable FAQs, videos, studies, & resources at *www.CIPPSafety.org*



Download free:

- 6 State Lining Report
- Recommendations
- Scientific studies
- FAQs
- Resources
- Videos/webinar
- NIOSH CIPP report
- And more…


Uncured RESIN tube delivered on a truck
Uncured RESIN tube inserted into damaged pipe (raw chemicals)
Uncured RESIN tube inflated with air inside host pipe
"Curing (Hardening) Method"
Hot Water or Steam or UV Light
Hard ends are cut off
Pipe allowed into service
Water flow

A Few Debunked Safety Claims

"Styrene vapor of at most few ppm" - False
"is not a human health risk" - False
"is safe for people and animals" - False
"it is harmless steam" - False
"no hazardous conditions posed" - False
"don't be alarmed" - ?
"some people are offended by this odor and are fearful of it; even though the concentrations they smell present no harm" – If you smell something it may in fact be harmful.

Contractors, Municipalities, and Engineering Firms have issued these statements. - Don't do it.

Solvable problems exist for this innovative technology.

Emissions and exposures can present acute and chronic human health risks and environmental hazards.

August 2019 in Carlisle, PA

1 of the top 10 trout streams in the US

Fish kill (200+) associated with CIPP contractors

Styrene found, temperature not high

NOV issued to city; Criminal/law enforcement, and environmental enforcement investigations remain open

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There are several factors that have contributed to past chemical contamination incidents

SPECIFICATION did not articulate how to and when contractors should prevent environmental contamination

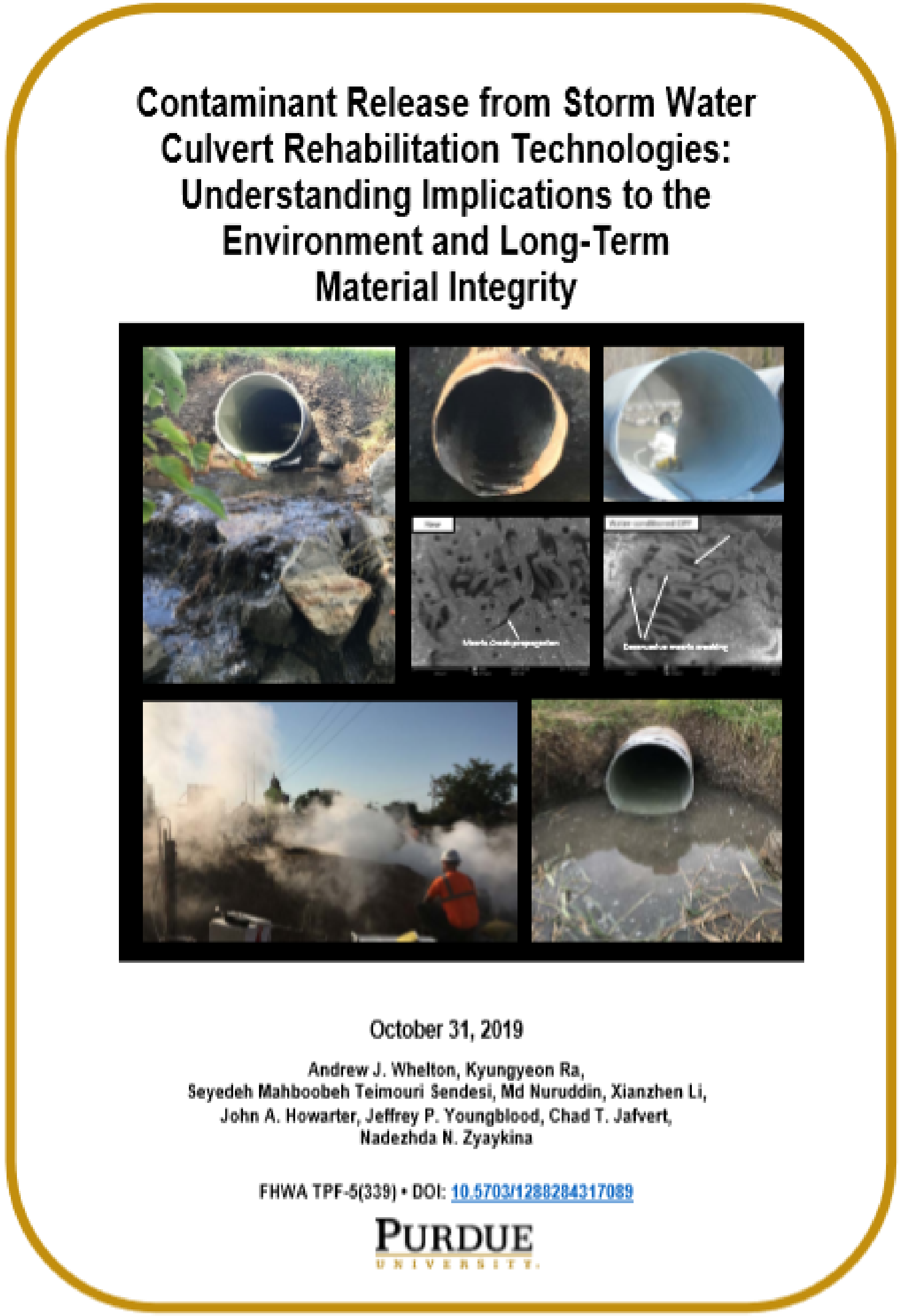
CONSTRUCTION INSPECTOR did not understand the type and magnitude of chemical emissions or when they can occur

ENGINEERING FIRM did not understand the type, magnitude of chemical emissions, or when they can occur

CONTRACTORS did not understand the type and magnitude of chemical emissions from the technology

CONTRACTORS did not follow the construction specifications

Q: What actions are needed to appropriately reduce the chances that a lining project causes public and environmental impacts?



Contaminant Release from Storm Water Culvert Rehabilitation Technologies: Understanding Implications to the Environment and Long-Term Material Integrity

October 31, 2019

Andrew J. Whelton, Kyungyeon Ra, Seyedeh Mahboobeh Teimouri Sendesi, Md Nuruddin, Xianzhen Li, John A. Howarter, Jeffrey P. Youngblood, Chad T. Jafvert, Nadezhda N. Zyaykina

FHWA TPF-5(339) • DOI: 10.5703/1288284317089

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NEW: FREE "6 STATE LINING STUDY" REPORT

1. Go to the Purdue Libraries website and click on the "JTRP Program Affiliated Reports:
https://docs.lib.purdue.edu/jtrpaffdocs/

2. Now click on the report title:
Contaminant Release from Storm Water Culvert Rehabilitation Technologies: Understanding Implications to the Environment and Long-Term Material Integrity,

REPORT OUTLINE

Executive Summary
Section 1. Project goal & objectives
Section 2. Spray-on lining: Incidents & agency construction spec survey
Section 3. CIPP lining: Incidents & agency construction spec survey
Section 4. CIPP lining: Water quality impacts in multiple states
Section 5. Laboratory aging tests for CIPP
Section 6. CIPP safety observations and recommendations
Section 7. Construction spec recommendations
7.1 Spray-on lining
7.2 CIPP lining

Protect your people and the public

1. Mandate chemical emission capture and confirmation by chemical air monitoring

2. Require appropriate PPE even for site observers (inspectors, consultants) as determined necessary by NIOSH, or other occupational health and public health regulatory agencies. This may include respirators and chemically resistant gloves, depending on the potential exposure routes (inhalation, dermal).

3. Require a Construction Inspector onsite *for every CIPP project* with expertise in environmental testing, occupation hygiene, pollution identification, *and* plastic manufacture.

Protect your people and the public (cont.)

4. Minimize your employee and general public chemical exposures by dermal contact and inhalation by restricting site access.

5. Require setback distances, delineate the location of hot zones / chemical fall out zones. The perimeter and setback distance will depend on CIPP process being used, worker practices, environmental conditions, and site conditions. Perimeter and setback distance recommendations can be made by a free NIOSH health hazard evaluation.

6. Contact NIOSH, get FREE PPE advice, request a FREE health hazard evaluation for projects happening in your area (or being paid for or overseen by you).

Infrastructure Owners and Engineering Companies should contact NIOSH for FREE advice and help

Request a –FREE– NIOSH health hazard evaluation (HHE) to better protect your employees and this should improve public safety

Promoting productive workplaces through safety and health research / NIOSH®

National Institute of Occupational Safety and Health

Health Hazard Evaluations help workers learn what health hazards are present at their workplace and recommends ways to reduce hazards and prevent work-related illness.

Dr. Ryan LeBouf, CIH (igu6@cdc.gov)
Dr. Rachel Bailey (feu2@cdc.gov)

Today NIOSH is helping:

- 1 UV CIPP company
- 2 state DOTs

Before the Contractor Begins Work….

1. The Engineer shall review Appendix B of the "6 State Lining Report" to identify potential opportunities for chemical release into the environment due to the CIPP manufacturing activity. This lists contamination potential by work task.

2. The Engineer shall determine the suitability of CIPP and necessary controls for the CIPP manufacturing based on site location and conditions.
   - Proximity to sensitive populations (i.e., schools, residences) and environmental areas,
   - Proximity to drinking water wells and water bodies,
   - Nearby surface and ground water quality,
   - State and federal water quality standards,
   - Nearby land uses,
   - Watershed area,
   - Environmental conditions.

Before the Contractor Begins Work (cont.)….

3. The Contractor shall submit a Worksite Safety and Sampling Plan.

   - Description of chemical exposure hazards during setup, installation, and cleanup, as well as a list of chemicals for the liner and resin mixture that are used or generated before, during and after the onsite curing process.

   - Map denoting the location of equipment, including exhaust or fugitive emission points, location of setback distances from public ways, private property, buildings nearby to include schools, health care facilities, if any, expected heights of any emission discharge points, chemical fallout areas, and waste capture systems.

   - Description of PPE CIPP workers shall wear at the plastic manufacturing site as recommended by industrial hygienists, to protect workers from worksite and installation hazards, including chemical exposure through inhalation, dermal exposure, or eye exposure. This should be listed by job duty. The type of PPE recommended can be determined by the CIPP Contractor, Engineer, or Consultant requesting a free NIOSH health hazard evaluation.

Before the Contractor Begins Work (cont.)….

4. Contractor shall provide the Engineer a copy of the written approval for the disposal of wastes to be generated during the setup, installation, and cleanup process. This includes both solid and hazardous wastes as applicable.

5. Contractor shall agree, in writing, to report any accidental discharge, small or large, to the Engineer and environmental regulatory officials immediately, so that downstream water supplies, the environment, and surrounding populations can be protected.

Before the Contractor Begins Work…

6. The Engineer will provide a list of the contaminants to the Contractor based on information from state and federal water quality standards, and by any other additional available information.
   - Chemicals listed in Appendix C of the “6 State Lining Report” as well as on material safety data sheets, product sheets, and additional information as it comes available should be considered.
   - Material safety data sheets (MSDS) should not be solely relied upon to identify chemicals of concern as they have shown not to list all chemicals of environmental concern that are present.
   - Chemicals detected shall not exceed state water quality limits or specific aquatic species toxicity thresholds for chemicals deemed a concern by the Engineer and other agencies as noted.

Before the Contractor Begins Work…

7. The Engineer shall consult with state environmental and public health agencies about the type of monitoring CIPP lining sites should be conducted. Different requirements may exist for or be required by different states.

   - Chemicals required for monitoring and/or their concentrations may vary between and within states, depending upon which waterways are near the installation site and other factors as deemed important by the Engineer and regulatory agencies.

Consult the Tables in the 6 State Lining Report

Additional Specification Recommendations

1. The Engineer shall assign a transportation agency construction inspector who is trained to recognize environmental emissions and pollution during plastic manufacture to each CIPP worksite.
2. Contractors shall record and report the amount and type of pollutant captured, and describe the waste generated (i.e., condensate, rinse water, plastic cutting dust, recirculation water, uncured resin tube).
3. Contractors shall only dispose of waste in accordance with local, state, and federal regulations. This includes compliance with the Clean Water Act, Land Disposal Rule, air quality regulations, as well as other applicable regulations.
4. Contractor shall capture all particles and shavings created during any CIPP cutting activities and not permit their entry into the environment. This capture activity may include, but is not limited to, a portable device to capture emitted particulate dust as generated with negative pressure.

Specific Specification Requirements(cont.)…

5. Contractor shall not permit floating materials to enter the surface water or nearby vegetation.
6. Contractor shall use sufficiently thick plastic sheets (i.e., greater than 10 mils thick) immediately upstream and downstream of the pipe to help prevent chemicals from entering the environment. The protected area's size may depend on the pipe size and area morphology.
7. Water flow should be diverted from the pipe until a complete cure has been established. A barrier material shall be placed in the inlet and outlet work area to prevent the uncured resin tube from contacting the ground.
8. Contractor shall collect and dispose of materials deposited on the barrier material in accordance with regulations.

Specific Specification Requirements (cont.)

9. The entire newly manufactured CIPP's inner surface area shall be rinsed, and the rinse water shall be collected and disposed in accordance with Clean Water Act, and other applicable federal and state laws.

10. Water or steam condensate used for curing or rinse water shall not enter the environment (waterways, soil) and should be collected. These materials should be properly discharged to a publicly owned treatment works (POTW), with preapproval of the POTW, or other approved facility. For example, if disposal at a POTW is not a feasible option, liquid waste may need to go to a permitted Resources Conservation and Recovery Act (RCRA) or industrial wastewater treatment plant that is permitted to accept non-hazardous industrial liquid waste.

Specific Specification Requirements (cont.)

11. In the absence of waste collection, **any discharge to the environment must have preapproval by the state or federal agency responsible for pollutant discharge.** The Contractor shall present this discharge authorization to the Engineer before the project begins. This approval may not be permitted in all states, but the state and federal agency responsible should be contacted for clarification. *[No dumping in "streams and ditches"!]*

12. Contractors shall report any accidental discharge or release, small or large, to state officials immediately, including the state environmental protection agency, so actions can be taken to protect downstream water supplies, the environment, and nearby population. Some raw materials and wastes generated during CIPP manufacture are highly concentrated and small amounts can cause acute and lasting environmental damage (i.e., dissolve fresh water organisms).

Specific Specification Requirements (cont.)

13. Water testing shall be conducted to determine if applicable water quality standards have been exceeded.
    - Chemical testing shall not be solely based on the material safety data sheet (MSDS) because chemicals of concern and those generated by the liner manufacturing process are not all reported on safety data sheets.
    - Water testing methods shall be capable of detecting all contaminants of concern. Test procedures, analytical methods, locations, number of samples, and temporal extent (i.e., to include pre- and post-installation) need to be clearly defined. Independent organizations, properly trained on environmental sampling, sample preservation, and analysis, shall conduct testing. Results shall be rapidly obtained and compared against state and federal water quality limits for allowable pollutant discharge, limits in construction specifications, and to acute and chronic toxicity limits for native aquatic species. It is recommended that prior to the project beginning the Engineer consult with state environmental and public health agencies about the type of monitoring CIPP lining sites should be conducted. Different requirements may exist for different states, areas, and sites.
    - Sampling at the pipe inlet and outlet immediately before and after the CIPP is placed in service shall constitute temporal (and spatial) sampling events (estimated to be 4 samples).

Water testing (cont.)

- Any discharges to receiving waters that exceed state water quality standards and limits set forth in specifications or defined by environmental and public health agencies should trigger additional water testing for that CIPP site/location as well as state environmental and public health agency notification.
  - The Contractor is responsible for immediately alerting the responsible agencies. As known contamination incidents and existing studies have indicated, follow-up testing for days to months may be necessary if contamination is suspected or discovered.
  - This testing will be the financial and logistical responsibility of the Contractor. This follow-up testing will be conducted at the direction of the state environmental and public health agencies and is not the financial responsibility of the Engineer. Remediation actions, if determined necessary by either state environmental or public health agencies, would also be the responsibility of the Contractor not the Engineer.
- If rinse water is used, a sample of that water before entry into the new CIPP (control sample) and a water sample collected as the first water exits the CIPP shall be collected. This sampling is to be conducted even if the rinse water is planned for disposal, and can help document the immediate CIPP impact on the water. If drinking water is used for CIPP rinsing, appropriate methods must be used to neutralize drinking water disinfectant onsite to preserve the integrity of the collected water sample.

Specific Specification Requirements (cont.)

- The Contractor's staff and its subcontracted organizations shall not conduct water sampling or analysis. Instead, a third-party organization with proper environmental monitoring expertise shall conduct and be responsible for water sampling, analysis, and reporting to the Engineer.

- New CIPPs shall not be placed in service until testing of receiving water indicates no water quality limit exceedances unless representative chemical testing data specific to that site indicates the construction activity did not release materials (i.e., cutting dust, resin, etc.) and the liner does not contain or leach compounds that exceed aquatic organism toxicity thresholds for chemicals of concern or state water quality standards.

- Chemicals identified in the "6 State Lining Report" and others, should be considered for water testing.

Specific Specification Requirements (cont.)

14. Because partially cured resin, particulates, and contaminated water, are emitted into the air during steam CIPP manufacture, <u>pollution emissions into air should be captured and monitored to confirm complete capture for processes that involve water, and on a case by case basis for UV and ambient cure applications.</u> This capture activity may include, but is not limited to, a portable device to capture emitted materials as generated.

Product Quality/Testing Recommendations

1. A sample of upstream and downstream sections of the installed liner should be removed and physically and chemically characterized. This may be facilitated by the use of an external sleeve or collar with similar thermal/chemical resistance characteristics as the host pipe being repaired. This material can then be removed without damaging the new CIPP and should be characterized to determine:
   - The presence of unreacted chemicals in the liner by differential scanning calorimetry (DSC). The method is listed in Appendix A of the six state lining study report.
   - The amount of volatile material (reported as percent weight) remaining in the new liner by thermogravimetric analysis (TGA). The method is listed in Appendix A of the six state lining study report.
   - The amount of hazardous air pollutant (reported as percent weight) and water quality pollutants listed in state code (reported as percent weight) by liquid-solid extraction (LSE) gas chromatograph / mass spectrometry (GC/MS). The method is listed in Appendix A of the six-state lining study report.

A Few Observations

- All of the problems are significant and can be corrected
- Upgrades needed for CIPP lining specifications, 3rd party monitoring, construction inspector duties, and DOT project oversight
- The CIPP process is innovative, but is saddled by problems caused by improper waste discharge into air, waterways, soil, associated with fish kills, NOVs, as well as impacts to workers and the public.
- CIPP can likely be used without endangering human health or the environment if appropriate controls were implemented
- Evidence is clear, appropriate controls are lacking. The 6 State Lining Report and this presentation outlines recommendations.
- More information coming ….

Questions?

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