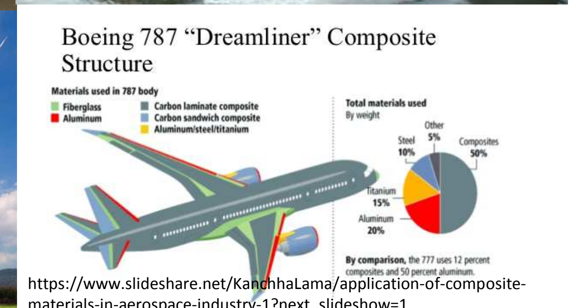
A Primer on Fiber Reinforced Polymer Composites


Coastal Engineering 98 (2015) 16–25


https://www.tes.com/lessons/pcQxUYMrDAPjKw/bridges


http://www.kcautoacc.com/AUTOart-76027-McLaren-P1-Matt-Black-with-Red-Accents-118-Scale-Composite-Car-_p_18280.html


http://www.shridhanalakshmi.com/wind.php



https://www.slideshare.net/KanchhaLama/application-of-composite-materials-in-aerospace-industry-1?next_slideshow=1


http://www.luxury
composite

https://www.usatoday.com/story/news/nation-now/2016/02/24/army-combat-shirt-body-armor-2019/80851048/


http://www.onur.net/en/references/mobile-air-traffic-control-towers-project-for-turkish-airforce-8/

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-corrosive (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!

Fiber type is dependent upon many factors

Aramid/UHMWPE

- Advantages: Moderate strength, High stiffness, Low density, High toughness
- Disadvantage: SUPER high cost, Difficult to bond

Carbon Fiber

- Advantages: High strength, High stiffness, Low density
- Disadvantage: High cost, Brittle

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

Glass Fiber

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

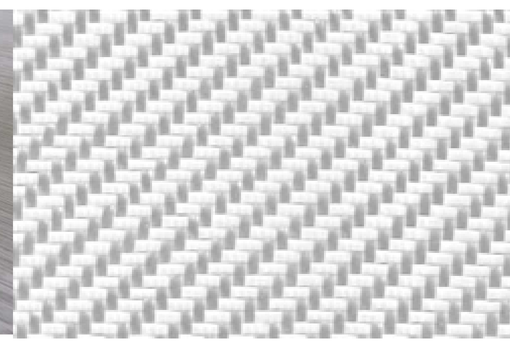
Staple Polymer

- Advantages: Extremely low cost, High toughness, Low density
- Disadvantages: Low stiffness, Low strength, low temp, solvent/ESC, CREEP!

https://www.alibaba.com/showroom/concrete-fiberglass-chopped-strand.html

http://vectorply.com/reinforcement-fibers/

https://www.uscomposites.net/ProductDetails.asp?ProductCode=FG-7725-38-10



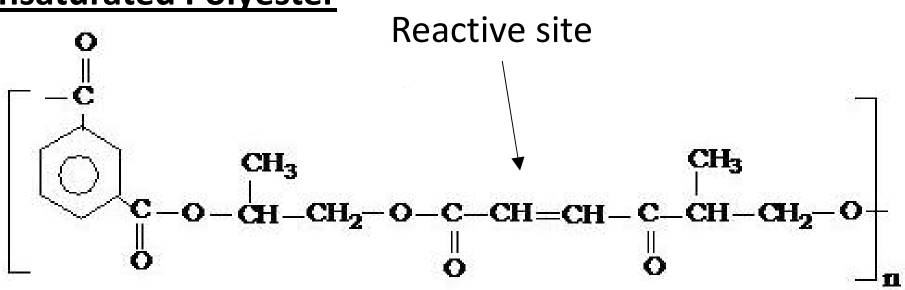
https://www.lih-fe.com/en/product/S-glass-fiber-needle-mat-850C/fiberglass_needled_mat-004.html

Form plays a huge role – continuous (weave) vs discontinuous (mat)

While fibers are the focus for properties, there are many possible resins that also dictate performance

Unsaturated Polyester

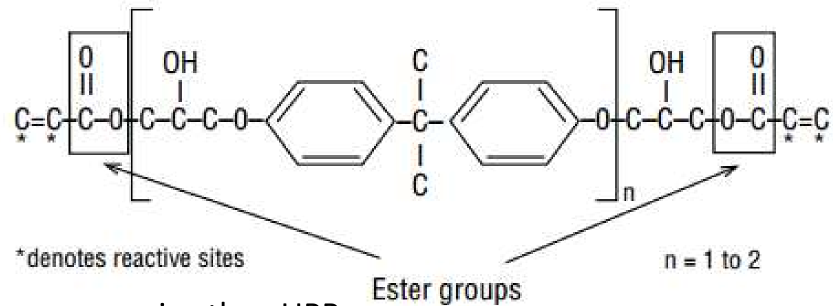
Materials Science, dited by Hosam El-Din M. Saleh, ISBN 978-953-51-0770-5



- Cheapest resin
- Diluted 30-60% in reactive solvent (styrene)
- Multiple types (Ortho- vs Iso-)
- Thermal (peroxide), Redox (MEKP), or UV (Irgacure) radical cure
- Good water performance

Vinyl ester

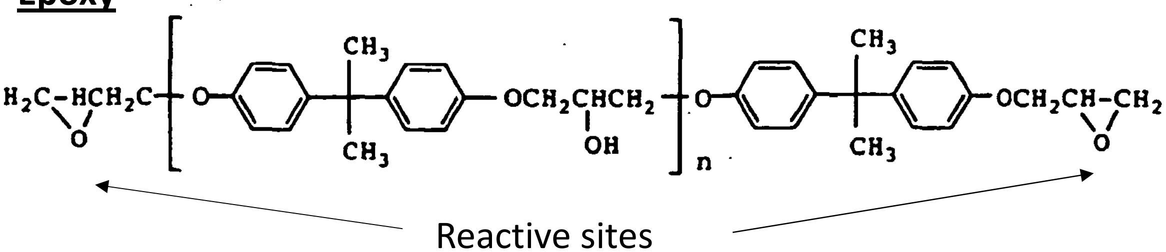
https://netcomposites.com/guide-tools/guide/resin-systems/vinylester-resins/



- More expensive than UPR
- Better performance than UPR
- Diluted 30-60% in reactive solvent (styrene)
- Thermal (peroxide), Redox (MEKP), or UV (Irgacure) radical cure
- Good water performance

Epoxy

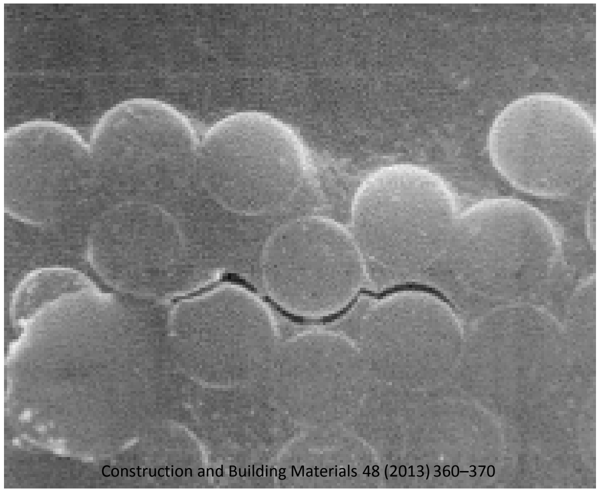
Patent, Publication number EP1666515 B1



- Most expensive
- Best performance
- No reactive solvent
- Many types (BPA, BPF, CA) and hardeners (amine, sulfide, etc)
- Can have poor water performance

While excellent materials, there are issues of degradation associated with FRPCs in civil infrastructure

- FRPCs are sensitive to moisture, alkalinity, thermal effects, creep, fatigue, ultraviolet radiation
- Moisture
  - The fibers, matrix, fiber–matrix interface and adhesive are all susceptible to deterioration.
  - Moisture can increase creep and relaxation, introduce residual stresses, cause osmotic pressure, and degrade polymers, fibers, and fiber/matrix interfaces via hydrolysis and chemical attack.
  - Moisture can accelerate fatigue degradation of composites, and shorten their fatigue life.
  - Moisture damage begins near the surface of the material and spreads inward over time.
  - Moisture can initiate localized cracking of matrix. Cracks allow easier penetration of water into the composite system via capillary action and diffusion.


Construction and Building Materials 48 (2013) 360–370

Hygrothermal aging can be important in wet environments

- During hygrothermal aging, water molecules diffuse into polymer network
- The glass transition temperature (Tg), modulus and strength are reduced because of plasticization effect of water molecules
  - Depends on hydrophobicity of matrix
- Polymer matrix swells by sorption of water molecules
  - Differential swelling of fiber and matrix creates internal stress
- This stress has detrimental effect at the fiber/matrix interface, causing matrix cracking, poor adhesion between fiber/matrix interface and delamination between the ply of the composite lamina

pH can have an effect

- Acidity
  - Exposure to acidic solution was found to decrease resistance to fatigue cracking.
  - Lower resistance causes shorter time to mechanical failure.
  - Cracks initiates and increases the opportunity for corrosive acidic solutions to attack the fibers.
- Alkalinity
  - The typical source of alkalinity is concrete pore water solution.
  - Alkaline solutions tend to degrade the fiber/matrix interface.
  - By weakening fibers and disrupting bonds between the fibers and the resin, resulted in lower bond strength of fiber-matrix interface and modulus of fibers over time.
  - Matrix cracking depends on the nature of the resin. Unsaturated polyester resins are susceptible to more severe deterioration than vinyl ester resin.

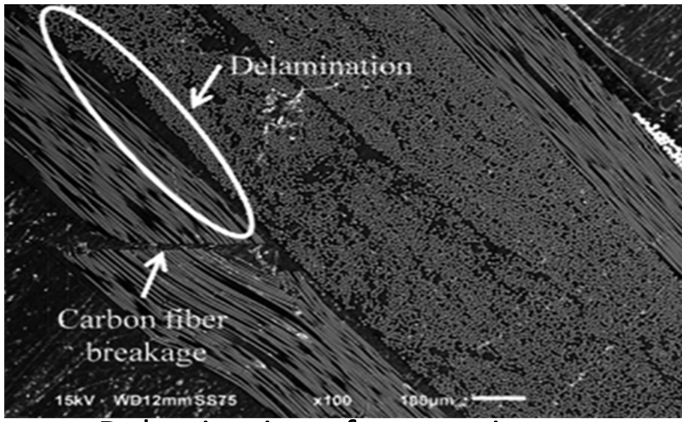
Other concerns in civil infrastructure

- Salts
  - The most likely source of salts are roadway deicing treatments, runoff, or other sources, which causes FRPC deterioration.
  - Accelerated crack in the FRPC are prominent, due to the expansion of salt crystals in the microcracks.
  - Several study suggested that salt water caused more severe deterioration of bond strength than deionized water.

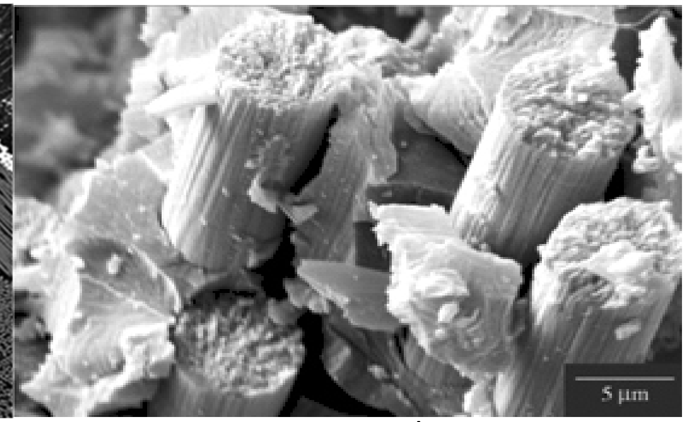
Construction and Building Materials 48 (2013) 360–370

- Ultraviolet radiation
  - Typically damaging only the top 50–100 μm of composite surface.
  - UV exposure causes increase in matrix brittleness due to increase in polymer crosslinking density
  - Extended exposure to ultraviolet radiation results in discoloration, because of chain scissioning

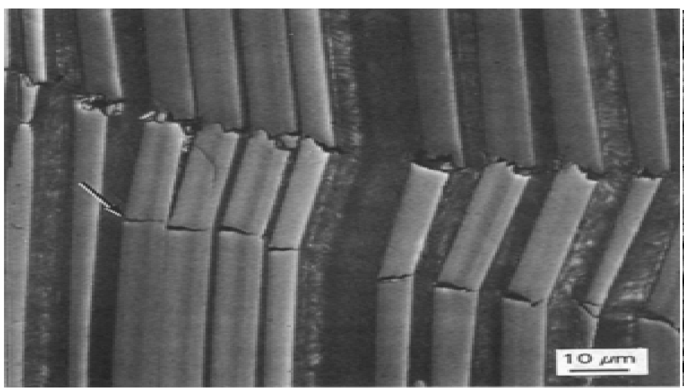
There are many types of failure of FRPCs



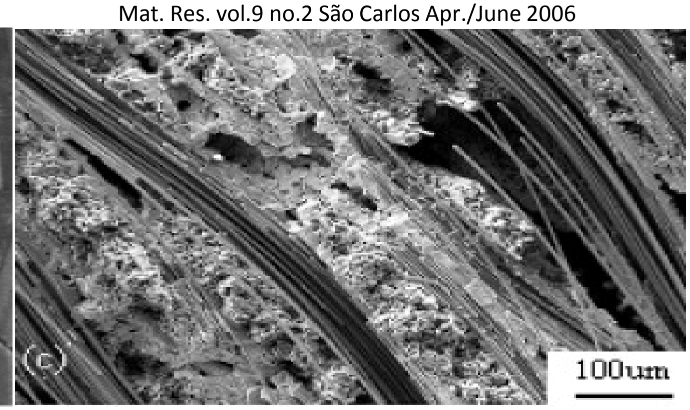
Delamination of composites
RSC Advances, *6*(12), 9495-9506.



Poor adhesion at Fiber/Matrix interface
Mat. Res. vol.9 no.2 São Carlos Apr./June 2006



Kink band failure mode
J. Mat. Sci., 30 (1995) 4343-4348



Fiber pull-out
Mat. Sci. Eng., 528(22-23), 6998-7004, 2011,

Changing mode of failure changes composite strength

Inter laminar shear strength (ILSS) controls composite strength via:

- Debonding and
- Redistribution of local stress transfer following fiber fracture

As shown for CFRP in compression,

Mode-1: Delamination

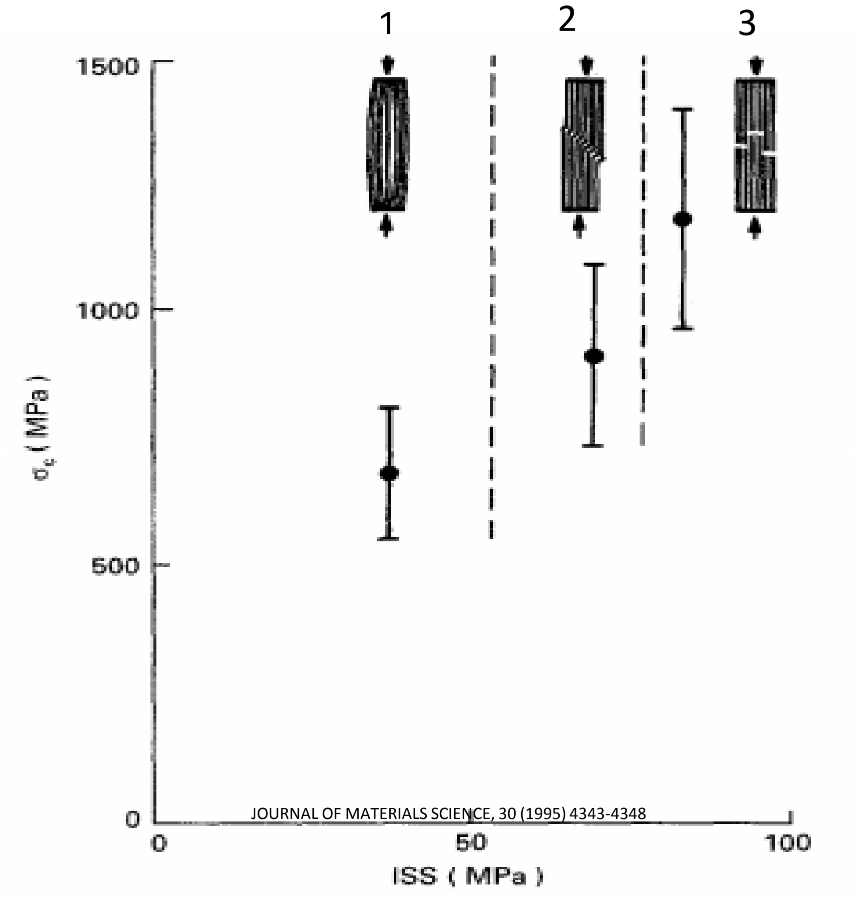
Lowest strength

Mode-2: Microbuckling (Kinking)

Intermediate strength

Mode-3: Compressive failure

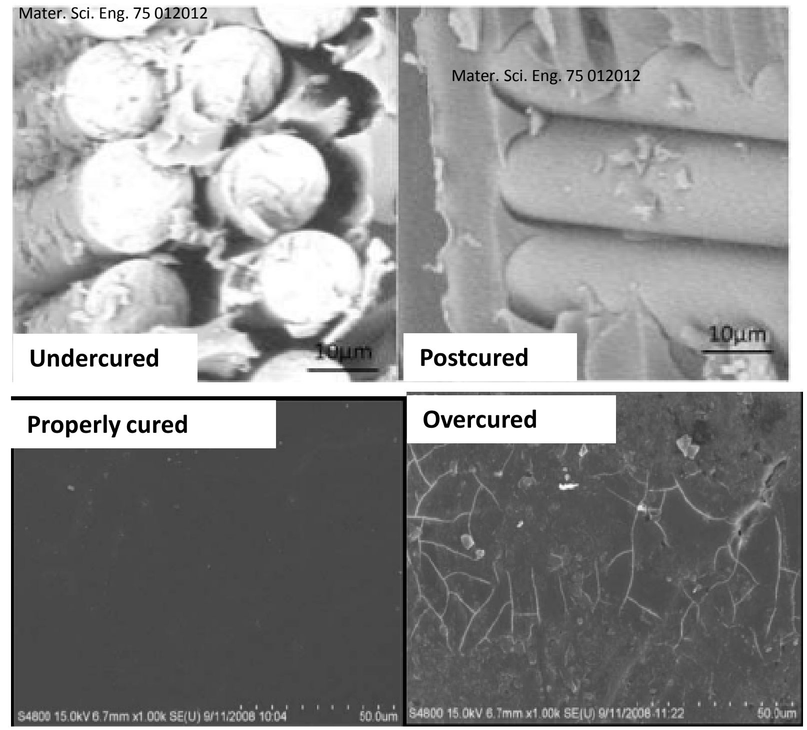
Highest strength



Similar results in flexure/3-pt bend (same loading of CIPP?)

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 ILSS increases
  - Can post-cure to improve
- Many possible issues with curing
  - Undercuring: Lack of complete reaction. Lowers Tg and ILSS and leaves residual monomer
  - Overcuring: Causes chain scissioning, matrix cracking and debonding at fiber/matrix interface. Lowers Tg and ILSS. 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 schedule and type
- Residual organic compounds will be leached out over time and may change mechanical properties of the composites.
  - Monomers such as cycloaliphatic amine and polyoxylalkyl amine (for epoxy resin), and styrene (for unsaturated polyester or vinyl ester resin) remain unreacted.
    - 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.
    - Become embrittled over time
  - 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 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

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
- Possibly 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

So what have we seen with CIPP?

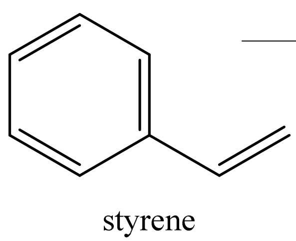
Characterization Techniques

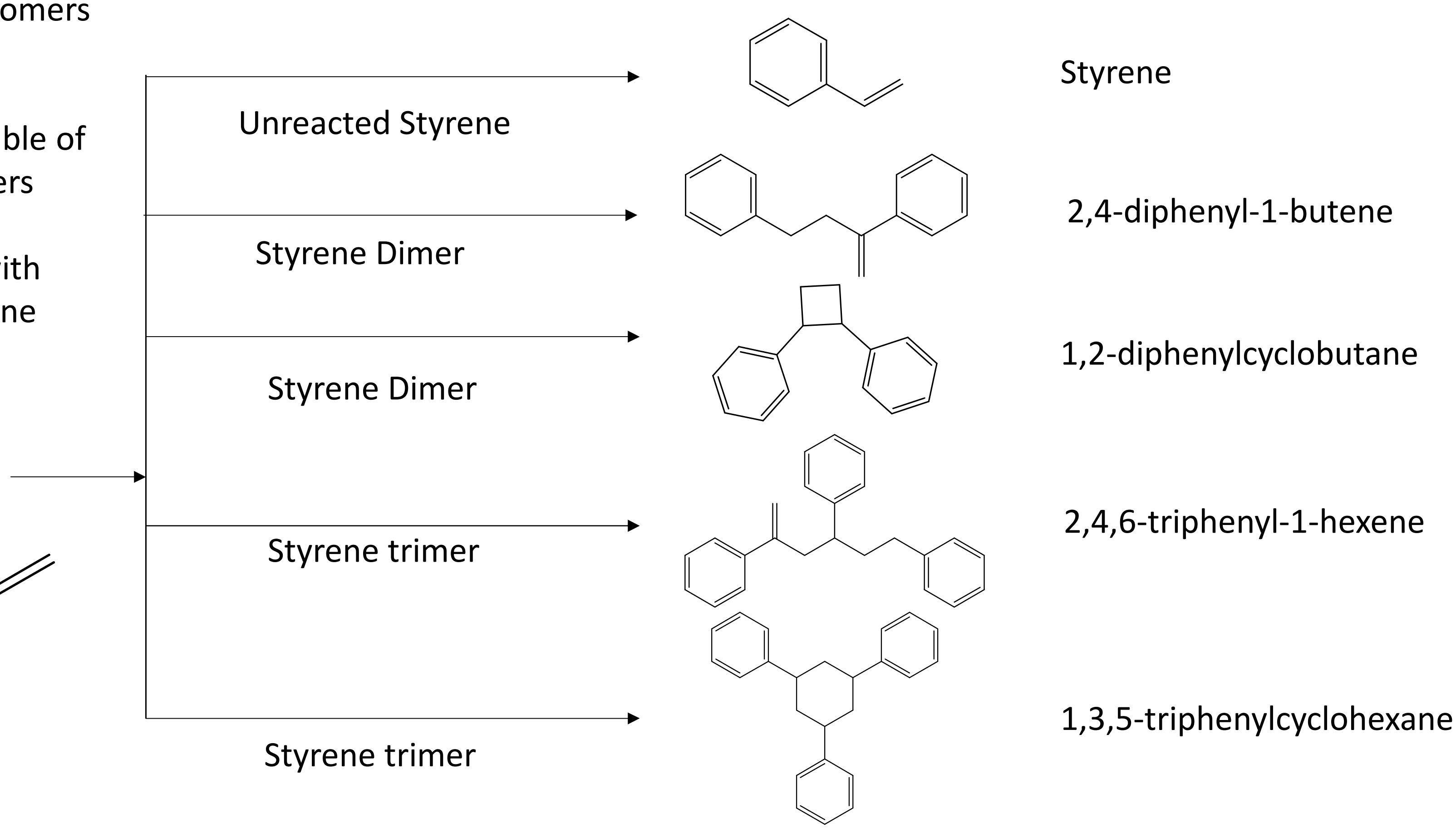
- H-NMR – Identifies the leachable chemicals from cured CIPP
  - Used as secondary validation of mass-spectrometry
- Thermogravimetric Analysis (TGA) – Determination of percentage of volatile compounds and degradation behavior of CIPP
  - Material is heated slowly while mass loss is measured
- Differential Scanning Calorimetry (DSC): Curing exotherm, crystallization and melting of CIPP components

Predicted Compounds From Styrene monomers

Aborted reactions of the styrene polymerization can result in dimers, trimers and oligomers of styrene.

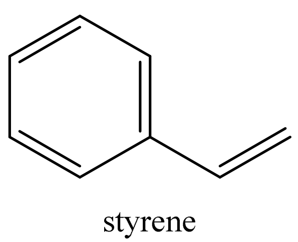
H1-NMR is capable of identifying dimers and trimers of styrene along with unreacted styrene monomer

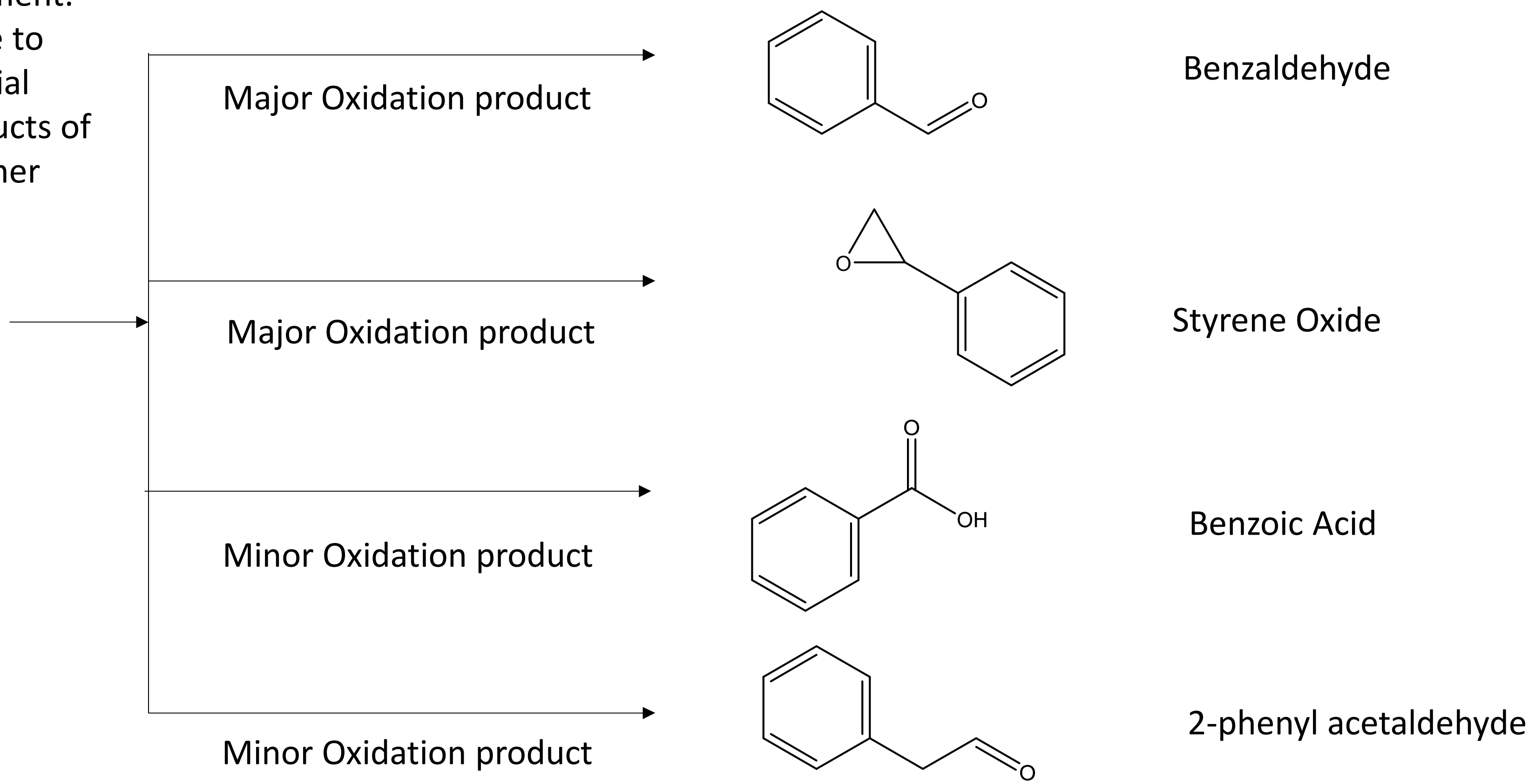




Predicted Compounds From oxidation of styrene

Styrene which does not successfully polymerize can also oxidize in the hot steam environment. H1-NMR is able to identify potential oxidation products of styrene monomer





8 slides redacted due to copyright.

CIPP is a wonderful technology, but there is still much we do not know

- Just because it is good, doesn't mean it has no issues or cannot be improved
- Cannot simply assume that aerospace issues are same, field and lab are same, etc.
- However, many issues were solved by other industries (due to lawsuits and regulatory action)
- Some possible avenues to explore (what do we need?)
  - Best practices/deign to minimize worker exposure
  - Best practices/design to limit environmental (VOC, COD) release
  - Lab scale experiment and model for curing kinetics so proper cure schedule (time/temp/pressure) can be performed on CIPP in the field
  - Long term performance data on lab scale and model over realistic conditions (strength, stiffness, creep, fatigue, etc)
  - Identify what structural changes are occurring that we can measure to relate to field level materials.

Thanks

Any Questions?

Cured-in-Place-Pipe (CIPP) for Sanitary Sewer and Storm Sewer Repairs

Worker and Public Safety, Environmental Impacts, and Long-Term Material Integrity

Andrew J. Whelton, Ph.D.
John Howarter, Ph.D.
Jeffrey Youngblood, Ph.D.

February 14, 2018

Ft. Meyers, FL

Andrew J. Whelton, Ph.D., Lyles School of Civil Engineering and Division of Environmental and Ecological Engineering, 16 years of experience in infrastructure rehabilitation technologies, environmental chemistry, and polymer materials. Consulting firms, NIST, U.S. Army, Virginia Tech, University of South Alabama. Ph.D. Virginia Tech.

John A. Howarter, Ph.D., School of Materials Engineering and Environmental and Ecological Engineering, 14 years of experience in polymer characterization, polymer degradation, polymer-water interactions in the environment. NIST. Ph.D. Purdue University.

Jeffrey Youngblood, Ph.D., School of Materials Engineering, 21 years of experience in polymer chemistry, composites, and surface science. Cornell University. Ph.D. UMASS Amherst.

Time	Topic
11:15-11:20	Welcome
11:20-12:10	A Primer of Fiber Reinforced Polymer Composites
12:10-12:20	Break
12:20-12:45	CIPP Chemical Air Emission Study funded by the National Science Foundation
12:45-1:00	Culvert Lining Study funded by state transportation agencies

LEARNING OBJECTIVES:

1. <u>List</u> the factors that can influence polymer composite manufacture and quality

2. <u>Describe</u> Purdue University CIPP chemical emission studies

3. <u>Recognize</u> how to contact the NIOSH for a health hazard evaluation

4. <u>List</u> recommended practices that can help understand minimize chemical emissions and exposures

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12:45-1:00	Culvert Lining Study funded by state transportation agencies
1:00-1:15	Q&A

CIPP Chemical Air Emission Study
funded by the National Science Foundation
(http://www.NSF.gov)

RAPID: Chemical Air Emissions from Cured-in-Place-Pipe (CIPP) Pipe Repair Activity

2016 RAPID Response Study was funded by the National Science Foundation (www.NSF.gov)

Environmental Science & Technology LETTERS

Worksite Chemical Air Emissions and Worker E Sanitary Sewer and Stormwater Pipe Rehabilita Cured-in-Place-Pipe (CIPP)

Seyedeh Mahboobeh Teimouri Sendesi,[†] Kyungyeon Ra,[‡] Emily N. Co Md. Nuruddin,[§] John A. Howarter,[‡,§] Jeffrey P. Youngblood,[§] Lisa M. K Chad T. Jafvert,[†,‡] and Andrew J. Whelton*[,†,‡]

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PURDUE UNIVERSITY | CIPP Safety Solutions Group

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Cured-in-Place Pipe Safety Study

News | In the News

Scientific report files & associated video files, *Environmental Science & Technology Letters*, July 2017

Frequently Asked Questions (FAQ)

- General Questions
- What Can I Do?
- Questions about Chemicals in the Air, in Building, and Exposure
- Questions about CIPP Technology
- Worker Safety

Incorrect assertions about the CIPP study

In 2016, Purdue researchers began investigating chemical emissions and exposures caused by cured-in-place-pipe (CIPP) water pipe repair sites. CIPP is the most popular water pipe repair technologies used in the U.S. Because this technology uses raw chemicals in the field and manufacturers a new plastic pipe inside an existing damaged water pipe, chemicals can be emitted into the environment and enter nearby buildings. CIPP is used for sanitary sewer, storm sewer, and drinking water pipe repairs.

Questions? Contact us at CIPPSafety@purdue.edu

Visit http://CIPPSafety.org or https://engineering.purdue.edu/CIPPSafety

- ✓ FAQs
- ✓ Links to studies
- ✓ Links to resources

Resin Types	**Polyester (est. most popular)**	**Vinyl ester (est. > cost of polyester)**	**Epoxy (est. >> cost of polyester)**

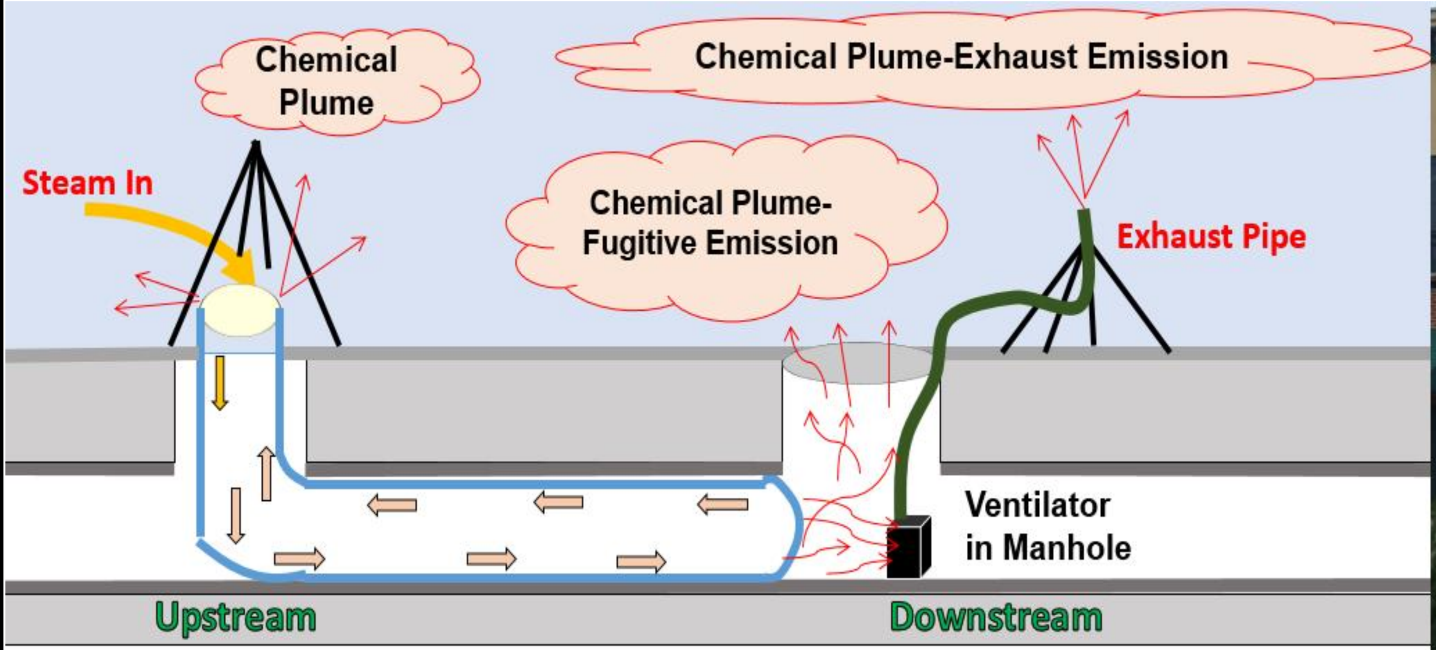
People also say “Styrene resin” vs. “Non-styrene based” resin

Resin + Solvents + Fillers + Catalysts + Initiators are added to create an uncured resin tube

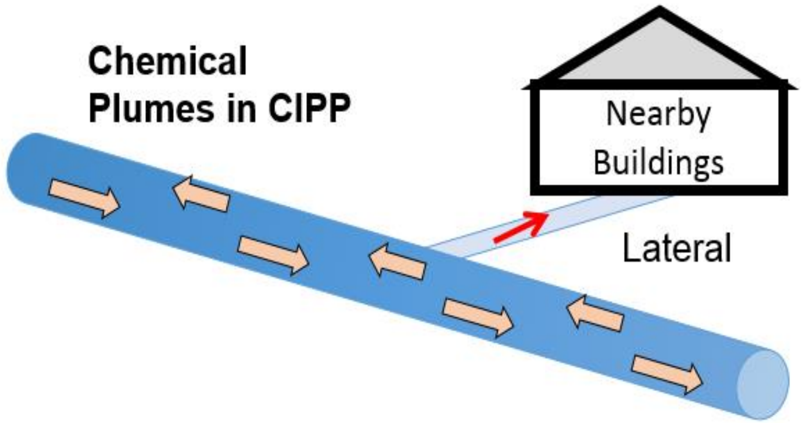
Method to insert uncured resin tubes	**Air inversion**	**Water inversion**	**Pull in place**

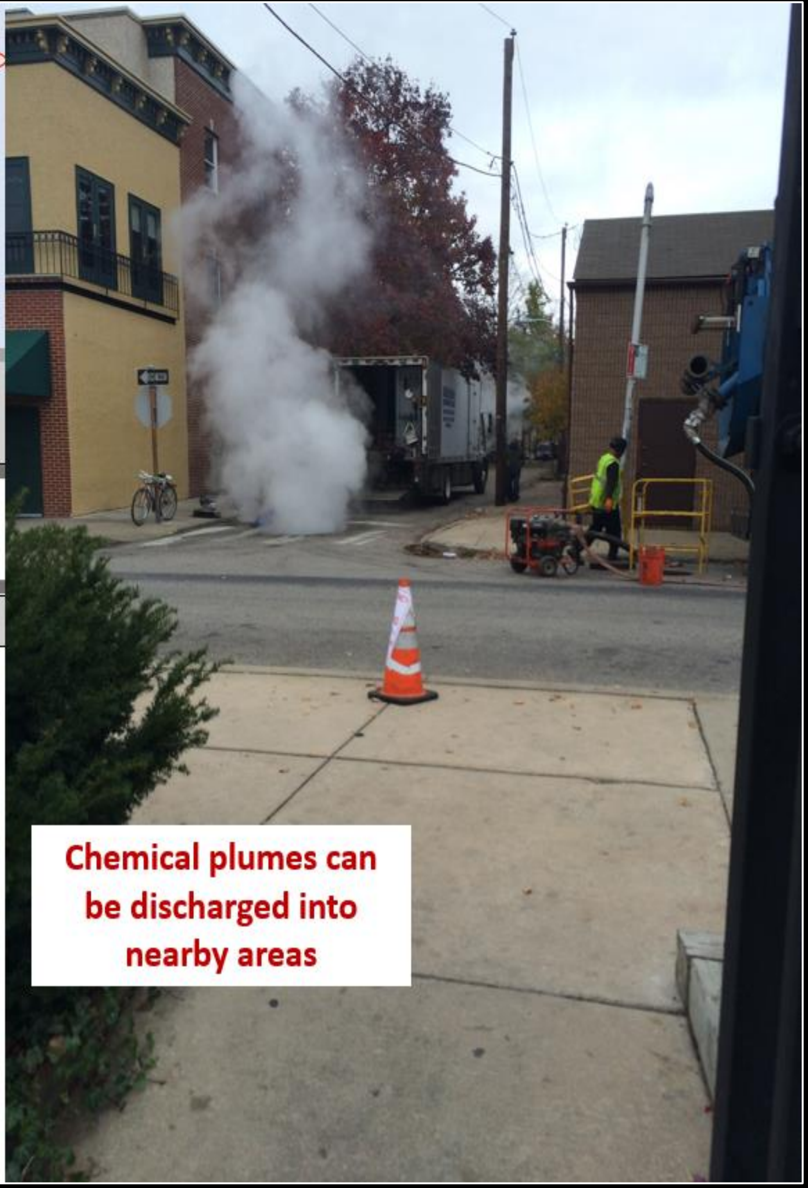
Sometimes resin may leave the tube and flow into cracks and sewer laterals. Tubes sometimes have a plastic coating. Plastic “preliners” sometimes used.

Method to polymerize resin	**Thermal – Steam injection (most popular)**	**Thermal – Hot water recirculation**	**UV – Light exposure (est. most growth)**
Cooldown method	**Forced hot air**	**Forced ambient air**	**Recirculated water**

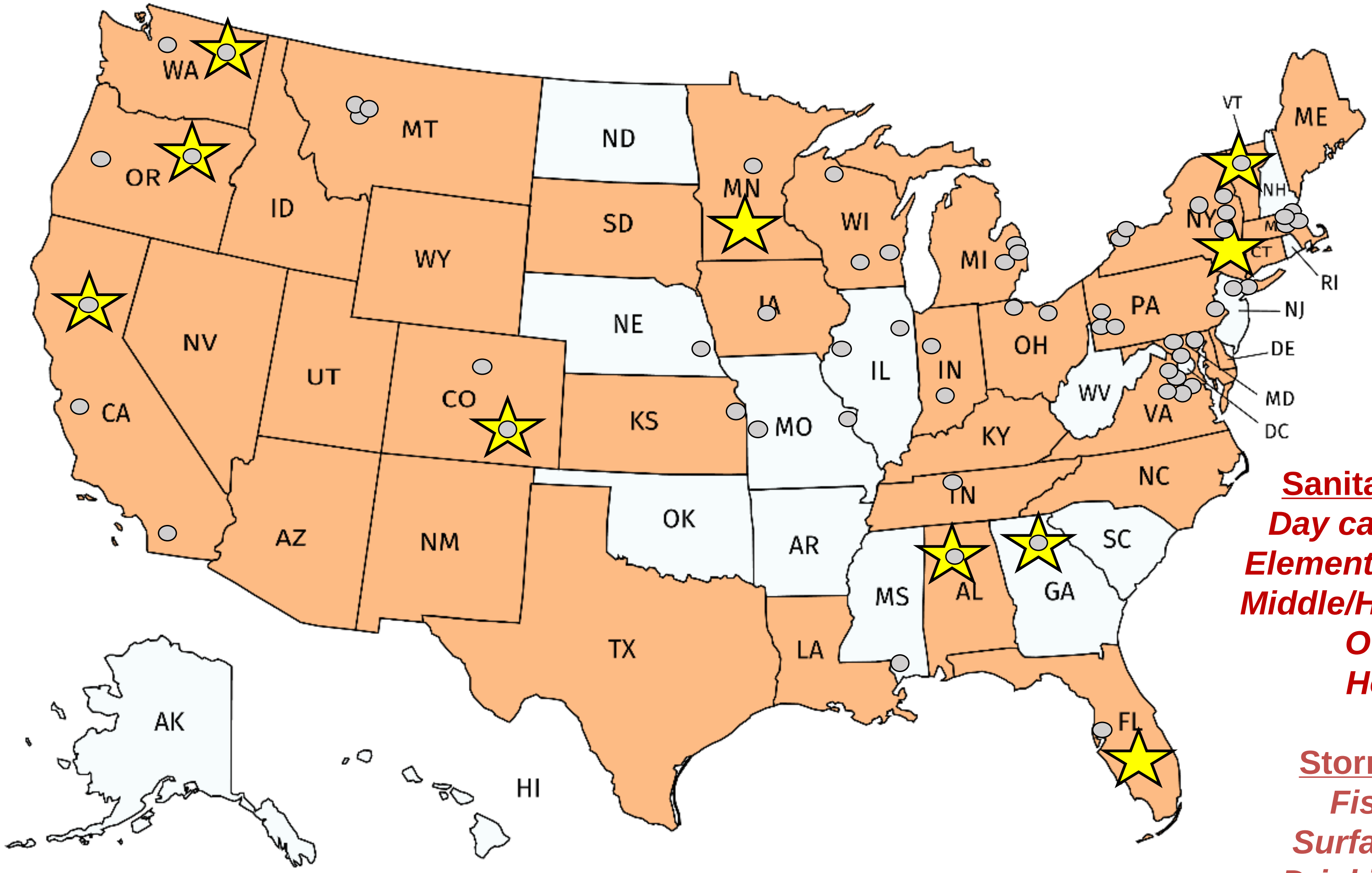


Chemical Plumes Generated by CIPP can Escape the Pipe Being Repaired





Are chemical emissions a problem?



Sanitary Sewer

Day care centers
Elementary schools
Middle/High schools
Offices
Homes

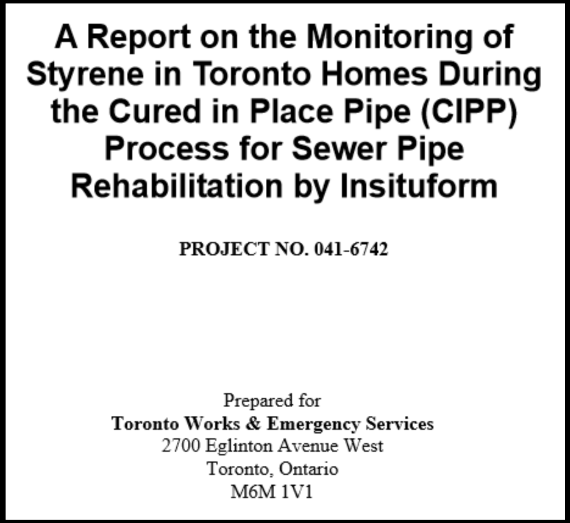
Storm Sewer

Fish kills
Surface water
Drinking water

Contractor and Municipality Statements to the Public

“styrene vapor of at most few ppm”
“is not a human health risk”
“is safe for people and animals”
“it is harmless steam”
“no hazardous conditions posed”
“don’t be alarmed”
“50 ppm styrene is the safe exposure level”
“open windows to allow ventilation”
“place plastic bags filled with water and wet towels over drains/sinks/toilets”
“pour 1 gallon, 1-2 cups water down drains”
“some people are offended by this odor and are fearful of it; even though the concentrations they smell present no harm”

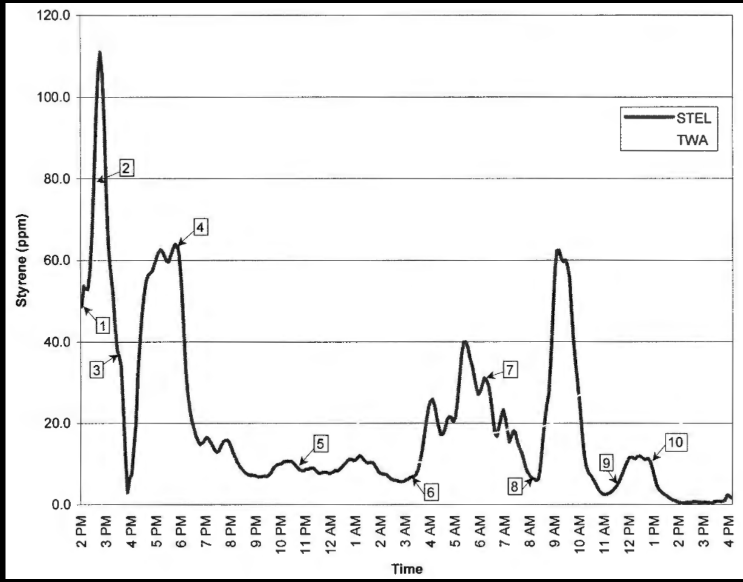
Only 4 CIPP air monitoring studies have been conducted in the past 16 years


A Report on the Monitoring of Styrene in Toronto Homes During the Cured in Place Pipe (CIPP) Process for Sewer Pipe Rehabilitation by Insituform

PROJECT NO. 041-6742

Prepared for
Toronto Works & Emergency Services
2700 Eglinton Avenue West
Toronto, Ontario
M6M 1V1

AirZone, Inc. (2001)

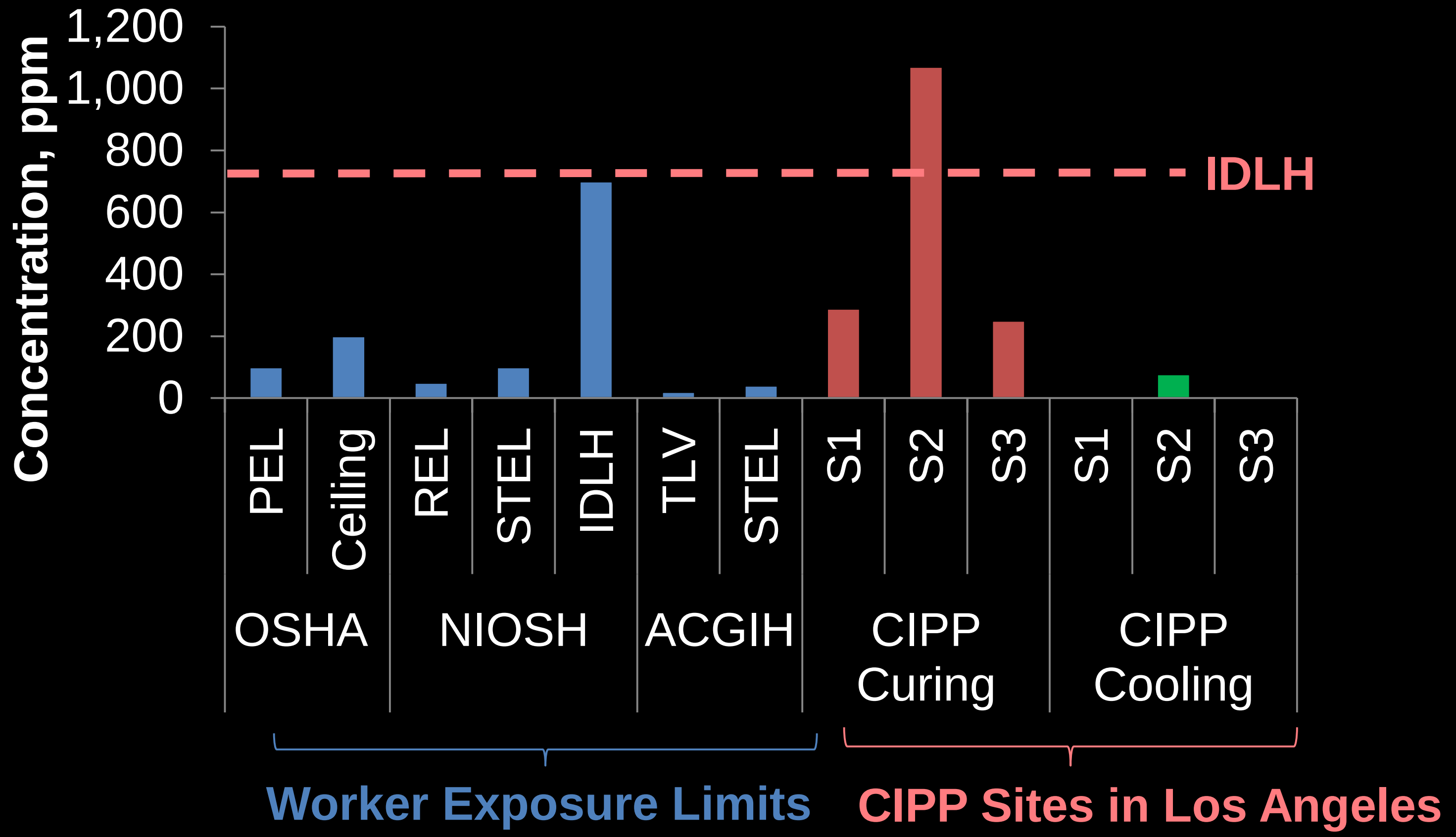


Bauer (2004)

ATSDR (2005)

2015, Styrene Exiting a CIPP Sewer Manhole Exceeded the NIOSH IDLH

IDLH: a concentration from which a *worker* could escape without injury or without irreversible health effects in the event of respiratory protection equipment failure



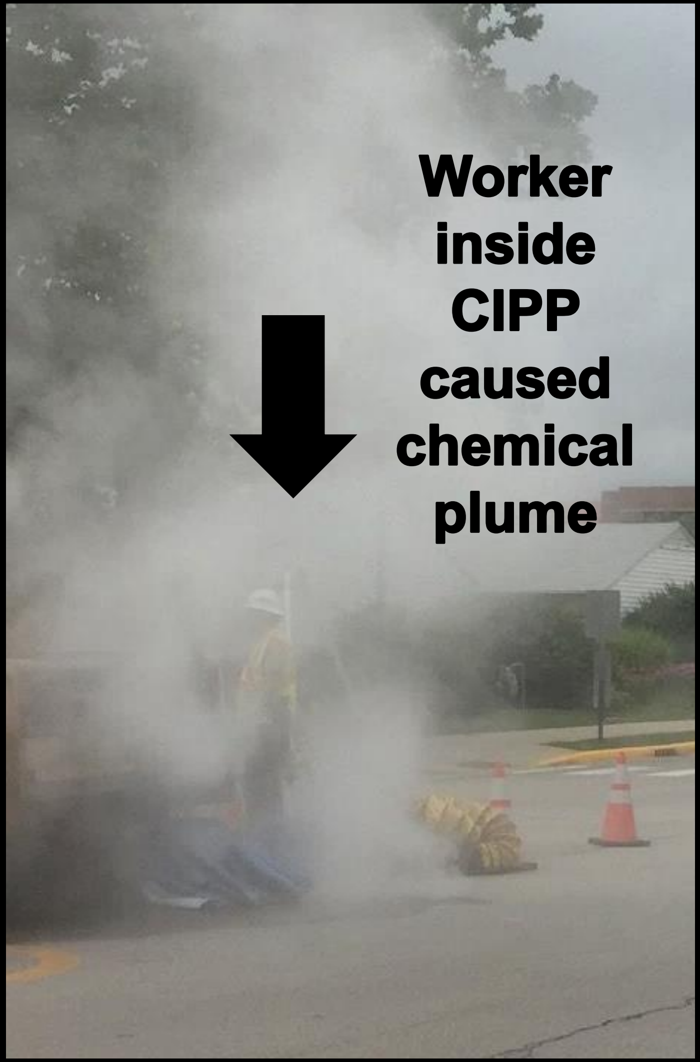
Adjari (2016)

NSF RAPID Response Study

To better understand materials emitted from CIPP sanitary sewer pipe and storm water pipe repair installations and their potential toxicity

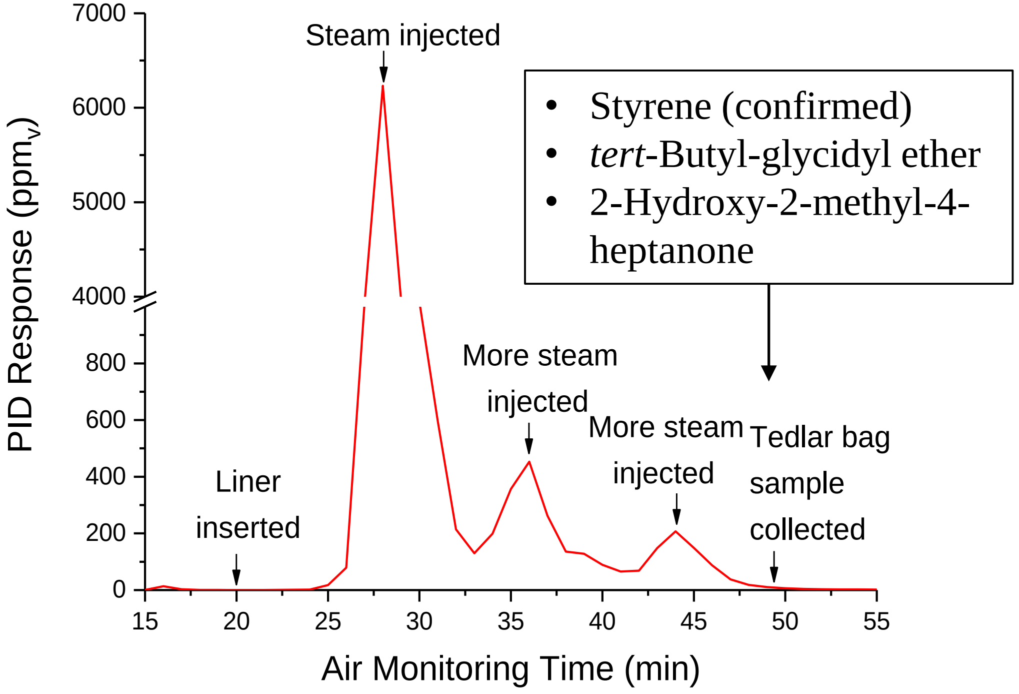
2017 Study Objectives

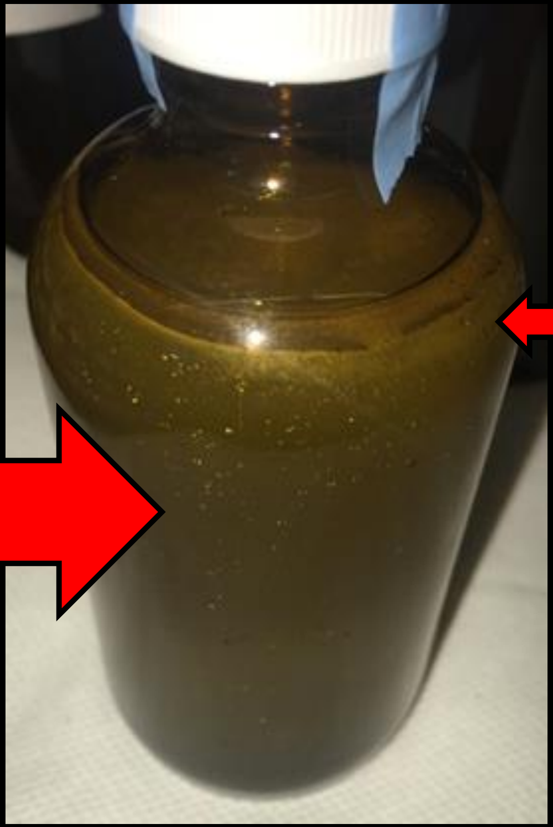
1) Conduct air sampling and analysis for 7 steam CIPP installation sites that use non-styrene and styrene resins
2) Characterize the raw materials, materials emitted, and their magnitudes
3) Evaluate chemical plume toxicity to mouse lung cells
4) Identify worksite safety issues and provide recommendations on future technology use



Before uncured resin tube was cured

Results: Chemicals were emitted from the uncured resin tube *before* installation and from the downstream manhole *during* installation



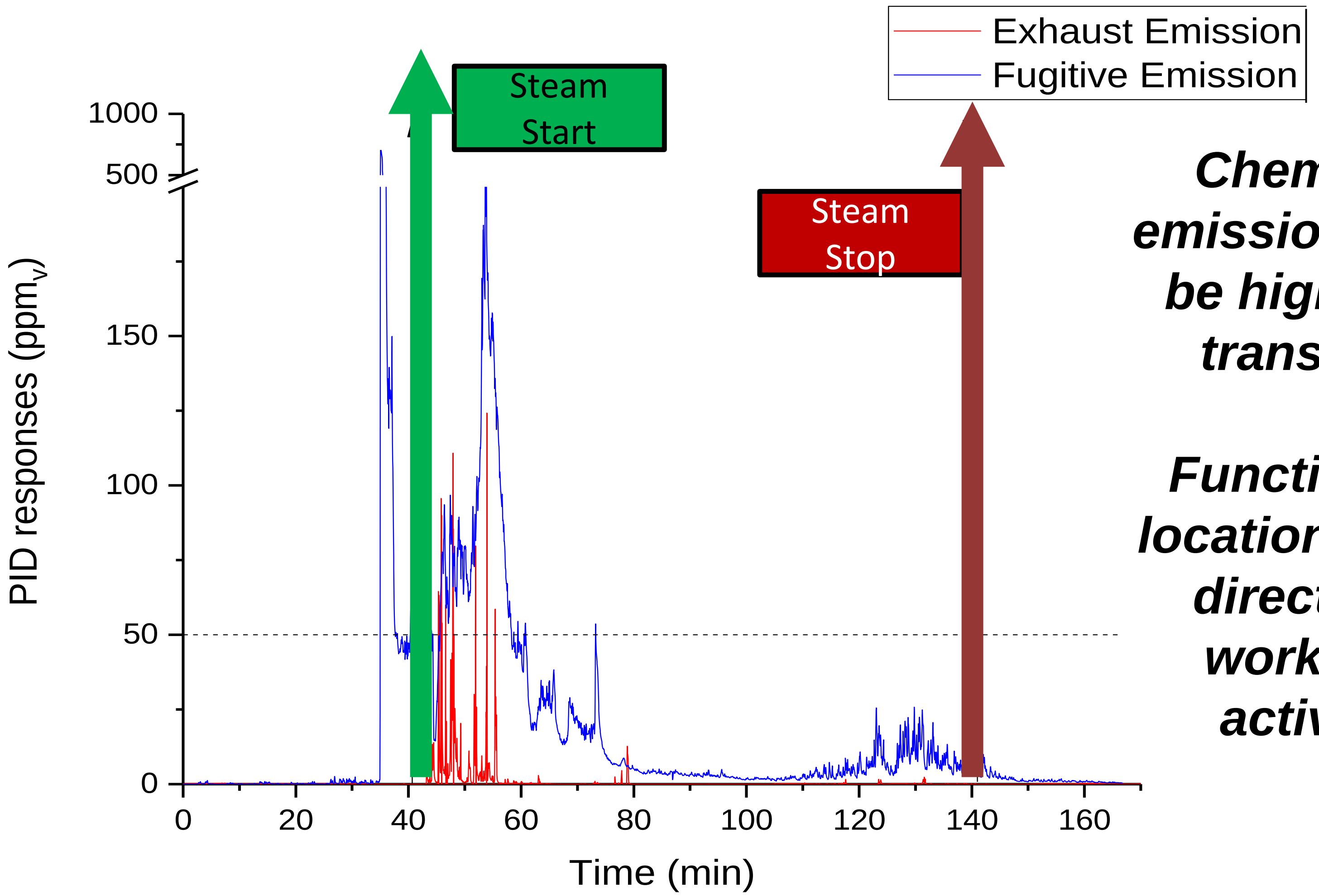


This is a Multiphase Chemical Mixture, **NOT Steam**
(particulates, droplets, partially cured resin, etc.)

We Found Several Compounds Emitted into the Air at the CIPP Sites and Some, but Not All, were Present in the Uncured Resin Tubes

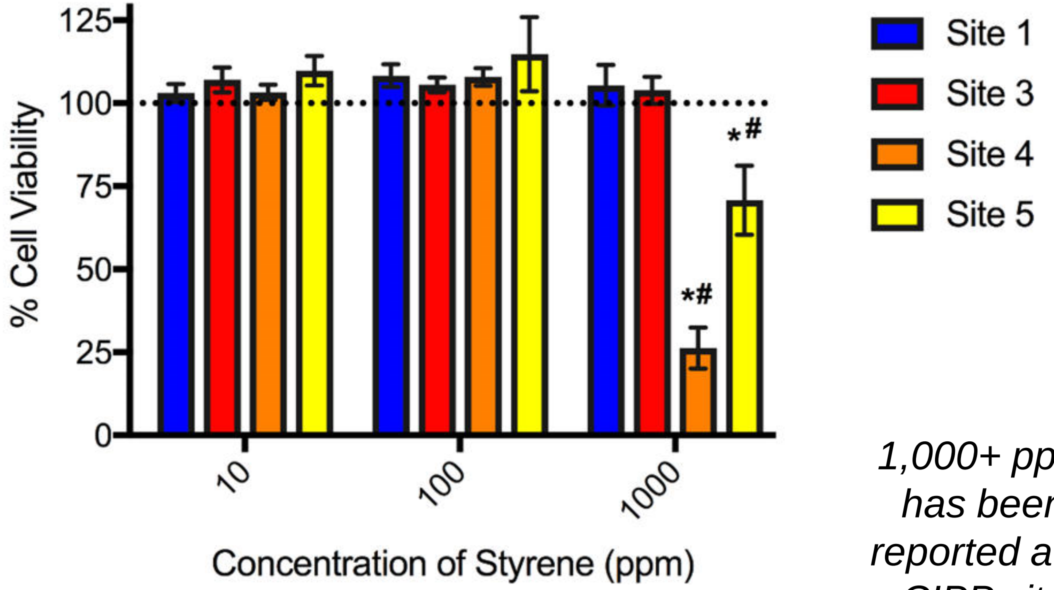
Acetone	
Acetophenone	Hazardous Air Pollutant
Benzaldehyde	
Benzoic acid	
BHT	
4-*tert*-Butylcyclohexanone	
4-*tert*-Butylcyclohexanol	
Dibutyl phthalate	Hazardous Air Pollutant / EDC
Phenol	Hazardous Air Pollutant
Styrene	Hazardous Air Pollutant/ Ant. Carcinogen*
1-Tetradecanol	
Tripropylene glycol diacrylate	
1-Dodecanol	

Additional literature indicates that the emission of other HAPs, carcinogens, EDCs, and compounds may occur



Chemical emissions can be high and transient

Function of location, wind direction, worksite activity



1,000+ ppm has been reported at a CIPP site

Mouse lung cell experiments indicated that toxicity occurred and future health impact investigations are necessary

Recommendations

(1) Minimize dermal and inhalation exposures

(2) Monitor emissions

(3) Use appropriate personal protective equipment (PPE)

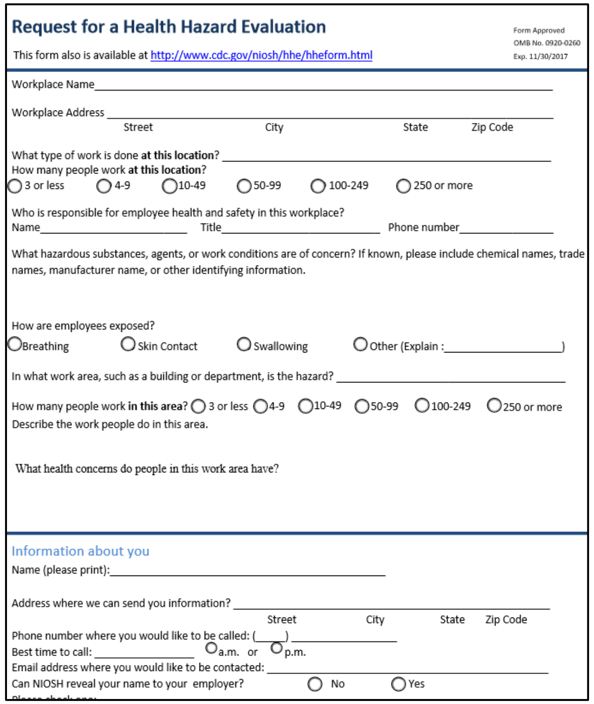
(4) Capture emissions and confirm this by monitoring

CURED-IN-PLACE-PIPE (CIPP)
Employees OR Employers OR Unions should
Request –FREE– Help from NIOSH
National Institute of Occupational Safety and Health

Right now you can…

- Request feedback about what PPE to wear
- Request a **-FREE-** Health Hazard Evaluation from NIOSH

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.



Request for a Health Hazard Evaluation

Form Approved
OMB No. 0920-0260
Exp. 11/30/2017

This form also is available at http://www.cdc.gov/niosh/hhe/hheform.html

Workplace Name____________________

Workplace Address ____________________
Street City State Zip Code

What type of work is done **at this location**? ____________________
How many people work **at this location**?
○ 3 or less ○ 4-9 ○ 10-49 ○ 50-99 ○ 100-249 ○ 250 or more

Who is responsible for employee health and safety in this workplace?
Name__________ Title__________ Phone number__________

What hazardous substances, agents, or work conditions are of concern? If known, please include chemical names, trade names, manufacturer name, or other identifying information.

How are employees exposed?
○ Breathing ○ Skin Contact ○ Swallowing ○ Other (Explain :__________)

In what work area, such as a building or department, is the hazard? ____________________

How many people work **in this area**? ○ 3 or less ○ 4-9 ○ 10-49 ○ 50-99 ○ 100-249 ○ 250 or more
Describe the work people do in this area.

What health concerns do people in this work area have?

Information about you

Name (please print):____________________

Address where we can send you information? ____________________
Street City State Zip Code
Phone number where you would like to be called: (____) __________
Best time to call: __________ ○ a.m. or ○ p.m.
Email address where you would like to be contacted: ____________________
Can NIOSH reveal your name to your employer? ○ No ○ Yes

Requests can be made in writing or online:
https://www.cdc.gov/niosh/hhe/hheform.html

CONTACT THESE PEOPLE TO DISCUSS WHAT COULD BE INVOLVED:

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

You can access FREE CIPP worker and public safety resources

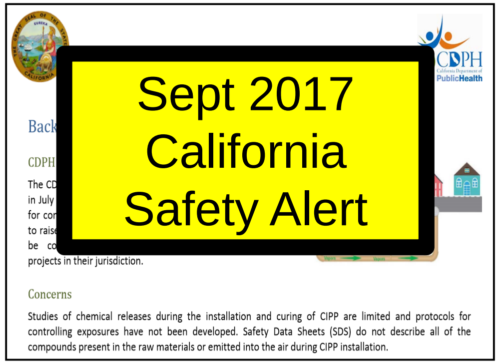
CIPP SAFETY STUDY WEBINAR (Oct 2017)
neha.http://neha.org/node/59333

To help local, state, and county health professionals better understand public health and occupational exposures with CIPP. Results of a July 2017 Purdue University CIPP safety study were presented as well as lessons learned from a NIOSH workplace Health Hazard Evaluation, and options for health officials, agencies, companies, and workers to gain technical assistance.

NATIONAL ENVIRONMENTAL HEALTH ASSOCIATION

Promoting productive workplaces through safety and health research NIOSH

PURDUE UNIVERSITY



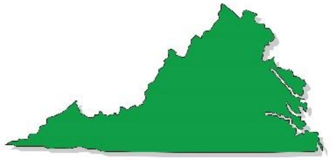
Pooled Fund Project Overview, 2016-

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

Determine:

(1) The scope of the problem across departments of transportation (DOTs) (i.e., the extent of use of these technologies and the scale of their impacts to water quality);
(2) The effectiveness of existing construction specifications at minimizing contaminant release from rehabilitated culverts; and
(3) The degree to which the structural integrity and longevity of rehabilitated culverts are compromised by chemical leaching.

Focusing on Spray-On Liners and CIPP






Chemical Emission Concerns

- Aquatic toxicity (i.e., fish kills)
- Surface water contamination (i.e., downstream, water supplies)
- Wastewater toxicity to wastewater treatment facilities
- Leaching magnitude and duration
- Emission into air / complaints and exposures (i.e., inhalation, dermal)

Transportation agencies want to best use technologies but need information to make more informed selection and specification development decisions

Task 1: To better understand existing CIPP construction practices and past chemical contamination incidents focused on storm sewer

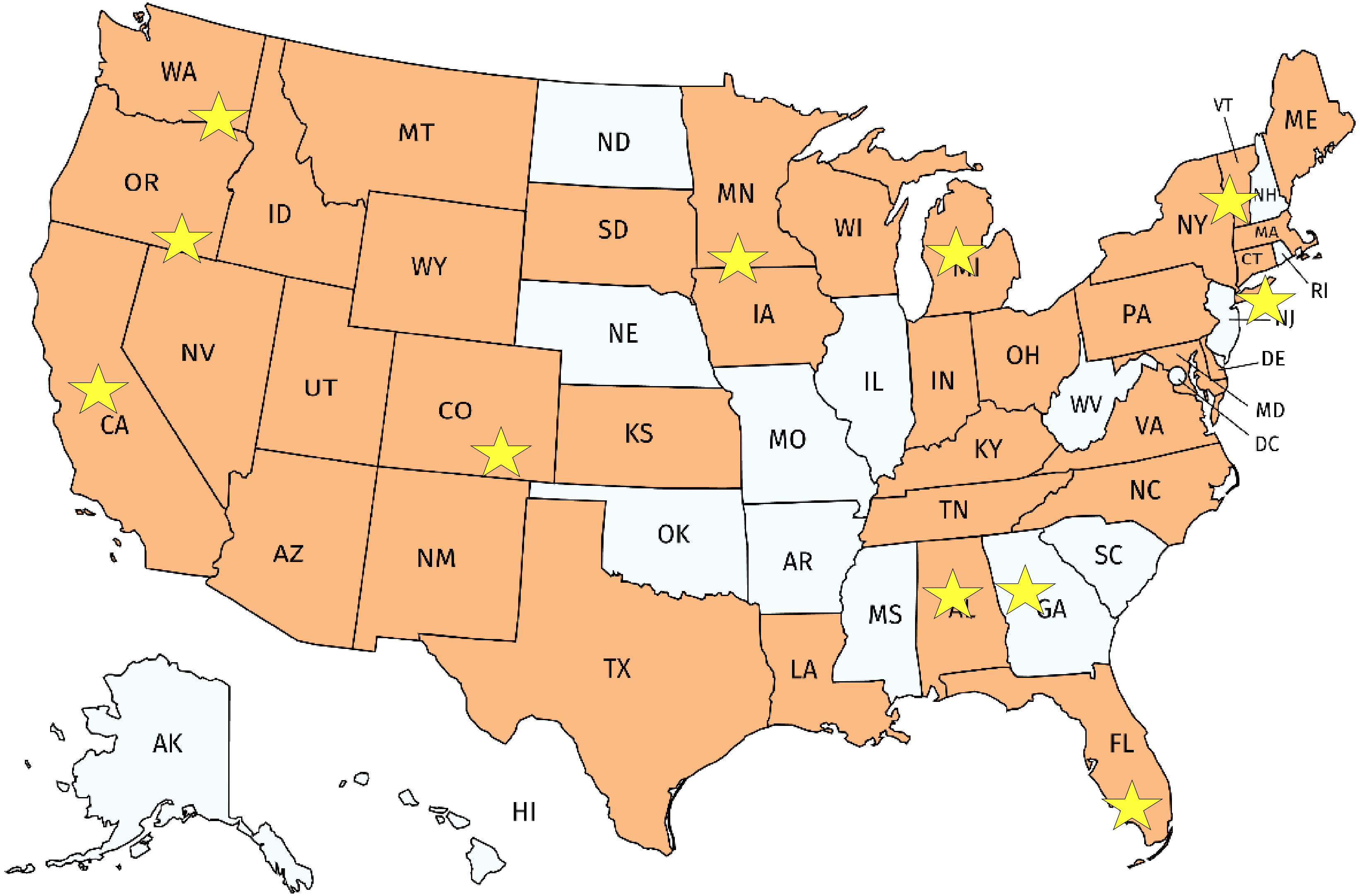
Objectives

(1) Compile and review CIPP-related surface water contamination incidents: *incident = outside a research study*

(2) Analyze CIPP water quality impacts

(3) Evaluate construction practices for state transportation agencies

13 water contamination incidents were found



- **Alabama (2010):** National Response Center
  - 70,000 gallons of CIPP wastewater released to a dry creek bed
  - Styrene concentration in the creek water (143 mg/L), contaminated nearby drinking water well (4 mg/L)
- **Colorado (2011):** DOT, Department of Public Health and Environment
  - Chemicals entered surface water and downstream drinking water
  - Maximum styrene level detected in water (18 mg/L) and 14 mg/kg in soil
  - Variety of other chemicals present associated with CIPP
- **Vermont (2013):** DOT, Vermont Department of Environmental Conservation
  - Maximum styrene level in the Creek the day of installation was reported as 5,160 mg/L
  - Styrene level decreased over the two month monitoring period, but other compounds were detected: acetone, 1,2,4-TMB, 1,3,4-TMB, *tert*-butanol

Styrene: 0.1 mg/L (EPA); 2.5 mg/L (VDOT), 1.0 mg/L (VTDOT), 0.005 mg/L (NYSDOT)
Other chemicals found in contaminated water, not just styrene

Few studies have determine the degree CIPP installations cause water quality impacts

- 7 total studies, funded by VDOT, CALTRANS, NYSDOT
- Total CIPPs monitored: 18 steam, 4 hot water, 3 UV
- Styrene, a common ingredient for some CIPPs, found often
  - Reported in waterway: Up to 77 mg/L
  - Detectable in water: 88 days
  - In curing water: Up to 250 mg/L
  - Found leaching from a non-styrene based CIPP
- Other compounds detected at UV- and steam-CIPP sites
  - Vinylic monomer exceeded the aquatic toxicity threshold for 120 days; Other chemicals found: acetone, benzene, chloroform, isopropyl benzene, *tert*-butyl alcohol, methylene chloride, methyl ethyl ketone, *n*-propyl benzene, toluene, xylenes, 1,2,4-TMB, 1,3,5-TMB
  - Steam-CIPP condensate highly concentrated, dissolved aquatic organisms at room temperature within 24 hours

4 slides redacted due to copyright

Parting Thoughts

- **CIPPs** are products chemically manufactured *in the field.*
  - They are not installed like other materials. Raw chemicals and other hazards are used *in the field.*
  - They can present different and sometimes additional risks of chemical release compared to other rehabilitation technologies.

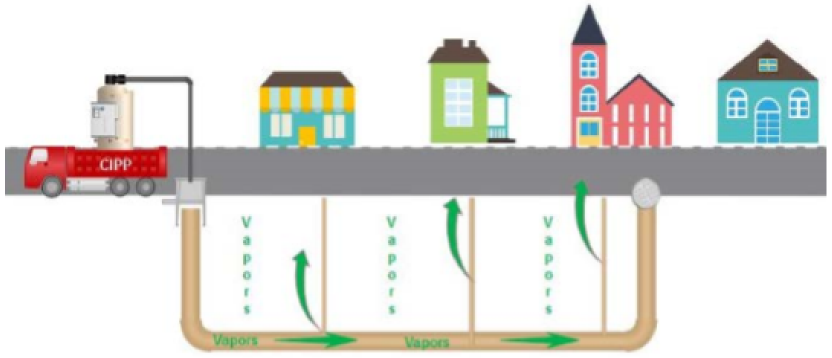
- Some CIPP related incidents have **contaminated drinking water supplies**, prompted **emergency responses**, **contaminated drinking water**, caused **fish kills**.

- Incidents found may be outlier events or they may represent the risks inherent of typical installations.

California Department of Health, September 2017

Cure-In-Place Pipe (CIPP)
Additional Considerations for Municipalities

“Persons who detect an odor and experience health symptoms…. should contact their medical provider and local health department; Utilities, engineering firms, and contractors should not tell residents the exposures are safe. There is no credible testing data for all CIPP installation scenarios” – *California Department of Public Health, 2017*



https://www.cdph.ca.gov/Programs/CCDPHP/DEODC/CDPH%20Document%20Library/CIPP%20additional%20considerations.pdf

Some, but Not All, Recommendations

1. **<u>Today, request</u>** NIOSH to conduct a health hazard evaluation for your crew
2. **<u>Wear</u>** appropriate PPE (i.e., inhalation, dermal, eye protection) as determined by NIOSH
3. **<u>Submit</u>** a POTW permit to the DOT Engineer to verify pre-approval for POTW disposal of rinse water, wastewater, and/or condensate
4. **<u>Conduct</u>** real-time and grab sample air monitoring
5. **<u>Divert</u>** water flow until "acceptable degree of cure" established and new CIPP passes water quality tests
6. **<u>Utilize</u>** impermeable plastic sheets (i.e., 10 mil thick) immediately upstream and downstream of the pipe
7. **<u>Prohibit</u>** chemicals from exiting the pipe <u>during</u> the CIPP manufacturing process (collect gases, liquids, or solids)
8. **<u>Rinse</u>** the new CIPP after manufacture (collect liquids and solids)
9. **<u>Prohibit</u>** wastewater, rinse water, or condensate to be discharged to waterway unless written approval by state environmental agency
10. **<u>Conduct</u>** water testing before and after installation - compare to standards/specs (use tests capable of detecting <u>ALL</u> chemicals of concern) - Any exceedance triggers additional testing
11. **<u>Capture</u>** particles and shavings created during cutting the end of CIPP
12. **<u>Report</u>** accidental discharge, small or large, to state DOT and Environmental Regulatory officials immediately, so downstream water supplies, the environment, and population can be protected.

Additional recommendations and guidance will be released. Ongoing work pertains to CIPP longevity and chemical release.

PURDUE UNIVERSITY | CIPP Safety Solutions Group

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News | In the News

Scientific report files & associated video files, *Environmental Science & Technology Letters*, July 2017

Frequently Asked Questions (FAQ)

- General Questions
- What Can I Do?
- Questions about Chemicals in the Air, in Building, and Exposure
- Questions about CIPP Technology
- Worker Safety

Incorrect assertions about the CIPP study

In 2016, Purdue researchers began investigating chemical emissions and exposures caused by cured-in-place-pipe (CIPP) water pipe repair sites. CIPP is the most popular water pipe repair technologies used in the U.S. Because this technology uses raw chemicals in the field and manufacturers a new plastic pipe inside an existing damaged water pipe, chemicals can be emitted into the environment and enter nearby buildings. CIPP is used for sanitary sewer, storm sewer, and drinking water pipe repairs.

Questions? Contact us at CIPPSafety@purdue.edu

Visit http://CIPPSafety.org or https://engineering.purdue.edu/CIPPSafety

- ✓ FAQs
- ✓ Links to studies
- ✓ Links to resources

LEARNING OBJECTIVES:

1. List the factors that can influence polymer composite manufacture and quality
2. Describe Purdue University CIPP chemical emission studies
3. Recognize how to contact the NIOSH for a health hazard evaluation
4. List recommended practices that can help understand minimize chemical emissions and exposures

Thank You.

Please contact us if you have any questions.

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