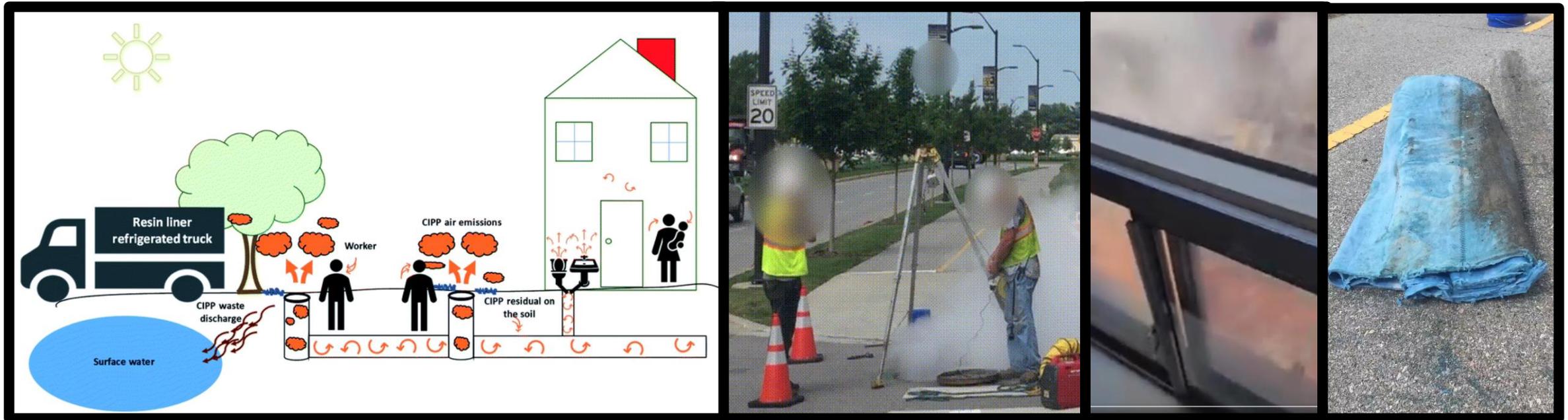


Outdoor Plastic Liner Manufacturing for Water and Sewer Repairs: Chemical Exposures and Safety Lessons

Andrew Whelton, Ph.D., awhelton@purdue.edu

A compilation of efforts by many





A special thanks to the many people who made this possible

Water Infrastructure Needs

USEPA: \$200 billion for drinking water pipe repairs

USEPA: \$600 billion for sanitary sewer pipes

FHWA: Millions of feet of culverts require repair

Private water and sewer pipes require repair. In-building plumbing require repairs.

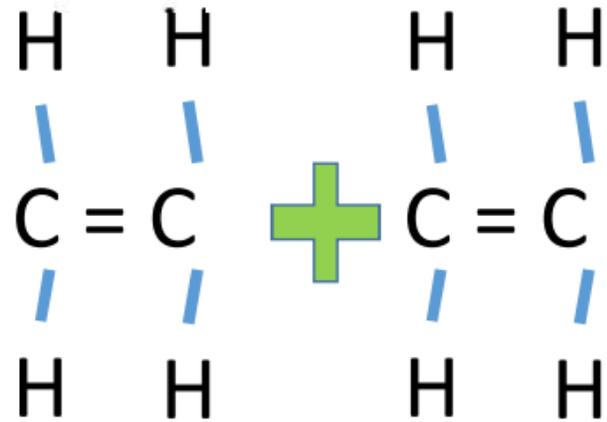
Mechanical pipe failures can be catastrophic
(traffic disruption, public safety, \$\$\$)



Plastics are ...Polymers = *Many...Unit...compound*

Long-chain molecules of very high molecular weight (n = tens of thousands)

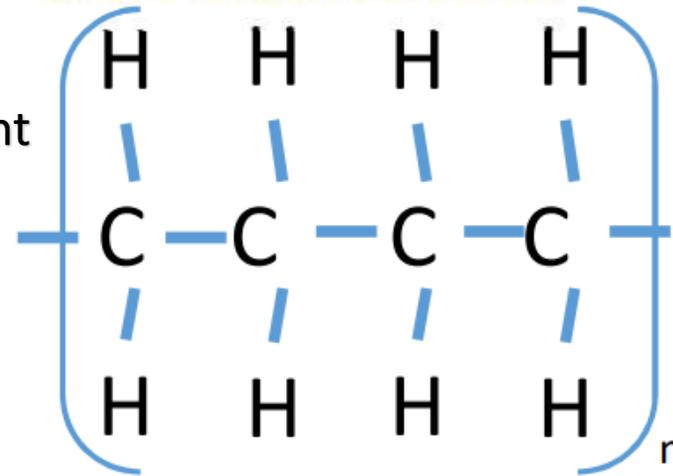
MER UNITS



Initiator(s)
+heat or UV light



POLYMERIZATION

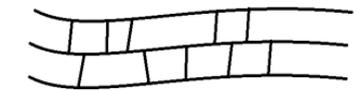


Straighten the spaghetti strands



Not crosslinked

Bond the spaghetti strands



Crosslinked

POLYMER CHAINS ... THINK SPAGHETTI !

Linear



Branched



Place of Manufacture

Before onsite
HDPE, PVC, cPVC, PEX, etc.

Inside the water system
Coatings and CIPP liners

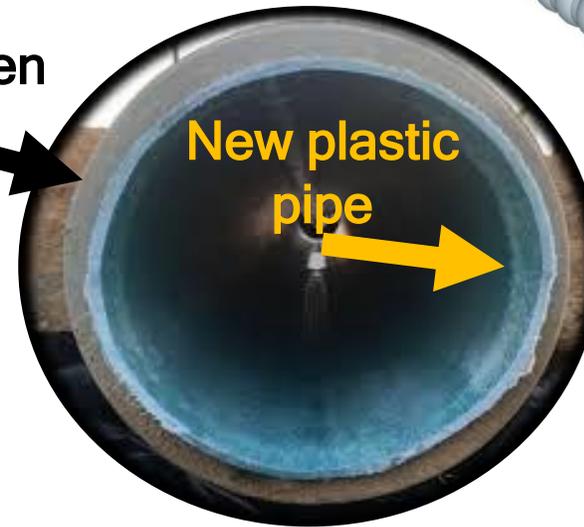
Cured-in-place-pipe (CIPP) projects, practices, and chemicals

Sanitary sewer, storm sewer, drinking water pipes (4 inch to >8 feet diam.)

Can be 60-80% less expensive than other pipe repair options

Pipes can be repaired in 1-3 hours instead of days or weeks

Old broken pipe

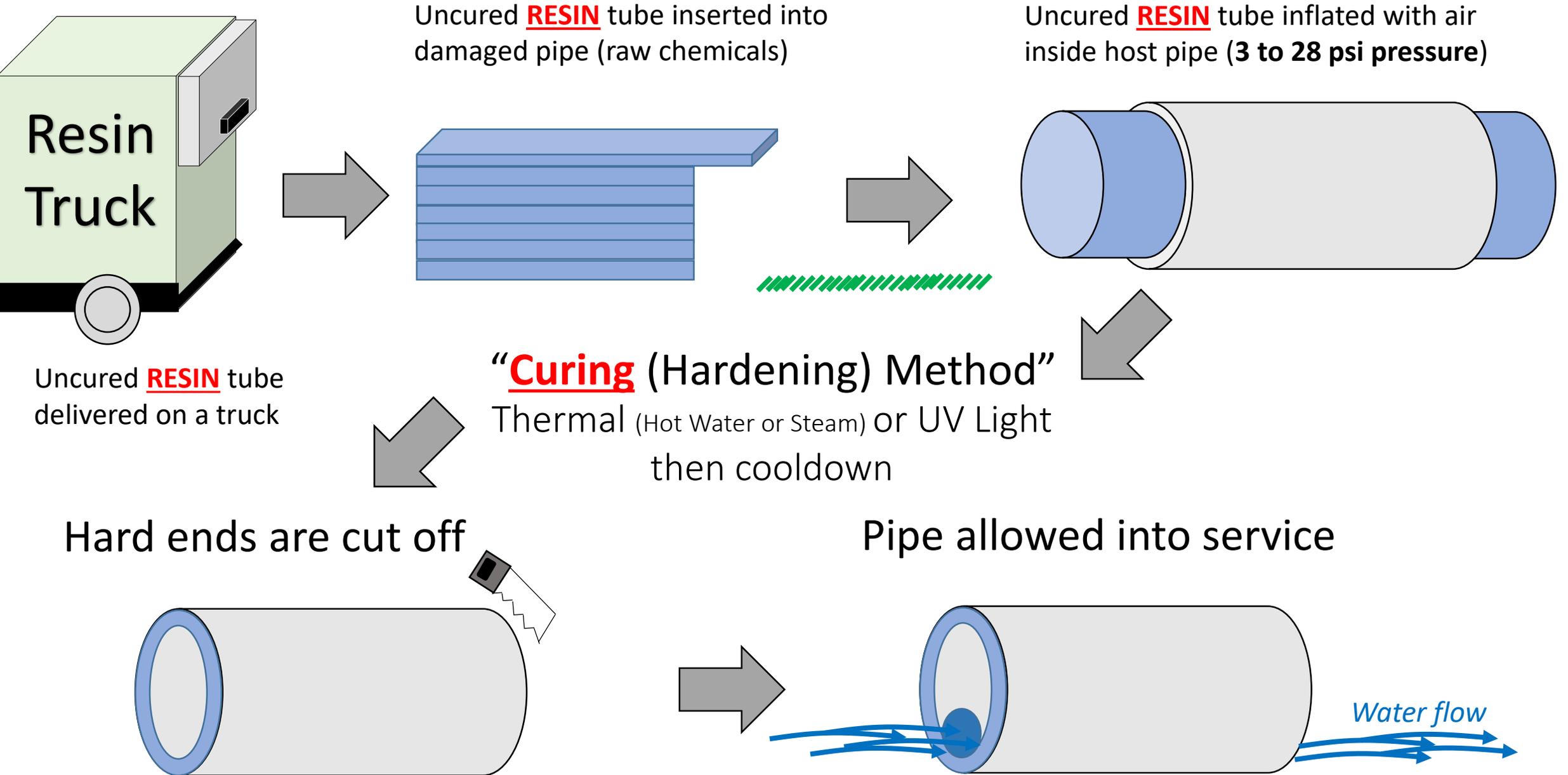


Curing Popularity: Steam >> hot water > UV light

CIPP Resin Popularity: Unsaturated polyester > vinyl ester >> epoxy

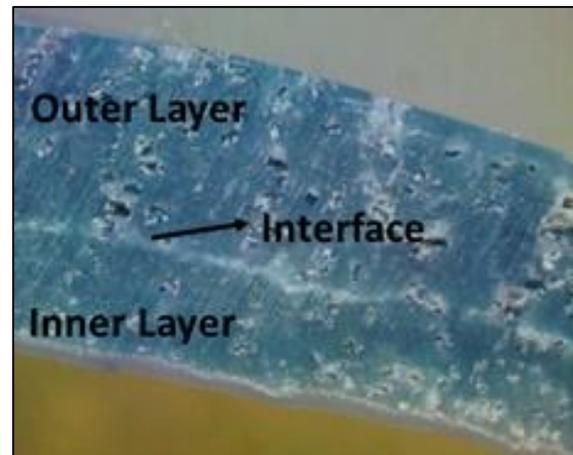
Resin Type Popularity: Styrene >>>> Nonstyrene Resin Types

Popup worksites that manufacture a plastic pipe (or liner)

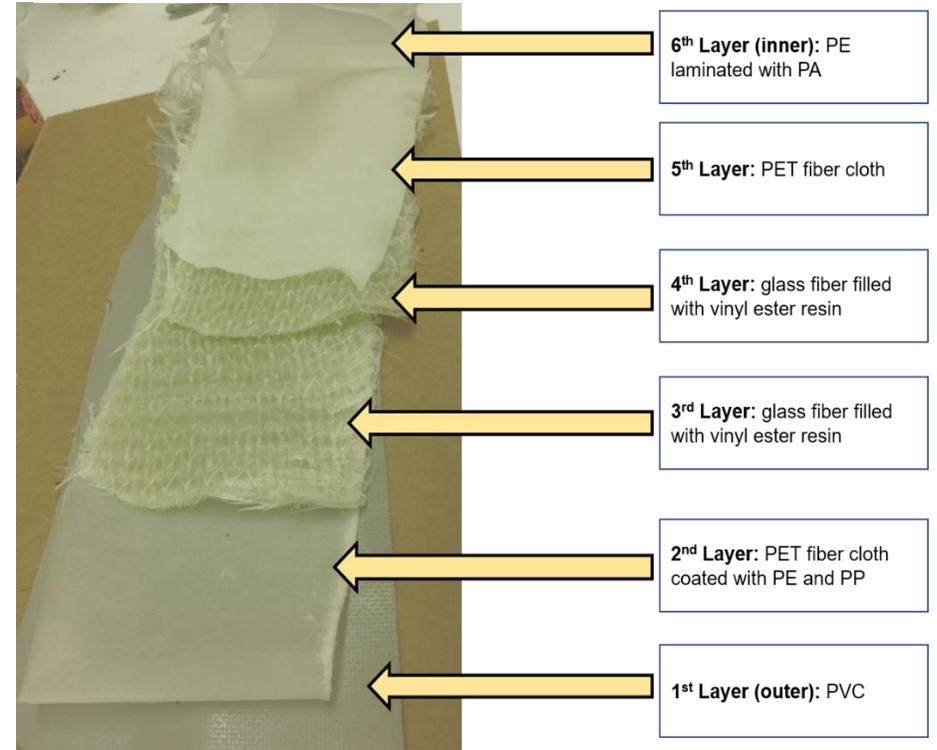




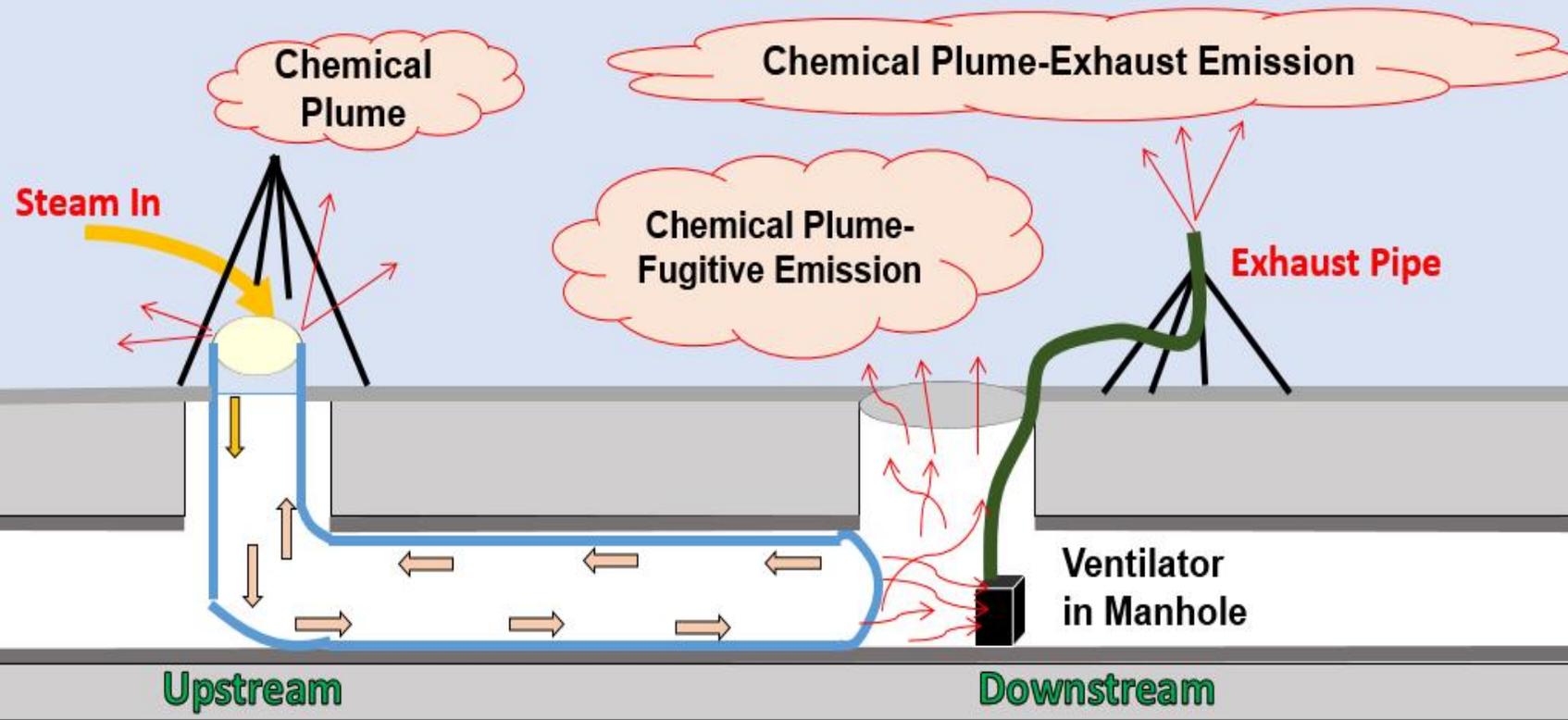
Uncured PET felt resin tube before steam curing



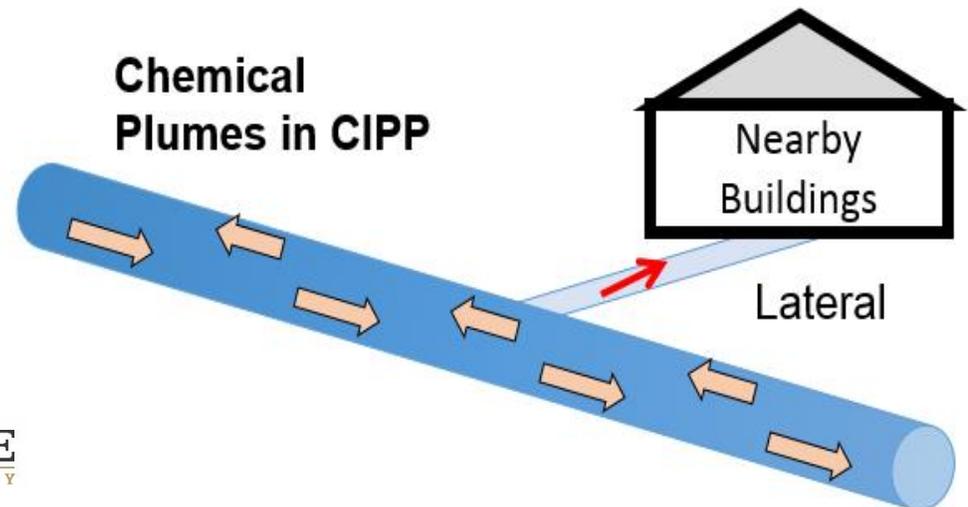
Cross-section of new UV cured CIPP with fiberglass layers



Cross-section of new thermally cured CIPP with PET felt layers



Chemical Plumes Generated by CIPP can Escape the Pipe Being Repaired



Chemical plumes can be discharged into nearby areas

**There are demonstrated human health risks
to workers *-and-* bystanders
(infants, children, adults).**

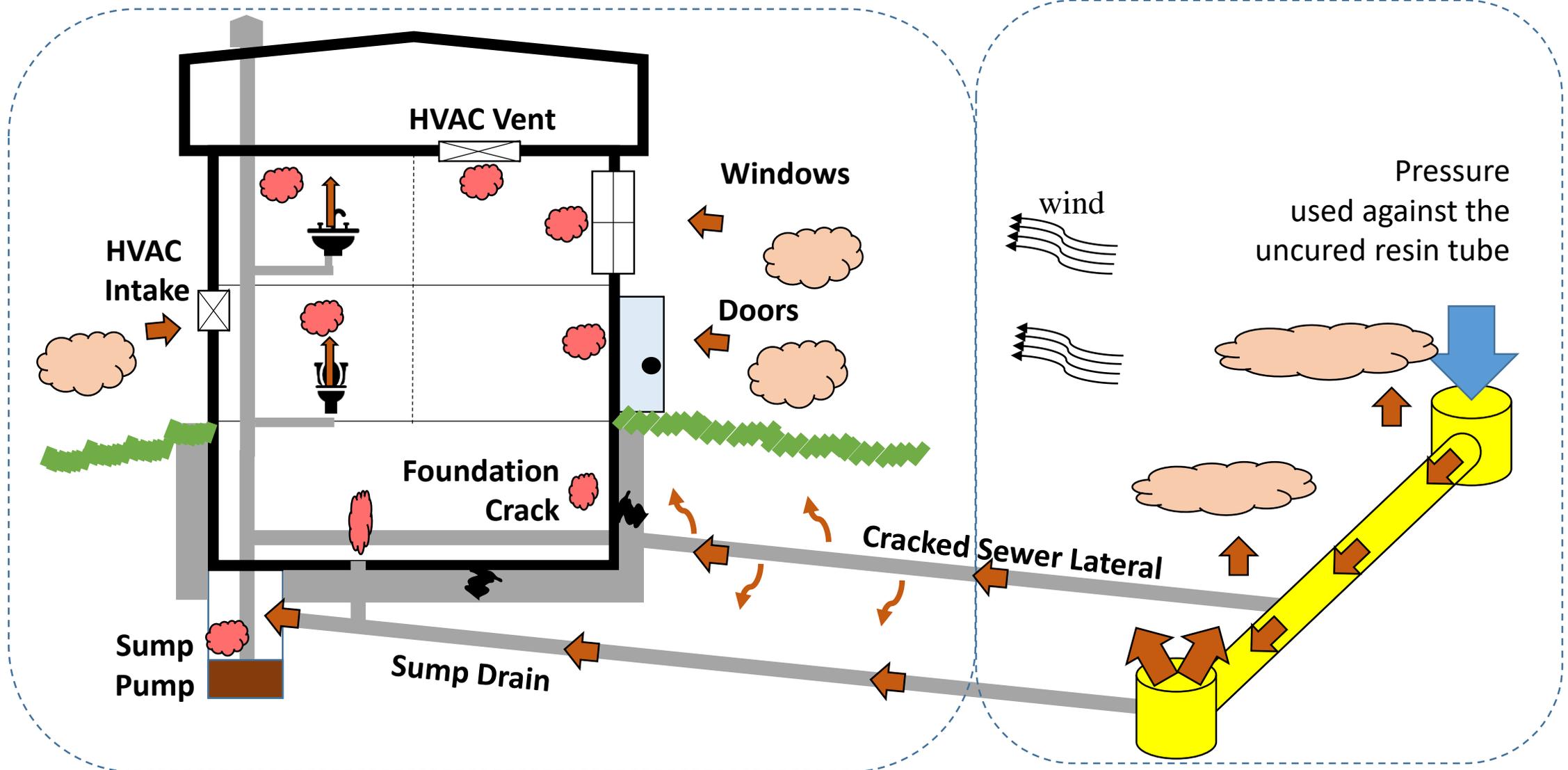
Chemical exposure to the plastic manufacturing waste
is the primary risk.



Waste: (noun) "an unwanted byproduct of
a manufacturing process"

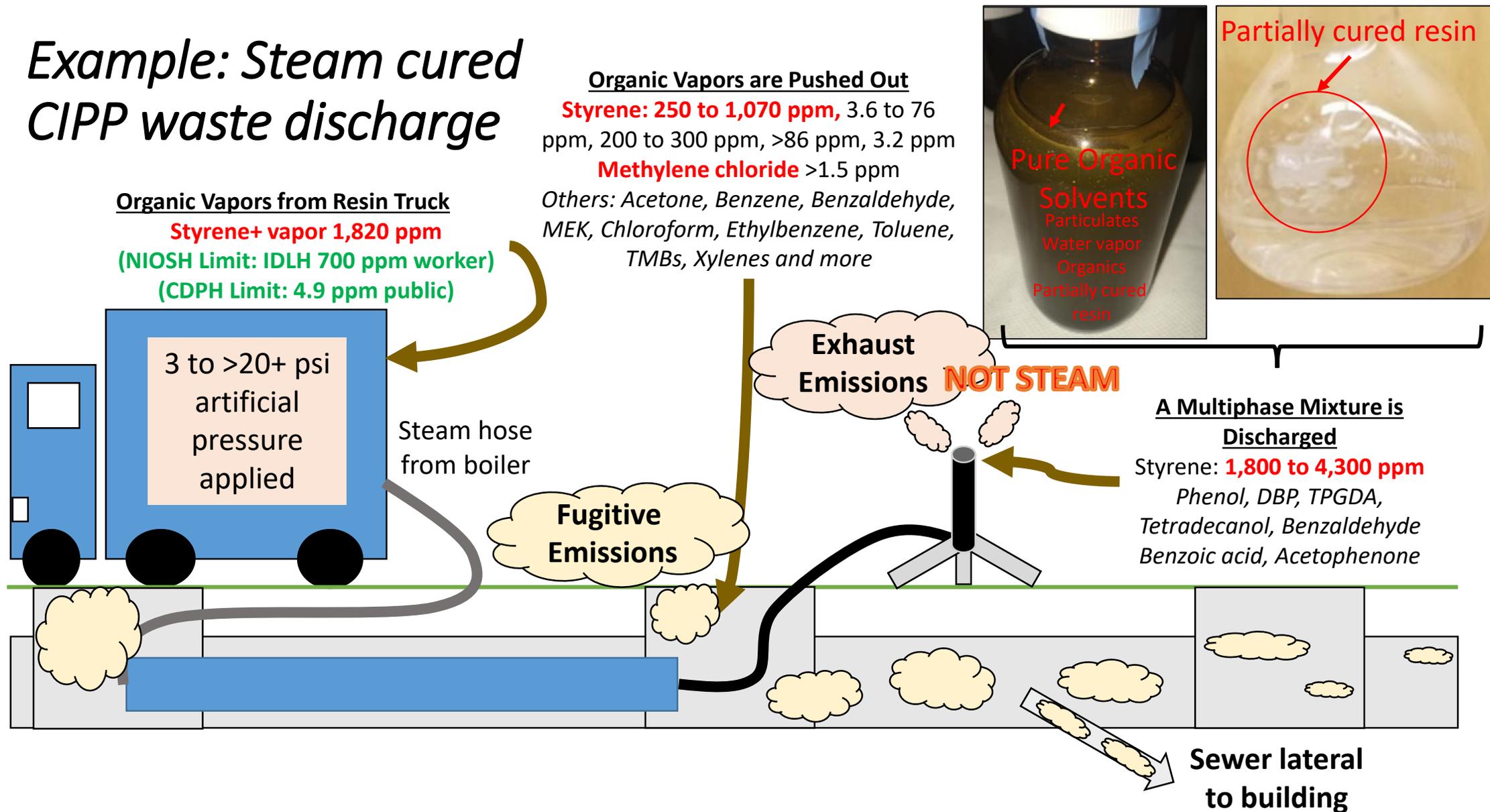
Private Property
(not for contractors)

Utility/City Property
(Worksite only for contractors)



Concentrations in and outside buildings differ by activity:
Setup vs. Curing vs. Cooldown vs. Mechanical cutting

Example: Steam cured CIPP waste discharge



CIPP plastic manufacturing waste has had significant bystander health consequences, 140+ incidents

Cancer Care Center of Decatur evacuates due to odor caused by city sewer project
Illinois: Feb 20, 2020

Spooner Middle School reopens, identifies 'chemical exposure' that sickened 64 students and staff

Some parents aren't comfortable sending children back, saying district hasn't been open about what caused Nov. 10 evacuation

By Rich Kremer

Published: Tuesday, December 21, 2021, 6:10pm

Fumes Sicken 28 Pupils at Zamorano Elementary
California: Sept 21, 2017

Odor from sewer work causes teachers to fall ill at Riverview Elementary School
Washington: Oct 10, 2018

Visit and read about
the incidents we found:
www.CIPPSafety.org

Website →
Resources →
CIPP Incident List

Illnesses, hospitalizations, explosion

Schools, daycare centers, hospitals,
homes, restaurants, municipal
buildings, office buildings, and more..

Human and Environmental Incident List

--THIS LIST IS BEING UPDATED AS OF FEBRUARY 2022--

List of CIPP associated air contamination incidents reported by [Noh et al. \(2022\)](#), [Sendesi et al. \(2020\)](#), [Ra et al. \(2019\)](#), [Teimouri et al. \(2017\)](#), and others to date. Web links provided where available.

Information presented in the table is verbatim or summarized from the references; Table Notes: nr = not reported in the reference; PERSONAL COMMUNICATION indicates the source contacted co-author Dr. Whelton individually; FOIA indicates records were obtained from an organization by a Freedom of Information Act (FOIA) records request. Information obtained from that request, where applicable, was described. Acronyms: DEP = department of environmental protection; DOL = department of labor; DOT = department of transportation; EMS = emergency medical service; HAZMAT = hazardous materials; HVAC = heating ventilation and air conditioning; MH = manhole; MSDS = material safety data sheet; MWRA = Massachusetts Water Resources Authority; PID = photoionization detector; PPE = personal protective equipment; SCBA = self-contained breathing apparatus; USFS = United States Forest Service.

Year	Location	Styrene Level	Special Notes
2021	Montreal (Canada)	nr	MEDIA REPORT: Tenants of a housing cooperative in Montreal were seriously inconvenienced by toxic fumes following rehabilitation work on a sewer line. The odors that normally disappear after a few hours after such work have infiltrated the building and remained there for months. Result: evacuated tenants and a condemned apartment. However, neither the City of Montreal nor the company in charge of the work, wants to take responsibility for the damages they suffer and the expenses that accumulate.
2021	Towson, MD	nr	MEDIA REPORT: An odor in Towson that closed a road Thursday morning (10/14) was determined to have been caused by epoxy. It was nontoxic, according to Baltimore County Emergency Management officials. Initially, firefighters said the odor in the 1000 block of Cowpens Avenue was believed to be natural gas. A hazardous materials crew was called, officials said. "The road is blocked," the Providence Volunteer Fire Company reported before 10:30 a.m. By noon, the fire company reported that investigators determined an epoxy used in a sewer line repair caused the odor in some homes in the area. Nobody was injured, and no schools were affected, according to the Providence Volunteer Fire Company, which used fans to ventilate the impacted residences.
			MEDIA REPORT: Spooner Middle School will remain closed and remote learning will begin next week after a strong epoxy-like odor prompted an evacuation Wednesday (11/10) and caused 60 staff and students to seek medical treatment. Spooner Area School District Superintendent told WPR a student first reported what they believed to be a gas leak around 8:40 a.m. Wednesday. Staff members investigated the source of the smell, which was near the gym and a classroom wing. Not long after, students and staff began reporting that they weren't feeling well, and the principal ordered an evacuation to a nearby church a half hour later. The district closed the school for the remainder of the day, and students were sent home. The district reported 36 students and 24 staff members have sought medical care since Wednesday, reporting symptoms of nausea and lightheadedness. At least two students were transported to medical facilities outside the area. Officials have yet to identify the cause behind what made people sick. "There's been extensive ongoing carbon monoxide testing, which has all fallen within normal levels," the Superintendent said late Thursday (11/11). "We're working with

When incidents have occurred a number of persons have reached out to us for help

Bystanders
CIPP laborers/workers
CIPP company owners
Firefighters
Police
Emergency room doctors/nurses
Public works/Utility staff
Public health department investigators
Law enforcement/criminal investigators

OSHA 21 year old CIPP worker fatality investigators
Building owners/tenants
Business owners
Industrial hygiene consultants



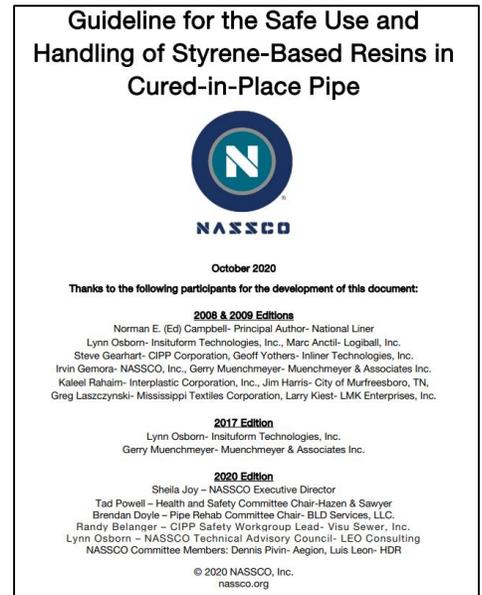
The risk of chemical exposure can be minimized, but facts must be acknowledged

Worksite Differences

Styrene vs. Nonstyrene resins
VOC vs. “No VOC” vs. “VOC free” resins
Thermal (steam, hot water), UV curing

1. All CIPP processes have emissions. Magnitudes and chemistry are different.
2. Material SDSs do not disclose all chemicals emitted into the air or are generated during manufacture. People wrongly assume that if chemicals are not listed on SDS, they are not present or created.
3. The CIPP process –creates– new chemicals during manufacture.
4. Unlike other industries, plastic manufacturing waste is not captured, but openly discharged.
5. 4-gas meters (H₂S, O₂, CO and LEL) and PIDs are not reliable to understand the health risk of exposure due to hazardous atmosphere complexity, sometimes 10x to 1000x off.
6. Contractors have cross-contaminated both styrene/nonstyrene resins and equipment.
7. Contractors can and have overpressured plumbing trap water seals and toilet seals.
8. Hazardous air pollutant (HAP) emission is regulated under the Clean Air Act. Many chemicals are HAPs (including Nonstyrene resins). Some government agencies are looking at issuing Air Permits for any CIPP job.

CIPP companies *and* engineering consultants openly encourage CIPP companies to discharge the chemical waste into the air for the steam curing process by **“...maximizing the flow of air through the curing CIPP...”**



An estimated **6 to 33 tons of VOC** is discharged into the air *per project*

- CIPP companies seem to be discharging HAP/EDC/CAR air pollution at scales classified under the *Clean Air Act*

New CIPPs release VOCs into the air *after* being placed into service

Styrene-free, VOC-free, Non-styrene CIPPs release pollution too

Our 2022 Study: Change or upgrade the resins to reduce pollution / exposure

Environmental and Human Health Risks of Plastic Composites can be Reduced by Optimizing Manufacturing Conditions

Download FREE here:

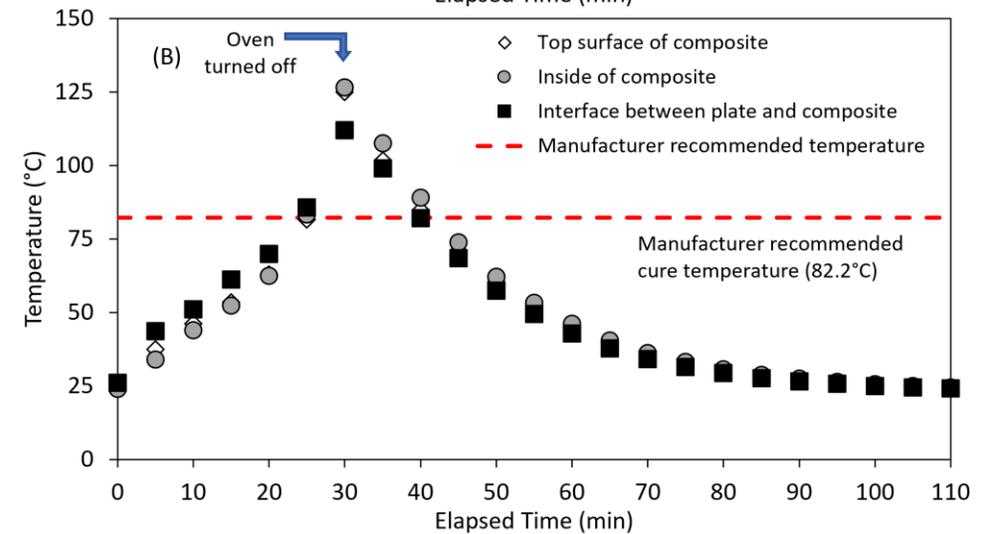
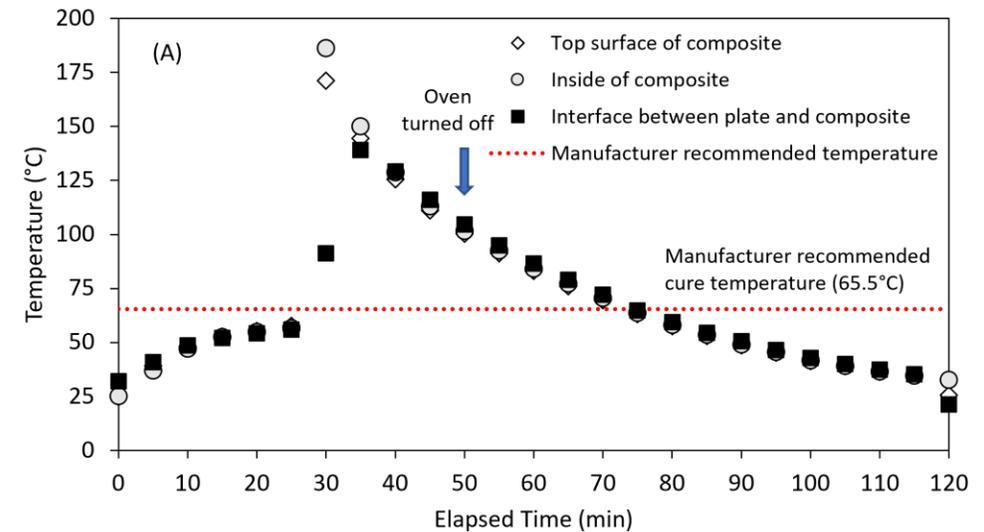
<https://doi.org/10.1016/j.jclepro.2022.131803>

Styrene resin (39% VOC) vs. Nonstyrene resin (4% VOC)

Resin manufacturer contaminated their Nonstyrene resin with a styrene resin

By increasing the initiator loading we reduced styrene (-42%) and styrene oxide (-32%) residuals.

Only 2 compounds listed on MSDS, but 8 chemically identified



1. Learn about CIPP and plastics

Visit the Purdue University website:

1. Basics of plastics
2. The CIPP process
3. What is that waste?
4. Chemicals entering nearby spaces
5. Human health and environmental impacts

Website →

Resources →

Online Education

The screenshot shows a webpage titled "Resources" with a sidebar menu and a main content area. The sidebar menu includes: Presentations, Reports, Videos, Online Education, CIPP Incident List, External Resources, Frequently Asked Questions - DOT Lining Study 1 (Surface and Storm Water Quality), Frequently Asked Questions - DOT Lining Study 2 (UV CIPP Water Quality), Frequently Asked Questions - NSF Rapid CIPP Study 1 (Worker, Public Safety, and Chemical Air Emissions), and Frequently Asked Questions - NSF Rapid CIPP Study 2 (Worker, Public Safety, and Chemical Air Emissions). The main content area is titled "Online Plastics & CIPP Education" and contains several sections: "Meeting Files for March 16, 2020" with a list of presentations and demos; "Online Educational Materials" with a sub-section "Basics of Plastics" containing a list of questions and answers; and "The CIPP Manufacturing Process".

Resources

- Presentations
- Reports
- Videos
- Online Education
- CIPP Incident List
- External Resources
- Frequently Asked Questions - DOT Lining Study 1 (Surface and Storm Water Quality)
- Frequently Asked Questions - DOT Lining Study 2 (UV CIPP Water Quality)
- Frequently Asked Questions - NSF Rapid CIPP Study 1 (Worker, Public Safety, and Chemical Air Emissions)
- Frequently Asked Questions - NSF Rapid CIPP Study 2 (Worker, Public Safety, and Chemical Air Emissions)

Online Plastics & CIPP Education

Meeting Files for March 16, 2020

- [\[Presentation\]](#) Welcome, introductions, overview of the meeting
- [\[Presentation\]](#) Vapor intrusion alternative pathways
- [\[Presentation\]](#) Sewer pipe repair technologies and the most popular sewer repair technology, CIPP: Raw materials, the manufacture process, and defects
- [\[Online Demos\]](#) Plastics education and sewer technology demonstrations: Plastic ingredients, manufacture wastes, building contamination, health effects
 - [Overview File - The Basics of Plastics](#)
 - [Overview File - The CIPP Manufacturing Process](#)
 - [Overview File - Waste Created from CIPP](#)
 - [Overview File - Chemicals can Enter Nearby Buildings and Public Spaces](#)
 - [Overview File - Human and Environmental Impacts](#)
- [\[Presentation\]](#) CIPP chemical emissions, environmental significance, occupational and public exposure hazards, plumbing traps, air testing
- [\[Presentation\]](#) Consideration of weather conditions, building characteristics, VOC indoor air concentration fluctuations at vapor intrusion sites

Online Educational Materials

Basics of Plastics

- *Plastics*. Websters Dictionary [definition](#): (noun) "Any of numerous organicsynthetic or processed materials that are mostly thermoplastic or thermosetting polymers of high molecular weight and that can be made into objects, films, or filaments"
- What plastics are used for sewer repair? [\[PDF\]](#)
- What ingredients are used for plastic polymerization [\[PDF\]](#)
- Additives impact physical properties [\[Video.mp4\]](#)
- What is polymerization? [\[PDF\]](#)
- How do thermoplastic vs. thermoset plastics differ? [\[Video.mp4\]](#)
- Created plastics are not pure [\[PDF\]](#)
- Plastics can be damaged by chemical or physical forces during manufacture or use [\[PDF\]](#)

The CIPP Manufacturing Process

2. Review the posted government reports about CIPP: NIOSH, ATSDR, CDPHE, FLDOH, OSHA, and supported by FHWA.



HealthHazard[®] Evaluation Program [2021]

Evaluation of Exposures to Styrene during Cured-in-place Pipe Liner Preparation and during Pipe Repairs using Hot Water and Steam

HHE Report No. 2019-0080-3379
July 2021

[2005]

Health Consultation

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

SEPTEMBER 13, 2005

U.S. D

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

[2019]

U.S. Department of Transportation
Federal Highway Administration

[2018]

Safety Alert
Cure-In-Place Pipe (CIPP)
Vapor Migration into Buildings

Background
The use of CIPP for sewer line and culvert rehabilitation is widespread throughout the country and abroad. Styrene-based resins are the most widely used. There is a possibility for chemical releases with CIPP processes. In addition to styrene, recent studies have shown numerous volatile chemicals being released during CIPP installations that have previously been unreported. Migration of vapors from volatile chemicals can impact indoor air, reoccupants. There have been over 130 CIPP exposure incidents reported in 30 states. A project involving a large diameter CIPP sewer line installation results into an office building, which exceeded acceptable exposure levels. Health symptoms. Styrene was measured for up to three months for Styrene is not the only chemical emitted, but it may serve as a surrogate for other chemicals.

Styrene health effects

- Central nervous system depressant.
- Mucous membrane irritant (upper respiratory tract, eyes, nose and throat).
- Nervous system effects include headache, fatigue, changes in cold and flu susceptibility, and balance problems.
- Potential to cause cancer.

Concerns during CIPP installation

- Styrene and other toxic vapors can migrate during cure-in-place pipe installation through windows, doors, cracks in foundations, late connections, and subsurface voids, resulting in potentially harmful exposures.
- Vapor migration is highly variable due to subsurface conditions and installation characteristics.

California Department of
Public Health

[2020]

Florida Health

CURED-IN-PLACE-PIPE (CIPP)

Mission: To protect, promote & improve the health of all people of Florida through integrated state, county & community efforts.

Vision: To be the Healthiest State in the Nation

Cured-in-place-pipe (CIPP) installation is a relatively new method used for sewer line and culvert rehabilitation. Recently, concerns were raised regarding the possibility of residual chemical releases during the installation process and related harm to human health.

This factsheet will help you to learn more about the CIPP process — what it is, how it may harm your health and how to protect yourself and your family from possible health effects.

General Facts

What is CIPP?
Cured-in-place-pipes (CIPP) are jointless, seamless, flexible plastic pipe liners chemically installed within an existing sewer, water, gas or other pipe.

CIPP is used during the repair process of defective sewer lines, culvert and drinking water pipes. The process involves the insertion of an uncured tube of resin into the existing, defective pipe. Hot air and/or water or ultraviolet light are used, expanding and hardening (curing) the tube creating a liner to fit against the wall of the "broken" pipe.

The purpose of the curing process is to reduce, and ideally eliminate, cracks and holes that would otherwise allow rainwater and roots to enter the sewer pipe and cause operational problems such as stoppages and overflows. The new liner can also help prevent mechanical failure.

Why is CIPP used?
CIPP is used to repair pipes without disturbance to surface structures or other utilities near broken pipes. It is advertised by some contractors to be a more efficient and cheaper process to repair pipes. Some, newer CIPPs are designed to have an estimated 50-year lifespan.

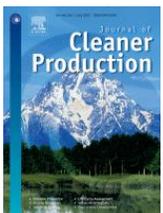
What does CIPP consist of?
A new CIPP is created using a number of materials: a resin, a chemical initiator package, a reinforcement material and other additives. The most popular resins today include:

- Styrene-based polyester
- Styrene-based vinyl ester
- Vinyl ester (styrene free)
- Epoxy (styrene free)

Why is the CIPP process a concern?
Chemicals are released into the air during a CIPP project setup, while the CIPP is made and after the plastic liner has been created. The tube of uncured resin as well as its delivery and handling can release chemicals into the air. In addition, forced air, steam and hot water use also releases chemicals into the air and can potentially transfer the chemicals from the process into a worksite, nearby pipes, nearby residences through plumbing, open windows, doors, cracked foundations and in the environment causing

UPDATED: 09-28-2020 1 | Page

3. Read the scientific reports. These and more...



[2022]

Environmental and human health risks of plastic composites can be reduced by optimizing manufacturing conditions



[2022]

Emergency responder and public health considerations for plastic sewer lining chemical waste exposures in indoor environments



[2020]

An emerging mobile air pollution source: outdoor plastic liner manufacturing sites discharge VOCs into urban and rural areas



[2019]

Considerations for emission monitoring and liner analysis of thermally manufactured sewer CIPPs

Journal **AWWA**

[2019]

Critical Review: Surface Water and Stormwater Quality Impacts of CIPP Repairs



[2017]

Worksite Chemical Air Emissions and Worker Exposure during Sanitary Sewer and Stormwater Pipe Rehabilitation Using CIPP



[2020]

In vitro toxicity assessment of emitted materials collected



[2020]

Outdoor manufacture of UV-Cured plastic linings for storm water culvert repair: Chemical emissions and residual



[2020]

Influence of aggressive environmental aging on mechanical and thermo-mechanical properties of Ultra Violet (UV) Cured in Place Pipe liners



[2020]

Evaluation of the physical, chemical, mechanical, and thermal properties of steam-cured PET/polyester cured-in-place pipe

Funded by:



National Institute of Environmental Health Sciences



CIPP can likely be used without endangering human health if appropriate controls were implemented.

To reduce risks posed...

1. CIPP companies should be required to minimize and prevent chemical discharge to protect workers and bystanders.
2. Utilities/Municipalities should select practices with lower risk or require CIPP waste minimization and/or capture.
3. Require the Public Health Department be notified before projects begin and act as THE lead agent for any suspected odors or illness investigations.
4. Learn more and request a free NIOSH health hazard evaluation for worksites and buildings (Staff safety)
5. SRF applications require environmental impact disclosure. CIPP waste has known environmental impact.

Not all CIPP processes and companies are equal. Some pose less of a human health and environmental risk than others. Often, workers are not thoroughly informed about the chemical risks.



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

PURDUE UNIVERSITY | CIPP Solutions Group

Home Resources News Team Intranet

Cured-in-Place Pipe Safety Study

Watch later Share

News In the News

- Emergency Responder and Health Official Response Study
 - Scientific file, *Journal of Hazardous Materials*, September 2021
- Air Impact and Waste Study (Worker and Environmental Safety)
 - Scientific file, *Environmental Science: Processes and Impacts*, September 2020
- Human Toxicology Study 1 (Worker and Public Safety)
 - Scientific file, *Inhalation Toxicology*, June 2019
- DOT Lining Study 3 (Physical and Chemical Integrity)
 - Scientific file, *Journal of Composite Materials*, June 2019

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

- ✓ External Resources
 - Government investigations, factsheets, and reports
- ✓ Primer on Plastics
- ✓ List of FAQs
- ✓ Videos
- ✓ Public health agency webinars
- ✓ Peer-review scientific studies
- ✓ 6 State Lining Report & Recommendations

Funded by:

