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Engineers | Environmental Specialists


# CURED IN PLACE PIPE (CIPP) PROCESS, RISKS, & CONTROLS

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# Discussion Outline

- **Cured in Place Pipe**
  - A History
  - The Process
  - Applications and Benefits
- **Standards**
  - EPA
  - OSHA
  - Sampling Methods
  - OSHA Enforcement and Inspection Guidelines
- **Exposure Relationships**
  - Environmental
  - Community
  - Worker
- **Exposure Monitoring**
  - Compounds Isolated
  - Steam and Non-steam
  - Study Results
- **Best Practices on Exposure Prevention**
  - Environment
  - Community
  - Worker

# A History

- Pipe maintenance is critical to an infrastructure
- PVC, Acrylonitrile Butadiene Styrene (ABS), Steel, Cast Iron / Galvanized (Hexavalent Chromium), Copper, Clay, Concrete (Silica), Orangeburg (hot pitch and wood pulp)
  - Warps in heat
  - Loud
  - Expensive
  - Limited to indoor use
  - Toxicity concerns

- Install in most cases requires trenching
  - Working around existing infrastructure
  - Roadways, traffic, structures
  - Pedestrian safety
  - Impacts to customers and water plant operation
  - Replacing pipes requires trenching and creates greater risks
  - All add costs

# CIPP – A History

- CIPP is designed to be a trenchless system
- Invented in London England in 1971
- Implemented in Europe across the 70s
  - Eric Wood invented the CIPP process to control a leaky pipe in his garage
  - He didn't want to pull up the flooring
  - He called his product Insit U Form (form in place)
  - Applied for patent January 29, 1975
- Insituform Technologies commercialized the product
  - Brought it to the United States

- It is estimated the 50% or more of pipe repair is now done with CIPP methods
- Generally, < 60 min cure time

# CIPP – Process

The process involves inserting a flexible liner (felt or fiberglass) inside an existing pipe. Inflating the liner, then exposing it to heat (hot water / steam) or ultraviolet light to harden. The liner creates a smooth surface restoring it to near-new condition.

# CIPP – Applications and Benefits

- Can be used in sewer, water, gas, chemical, and heating pipelines
- Limits impacts on surface traffic, pedestrians, and facilities
- Allows existing infrastructure to remain in place
- No or limited trenching work needed
- Fast process with rapid hardening
- Used in short and long pipe runs
- 50+ years lifespan

# CIPP – Process

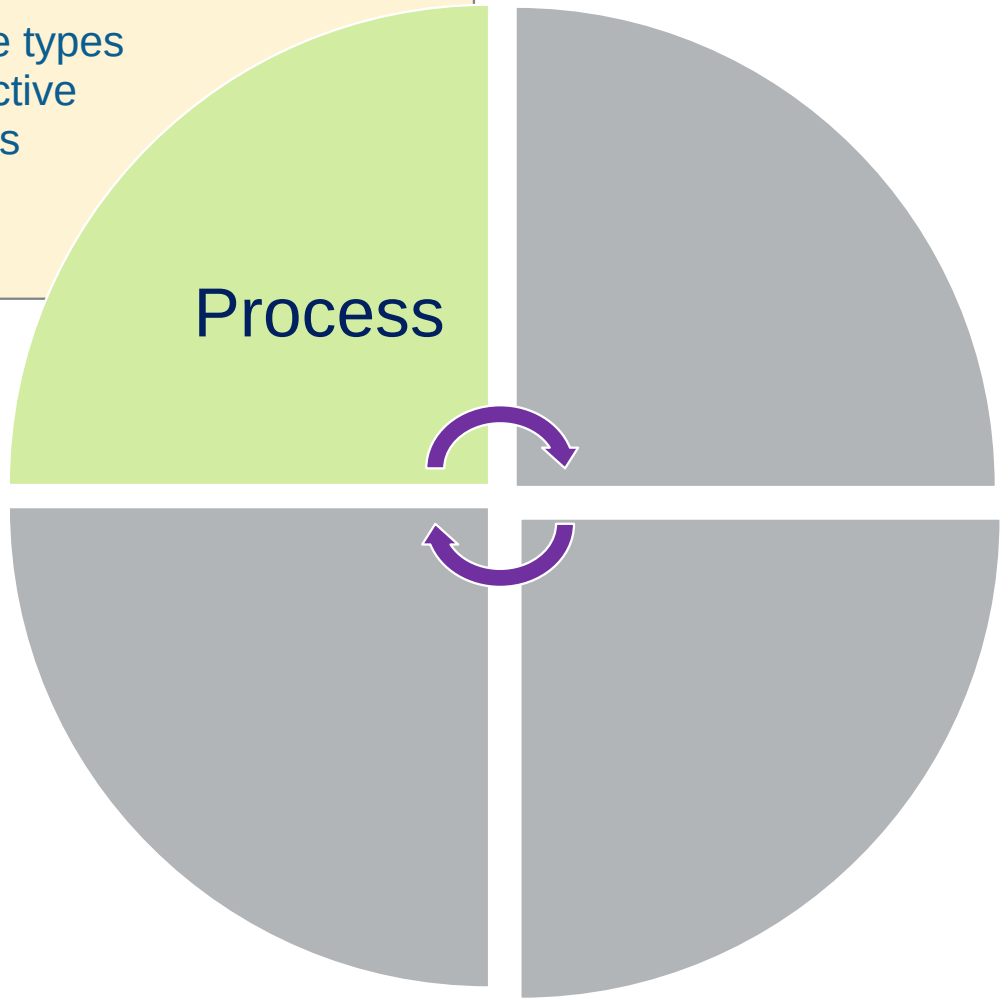
Emissions have been historically communicated as only steam, sampling shows the emission from the process contains multiple compounds and high heat released throughout the process.

Discharges May Contain
Volatile organic compounds (VOC)
Semi-volatile organic compounds (SVOC)
Particles
Liquid droplets

Most Common Resins Used Today:
Styrene-based polyester
Styrene-based vinyl ester
Vinyl ester (styrene free)
Epoxy (styrene free)

# CIPP – Circle of Safety

- Multiple pipe types
- Non-Destructive
- Fast Process
- VOCs




Let's move on to existing standards……

# Risk Pathways


# EPA – Environmental, Community

Boat manufacturing is a major source of HAPs, including styrene, methyl methacrylate (MMA), methylene chloride (dichloromethane), toluene, xylene, n-hexane, methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), and methyl chloroform (1,1,1- trichloroethane). Facilities are point sources. Easy to find.

California Department of Public Health issued a “Safety Alert” on the issues of CIPP work, based on their research. Updated that alert asking community members to call their medical provider if they detect odors.

Canton Connecticut sent a notice out prior CIPP work stating odors “may get into the building through improper or clogged venting, dry traps, or, in some older homes, floor drains that are connected to the sanitary sewer. If you detect an odor, please ventilate your home by opening a window.” They also stated, “The odor is not harmful and will dissipate quickly.”

CIPP projects are pop up operations, very difficult to monitor and control. EPA has standards on chemicals in the environment, but not on how CIPP should prevent it.

# EPA – Environmental, Community

Chemicals, in varying amounts, are released into the air throughout the process.

Into the worksite, through nearby pipes, residential pumping, open windows, doors, foundation cracks. Sometimes community members are notified of work, other times not.

# OSHA – Worker Safety

- Standards on Exposure levels
- Workplace Hazards Training
- Confined Space Standards
- PPE Requirements
- LOTO Standards
- Fall Protection


Nothing specifically on CIPP.

Deaths have occurred…..

# OSHA – Worker Safety

Accident Report Detail
Accident Summary Nr: 100333.015 - EMPLOYEE IS WORKING IN CONFINED SPACE AND BECOMES UNRESPONSIVE

Accident Summary Nr: 100333.015 -- Report ID: 0524200 -- Event Date: 10/25/2017

| Inspection Nr | Date Opened | SIC | NAICS | Establishment Name |
|---|---|---|---|---|
| 1274028.015 | 10/25/2017 | | 237110 | Benchmark Construction Co., Inc. |

Abstract: At 6:30 p.m. on October 25, 2017, an employee was working with a crew that was engaged in sewer line rehabilitation work using a cured-in-place-pipe (CIPP). The CIPP process is a trenchless method for the sewer pipe repair which involves a resin-impregnated fiberglass liner inverted into the damaged sewer pipe. The employee crawled into a 24-inch horizontal sewer line and was in approximately 30 feet, cutting ropes and lying flat hot water circulation hoses. The employee began to mumble and became unresponsive. Emergency Services responded and the employee's body was recovered by the Fire Department Rescue Team and the employee was pronounced at the scene. Drowning with styrene toxicity was listed as a significant contributing factor.

# OSHA – Worker Safety

The OSHA citations state that Benchmark did not train its workers to do the job safely, that workers did not monitor air in the pipe for styrene, and two employees working underground were not connected to a retrieval line.

**Violation Summary**

| Violations/Penalties | Serious | Willful | Repeat | Other | Unclass | Total |
|---|---|---|---|---|---|---|
| Initial Violations | 6 | | | | | 6 |
| Current Violations | 6 | | | | | 6 |
| Initial Penalty | $77,604 | $0 | $0 | $0 | $0 | $77,604 |
| Current Penalty | $55,000 | $0 | $0 | $0 | $0 | $55,000 |
| FTA Penalty | $0 | $0 | $0 | $0 | $0 | $0 |

What about enforcement – it's easy right?

# OSHA Enforcement & Inspection – 1910

## General Industry (1910) Standards Triggered:

- 1910.1200 - Hazard Communication (2)
- 1910.147 - The Control of Hazardous Energy (6)
- 1910.134 - Respiratory Protection (7)
- 1910.146 - Permit-Required Confined Spaces

## Top 1910 Citations issued 2023-2024

- 1910.1200 Hazard Communication, general industry (2)
- 1910.147 Control of Hazardous Energy (6)
- 1910.134 Respiratory Protection, general industry (7)

# OSHA Enforcement & Inspection – 1926

**Construction (1926) Standards Triggered:**

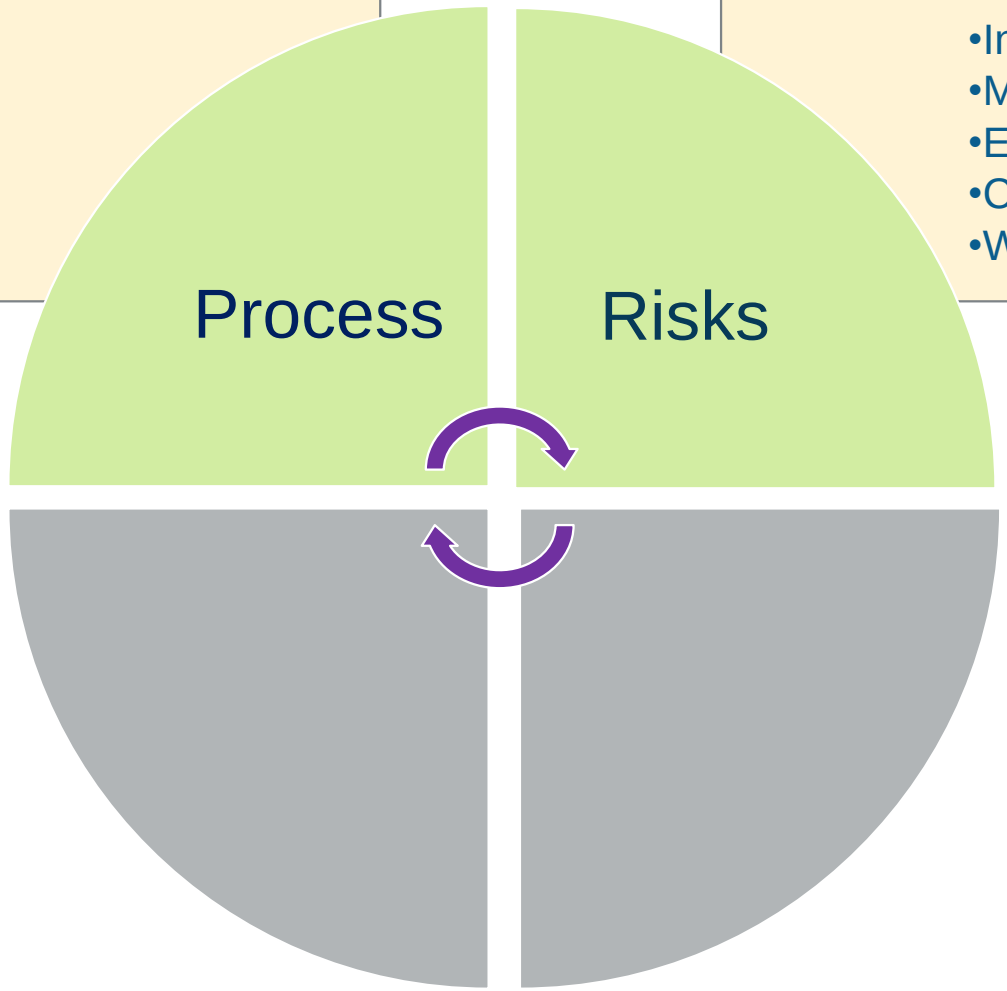
- 1926.21 - Safety Training and Education
- 1926.29(b) - Boilers
- 1926.56 - Illumination
- 1926.95 - Criteria for Personal Protective Equipment
- 1926.102 - Eye and Face Protection (9)
- 1926.103 - Respiratory Protection
- 1926.501 - Duty to have fall protection (1)
- 1926.651 - Specific Excavation Requirements
- 1926 Subpart AA - Confined Spaces in Construction

**Top 1926 Citations issued 2023-2024**

- 1926.501 - Fall Protection (1)
- 1926.102 - Eye and Face Protection (9)

# CIPP – Circle of Safety

- Multiple pipe types
- Non-Destructive
- Fast Process
- VOCs




- Inspection Difficulty
- Minimal Regulations
- Environmental
- Community
- Worker

Let’s move on to exposure relationships…….

# Exposure Relationships

# Purdue Study

# Compounds Isolated

While styrene is the primary compound collected in samples above exposure levels, all these compounds have been identified in air samples during CIPP operations.

- Acetone
- Acetophenone
- Benzaldehyde
- Benzene
- Benzoic acid
- Butylated hydroxytoluene (BHT)
- 4-*tert*-Butylcyclohexanol
- Carbon disulfide
- Carbon tetrachloride
- Chloroform
- Cyclohexane
- Dibutyl phthalate (DBP)
- 1,4-Dioxane
- 1,4-Ethanol
- Ethyl acetate (Vinyl acetate)
- Ethylbenzene
- Hexane
- Isopropanol
- 2-Methylbutane
- Methylene chloride
- Methyl ethyl ketone (MEK)
- Phenol
- Styrene
- 1-Tetradecanol
- Toluene
- 1,2,4-Trimethylbenzene
- 1,3,5-Trimethylbenzene
- m,p-Xylene
- o-Xylene

How were they collected……

# Sample Methodologies

NIOSH 1501: Sorbent tube – Gas Chromatography

- Used for peak, ceiling, and TWA
- High humidity may reduce breakthrough volumes

NIOSH 3800: Portable direct-reading instrumentation Extractive Fourier Transform Infrared Spectrometry (FTIR)

- General characterization of workplace air
- Overlap of infrared absorption may affect quantification

Photo-Ionization Device (PID)

- 0.1 TO 2000 PPM range (Various VOCs)
- Must be calibrated to determine VOC of interest
- Not selective

Tedlar Bag Sampling

- Hold times for analysis are short
- May lose some VOC in transport and sampling

Organic Vapor Monitors

- Passive sampling
- Active sampling

# Exposures – Symptoms

Changes in color vision
Balance Problems
Nausea
Eye Irritation
Slow Reaction Time

Hearing Loss
Feeling Drunk
Concentration Problems
Headache
Nasal Irritation

Tiredness
Vomiting
Breathing difficulties

# Exposure Routes, Symptoms, Target Organs

**Styrene (Reasonably Anticipated to be a Human Carcinogen)**

| | |
|---|---|
| Exposure Route: | Inhalation, Absorption, Ingestion, Skin and Eye Contact |
| Symptoms: | Irritation of eyes, nose, respiratory system, headache, malaise, dizziness, confusion, drowsiness, unsteady gait, possible liver and teratogen |
| Target organs: | Eyes, skin, respiratory system, central nervous system, liver, reproductive system |
| PEL: | 100 ppm |

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**Benzene (Carcinogen)**

| | |
|---|---|
| Exposure Route: | Inhalation, Absorption, Ingestion, Skin and Eye Contact |
| Symptoms: | Irritation of eyes, nose, respiratory system, headache, nausea, dizziness, staggered gait, drowsiness, anorexia, weakness - exhaustion, bone marrow depression |
| Target organs: | Eyes, skin, respiratory system, central nervous system, liver, reproductive system |
| PEL: | 1 ppm |

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**Methylene Chloride (Potential Occupational Carcinogen)**

| | |
|---|---|
| Exposure Route: | Inhalation, Absorption, Ingestion, Skin and Eye Contact |
| Symptoms: | Irritation of eyes and skin, weakness - exhaustion, drowsiness, numbness, nausea |
| Target organs: | Eyes, skin, cardiovascular system, central nervous system, |
| PEL: | 25 ppm |

# Exposures: Environmental

Water contamination has been found in US and Canada after installation. A Virginia study found styrene concentrations in drinking water at 5 study sites were higher than the EPA maximum limits (**0.1 mg/L**). High levels were found from 5 to 72 days after installation.

Sampling after a 3000-gallon CIPP wastewater discharge directly to a creek in Georgia identified **1,300 ug/L** of styrene 1000 feet downstream 19 hours after the event. Other VOC were identified as well.

After a spill incident in Connecticut, **219 ug/L** of styrene was found downstream 12 days later.

In Alabama roughly 70,000 gallons of CIPP wastewater was released to a dry creek bed. Traveling downstream, concentrations in the flow were **143 mg/**L. The waste would eventually contaminate a drinking water well where concentrations were **4 mg/L**.

# Exposures: Community (odor)

In 2011, daycare centers in Worcester Mass and Port Huron Michigan were evacuated when emissions from CIPP work overcame children and staffers. The same year, CIPP work sent five students and high school staff in Birmingham Michigan to the hospital.

In 2014 a family in Prairie Village, Kansas had to vacate their home due to odors. The father called the exposure experience “ghastly.” Later that year, a retiree moved out of her townhouse in Baltimore for three and a half weeks to escape fumes and odors associated with a CIPP project in front of her home.

In September 2017, 36 elementary students reported nausea, coughing, or headaches after exposure to CIPP emission in San Diego.

2020 a Puget Sound Seattle family was overcome with the odor causing multiple symptoms. They were out of their home for 2 months + pending cleaning actions.

# Exposures: Worker

- Emission are not only steam as originally proposed
- Multiphase mixture of organic vapor, water vapor, particulate and liquid droplets
- Styrene >86.4ppm and Methylene Chloride >1.56 PPM identified
- EPA identifies styrene as a known carcinogen
- Styrene was only compound consistently found at levels posing health risk

- Acetone
- Acetophenone
- Benzaldehyde
- Benzene
- Benzoic acid
- Butylated hydroxytoluene (BHT)
- 4-*tert*-Butylcyclohexanol
- Carbon disulfide
- Carbon tetrachloride
- Chloroform
- Cyclohexane
- Dibutyl phthalate (DBP)
- 1,4-Dioxane
- 1,4-Ethanol
- Ethyl acetate (Vinyl acetate)
- Ethylbenzene
- Hexane
- Isopropanol
- 2-Methylbutane
- Methylene chloride
- Methyl ethyl ketone (MEK)
- Phenol
- Styrene
- 1-Tetradecanol
- Toluene
- 1,2,4-Trimethylbenzene
- 1,3,5-Trimethylbenzene
- m,p-Xylene
- o-Xylene

# Exposures: Worker

- Researchers in California were required to wear full-face carbon filtered masks
- Wind direction, speed, and worker location affects exposures
- There are differences between sites using the same methods and contractor

- Acetone
- Acetophenone
- Benzaldehyde
- Benzene
- Benzoic acid
- Butylated hydroxytoluene (BHT)
- 4-*tert*-Butylcyclohexanol
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# CIPP – Circle of Safety

- Multiple pipe types
- Non-Destructive
- Fast Process
- VOCs


- Inspection Difficulty
- Minimal Regulations
- Environmental
- Community
- Worker

- Confirmed VOCs
- Limits to Sampling
- Carcinogenic Potential
- Variations from site to site

Let's move on to best practices on exposure prevention……

# Best Practices on Exposure Prevention

# Exposure Prevention: Community

Community:

Odors detected: Recommend to avoiding breathing in compounds by leaving home until cleared. Nose can detect Styrene at 0.4 - .75 ppm (very low).

House: Keep water in P traps, fill sinks with water, keep windows and closed during CIPP events. Place plastic bags over faucets. When completed, open to refresh air. Studies have shown P-Trap use will prevent high styrene emissions entering buildings. Risk of exceeding high concentrations is very low.

Communication: Provide communities, businesses, and public areas notice of work being performed to allow for risk planning.

# Exposure Prevention: Worker

**Personal:**

- Respirator usage (Carbon Filter Full Face) – Inhalation / Occ Asthma,
- Skin covering – Epoxy Resins are Skin Irritants
- Nitrile Gloves, skin cream barriers – Contact Dermatitis
- Hardhat, vests, safety glasses, safety shoes – General site safety

**Technology**:

- NOAA Weather App - Weather had a lager impact on site exposures
- NIOSH Heat App - High heat keeps particulate low
- EAA Air Now App - Air Quality creates health issues alone

**Education**:

- TRAINING! - Confined Space, LOTO, PPE, Exposure….
- HAZCOM - Emission exposures, risks, heat issues….
- CIPP - Training on industry standards and process

# Exposure Prevention: Employers

- Ensure clear separation between work areas and rest areas.
- Ensure workspaces are well-ventilated.
- Monitor air quality and ventilation before workers enter confined spaces and while they are in the confined space.
- Conduct personal air monitoring on workers to ensure styrene concentrations remain below occupational exposure limits.
- Provide personal protective equipment (PPE) and PPE training to workers, such as respirators with organic vapor cartridges
- Use non-styrene-based resins, if possible.
- Provide workers education on chemicals they work with and potential health effects of exposure.

# CIPP – Circle of Safety

- Multiple pipe types
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- Inspection Difficulty
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- Community
- Worker


- PPE Usage
- Communication
- Proper Training
- Limit Exposure Pathways

- Confirmed VOCs
- Carcinogenic Potential
- Limits to Sampling
- Variations from site to site

Let's review ……

# Discussion Summary

**Process**:
CIPP: non destruction pipe repair process
Used extensively throughout the US
Fast process with rapid hardening

**Risks**:
Steam, hot water, process safety risks
Emission into environmental systems
VOC emissions into ambient air

**Standards**:
OSHA has limited protections
EPA minimum standards
Not a lot of data

**Protection**:
Communication
Education
PPE


# CURED IN PLACE PIPE (CIPP)

## PROCESS, RISKS, & CONTROLS

**Safety & Health**

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Tighe&Bond

# Partial Reference List


Teimouri, et al. (2017). Worksite Chemical Air Emissions and Worker Exposure during Sanitary Sewer and Stormwater Pipe Rehabilitation Using Cured-in-Place-Pipe (CIPP). *Environmental Science & Technology Letters*. 4. 10.1021/acs.estlett.7b00237.

Kaushal et al. (2019). Review of Literature on Chemical Emissions and Worker Exposures Associated with Cured-In-Place Pipe (CIPP) Installation. 10.1061/9780784482506.059.

Knight et al. (2023). Health Risks Assessment from Cured-in-Place Pipe Lining Fugitive Styrene Emissions in Laterals. *Journal of Pipeline Systems Engineering and Practice*. DOI:10.1061/(ASCE)PS.1949-1204.0000690

Kobos et al. (2019). In *vitro* toxicity assessment of emitted materials collected during the manufacture of water pipe plastic linings. *Inhal Toxicol*. 31(4), 131-146.

LeBouf, Ryan F. and Burns, Dru A. (2019). Evaluation of exposures to styrene during ultraviolet cured-in-place pipe installation.

Mahboobeh et al. (2017). Worksite Chemical Air Emissions and Worker Exposure during Sanitary Sewer and Stormwater Pipe Rehabilitation Using Cured-in-Place-Pipe (CIPP). *Environmental Science & Technology Letters*. 4. 10.1021/acs.estlett.7b00237.

Noh et al. (2023). Regulatory significance of plastic manufacturing air pollution discharged into terrestrial environments and real-time sensing challenges. Environmental Science & Technology Letters*. 10, 152-158.*

Ra et al. (2018). Critical review: surface water and Stormwater quality impacts of cured-in-place-pipe repair. J*ournal AWWA.* 110*(5), 15-32.*

*Ra et al. (2019). Considerations for emission monitoring in liner analysis of thermally manufactured sewer cured-in-place-pipes (CIPP). Journal of Hazardous Materials. (371), 540-549.*

*Whelton et al. (2017). Cured-in-place (CIPP): inhalation and dermal exposure risks associated with sanitary sewer, storm sewer, and drinking water pipe repairs.* NIOSH Science Blog.