# Chemical Air Contamination and Exposures Associated with Sewer Pipe Repairs


**Andrew J. Whelton, Ph.D.**

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Indiana Environmental Health Association | September 25, 2018 | Evansville, IN

# Aging Water Pipes MUST be Addressed

Mechanical failures can be catastrophic
(traffic disruption, public safety, hygiene)

| | |
|---|---|
| Public drinking water pipes | 0.97 million |
| Public sewer pipes | 0.8 million |
| Private drinking water pipes | > 6 million |
| Private sewer lateral pipes | 0.5 million |

**40%+ need to be repaired or replaced**

# The Way things Used to Be…

## Damaged Pipe? Dig it up and Replace

Water outages

Traffic disruptions

Closed roads

Safety issues

# Today, Transportation Agencies and Municipalities are Choosing to Install Cured-in-Place-Pipes (CIPP)

Resin impregnated tube hardened inside a broken pipe

Curing methods: Hot water, Steam, UV light

Deliberate curing time: Hours to many days

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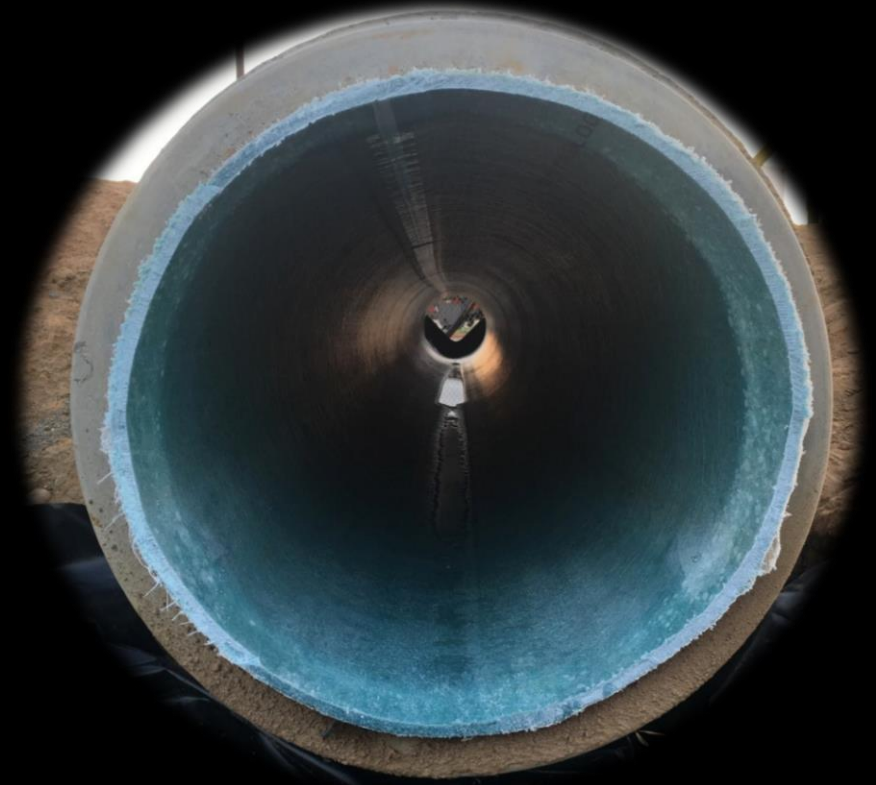
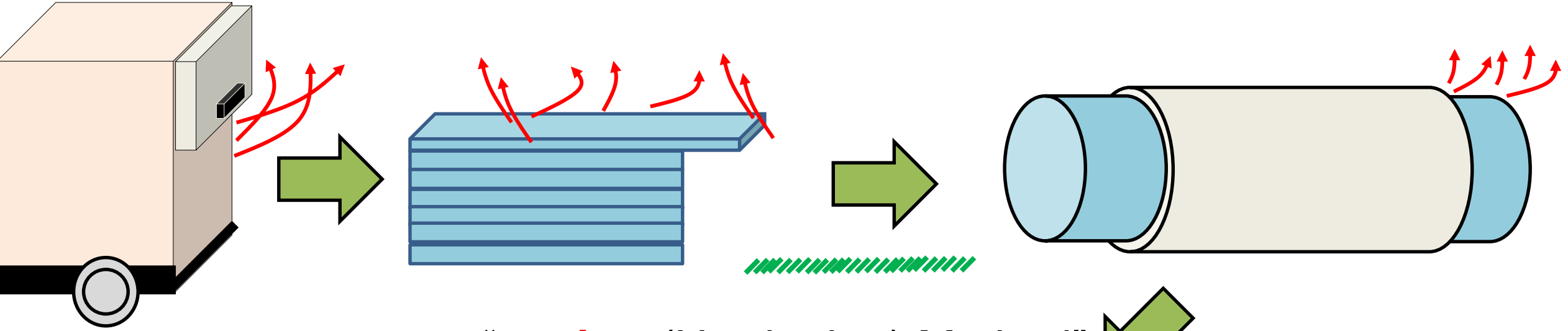


Uncured **RESIN** tube delivered on a truck

Uncured **RESIN** tube inserted into damaged pipe (raw chemicals)

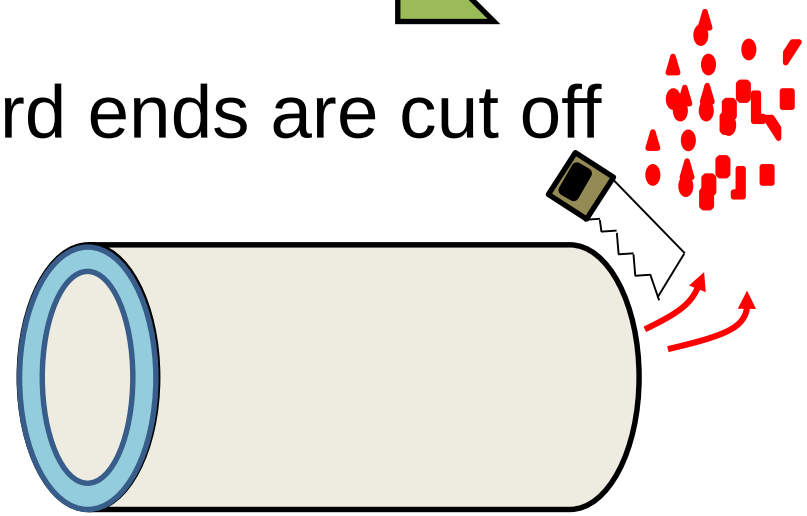
Uncured **RESIN** tube inflated with air inside host pipe



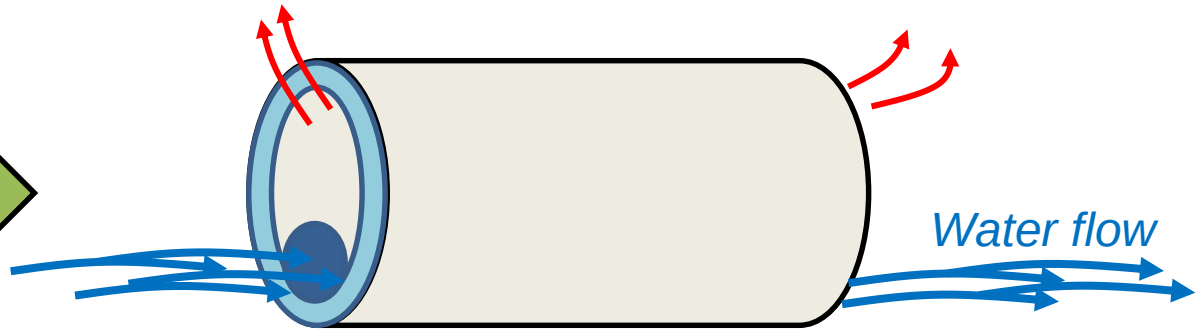
"**Curing** (Hardening) Method"

Hot Water or Steam or UV Light

Hard ends are cut off



Pipe allowed into service




September 2017

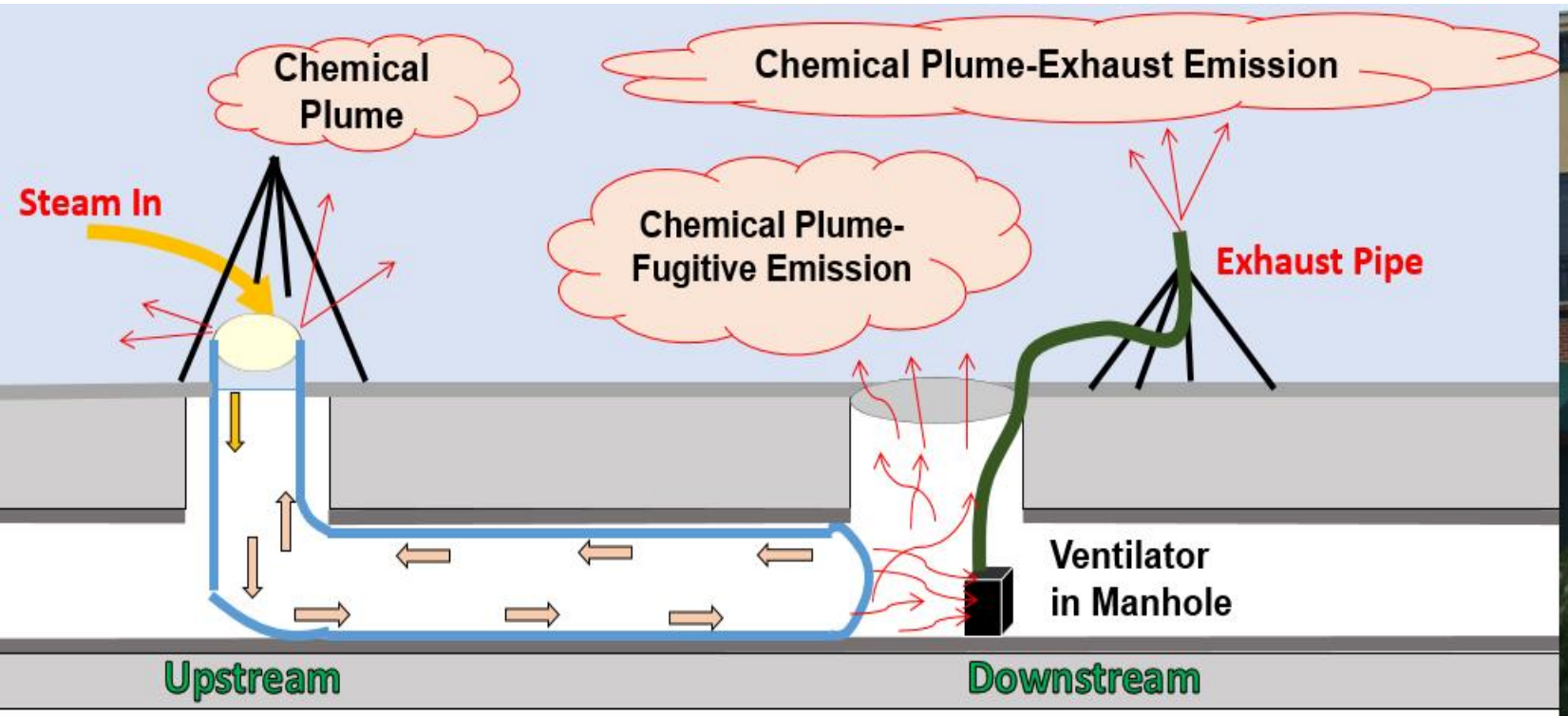
# By 2022 it is predicted to be a $2.48 Billion global market

North America is and predicted to remain the largest CIPP market

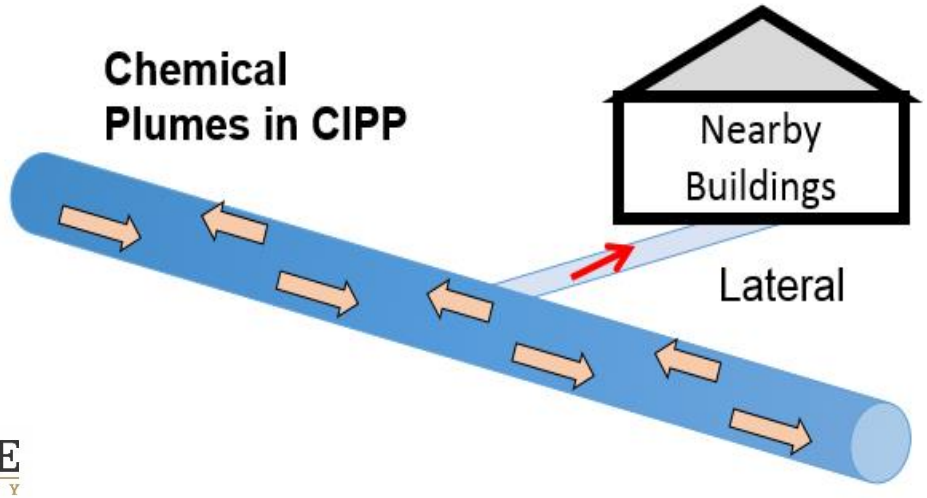
RESIN: Polyester predicted to remain most popular, vinyl ester expected to witness growth

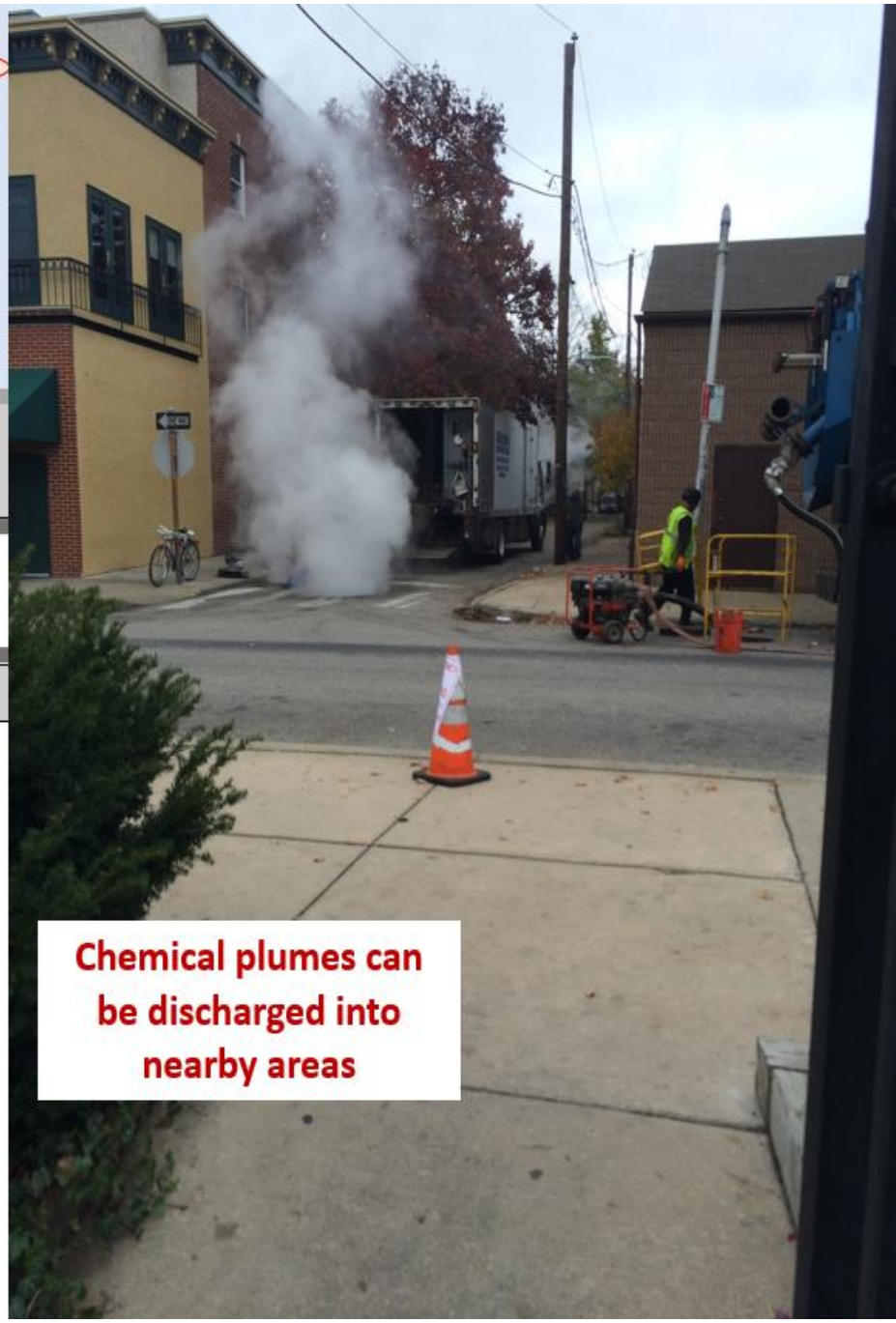
FABRIC: Polyester predicted to remain popular, glass expected to witness growth

CURING: Steam predicted to remain most popular, UV expected to witness the growth




Chemical Plumes Generated by CIPP can Escape the Pipe Being Repaired

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Arlington, VA  Nov 2010


Dublin, CA  Aug 2017


Richmond, VA  May 2018


Ann Arbor, MI  Oct 2011


San Diego, CA  Sept 2017

New York City, NY June 2018


Nyack News & Views

Nyack, NY  July 2017

Honolulu, HI  Mar 2018

And more...

# Safety Claims circa 2016 from Contractors & Municipalities

"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"
"some people are offended by this odor and are fearful of it; even though the concentrations they smell present no harm"

## Seems to be common in the US

No chemical capture
No formal setback distances
No formal respiratory protection
No formal air monitoring

*Source: Daily Herald*

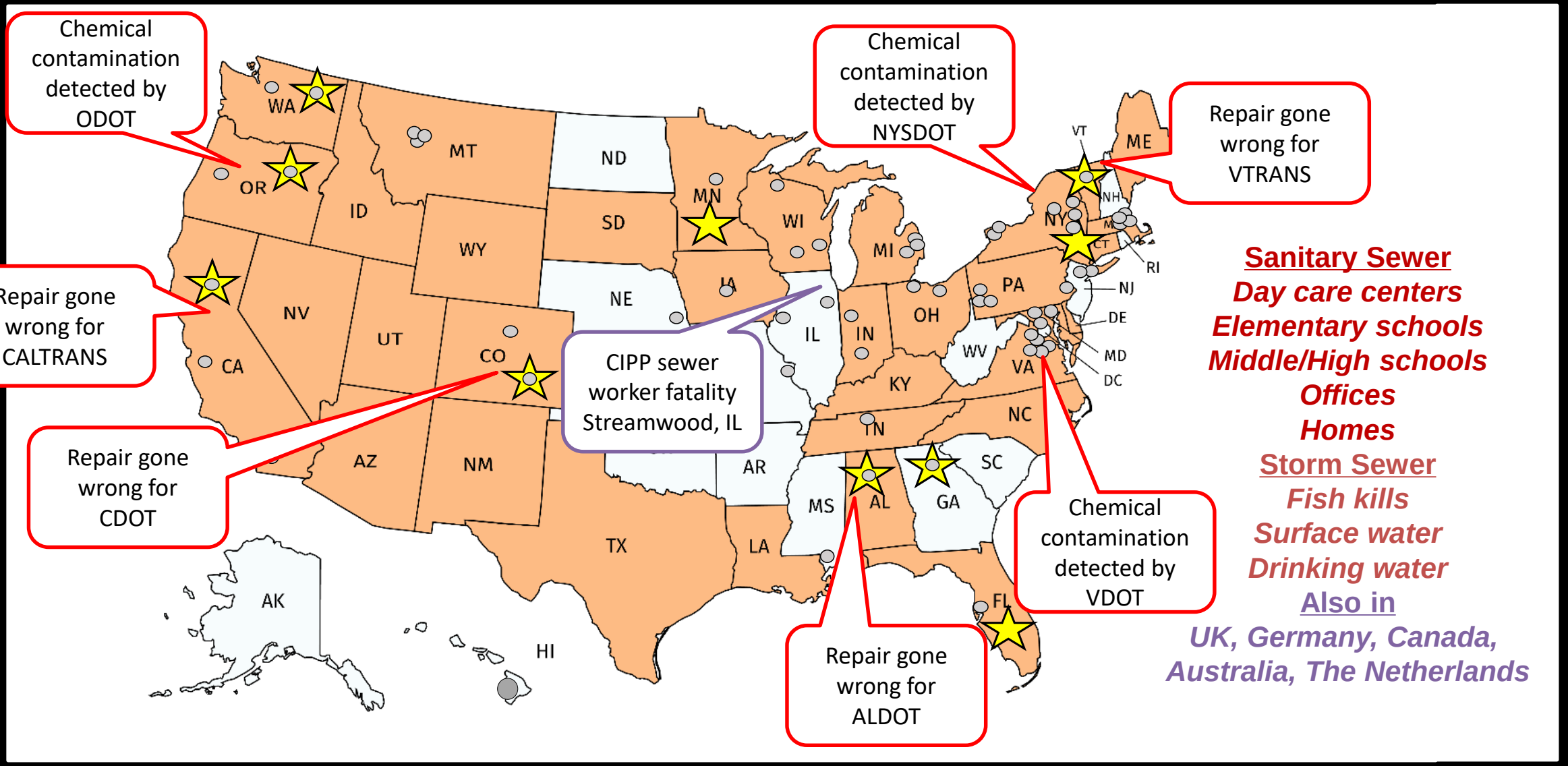
October 2017

Streamwood, Illinois

CIPP sewer worker fatality

OSHA found 220-270 $ppm_v$ styrene exposure based on blood analysis

# What does the scientific literature say?




**Sanitary Sewer**

***Day care centers***

***Elementary schools***

***Middle/High schools***

***Offices***

***Homes***

**Storm Sewer**

***Fish kills***

***Surface water***

***Drinking water***

**Also in**

***UK, Germany, Canada, Australia, The Netherlands***

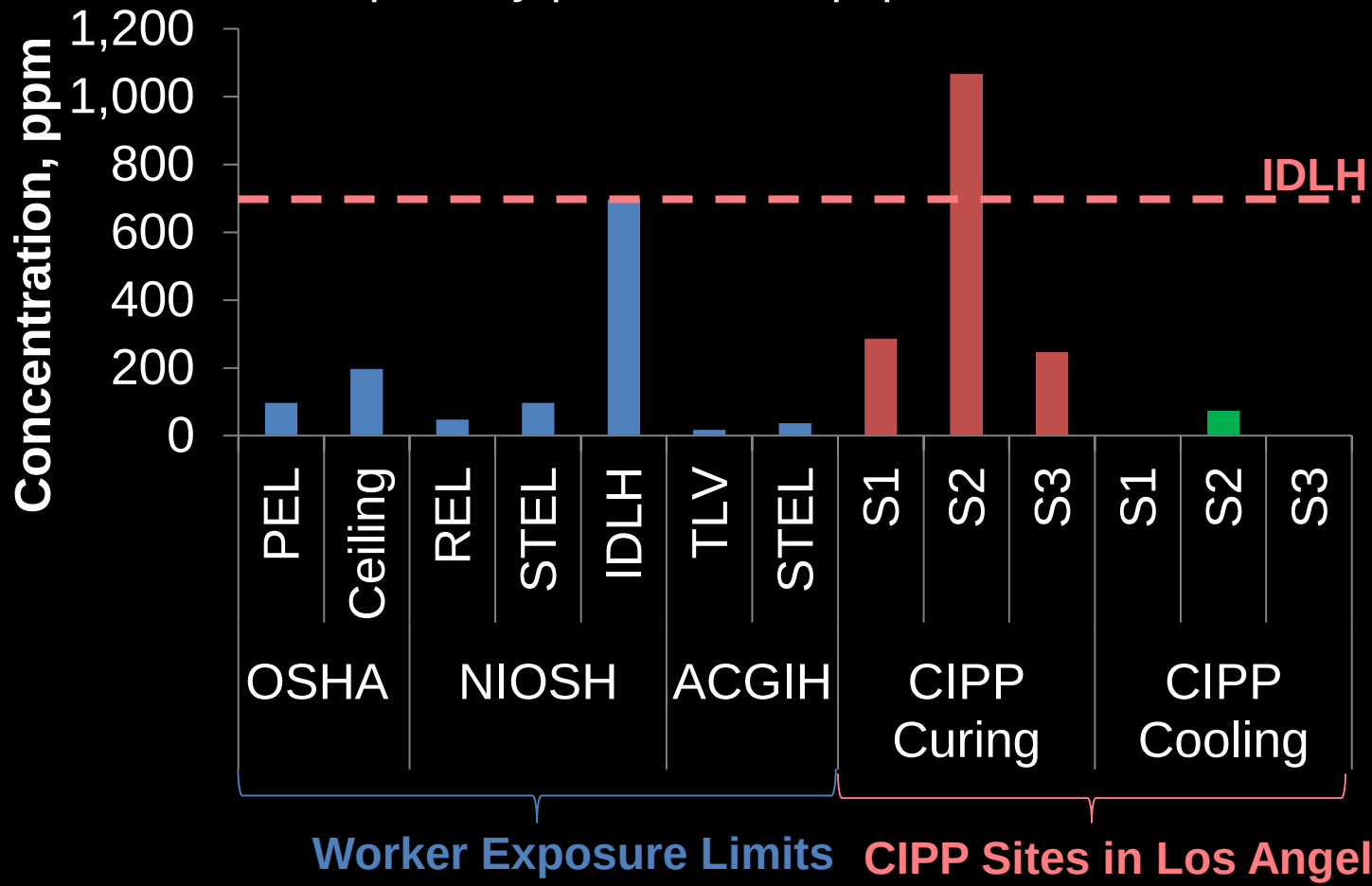
# Since 2001…

## *14 air testing reports (5 in US)*
## *Only 1 was peer-reviewed*


1. Very limited air monitoring data available
2. Air flows unclear
3. Monitoring conducted far from chemical emission points
4. Only looked for styrene
5. Assumed PID devices only detected styrene and were accurate
6. *Very few* CIPP contractors and resin systems monitored
7. No characterization of resin or CIPP, What could be released?
8. In 2004, air monitoring began *after* liner installation
9. Chemicals emitted may have sorbed to equipment or sampling materials
10. Multi-hour sample misses more transient, higher concentration exposures

# In 2015, Styrene was Discovered Exiting a CIPP Sewer Manhole that Exceeded the NIOSH IDLH Concentration of 700 ppm

**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)*

# From our review: Some CIPP ingredients (initiators) are designed to fall apart and create new chemicals

**Trigonox®**

Acetone
Acetophenone
Benzene
Benzoic acid
*tert*-Amyl alcohol
*tert*-Butanol
3-*tert*-Butoxyheptane
2-*tert*-Butyloxy-24,4-trimethylpentane
Carbon dioxide
3-(1,1,Dimethylpropoxy) heptane
Ethane
2-Ethylhexanoic acid
Heptane
Methane
2-Phenylisopropanol
3,3,5-Trimethylcyclohexanone

**Perkadox®**

Benzene
Benzoic acid
4-*tert*-Butylcyclohexanone
4-*tert*-Butylcyclohexanol
Carbon dioxide
Diphenyl
Phenylbenzoate
Tetradecanol

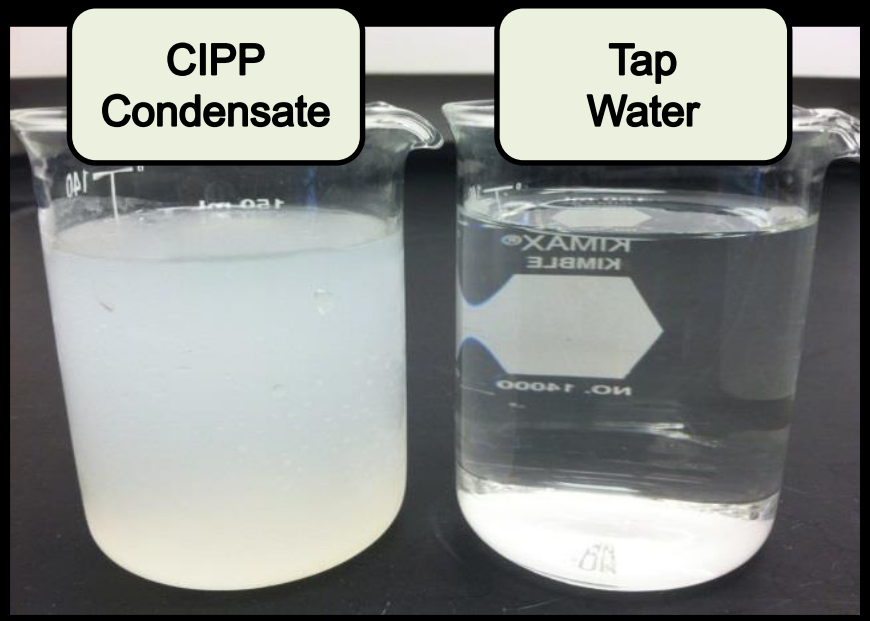
**Butanox®**

Acetic acid
Carbon dioxide
Formic acid
Propanoic acid
Methyl ethyl ketone

***N,N*-Dimethylaniline**

Aniline
Carbon oxides
Nitric oxides

Ra et al. (2018) Critical Review: Surface Water & Stormwater Quality Impacts of Cured-In-Place-Pipe Repairs. *J. Am. Water Works Assoc.*




Tabor et al. 2013. *Environ. Sci. Technol.*

**Carcinogens**

*Styrene*
*Benzene*
*Methyl ethyl ketone (MEK)*
*1,3,5-Trimethylbenzene (TMB)*
*1,2,4-Trimethylbenzene (TMB)*

**Endocrine disruptors**

*Diisooctyl phthalate (DOOP)*
*Dibutyl phthalate (DBP)*
*Diethyl phthalate (DEP)*

***Other chemicals detected, not shown here***
***Condensate dissolved daphnids in 24 hr at room temp.***

# Prior chemical leaching studies for stormwater impacts shows limited testing of CIPP installations

2012: Ontario wastewater treatment plants (WWTP) impacted by CIPP wastewater
2010: Some New York WWTPs ban CIPP wastewater
2009: Nevada WWTP required GAC treatment of CIPP wastewater to styrene < 2 mg/L before sanitary sewer discharge
2008: Massachusetts WWTP cease-desist order issued to CIPP contractor
2008: California WWTP processes upset by CIPP wastewater
2001: Germany researchers recommended 0.4 mg/L max. styrene sewer discharge limit

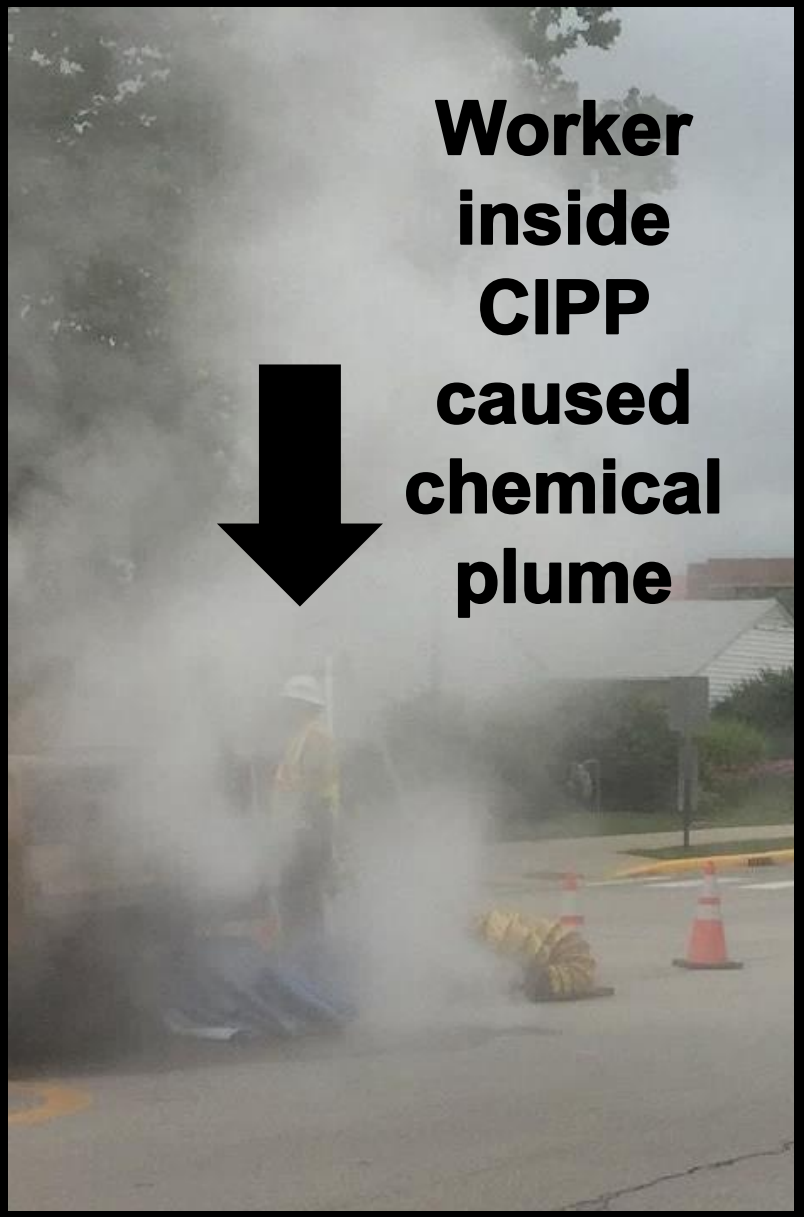
# Examples of Chemical Water Emissions

## Our 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

### Objectives

1) Conduct air sampling and analysis for 7 CIPP installation sites.
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

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

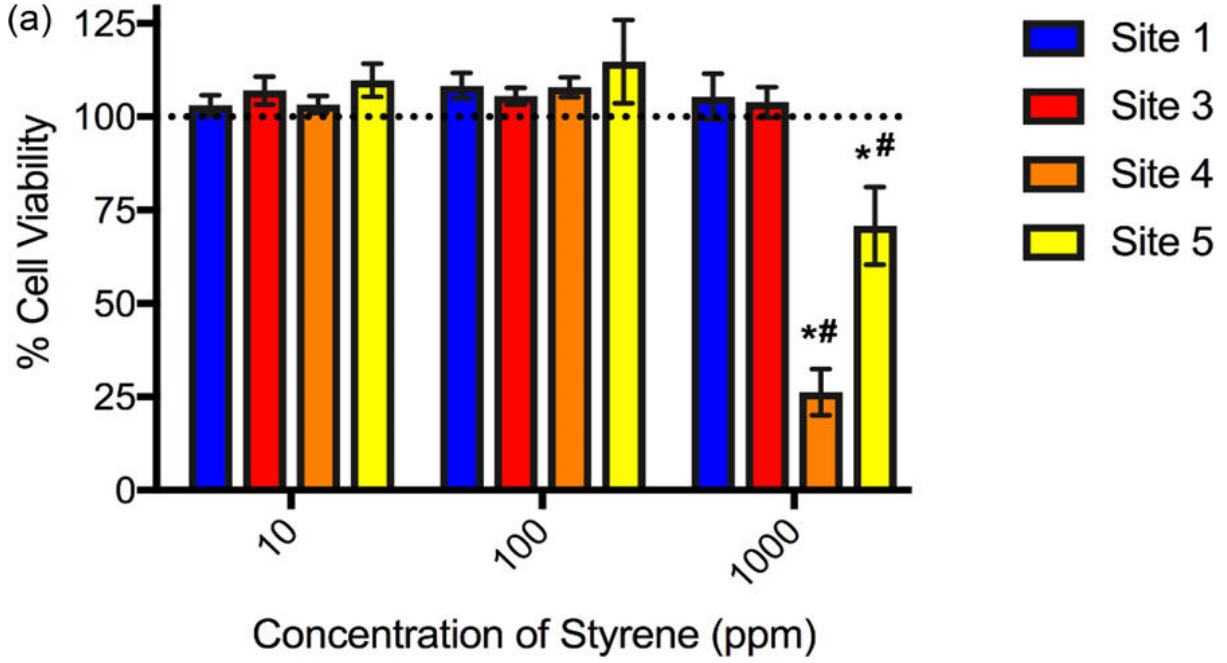
Teimouri et al. 2017. Worksite Chemical Air Emissions and Worker Exposure during Sanitary Sewer and Stormwater Pipe Rehabilitation Using Cured-in-Place-Pipe (CIPP). Env. Sci. Technol. Letters.

# It's NOT just styrene. Many compounds NOT listed on the SDSs have been found and have exposure limits.

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

Teimouri et al. 2017. Worksite Chemical Air Emissions and Worker Exposure during Sanitary Sewer and Stormwater Pipe Rehabilitation Using Cured-in-Place-Pipe (CIPP). Env. Sci. Technol. Letters.

# Exposures to mouse lung cells indicated some toxicity occurred and future health impact investigations are warranted




Teimouri et al. 2017. Worksite Chemical Air Emissions and Worker Exposure during Sanitary Sewer and Stormwater Pipe Rehabilitation Using Cured-in-Place-Pipe (CIPP). Env. Sci. Technol. Letters.

| STUDY | DETAILS | OBSERVATIONS |
|---|---|---|
| **2018; USA** | 2, Thermal/ Hot water, NR | Badges indicated 58 $ppm_v$ styrene exposure for a person onsite during an entire installation and who entered a manhole; For sanitary sewer manholes, outside and inside PID signals were < 20 $ppm_v$ and > 20 $ppm_v$, respectively; During site clean-up PID signals > 20 $ppm_v$; **Detected a max. 167 $ppm_v$ and > 100 $ppm_v$ for more than 15 min.** |
| **2017; USA** | 2, Thermal/ Steam, NR | For 2 steam CIPP sites, maximum 16.5 $ppm_v$ PID signal at one site and 104 $ppm_v$ maximum PID signal at the other site; ≤0.4 $ppm_v$ styrene detected on badges |
| **2017; USA** | 7, Thermal/ Steam, Styrene and non-styrene resin | **Max. PID signals reported for styrene-based CIPP (6,321 $ppm_v$) and non-styrene based CIPP (9.6 $ppm_v$); A multi-phase mixture of solids, liquids and gases was emitted into the air and were condensed to include partially cured resin; multiple VOCs and SVOCs, not just styrene, were detected; styrene was emitted into air during a non-styrene CIPP installation; toxicity was detected for mouse lung cells for some condensed materials; capture/monitoring recommended** |
| **2016; USA** | 3, Thermal/ Steam, Styrene resin | At sanitary sewer pipe manholes styrene detected during **steam curing (250–1070 $ppm_v$) and cool down (3.6–76.7 $ppm_v$);** flowrate exiting the exhaust pipe > 4 $m^3$/min |
| **2007; USA** | NR, NR, NR | Max. styrene level of 9.955 $ppm_v$ next to end of pipe |
| **2006; NED** | 1, Thermal/ Hot water, NR | Max. PID signal observed was 87 $ppm_v$ and **flowrate was estimated to be 6000 $m^3$/hr** |
| **2006; NED** | 3, Thermal/ Hot water, NR | Method description and results unclear; 7 $ppm_v$ PID signal detected in a nearby building; **Max. PID "styrene concentration" reported at 300 $ppm_v$; Ventilation recommended.** |
| **2005; NED** | 1, Thermal/ Hot water, Styrene resin | For continuous measurements the max. PID signal was 170 $ppm_v$, by GC-PID 280 $ppm_v$, and by IR for styrene was 270 $ppm_v$ and methane was 100 $ppm_v$. A 1,300 $ppm_v$ and 1,400 $ppm_v$ "styrene concentration" result was also reported for two locations, but the instrument used was unclear; "dozens of PPMs of styrene was detected above the worksite"; **1 km downstream in the sewer no decrease in styrene concentration was found.** |
| **2004; DEU** | 24, Thermal/ Steam, Hot water; UV-light, NR | Air monitoring results not reported; Recommended **no unauthorized persons should come within 5 m of installation site**; Recommended max. 400 mg/kg of styrene in pilot experiments should remain in new CIPP, and 500 mg/kg for pipes < 24 inch diameter and 1000 mg/kg for pipes at and larger than 24 inch diameter. |
| **Date NR; DEU** | 2, UV-light, NR | Max. 0.008 $ppm_v$ styrene reported in air. |
| **Date NR; DEU** | 1, Thermal/ Steam, NR | 10 $ppm_v$ Drager tube detection limit; Of 32 samples, five > 10 $ppm_v$; Max. **20 $ppm_v$ styrene concentration reported 5 m from the emission point**; **10 $ppm_v$ detected 20 m away.** |
| **Date NR; UK** | 4, Thermal/ Steam, Hot water, NR | Method description and results unclear; **Max. 165 $ppm_v$ styrene (method unclear) in manholes and 6 $ppm_v$ about 1 m away from the manhole.** |
| **2004; CAN** | 2, Thermal/ Steam, Styrene resin | Max. PID signal detected was 110 $ppm_v$ |
| **2001; CAN** | NR, Thermal/ Hot water, NR | **A max. 3.2 $ppm_v$ styrene level found above a manhole** |

*[before 2017, often stated in the U.S.]*

# 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.

# Often what we have found ….

- ❑ No inhalation worker protection
- ❑ No engineering or administrative controls
- ❑ No public or worker knowledge of multi-phase emissions
- ❑ Under-reported what chemicals were emitted and magnitudes
- ❑ Information provided to pipe owners & health officials incorrect
- ❑ Information provided to consulting engineering firms incorrect
- ❑ Information provided to the affected general public incorrect
- ❑ Highly variable practices applied by different contractors

Have we been here before?

**SORT OF…**

# Chemical air emissions were an issue for bathtub and boat manufacturers

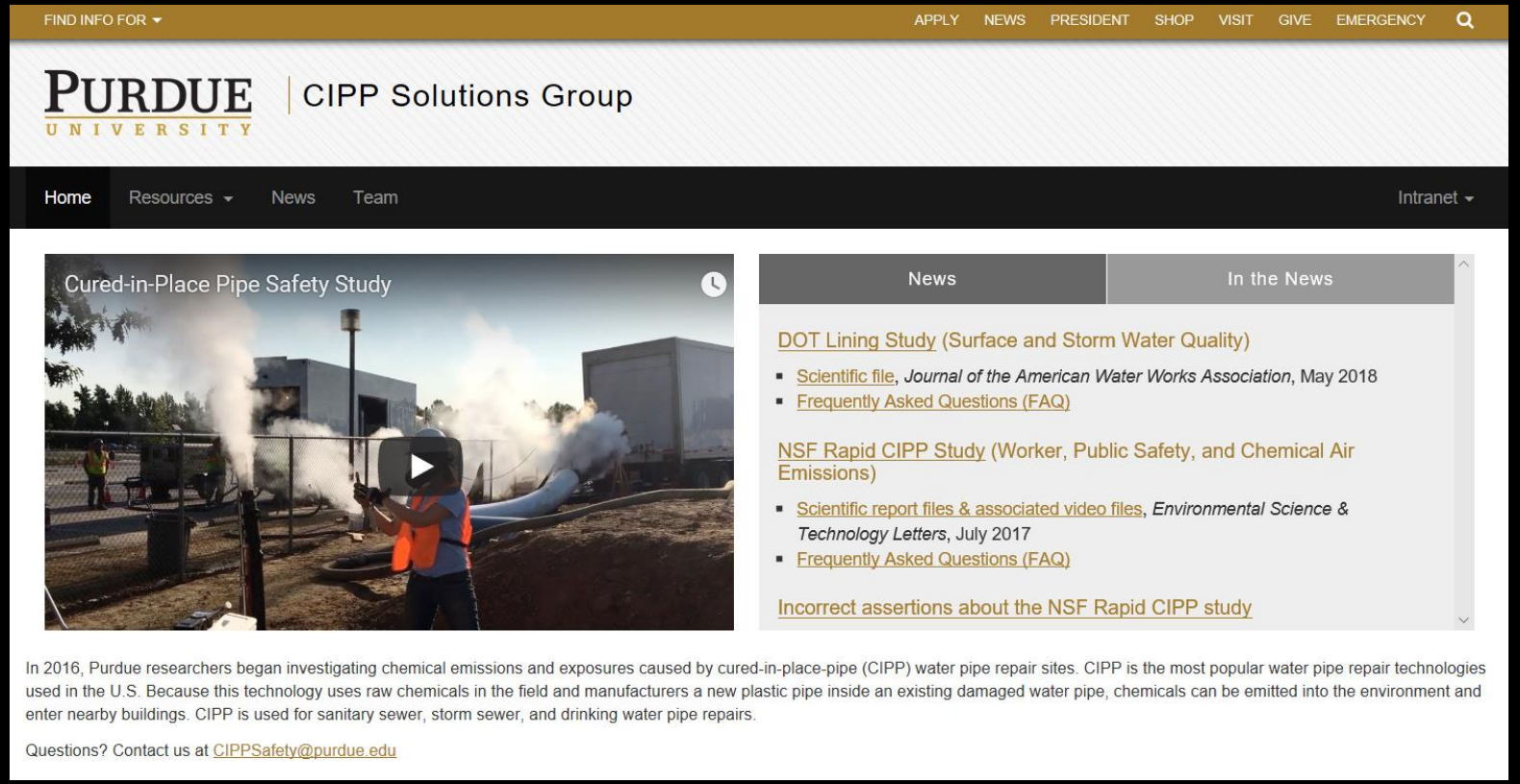
- Large scale manufacturers were forced to change procedures due to lawsuits and regulations
  - OSHA, EPA, DHHS all issued reports regarding styrene release
- Possibly solutions:
  - Industrially, proper ventilation, such as a push/pull ventilation system is necessary to remove styrene from the work 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

**What happened?**

1. Industrially, ventilation/ emission control was necessary
2. Proper PPE was needed (especially for small fabricators)

# Solvable problems exist for this innovative technology

# For Everyone: Learn More at www.CIPPSafety.org




Download free:

- Scientific studies
- FAQs
- Resources
- Videos

Require chemical capture, monitoring, setback distances, and PPE based on work task (with evidence)

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

# For CIPP Companies


## 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)

# For Workers, Pipe Owners, Health Officials, Consultants, and the Public

**WATCH THE FREE CIPP SAFETY STUDY** WEBINAR (Oct 2017)

neha.http://neha.org/node/59333



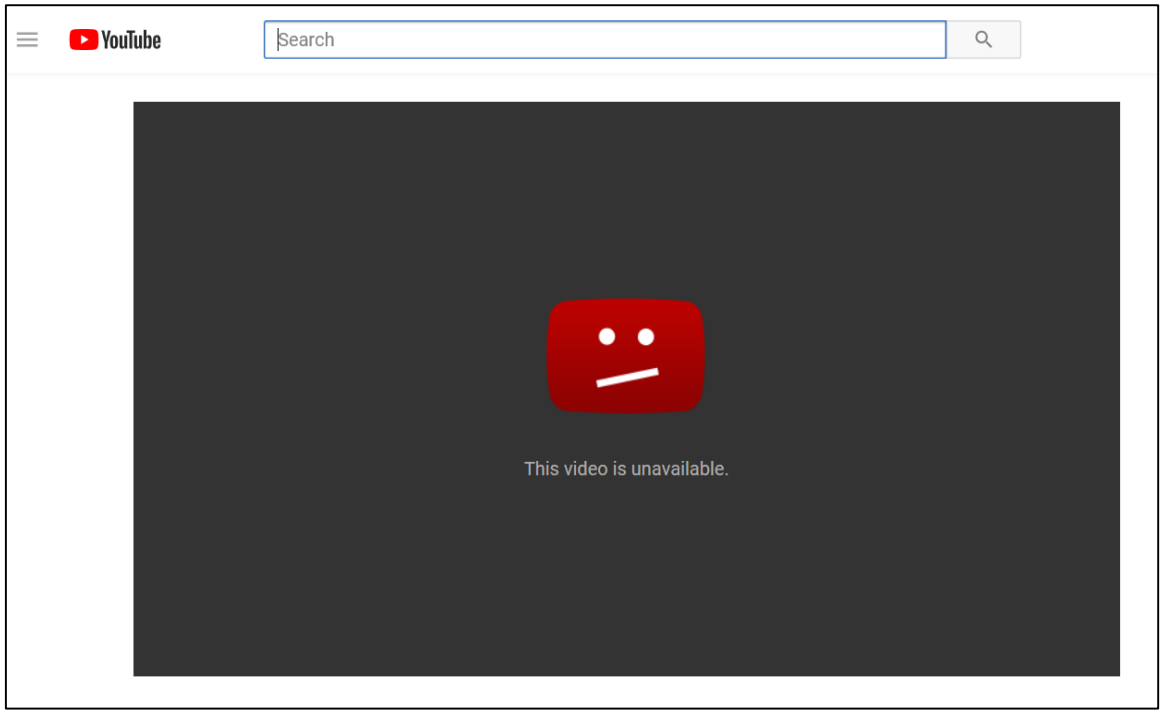
July 2017 California Safety Alert


Sept 2017 CDC NIOSH Blog Post


Sept 2017 California Safety Alert

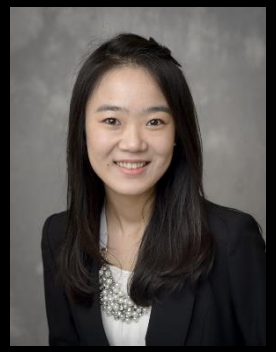
# Cured-in-Place Pipe: The Role of Engineers in Worker and Public Safety

*"Engineers, in the fulfillment of their professional duties, shall hold paramount the safety, health, and welfare of the public." – NSPE Code of Ethics, Canon 1*




1. *Remove claims emissions are "harmless", "do not be alarmed", purported maximum styrene levels*
2. *Require emission capture and confirmation*
3. *Direct people with questions to medical doctors not contractor or city employees*
4. *Notify current and former employees short- and long-term health effects of CIPP related exposures currently unknown*

Andrew Whelton, Civil/Environmental Eng.



Kyungyeon Ra Environmental Eng.

John Howarter, Materials Eng.

Md Nurrudin Materials Eng.

Brandon Boor, Air Quality Eng.

Chad Jafvert, Civil/Environmental Eng.

Nadya Zyaykina, Civil/ Environmental Eng.

Mabi Teimouri Civil Eng.

Jonathan Shannahan, Toxicology

Lisa Kobos Health Sciences

Emily Conkling Environmental Eng.

Jeffrey Youngblood, Materials Engineering

***+ 26 other people at Purdue University***

- Contacted **CIPP companies** and provided them the results, offered to help
- Directed **CIPP contractors** to **NIOSH for free Health Hazard Evaluations (HHEs)**
- Provided **CIPP workers**, engineering firms, municipalities and states info
- Briefed **30+ CIPP companies/representatives** and offered to help them
- Met with **CIPP resin suppliers** to outline issues
- Provided assistance to the **OSHA CIPP worker fatality investigation**
- Provided assistance to **fire fighters and emergency response** officials
- Provided assistance to municipalities, consulting engineers and state transportation and environmental agencies
- Provided feedback to industrial hygiene firms
- Provided assistance to government worker safety and public health organizations
- Held discussions with worker and public **safety agencies outside USA**
- Developed a working technological solution for emission capture and treatment
- 20+ freely available presentations (www.CIPPSafety.org)
- 1 freely available webinar sponsored by National Environmental Health Association
- Continuing to interpret results and prepare them for release
- And more…

# Thank You

*Andrew Whelton, Ph.D.*

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