Worker Safety, Public Safety, and Environmental Sustainability: Preempting Pollution Problems is Good Business Practice

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Partners for Pollution Prevention Annual Meeting September 19, 2018 Indianapolis, IN

Learning Objectives

(1) Explain the cured-in-place-pipe (CIPP) manufacturing process

(2) Recognize the source & types of chemical emissions

(3) Identify resources available for decisions

(4) Describe practices that can control emissions to improve worker and public safety and better limit environmental impacts

Water Pipes are Critical for Our Security, Economic Vitality, and Health of Communities

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

For example: Storm sewer pipes in the U.S.

2,272 miles of culvert in place

(FHWA 2005)

189+ miles require rehabilitation

(FHWA 2010)

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

The Way things Used to Be…

Damaged Pipe? Dig it up and Replace

Water outages

Traffic disruptions

Closed roads

Safety issues

Trenchless Technology

Disruptive Innovation

“Methods by which underground utilities may be installed without damage to overlying pavement, if proper precautions are observed”

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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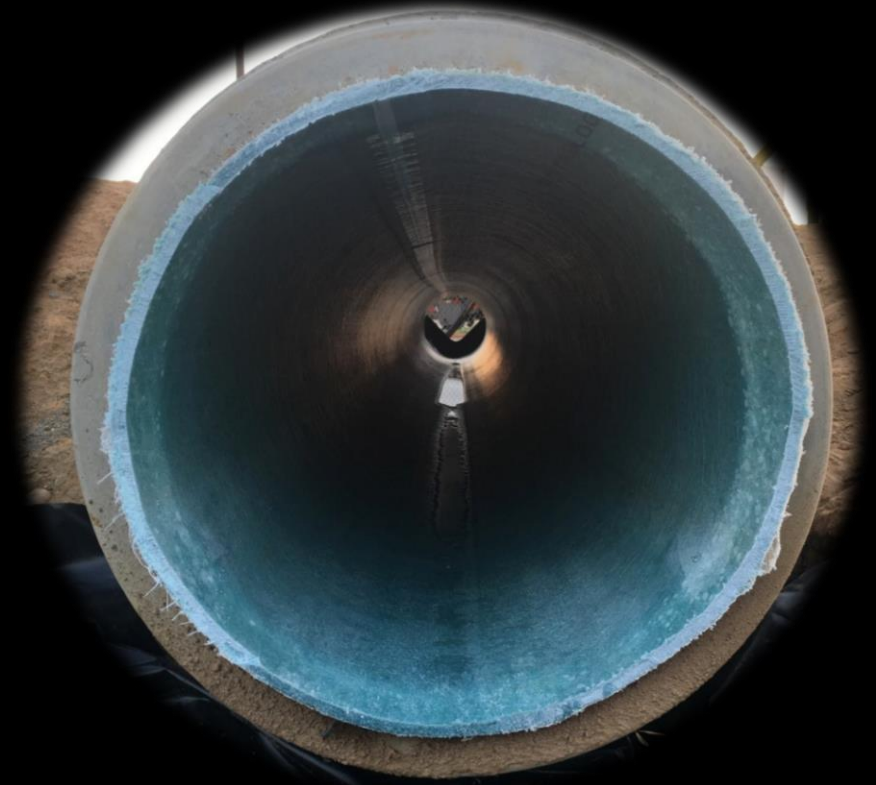
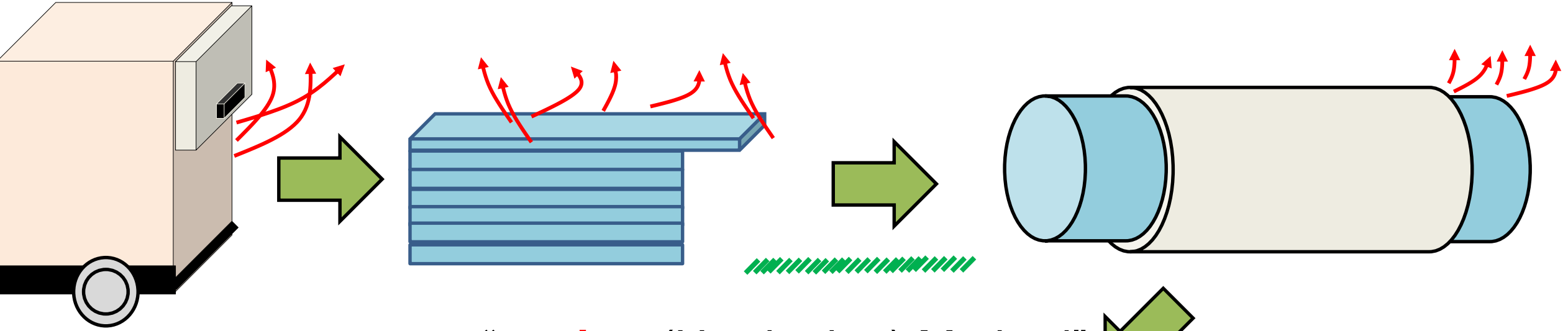


Uncured **RESIN** tube delivered on a truck

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

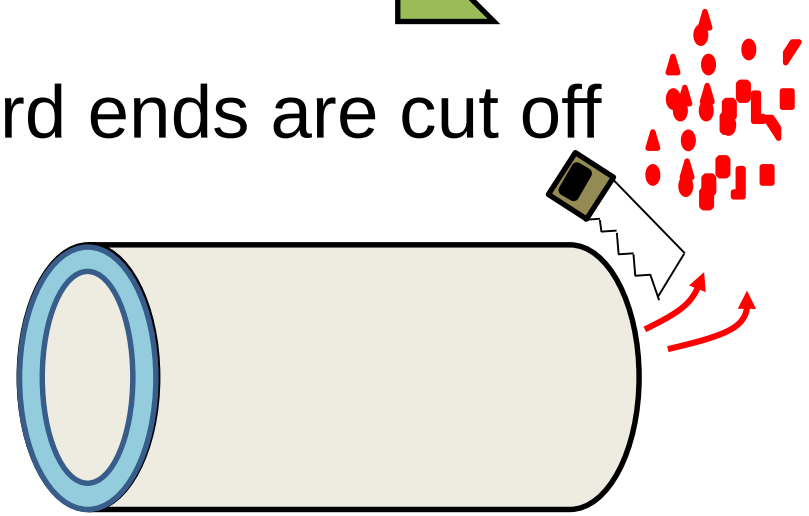
Uncured **RESIN** tube inflated with air inside host pipe



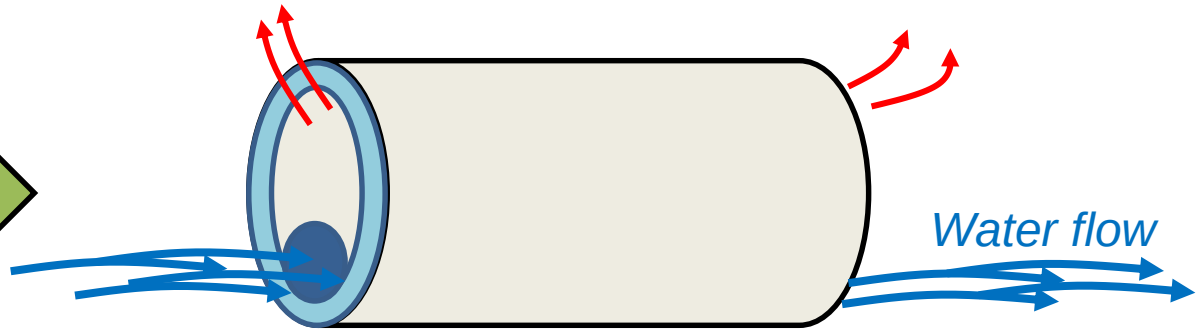
"**Curing** (Hardening) Method"

Hot Water or Steam or UV Light

Hard ends are cut off



Pipe allowed into service



How long does a CIPP last?

"50 year design life"?
"100 year design life"?
Some CIPPs installed for 30 years already

CIPP manufacturing sites are highly transient, single installation being used from a few hours to a few days.

Unlike traditional manufacturing operations, no 'permanent address' to visit or inspect

Once complete, workers packup and move on

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

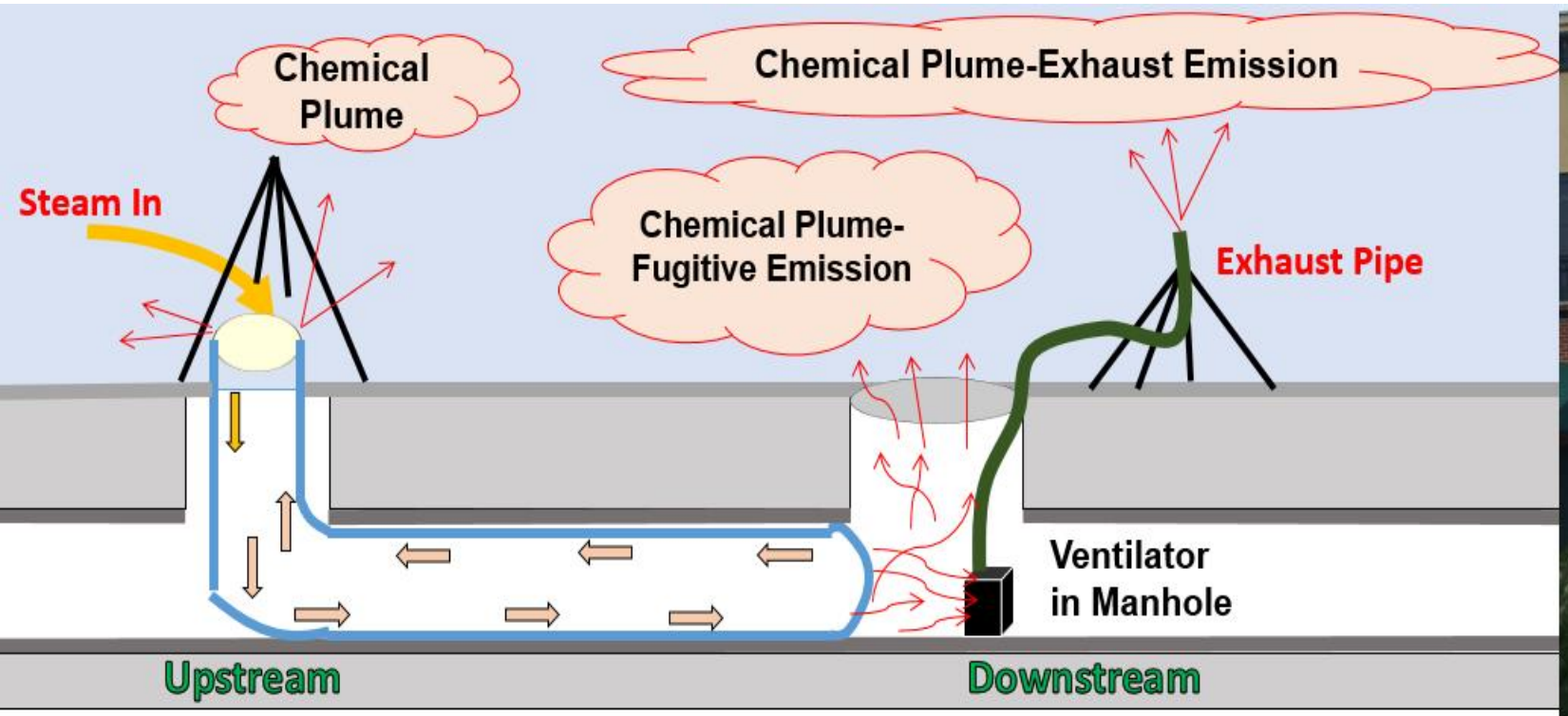
RESIN: Polyester predicted to remain most popular, vinyl ester expected to witness growth

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

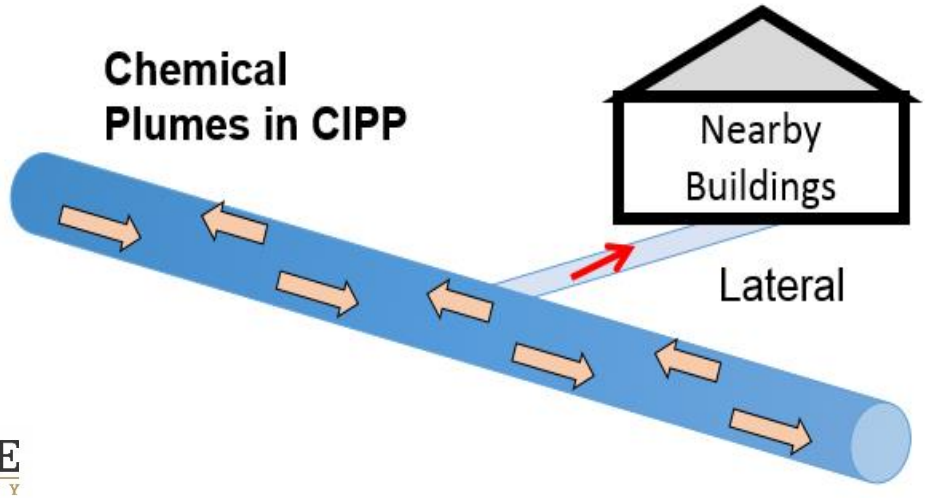
CURING: Steam predicted to remain most popular, UV expected to witness the growth

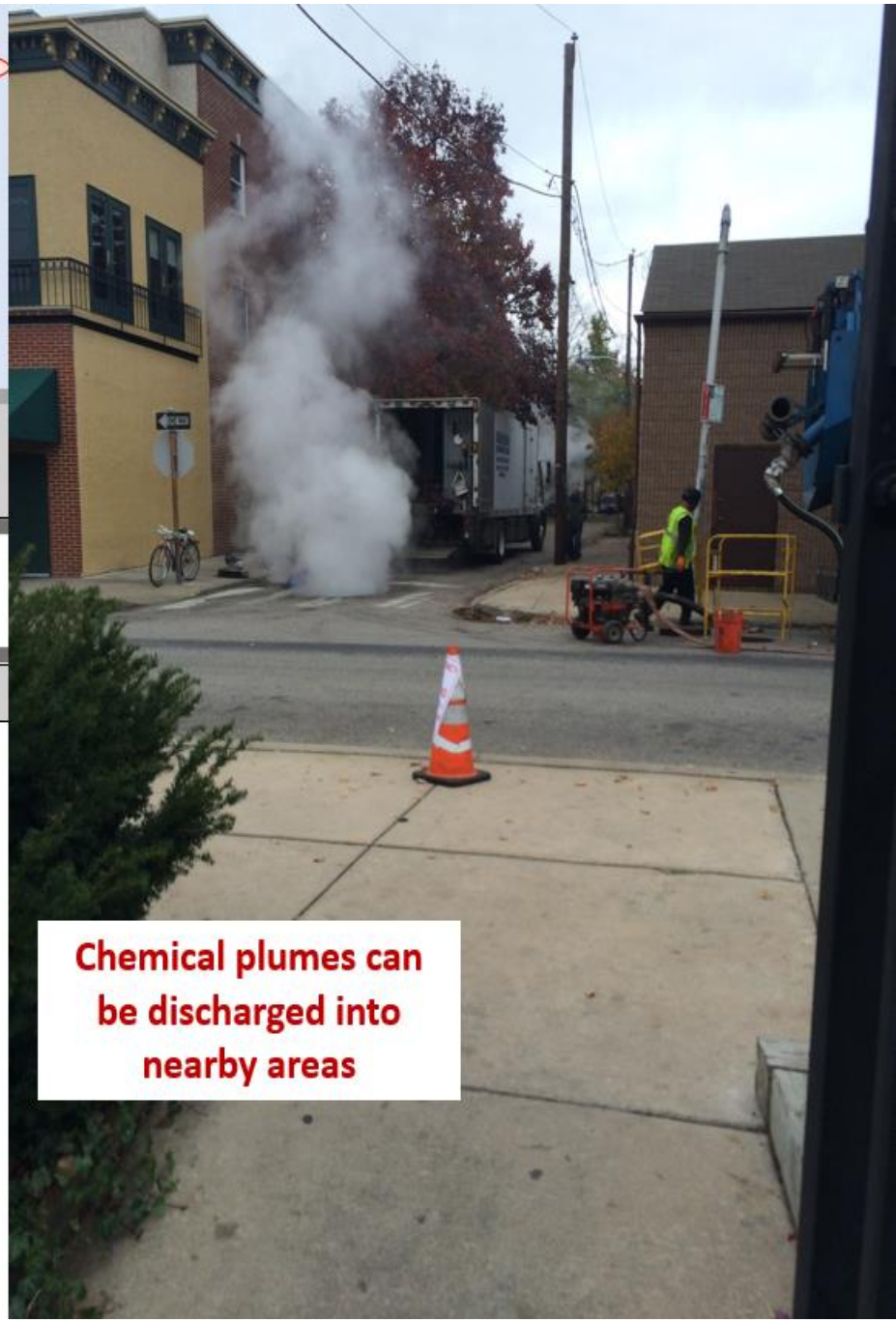
(2) Recognize the source and types of chemical emissions

Do pollutant emissions matter?



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 quite common in the US

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

Source: Daily Herald

2017

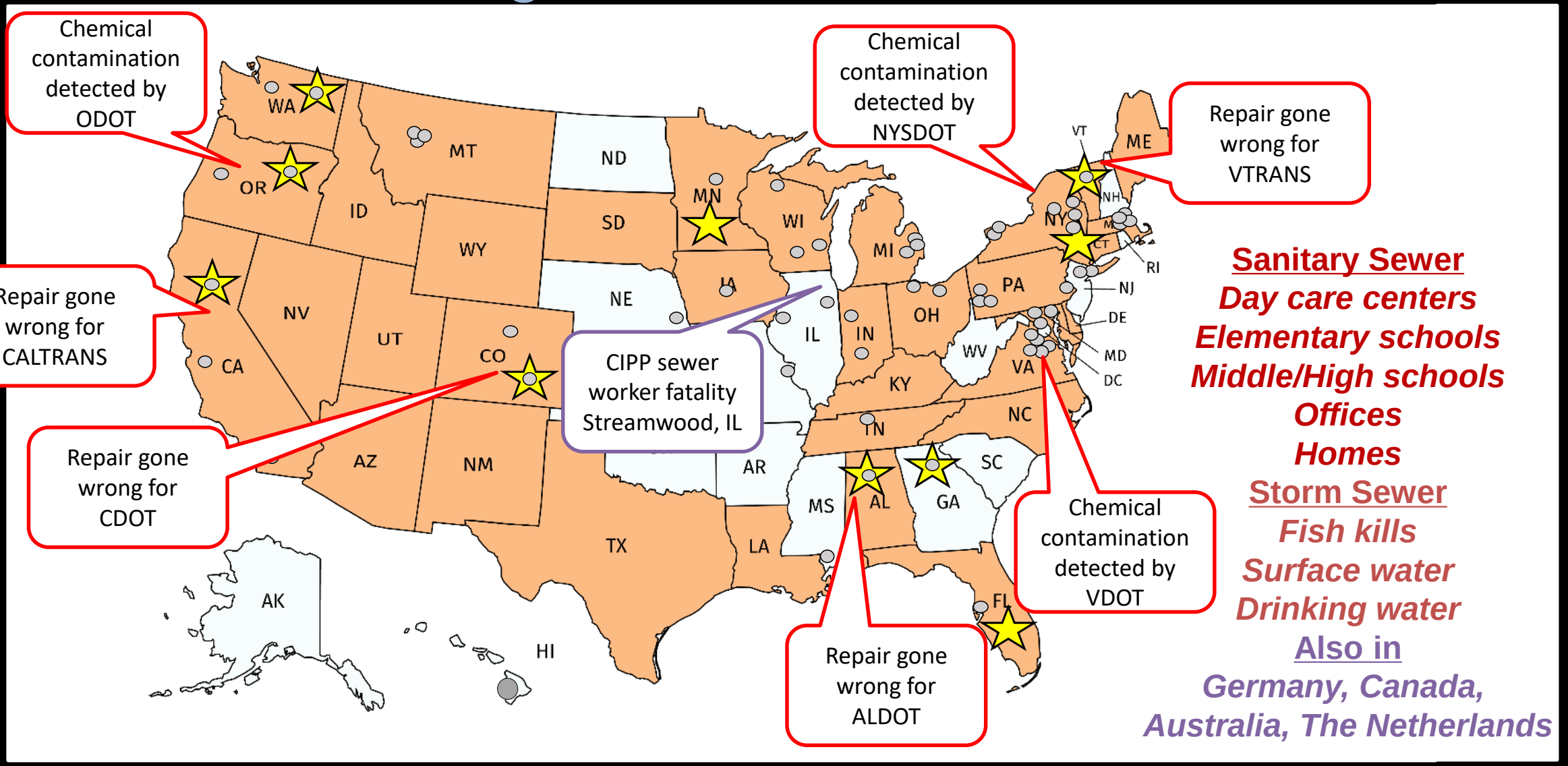
Streamwood, Illinois

CIPP sewer worker fatality

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

What does the scientific literature say?

Uncontrolled Chemical Emissions Are a Problem During and After CIPP Installs



Limitations with Past CIPP Air Testing Studies are Significant

Very limited air monitoring data available

Air flows unclear

Monitoring conducted far from chemical emission points

Only looked for styrene

Assumed PID devices only detected styrene at accurate concentration

Very few CIPP contractors and resin systems monitored

No characterization of resin or CIPP, What could be released?

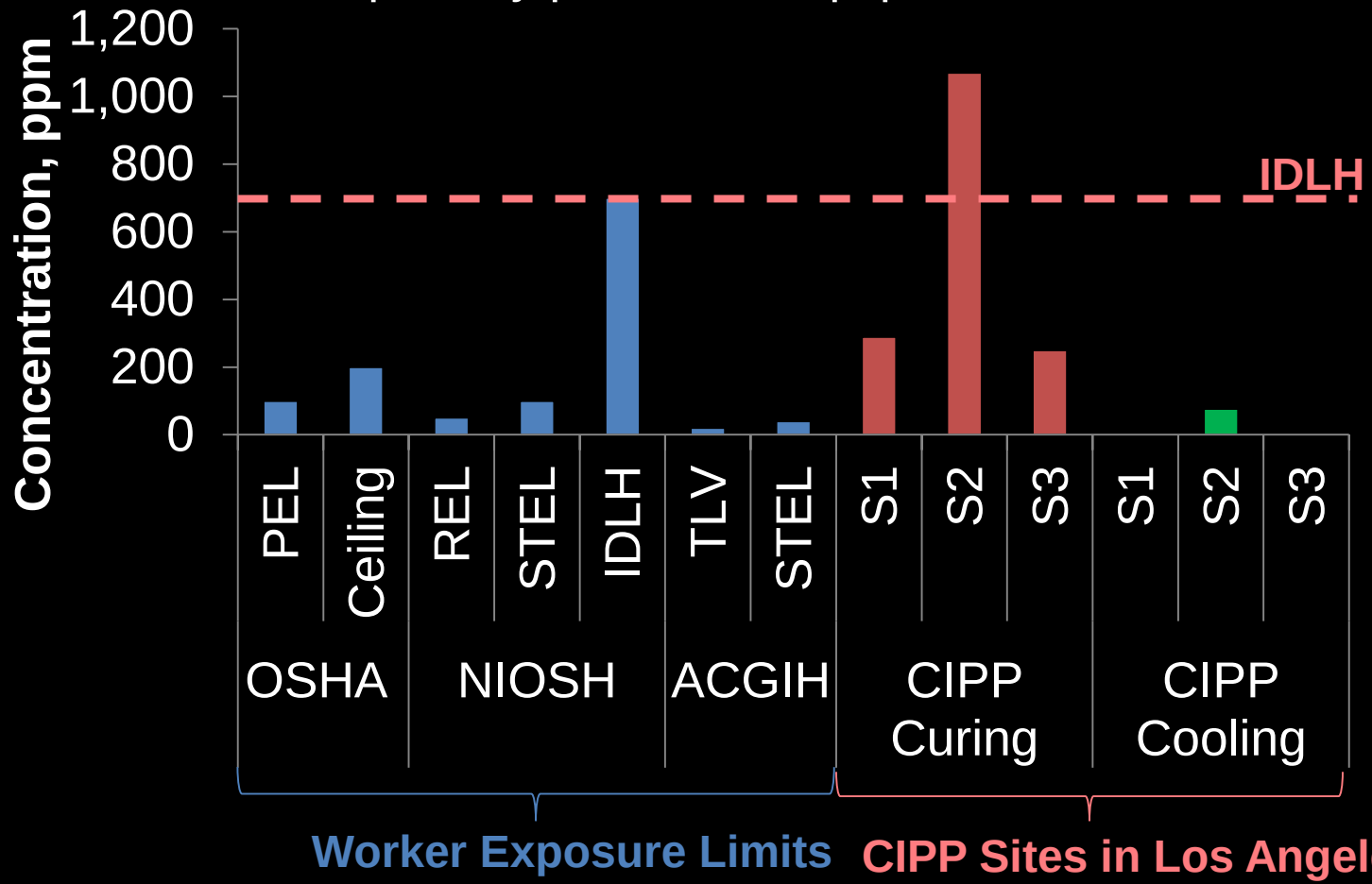
In 2004, air monitoring began *after* liner installation

Chemicals emitted may have sorbed to equipment or sampling materials

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

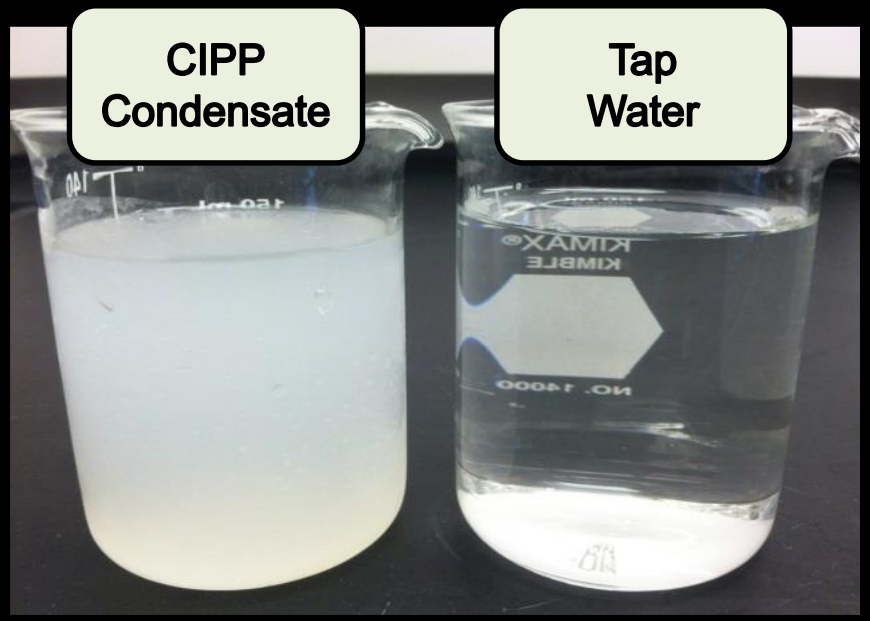
Butanox®

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

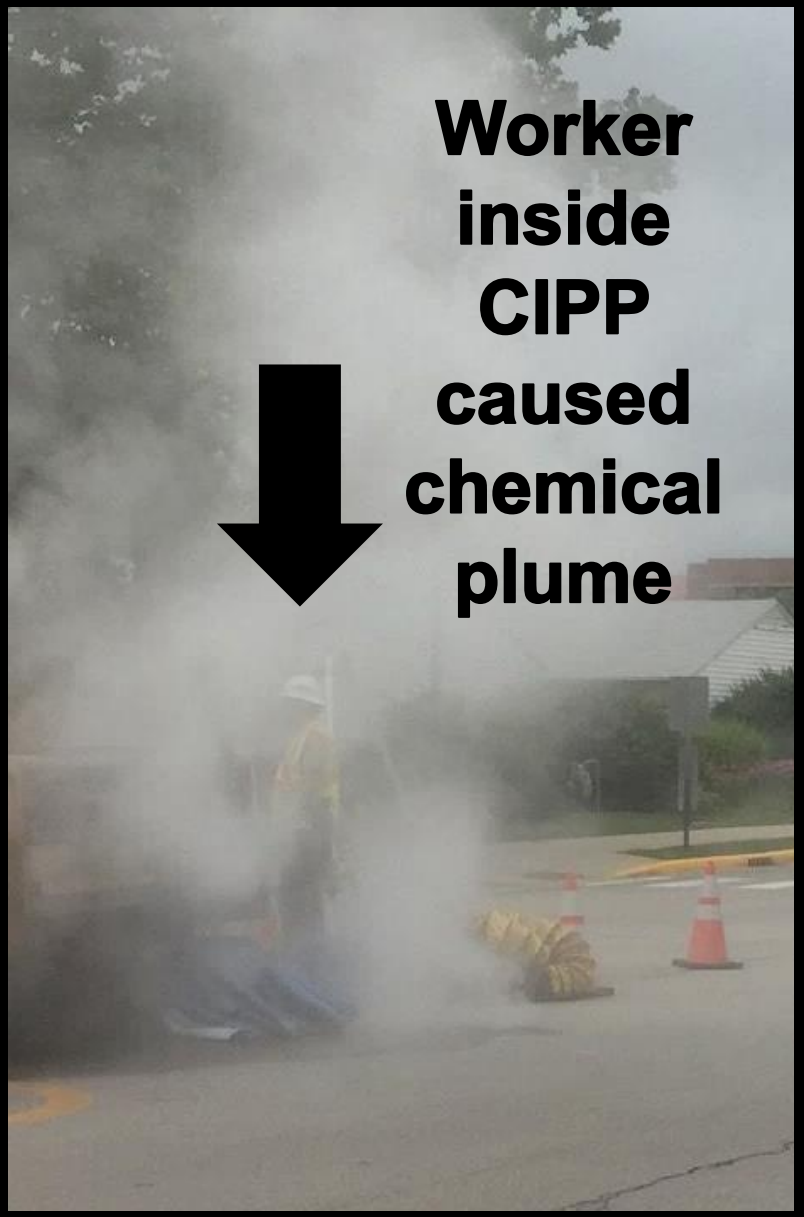
The day after

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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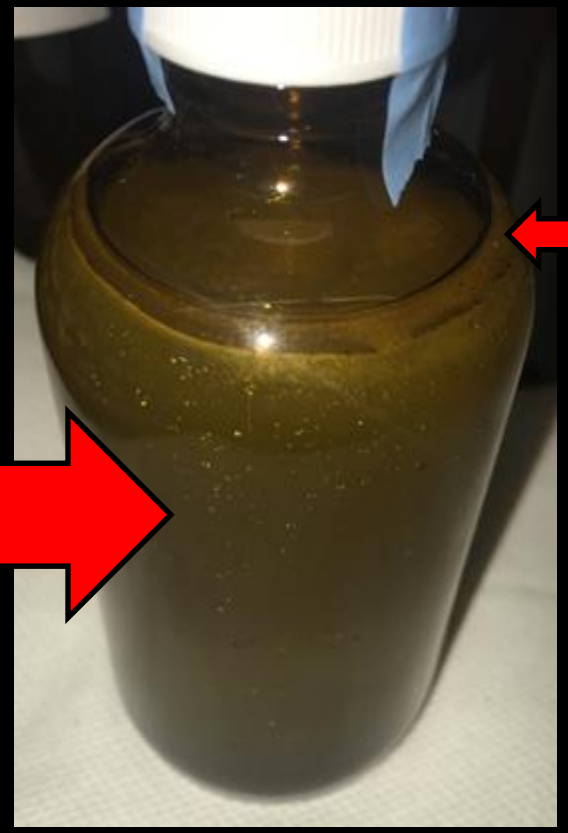


This is a Multiphase Chemical Mixture, **NOT Steam**
(particulates, droplets, partially cured resin, etc.)

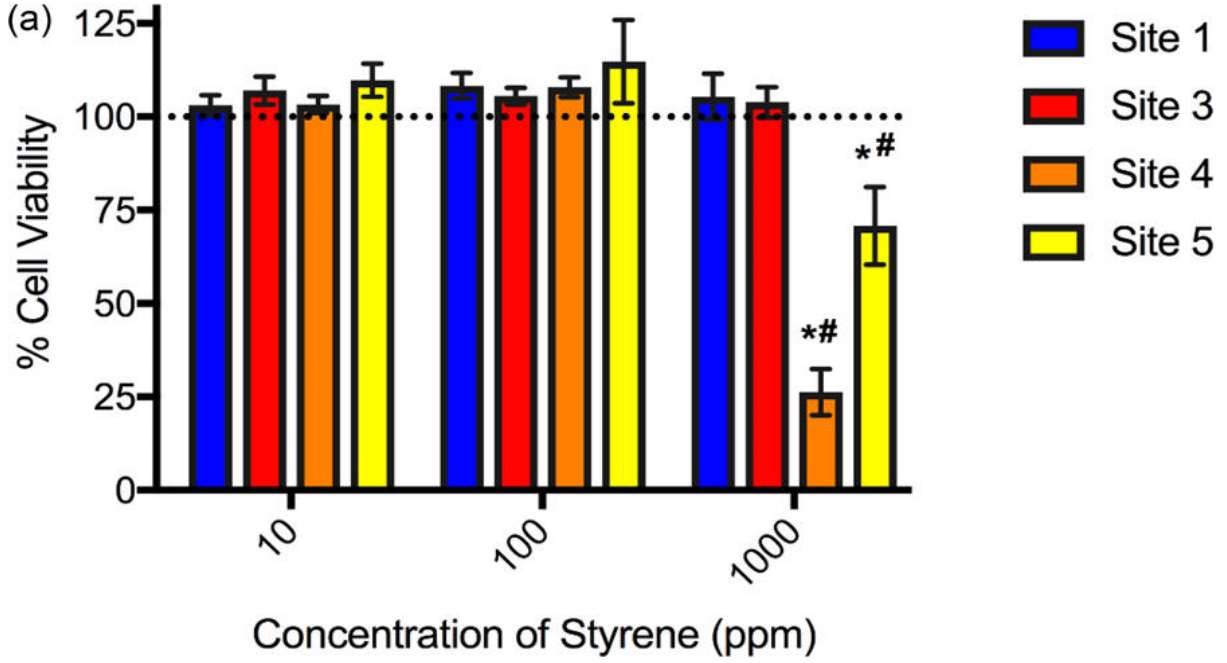
Teimouri et al. 2017. Worksite Chemical Air Emissions and Worker Exposure during Sanitary Sewer and Stormwater Pipe Rehabilitation Using Cured-in-Place-Pipe (CIPP). Env. Sci. Technol. Letters.

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.

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

(3) Have we been here before?

SORT OF…

Learn from the Past: Chemical air emissions were an issue for bathtub and boat manufacturers

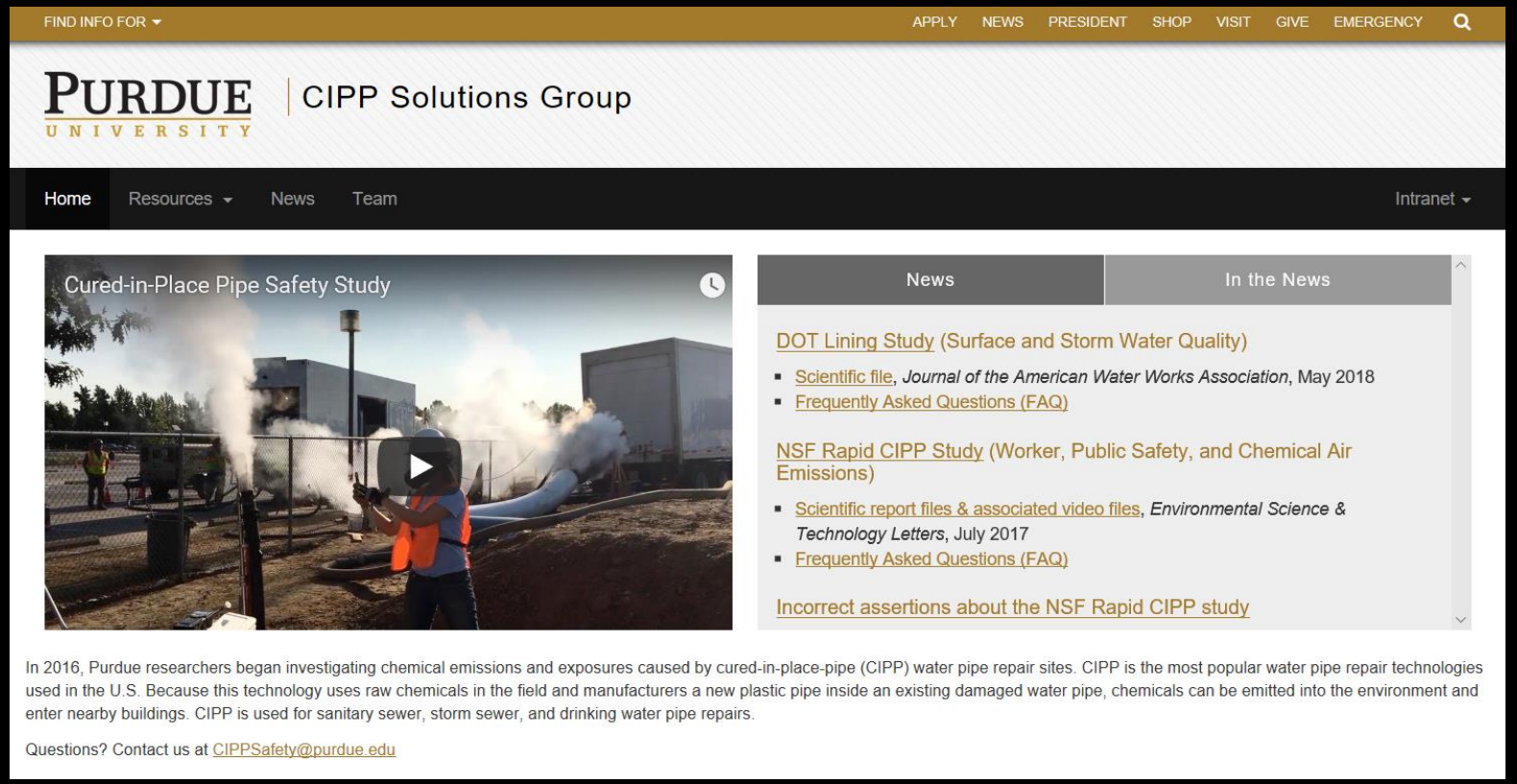
- Large scale manufacturers were forced to change procedures due to lawsuits and regulations
  - OSHA, EPA, DHHS all issued reports regarding styrene release
- Possibly solutions:
  - Industrially, proper ventilation, such as a push/pull ventilation system is necessary to remove styrene from the work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

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

Solvable problems exist for this innovative technology

(4) Describe practices that can control emissions to improve worker and public safety and better limiting environmental impacts

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



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

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

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

For CIPP Companies

Promoting productive workplaces through safety and health research

NIOSH®

National Institute of Occupational Safety and Health

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

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

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

NATIONAL ENVIRONMENTAL HEALTH ASSOCIATION

Promoting productive workplaces through safety and health research / NIOSH

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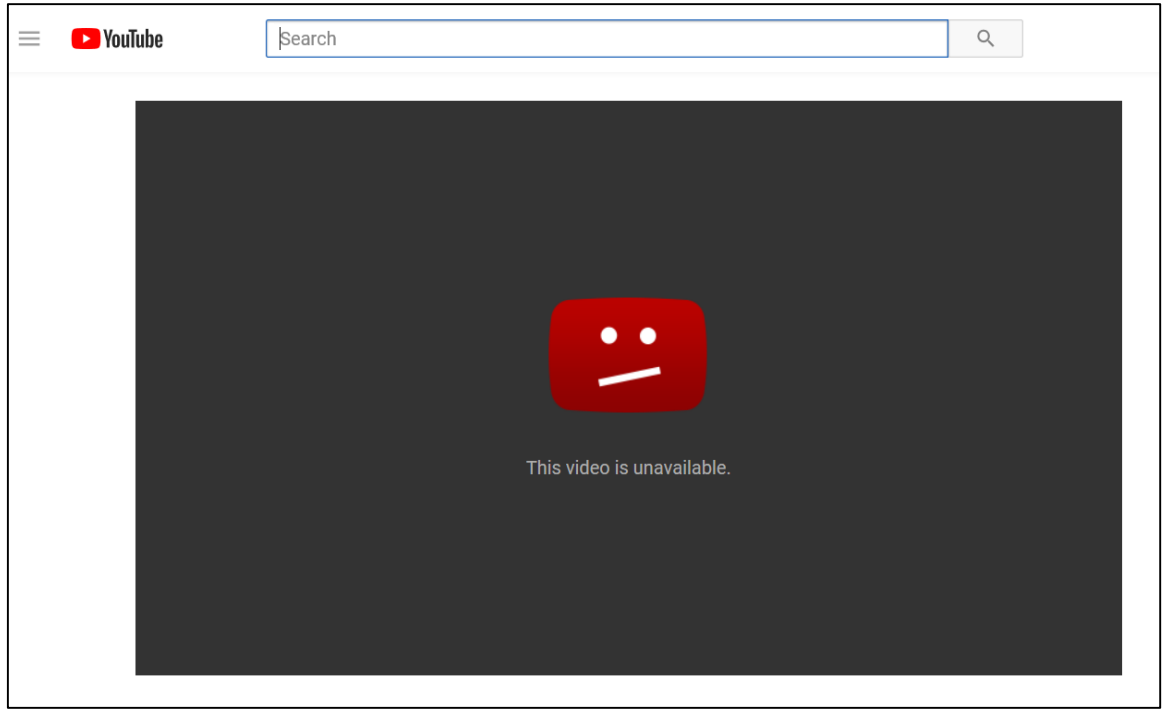
Cured-in-Place Pipe: The Role of Engineers in Worker and Public Safety

"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

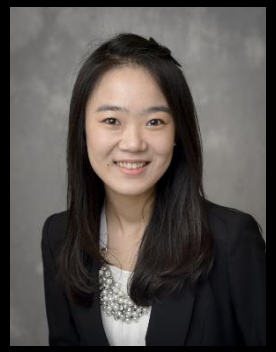


Remove claims that emissions are "harmless", "do not be alarmed", purported maximum styrene levels

Require emission capture and confirmation

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.

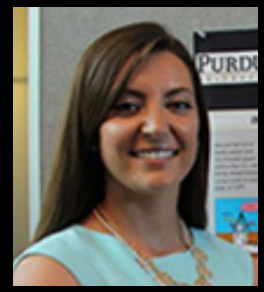
Chad Jafvert, Civil/Environmental Eng.

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**, consulting 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 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
- 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…

Technology Being Developed is Amazing! But Preempting Pollution Problems is Needed for Good Business Practice

- Ethics: Be a good human, environmental sustainability, Engineers Code
- Bottom-Line ($$): Lost business, cleanup, lawsuits
- Image/Perception/Technology Viability

Engage application expertise now so you can design out or counter critical technology flaws before investing lots of $, your livelihood, & credibility

Thank You

Andrew Whelton, Ph.D.

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