New Research on Plastic Water Pipes: Water Quality and Air Quality Challenges

Andrew J. Whelton

November 2, 2016

PURDUE UNIVERSITY

Webinar: Florida AWWA Section

Plastics are Being Used for Water Infrastructure

Pipes: HDPE, MDPE, PEX, PEX/AL/PEX, PP, PVC, cPVC, FRP, and more…

Gaskets: EPDM, SBR, nitrile, and more…

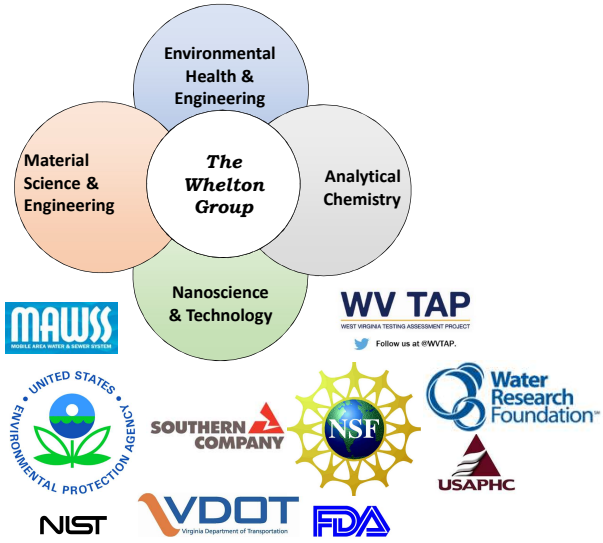
In-situ: Cured in place pipe (CIPP), epoxy, polyurethane, polyurea, PU/PEUU blends

Overwraps: HDPE, LDPE, PP

Membranes: Polyamide (PA), polysulfone (PSF), polycarbonate (PC), polyvinylidene fluoride (PVDF), and more…

Tanks & chemical barrier: HDPE, PET, PVC, and more…

Our Team Operates at the Interface of the Environment-Infrastructure-Public Health



Education Actions

Fund. Environ. Eng.
Polymer in Infrastructure & the Environ.
Environ. Eng. Design
NESCC and ILSI Expert Panels
Plastics training workshops
Industrial workshops & conferences

Research

Infrastructure materials
Polymer degradation
Aquatic chemistry
Water distribution
Water quality & treatment

3

Our Recent Projects Related to Plastics in Water and Energy Infrastructure

Degradation of HDPE pipes in nuclear and fossil power stations

Chemical release from CIPP, polyurethane and polymer enhanced cement mortar coatings

Chemical, microbiological, and aesthetic impacts of plastic piping for buried water service and plumbing

Contamination and decontamination issues associated with plastic water infrastructure components

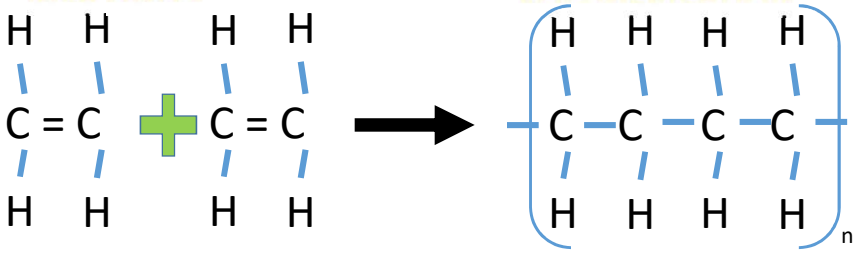
Degradation and leaching of carbon nanofiber polyester composites

And others….

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

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

MER UNITS **POLYMERIZATION**



POLYMER CHAINS … THINK SPAGHETTI !

Linear

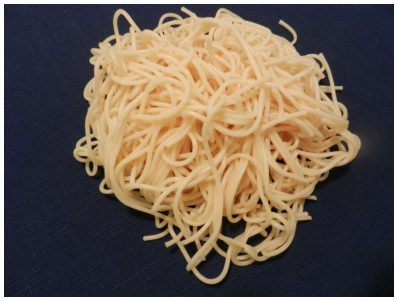
Branched

Place of Manufacture

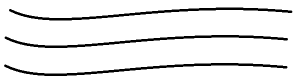
Before onsite
HDPE, PVC, cPVC, PEX,etc.

Inside the water system
Coatings and CIPP liners

How to Make Plastics (*Think Spaghetti*)



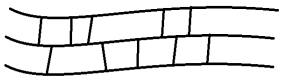
Straighten the spaghetti strands



Not crosslinked

HDPE, PVC, etc.

Bond the spaghetti strands



Crosslinked

CIPP, gaskets, coatings, PEX

Flexible: HDPE vs. LDPE (LDPE has more free volume/space between chains)

Flexible: HDPE vs. PEX (HDPE has greater chain mobility)

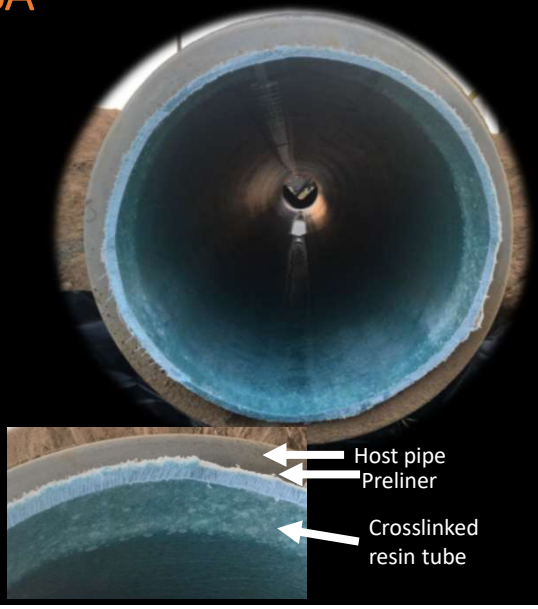
Today, Cured-in-Place-Pipe (CIPP) is used to repair 50% of all water pipes in the USA

Trenchless technology: "No Dig" "No Excavation"

Resin impregnated tube hardened in a broken pipe

Curing method: Hot water, Steam, UV light

Deliberate curing time: Hours to many days



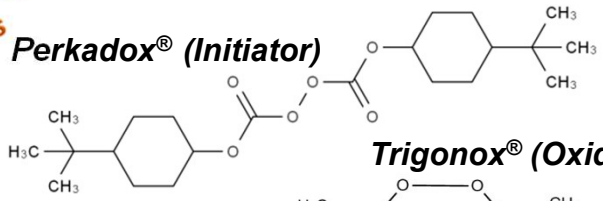
CIPP Is *Created* In the Field
Where Chemicals are Mixed and Reacted

Resin + Hardener + Initiators + Plasticizers

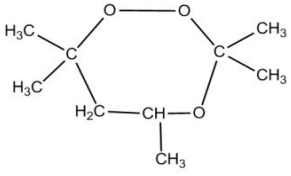
Initiation can be hot water, steam, or UV light

Some Listed CIPP Formulation Ingredients

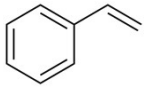
Perkadox® (Initiator)

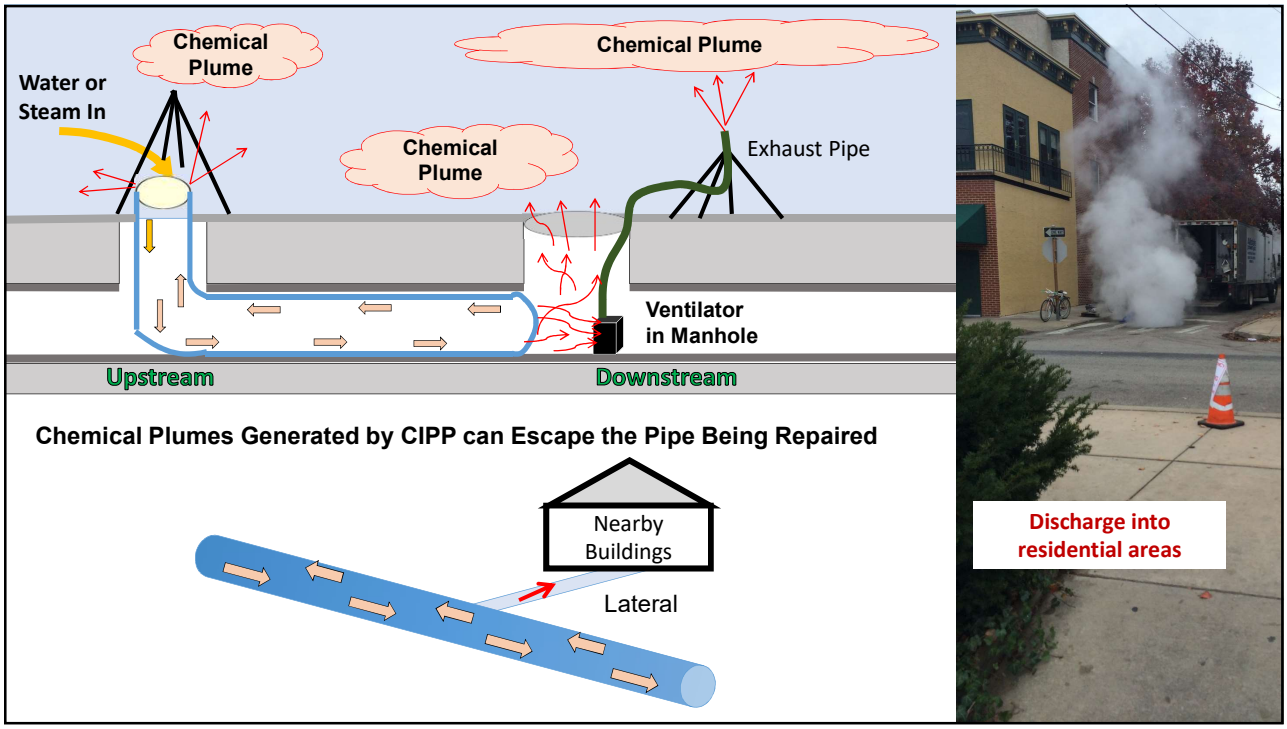


Trigonox® (Oxidizer)



Styrene (Reactive Dilutent)





Incident Location	Styrene	Description of Events from Reference
West Lafayette, IN (Whelton 2016)	nr	Fumes entered campus building through floor drains; doors opened to ventilate; no fire department called; contractor said just odor, not harmful
Good Hope, IL (Langhout 2016)	nr	Steam filled the post office 4 different times; no fire department called; lateral not plugged allowed chemical plume to enter building; blew off toilet
Montreal, Québec (Gagnon 2015)	nr	Fumes stayed in building for 1 month. Installers claimed styrene trapped underground and drifted into house. Installers installed blowers. After the 2nd month (1 month of ventilation) odor went away.
Buffalo Grove, IL (Andrews & Johnson 2015)	nr	Neighbors reported that they became nauseated and dizzy from chemical smell in their homes. One resident reported short of breath and headache. Another resident went to hotel due to the severe smell in their homes. They were repulsed, groggy, and confused.
Lincoln, NB (Fili 2015)	nr	Several homes evacuated; fire department called
Antigo, WI (Linder 2015)	nr	Illness symptoms reported; Whistling heard in drain inside building
Rensselaer, NY (Gagnon 2015)	nr	Chemical seeped to residential homes from sewer CIPP lining neighborhood displaced, residents reported that styrene permeated the clothing in their drawers, closets, and couches
Prairie Village, KS (Braun 2014)	nr	Smell of superglue in house, headaches and nostrils burning; utility contacted and told resident vapors nontoxic. Windows and doors opened for ventilation, but odor remained. County did not investigate and told resident chemicals were nontoxic.
Baltimore, MD (Ashton 2014)	nr	Resident evacuated house after detecting odor and experiencing chemical exposure symptoms; sought medical attention; Odors got stronger when it rained.
Ottawa, CN (Bauer 2012)	nr	Odors detected kilometers from worksite
Fayetteville, NY(Doran 2012)	nr	Odors permeated into nearby residences; residents complained and evacuated their homes
Brisbane, AUS (Woods 2012)	nr	Odors detected and exposure lasted 5 days in home; Health department investigated and demanded home be decontaminated; Pets died.
Birmingham, UK (Brody 2011)	nr	Six people and five students and a staff from high school were taken to hospital after the smell from sewer repair work made them sick.
Worcester, MA (Dayal 2011)	60 - 70	Fumes caused daycare center evacuation; headaches reported; emergency responders called to site
Minnesota (Marohn 2011)	nr	Odor caused building evacuations
Southfield, MI (Banovic 2011)	nr	Hazardous materials response team (HAZMAT) responded; vapors from nearby CIPP operation entered school ventilation system; building evacuated; children transported to hospital for chemical exposure symptoms
Saugus, MA (Tempesta 2011)	nr	Firefighters ordered evacuation of elementary school because of strong odor; dizzy and light-headed symptoms reported
Pittsburgh, PA (Hayes & Biedka 2011)	nr	Elementary and high school students were evacuated for fear of gas leak; odors from nearby CIPP operation were the cause
Birmingham, UK (Pub. Health England 2011)	20 - 200	Odor detected. Residences evacuated at contractors recommendation. Contractor did not disclose styrene present in homes above health limits until days after health agency involved.
Helena, MT (Banks 2010)	nr	Fire department evacuated affected building because of complaints of strong odors, nausea, and headaches
Arlington, VA (ARLnow.com 2010)	nr	Nearby CIPP installation caused odor; fire department responded
Pittsburgh, PA (WPXI-TV 2009)	nr	Firefighters evacuated apartment buildings; initially suspected cyanide gas, but styrene was ultimately detected from nearby CIPP
Somerset, United Kingdom (Wills 2007)	nr	Foul CIPP styrene odor permeated into residence through drain because of nearby installation
Brooklyn, NY (Lysiak 2007)	nr	Foul CIPP styrene odor permeated into buildings through drain because of nearby installations
Ottawa, CN (Bauer & McCartney 2004)	20, 115	Venting determined to be necessary to prevent air backup into nearby residences/ buildings
Alexandria, VA (Gowen 2004)	500	HAZMAT team responded because of styrene vapor backup into nearby buildings; illness symptoms reported
Milwaukee, WI (ATSDR 2004)	0.01 - 0.32	An office building that a large diameter sewer line was located under an old brewery building. All occupant complained about the strong odor. US federal health agency investigated. At least 11 employees were away from their work location for some portion of 17 days.
Toronto, CN (City of Toronto, 2001)	3.2	Eight houses were investigated but only two houses showed styrene due to traps engineered to be dry

In 2001, Styrene was the Only Organic Chemical Detected from the CIPP Effort, Few ppm was the Highest Level

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)

Buildings tested 7 (2000), 2 (2001)
Sewer pipe layout unclear

Manholes (Single 2-8 hr samples)
0.16 to 1.5 ppm with preliner
3.2 ppm maximum without preliner

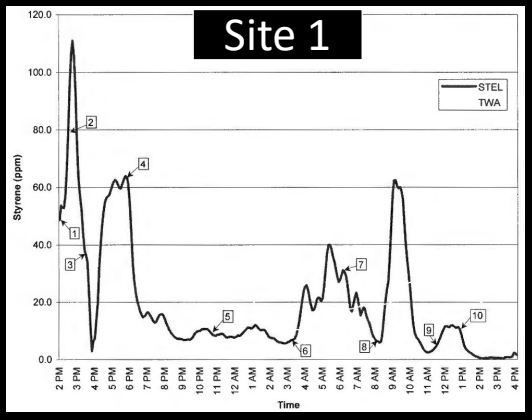
Breathing zone (Single 4-9 hr samples)
0.08 to 0.5 ppm, workers

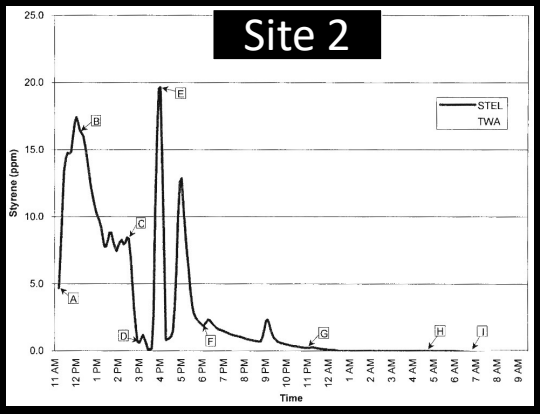
Indoors (Single ~24 hr samples)
0.1 to 0.2 ppm, worst-case during the CIPP process
Highest concentrations, dry plumbing traps

"…it does not appear that it is a significant source of any other VOCs…."

In 2004, CIPP PID Air Testing Study was conducted in Canada

Bauer & McCartney. 2004. Proc. No-Dig.





Observations:

PID set for styrene
One air sample collected every 15 minutes (4/hr)
Did not start monitoring until after CIPP installed

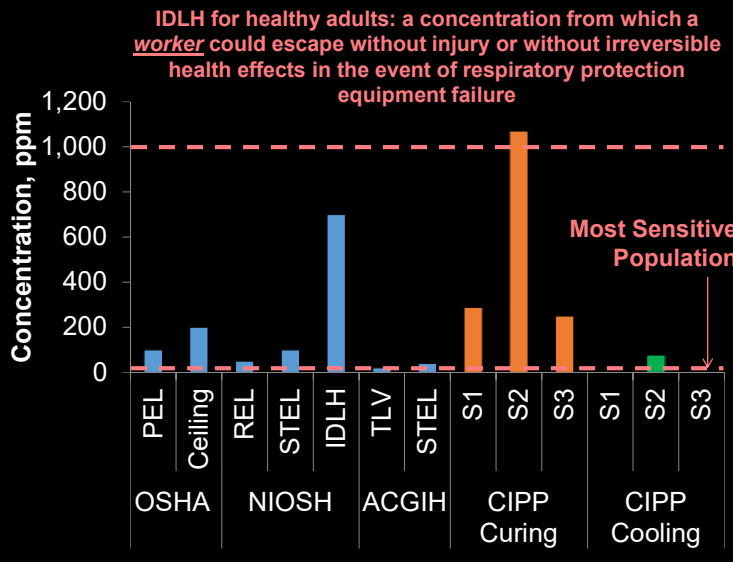
In 2005, ATSDR Found CIPP Styrene and Other VOCs Entered Office Building through the Foundation, Chemicals Lingered for Months

Date	Total VOC, ppm	Styrene, ppm
12/10	Evacuation	Evacuation
12/13	Evacuation	Evacuation
12/13-22	nd – 1.45	Not tested
12/22	nd – 199.0	Not tested
1/12	0.5 – 30.0+	Not tested
1/13	nd – 1.77	nd – 0.30
1/18	nd – 1.60	Not tested
1/21	nd – 0.86	nd – 0.22
2/4	nd – 0.21	nd – 0.15
2/7	nd – 0.57	nd – 0.04
3/28	nd – 0.22	nd – 0.01

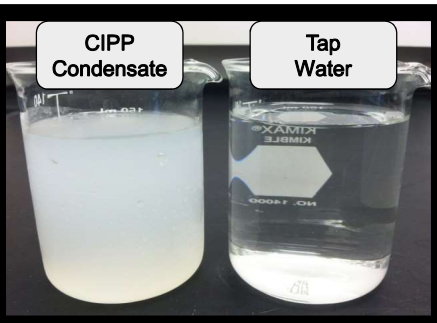
"…past conditions at the site are classified as a public health hazard."

Styrene odor threshold < 0.1 ppm

2015, Styrene Reported Exiting Sewer Manhole Exceeded the NIOSH IDLH



Adjari (2016)



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

Prior studies have shown CIPP released more than just styrene into condensate waste/water

2012: Ontario WWTPs 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

CIPP Condensate Waste after Steam Curing

Property	Typ. Domestic Sewage	CIPP Condensate, 23°C
Water pH	6 to 8	6.2
COD, mg/L	10 to 30	35,666
Styrene, mg/L	< 0.001	> 310
Zinc, mg/L	< 0.20	1.20
Copper, mg/L	< 0.01	0.03
24-hr Daphnid Toxic	Not toxic	**Dissolved organisms**

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

Industry does not seem to understand the Clean Water Act or the toxicity of their generated waste

Page 11: Recommends "release of process waters to ditches and/or waterways containing water and/or aquatic life … should not create any environmental harm." "… the condensate may be released once it has cooled to near ambient temperature.."

NASSCO GUIDELINE Report FOR CIPP Installation: 2009, Revised 2011

Some of the Environmental Impacts of CIPP Have Been Studied but Much Remains Unknown

Environmental Science & Technology

Stormwater Chemical Contamination Caused by Cured-in-Place Pipe (CIPP) Infrastructure Rehabilitation Activities

Matthew L. Tabor, Derrick Newman, and Andrew J. Whelton

Impact of Infrastructure Coating Materials on Storm-Water Quality: Review and Experimental Study

Andrew J. Whelton, Ph.D., M.ASCE; Maryam Salehi, Ph.D.; Matthew Tabor, S.M.ASCE; Bridget Donaldson; and Jesus Estaba

Impact of Stormwater Pipe Lining Materials on Water Quality

Field Study and Resulting Specifications

Bridget M. Donaldson and Andrew J. Whelton

Virginia Center for Transportation INNOVATION & RESEARCH

Standardized Test Method to Quantify Environmental Impacts of Stormwater Pipe Rehabilitation Materials

http://www.virginiadot.org/vtrc/main/online_reports/pdf/15-r11.pdf

ANDREW J. WHELTON, Ph.D.
Assistant Professor of Environmental Engineering
Lyles School of Civil Engineering, Purdue University

MATTHEW L. TABOR
Graduate Student
Department of Civil Engineering, University of South Alabama

ANNE BOETTCHER, Ph.D.
Professor of Biology
Department of Biology, University of South Alabama

KEVIN D. WHITE, Ph.D., P.E.
Chair and Professor of Civil Engineering
Department of Civil Engineering, University of South Alabama

DERRICK NEWMAN
Visiting Scholar
Departments of Civil Engineering and Biology, University of South Alabama

DOTs Recognized They Needed More Information to Design CIPP Culvert Rehab Construction Specifications to Best Protect the Environment

Caltrans · Kansas Department of Transportation · Oregon Department of Transportation · VDOT Virginia Department of Transportation · North Carolina Department of Transportation · New York State Department of Transportation

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

(1) Survey state DOTs to determine (a) proportion of projects using technologies with polymer components (i.e., CIPP, coatings, liners, polymer-enhanced materials) and (a) document any specifications in place.

(2) Conduct water quality testing from culvert rehabilitation sites in multiple states to determine implications to the aquatic environment and the effectiveness of any existing specifications.

(3) Determine the relationship between chemical leaching, liner structural integrity, and longevity through accelerated aging tests and analyses of exhumed materials from the field.

(4) Provide: (a) report that recommends construction specifications to minimize environmental impacts and maximize performance, and (b) Hands-on training workshop about current and emerging culvert rehabilitation technologies, specification considerations, and factors to consider for environmental and structural performance.

FHWA Project Underway 2016 at Purdue: Whelton, Howarter, Jafvert, Youngblood, Zyaykina

2016 NSF RAPID Response Study Underway

Andrew Whelton, Brandon Boor, Mabi Teimouri, Emily Conkling, Kyungyeon Ra, Nadya Zyaykina, John Howarter

Goal

To better understand chemical emission from CIPP installations

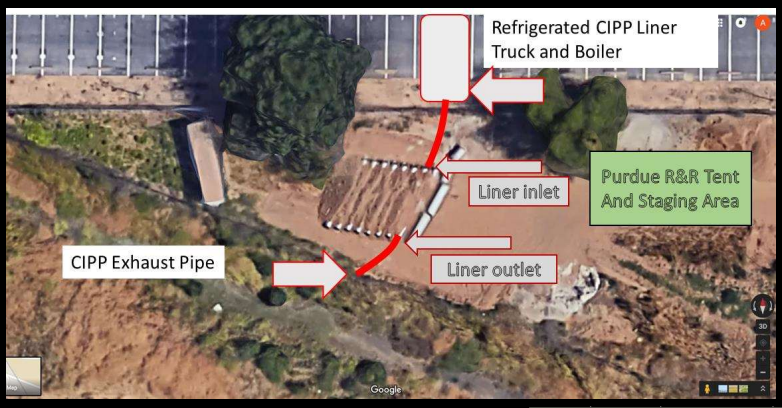
Objectives

1) Compare different air sampling strategies
2) Evaluate chemical air emissions under different installation conditions
3) Identify chemicals emitted and their magnitudes

PURDUE UNIVERSITY

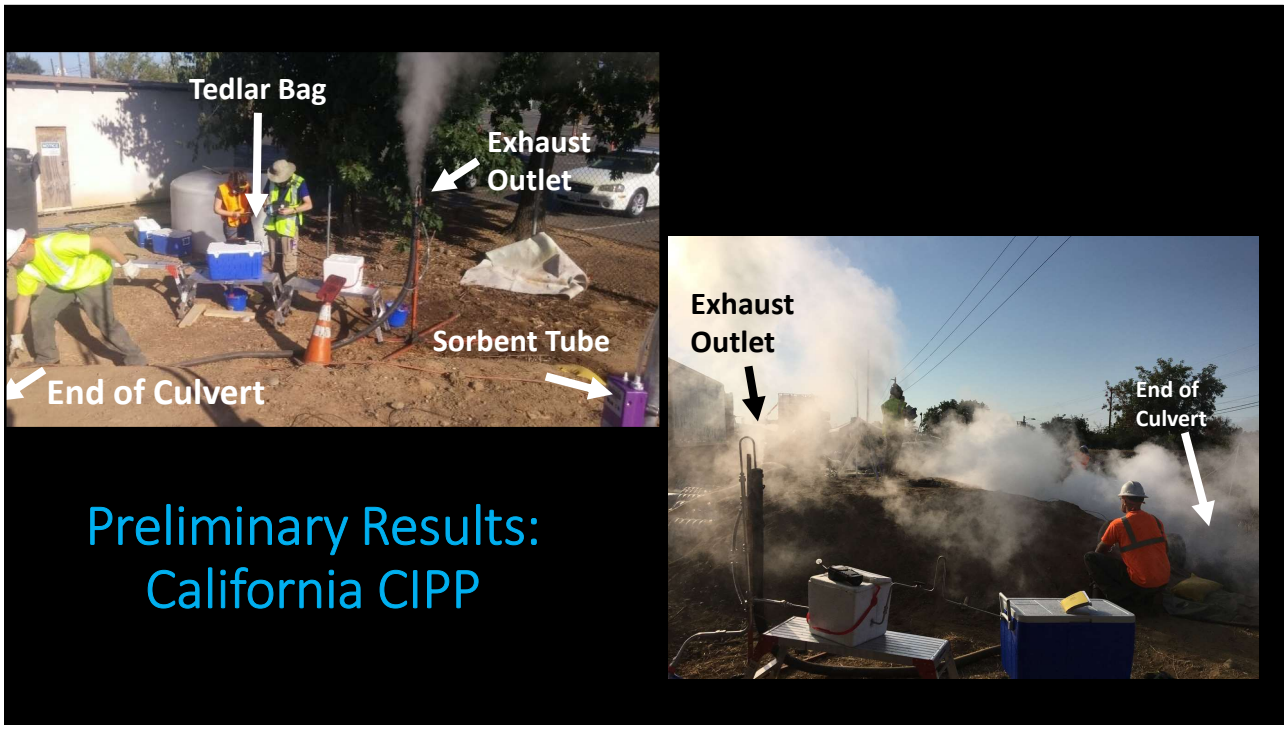
Crowdfunding

SACRAMENTO STATE

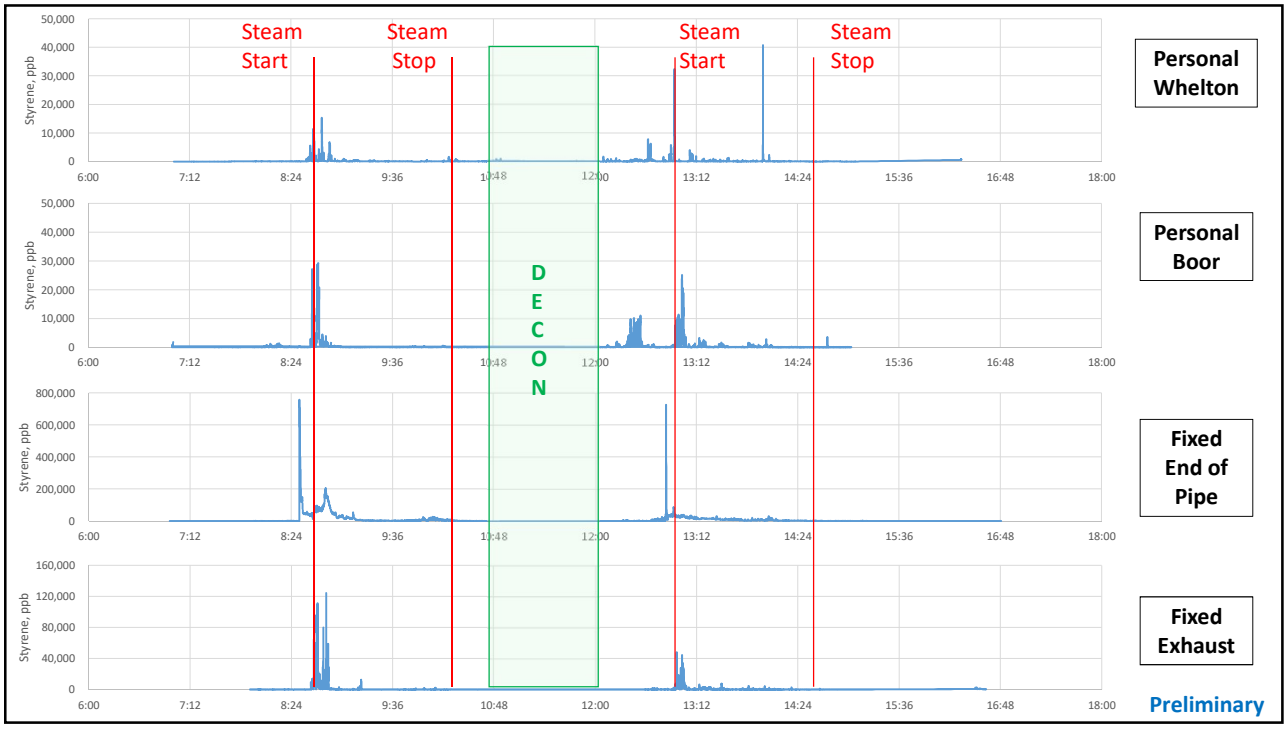


Preliminary Results: California CIPP

Site	Host Pipe	Pulled Separate Preliner	Resin Type	Cooldown Method	Insertion Method
1	CSP	Yes, 1	A	Ambient air	Air inversion
2	CSP	No, 0	B	None	Air inversion
3	CSP	Yes, 2	A	Hot air	Air inversion
4	RCP	Yes, 1	A	None	Air inversion
5	CSP	No	A	None	Pull-in



Preliminary Results: California CIPP



We are still analyzing
and interpreting CIPP air study data.

A Few Preliminary CIPP Air Testing Observations

Independent air testing data is *extremely* limited

Air testing by CIPP contractors and pipe owners not routine

One contractor used wrong device to characterize styrene level in air

One contractor used wrong respirator for worker entry into manhole

Emissions were highly transient, high temperature, high flowrate

Different chemical safety postures applied by CIPP companies

Chemical plume and waste composition poorly understood

Myth: Plumbing traps are the only cause of indoor air contamination by CIPP

How you conduct air testing can strongly influence your results

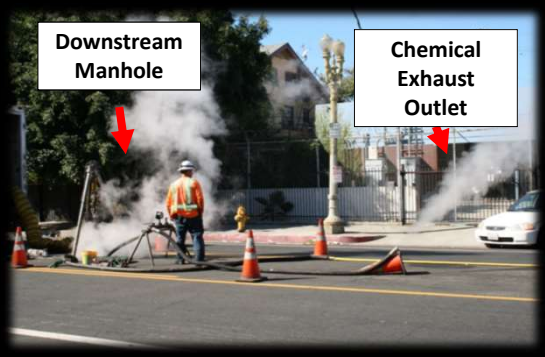
Preliminary CIPP Air Project Next Steps

We are looking for additional partners and CIPP sites

We will complete California data analysis and report

Controls and specification upgrades

Education



Ajardi (2015)

PURDUE UNIVERSITY

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

www.WheltonGroup.org
@TheWheltonGroup

CIPP air toxics RAPID response:
https://crowdfunding.purdue.edu/project/2768