Environmental Performance Evaluation of Low–Volatile Organic Compound (Low-VOC) Liners in CIPP Technology

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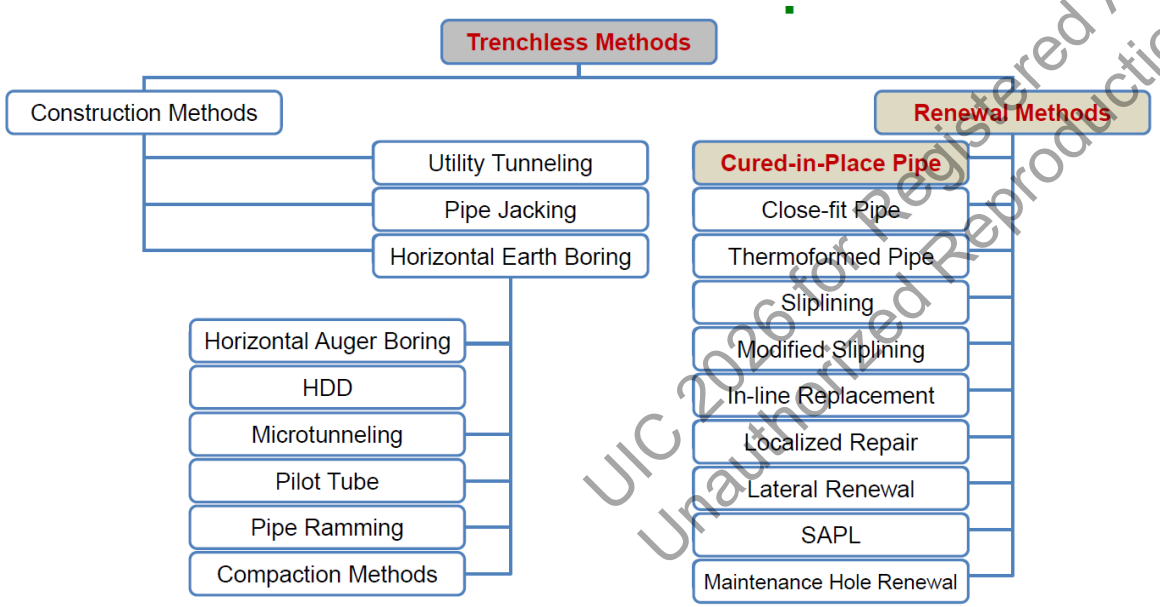
Introduction

- U.S. infrastructure received an overall grade of “C," indicating **mediocre**.
- Most of the U.S. underground infrastructure reached an average span of 100 years.

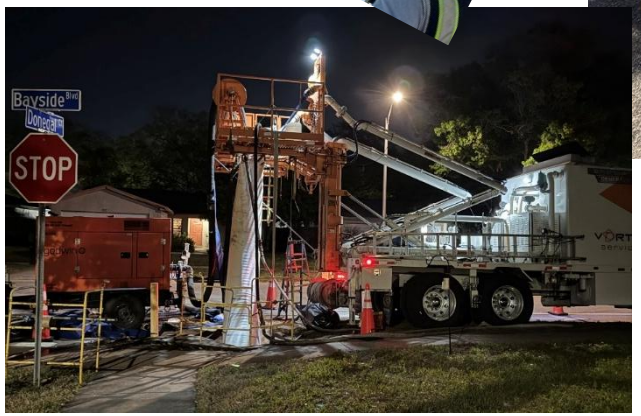


(Najafi, M. and Gokhale, S., 2022)

Source: 2025 ASCE Report Card

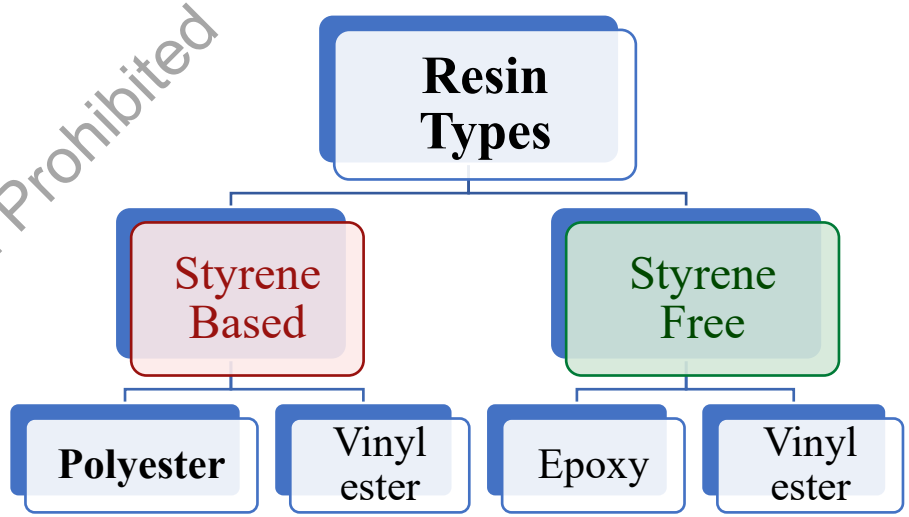
CIPP Advantages

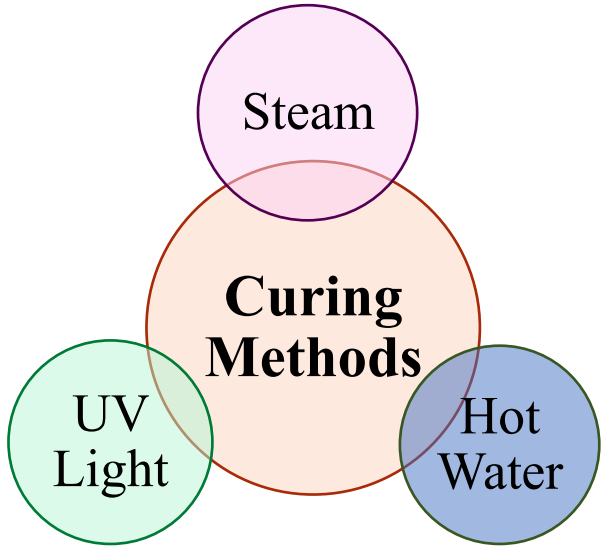
- ✓**CIPP** is the most common pipeline renewal method.
- ✓**CIPP** offers a fast and efficient repair solution.
- ✓**CIPP** is applicable for a wide range of pressure and gravity pipes
- ✓**CIPP** is applicable for various pipe sizes, shapes, and materials.



CIPP Concerns

- CIPP installations release volatile organic compounds (VOCs) into the air (Ajdari, 2016).
- VOCs are linked to both short- and long-term health effects.
- Styrene-based resin (almost 30-50% of styrene) is widely used due to its low cost in CIPP, and it raises questions about proper monitoring of styrene emissions at the worksite (Knight et al., 2022).





Styrene Exposure Levels

Styrene Exposure Guidelines

Guideline	Exposure Duration		
	5 min	15 min	8 hr.
	ppm	ppm	ppm
OSHA PEL[1]	-	-	100
OSHA Acceptable Peak[1]	600	-	-
NIOSH REL[2]	-	100	50
NIOSH IDLH[2]	700	-	-
CAL/OSHA PEL[1]	-	-	50

USEPA Acute Exposure Guideline Levels[3]

Guideline		Exposure Duration				
		10 min	30 min	1 hr.	4 hr.	8 hr.
		ppm	ppm	ppm	ppm	ppm
AEGL 1	Non-Disabling	20	20	20	20	20
AEGL 2	Disabling	230	160	130	130	130
AEGL 3	Lethal	1,900	1,900	1,100	340	340

[1] Occupational Health and Safety Administration, 2019, https://www.osha.gov/dsg/annotated-pels/index.html
[2] National Institute of Occupational Safety and Health, 2019, https://www.cdc.gov/niosh/npg/
[3] Environment Protection Agency, 2008, https://www.epa.gov/sites/default/files/2014-08/documents/styrene_interim_feb_2008.v1.pdf

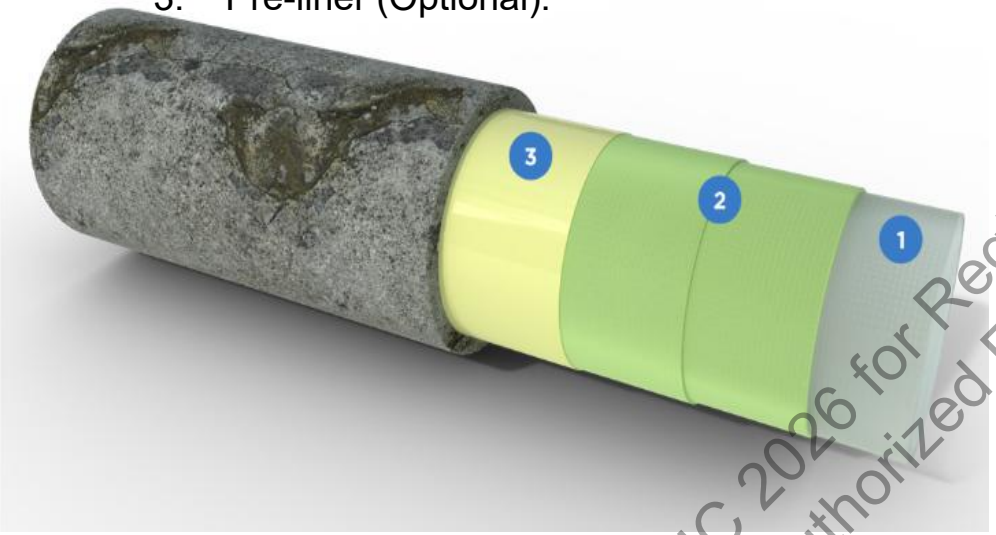
Styrene Health Impacts

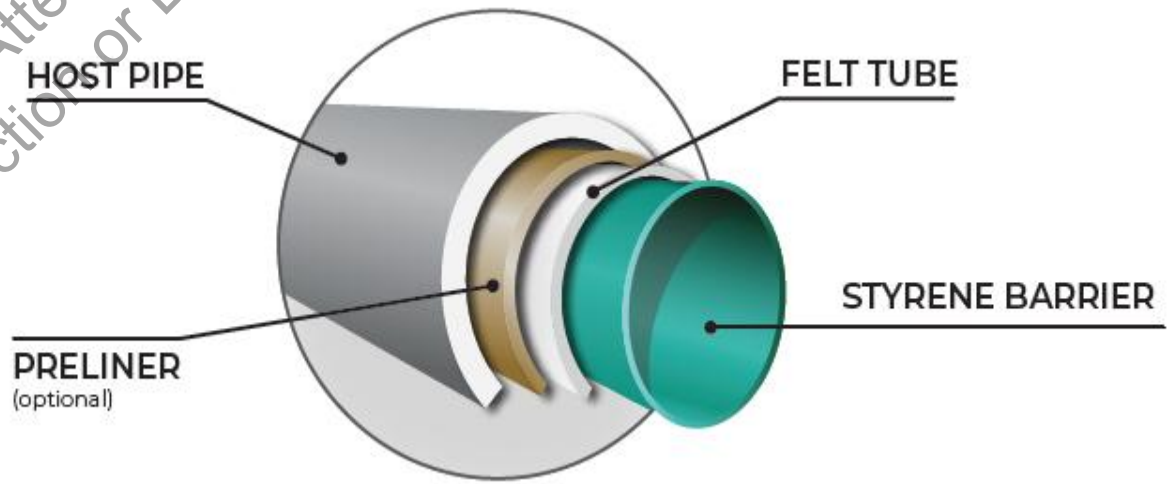
- Exposure to styrene elevated the risk of lymphohematopoietic cancers (Bertke et al., 2018)
- Long-term exposure to styrene can cause skin problems such as blistering and dermatitis, due to its drying effect (NCBI, 2025).
- The target organs affected by styrene emissions in the human body include the Eyes, skin, respiratory system, central nervous system, liver, and reproductive system.
- Immediate symptoms of styrene exposure (EPA, 2008 _ AEGL-1) include:
  - Mild eye and respiratory irritation
  - Headache and weakness
  - dizziness, confusion

*The effects are not disabling and are temporary and reversible upon stop of exposure.

New CIPP Solutions -(Low-VOC) Liners

1. Inner Felt Layer - With Styrene Barrier Coating
2. Felt Liner Layers - Resin Saturated
3. Pre-liner (Optional).



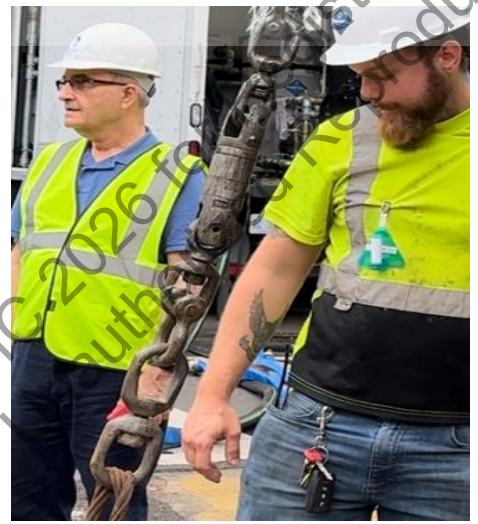


Projects Overview

Site #	Environment	Date	City	Liner	Curing Method	Segment Length (L.F)	Pipe Diameter(in)
1	Residential	06.08.23	Garland, TX	Regular	Water Cure	1091	48
2	Residential	01.29.24	Forney, TX		Steam Cure	672	8
3	Residential	11.06.24	Flower Mound, TX		Water Cure	464	12
4	Residential	3.17.25	Tampa, FL	New CIPP solution (Low-VOC)	Water Cure	350	24
5	Residential	10.15.24	Washington, DC		Steam Cure	143	24

Data Collection

- **Real-time Monitoring**
  - Photoionization Detectors (PIDs)
- **Laboratory Analysis**
  - Suma Canisters
  - Worker Samples



Real-Time Monitoring (PIDs)

🧪 Testing Method

- ✓Continuous 15-minute TVOC average concentrations.
- ✓Hand-held instantaneous TVOC measurements.

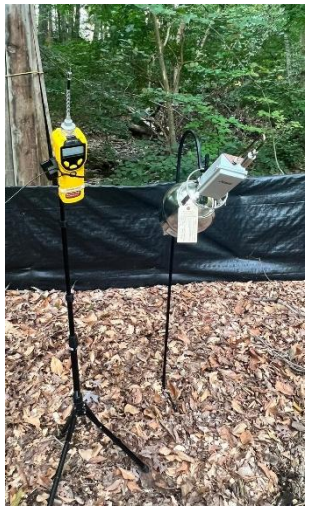
📍 Monitoring Locations

- ✓Upwind of Insertion MH
- ✓Downwind of Insertion MH
- ✓Hand-held PID (every 30 minutes, different locations)

Continuous TVOC Measurement Using PID Positioned Upwind and Downwind of the Insertion Manhole

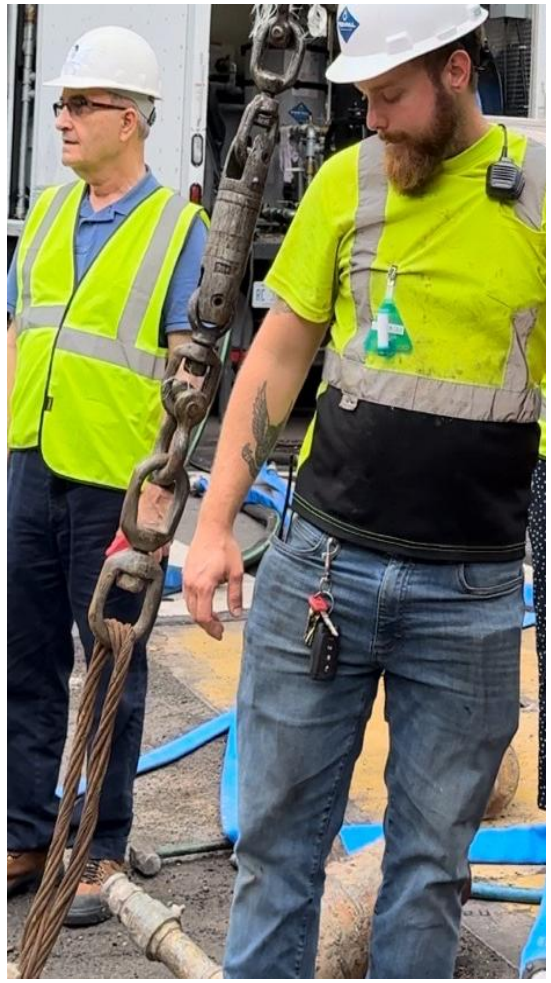
Laboratory Analysis (Suma Canisters)

- **Baseline Measurements:**
  - Upwind of the Insertion manhole (1-4 hours period).
  - Downwind of the Insertion manhole (1-4 hours period).
  - Downwind of terminal discharge manhole (1-4 hours perio
- **Measurements during liner installation:**
  - Upwind of the Insertion manhole (8-12 hours period).
  - Downwind of the Insertion manhole (8-12 hours period).
  - Downwind of terminal discharge manhole (8-12 hours period).
- **Measurements during Curing:**
  - 4 inches above the center of the Insertion Manhole (4-8 hours per
  - 4 inches above the center of the terminal discharge manhole (4-8 hours period).

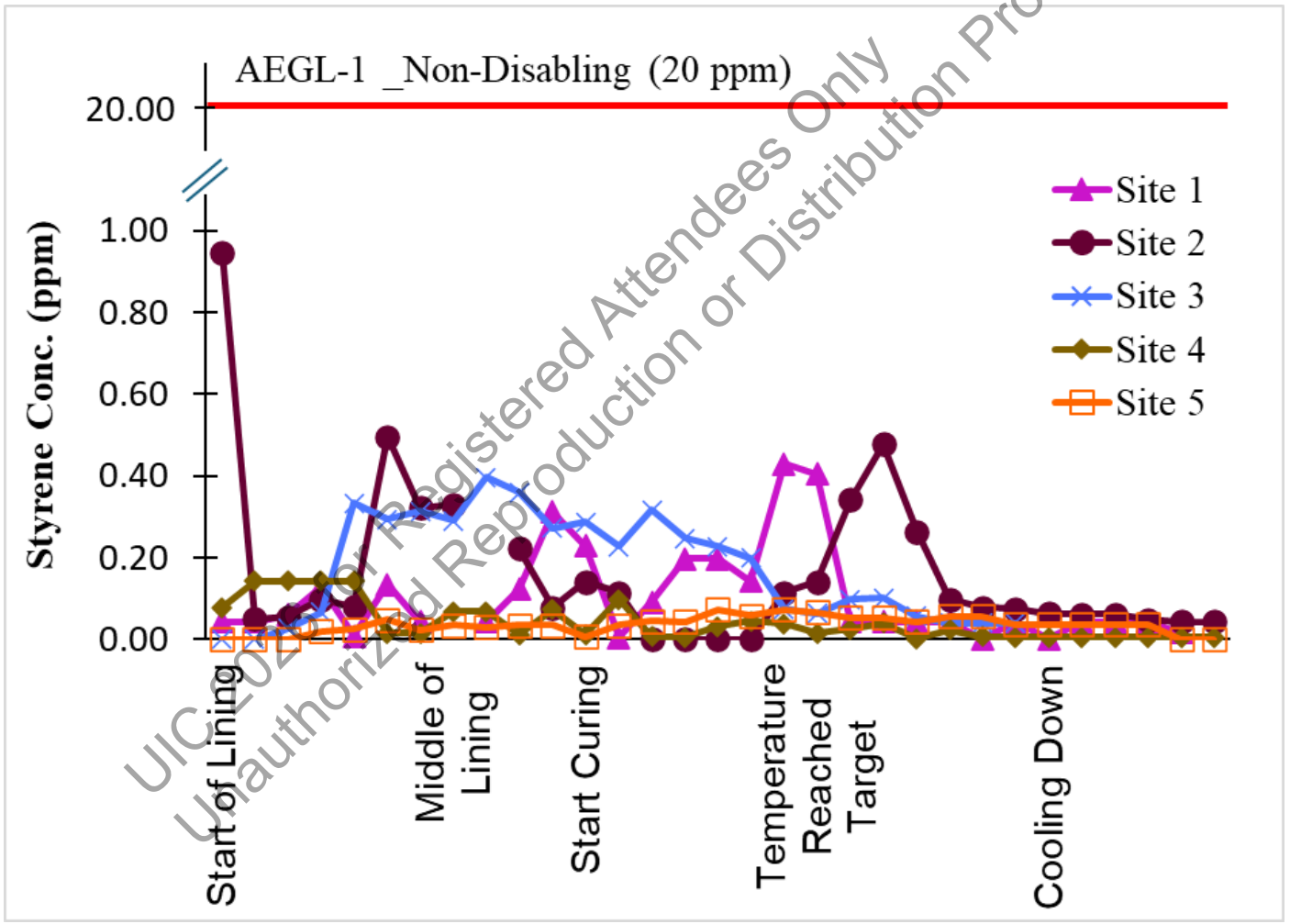


Laboratory Analysis (Worker Samples)

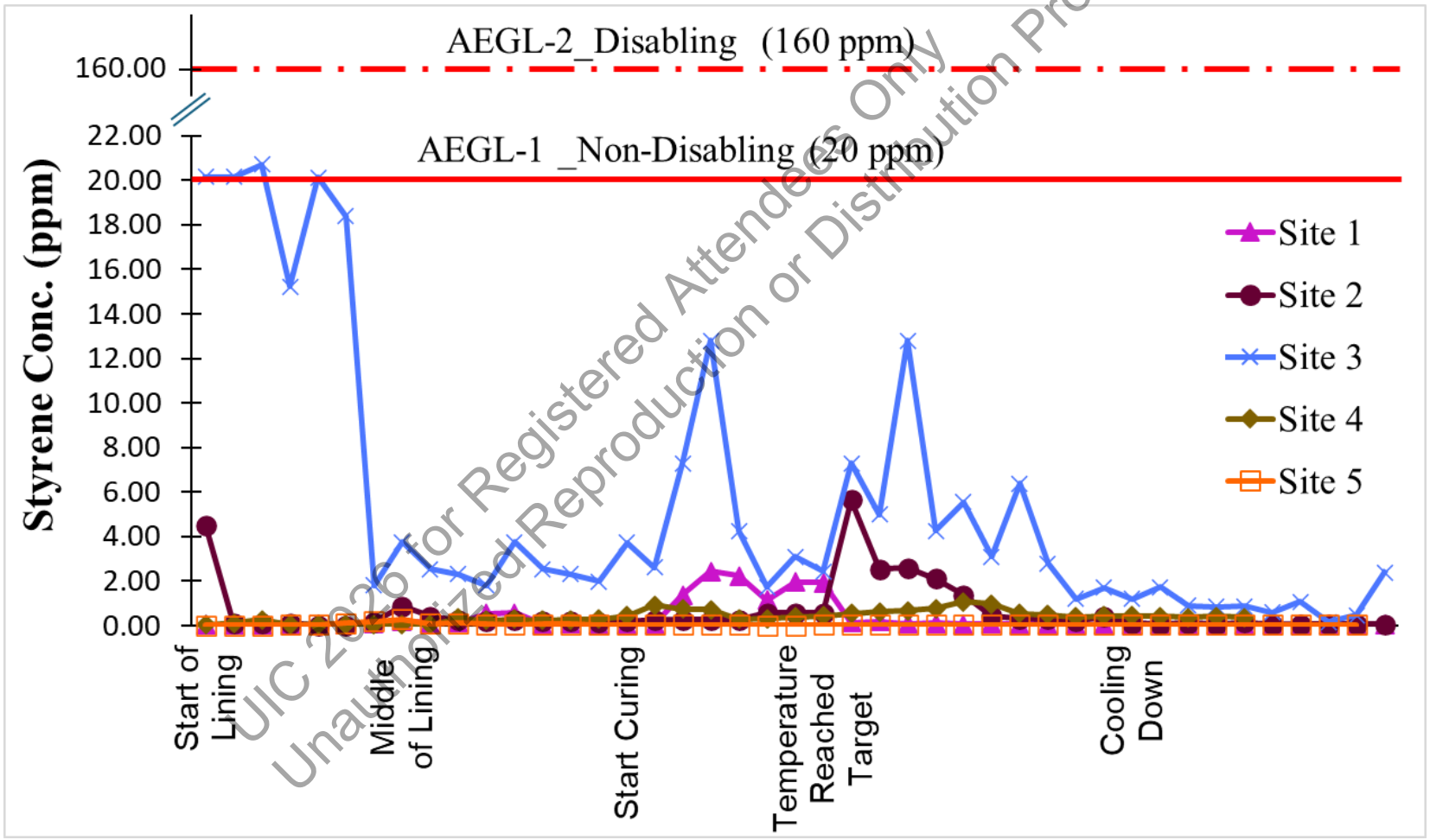
- ✓Two workers at each site were monitored using personal air sampling devices during an 8-hour shift.
- ✓The selected workers were involved in various critical activities, including:
  - Opening the refrigerated truck
  - Feeding the liner into the inlet manhole
  - Inflating the liner
  - Curing process at both the inlet and terminal manholes.



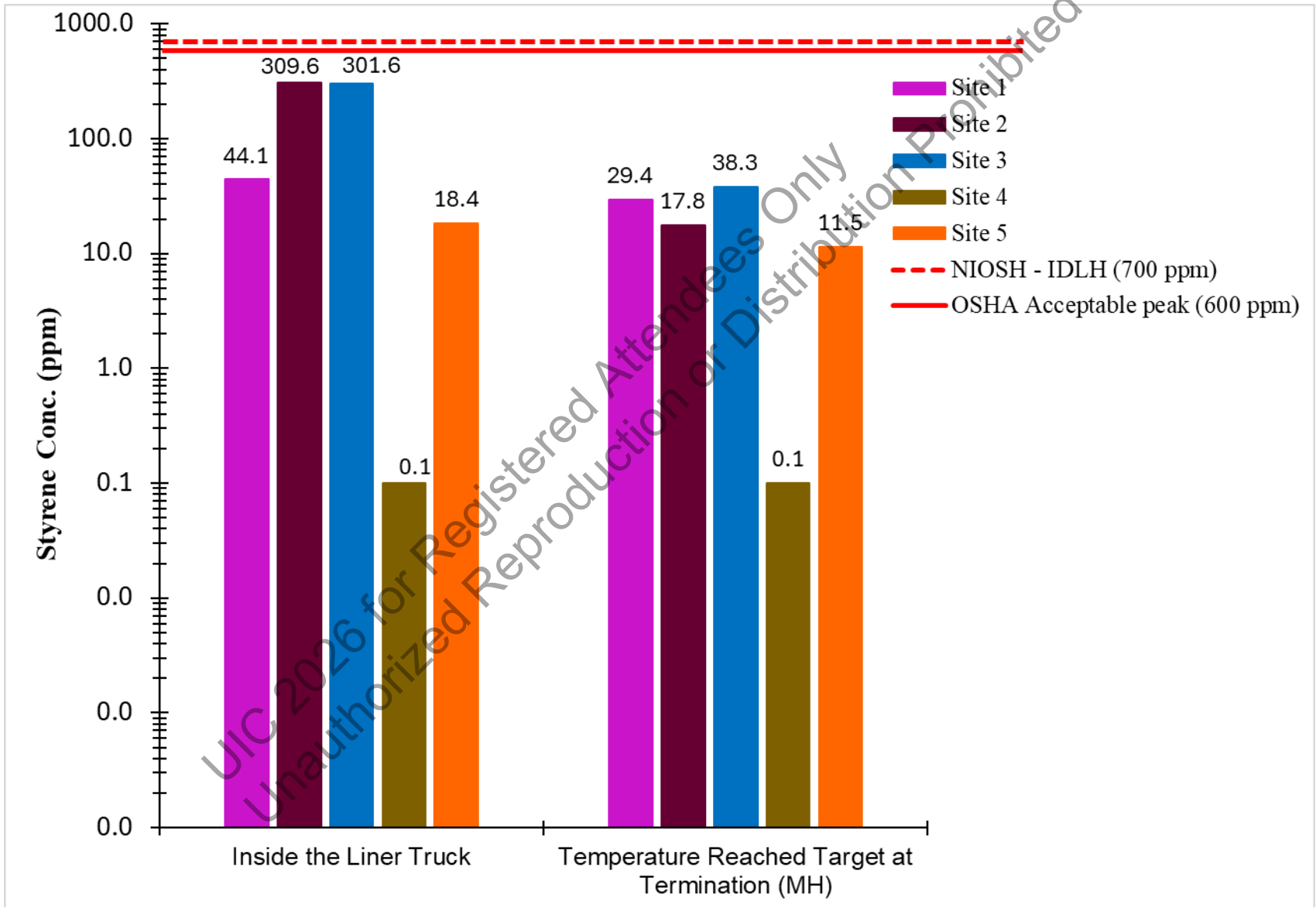
Styrene Concentration
Upwind of Insertion Manhole (15-Minute Average)



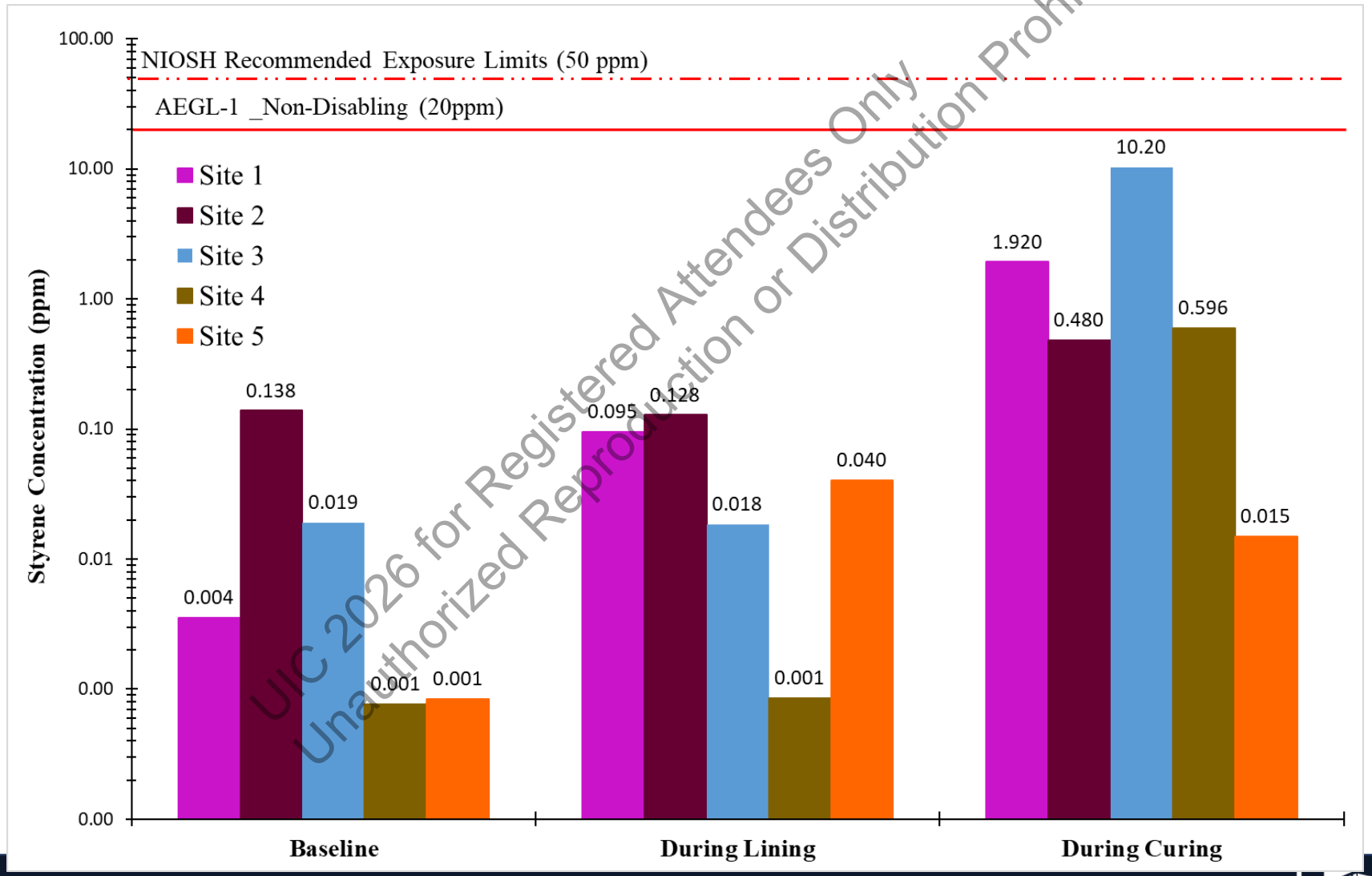
Styrene Concentration Downwind of Insertion Manhole (15-Minute Average)



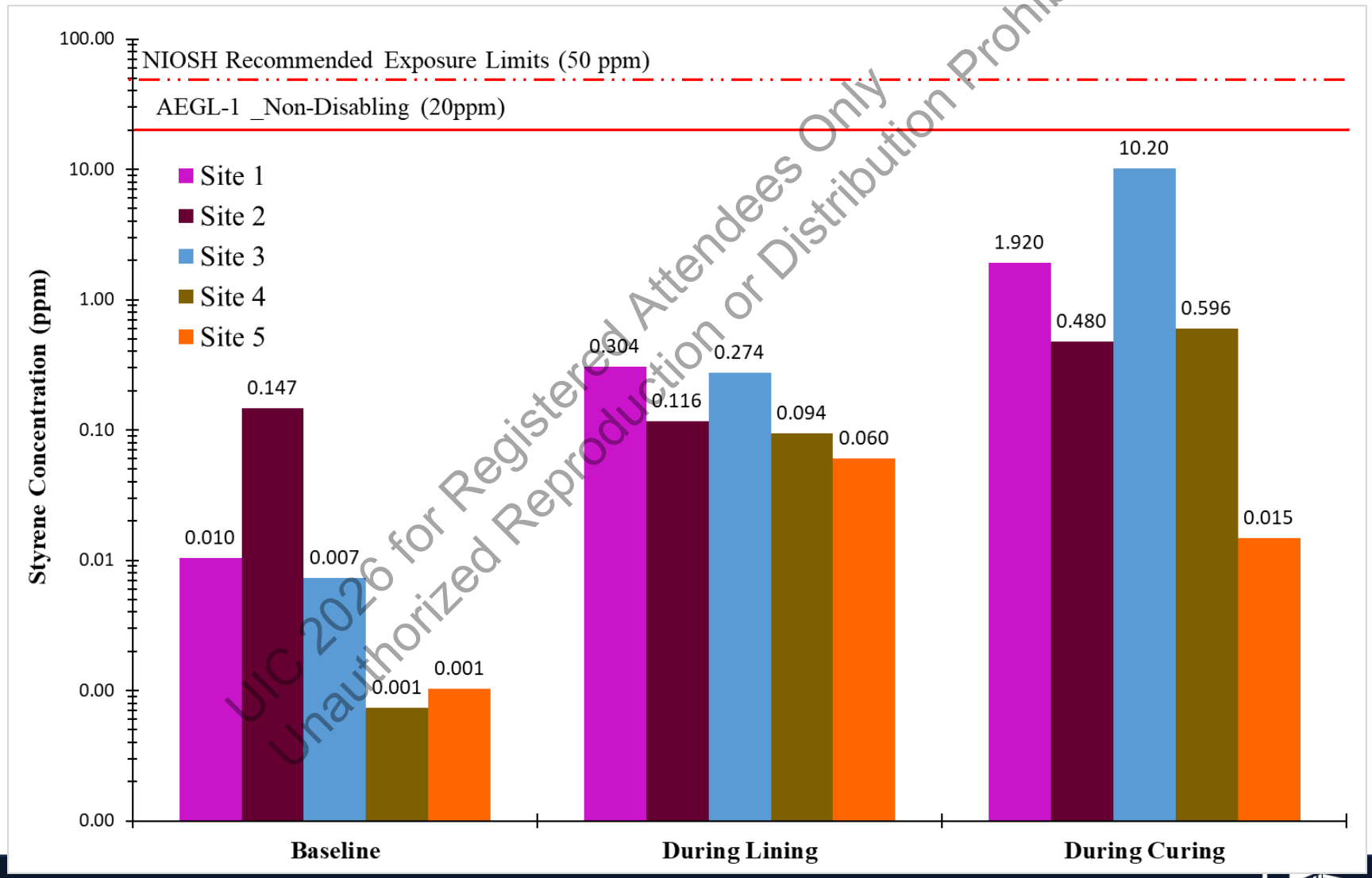
Maximum Styrene Concentration _ Instantaneous Observation



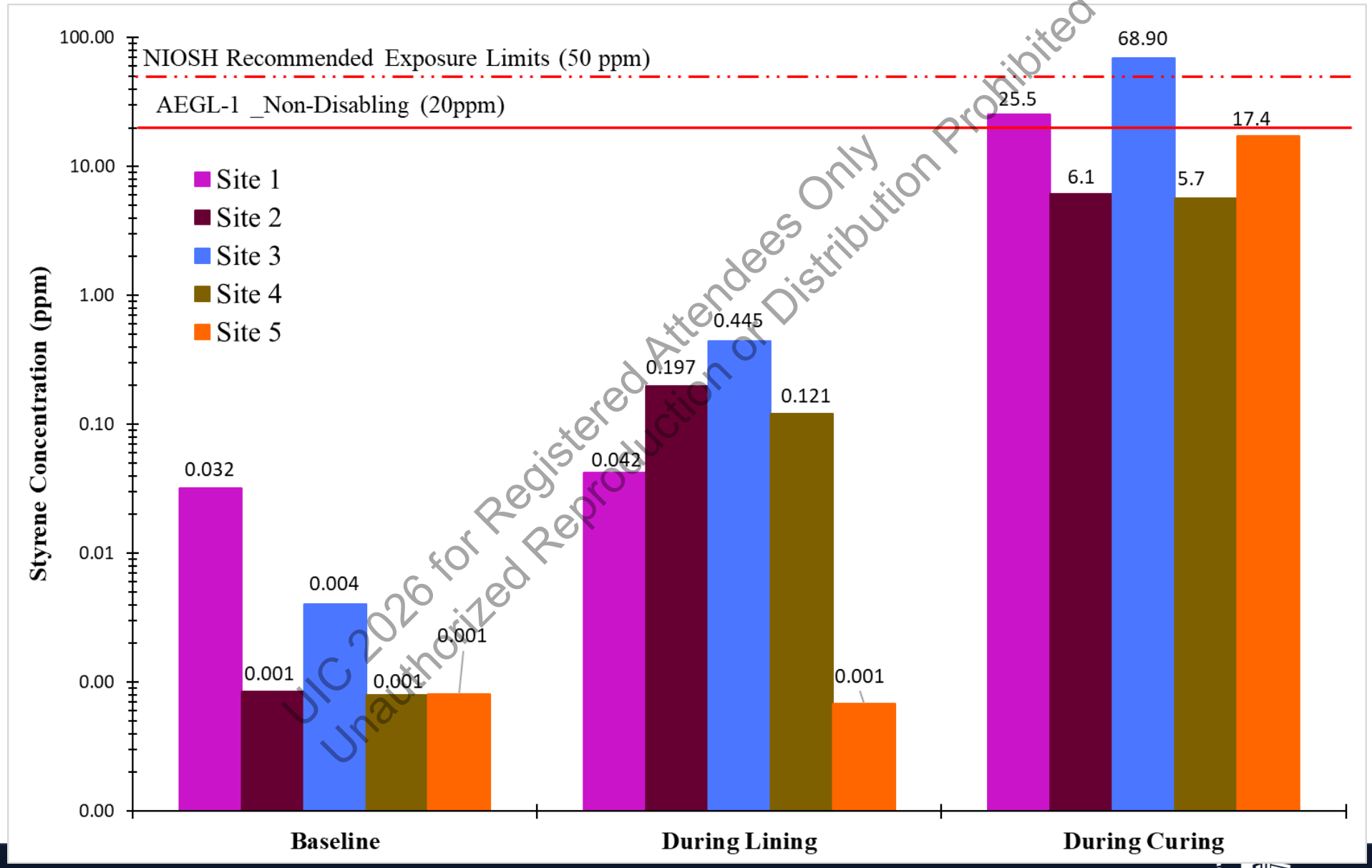
Time Weighted Average (TWA) Styrene Concentration Upwind of Insertion Manhole



Time Weighted Average (TWA) Styrene Concentration Downwind of Insertion Manhole



Time Weighted Average (TWA) Styrene Concentration Termination Manhole



Time Weighted Average (TWA) Styrene Concentration Worker Sample Results

Site #	Date	Styrene Concentration (µg/m³)		Action Level
		Worker 1	Worker 2	
1	6/8/2023	12,000	59,000	20 ppm = 85,186 µg/m³
2	1/29/2024	6,200	35,000	
3	11/6/2024	7,900	6,200	
4	3/17/2025	3,700	360	
5	10/15/2024	140	180	

Conclusions

- Non-VOC liners were effective in reducing real-time styrene concentrations during CIPP installations.
- Time-weighted average (TWA) measurements confirmed a reduction in styrene exposure when using non-VOC liners.
- Personal worker sampling results showed a significant decrease in styrene concentrations, indicating improved occupational safety.
- Overall, this study demonstrates that non-VOC liners offer superior environmental and worker-health performance compared to traditional styrene-based liners.
- Further research is recommended to evaluate new liner performance under varying field conditions, curing methods, and installation scenarios.
- Real-time air monitoring is recommended to support on-site decision-making and enable comprehensive emissions assessment during CIPP installations.

Industry Workshop

The workshop will take place in a hybrid format in **Detroit**.

at **Great Lakes Water Authority (GLWA)** → Wednesday, **April 22, 2026**, 12:30 PM – 3:00 PM

WRF Project 5292 - Pipeline Infrastructure Replacement Costs Guide		
Time	Presentation	Lead / Presenter(s)
12:30 – 12:45 AM (15 min)	Welcome, Introductions, and Project Overview (WRF 5292 objectives, scope, expected outcomes, and workshop structure)	Dr. Mo Najafi, PI, P.E., F. ASCE, BC.PLW and Dr. John Norton
12:45 – 1:05 AM (20 min)	WRF Management Perspective and Project Context (WRF goals, relevance to utilities, and expected outcomes)	Dr. Jian Zhang, PE – WRF*
1:05 – 1:20 AM (15 min)	Project Presentation – Part 1: Literature Review Findings (Summary of completed literature review, life-cycle cost of a project including preconstruction, construction, and postconstruction costs, cost estimation methodology, and limitations of existing cost curves and cost databases)	Paria Hamidzadeh, PhD Candidate
1:20 – 1:40 AM (20 min)	Project Presentation – Part 2: Survey Results (response summary), discussion on trenchless technologies and cost parameters, data normalization, methodology for development of cost curves, and inflation adjustment	Paria Hamidzadeh, PhD Candidate
1:40 – 1:45 AM (5 min)	Short Break	–
1:45 – 2:10 AM (25 min)	Utility Presentation 1	Participating Utility (TBD)
2:10 – 2:35 AM (25 min)	Utility Presentation 2	Participating Utility (TBD)
2:35 – 3:00 PM (25 min)	Facilitated Discussion: Utility Input on Final Cost Estimation Guide (preferred format, usability, methodology for development of cost curves and cost estimation tool, and case study), and Open Dialogue (Questions, feedback, and discussion forum from workshop participants)	Utilities & Project Team

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Questions?

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