Review of Literature on Chemical Emissions and Worker Exposures Associated with Cured-in-Place Pipe (CIPP) Installations (Phase 1)

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Presentation Outline

- Introduction
- Background
- Objectives
- Methodology
- Task A
  - Literature Review
  - Results
- Task B
  - Phase 2 Work Plan
- Conclusions
- Recommendations for Future Research

Introduction

- Cured-in-Place Pipe (CIPP) installation was introduced in 1971 as an alternative to digging up and replacing sewers.
- The Cured-in-Place Pipe (CIPP) process involves:
  - A liquid thermoset resin-saturated material that is inserted into the existing pipeline by hydrostatic, or air inversion, or by mechanically pulling-in and inflating.

- Renewal Solutions
  - SAPLs
    - Cementitious
      - Cementitious
      - Geo-Polymers
    - Polymers
      - Epoxies
      - Polyurethane
      - Polyurea
  - Liners
    - Sliplining
      - PVC
      - PE
      - GRP
    - Cured-in-Place-Pipe (CIPP)
      - Polyester
      - Vinyl Ester
      - Epoxy

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neutral independent non-profit institute IKT - Institute for Underground Infrastructure

CUIRE

UCT

Introduction (*Cont'd*)

- The liner material is cured-in-place using:
  - Hot water, steam or light cured using UV light resulting in the CIPP product.
- Polyester, epoxy, or vinyl ester resins are used for curing.
- *This study is focused on styrene emissions with polyester resin use during CIPP installations.*

Introduction (*Cont'd*)

CIPP with Steam Curing -- Source: Insituform Technologies

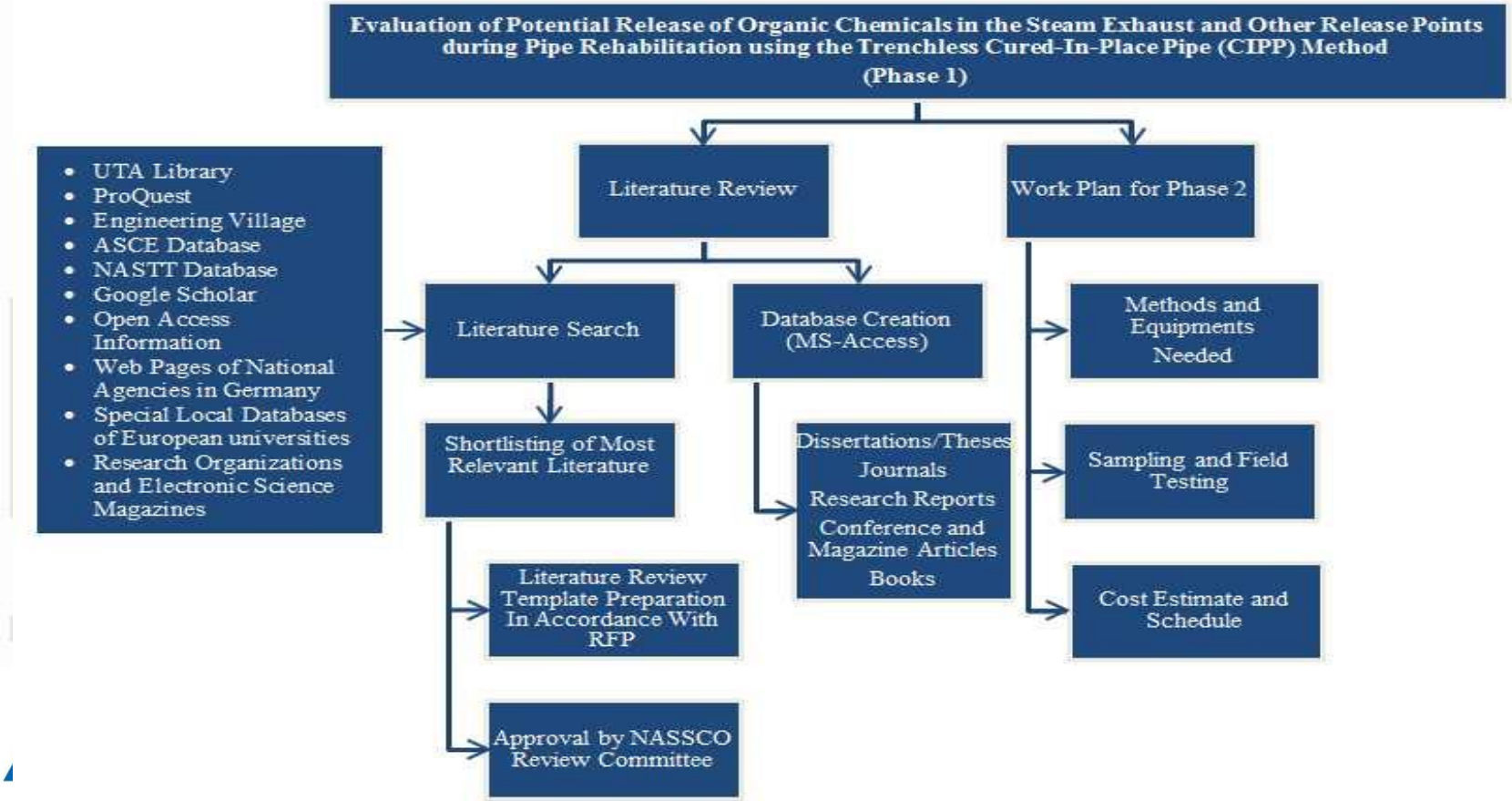
Background

- In response to the growing usage of CIPP installations and recent industry reports, NASSCO issued a request for proposals to facilitate a formal review of chemical emissions and worker exposure associated with CIPP.
- CUIRE at UT Arlington submitted a proposal and was awarded the contract in December 2017 for this project.
- Institute of Underground Infrastructure (IKT), Germany was a CUIRE partner in this study.
- The duration of the project was four months and completed in April 2018.

Objectives

- This study included the following objectives:
  - Task A:
    - To review recent literature related to CIPP emissions.
  - Task B:
    - To develop a work plan for additional sampling and analysis of emissions during the field installation of steam-cured CIPP and to measure potential release of emissions into air from six CIPP sites.

Research Methodology



Jobsite Visit

Inlet Manhole

Termination Manhole

Task A – Literature Review

Reviewed Papers

- CUIRE shortlisted and reviewed 16 published papers related to Steam-Cured CIPP Emissions in the United States.
- Shortlisting was based on recent publications addressing concerns about CIPP steam-cured emissions and worker exposures.
- IKT shortlisted and reviewed 5 papers related to steam-cured CIPP installations in Germany, the U.K., and the Netherlands.
  - 4 out of 5 IKT papers were confidential.

Methodology: Creating a Database

- First a searchable database using MS Access was created to include all the literature related to CIPP installations.
- A total of 155 publications including 6 books, 37 conference papers, 9 dissertations and theses, 58 refereed journals, 29 magazines, and 16 research reports were found.

Regulatory Standards/Guidelines for Styrene

- To review literature, the following standard guidelines were used:
  - Occupational Safety and Health Administration (OSHA) (from ACGIH)
  - National Institute for Occupational Safety and Health (NIOSH)
  - US Environmental Protection Agency (EPA)
  - Texas Commission on Environmental Quality (TCEQ)
- Above agencies mostly have short-term guidelines and standards.

Previous Field Measurements of Styrene Concentrations

No.	Reference	Type of Reference	Location	Cure Type	No. of Sites	Process Phases	Liner Length, Dia., Thick-ness	Curing Time & Temp	Measurement/ Analysis Method	Styrene Concentrations				
										Termination MH (ppm)	Surrounding Property		Worker Exposu-re (ppm)	Other (ppm)
											Outdoor (ppm)	Indoor (ppm)		
MEASUREMENTS IN RESPONSE TO CITIZEN COMPLAINTS														
1	Washington Post (Gowen, 2004)	Article	Alexandria, VA	NA	1	Not known	N/A	N/A	N/A	N/A	N/A	N/A	N/A	500: hose at site
2	U.S. Agency for Toxic Substances & Disease Registry (ATSDR, 2005)	Article	Milwaukee, WI	NA	1	Not known	N/A	N/A	N/A	N/A	N/A	0.32	N/A	N/A
3	Public Health, England (CRCE, 2011)	Project Report	Birmingha m, UK	NA	1	After cooling	N/A	N/A	N/A	N/A	N/A	15-200	N/A	N/A
4	Worcester Telegram and Gazette (Dayal, 2011)	Article	Worcester, MA	NA	1	Not known	N/A	N/A	N/A	N/A	N/A	60-70	N/A	N/A

Previous Field Measurements of Styrene Concentrations (*Cont'd*)

No.	Reference	Type of Reference	Location	Cure Type	No. of Sites	Process Phases	Liner Length, Dia., Thickness	Curing Time & Temp.	Measurement/ Analysis Method	Styrene Concentrations				
										Termination MH (ppm)	Surrounding Property		Worker Exposure (ppm)	Other (ppm)
											Outdoor (ppm)	Indoor (ppm)		
STUDIES WITH WATER OR UV CURE														
5	AirZOne (2001)	Project Report	Toronto, Canada	Hot water	N/A	Before, during, after CIPP installation	N/A	4-6 h at 80°C	Sorbent tubes with sampling pumps, GC/MS	0.16-3.2	Outside homes, upwind of man-holes	0.1-0.2 (8 houses)	0.08-0.5	N/A
6	IKT (2007, 2008, 2013)	Project Report	Special test stand, Germany	UV	6	Before, during, after curing	8.7' x 23.6" x 0.28"; 8.7' x 11.8" x 0.15"	N/A	Air layer of test rig, closed & sealed against ambient air, measure-ments via adsorption (charcoal tubes) with auto sampler	N/A	N/A	N/A	N/A	0.001 – 0.013 ppm, air layer of test stand, closed & sealed against ambie

Previous Field Measurements of Styrene Concentrations (*Cont'd*)

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										Termination MH (ppm)	Surrounding Property	
											Outdoor (ppm)	Indoor (ppm)
STUDIES WITH STEAM CURE												
7	Bauer & McCart-ney (2004)	Confer-ence Paper	Ottawa, Canada	Steam	4	Before, during, after curing	253' x 30" x 1.16"; 53' x 30" x 1.34"	N/A	PID: PE Photovac Model 2020	20, 115		2.5
8	Ajdari (2016) (U. of New Orleans)	Thesis	New Orleans, LA, US	Steam	3	Before, during, after curing	235', 304', 309'; x 8"	45-60 min., 60°C	Tedlar bag with pump, GC	250-1,070	N.D. (One location only)	N/A
9	Wessex Water (2016)	Project Report	Bath, UK	Steam (1) & water (3)	4	Before, during, after curing (cont.)	568' x 11.8" x 0.24"	4 h, 40°C - 100°C	Field PID – 4 sites; Sorbent tubes (thermal desorption/ GC) – 2 sites	PID: Steam cure max.: 165	Steam cure: PID: max 6 (1 m from term MH), 24 (in gully); Sorbent tubes: all 8 < UK 8-h TWA & 15-min	N/A

Previous Field Measurements of Styrene Concentrations (*Cont'd*)

No.	Reference	Type of Reference	Location	Cure Type	No. of Sites	Process Phases	Liner Length, Dia., Thickness	Curing Time & Temp.	Measurement/ Analysis Method	Styrene Concentrations				
										Termination MH (ppm)	Surrounding Property		Worker Exposure (ppm)	Other (ppm)
											Outdoor (ppm)	Indoor (ppm)		
STUDIES WITH STEAM CURE														
10	Sendesi et al. (2017)	Journal Paper	CA (5 sites); IN (2 sites)	Steam	7	Before, during, after curing (cont.)	19.7' x 18" x 0.3"	N/A	PID	Styrene not indepen-dently measured	N/A	Styrene not indep en-dently measu red	Styrene not indepen-dently measured	N/A
11	Prince William County Service Authority (2017)	Project Report	VA	Steam	4	Before, during, after curing (cont.)	353'; 248, 272, and 124'	N/A	Personal PID & passive monitoring badge on 2 employees	N/A	N/A	N/A	104 ppm peak; 0.077 avg	N/A
12	Unpub-lished Data (2017)	N/A	N/A	Steam	N/A	N/A	N/A	N/A	Personal data logger, GC/MS	N/A	N/A	N/A	1.4 ppm 8-h TWA	N/A

Previous Field Measurements of Styrene Concentrations (*Cont'd*)

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										Termination MH (ppm)	Surrounding Property		Worker Exposure (ppm)	Other (ppm)
											Outdoor (ppm)	Indoor (ppm)		
STUDIES WITH STEAM CURE														
13	IKT (2011)	Project Report	Ruhr, Germany	Steam	1	During curing	15.7" dia.	N/A	DRÄGER Accuro tubes/ pump	N/A	20 at 5 m away from term. MH, 1.5 m height	N/A	N/A	N/A
14	RIVM (2006)	Project Report	Cuijk-Vianen, Barendrecht, Sevenum, The Netherlands	Not known (likely steam)	3	During & after curing & cooling, during cutting of holes for laterals	249' x 11.8", 167' x 13.8", 469' x 17.7"	N/A	Not known	300 in MH; 85 (vent)	N/A	9	N/A	N/A

Paper Review Methodology
Part A: Literature Information

- Citation
- Abstract
- Introduction
- Objectives
- Methodology
- Results
- Conclusions and Recommendations for Future Research

Paper Review Methodology
Part B: Reviewer's Critique

- Test Methods, Equipment, and Instrumentations Used
- Data and Analysis
  - QA/QC
  - Does the data sample collected represent the whole population?
  - Reporting and detection limits
  - Did the document include employee sampling data from NASSCO companies?
  - CIPP materials used (including resin systems)
  - Do references support conclusions?

Paper Review Methodology

Part B: Reviewer's Critique (Cont'd)

- Data and Analysis
  - Peer review documentation of literature or study findings
    - Whether literature cited were peer-reviewed?
    - Whether findings were peer-reviewed?
- Statistical Analysis
  - What types of models were used?
  - Were the models used representative, calibrated and validated?
- Verification of CIPP Product Definition
- Whether other compounds besides styrene were evaluated?

Paper Review Methodology
Part B: Reviewer's Critique (Cont'd)

- Discussion of Employee/Public Safety and Health Standards and Regulations Including OSHA, ACGIH, NIOSH, and Other Regulatory Limits
  - Review of Data with Respect to Environmental Impacts, Toxicology and Employee Chemical Exposure
  - Chemical exposure limits at different locations relative to steam exhaust discharge source
  - Determination of Actual Short-term and Long-term Health Issues Identified from Odor Complaints as Verified By Professional Medical Personnel
- Verification of Test Methods (lab and/or field)

Paper Review Methodology

Part C: Overall Review

Applicability, Originality, Completeness, Limitations, etc.

- Strengths of the Study
- Weaknesses of the Study

Overall Results

- Most of the steam-cured studies captured variations in emissions, by measuring concentrations before, during, and after curing.
- Most studies measured styrene around the termination manhole, or inside the manhole or sewer pipe itself.
- Maximum values at the outlet point and inside the terminal manhole were reported to range from 20 to 1,070 ppm, which are expected to exceed exposure limits.

Overall Results (*Cont'd*)

- Since workers and certainly the public should not typically enter or stand directly at the termination manhole in the exhaust plume, information in some of the literature was not helpful.
- Only four of the steam-cured studies measured concentrations at locations surrounding the terminal manhole at a distance of at least 3 ft.
  - Since air concentrations are expected to vary as a function of distance from the manhole, *measuring at few locations gave an incomplete picture.*

Overall Results (*Cont'd*)

- Air concentrations are expected to vary with wind speed and wind direction, so measuring in one day does not capture what levels may be under differing meteorological conditions.
- Finally, measuring concentrations at one site does not capture variability in emission rate, such as, for projects with larger diameter pipes, longer pipe segments, higher curing temperatures, etc.

Overall Results (*Cont'd*)

- In one of the studies (Loendorf and Waters, 2009), employees walked the construction area periodically but spent a good deal of time in their work trucks due to the cold weather, so not much impact on workers.
- Hence, these measurements were likely not typical of worker exposures.

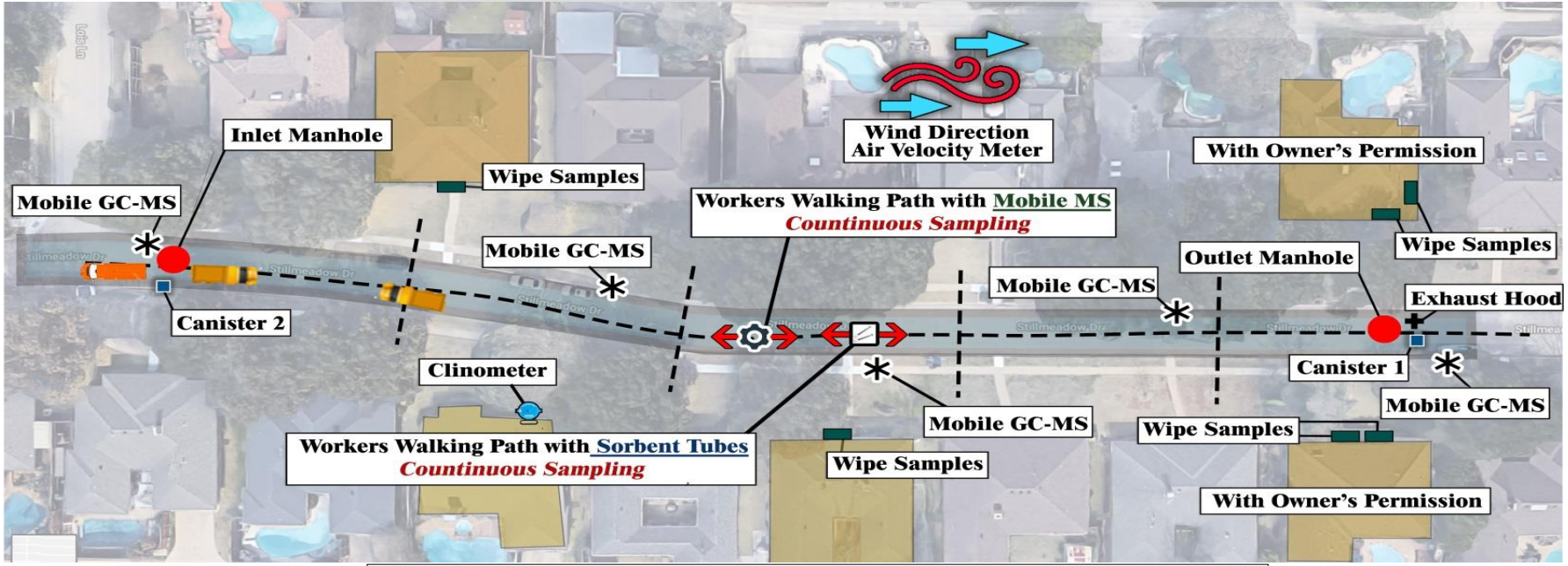
Result Summary

S.No.	Reviewed Reference	Peer Reviewed	Statistical Analysis	CIPP Materials Used	CIPP Product Definition Verification	Styrene Regulatory Limits (OSHA, NIOSH, ACGIH) Exceeded
US Literature						
1	Sendesi (2017)	Yes	No	L713-LTA (styrene-based resin) and EcoTek (non-styrene-based resin)	Yes	N/A
2	Ajdari (2016)	Yes	No	Polyester	Yes	Yes
3	Kampbell (2009)	No	No	Polyester	Yes	Yes
4	Lee (2008)	Yes	No	Polyester	Yes	Yes
5	Tabor (2014)	Yes	Yes	Polyester	Yes	Yes
6	Currier (2017)	Yes	No	Polyester, Vinyl ester	Yes	Yes
7	Donaldson and Baker (2008)	Yes	No	N/A	Yes	Yes
8	Tabor (2014)	Yes	No	Polyester, Vinyl ester	Yes	Yes
9	Das et al. (2016)	Yes	No	N/A	Yes	Yes
10	Whelton et al. (2012)	Yes	Yes	Epoxy, Polymer enhanced cement mortar, Polyurea	Yes	N/A
11	Crawford and Lungu (2011)	Yes	No	Vinyl ester	Yes	No
12	Loendorf and Waters (2009)	No	No	Polyester	Yes	No
13	Donaldson (2012)	Yes	No	Vinyl ester	Yes	Yes
14	Bauer and McCartney (2004)	No	No	Polyester	Yes	No
15	Caltrans (2012)	Yes	No	Polyester, Vinyl ester and Epoxy	Yes	N/A
16	Willett (2017)	N/A	No	N/A	Yes	No
European Literature						
17	Dusseldorp and Schols (2006)	N/A	No	Polyester	Yes	No

Task B –Work Plan for Next Phase

Proposed Methodology for CIPP Emission Sampling

- For Task B, a methodology for CIPP emission sampling was developed.



GC – Gas Chromatography, MS – Mass Spectrometer

Proposed Schedule

No	Activity	Estimated Project Duration (Month)									
		1	2	3	4	PR*	5	PR*	6	7	M**
1	Field Site Measurements (Section 5.4)					Report of Sec. 5.4		Report of Sec. 5.5 & 5.6			Final Report
2	Dispersion Modelling (Section 5.5)										
3	Determination of Health and Odor Risks (Section 5.6)										
4	Preparation of Project Reports										

* Periodic Report
** Milestone

Conclusions

- Existing studies did not adequately capture worker exposures, or levels in the surrounding areas to which workers or citizens might be exposed.
- Spatial variation of concentrations, and variations in concentrations with different meteorological conditions, were not determined.
- Studies also did not adequately capture variations in concentrations from different kinds of pipes (different diameters, lengths, curing temperatures, etc.).

Conclusions (*Cont'd*)

- A total of 21 papers were reviewed.
- These papers had questionable methodologies, and therefore, it was found that the results presented were not conclusive.
- A plan was developed for further sampling and analysis of steam-cured CIPP projects.

Recommendations for Future Research

- Additional sampling and data evaluation and analysis should be carried out as a next phase of this study.
- Additional field measurements of styrene concentrations surrounding the terminal manhole are needed.
- Additional field measurements of worker exposure to styrene are also needed.

Recommendations for Future Research (*Cont'd*)

- Additional worker exposure data should be collected to capture variability in source emission rate, meteorological conditions, and the worker's location with respect to the terminal manhole.

Questions?

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