SUPPORTING INFORMATION

Worksite Chemical Air Emissions and Worker Exposure during Sanitary Sewer and Stormwater Pipe Rehabilitation using Cured-in-Place-Pipe (CIPP)

Seyedeh Mahboobeh Teimouri Sendesi[1], *Kyungyeon Ra*[2], *Emily N. Conkling*[2], *Brandon E. Boor*[1], *Md. Nuruddin*[3], *John A. Howarter*[2,3], *Jeffrey P. Youngblood*[3], *Lisa M. Kobos*[4], *Jonathan H. Shannahan*[4], *Chad T. Jafvert*[1,2], *Andrew J. Whelton*[1,2,*]

[1] Lyles School of Civil Engineering, Purdue University, West Lafayette, Indiana USA 47907

[2] Division of Ecological and Environmental Engineering, Purdue University, West Lafayette, Indiana USA 47907

[3] School of Materials Engineering, Purdue University, West Lafayette, Indiana USA

[4] School of Health Sciences, Purdue University, West Lafayette, Indiana USA 47907

**Corresponding author: T: (765) 494-2166; F: (765) 494-0395; E: ajwhelton@gmail.com; awhelton@purdue.edu*

S1. INTRODUCTION

Table S1. List of reported CIPP caused air contamination incidents found by the authors and styrene concentration reported in air

Information presented in the table is verbatim or summarized from the references; Table Notes: nr = Not reported in the reference; PERSONAL COMMUNICATION indicates the source contacted co-author Dr. Whelton individually; FOIA indicates records were obtained from a utility by a Freedom of Information Act (FOIA) records request. Information obtained from that request, where applicable, was described. FOIA requests were submitted to the following organizations based on input from CIPP industry representatives and author contacts: Bureau of Engineering, City of Los Angeles, CA; Orange County Sanitation District, Orange County, CA; St. Louis Metropolitan Sewer District, St. Louis, MO; Citizens Energy Group, Indianapolis, IN; City of Chicago Division of Water Management, Chicago, IL; DC Water, Washington, DC; Washington Suburban Sanitation Commission, Laurel, MD. Citizens Energy Group did not provide documents to the authors in response to their January 2017 FOIA request by the time this manuscript was submitted.

Incident Location (Year)	Styrene	Description of events from reference
West Lafayette, IN (2016) [1]	nr	Fumes entered a University campus office building through floor drains; chemicals were generated by a nearby CIPP sewer pipe repair activity; building inhabitants complained to the University safety department and onsite CIPP contractor about odors; doors were opened to ventilate building before the safety department representative arrived to investigate; fire department was not called; University safety department conducted spot PID testing after building ventilation; contractor stated there was no health risk just an unpleasant odor.
Good Hope, IL (2016) [2]	nr	Report that ‘steam’ filled the post office four different times; no fire department called; lateral not plugged allowed chemical plume to enter building; "It blew the water out of the toilet," Town Manager said. "It blew the wax seal out because steam was coming out between the floor and the toilet, and steam was coming out of the toilet….and it was coming out of the roof vent. I came up here six times." I got phone calls from the post office out of Bloomington, out of La Harpe, out of Galesburg and like three times up here...The first time, it ruined their computer, and they had to replace their computer inside. It was so wet, there was water dripping from the ceiling. Everything in there was just covered, and the floors were just sopping wet.”
Madison, WI (2016) [3]	nr	Hazardous materials team responded; odor-permeating basements of local businesses and exiting storm drains; The reporter stated, “A white haze that was unidentifiable on monitoring equipment was seen coming out of a storm sewer drain, so firefighters called in the hazardous incident team. Chemical identified was styrene.” "An employee of the CIPP company said they used styrene and the chemical had been disposed of in a drain about four blocks away," per the fire department.

Incident Location	Styrene	Description of events from reference
Bethlehem, NY (2016) [4]	nr	Reported stated that there was a foul smell up and down the street where cured in place pipe installation for sewer repair was occurring; Insituform hired by town for sewer work; Residents were asked to cover toilets.
Cheetowaga, NY (2016) [5]	nr	Resident complained "it automatically takes your breath away. You're like what is that smell?" The Cheektowaga resident said it's coming from a silvery liquid that settled in her basement sump pump. It stems from sewer work performed by a company called Insituform last week. The letter also said homeowners might experience an odor. Resident said "I woke up in the middle of the night sick to my stomach from it." Resident said she contacted Insituform and they did come and check out the problem. But, she said it hasn't been resolved. Resident worries what kind of effect the smell might have on her health. "… What is causing that smell?" The Town of Cheektowaga said they've received a handful of complaints. It said the gas is coming through a faulty trap or an illegal sump pump. The town recommends running water through the trap to fix it. But, it is on the homeowner to fix a faulty trap or an illegal sump pump.
Cornwall, UK (2016) [6]	nr	Resident claimed, "Suffered from burning eyes, abdominal pain, aching joints and memory loss at their home"; Water utility stated, "No evidence their work caused the family's ill health. As a gesture of goodwill, they were paying for the family to stay in a B&B." In a letter, specialist doctor at hospital said, "resident presented with symptoms of styrene poisoning and was advised not to enter the house until it had been cleared of the chemical." Water utility stated, "styrene is widely used across the country to line water mains and sewers and there is no regulatory requirement to wear respiratory masks whilst working with the substance."
Alexandria, VA (2016) [7,8]	nr	FOIA: Fire department responded to a resident complaint; collected dräeger tube air sample; RK&K, Inc. contractor took them to the downstream manhole. Later, someone with a baby came by and said they called the fire department; fire department told her to open her windows and pour water down her basement drain. RK&K, Inc. contractor told person to additionally put a wet rag over the opening. RK&K, Inc. contractor thinks some people are more sensitive to styrene than others or their house somehow captures more odors due to their lateral location. Contractor recommends set up a fan "even if it is for show." Per RK&K, Inc., "There was no visible steam or odor from the manhole although [fire department] took their reading about 4 inches from the bags' end which will/may result in a high reading. They did not return for further discussions."
Alexandria, VA (2016) [9]	0 ppm	FOIA: City spoke with resident who filed odor complaint April 14, 2016 to report styrene odor; RK&K, Inc. contractor visited home and used PID, which stated "0.0 ppm at all times when they were in the house. "Homeowner called again on April 27, 2016, 13 days after the lining cool down, to report the styrene odor again. RK&K went to the home again and this time there was a reading as they entered the front door. RK&K, Inc. walked outside, went back in and the reading was 0.0 both at the door and at the basement trap; Homeowner called May 16, 2016 (today) to request another reading; City explained to him that the work was accomplished over 3 weeks ago and that if there was an odor it was not caused by the sewer lining.

Incident Location	Styrene	Description of events from reference
North Tonawanda, NY (2016) [10]	nr	Reporter stated “For about a month, noses have been picking up a distinctive smell near the site of the former Durez Corp. plastics and chemical plant that was torn down in 1997.” Sewer pipes were being repaired with cured in place pipe and the odor was suspected to be caused by the construction activity per the City Engineer. The reporter stated that community air monitoring was performed throughout the project.
Québec, CN (2015) [11]	nr	PERSONAL COMMUNICATION: 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.
Picayune, MS (2015) [12]	nr	Calls to utility during weeks and typically with older homes; Utility suspects most residents that notice a smell may be living in a home with inadequate vent or trap which is allowing the odor to enter the home from the wastewater lines; CIPP contractor recommends residents add water to sewer traps and if smell intrudes home they should open windows for a short time; CIPP contractor assures the smell is not harmful and cites a 2001 study to determine the levels of styrene concentration during the installation and a worst case scenario; Contractor states during testing the concentration detected with a working trap was 0.0002 ppm while faulty vents had 0.1 and 0.2 ppm; Claimed person standing over a manhole would experience 3.2 ppm styrene; Contractor reported that if odor does enter house it could remain for up to two days.
Lincoln, NB (2015) [13]	nr	Several homes evacuated; fire department called and stated “The readings in one of the houses was significantly high, higher than expected levels or safe levels;" Fire department chief stated "When they inject steam into the sewer line and in that steam is a chemical called styrene.” City health specialist stated, “Our assumption is it pushed a bunch of this odor through the sewer line, on down stream of where they were working." Fire department opened windows in the affected homes and set fans up to help aerate them, and residents were allowed back inside later that day.
Ottawa, CN (2015) [14]	nr	Residents and businesses complained about chemical exposures: "The smell was so intense that I had to let my secretary go home because she was ready to vomit.” The city paid for one family to be put up into a home; the city stopped CIPP work to investigate; city recommended work only be conducted in summer when buildings can be better aired out.
Ottawa, CN (2015) [15]	nr	Residents state that odors come through drains and circulate in the building through air vents and started about a month ago, “Using incense to cover the smell”; Ottaway Public Health monitored air; City Hall recommends that residents open their windows until the smell goes away; the business owner interviewed however did not have windows that can be opened.

Incident Location	Styrene	Description of events from reference
St. Petersburg, FL (2015) [16]	nr	Resident filed complaint to city that "For two days having some strong chemical (epoxy or glue-like odor) coming from drains periodically. The smell has resulted in irritation to the back of our nasal passages in just a short period of time breathing it."
Antigo, WI (2015) [17]	nr	Illness symptoms reported by child; pregnant woman concerned about the exposure; firefighters responded to homes; firefighters said, "According to the MSDS sheet it was not safe to just be breathing those inhalants." Resident explained, "The basement was incredibly full of fumes, and whatever they're shooting into the pipes was shooting up out of our drain pipe into our basement so forcefully it was actually whistling."
Alexandria, VA (2015) [18-21]	nr	FOIA: City tells residents, "Higher ambient temperatures have a tendency to exacerbate odors associated with the relining." Homeowner association representative stated, "Different homes very near to one another have been affected to widely varying degrees. Just speaking in my home, the basement and main floors were worse than the second floor. Some houses were not affected. In addition, when all windows were opened, fumes dissipated fairly well and resident thought the threat was over. When resident closed windows, and turned on air conditioning, and left to go to the store, fumes became bad again. The fumes were also bad last night even though the crew finished work about 5:30pm the day before, albeit not nearly as bad as while they were working." City declared, "People and Pets are safe because the contractors are not working with enough styrene to be dangerous. Styrene is only dangerous in large quantities."
Kensington, MD (2015) [22,23]	rr	FOIA: Resident called utility and left message about complaint and claimed he and several neighbors who were ill due to the smell exposure that caused a nose bleed; utility CIPP contractor was lining a 30 inch diameter sewer pipe in the area with steam curing and utility suspects that would cause the styrene odor; utility spoke with one resident who claimed that there was a shift in the wind causing the odor to linger about his house and his neighbors causing temporary illness; utility staff explained they are working to figure out what chemicals were used; follow up by utility indicates that, "Customers contacted WSSC regarding the resin odor which is typical when lining sewers." CIPP contractor installation failed (400 linear feet of the 500 linear foot liner) and contractor has been cutting/removing the failed liner.
Rensselaer, NY (2015) [24]	nr	Chemical entered homes from sewer CIPP lining; one resident taken to hospital; city paid for hotel rooms for 5 homes impacted. Resident claimed, "Styrene permeated the clothing in their drawers, closets, and couches."
Botany Village, NJ (2015) [25]	nr	Resident reported strong and fragrant sewer odor pervaded the neighborhood; yearlong project.

Incident Location	Styrene	Description of events from reference
St. Louis, MO (2014) [26]	nr	Residents report odors in homes; Described them as “toxic, permanent-marker-type smell.” Sewer utility [Metropolitan St. Louis Sewer District] spokesperson stated: The heating/curing process is known to release smells that, while gross and annoying, don't pose a health risk, says LeComb. "Odors do come off sometimes, and we certainly apologize for the inconvenience. This is a very large sewer, so it'll have more of an odor impact than we usually see," says LeComb. However, Lacomb adds, it is possible for the smell to emanate from inside a home, likely through dried-out sink traps or basement drains. If you start to smell something funky indoors, he suggests pouring two or three cups of water in the sink or down the drain to seal those smells away.”
Prairie Village, KS (2014) [27]	nr	PERSONAL COMMUNICATION: Resident reported the 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.
Manchester, UK (2014) [28]	nr	Steam cured CIPP was installed; residents complained about odor, and health effects such as headaches and nausea. “A number of households were relocated to stay with relatives or in hotels. Subsequent investigations indicated that a small breach occurred in the liner during the early curing process. This allowed chemicals to escape and enter nearby properties, most likely through connections to the culvert.”
Baltimore, MD (2014) [29]	nr	PERSONAL COMMUNICATION: Resident evacuated house after detecting odor caused by CIPP sewer pipe repair activity nearby and experienced chemical exposure symptoms; sought medical attention; fire department responded conducted air testing but discrepancy between resident observed results [400 ppm styrene on draeger tube] and fire department filed report [nothing found]; moved out of house for 1 month; odors got stronger when it rained.
Illinois (2014) [30]	nr	PERSONAL COMMUNICATION: Resident claimed fumes from CIPP sanitary sewer installation backed-up into private residences and residents reported chemical exposure symptoms.
Kensington, MD (2014) [31]	nr	FOIA: Resident called utility and filed a complaint, chemical odor from nearby sewer work happening behind his house; utility staff recommended borrowing language provided to them by the CIPP when responding to the resident. The contractor language stated, but not limited to, “Don’t be alarmed. The CIPP industry is a worldwide 100 billion dollar industry that installs more than one million feet a year and thousands of people are involved with no diverse effects.”
Nashville, TN (2014) [32]	nr	Complaints from residents about chemicals emitted during CIPP activities; “We're having a hard time breathing, getting dizzy," Zach Shedd said. "Pretty much have to leave the house. It's got a very think, pungent smell, like burning plastic. When you inhale or breathe it, it literally coats the back of your throat." Utility stated “There is no research or studies showing that this is hazardous, styrene is actually in things we use every day. It's in certain foods, like strawberries or coffee. It's in automobile exhaust."

Incident Location	Styrene	Description of events from reference
Philadelphia, PA (2013) [33]	nr	PERSONAL COMMUNICATION: Resident took 4 month old baby to a medical center after exposure to fumes inside a house generated during nearby CIPP sanitary sewer repair.
Fayetteville, NY (2012) [34]	nr	Odors permeated into nearby residences; residents complained and evacuated their homes; city engineer stated odor "Is not toxic, not dangerous"; contractor stated, "Odor from it is not harmful. There is no health risk. The contractor's personnel are trained in handling the liner properly, and once it hardens, there is no residual left. There is no exposure other than an odor blown off the material. It's no different than smelling turpentine or gas."
Brisbane, AUS (2012) [35]	nr	PERSONAL COMMUNICATION: Resident reported that odors were detected and exposure lasted 5 days in home; person hospitalized; health department investigated and demanded home be decontaminated; resident reported his and his neighbor's pets died.
Ontario, CN (2012) [36]	nr	Odors detected kilometers from worksite and within nearby private residences; exhaust fans used for manholes.
Ontario, CN (2012) [37]	nr	CIPP wastewater discharged to sanitary sewer; odors reported near worksites.
Worcester, MA (2011) [38]	60 - 70	Fumes caused daycare center evacuation; headaches reported; emergency responders called to site; Fire chief reported, "For the styrene to be dangerous, it needs to be 10 times that amount."
Minnesota (2011) [39-41]	nr	Odor caused by resin spill prompted building evacuations; residual remained for five months.
Port Huron, MI (2011) [42]	nr	Daycare owner sent children home early and remained closed; claimed odors made staff and children sick and dizzy; residents reported strong odors in homes; firefighters responded and said no toxic or flammable fumes in homes; officials told residents to pour water in their traps to keep odors out of homes.
Port Huron, MI (2011) [43]	nr	Firefighters responded to reports of a strong odor; resident claimed it smelled like turpentine, started puking, removed her three dogs, and opened house windows.
Southfield, MI (2011) [44-46]	nr	Five students and one staff member at high school transported to hospital after becoming nauseated; 20-25 classrooms affected; fire fighters responded with local HAZMAT unit; odor reportedly entered building day before and students were moved by teachers to different part of building; Oakland County Water resources (water utility) manager stated, "At levels present in the resin, neither the styrene nor the other chemicals were toxic." Civil Engineer at water utility stated, "It's not uncommon to have people complain about the odor, and we have had complaints (about the odor) from the public before, but we've never had people go to the hospital until this incident. Up to this point, it's really just been about odor. We have had complaints about eye irritation and gastroenterological problems, but nothing worse than that. It's never really been a public health concern…..the process only produces one to three parts per million when you're exposed."

Incident Location	Styrene	Description of events from reference
Saugus, MA (2011) [47,48]	nr	Firefighters ordered evacuation of elementary school because of strong odor; dizzy and light-headed symptoms reported; the following day, after the building had been evacuated, the state health agency conducted air testing using a PID; odor detected outside above a manhole cover but PID did not respond; PID did not respond for VOCs in the in-building locations.
Pittsburgh, PA (2011) [49]	nr	Two schools evacuated; elementary and high school students evacuated for fear of gas leak, but odors turned out to be caused by nearby CIPP operation; theory was "The wind was blowing in such a way that the smell drifted to the schools, where windows were open." Utility stated, "Did not believe chemicals used in the process would cause any danger to people in the schools, especially since schools were not in close proximity to the work and the contractors doing the work aren't required to wear masks or other breathing apparatus."
Clear Creek, CO (2011) [50-52]	nr	"Source Type: Culvert Lining. Cause Information: Styrene was released to the water of Clear Creek after it had been used on 2/4/11 by CDOT [Colorado Department of Transportation] as part of the process of lining a culvert near the water intake on Clear Creek for the Loveland Valley Ski Area. The ski area noted the smell on 2/7/11 and did a test that showed the presence of styrene." It had contaminated their drinking water. "…February 7, 2011 at 1125 a.m. the Clear Creek County Environmental Health Dept received information of a possible contamination of the waterway of Clear Creek at the Loveland Ski Area. An elevated, but unknown amount of styrene has been detected, and is suspected to be at the CDOT culverts …" Investigation discovered unknown amount of uncured resin was discharged to creek and styrene as well as other compounds known to be present in resin or produced during CIPP manufacture were detected in downstream waterways. Community affected by drinking water contamination was provided alternate drinking water supply followed by actions to remediate the affected area and wide area environmental sampling.
Birmingham, UK (2011) [53]	15 - 200	Odor complaints reported by residents; residences evacuated homes at contractor's recommendation; one resident claimed, "My 3 children (6yrs, 4yrs, 17 mths) have all been sick during the night and we have all suffered headaches, dizziness, tight chests and nausea. My baby has swollen & inflamed tonsils & throat which the GP feels is due to the irritation caused by styrene." 3 days after, reported styrene above 20 ppm in one home still; 8 days after incident 100 ppm styrene measured in one home and resident reporting chemical exposure symptoms; responders theorized there was a leak in the lining used for styrene CIPP sewer pipe repair; building ventilation conducted; health department did not conducted testing, relied on contractor results to make safety decisions; contractor did not disclose styrene present in homes above health limits until days after health agency involved.

Incident Location	Styrene	Description of events from reference
Williams Co. Village, OH (2010) [54]	nr	Residents complained, “Smelling a glue-like odor inside their houses for the last two weeks, and have suffered from severe headaches, nausea, and dizziness.” Some claimed, “They only began to link their symptoms to the fumes this week after the odor intensified.” Family began experiencing upset stomachs, diarrhea, severe headaches, dizziness, and lethargy about 2.5 weeks ago. Residents moved out of house and afraid to return home; some went to emergency room to seek help, hospital told them they do not have facilities to test for the chemicals. Village manager evacuated 19 families from their homes and put them up in a hotel for 2 nights at a total cost of about $3,000. Town manager stated, “There's flu going around. I can't tell you why they were sick.” Town manager said, “Smell came from a chemical called styrene which was used as a sealant for the sewer pipeline… odor got into people's homes through floor drains.” Reporter stated other substances - acetone, a polyester resin and chemical products named "Perkadox 16" and "Trigonox 42S" - also were used during the project.
Helena, MT (2010) [55]	nr	Fire department evacuated affected building because of complaints of strong odors, nausea, and headaches.
Helena, MT (2010) [56]	nr	Workers at local businesses left the office after smelling the CIPP causing odor. Businesses opened doors to ventilate their buildings; city hired contractor to test air, but was unaware of complaint by business interviewed by reporter; the prior week firefighters evacuated an area due to odors; businesses filed insurance claims due to lost business.
Helena, MT (2010) [57]	nr	Businesses closed; residents reported chemical exposure symptoms to include headaches; part of the old sewer pipe being repaired was exposed in a building’s basement, making it easier for the chemicals to escape. Complaints about the smell of paint thinner or glue caused firefighters to evacuate the building 3 days ago; at that time a peak of 67 ppm in the building’s basement was detected; following day, it was 10.2 ppm on average, and 3 days later, the level was 2.5 ppm. City workers set fans to pump fresh air into the building, which made the problem worse by pushing gases into other areas.
Lorain County, OH (2010) [58]	nr	Residents claimed, “They became nauseated or dizzy last week from 8 days ago from an overpowering chemical smell coming from their toilets or floor drains.” CIPP contractor stated, “Styrene odor can be irritating to some people but that rarely does anyone become ill.” 5 days after odor, engineering contractor conducted testing per residents; resident claimed, “Went in the bathroom and the pressure had shot up water out of the toilet -- and the smell just about knocked you over…couldn't breathe right and got a headache from it….felt confused, groggy, like I was drunk or slurring my speech."
Arlington, VA (2010) [59]	nr	Nearby CIPP installation caused odor; residents called, fire department responded; city publicly claimed, “The resin is not harmful to pets or people.” City claims pouring water in sewer traps “prevents sewer odors from entering the home.”
Willemette River, OR (2012) [60]	nr	Contractor discharged steam cured CIPP waste to Willamette River; “Styrene levels were so high that the responder had to wear a respirator to collect samples.”

Incident Location	Styrene	Description of events from reference
Bellevue, WA (2010) [61,62]	nr	CIPP storm water pipe cured by steam; plug failed and released waste to local waterway including styrene two different days; odors detected; city closed area to the public near spill to prevent exposures; odor remained for more than 14 days after the spill.
Pittsburgh, PA (2009) [63]	nr	Firefighters evacuated apartment buildings; initially suspected cyanide gas, but styrene was ultimately detected from nearby CIPP.
Des Moines, IA (2009) [64]	nr	Odor inside government building caused by CIPP nearby caused building inhabitants to evacuate twice; downtown workers and residents also noted the odor. Fire department stated, "Smell is harmless and will dissipate quickly."
Cambridge, MA (2008) [65]	nr	Contractor released contaminated process water down sewer line which exited downstream manhole; fans were used to divert fumes away from a neighborhood; cease and desist order issued by utility to contractor.
Snellville, GA (2007) [66]	nr	Resident contacted health department about chemicals entering homes during a recent storm sewer rehabilitation project and reportedly caused neighbors to experience headaches. Health department contacted the contractor who installed in-place polymer liners. The process involved running a polyester resin tube inside existing storm pipe, then filled with 180 degree water. A styrene based thermoset resin and catalyst system was used to cure the resin in place when the 180 degree water was added. According to the contractor, during this process, all the styrene was gassed off. Upon complaint by the resident, the contactor discovered an illegal drain pipe coming from the home that was connected to the storm pipe. Resident ventilated the house during the day, which health department told him was the right thing to do. Four days after the incident, the resident stated that the smell had diminished, but was still present. The health department informed the resident that the NIOSH relative exposure limit was set at a TWA of 50 ppm. Without measuring the actual indoor air concentration, the health department reported that there was no way of knowing whether his family was exposed to styrene gas above the REL. The resident continued to ventilate the home and the health department informed the resident that this was all that could be done and that the styrene gas would eventually dissipate.
Somerset, UK (2007) [67]	nr	Foul CIPP styrene odor permeated into residence through drain because of nearby installation; resident stated odor persisted for 12 days and rejected the offer of a masking spray. Utility (Wessex Water) stated, "The smell of styrene is not harmful and is generally short-lived."
Brooklyn, NY (2007) [68]	nr	Foul CIPP styrene odor permeated into buildings through drain because of nearby installations; Department of Environmental Protection adds pine deodorizer at the site cover the smell; odors first detected in 2006.
Boston, MA (2007) [69]	nr	CIPP installation prompted chemicals to enter the basement of a nearby restaurant.
Ottawa, CN (2004) [70]	20, 115	Venting determined to be helpful to prevent air backup into nearby residences/ buildings.

Incident Location	Styrene	Description of events from reference
Alexandria, VA (2004) [71]	500	HAZMAT team responded because of styrene vapor backup into nearby buildings; illness symptoms reported by residents and residents evacuated homes. Police officer stated he felt nauseated, light-headed, short of breath and his eyes were burning, like they were on fire. Went to urgent-care center and was diagnosed with an inhalation injury. Another resident who worked at the World Bank said, "The smell was so strong that he was afraid to return to his home with his 19-month-old son.". He reported vomiting repeatedly the next day, and thought he had food poisoning. City officials said yesterday, "That the toxic fumes might have affected more residents than they initially disclosed." Hose left behind by contractor was emitting 500 ppm of styrene; public works conducted tests in sewer and homes and declared styrene was "within acceptable levels"; city recommended residents fill "dry pipe traps with water to prevent fumes from entering through pipes. Workers also planned to ventilate manholes and flush sewer lines with water. Contractor stated, "On rare occasions, we've had people overreact, as we've had in this situation, and go to the hospital as a result of smelling the styrene . . . which can cause your eyes to burn and your nose to run, much like smelling ammonia."
Milwaukee, WI (2004) [72]	0.01 - 0.32; 30 ppm_v for total VOC	An office building became contaminated; building evacuated for 2 days. Occupants complained about irritant symptoms and strong odor. US federal health agency investigated; styrene and other VOCs detected; 4 months required to reduce styrene levels to background; greatest styrene levels detected in basement; ASTDR declared the exposures a public health hazard due to styrene levels exceeding acceptable ATSDR chronic (long-term) exposure levels. Recommendations made to ventilate the building basement to reduce exposure and odor. A temporary exhaust system was installed in the building basement near the point of vapor entry.

S2. MATERIALS AND METHODS

Photoionization detectors (PID)

RAE system ppbRae 3000 PIDs (10.6 eV lamp) were calibrated with isobutylene at 10 ± 0.03 ppm_v. PIDs were operated with a styrene correction factor of 0.43 and firmware v2.13.

Analytical standards

A variety of analytical standards were used to examine GC/MS results. They include 1,4-dichlorobenzene-d4 (CAS# 3855-82-1, Supelco), butyl hydroxytoluene (BHT) (CAS# 128-37-0, Supelco), benzaldehyde (CAS# 100-52-7, Sigma-Aldrich), acetophenone (CAS# 98-86-2, Sigma-Aldrich), benzoic acid (CAS# 65-85-0, Supelco), phenol (CAS#108-95-2, ARCOS Organics), 1-tetradecanol (CAS#112-72-1, Sigma-Aldrich), EPA phthalate esters mix (CRM48805, Supelco), 4-*tert*-butylcyclohexanol (CAS# 98-52-2, ACROS Organics), 4-*tert*-butylcyclohexanone (CAS# 98-53-3, ACROS Organics), tripropylene glycol diacrylate (TPGDA) ≥90% stabilized with MEHQ (CAS# 42978-66-5, TCI America), naphthalene-d8 (CAS# 1146-65-2, Supelco), toluene-d8 (CAS# 2037-26-5, Sigma-Aldrich), phenanthrene (CAS# 85-01-8, Supelco), chlorobenzene-d5 (CAS# 3114-55-4, Supelco), and styrene ≥99% that contained 4-*tert*-butylcatechol stabilizer (CAS# 100-42-5, Sigma-Aldrich).

Calibration curves were also created for methylene chloride extracts. These were for styrene (R^2=0.998 for medium range (240 ppb to 2.5 ppm) and R^2 for the high range (R^2=0.995, 0.997 & 0.998 for concentration in the range of 120.8 ppb to 7.25 ppm), benzaldehyde (R^2=0.995, 0.998 for concentration in the range of 69.9 ppb to 20.88 ppm) and BHT (R^2=0.995 & 0.996 for the concentration in the range of 43.5 ppb to 4 ppm), benzoic acid (R^2=0.996, for the concentration range of 3.7 ppm to 11.2 ppm), phenol (R^2=0.999, for the concentration in the range of 22 ppb to 17.6 ppm, 1-tetradecanol (R^2=0.996, for the concentration in the range of 246.7 ppb to 5.18 ppm), 4-*tert*-butylcyclohexanol (R^2=0.998 for the concentration in the range of 1.22 ppm to 31.22 ppm), DBP (R^2=0.994, for the concentration in the range of 80 ppb to 2.4 ppm) and acetophenone (R^2=0.997, for the concentration in the range of 412 ppb to 10.99 ppm) were developed.

Calibration curves were also developed for hexane extracts. These were for styrene (R^2= 0.994, 0.998 & 0.999 for concentration in the range of 120.8 ppb to 30.2 ppm), TPGDA (R^2 = 0.992 & 0.994 for concentration in the range of 1.24 ppm to 44.66 ppm), benzaldehyde

(R^2=0.991 & 0.999 for concentration in the range of 139.2 ppb to 48.72 ppm), 1-tetradecanol (R^2=0.993, for concentration in the range of 400 ppb to 30 ppm), acetophenone (R^2=0.997, for concentration in the range of 137.33 ppb to 13.73 ppm), 4-*tert*-butylcyclohexanol (R^2=0.999, for concentration in the range of 1.04 ppm to 31.23 ppm, BHT (R^2=0.994, 373.3 ppb to 23.33 ppm).

Site safety and equipment cleaning

To minimize chemical exposure and at the recommendation of Purdue University Radiological and Emergency Management (REM) industrial hygiene staff, the authors wore long-pants, closed toe shoes, hardhats, safety glasses, shirts, and safety vests. Nitrile gloves were worn by the authors when handling samples. Neoprene gloves on top of a double layer of nitrile gloves were worn to handle the uncured resin. A few times, contractors handed uncured resin sample to the authors using their bare hands. Air testing results obtained from the Indiana CIPP sites resulted in the authors and Purdue University industrial hygienists concluding that full-facemask respirators with carbon filters should be used for field work in California. The authors were fit tested and used full face respirators (3M 6800, North 5400) with organic vapor carbon filter cartridges (3M 6610, N75001). A site safety plan was prepared by the authors for the California field work, was reviewed by Purdue University industrial hygienists, and provided to California State University Sacramento for informational purposes. The California field work was conducted on the California State University campus.

In Indiana, the air sampling manifold was used only one time. In California, after each CIPP installation sampling event, equipment was cleaned to include the stainless steel air sampling manifolds and respiratory protection. Decontamination activities were conducted in a nearby wet chemistry laboratory fume hood using high purity acetone. Stainless steel manifold pieces were rinsed at least three times with acetone, exposed to high-pressure air purging for 5 min, and then air dried. Stainless steel caps and PTFE stoppers were used to cap the end of manifold tubing during acetone rinsing.

Material SDS of resin impregnated tube in Indiana

A material SDS described that resin impregnated felt contained: ITI 191024 CTDFelt 15 mil 69 (11% wt. to 29% wt.), polyester/vinyl ester resin (38% wt. to 47% wt.), amorphous fumed silica (0% wt. to 2% wt.), styrene (15% wt. to 31% wt.), various organic peroxides (0.5% wt. to

0.7% wt.), fiber glass (0% wt. to 20% wt.), and proprietary filler (0% wt. to 22% wt.).[73] A high molecular weight isophthalic unsaturated polyester resin, 102T/TA, with unreported composition was used for the installation[74].

Material SDS of resin impregnated tube in California

Vipel® isophthalic based polyester resin was used for styrene based CIPP installations[75,76]. The material SDS indicated this resin included 0.5% Trigonox® KSM and 1% di-(4-*tert*-butylcyclohexyl) peroxy dicarbonate initiators. The resin was L713-LTA-12 and was reported to contain: Styrene (32.0% wt.) and Talc (20% wt. to 30% wt.). For the low VOC CIPP installation, EcoTek™ L040-TNVG-33 vinyl ester resin was used and the initiators were not disclosed[77].

Potential contractor application of a lubricant when the air inverted resin impregnated tubes were inserted into California target pipes

For the uncured resin tubes inserted by air inversion, a small amount of Crisco® may have been used by the contractors to help lubricate the tube so that it could be initially inserted into the shooter. The shooter was used to invert the uncured resin tubes using forced air into the target pipes. The degree and how much Crisco® was added was not documented by the contractors and they did not describe how much they applied. Uncured resin tube lubrication is common when tubes are inserted using air inversion. Crisco® and vegetable oil have been seen at other sites.

Method for extracting uncured resin tube and analyzing extracts for the Indiana and California sites

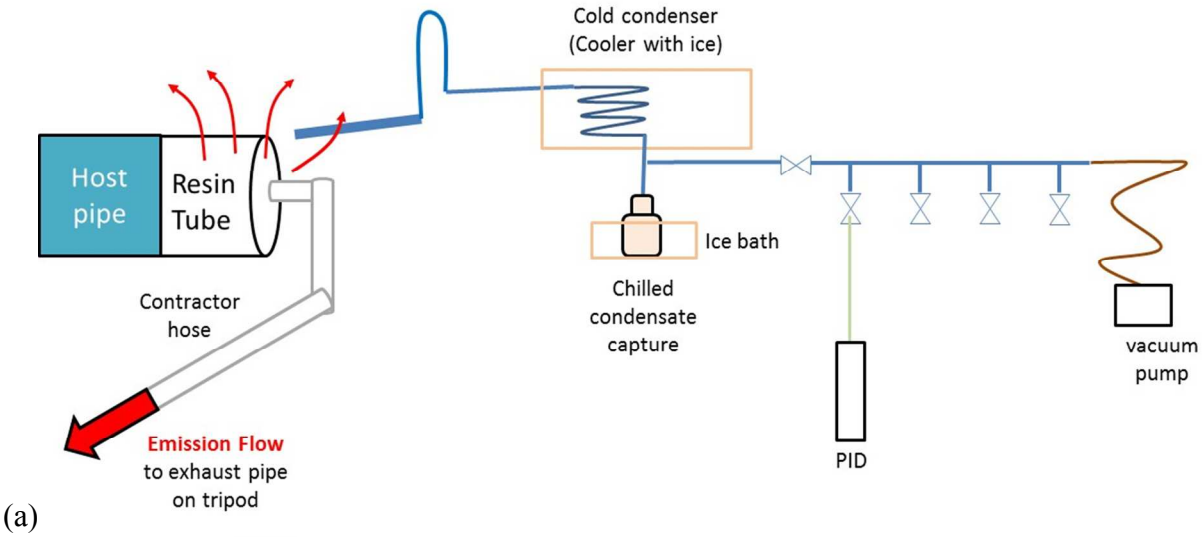
Samples of felt tube impregnated with uncured resin were obtained for each CIPP site, immersed in hexane and dichloromethane (1.69 ± 0.25 g sample / 22.87 ± 0.53 mL solvent) and stored at 4°C for four months. Extracts were filtered, diluted 10,000x and analyzed in scan mode with a GC/MS-TQ8040 (Shimadzu). The temperature program of the GC-2010 Plus started at 40°C, was held for 4 min, was ramped at 12°C/min to 250°C and held for 3 min. Purge flow and column flow (Helium) were 3.0 mL/min and 1.5 mL/min, respectively. Samples were injected in split mode (ratio 1:10) at 280°C. Quantification was performed based on response of 1,4-dichlorobenzene-d4 (internal standard, 1 ppm).

Method for assessment of pipe condensate cytotoxicity

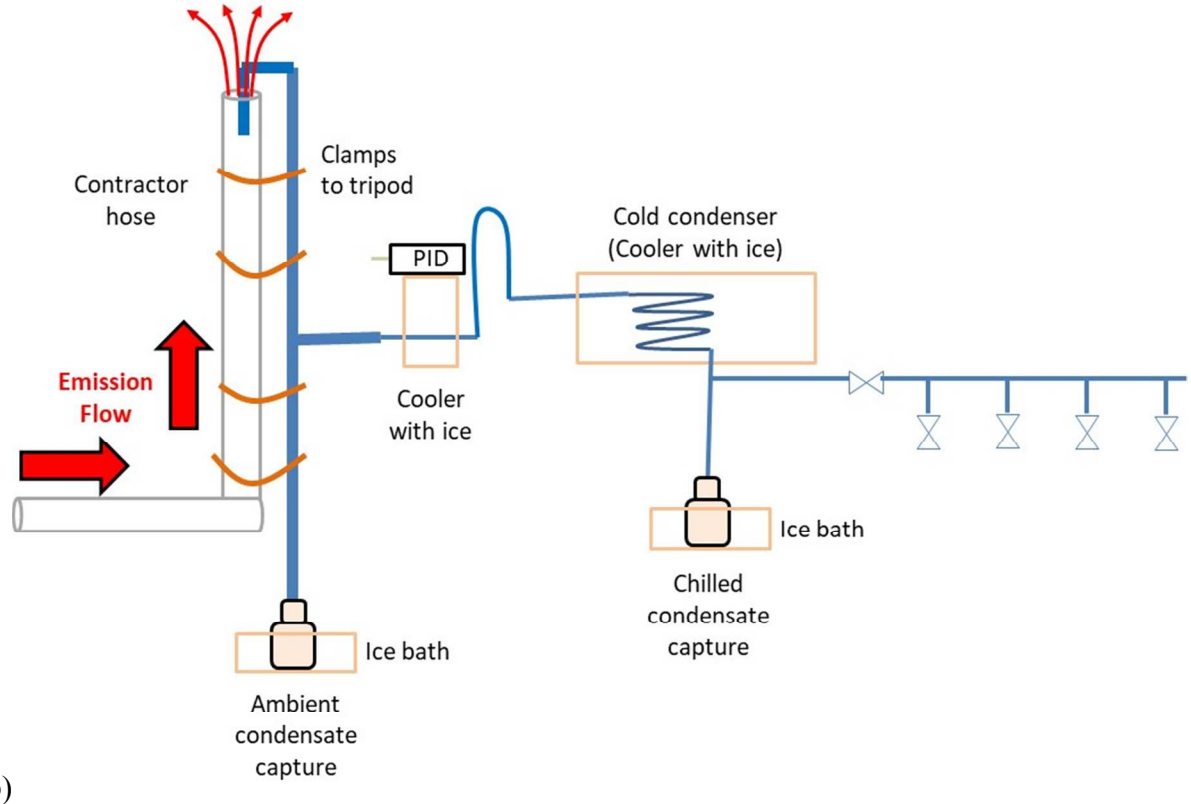
Changes in cell viability for mouse alveolar macrophages and alveolar type II cells were observed for condensates collected from California CIPP installations. Mouse alveolar macrophages (RAW 264.7) and mouse alveolar type II (C10) cells were cultured individually in dulbecco's modified eagle's media containing 10% FBS and maintained under standard conditions of 37°C and 5% CO_2. Experiments to evaluate cytotoxicity were performed at 90% confluency, in 48 well plates, and in serum-free media conditions. Cells were exposed to condensates diluted to 10, 100, or 1,000 ppm of styrene, serum-free media only (controls), or 400 μg/mL of zinc oxide nanoparticles (positive control). Condensate captured from the exhaust emission point of site 2 was not evaluated for cytotoxicity due to styrene levels being too low compared to other condensate samples during the first 20 min capture period. Following a 24 hr exposure to the diluted condensates, changes in cell viability were assessed via the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay (Sigma-Aldrich, St. Louis, MO) via the instructions of the manufacturer using a spectrophotometer (Molecular Devices, Sunnyvale, CA). Briefly, following the 24 hr exposure, the condensates were removed from the cells and the cells were washed with phosphate buffered saline. Cells were then incubated with MTT at 37°C. Dehydrogenase enzymes in viable cells reduce MTT to generate purple formazan salt crystals. These salt crystals are then solubilized by dimethyl sulfoxide and transferred to a new plate. The absorbance was then quantified using a spectrophotometer at a wavelength of 570 nm. The absorbance (generation of salt crystals) is proportional to the number of viable cells present. The absorbance values from exposed cells were compared to control (untreated) cells to determine alterations in cell viability. Control cells were considered 100% viable. Exposure to the positive control (zinc oxide nanoparticles) resulted in cell viability of 23.27 $\pm$ 6.87% in macrophages and 17.12 $\pm$ 2.70% in epithelial cells (data not shown). Data are presented in the graphs as mean $\pm$ standard error of the mean and an n = 4/group, with each sample consisting of three technical replicates. Data were analyzed by two-way analysis of variance (ANOVA) with differences between groups assessed by Tukey's post hoc tests. All graphs and analysis were performed using Graph Pad Prism 6 software (Graph Pad, San Diego, CA). Statistical significance was determined when p was found to be less than or equal to 0.05 between groups. Cytotoxicity for condensate collected from the low VOC CIPP installation was not examined.

Method for the analysis of particulate captured and condensed from the chemical plume at the Indiana site

Three different techniques were applied to examine particulate captured and condensed from the chemical plume. Thermal stability was studied using thermogravimetric analysis (TGA) on a Q500 from TA Instruments, Inc. (New Castle, DE). Platinum pans were used with samples weight maintained between 10 mg to 15 mg, while scans were performed at 10°C/min from 30°C to 200°C. TGA was performed under nitrogen environment with a purge flow rate of 60 mL/min. Differential scanning calorimeter (DSC) analysis was performed using Q2000 from TA Instruments, Inc. (New Castle, DE). Aluminum pans were used with sample weight approximately 10 mg to 15 mg. Two heating and cooling scan were performed at a heating rate of 5^{o}C/min across a temperature range of -100°C to 200°C. Nuclear magnetic resonance (NMR) spectroscopy was performed and ^{1}H NMR spectra were collected using 32 scans on a 500MHz Bruker spectrometer (Bruker Bio Spin, Fremont, CA) equipped with Top Spin software; specimens were analyzed in deuterated chloroform.



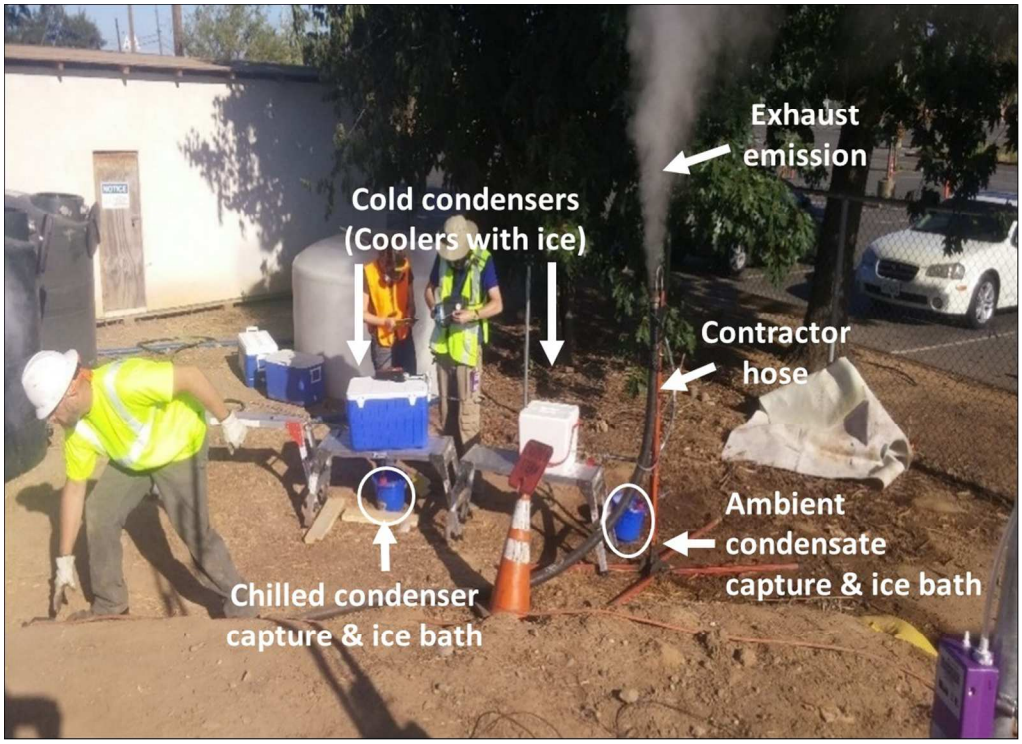
(a)



(b)

Figure S1. Schematic diagram of California site (a) fugitive and (b) exhaust emission capture system

(a)



(b)

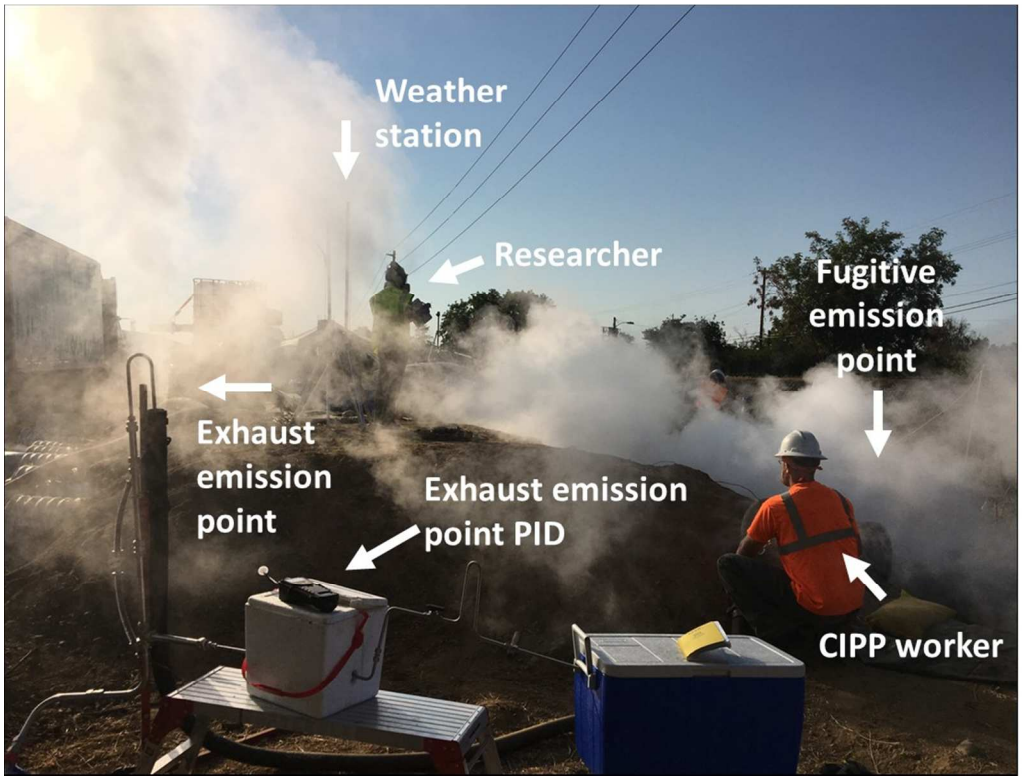


Figure S2. Images of the California site (a): exhaust emission capture system, (b) exhaust emission and fugitive emission points for one CIPP installation. The black hose used by the contractor connecting the uncured resin tube to the exhaust emission point was ethylene propylene diene monomer (EPDM).

Table S2. Design characteristics of each CIPP installation in Sacramento, California

Install. Number	Host pipe (Length-m, Diameter-cm)	Used Preliner, Number Used	Resin Type	Cool down Method	Liner Insertion Method
1	CSP (6,45.7)	Yes, 1	L713	Ambient Air	Air inversion
2	CSP (6,48.2)	No, 0	EcoTek	None	Air inversion
3	CSP (6,45.7)	Yes, 2	L713	Hot Air	Air inversion
4	RCP (6,45.7)	Yes, 1	L713	None	Air inversion
5	CSP (6,45.7)	No	L713	None	Pull-in

CSP = Corrugated Steel Pipe; RCP = Reinforced Concrete Pipe; According to the contractor's submittal the target thickness of the uncured liner wall was to be 9 mm and after curing the CIPP wall thickness was to be no less than 7.62 mm; Design conditions were predetermined by Currier[11]who examined water quality impacts of the CIPP installations. Two AOC, LLC resins were used for CIPP installations: L713-LTA (styrene based resin) and EcoTek (non-styrene based resin).

Table S3. Operational conditions for each CIPP installation in Sacramento, California

Install. Number	Cure Time (min)	Interface Range Temperature (°C)	Steam Range Temperature (°C)
1	130	14.4 to 93.3	115.5 to 121.1
2	150	14.4 to 80.5	115.5
3	165	18.3 to 117.7	110 to 121.1
4	175	15.5 to 76.6	110 to 121.1
5	155	15.5 to 137.7	120 to 121.1

Contractors reported that pressure inside the uncured resin tube for each installation was 34.4 kPa.

Meteorological Condition Monitoring

Meteorological conditions were monitored using a Davis Vantage Pro 2 wireless weather station. Measurements monitored included: wind speed, wind direction, rainfall, temperate, humidity, and barometric pressure. Additionally, the weather station was programmed with Sacramento's latitude and longitude, altitude, rainy season, and time zone. Every minute, data was logged and sent to the wireless monitor, which was downloaded at the end of each day. The weather station was placed roughly 1 m off the ground, while the anemometer was roughly 1.8 m off the ground.

S3. RESULTS AND DISCUSSION

Video S1. Video of white chemical plume movement due to local conditions and nearby vehicle movement

Video uploaded to ACS Manuscript submission system

Text Posted: This video was recorded as part of a National Science Foundation RAPID response research project (CBET-1624183) in July 2016. Cured-in-place-pipe (CIPP) technology is used to repair damaged sewer, storm water, and drinking water pipes. As part of the repair, a new plastic pipe is chemically manufactured onsite, inside the existing damaged pipe. The video above was recorded at a CIPP sewer pipe installation site where, after contractors inserted an uncured resin tube into the host pipe, steam was added to cure or harden the CIPP in place. Contractors injected steam into one end of the pipe and this material exited the latter end of the pipe and exiting the manhole shown above where it entered the environment/worksite. Environmental conditions and nearby traffic influenced the direction and size of the white chemical plume that was emitted.

Video S2. Video of chemical emission into the air from an uncured resin tube (used for CIPP) before curing

Video uploaded to ACS Manuscript submission system

Text Posted: This video was recorded as part of a National Science Foundation RAPID response research project (CBET-1624183) in July 2016. Cured-in-place-pipe (CIPP) technology is used to repair damaged sewer, storm water, and drinking water pipes. As part of the repair, a new plastic pipe is chemically manufactured onsite, inside the existing damaged pipe. The blue material seen in the video is an uncured resin tube. The video above was recorded at a CIPP installation site and shows a white substance being emitted from an uncured resin tube. The uncured resin tube is then inserted into a damaged pipe and then cured or hardened in place.

Video S3. Video of the uncured resin tube guided from a refrigerated truck into a sewer manhole for CIPP

Video uploaded to ACS Manuscript submission system

Text Posted: This video was recorded as part of a National Science Foundation RAPID response research project (CBET-1624183) in July 2016. Cured-in-place-pipe (CIPP) technology is used to repair damaged sewer, storm water, and drinking water pipes. As part of the repair, a new plastic pipe is chemically manufactured onsite, inside the existing damaged pipe. The blue material seen in the video is an uncured resin tube. The video above was recorded at a CIPP installation site and shows a substance emitted into the air while the uncured resin tube is removed from a refrigerated truck and guided into a sewer manhole below. Once inserted into the sewer pipe and positioned, the uncured resin tube was then cured or hardened in place.

Video S4. Video of a CIPP exhaust pipe emitting materials into the environment and worksite

Video uploaded to ACS Manuscript submission system

Text Posted: This video was recorded as part of a National Science Foundation RAPID response research project (CBET-1624183) in August 2016. Cured-in-place-pipe (CIPP) technology is used to repair damaged sewer, storm water, and drinking water pipes. As part of the repair, a new plastic pipe is chemically manufactured onsite, inside the existing damaged pipe. The video above was recorded at a CIPP installation site where, after contractors inserted an uncured resin tube into the host pipe, steam was added to cure or harden the CIPP in place. Contractors injected steam into one end of the pipe and this material exited the latter end of the pipe and then traveled through this EPDM plastic hose to where it entered the environment/worksite. This discharge point is located at the worksite.

Video S5. Video where a researcher walked by a CIPP exhaust pipe and his PID detected chemical exposure

Video uploaded to ACS Manuscript submission system

Text Posted: This video was recorded as part of a National Science Foundation RAPID response research project (CBET-1624183) in August 2016. Cured-in-place-pipe (CIPP) technology is used to repair damaged sewer, storm water, and drinking water pipes. As part of the repair, a new plastic pipe is chemically manufactured onsite, inside the existing damaged pipe. The video above was recorded at a CIPP installation site where, after contractors inserted an uncured resin tube into the host pipe, steam was added to cure or harden the CIPP in place. Contractors injected steam into one end of the pipe and this material exited the latter end of the pipe and then traveled through a plastic hose to where it entered the environment/worksite. A CIPP worker is stationed at the Exhaust Pipe monitoring the installation. The photoionization detector (PID) affixed to a Purdue researcher is shown at the bottom of the screen. As the Purdue researcher approaches the worker and Exhaust Pipe location where emissions are occurring, the Purdue researcher's PID signal increases. The signal represents the magnitude of chemical exposure experienced by the person as the person was wearing a real-time air monitoring device. The device readings and video footage have been linked to one another using EVADE video exposure monitoring software (http://www.cdc.gov).

S3.1 Indiana Investigation of Sanitary Sewer Pipes.

PID readings. Spot PID readings at the open refrigerated truck's back door were 72.4 ppm_v and 79.3 ppm_v. When the PID was placed on the pavement approximately 1.82 m from the manhole while the uncured resin tube was installed a maximum 77.7 ppm_v PID reading was observed. During steam curing, when a white chemical plume exited the downstream manhole, spot PID readings at nearby active sidewalks reached 19.5 ppm_v, but wind shifted and rapidly reduced this maximum signal to 0 ppm within 2 min. A spot PID reading of 514 ppm_v was recorded in the breathing zone about 4.5 m from the exhaust pipe during curing. When contractors started venting the CIPP, the PID signal from a location approximately 3.0 m from the downstream manhole (2.2ppm_v) increased to 52.8 ppm_v.

Table S4. Styrene (Confirmed) and List of Tentatively Identified Compounds Detected in the Tedlar Bag Sample Collected at the Indiana Site

RT, min.	Tentatively Identified Compound (TIC)	Similarity Index	Area	m/z	Area*, %
2.55	(Z)-2-Heptene	94	53,945,944	41	7.2
2.63	2-Heptene, (E)-	97	66,143,075	56	8.8
2.73	2-Heptene	97	18,821,568	56	2.5
2.81	2-Heptene	92	299,946	41	<0.1
3.19	1-Hexanol, 2-ethyl-	86	230,025	57	<0.1
3.36	3-Octene, (E)-	88	173,703	41	<0.1
3.42	Toluene	81	83,670	91	<0.1
3.49	Octanal	87	146,754	43	<0.1
4.46	2,4-Dimethyl-1-heptene	88	86,730	43	<0.1
4.76	Benzene, ethyl-	91	522,913	91	0.1
4.86	Heptane, 3-ethyl-	95	1,736,566	57	0.2
4.97	*N,N*-Dimethylacetamide	98	9,923,726	44	1.3
5.23	Styrene (confirmed with standard)	89	419,446,197	104	55.8
5.62	Benzene, (1-methylethyl)-	95	5,569,848	105	0.8
5.71	1,3,5,7-Cyclooctatetraene	88	122,212	104	<0.1
5.89	Benzene, 1-propenyl-	95	1,583,939	117	0.2
6.00	Benzene, propyl-	98	2,413,702	91	0.3
6.06	Heptane, 2,2,4,6,6-pentamethyl-		149742		<0.1
6.23	Pentane, 3-ethyl-2,2-dimethyl-		66886		<0.1
6.31	Phenol	93	2,861,046	94	0.4
6.36	Benzene, (1-methylethenyl)-	94	646,193	118	0.1
6.44	Undecane, 2,2-dimethyl		214,994		<0.1
6.48	Benzene, 1-propenyl-	93	561,691	117	0.1
6.55	Dodecane	82	70,657	43	<0.1
6.71	Benzene, (1-methylpropyl)-	88	1,054,450	105	0.1
6.83	Octane, 2,2-dimethyl-	94	2,522,918	57	0.3
6.92	Heptane, 2,2,4,6,6-pentamethyl-	95	1,334,137	57	0.2
6.96	*tert*-Butyl glycidyl ether	88	24,415,516	57	3.2
7.03	2,4-dimethyl-3-pentanol	88	1,486,567		0.2
7.06	Cyclohexanone, 3,3,5-trimethyl-	95	866,071	83	0.1
7.15	Dodecane, 4,6-dimethyl-	91	552,667	71	0.1
7.20	Pentane, 2,2,3,4-tetramethyl-	91	8,297,266	57	1.1
7.92	Pentane, 2,2,3,4-tetramethyl-	89	2,236,912	57	0.3
7.24	Hexane, 2,2,5-trimethyl-	91	2,784,190	57	0.4

(Table Continued)

RT, min.	Tentatively Identified Compound	SIM, %	Area	m/z	Area*, %
7.30	Undecane, 2,6-dimethyl-	92	8,405,959	57	1.1
7.34	Undecane, 2,2-dimethyl-	86	856,447	57	0.1
7.37	Undecane, 2,6-dimethyl-	90	1,138,972	57	0.2
7.41	Undecane,5-methyl-	92	403,215	57	0.1
7.45	Dodecane, 4,6-dimethyl-	92	11,121,542	71	1.6
7.51	Undecane, 2,6-dimethyl	91	804,680	57	0.1
7.57	Dodecane, 2,6,11-trimethyl-	92	3,329,807	71	0.4
7.69	Dodecane, 4-methyl-	92	3,310,417	71	0.4
7.77	Decane, 3-methyl-	92	648,003	57	0.1
7.81	Octane, 2,2-dimethyl-	90	1,081,405	57	0.1
7.88	Dodecane, 2,6,11-dimethyl	93	586,989	57	0.1
7.92	Pentane,2,2,3,4-tetramethyl	89	2,236,912		0.3
7.97	Undecane, 2,2-dimethyl-	92	3,851,513	57	0.5
8.11	2-Hydroxy-2-methyl-4-heptanone	82	55,034,610	71	7.3
8.31	Undecane, 3-methyl-	92	558,061	57	0.1
8.34	Decane, 2,2,3-trimethyl-	91	865,423	57	0.1
8.41	Octane, 3,6-dimethyl-	92	4,975,979	57	0.7
8.44	Octane, 2,2-dimethyl-	91	3,321,016	57	0.4
8.48	Decane, 1-iodo	90	1,121,860	85	0.1
8.71	Heptadecane	91	451,982	57	0.1
8.79	Undecane, 3-methyl-	92	190,060	57	<0.1
8.89	Undecane, 3-methyl-	92	144,370	57	<0.1
8.98	Undecane, 3-methyl	88	239,103	57	<0.1
9.01	3-Methyl tetradecane	88	189,352	57	<0.1
9.55	Hexadecane	90	197,902	71	<0.1
9.72	Tetradecane	87	67,601	57	<0.1
9.97	Dotriacontane	87	94,790	71	<0.1
14.29	Nonadecane	90	405,287	57	0.1
15.38	Nonasocane	92	803,372	57	0.1
16.27	Nonasocane	88	683,126	57	0.1
17.03	Heptasocane	82	577,602	207	0.1
17.71	Heptasocane	64	339,712	207	<0.1

*Results shown only represent chromatogram signals greater than 50,000 a.u.; The total area for the signals shown is 739,409,490; The total area of unidentified compounds is 12,843,661 implying 1.71% of their proportion in the chromatograph; Styrene peak on the chromatogram was confirmed with an analytical standard.

S3.2 California Investigation of Stormwater Pipes.

Site safety. The authors did not see CIPP workers using PPE such as respirators and earplugs. Some workers crouched or sat next to the white chemical plume emitted from the fugitive emission and also exhaust emission points. Contractors also walked through the plumes periodically. Workers monitored a pressure gage to determine when the workers at the boiler needed to inject more steam. Also observed was that contractors carried the uncured resin tube and cured CIPP with their bare hands.

Composition of uncured resin tubes. Compounds extracted from sites 1, 3, 4, and 5 were similar (**Table S5**). Methylene chloride extracted a greater number of compounds than hexane. The low-VOC uncured resin tube did not have a detectable amount of styrene, while styrene was present in all styrene based uncured resin tubes. Tripropylene glycol diacrylate (TPGDA), a known reactive acrylic diluent, was found in the low-VOC resin tube. Butyl hydroxyltoluene (BHT), an antioxidant, was found in a few uncured resin tubes, and benzaldehyde was only found in styrene based uncured resin tubes.

Table S5. Loading of compounds present in each uncured resin tube from Sacramento, California

Compound	Installation Site (Resin Type), mg Compound / g Resin				
	1 (L713)	**2 (EcoTek)**	**3 (L713)**	**4 (L713)**	**5 (L713)**
Methylene chloride extracts					
Styrene	52.85 ± 6.72 [b]	-	72.91 ± 4.39 [c]	66.23 ± 7.53 [c]	45.27 ± 9.47 [c]
BHT	5.33 [a]	>HCL	7.3 [a]	-	-
Benzaldehyde	1.65 [a]	-	1.69 ± 0.68 [c]	-	1.41 [a]
Hexane extracts					
Styrene	44.51 ± 6.69 [b]	<MRL [b]	61.35 ± 5.25 [c]	53.72 ± 3.63 [c]	49.26 ± 2.8 [c]
TPGDA	-	319.63 ± 24.29 [c]	-	-	-

Two resins were used for CIPP installations: L713-LTA (styrene based resin) and EcoTek (non-styrene based resin); Three replicate extractions were conducted for each uncured resin tube. Sometimes compounds were detected in some, but not all, replicates. The number of replicates where compounds were detected are denoted by the use of roman numerals: a: 1 replicate; b: 2 replicates; c: 3 replicates. Lowest concentration minimum reporting level (MRL) on calibration curve: styrene (in hexane): 1.208 ppm, styrene (in methylene chloride): 0.241 ppm, Benzaldehyde: 20.88 ppb, BHT: 43.52 ppb, Highest concentration maximum reporting level (HCL) on calibration curve: Styrene (methylene chloride) = 2.47

ppm, BHT: 195.8 ppb. For the installation 1 hexane extraction, one replicate resulted in zero compounds detected.

Meteorological conditions. Meteorological conditions during the CIPP heat up, curing, and cool down periods are described in **Table S6**. The wind speed was greatest at sites 3 and 4. The highest detected wind speed on this day was 7 mph, while the highest wind speed overall was 8 mph, which occurred at site 2 (low VOC CIPP). As an overall trend, both humidity and temperature increased during the day, while pressure decreased slightly. The average value of the period is found within the cell. The values in the parentheses represent the minimum and maximum values within that same period.

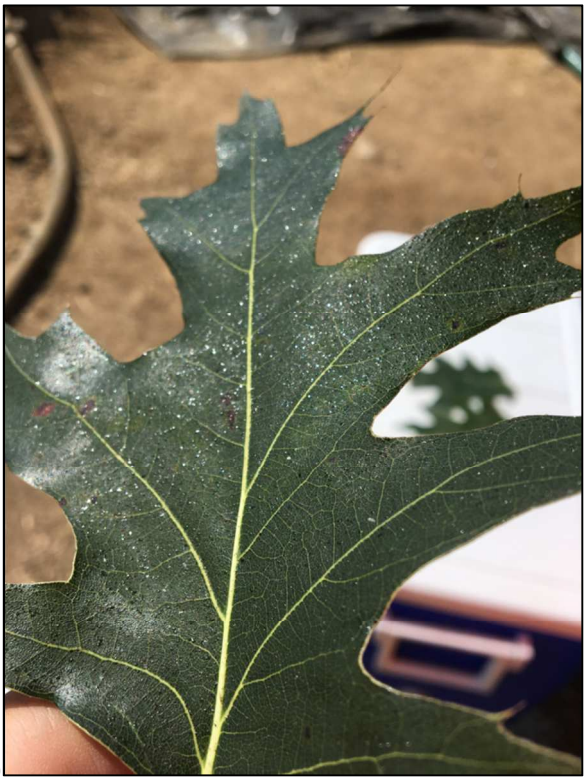
(a)  (b) 

Figure S3. Images of (a) exhaust emission point and (b) Oak tree leaf directly above the exhaust emission hose that was exposed the white chemical plume at the California site. White material seen on the leaf surface and was not found on unexposed leaves.

Table S6. Overview of average meteorological conditions at CIPP installation sites

Site (Resin Type) and Date	Sampling Period (Time)	Temp (°F)	Temp (°C)	Humidity (%)	Barometric Pressure (Hg)	Barometric Pressure (Torr)	Predominant Wind Direction	Wind Speed (mph)	Number of Data Points
1 (L713) 8/9/2016	heat up (8:26-10:12)	70.254 (66.5 - 74.4)	21.252 (19.167-23.556)	59.99 (52-68)	29.774 (29.77 - 29.777)	756.261 (756.160 - 756.337)	E	2.430 (0 - 5)	106
	curing (10:12- 11:44)	79.263 (74.5 - 83.7)	26.257 (23.611 - 28.722)	46.94 (37 - 61)	29.776 (29.772 - 29.78)	756.312 (756.210 - 756.414)	NNW	1.848 (0 - 4)	92
	cool down (11:45-12:29)	85.740 (83.8 - 87.3)	29.856 (28.778 - 30.722)	35.53 (34 - 38)	29.767 (29.762 - 29.772)	756.083 (755.956 - 756.210)	NNW	2.044 (1 - 5)	44
	overall (8:26- 12:29)	**76.507 (66.5 - 87.3)**	**24.726 (19.167 - 30.722)**	**50.56 (34 - 68)**	**29.773 (29.762 - 29.78)**	**756.236 (755.956 - 756.414)**	**ENE**	**2.139 (0 - 5)**	242
2 (EcoTek) 8/9/2016	heat up (13:12 - 14:12)	90.677 (88.9 - 92.1)	32.598 (31.611 - 33.389)	27.93 (25 - 32)	29.744 (29.733 - 29.753)	755.499 (755.220 - 755.728)	NNW	2.333 (0 - 5)	60
	curing (14:12 - 16:03)	94.622 (91.3 - 96.6)	34.790 (32.944 - 35.889)	23.96 (19 - 31)	29.714 (29.695 - 29.733)	754.737 (754.255 - 755.220)	NW	2.473 (1 - 8)	81
	cool down (16:03 - 17:19)	96.575 (95.3 - 97.9)	35.875 (35.167 - 36.611)	18.18 (16 - 24)	29.689 (29.684 - 29.699)	754.102 (753.975 - 754.356)	SW and NW*	2.658 (0 - 7)	76
	overall (13:12 - 17:19)	**94.266 (88.9 - 97.9)**	**34.592 (31.611 - 36.611)**	**23.15 (16 - 32)**	**29.714 (29.684 - 29.753)**	**754.737 (753.975 - 755.728)**	**NW**	**2.496 (0 - 8)**	217
3 (L713) 8/10/2016)	heat up (7:12 - 8:34)	66.742 (64 - 69.1)	19.301 (17.778 - 20.611)	65.9 (62 - 71)	29.809 (29.796 - 29.822)	757.150 (756.820 - 757.480)	S	3.988 (2 - 6)	82
	curing (8:34 - 10:17)	72.630 (69.2 - 75.8)	22.572 (20.667 - 24.333)	60.55 (54 - 76)	29.822 (29.82 - 29.826)	757.480 (757.430 - 757.582)	S	3.786 (2 - 6)	103
	cool down (10:17 - 10:44)	76.956 (76 - 78.1)	24.976 (24.444 - 25.611)	50.85 (49 - 55)	29.829 (29.825 - 29.832)	757.658 (757.557 - 757.734)	SW	3.037 (1 - 5)	27
	overall (7:12 - 10:44)	**70.884 (64 - 78.1)**	**21.602 (17.778 - 25.611)**	**61.41 (49 - 71)**	**29.818 (29.796 - 29.832)**	**757.379 (756.820 - 757.734)**	**S**	**3.770 (1 - 6)**	212
4 (L713) 8/10/2016	heat up (12:04 - 12:53)	86.342 (83.9 - 88.7)	30.190 (28.833 - 31.5)	37.48 (33 - 41)	29.820 (29.814 - 29.826)	757.430 (757.277 - 757.820)	SW	3.813 (1 - 7)	49
	curing (12:53 - 14:33)	91.236 (88.3 - 93.9)	32.909 (31.278 - 34.389)	30.91 (26 - 45)	29.806 (29.793 - 29.815)	757.074 (756.744 - 757.303)	SW	3.733 (0 - 6)	100
	cool down (14:33 - 15:30)	94.753 (93.2 - 96.2)	34.863 (34 - 35.667)	25.39 (24 - 29)	29.787 (29.779 - 29.791)	756.591 (756.388 - 756.693)	SW	3.263 (1 - 7)	57
	overall (12:04 - 15:30)	**91.068 (83.9 - 96.2)**	**32.816 (28.833 - 35.667)**	**30.91 (24 - 45)**	**29.804 (29.779 - 29.826)**	**757.023 (756.388 - 757.820)**	**SW**	**3.621 (0 - 7)**	206
5 (L713) 8/11/2016	heat up (8:00 - 8:16)	63.956 (63.6 - 64.5)	17.753 (17.556 - 18.056)	71.69 (71 - 72)	29.920 (29.917 - 29.923)	759.970 (759.893 - 760.046)	SW	2.313 (0 - 4)	16
	curing (8:16 - 10:00)	68.920 (64.6 - 72.9)	20.511 (18.111 - 22.722)	68.17 (59 - 87)	29.930 (29.923 - 29.934)	760.224 (760.046 - 760.325)	SSW	2.375 (0 - 4)	104
	cool down (10:00 - 10:17)	73.724 (73.1 - 74)	23.180 (22.833 - 23.333)	58.41 (56 - 71)	29.929 (29.928 - 29.932)	760.198 (760.173 - 760.274)	SSE and SSW*	2.765 (1 - 4)	17
	overall (8:00 - 10:17)	**68.936 (63.6 - 74)**	**20.520 (17.556 - 23.333)**	**67.37 (56 - 87)**	**29.929 (29.917 - 29.932)**	**760.198 (759.893 - 760.274)**	**SSW**	**2.416 (0 - 4)**	137

Daily Averages at Sacramento Airport according to Weather Underground	Day 1 - 08/09/2016	76.00	24.444	51.00	29.770	756.160	SSW	5
	Day 2 - 08/10/2016	75.00	23.889	52.00	29.820	757.430	SSW	7
	Day 3 - 08/11/2016	75.00	23.889	55.00	29.920	759.970	SSW	6

S4. REFERENCES SPECIFIC TO THE SUPPORTING INFORMATION

(1) Whelton AJ. Direct involvement in investigating CIPP caused indoor air contamination incident on University campus with University safety department during sewer pipe rehabilitation. July 2016. West Lafayette, Indiana.

(2) *The VOICE*, Good Hope overcoming recent water/sewer issues. Langhout, M. June 16, 2016. Macomb, IL. http://www.mcdonoughvoice.com/news/20160616/good-hope-overcoming-recent-watersewer-issues (Accessed July 1, 2017)

(3) *Wisconsin State Journal,* Strong chemical odor on East Side was non-toxic, fire department says. Novak, B. November 17, 2011. Madison, WI. http://host.madison.com/wsj/news/local/crime-and-courts/strong-chemical-odor-on-east-side-was-non-toxic-fire/article_c78a3b80-cf9f-5ea6-8851-c905bbeb6236.html (Accessed July 1, 2017)

(4) *Times Union*, Bethlehem installing new sewer lines without digging. Rulison, L. March 7, 2016. Albany, NY. http://blog.timesunion.com/bethlehem/9270/bethlehem-installing-new-sewer-lines-without-digging/ (Accessed July 1, 2017)

(5) *WKBW,* Homeowners Complain of Odor From Sewer Work. Touhey, A. March 22, 2016. Buffalo, NY. http://www.wkbw.com/news/odor-bothers-some-homeowners-in-cheektowaga (Accessed June 30, 2017)

(6) *BBC News*, Cornwall family suffer suspected styrene poisoning in own home. March 8, 2016. London, U.K. http://www.bbc.com/news/uk-england-cornwall-35754165 (Accessed July 1, 2017)

(7) Schmidt, J. SUBJECT: styrene complaints. Email from J Schmidt, RK&K to Keith Eysaman, RK&K. April 14, 2016a. Emailed to City of Alexandria, Mary Martin from Keith Eysaman, RK&K April 14, 2016. Obtained by FOIA request to City of Alexandria, VA USA.

(8) Schmidt, J. SUBJECT: styrene complaints. Email from J Schmidt, RK&K to Mary Martin, City of Alexandria. April 14, 2016b. April 14, 2016. Obtained by FOIA request to City of Alexandria, VA USA.

(9) Martin, M. SUBJECT: Styrene Complaint – 28 Mt. Vernon Ave. Email from Mary Martin, City of Alexandria to Mitchell Burnstein, City of Alexandria. May 9, 2016. Obtained by FOIA request to City of Alexandria, VA USA.

(10) *Buffalo News*, Stink along Walck Road in North Tonawanda is expected to linger for weeks. Fischer, NA. September 20, 2016. Buffalo, NY. http://buffalonews.com/2016/09/20/stink-near-former-durez-site-causes-concern-in-north-tonawanda/ (Accessed July 3, 2017)

(11) Gagnon, S. Research on styrene release from CIPP. *Personal Communication.* January 24, 2015. Montreal, Quebec, CAN.

(12) *Picayune Item*, Work to line old wastewater lines creates smell, but is considered safe. Pittari, J. June 2, 2015. Picayune, MS. http://m.picayuneitem.com/2015/06/work-to-line-old-wastewater-lines-creates-smell-but-is-considered-safe/ (Accessed July 1, 2017)

(13) *KLKN-TV*, Homeowners evacuated after chemical leak. June 6, 2015. Fili, S. Lincoln, NB. http://www.klkntv.com/story/29486797/homeowners-evacuated-after-chemical-leak (Accessed July 1, 2017)

(14) *CBC News*, Chemical odour leads to Hintonburg home evacuations: Businesses raise a stink after sewer work brings styrene smell to their doors. February 12, 2015. Ottowa,

CAN. http://www.cbc.ca/news/canada/ottawa/chemical-odour-leads-to-hintonburg-home-evacuations-1.2955145 (Accessed July 1, 2017)
(15) *Ottawa Citizen,* Residents, businesses raise stink about Wellington West sewer fixes. Spears, T. February 13, 2015. http://ottawacitizen.com/news/local-news/residents-businesses-raise-stink-about-wellington-west-sewer-fixes (Accessed July 1, 2017)
(16) Coquina Key Property Owners Association (CKPOA). Strong chemical odor coming from sewer pipes. December 15, 2015. *City of St. Petersburg, FL Mayors Action Center.* https://en.seeclickfix.com/issues/2106914-strong-chemical-odor-from-sewer-pipes (Accessed July 1, 2017)
(17) *WSAW-TV*, Antigo family says nearby sewer repair is making them ill. Linder, L. October 21, 2015. Wausau, WI. http://www.wsaw.com/home/headlines/Antigo-family-says-nearby-sewer-repair-is-making-them-ill-335297801.html (Accessed July 1, 2017)
(18) Bernstein, M. Subject: Please Respond- Peagram-Strawberry Hill Sewer Project. Email to Resident Ahmad. Friday, June 5, 2015. Obtained by FOIA request to the City of Alexandria, VA USA.
(19) Petry, B. SUBJECT: RE: [wakefield-tarleton] Sanitary Sewer Line-Curing Process. Email from Resident to Homeowner Association Listserve and cc to City government. May 28, 2015. City of Alexandria, VA USA.
(20) Ahmad, A. SUBJECT: [wakefield-tarleton] Fumes related to sanitary sewer project. Email from Resident to Homeowner Association Listserve. May 27, 2015. Obtained by FOIA request to the City of Alexandria, VA USA.
(21) Roll, J. SUBJECT: RE: Customer Complaint-PM6003A11-TO8-Sheet 18-Layne. Email from Joshua Roll, Systems Inspection Group, WSSC to WSSC staff. October 15, 2015a. Obtained by FOIA request to Washington Sanitation Suburban Commission, Laurel, MD USA.
(22) Roll, J. SUBJECT: RE: Customer Complaint-PM6003A11-TO8-Sheet 18-Layne. Email from Joshua Roll, Systems Inspection Group, WSSC to Brandon Stewart, WSSC. October 15, 2015b. Obtained by FOIA request to Washington Sanitation Suburban Commission, Laurel, MD USA.
(23) *NEWS10,* Neighbors displaced after chemical reaches homes in Rensselaer. Nielsen, L. February 2, 2015. Albany, NY. http://news10.com/2015/02/02/neighbors-displaced-after-chemical-reaches-homes-in-rensselaer/ (Accessed July 1, 2017)
(24) *The Record,* Botany sewer project in Clifton nears end. Gicas, T. April 3, 2015. Woodland Park, NJ. http://archive.northjersey.com/news/botany-sewer-project-nears-end-1.1302021?page=all (Accessed July 1, 2017)
(25) *Riverfront Times,* Hey Dogtown, This is Why Your Sewers Smell Awful (Hint: It's Not Poop). Wicentowski, D. December 16, 2014. St. Louis, MO. http://www.riverfronttimes.com/newsblog/2014/12/16/hey-dogtown-this-is-why-your-sewers-smell-awful-hint-its-not-poop (Accessed July 1, 2017)
(26) Braun, S.J. CIPP Fumes Enter Homes; *Personal Communication*: Prairie Village, KS, 2014.
(27) *Chemical Hazards and Poisons Report*, Public Health England, the Centre for Radiation, Chemical and Environmental Hazards: London, UK, September 2014. Issue 24. https://www.gov.uk/government/publications/chemical-hazards-and-poisons-report-issue-24 (Accessed July 1, 2017)

(28) Ashton, T. *Health Risks Associated with CIPP Odor*; Personal Communication: Baltimore, MD, October 29, 2014.
(29) Swanson, S. CIPP Environmental Question; *Personal Communication*: IL, 2014.
(30) Stewart, B. SUBJECT: Customer Complaint/Customer complains about chemical odor from nearby sewer work happening behind his house. Email from Glen Diaz, Utility Management Group. October 14, 2015. Obtained by FOIA request to Washington Sanitation Suburban Commission, Laurel, MD USA.
(31) Haynes, K. CIPP Fumes Exposure and its Affect on Children in a Home where CIPP Fumes Backed up and Resulted in a Hospital Visit; *Personal Communication*: Philadelphia, PA, 2013.
(32) *WSMV,* East Nashville neighborhoods concerned about smell from steam. Sept. 24, 2014, Nashville, TN. http://www.wsmv.com/story/26620714/east-nashville-neighborhoods-concerned-about-smell-from-steam (Accessed July 11, 2017)
(33) *The Post Standard,* Fayetteville resident worries sewer repairs are exposing residents to toxic chemicals; village says work is safe. Doran, E. March 1, 2012. Syracuse, NY. http://www.syracuse.com/news/index.ssf/2012/03/fayetteville_resident_worries.html (Accessed July 1, 2017)
(34) Woods, J. Family exposed to styrene, home had to be decontaminated with health department insistence. *Personal Communication.* June 28, 2014. Brisbane, Australia.
(35) Bauer, G. (2012). Styrene: An overview—An awareness. *Presentation for the Underground Infrastructure Research Int. Conf. and Trenchless Technology Road Show, Center for Advancing Trenchless Technology*, Waterloo, ON.
(36) Sullo, A. (2012). King Street sewer rehab and water quality impacts. *Presentation at Underground Infrastructure Research Int. Conf. and Trenchless Technology Road Show, Center for Advancement of Trenchless Technologies*, Waterloo, ON CAN.
(37) *Worcester Telegram and Gazette*, Worcester day care center evacuated. Dayal, P. Oct. 28, 2011. Worcester, MA. http://www.telegram.com/article/20111028/NEWS/111029554/1116 (Accessed July 1, 2017)
(38) *St. Cloud Times*, Marohn, K. Hazardous Material Sits since October. March 13, 2011. St. Cloud, MN.
(39) *St. Cloud Times*, Marohn, K. Cleanup to Begin at Site of October Resin Accident. March 31, 2011. St. Cloud, MN.
(40) *St. Cloud Times*, Marohn, K. Cleanup Work on Months-Old Resin Spill is Underway. April 8, 2011. St. Cloud, MN.
(41) *The Times Herald,* Stench brings alarm, no apparent danger. Shepard, L. October 11, 2011. Norristown, PA.
(42) *The Times Herald,* No change yet for stench from sewer repairs. Shepard, L. October 28, 2011. Norristown, PA.
(43) *Birmingham Patch,* UPDATE: Seaholm Students Dismissed Early After Foul Odor Sickens Kids. Houser, L. October 6, 2011. Birmingham, MI. http://www.birmingham.patch.com/articles/Seaholm-students-dismissed-early-after-foul-odor-sickens-kids (Accessed July 1, 2017)
(44) *MLive.* Foul odor sickens students, leads to cancelled classes at Birmingham Seaholm High School. Associated Press. October 6, 2011. http://www.mlive.com/news/detroit/index.ssf/2011/10/foul_odor_sickens_students_lea.html (Accessed July 1, 2017)

(45) *WXYZ-TV Channel 7*, Birmingham Seaholm High School dismissed students early due to noxious gas in school. Banovic, J. Oct. 6, 2011. Southfield, MI.
(46) *DOWNTOWN,* Styrene. Brody, L. November 21, 2011. Birmingham, MI. http://www.downtownpublications.com/pdalpeditorial.lasso?-token.story=210208.112113 (Accessed July 1, 2017).
(47) *Wicked Local.com*, Veterans School Reopens Thursday. Gaffnery, M. October 26, 2011. Danvers, MA. http://saugus.wickedlocal.com/x1626909690/Saugus-Veterans-School-evacuated-for-odor, (Accessed July 1, 2017).
(48) *Odor Assessment: Veterans Memorial Elementary School*, Massachusetts Department of Public Health, Bureau of Environmental Health Indoor Air Quality Program. February 2012. http://www.mass.gov/eohhs/docs/dph/environmental/iaq/2012/saugus-veteran-memorial-school-odor-february-2012.pdf (Accessed July 1, 2017).
(49) *Valley News Dispatch*, Bad smell keeps New Kensington-Arnold students out of doors. Hayes, L.; Biedka, C. September 29, 2011. Pittsburgh, PA. http://triblive.com/x/valleynewsdispatch/s_759303.html (Accessed July 1, 2017).
(50) Stasinos, G. SUBJECT: FW: Alert message. Email to Ann Nedrow of Colorado Department of Public Health and Environment (CDPHE). February 09, 2011 2:46 PM. Denver, CO.
(51) *Environmental Release and Incident System Report 2011-0066*; Colorado Department of Public Health and Environment (CDPHE); Denver, CO, February 8, 2011.
(52) *Letter to the Department of Transportation's Joint Budget Committee Hearing Responses from Executive Director Don Hunt*; Colorado Department of Transportation (CDOT). Denver, CO, January 5, 2012.
(53) *Log of styrene incident, March 2012,* Public Health England, Centre for Radiation, Chemical and Environmental Hazards. March 16-21, 2012. Provided by Environmental Public Health Scientist, Birmingham, Manchester, U.K.
(54) *The Blade,* Sewer work fumes blamed for sickness in Montpelier. Boyd-Barrett, C. November 12, 2010. Toledo, OH. http://www.toledoblade.com/local/2010/11/12/Sewer-work-fumes-blamed-for-sickness-in-Montpelier.html (Accessed July 1, 2017).
(55) *KPAX–Missoula*, Sewer project blamed for Helena building evacuation. Banks, M. October 1, 2011, Missoula, MT. http://www.kpax.com/news/sewer-project-blamed-for-helena-building-evacuation/ (Accessed July 1, 2017).
(56) *Independent Record,* Odorous gas hits downtown again. Kline, L. January 20, 2010. Helena, MT. http://www.helenair.com\news\local\article_6d95e828-058d-11df-b4c6-001cc4c002e0.html (Accessed July 1, 2017).
(57) *Independent Record,* Smelly gas begins to dissipate. Kline, L. January 20, 2010. Helena, MT. http://helenair.com/news/smelly-gas-begins-to-dissipate/article_d305a00e-00d3-11df-8a80-001cc4c002e0.html (Accessed July 1, 2017).
(58) *The Plain Dealer,* Some in Lorain County lake community complain of chemical odors from sewer rehab work. Scott, M. September 28, 2010. Cleveland, OH. http://blog.cleveland.com/metro/2010/09/some_in_lorain_county_lake_com.html (Accessed July 1, 2017).
(59) *ARLnow,* Sewer Work Prompts Numerous Fire Department Calls. Local News Now, LLC. November 23, 2010. Arlington, VA. https://www.arlnow.com/2010/11/23/sewer-work-prompts-numerous-fire-department-calls/ (Accessed July 1, 2017).

(60) *Environmental Effects of Cured-In-Place Pipe Repairs*. CTC Associates, LLC, 2012.: Prepared for: California Department of Transportation, Sacramento, CA.
(61) Washington State Department of Ecology (WSDOE). Contractor fined for Bellevue chemical spill; warning issued to transportation agency. February 8, 2010. *Press Release*, Olympia, WA. https://listserv.wa.gov/cgi-bin/wa?A2=ind1002b&L=ECOLOGY-NEWS&P=72 (Accessed July 1, 2017).
(62) *Seattle PI,* Company fined for Bellevue chemical spill. Stang, J. February 7, 2010. Seattle, WA. http://www.seattlepi.com/local/article/Company-fined-for-Bellevue-chemical-spill-888654.php (Accessed July 1, 2017).
(63) *WPXI-TV,* Strong-Smelling Styrene Forces Avalon Apartment Bldg. Evacuation. Pittsburgh, PA, 2009.
(64) *Des Moines Register,* Foul odor blamed on sewer repairs. Section B.2. Gannett Co., Inc. November 11, 2009. Des Moines, IA. http://desmoinesregister.newspapers.com/image/131611964/?terms=Foul%2Bodor%2Bblamed%2Bon%2Bsewer%2Brepairs (Accessed July 1, 2017).
(65) *The Harvard Crimson,* Toxic release prompts Allston residents to question risks of Harvard construction—Residents say that they are concerned about future accidents from construction as Harvard builds massive new campus. Moore, L.A. August 13, 2008. http://www.thecrimson.com/article/2008/8/13/toxic-release-prompts-allston-residents-to/ (Accessed July 1, 2017).
(66) *Technical Assistance, Gwinnett County Styrene Inhalation March 29, 2007*, Georgia Department of Community Health, Chemical Hazards Program, Environmental Branch. Atlanta, GA. 2007. https://dph.georgia.gov/sites/dph.georgia.gov/files/EnvHealth/Chemical/Sites/GwinettStyreneInahalation%28TA%2907.pdf (Accessed July 1, 2017).
(67) *County Gazette,* Drain repairs cause a stink. Wills, J. December 11, 2007. Taunton, U.K. http://www.somersetcountygazette.co.uk/news/1895931.drain_repairs_cause_a_stink/ (Accessed July 1, 2017).
(68) *NY Daily News,* DEP dumps pine deodorizer to cover smell from Brooklyn pipe project. Lysiak, M. December 3, 2007. New York, NY. http://www.nydailynews.com/news/dep-dumps-pine-deodorizer-cover-smell-brooklyn-pipe-project-article-1.271380 (Accessed July 1, 2017).
(69) Shea, S. *Trenchless Rehabilitation of Large Brick Conduits in Boston*, Proceedings of the ASCE Pipelines Conference: Advances and Experiences with Trenchless Pipeline Projects, 2007; p 1-11.
(70) Bauer, G.; McCartney, D. (2004). Odour control—More than sewage when installing cured–in–place sewer pipe. *Proceedings of the North American Society for Trenchless Technology (NASTT) NO–DIG Conf.* PaperD–3–02, Liverpool, NY, p 1-10.
(71) *Washington Post,* Fumes from Va. sewer work cited in illnesses: Alexandria officials reevaluating effects of styrene vapor on residents. Gowen, A. May 12, 2004. Section B08. Washington, D.C. http://www.washingtonpost.com/wp-dyn/articles/A19262-2004May11.html (Accessed July 1, 2017).
(72) US Agency for Toxic Substances and Disease Registry (ATSDR), Division of Health Assessment and Consultation, US Department of Health and Human Services. *Health Consultation, Schlitz Park Office Building, Milwaukee, Milwaukee County, Wisconsin*. September 13, 2005. Atlanta, GA.

https://www.atsdr.cdc.gov/HAC/pha/Schlitz%20Park%20Office%20Building/SchlitzParkHC091305.pdf (Accessed July 1, 2017).
(73) Insituform Technologies, Inc. *Impregnated Insitutube® Product Material Safety Data Sheet.* Chesterfield, MO. 2005.
(74) AOC, LLC. *102 TA Filled Polyester Resin, Production Information Sheet.* Collierville, TN. 2005.
(75) AOC, LLC. *Vipel® L713-LTA Series Polyester Resin, Production Information Sheet*; AOC, LLC: Collierville, TN. 2008.
(76) AOC, LLC. *L713-LTA-12 polyester resin, Material Safety Data Sheet.* Collierville, TN. 2007.
(77) AOC, LLC. *EcoTek™ L040-TNVG-33 Vinyl Ester Resin, Production Information Sheet*. Collierville, TN. 2010.