Table 1. List of water contamination incidents associated with CIPP related to pipe repairs and sanctioned storm sewer field studies not including New York and Virginia field testing results from the present study

Location (Reference)	Activity Type	Description	Curing Process; Resin Type
Pennsylvania (Walmer 2019; PA DEP 2019a; PA DEP 2019b)	Incident	More than 300 fish killed (250+ trout) and 75+ other fish; Odor of airplane glue in stream, testing initiated by the Pennsylvania Fish and Boat Commission and Pennsylvania Department of Environmental Protection, investigation ongoing at the time this report was complete; A maximum of 28.7 ug/L styrene was detected for the 5 samples collected; Sample water temperature approximately 18˚C; Time of spill/initial contamination were not reported; A notice of violation (NOV) was issued to the Borough of Carlisle (infrastructure owner) with pending enforcement action because this pollutant release violated state law.	Hot water; Styrene resin
California (Currier 2017)	Field study	Styrene was found leaching from both of styrene and non-styrene CIPPs. A low level of styrene leached from CIPP into simulated storm water; water flow through the pipe should be delayed at least 96 hours after CIPP installation. Other leached chemicals such as acetone, isopropyl benzene, *tert*-butyl alcohol, *n*-propyl benzene, toluene, xylenes, 1,2,4-trimethylbenzene, and 1,3,5-trimethylbenzene were also found.	Steam; Styrene and non-styrene resins
Georgia (UGA 2016)	Incident	CIPP contractors released chemicals into a waterway causing odor on university campus; Styrene and a variety of other CIPP associated compounds were detected in water.	Not reported; Not reported
Alabama (Tabor et al. 2014)	Field study	7.4 mg/L styrene downstream of culvert; Condensate was from steam- CIPP (at room temperature) dissolved test organisms within 24 hours; A variety of non-styrene compounds were found leaching from the CIPP for 30 days; *D. magna* toxicity testing showed non-styrene compounds were responsible for 48 hours acute toxicity	Steam; Styrene resin
California (Renda 2013)	Incident	Styrene leaked during CIPP repair at highway 49 sinkhole; Odor was first detected by nearby resident; Styrene leak contaminated the soil and the tributary to Wolf Creek; The stream was diverted to prevent possible contamination to the Creek, and no chemicals reported to be found in the Creek.	Not reported; Not reported
Vermont (VTDEC 2013)	Incident	Resident complained about water of Sherman Brook, highest concentration of styrene level of 5,160 mg/L found 225 ft below the culvert on the day of CIPP installation; Styrene level remained up to 0.08 mg/L 70 days after the installation; Acetone, 1,2,4-trimethylbenzene, 1,3,4-trimethylbenzene, and *tert*-butanol were also detected. State DOT and Environmental Agencies responded.	Steam; Styrene resin
Oregon (Fletcher & Trevis 2013)	Incident	CIPP was installed in a storm water culvert using steam curing; 174 mg/L styrene was reported.	Not reported; Not reported
Oregon (CTC 2012)	Incident	Contractor discharged steam cured CIPP waste to the Willamette River; "Styrene levels were so high that the responder had to wear a respirator to collect samples."	Not reported; Not reported
Colorado (CDOT 2011)	Incident	Styrene and other organic chemicals released to the Clear Creek Watershed, and passed through a drinking water intake, and contaminated water was distributed to a community; The maximum styrene level of 18 mg/L in water was found and styrene was found in soil at 14 mg/kg; Other compounds associated with CIPP installations were also detected. State DOT, Public Health, and Environmental Agencies responded.	Steam; Styrene resin
Minnesota (Marohn 2011)	Incident	Odor caused by the resin spill prompted building evacuations; Residual remained for five months. No water testing data were found.	Not reported; Not reported
Canada (Ministry of Transp. 2011)	Incident	Moratorium instituted; fish kill investigated due to CIPP activity; No water testing data were found.	Not reported; Not reported

(continued…)

Location (Reference)	Activity Type	Description	Curing Process; Resin Type
Alabama (NRC 2010)	Incident	More than 70,000 gallons of CIPP wastewater dumped into creek bed along with concentrated styrene from CIPP storm water culvert relining. Found 143 mg/L styrene in water; Residents complained drinking water from a local well had odor; Vapors originating from faucets reportedly made residents ill, 4 mg/L styrene levels were reported at building faucets and the health-based drinking water limit was 0.1 mg/L (EPA MCL); Incident recorded at the National Response Center; Styrene water testing results were only reported.	Not reported; Styrene resin
Virginia (Lee 2008)	Field study	3 CIPPs installed using water inversion, air inversion, pull-in-place and each was manufactured with either hot water, steam, or UV light; Styrene was tested for and found during liner inversion (0.004 mg/L), during hot water recirculation (max. 51 mg/L); When the new CIPPs were flushed 19 mg/L was found for the hot water-CIPP, 5.5 mg/L was found for the steam-CIPP. No styrene was reported for the UV CIPP, but the method detection limit wasn't reported.	Steam, hot water, UV; Styrene resin
Virginia (Donaldson 2009)	Field study	More than 77 mg/L styrene found in storm water after CIPP installation was completed.	Steam; Styrene resin
Florida (Donaldson 2009)	Incident	Uncured resin was released into a storm drain during CIPP installation, and a fish kill was found.	Not reported; Not reported
New York (O'Reilly 2008)	Field study	Hot water was discharged into a creek and was associated with a CIPP storm sewer culvert installation; Only styrene data was reported and styrene (130 mg/L) was detected.	Hot water; Styrene resin
West Virginia (Spiniello 2008)	Incident	A styrene concentration of 117 to 446 mg/L in cure water was found at Marmet Locks, WV. The styrene levels found in another CIPP liner wastewater were 75 to 83 mg/L; However, "the levels were 14 hours into the cool down process which used cool water to dilute the water"; "The styrene molecules present in the resin are smaller than molecules comprising the polyurethane membrane. Therefore, as the liner is cured the water temperature is raised and the styrene molecules begin to migrate through the polyurethane into the cure water"; "No controls are expected due to the specifications lacking the appropriate language that the contractor must follow and no inspections are enforced. Specifications spell out mechanical properties and other standards they must follow but there is a lack of environmental controls as in other industries using hazardous materials"	Hot water; Styrene resin
Unknown (Lockheed Martin 2007)	Incident	About 11.3 to 15.1 L of uncured resin was released into a storm sewer during CIPP installation; More than 5,500 fish were killed. 100 mg/L styrene detected downstream.	Not reported; Not reported
Canada (Gerrits 2007)	Incident	Water was discharged into nearby tributary and a fish kill found; Only styrene data were found and styrene was estimated to be present in water at 2 to 85 mg/L.	Not reported; Not reported
Connecticut (GESI 2004)	Incident	Water and resin from a CIPP installation was released to from the installation site and retention pond; An estimated 18.1 to 73.0 kg of wastewater was released; 0.0291 mg/L styrene concentration was detected in the water sample which was collected 12 days after the installation.	Not reported; Not reported

NOTES: The Pennsylvania (2019) and West Virginia (2008) incidents were not found until after the Ra et al. (2018) paper was published.