VOC Fate in Water Systems

Discussion to Support the Water Systems Task Force

11:30 AM EST (8:30 AM PST)
March 4, 2019

Convener: Andrew Whelton, awhelton@purdue.edu
Caitlin Proctor, Juneseok Lee, Amisha Shah
Purdue University & Manhattan College

CALL IN INFO

Time: Mar 4, 2019 11:30 AM Eastern Time (US and Canada)

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Agenda

5 min	Review of some PID water contamination data
5 min	Purdue's work on building plumbing and plastics
5 min	EPA's work relating water systems
45 min +	Open discussion

Only a few slides will be touched upon by Purdue/EPA. Other slides provided for background.

KEY TERMS
PID = Paradise Irrigation District
VOCs = Volatile organic compounds
SVOCs = Semi-volatile organic compounds

Review of some PID water contamination data

Andrew Whelton, awhelton@purdue.edu
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Review of PID's Water Contamination Data:

Let's First Compare PID and the City of Santa Rosa Fire Damage Areas

Fire Impact Characteristics	PID, 2018 Camp Fire	City of Santa Rosa, 2017 Tubbs Fire
# of People	26,032	932 (35 in standing homes)
# of Service Lines	10,480	542 (13 remained)
Types	HDPE, copper, PB	HDPE, copper, PB
Water Mains, miles	172	5.2
Types	PVC (35%), Steel (33%), CML (19%), AC (10%), Irons (6%)	PVC (85%), AC (15%)
# of Hydrants	1,400	64
Storage Tanks	6 for 10 Million Gallons	0
Pump Stations	1 of 1	0

Santa Rosa serves 175,155 people. Less than 0.5% were affected by the Tubbs Fire

Review of PID's Water Contamination Data:

So far benzene has exceeded the drinking water limit, but PID results are too limited to predict the future

Chemical Detected	PID as of Feb. 13		DDW 1 sample in PID	City of Santa Rosa as of Feb. 23	
	n	Max		*n*	Max
Benzene	118	**410**	**2,217**	8,222	**40,000**
Naphthalene	35	278	**693**	661	**6,800**
Styrene	35	30.0	**378**	6,062	**460**
TBA (NL)	**0**	-	-	339	**29**
Toluene	35	90	**676**	8,222	**1,130**
Vinyl chloride	35	ND	-	6,062	**16**

CA Notification levels (NL): health-based advisory levels established by DDW for chemicals in drinking water that lack maximum contaminant levels (MCLs).

- Santa Rosa: Highest levels typically found at meters
- PID: Not many meter samples yet

TBA, tert-butyl alcohol has a health based drinking water limit, is an EPA Method 524.2 compound, but PID has not tested for it

Other Chemicals were Found during Santa Rosa's Exploratory Testing

VOCs

- 18 others found in Santa Rosa and tentatively identified compounds (TICs)
- PID has not tested for 5 VOCs or TICs

  Waterboard analyzed TICs for 1-2 samples

SVOCs

- Santa Rosa tested for SVOCs during exploratory testing
- PID has not tested for SVOCs

After the exploratory phase was complete, Santa Rosa decided on 33 specific chemicals (wide scan VOC) for recovery testing

Chemical Detected	PID		DDW in PID + TICs	City of Santa Rosa	
	n	Max		*n*	Max
Acetone	0	-	-	660	880
Acetonitrile	0	-	-	339	9.1
Acrylonitrile	0	-	-	660	7,300
N-Butyl benzene	35	1.4	-	661	2.3
Chlorobenzene	35	5	-	6,062	50
Chloroethane	35	nd	-	661	1.6
o-Dichlorobenzene	35	0.5	-	6,062	2.2
p-Dichlorobenzene	35	1	-	6,062	nd
Ethyl benzene	35	24.6	76.0	8,222	106
Isopropyl benzene	35	0.6	-	661	5.1
N-Propyl benzene	35	nd	-	661	2.2
MEK, Methyl ethyl ketone	0	-	-	660	230
MTBE	35	nd	-	6,062	2.5
THF	0	-	-	339	1,100
1,3,5-Trimethylbenzene	35	1.3	-	661	2.1
1,2,4-Trimethylbenzene	35	3.2	-	661	12
o-Xylene	35	18.4	27.6	8,222	77
m-,*p*-Xylene	35	50	39.5	7,883	55

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Purdue University's Work on Building Plumbing and Plastics

Andrew Whelton, awhelton@purdue.edu
Caitlin Proctor, Juneseok Lee, Amisha Shah

Visit www.PlumbingSafety.org

plumb·ing

[ˈpləmiNG] **NOUN**

the system of pipes, tanks, fittings, and other apparatus required for the drinking water supply, heating, and sanitation in a building

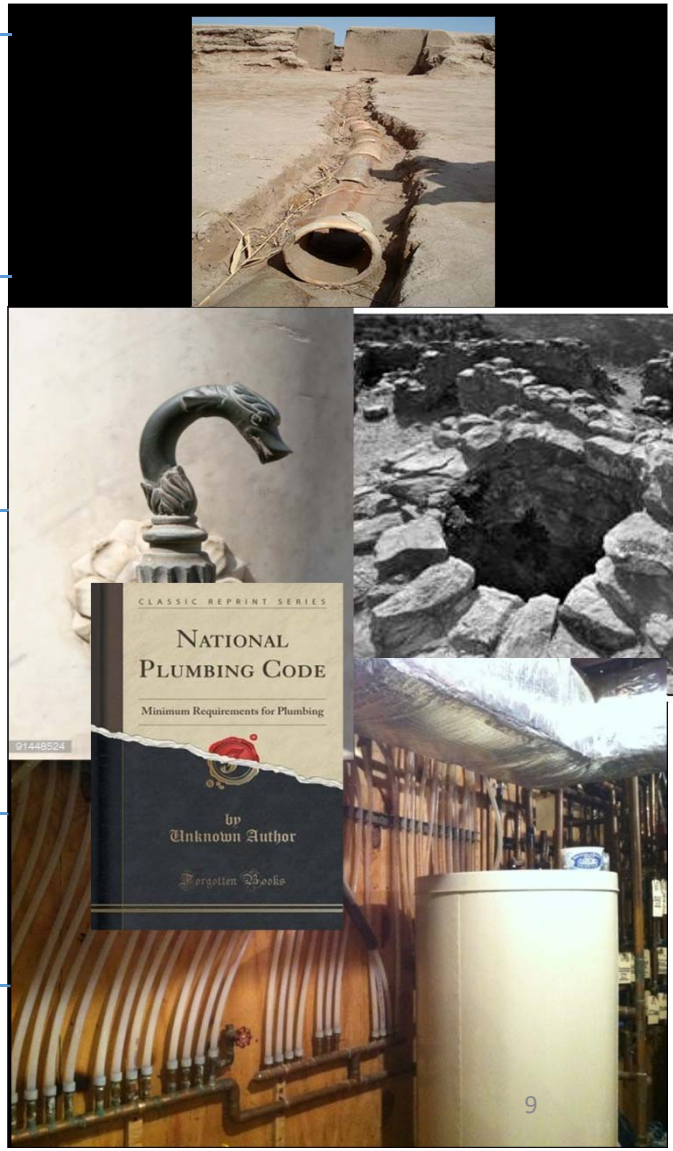
4000-3000 BCE
Copper water pipes in buildings (India)

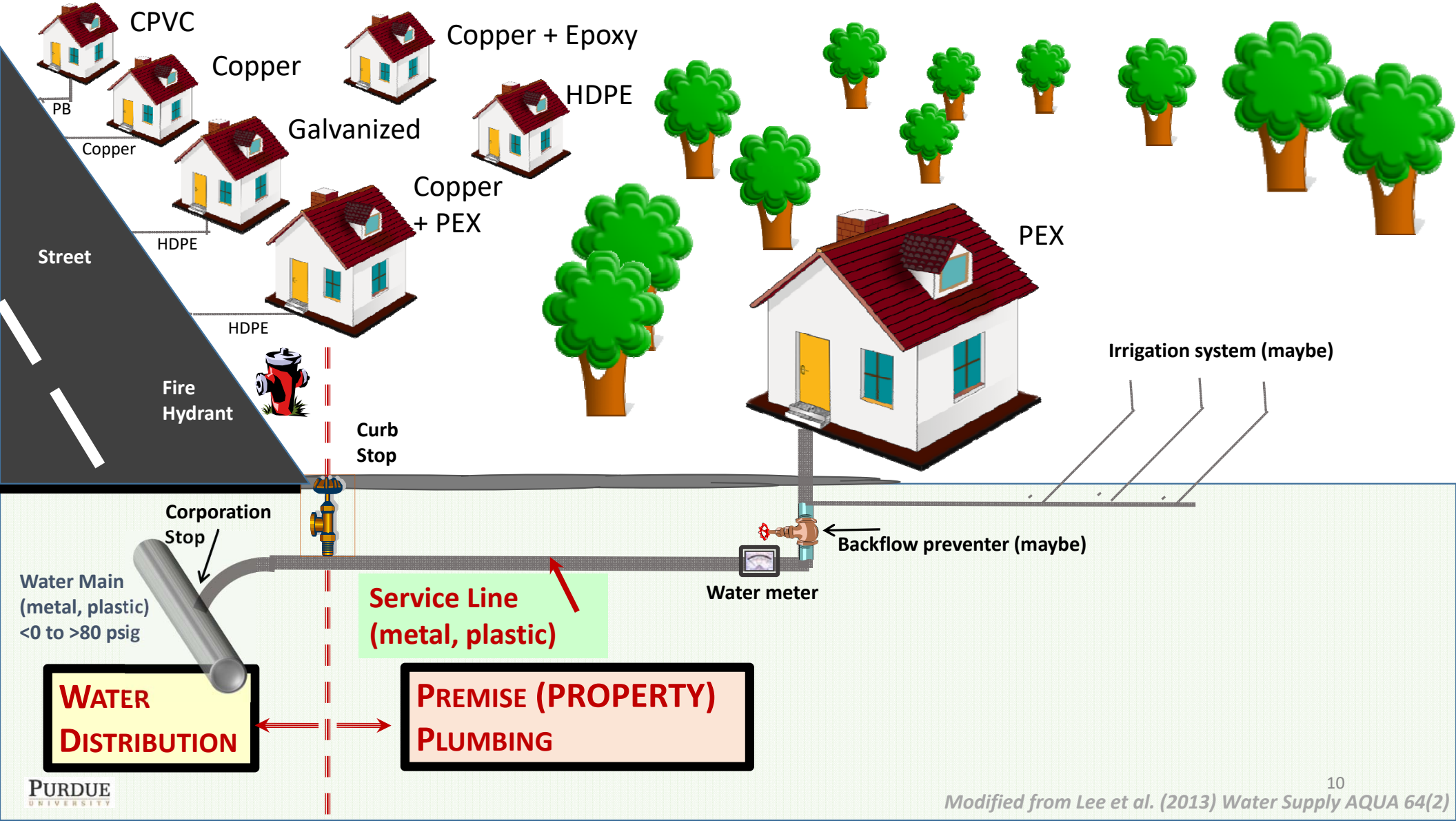
1500 BCE
Rainwater cisterns (Greece)

500 BCE- 250 AD
Lead & bronze pipes, marble fixtures, gold & silver fittings (Egypt)

1928
First US plumbing code

1966
Copper shortage enabled plastics entry





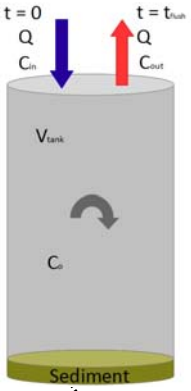
Modified from Lee et al. (2013) Water Supply AQUA 64(2)

Metals and Plastics

Fixtures and Aerators

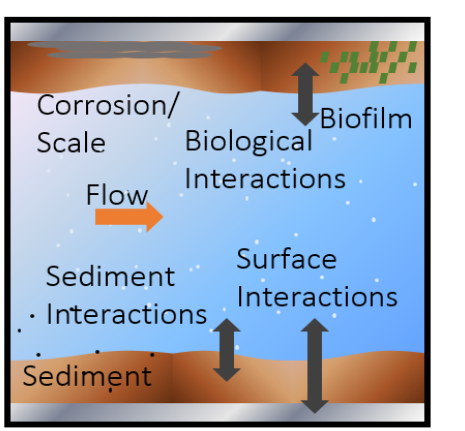
Hot vs. Cold Water Pipes

POU Devices



Water Heater

Corrosion Products



Habitat

Water Softener

Whole House Filter

Service Line

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A single faucet can contain a variety of metal and plastic materials

Inside of a single faucet (pictured left), one can find many different materials (right), including several types of plastic.

Residential Plumbing ≠ Commercial Plumbing

- Flow demands
- Fixture use (stagnation) frequency
- Pipe size and device layouts
- Types of contact materials (SA/V)
- In-building storage volumes
- In-device temperatures and profiles
- And more…

Commercial

Schools
Offices
Multi-Family
Hospitals
Daycares
Extended Care
Government Buildings
Correctional Institutions
Hotels & Motels
Sports & Entertainment Venues
Summer Communities,
Casinos,
and more…

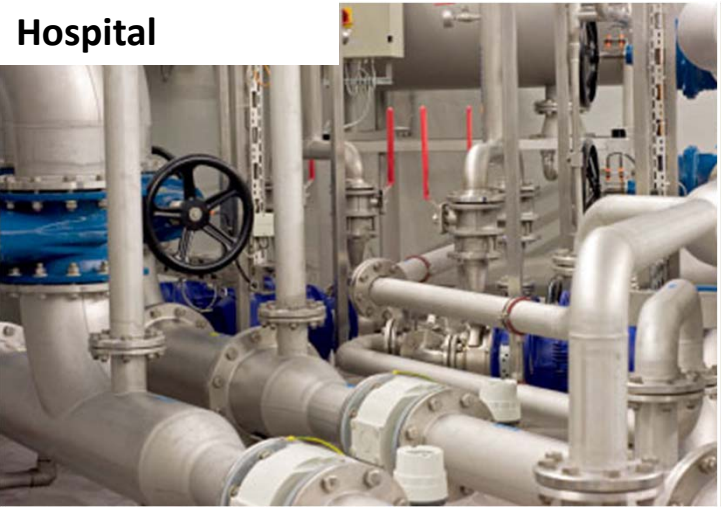
Premise plumbing is complex

Food Prep Facility

Domestic Hot Water

PEX pipe with copper manifold

Hospital



Cartridge Filters

Some images courtesy of: Gordon & Rosenblatt, LLC

Copper pipe to cPVC pipe

Where plastics can be in building drinking water plumbing

At Fixtures

- Faucets
- Faucet connectors
- Showerheads
- Shower/tub wand

Drinking water pipe – cold

- HDPE, PVC

Drinking water pipe – cold/hot

- PB, PEX, CPVC, PP, multilayer

Interior pipe coatings

Appliances

- Water heaters, dishwashers, washing machines, humidifiers, refridgerators

In-building devices

- Water softeners, filters, tanks

Other places

- Valves, fittings, couplings, refrigerator lines, gaskets

And more…

Water Stagnates Differently in Different Parts of the Plumbing

Location in Single Family 3 Bed, 1.5 Bath Home	Daily *Average* Stagnation Time
Building Service Line	0.1 to 0.5 hours
1st Floor Kitchen Sink Cold	1.0 to 2.2 hours
2nd Floor Bathroom Sink Cold	2.2 to 5.3 hours
Water Heater	0.4 to 0.7 hours
1st Floor Kitchen Sink -Hot	1.0 to 1.6 hours
2nd Floor Bathroom Sink Hot	1.1 to 2.5 hours
2nd Floor Shower	2.3 to 5.7 hours

More than 1 million measurements per location, 2017-2018, Indiana

Stagnation can allow time for chemicals to DIFFUSE into and out of plastics.

After a disaster, in-building stagnation can increase because of less water use

VOCs and SVOCs can be difficult to remove from plastic materials

- Purdue (2017): VOCs more easily removed from copper pipes than plastic. 30 days for benzene removal from PEX pipe after only short 24 hr exposure. Less time needed for CPVC pipe. 6 days for copper pipe.
- Purdue (2017): Surfactant solution found to catastrophically damage plumbing gaskets and PEX pipe
- Purdue (2017): Procedure for water heater decontamination by flushing
- Purdue (2015): Plumbing decontamination by flushing not always effective
- Others (2015): PVC resists VOC (BTEX) permeation at low concentrations
- Circa Purdue (2009/2011): Chemicals diffused *into* older plastic pipes faster than newer pipes, PB, HDPE, PEX vulnerable
- Pennsylvania (1981) and New Jersey (1987): Flushing unable to reduce pesticide plumbing chemical levels below acceptable exposure limits.
  - Hot water had significantly greater pesticide concentrations than cold water
  - Service lines and plumbing components were replaced.

Flushing for Plumbing Decontamination: https://pubs.rsc.org/en/content/articlehtml/2015/ew/c5ew00118h#cit38

Directly relevant studies can be found here…

Case study: the crude MCHM chemical spill investigation and recovery in West Virginia USA. 2017. *Environmental Science: Water Research & Technology*. DOI: http://doi.org/10.1039/C5EW00294J

Investigation of the factors that influence lead accumulation onto polyethylene: Implication for potable water plumbing pipes. *Journal of Hazardous Materials*. DOI: https://doi.org/10.1016/j.jhazmat.2017.12.066

Crude oil contamination of plastic and copper drinking water pipes. 2017. *Journal of Hazardous Materials*. DOI: https://doi.org/10.1016/j.jhazmat.2017.06.015

Predicting Contaminated Water Removal from Residential Water Heaters under Various Flushing Scenarios. 2017. *Journal of the American Water Works Association*. DOI: https://doi.org/10.5942/jawwa.2017.109.0085

Tap Water And Indoor Air Contamination Due To An Unintentional Chemical Spill In Source Water. 2016. *Interaction between Theory and Practice in Civil Engineering and Construction*. https://www.isec-society.org/ISEC_PRESS/EURO_MED_SEC_01/pdf/AW-11_v2_297.pdf

Residential Tap Water Contamination Following the Freedom Industries Chemical Spill: Perceptions, Water Quality, and Health Impacts. 2014. *Environmental Science & Technology*. DOI: http://doi.org/10.1021/es5040969

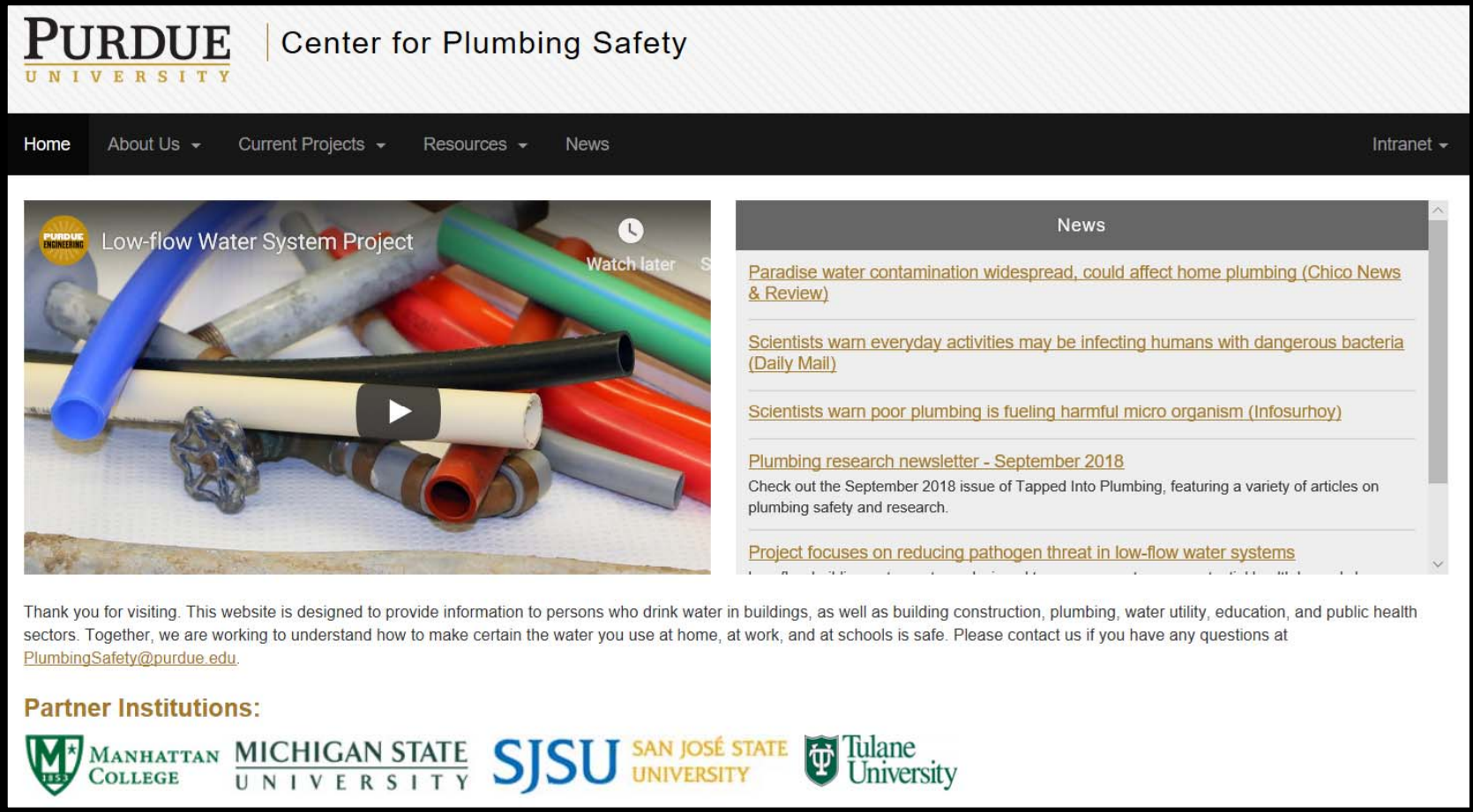
Case study: the crude MCHM chemical spill investigation and recovery in West Virginia USA. 2017. *Royal Society of Chemistry Environmental Science: Water Research and Technology*. DOI: http://doi.org/10.1039/C5EW00294J

Metal Accumulation in Representative Plastic Drinking Water Plumbing Systems. 2017. *Journal of the American Water Works Association*. DOI: https://doi.org/10.5942/jawwa.2017.109.0117

In-situ cleaning of heavy metal contaminated plastic water pipes using a biomass derived ligand. 2017. *Journal of Environmental Chemical Engineering*. DOI: http://doi.org/10.1016/j.jece.2017.07.003

We have field- and pilot-scale plumbing studies ongoing for other efforts

Plumbing Testing Facility at Purdue



Questions: Andrew Whelton, awhelton@purdue.edu

Learn more at www.PlumbingSafety.org

Tentative Analysis of Santa Rosa Water Quality Testing Results for Tubbs Fire

Caitlin Proctor, Andrew Whelton

Stages of Santa Rosa water quality response to the Tubbs Fire

- Q1 (Oct – Dec 2017). Immediately after fire, discovering problem.
- Q2 (Jan – Mar 2018). Deep into response phase, figuring out approach for sampling. Many samples taken with wide analysis.
- Q3 (Apr – Jun 2018)
- Q4 (July – Sept 2018)
- Q5 (Oct – Dec 2018)
- Q6 (Jan – Mar 2019)

Samples Taken	These chemicals exceeded health-based limits					
	Benzene	Naphthalene	TBA	Toluene	Styrene	Vinyl chloride
Q1	481	1	0	481	1	1
Q2	3375	660	339	3375	2089	2089
Q3	1739	0	0	1739	1345	1345
Q4	1782	0	0	1782	1782	1782
Q5	703	0	0	703	703	703
Q6	142	0	0	142	142	142

Was benzene a "good indicator" in Santa Rosa's WATER DISTRIBUTION SYSTEM?

- Looking at the 51 chemicals that were detected:
- For 17 chemicals, Benzene was a ***reasonably good*** **indicator**.
  - Whenever a sample was "benzene clear", the other chemical was **not** detected.
  - In at least one sample, benzene and this chemical co-occurred.
- For 15 chemicals, Benzene was a ***very bad*** **indicator**.
  - The *highest concentrations* were in samples that were "benzene clear".
  - **For TBA, this included several samples which exceeded notifiable limits.**
- For 19 chemicals, the relationship was **unclear, but likely *bad***.
  - Detected even if "benzene clear", but not in its highest concentration.
  - For 5 analytes, at least one "benzene clear" sample had a concentration in the same range (within 50%) as the highest concentration measured.

Tentative Analysis of Santa Rosa Water Quality Testing Results for Tubbs Fire

Seemed good for:

1,1-Dichloroethane
1,1,1-Trichloroethane (TCA)
1,2-Dichlorobenzene
1,2-Dichloropropane
1,2,3-Trichlorobenzene
1,2,4-Trimethylbenzene
1,3-Dichloropropane
1,3,5-Trimethylbenzene
Bromomethane
Chlorobenzene
Chloroethane
n-Butylbenzene
n-Propylbenzene
p-Isopropyltoluene
Tetrachloroethene (PCE)
trans-1,3-Dichloropropene
1,2-Dichloroethane (EDC)

Seemed bad for:

1,1,1-Trichloroethane
1,2,4-Trichlorobenzene
2-Butanone
Acetonitrile
Bromochloromethane
Bromodichloromethane
Carbon Disulfide
Carbon tetrachloride
Ethanol
Methyl isobutyl ketone
MTBE
Methylene chloride
Tert-Butyl Alcohol (TBA)
Tetrahydrofuran
Trihalomethanes (total)

Unclear relationship for:

Acetone
Acrylonitrile
Bromoform
Chloromethane
Ethylbenzene
Isopropylbenzene
m+p-Xylene
Naphthalene
o-Xylene
Styrene
Toluene
Vinyl chloride
Xylenes (total)

"benzene clear" sample in same range as max seen:

Chloroform
Dibromochloromethane
Iodomethane
Methyl ethyl ketone
Total Trihalomethanes

www.PlumbingSafety.org

Our website has historically been dedicated to answering plumbing safety questions for our other efforts.

Because of public demand, we will begin providing educational information to respond to Camp Fire plumbing questions.

A Camp Fire area continuing problem: There are no representative building plumbing testing results to make public health or safety decisions with.