Importance of science in responding to large-scale drinking water contamination disasters: Wildfires, chemical spills, & more

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Purdue University

Tuesday August 27, 2019
2:05 PM - 2:35 PM
Room 5A - San Diego Convention Center

Many thanks to many people

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Safe drinking water is critical for community health, safety, and economic security.

Natural and Man-Made Disasters Affect Drinking Water Infrastructure and Quality

Events

Hurricanes
Floods
Tornadoes
Earthquakes
Nor'easters
Wildfires
Tsunamis

Chemical Spill

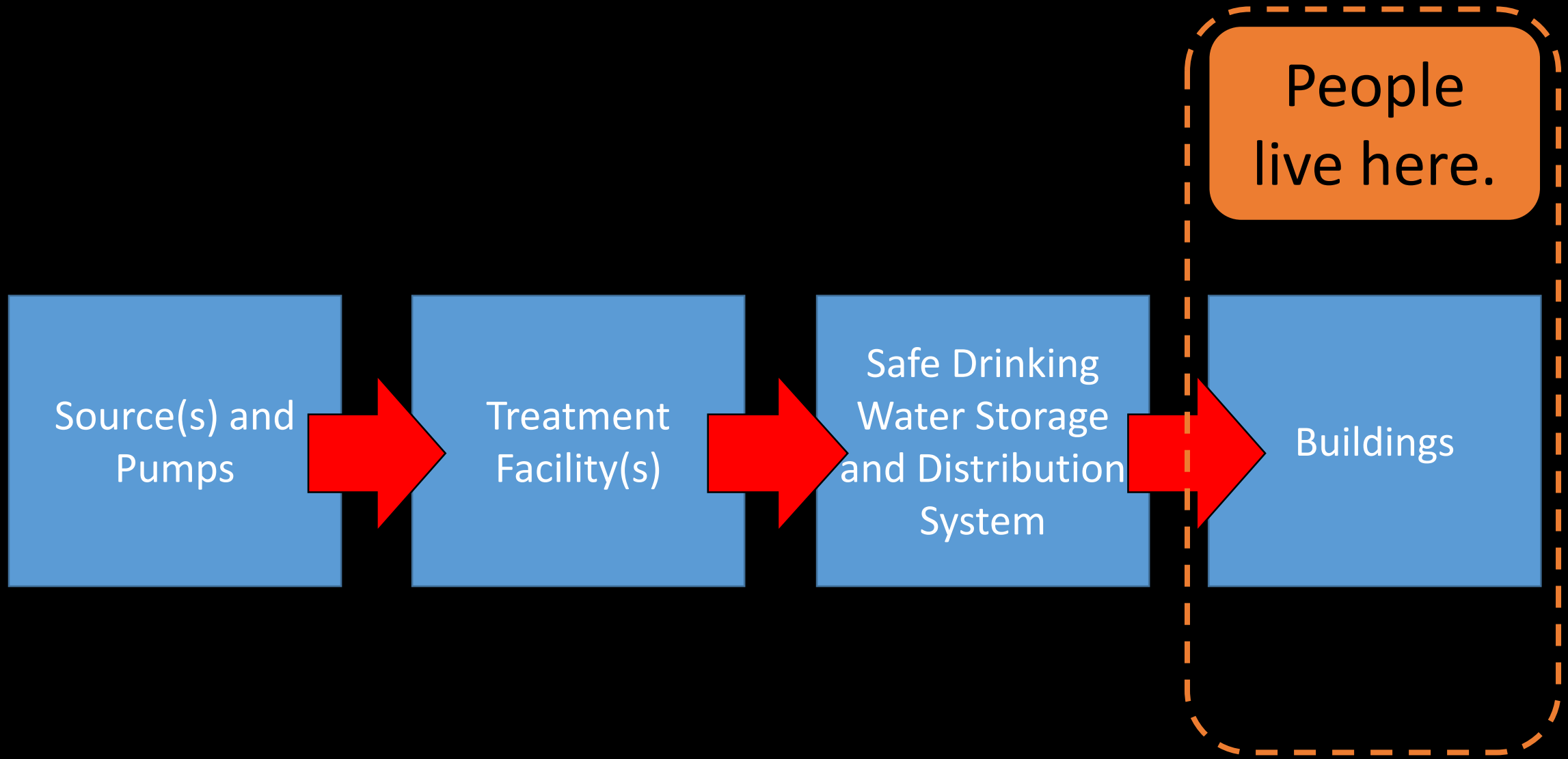
Tank spills
Truck spills
Pipeline spills
Rail car spills
Ship spills

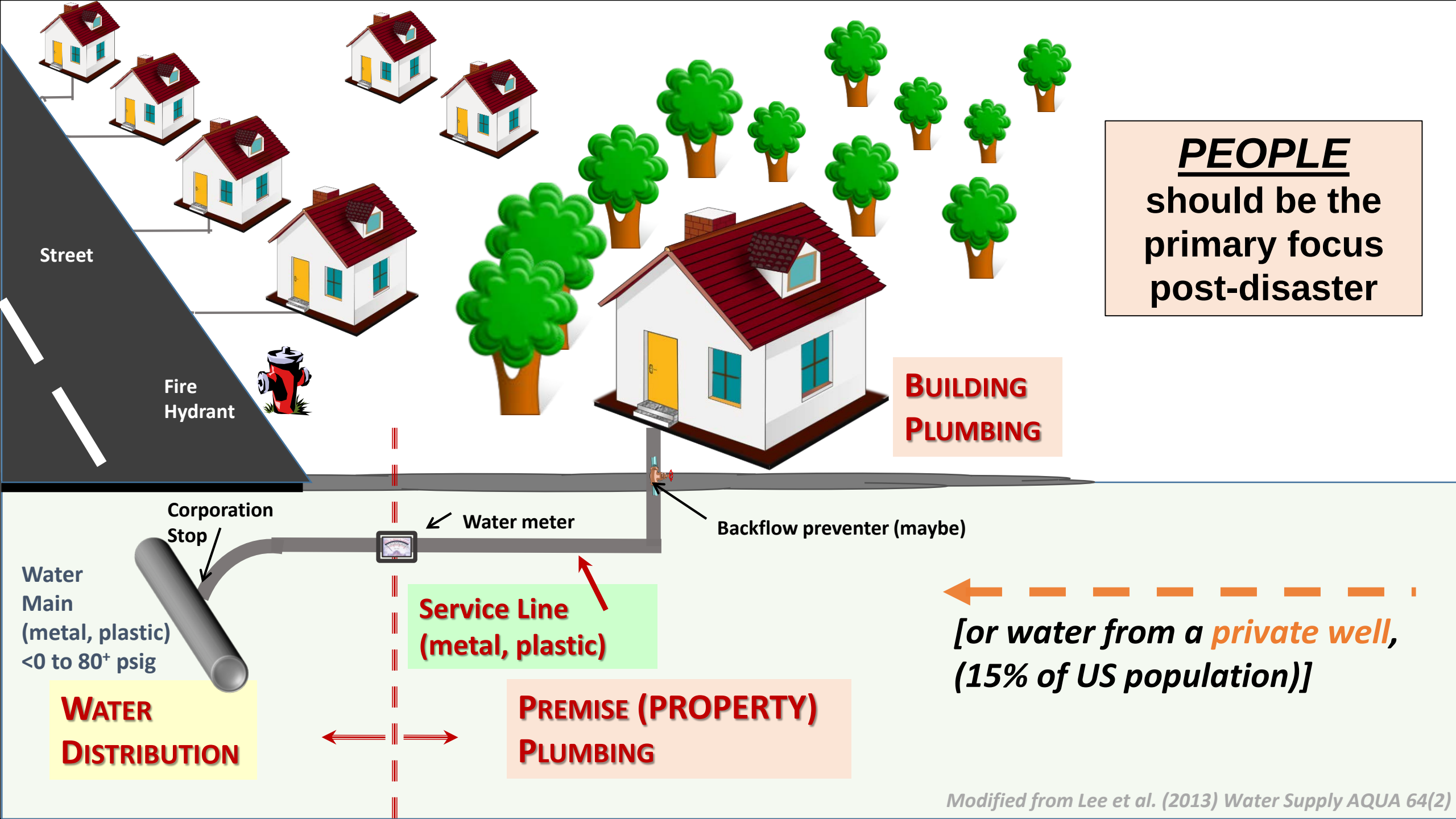
Intentional

Just a Few

2018 Butte County, CA
2017 Santa Rosa, CA
2015 Corpus Christi, TX
2015 Glendive, MT
2015 Longueil, CN
2014 Toledo, OH
2014 Charleston, WV

"…172,000 chemical spills that affected US waterbodies from 2004 to 2014. More than 8,000 of these spills involved non–petroleum-related chemicals." – Weidhass et al. *Journ. Environ. Qual.* (2016)


People live here.
Source(s) and Pumps
Treatment Facility(s)
Safe Drinking Water Storage and Distribution System
Buildings



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

2014 Freedom Industries Spill

January 9, 2014

No plants shutdown:
Public safety concerns

340,000+ people
9 counties
15%+ of West Va. pop.

2,200 mi. water mains
107 water tanks

8 days after the spill:
366 miles downstream

A few of the many lessons learned

State and water utility ….

- *Do Not Use* order issued
- Relied only on the MSDS only for water testing
- Only looked for a single VOC named 4-MCHM in water
- Assumed the tank company gave them everything they needed

CDC evaluated the health risk for only 1 chemical, not all present

- Multiple chemicals were present, VERY little toxicity data
- Only ingestion exposure considered, claimed inhalation could not be estimated
- USGS found MMCHC at building faucets, MMCHC exposure not evaluated

Water treatment facility GAC leached 4-MCHM for 3 months

Plumbing flushing guidance bungled by county, state, and utility

- Flushing guidance ignored plumbing design, operation, and personal safety
- Indoor air chemical exposure limits exceeded (found by modeling used post-disaster)

Whelton et al. 2017. Case study: the crude MCHM chemical spill investigation and recovery in West Virginia USA. *Environmental Sci.: Water Research & Technology.*

The Fundamental Problem with the Response was that Officials Did Not Understand what was in the Water

Chemicals in Tank 396 Liquid	MSDS		Est.	Chemical Analysis by Others			
	EastM 1/98	FDM 1/12	CDC 1/14	REIC 3/14	WVTAP 3/14	USGS 12/14	ATTY 4/15
4-MCHM (a.k.a. MCHM)	68 to 89%			79.6%	Detect	77-89%	940 g/kg
4-MMCHM	4 to 22%						
Water	4 to 10%						
MMCHC	5%		88.5%	1.6%		Detect	
DM14CHDC	1%						
Methanol	1%						
1,4–CHDM	1 to 2%			5.6%	Detect		
Polyglycolethers (9d after spill)		100%	7.3%				
PPH							
DiPPH				11.3%			
Formaldehyde							86 ppm
Methylene chloride							13,621 ppm
Water			4.2%				
2-Methoxyethoxybenzene					Detect		
Cyclohexanemethanol				1.8%	Detect		
1,4-CHDADME					Detect		
4-MMECHCA					Detect		
Other unidentified compounds				< 5%			

Commentary comes at survivors from all directions: There's often a lot of bad information

Statement by environmental activist:

"…the amount of chemical likely destroyed your home water treatment system."

"…if you had an RO system, the chemical likely ate the membrane."

"…your [plumbing] pipe material will not be impacted…"

Statement by scientist:

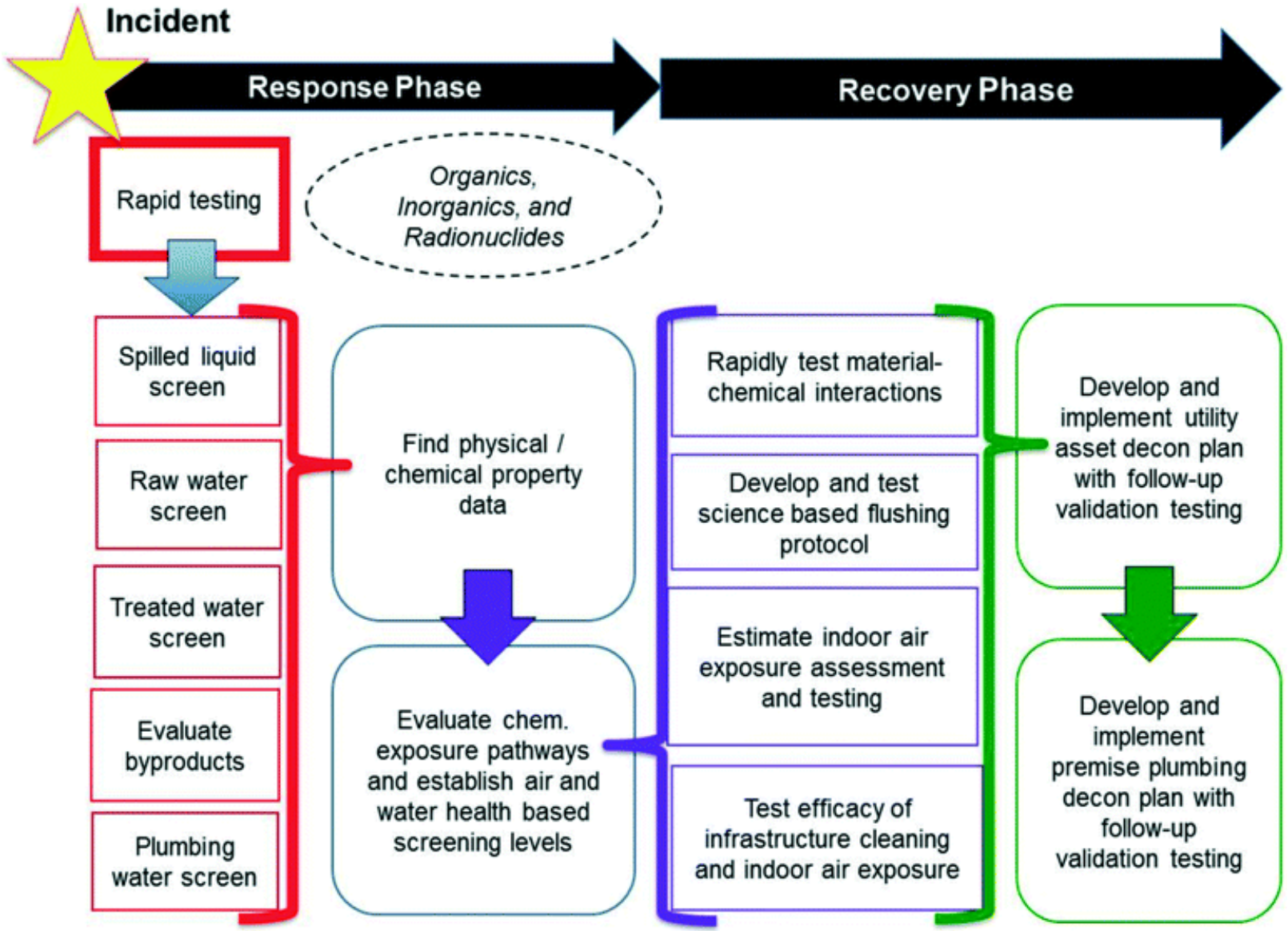
"It's a hydrophobic molecule like oil. You can't just flush it out of a system, a substance like that. It sticks to surfaces, and you have to use soap and water."

Plumbing decontamination advice *not* based on science

Location, Date	Contaminant	Plumbing Flushing Procedure
Nibley, UT, 2015	Diesel fuel (sVOCs, VOCs)	**Cold** water 35 min, **hot** water 30 min, run appliances, continue until odor gone
Glendive, MT, 2015	Crude oil (metals, SVOCs, and VOCs)	**Cold** water 20 min, **hot** water 15 min
Washington D.C., 2014	Estimated petroleum based solvent (Contaminants unknown, Possible SVOCs and VOCs)	Begin at the sink on the lowest floor, run each **cold** water tap 10 min, flush **cold** water from upper level sinks 5 min, refrigerator water dispenser 5 min
Toledo, OH, 2014	Microcystins	**Hot** water 15 min, **cold** water 5 min, appliances 5 min
Charleston, WV, 2014	Crude MCHM & Stripped PPH (SVOCs present)	**Hot** water 15 min, **cold** water 5 min, appliances 5 min
Stratford, CN, 2005	Car wash cleaning agent containing 2-Butoxyethanol (Possible VOCs)	**Cold** water 5 min
Charlotte, NC, 1997	Fire Suppressant (AFFF) - Hydrocarbon based surfactant	**Hot** water 10 min, **cold** water 10 min
Los Angeles, CA, 1994	Macrojet concentrate[i]	Flush both **hot** and **cold** water
Hope Mills, NC, 1986	Pesticide (heptachlor, chlordane) (Possible VOCs)	Flush to drain lines and **hot** water heaters
Macon, GA, 1984	Creosote (VOCs present)	Flush plumbing for 30 min

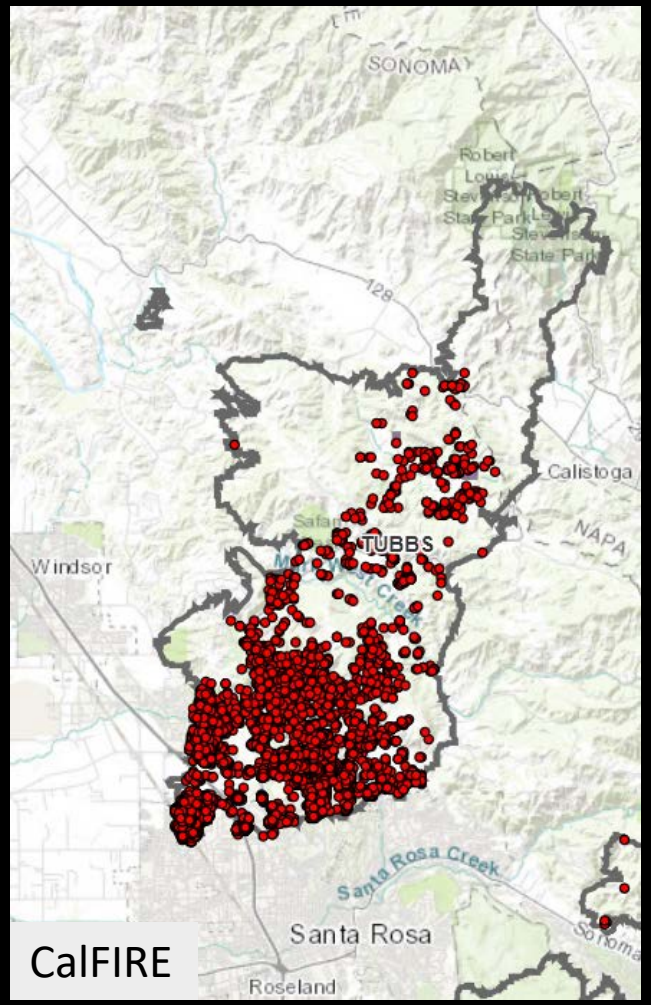
Casteloes KS, Brazeau RH, Whelton AJ. 2015. *Environ. Sci.:Water Research & Technology.* DOI: 10.1039/c5ew00118h

Key Actions Were Identified



Whelton et al. 2017. Case study: the crude MCHM chemical spill investigation and recovery in West Virginia USA. *Environmental Sci.: Water Research & Technology.*

2017 Tubbs Fire: Drinking Water System Volatile Organic Compound (VOC) Contamination was Discovered



Oct. 8, Fire began – Oct. 31, 2017 contained

- 36,807 acres
- 5,656 structures destroyed, in City of Santa Rosa 2,500 parcels burned

Oct. 10, City of Santa Rosa issued boil water advisory

Nov. 8, Drinking water *odor* complaint

- City found benzene > CA MCL (1 ppb) and USEPA MCL (5 ppb)

Nov. 10 – Oct. 11, 2018, Do Not Drink-Do Not Boil advisory

- 352 parcels in advisory area, 0.08% water mains, 0.2% hydrants, 5% of meters, ~5.2 miles
- *Affected only 9 of 13 standing homes (occupied)*
- Less than 20 people affected out of 175,155 on this water system
- Subsequent tests revealed much more VOC water contamination

Response and recovery was overseen by California's SWRCB and USEPA Region 9

- Initial estimated removal/replacement cost: $44 million
  - ❖Actual investigation and replacement cost: $8 million
- Multiple VOCs, SVOCs, TICs detected
  - ❖Multiple VOCs exceeded acute and chronic drinking water exposure limits
- DND-DNB advisory based on early benzene results

JOINT INFORMATION CENTER
SONOMA FIRES: CENTRAL LNU COMPLEX
PRESS RELEASE

City of Santa Rosa

FOR IMMEDIATE RELEASE
MEDIA CONTACT: 707-565-3040

Date: November 10, 2017

Do-Not-Drink and Do-Not-Boil Water Advisory Issued for Two Specific Areas of Fountaingrove

SANTA ROSA, CA – The City of Santa Rosa Water Department has issued notices to customers in select areas advising them to stop drinking tap water due to recent damage to the water system resulting from the fires.

A total of 13 homes in Fountaingrove received the advisory notice after slightly elevated levels of contaminants were detected in two isolated areas. The Department advised residents in these areas to not use the tap water for drinking and cooking until further notice.
Since the wildfires, the Water Department has increased water sampling beyond required regulations to closely monitor the integrity of the water system and ensure high-quality drinking water for residents. The enhanced sampling identified the contamination, and confirmed that the contamination is isolated to two specific areas of Fountaingrove only. To address the contaminations, Santa Rosa Water is flushing clean water through the system.

Those in the impacted area received the following recommendations:

- Do not drink your tap water – use only bottled water. Bottled water should be used for all drinking (including baby formula and juice), brushing teeth, washing dishes, making ice and food preparation until further notice.
- Do not try and treat the water yourself. Because of the nature of the water contamination, boiling or disinfecting your water will not make it safe to drink.

When the advisory is lifted, properties in the affected areas will be individually notified, and a media notification will also be issued.

###

A Few Lessons Learned

- Water tested for 100+ chems, 34 routinely later in response
- Repeated location sampling was necessary to find contamination
- Stagnation "soak time" was needed to find contamination (often ≥ 72 hr)
- More than benzene exceeded acute and chronic exposure limits
- Sometimes ± 77% benzene difference in duplicate water samples for single location
- Decided ≥ 0.5 ppb benzene prompted asset replacement
- Greatest VOC contamination found in service lines (max. 40,000 ppb benzene)
- All contaminated hydrants, water mains, ARVs, blow offs, service lines were replaced
- Long-term VOC monitoring required

The 2018 Camp Fire – A Different Scale

Executive Department
State of California

November 8, 2018

Proclamation of a State of Emergency

WHEREAS on November 8, 2018, the Camp Fire began burning in Butte County and continues to burn; and

WHEREAS this fire has destroyed homes and continues to threaten additional homes and other structures, necessitating the evacuation of thousands of residents; and

WHEREAS the fire has forced the closure of roadways and continues to threaten critical infrastructure; and

WHEREAS high temperatures, low humidity, and erratic winds have further increased the spread of this fire; and

WHEREAS the Federal Emergency Management Agency has approved a Fire Management Assistant Grant to assist with the mitigation, management, and control of the Camp Fire; and

WHEREAS the circumstances of this fire, by reason of its magnitude, are or are likely to be beyond the control of the services, personnel, equipment, and facilities of any single local government and require the combined forces of a mutual aid region or regions to combat; and

WHEREAS under the provisions of Government Code section 8558(b), I find that conditions of extreme peril to the safety of persons and property exists in Butte County due to this fire; and

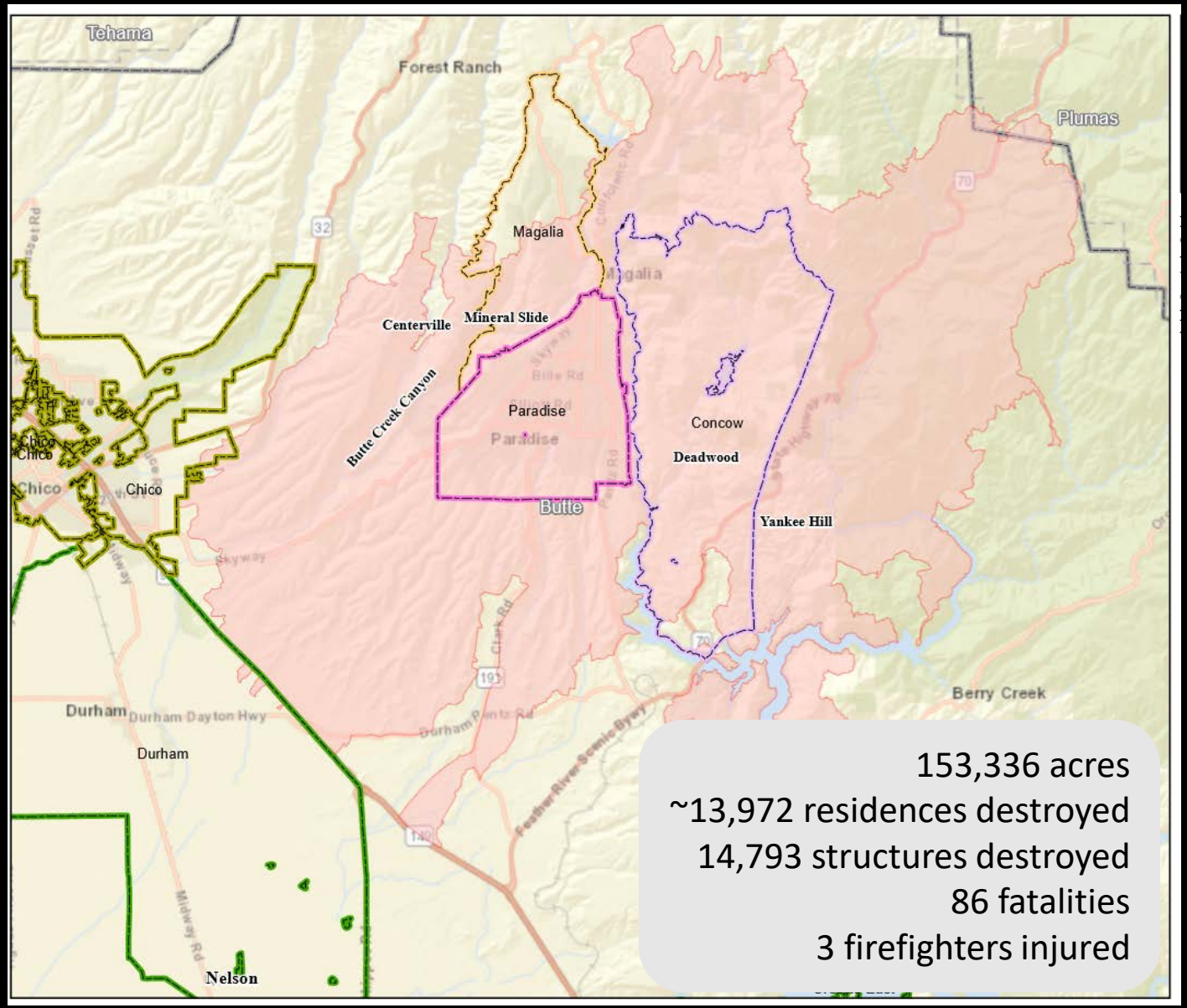
WHEREAS under the provisions of Government Code section 8571, I find that strict compliance with the various statutes and regulations specified in this order would prevent, hinder, or delay the mitigation of the effects of the Camp Fire.

NOW, THEREFORE, I, GAVIN NEWSOM, Acting Governor of the State of California, in accordance with the authority vested in me by the State Constitution and statutes, including the California Emergency Services Act, and in particular, Government Code section 8625, **HEREBY PROCLAIM A STATE OF EMERGENCY** to exist in Butte County due to the Camp Fire.

IT IS HEREBY ORDERED THAT:

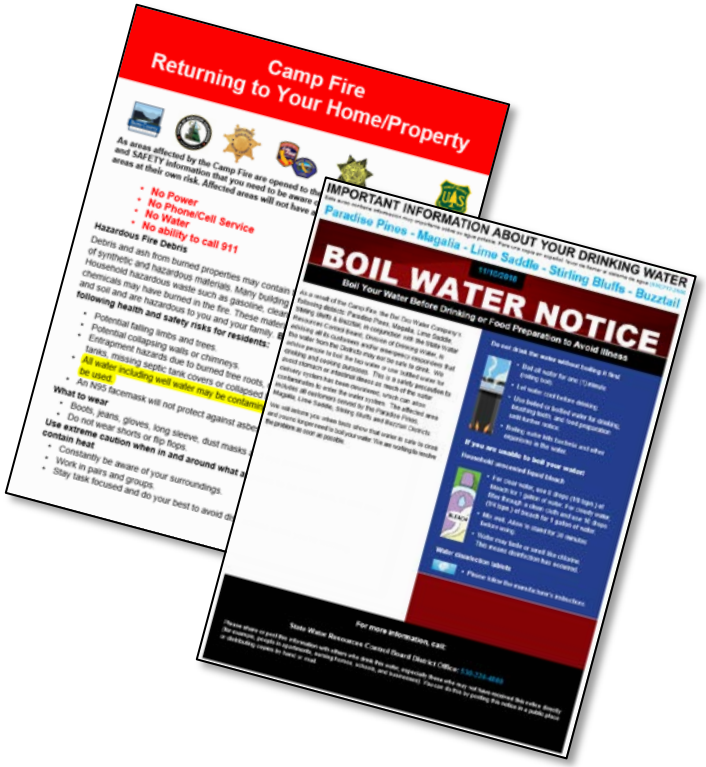
1. All agencies of the state government utilize and employ state personnel, equipment, and facilities for the performance of any and all activities consistent with the direction of the Office of Emergency Services and the State Emergency Plan. Also, all citizens are to heed the advice of emergency officials with regard to this emergency in order to protect their safety.

2. The Office of Emergency Services shall provide local government assistance to Butte County, if appropriate, under the authority of the California Disaster Assistance Act, Government Code section 8680 et seq., and California Code of Regulations, Title 19, section 2900 et seq.



Public Water Systems (% Homes Gone)	Population	Source Water
Paradise Irrigation District (PID) (-96%)	26,032	Surface
Del Oro Water Company – Paradise Pines (-38%)	11,324	Surface
Del Oro Water Company – Lime Saddle (-50%)	1,106	Surface
Del Oro Water Company – Magalia (-89%)	924	Ground
Del Oro Water Company – Stirling Bluffs (0%)	548	Surface
Del Oro Water Company – Buzztail (-34%)	106	Ground
Foothill Solar Community	180	Ground
Forest Ranch Mobile Home Park	25	Ground
Forest Ranch Mutual Water Company	92	Ground
Gran Mutual Water Company	202	Ground
Humboldt Woodlands Mutual Water Company	75	Ground
Meadowbrook Oaks Mobile Home Park	50	Ground
Mountain Village Homeowners Association	40	Ground

40,000 people issued a boil water advisory (BWA)



Private wells
13,227 exist in Butte County
2,438 wells in Camp Fire area

Some water meters did not survive

Some plastics melted,
decomposed, and cooled

Review of Tubbs Fire and Camp Fire Water Distribution System Data:

VOCs post-Camp Fire have exceeded *acute* and *chronic* exposure limits; Limited results cannot predict the future

Chemical	Tubbs Fire (11 mo.)		Camp Fire (6 mo. post-fire)					
	Santa Rosa 5.2 miles		PID 172 miles		SWRCB in PID	DOWC (3 systems)		Short-term USEPA 1d-Health Advisory
	n	Max	*n*	Max	*n*=1	*n*	Max	Exceeded
Benzene	8,222	**40,000**	509	**923**	**>2,217**	41-26-82	**8.1**-0-**46**	**Yes (200)**
Methylene chloride	-	< 5	p	**15**	-	p	p	No
Naphthalene	661	**6,800**	p	278	**693**	p	p	**Yes (500)**
Styrene	6,062	**460**	p	**100**	**378**	p	p	No
TBA (NL)	339	**29**	p	**13**	-	p	p	-
Toluene	8,222	**1,130**	p	100	676	p	p	No
Vinyl chloride	6,062	**16**	p	**1**	-	p	p	No

PID used 72 hr stagnation time; DOWC sometimes, but often used 0 hr
p = Utilities did not disclose enough information about their data

PURDUE UNIVERSITY

Possible Primary Sources

1. Thermal decomposition of plastics (PVC pipes, HDPE pipes, PB pipes, gaskets, meter components, etc.)

2. Contaminated air/materials drawn into depressurized system

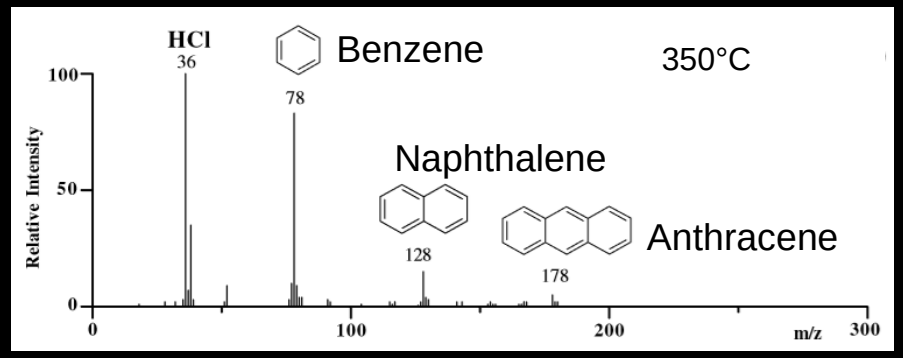
3. Contaminated water from building plumbing drawn into compromised system

Confirmed Secondary Sources

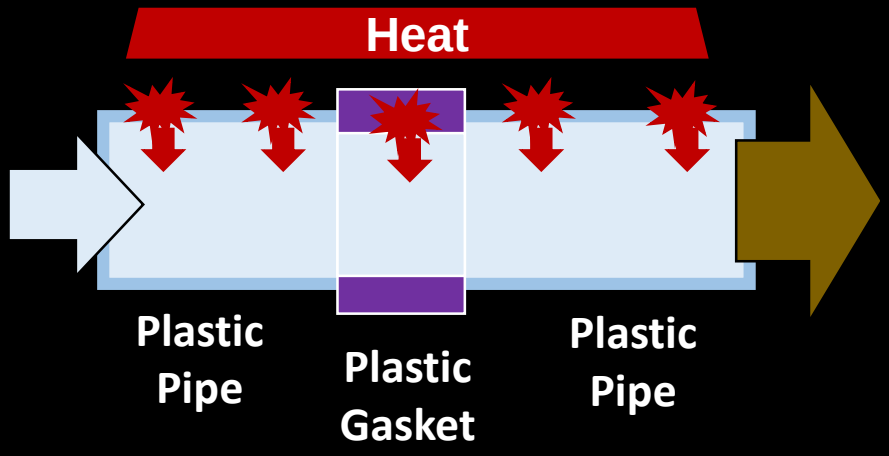
Partitioning/Adsorption/Absorption:
Water ⟷ Material

See video at
www.PlumbingSafety.org

1. Plastic Pyrolysis



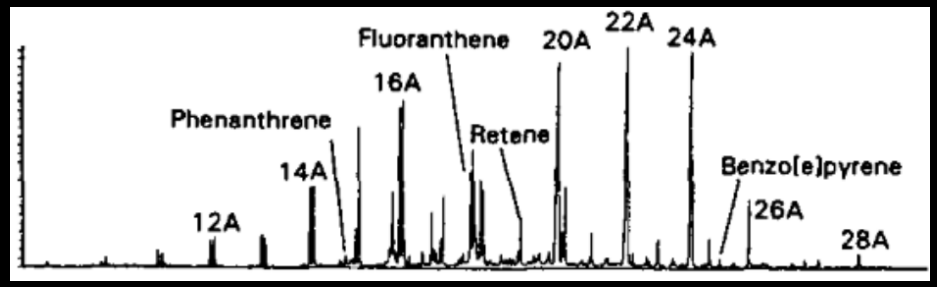
Montaudo & Puglisi (1991)



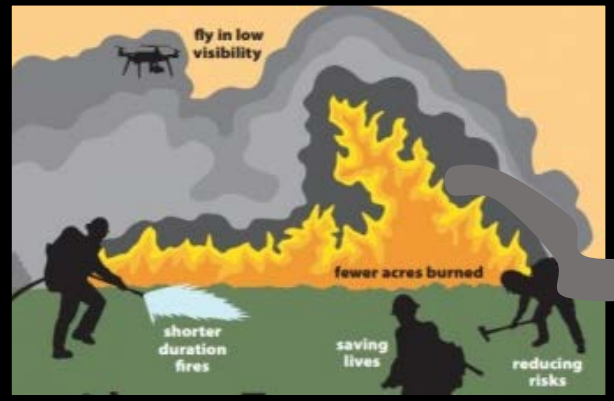
VOCs
SVOCs

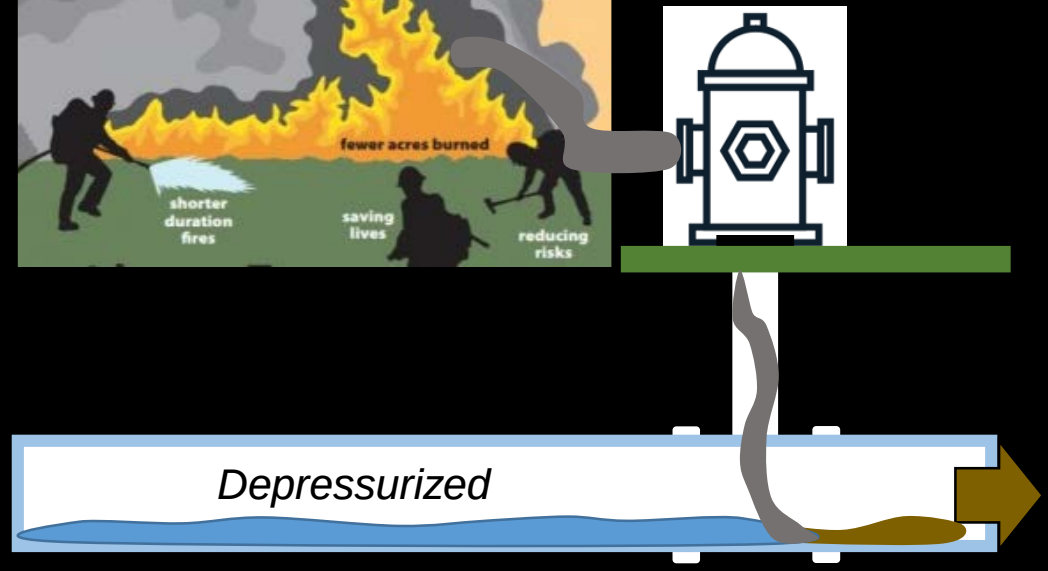
Benzene
Naphthalene
Toluene
Styrene
Xylenes
Benzo[a]pyrene
and more…

2. Forest Biomass Combustion

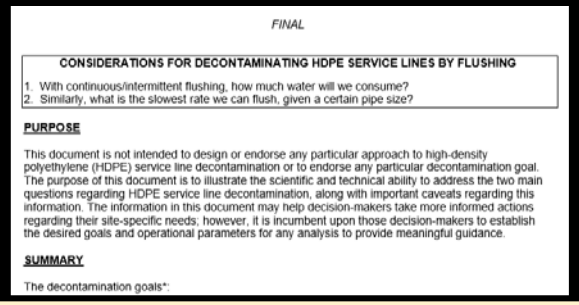


Simonet et al. (1999)





Science has been applied to some water distribution system testing and decontamination decisions, but more work is needed


FINAL

CONSIDERATIONS FOR DECONTAMINATING HDPE SERVICE LINES BY FLUSHING

1. With continuous/intermittent flushing, how much water will we consume?
2. Similarly, what is the slowest rate we can flush, given a certain pipe size?

PURPOSE

This document is not intended to design or endorse any particular approach to high-density polyethylene (HDPE) service line decontamination or to endorse any particular decontamination goal. The purpose of this document is to illustrate the scientific and technical ability to address the two main questions regarding HDPE service line decontamination, along with important caveats regarding this information. The information in this document may help decision-makers take more informed actions regarding their site-specific needs; however, it is incumbent upon those decision-makers to establish the desired goals and operational parameters for any analysis to provide meaningful guidance.

SUMMARY

The decontamination goals*:

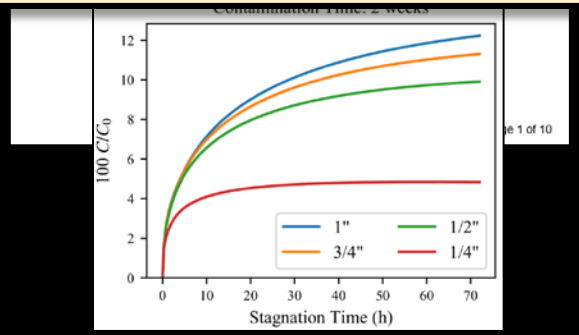
Water Distribution System Decontamination

Collaboration between Us & USEPA

Hydraulics

Polymer Science

Environmental Engineering



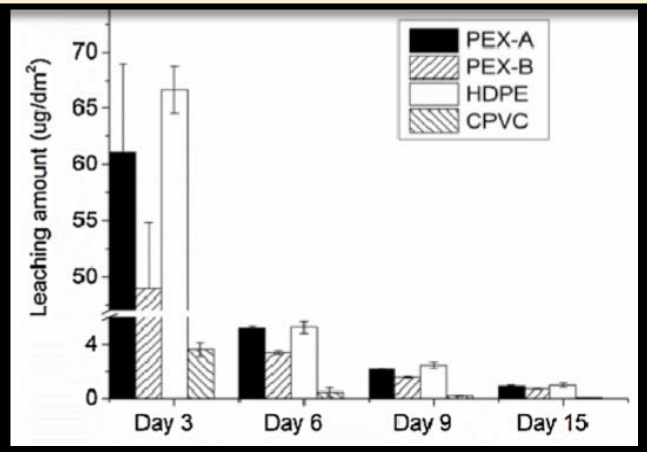
Numerical modeling:

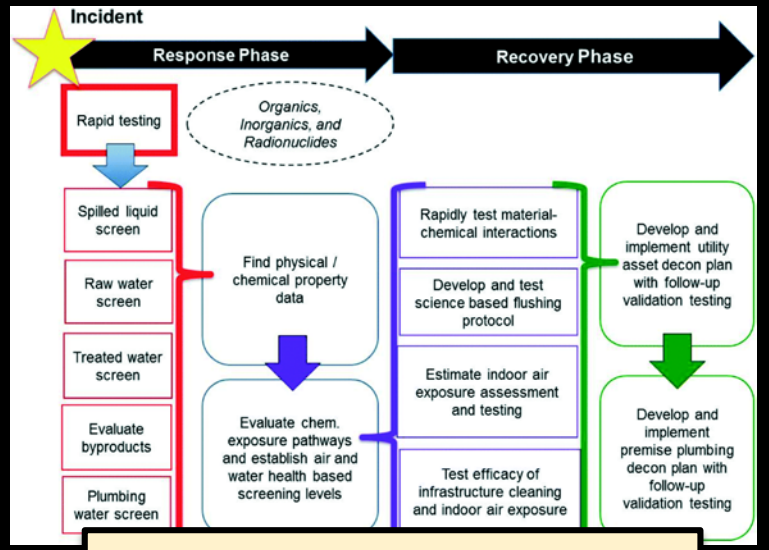
Greater than 286 days vs. less than 64 days of continuous water flushing for 1-inch HDPE service line

(Haupert et al. 2019)

Purdue *(Huang et al. 2017)*

Different plastic pipes uptake and leach different amounts of VOCs and SVOCs





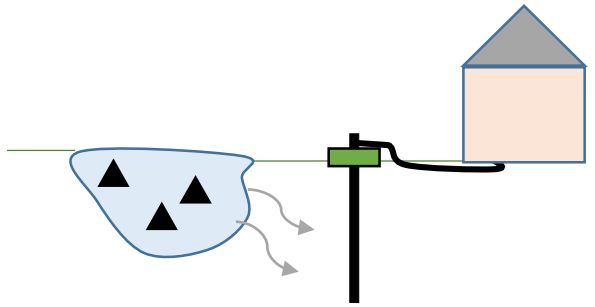
Purdue *(Whelton et al. 2017)*

There is a step-wise process for responding to and recovering from contamination

Public Health Implications: Standing Homes

Water use advisories (still in place)

- 2 DOWC systems contaminated, but have no water advisory
- Some PID customers are not following water use restrictions
- 26 ppb benzene posed an acute exposure risk (Max. so far >2,217 ppb in PID, 530 ppb DOWC)



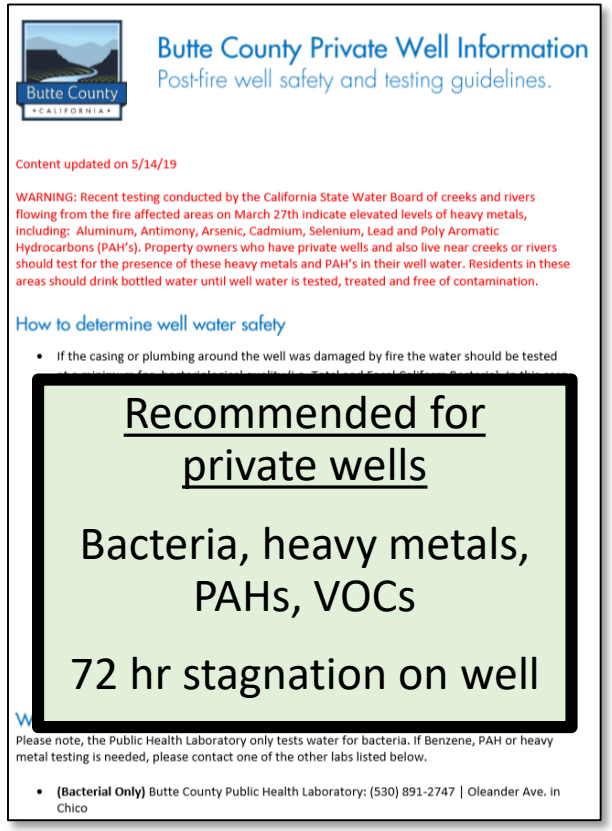
Contaminated water is entering and will continue to enter homes

- Utilities still trying to identify their contaminated assets
- Loss of pressure (main break, leak) *could move* contaminated water into a standing home service line

Plumbing has received months of contaminated water

Cold and hot water systems [Now nonpotable]
Trunk-and-branch vs. homerun designs
In-home treatment devices
Paying for water testing, results not representative
No credible plumbing testing guidance
Irrigation system contamination
External water tank maintenance and microbiological growth
Some have no economic capacity to purchase bottled water, devices

Insurance companies making decisions about in-home treatment



Butte County Private Well Information

Post-fire well safety and testing guidelines.

Content updated on 5/14/19

WARNING: Recent testing conducted by the California State Water Board of creeks and rivers flowing from the fire affected areas on March 27th indicate elevated levels of heavy metals, including: Aluminum, Antimony, Arsenic, Cadmium, Selenium, Lead and Poly Aromatic Hydrocarbons (PAH's). Property owners who have private wells and also live near creeks or rivers should test for the presence of these heavy metals and PAH's in their well water. Residents in these areas should drink bottled water until well water is tested, treated and free of contamination.

How to determine well water safety

- If the casing or plumbing around the well was damaged by fire the water should be tested

Recommended for private wells

Bacteria, heavy metals, PAHs, VOCs

72 hr stagnation on well

Please note, the Public Health Laboratory only tests water for bacteria. If Benzene, PAH or heavy metal testing is needed, please contact one of the other labs listed below.

- **(Bacterial Only)** Butte County Public Health Laboratory: (530) 891-2747 | Oleander Ave. in Chico

Response and recovery was overseen by California's SWRCB and USEPA Region 9

1 utility alone: Initial estimated removal/replacement cost: $300 million

The County and 1 public utility issued DND-DNB water use restrictions to protect population, but State and 1 private utility said that same water was safe

A Few Lessons Learned

- State and 1 private utility said that if water doesn't have an odor, it is safe [WRONG]
- Some laboratories incorrectly told survivors how to collect water samples
- Rapid health risk assessments needed, OEHHA warned 26 ppb presented acute risk
- More than benzene exceeded acute and chronic exposure limits
- When benzene not present other VOCs exceeded drinking water exposure limits
- State seems to have conducted testing on State employees using the contaminated drinking water - documented acute chemical exposure symptoms
- State found lab reproducibility issue: ± 287% benzene difference in duplicates
- Plumbing testing guidance bungled by State, at least 1 Commercial Lab, some Home Water Treatment Companies, at least 1 Insurance Company
- Insurance companies hired "experts". 1 said they didn't believe in or use stagnation

There are many research and innovation opportunities for positive impact. A volunteer drinking water disaster science corps is also needed.

1. Develop approach that can be rapidly deployed to identify a clear profile of contaminants of health consequence
2. Develop science-based water use restrictions that protect public health and recovery guidance
3. Develop and implement laboratory contamination controls, data reproducibility, and SOPs
4. Identify decontamination practices and strategies that can rapidly resolve the affected infrastructure in a reasonable time (abandon, replace, repair)
5. Address knowledge-gaps for property plumbing testing, contamination, decontamination, and home water treatment

Questions?

Andrew Whelton, Ph.D.
awhelton@purdue.edu

More Info, Visit www.PlumbingSafety.org

- ✓ Camp Fire Drinking Water Community Survey Results
- ✓ Science Communication & Engagement: Drinking Water and Plumbing After a Wildfire
- ✓ Prior disaster response and recovery studies