WASHINGTON STATE UNIVERSITY

Wildfire Impacts on Water Quality & Treatment

Rogue River Basin Source Water Protection Workshop

Amanda Hohner
Assistant Professor
Washington State University
ahohner@wsu.edu

Wildfire Impacts to Water Quality

- Increased particulates (TSS, turbidity)
- Elevated nutrients (P, N)
- Elevated dissolved organic carbon (DOC)
- **A wide range of responses have been observed**

Watershed specific factors	Wildfire specific factors
▪ Hydrologic regime ▪ Type and density of vegetation ▪ Soil type and moisture content	▪ Area burned ▪ Burn severity ▪ Extent of burn ▪ Location/proximity

How will drinking water treatment and finished water quality be affected?

Watershed Response	Treatment Implication
Increased particle loads	• Infrastructure problems • Coagulation, filtration, & disinfection challenges
Elevated nutrient levels	• Algal blooms • Algal organic matter
Altered dissolved organic matter	• Coagulation challenges • DBP formation & speciation

Case Study- High Park Wildfire

- The High Park wildfire burned the Cache la Poudre (CLP) watershed in northern Colorado
- Burned from June 9th- July 1st, 2012
  - 87,000 acres at mixed severities
  - Burned ~10% of total watershed
- The CLP River provides water to several northern Colorado communities

Watershed Response

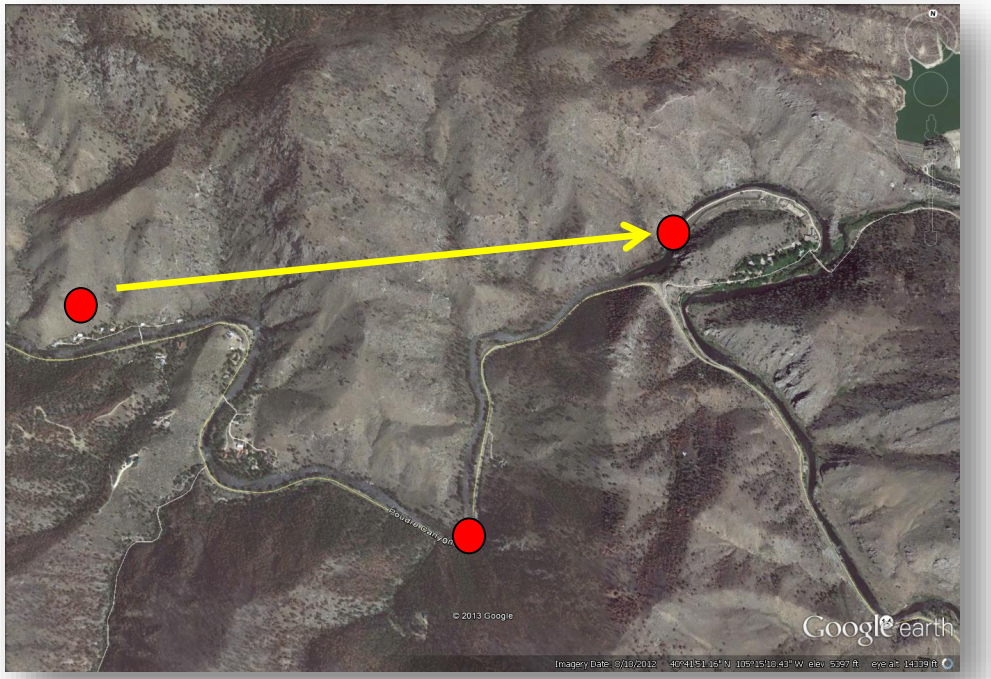
- Extensive loss of vegetation
- Moderate to high soil burn severity
- Hydrology shifted from subsurface to surface flow
- Even small, previously dry tributaries experienced very high, “flashy” flows

Fort Collins Utility Response

- Shut down CLP River water supply
- Used alternate water source (Horsetooth Reservoir) for over 100 days
- CLP River water was slowly blended back into drinking water source
- When turbidity exceeded 100 NTU the river intake was shut off again
- Rapidly designed and constructed a pre-sedimentation basin

Fort Collins Utility Response

- Installed early warning system
- Provides ~ 1 hour warning of highly turbid water
- Allows operators to shut down pipeline and avoid large sediment loads



Research Approach

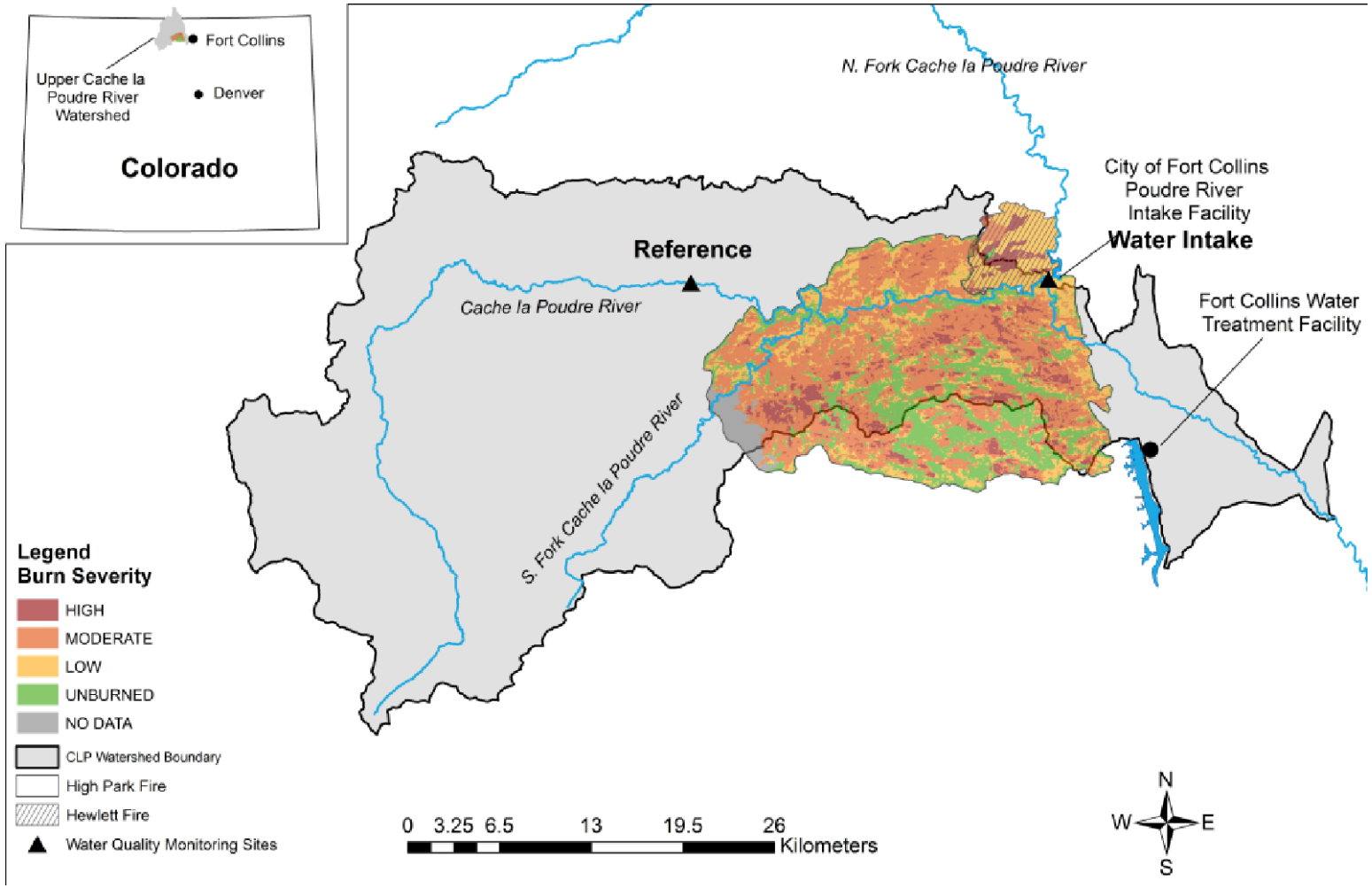
Bench-scale Treatability Evaluation

1. Post-fire monitoring of a drinking water intake

2. Leaching of wildfire-affected sediments

3. Controlled laboratory heating and leaching of soil and litter

Study 1. Post-fire Monitoring



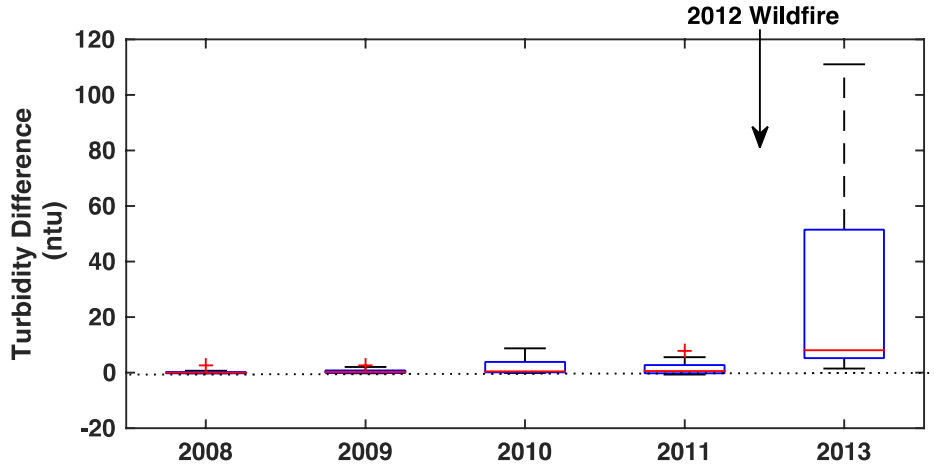
Water Intake

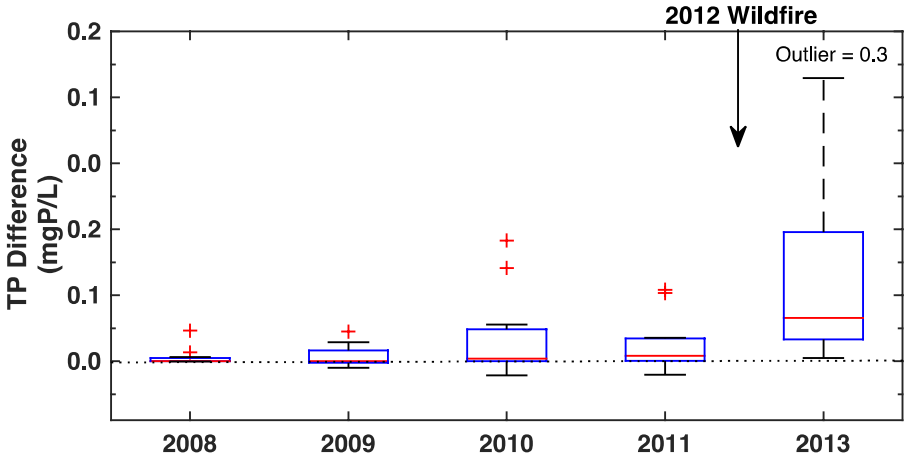
Reference Site

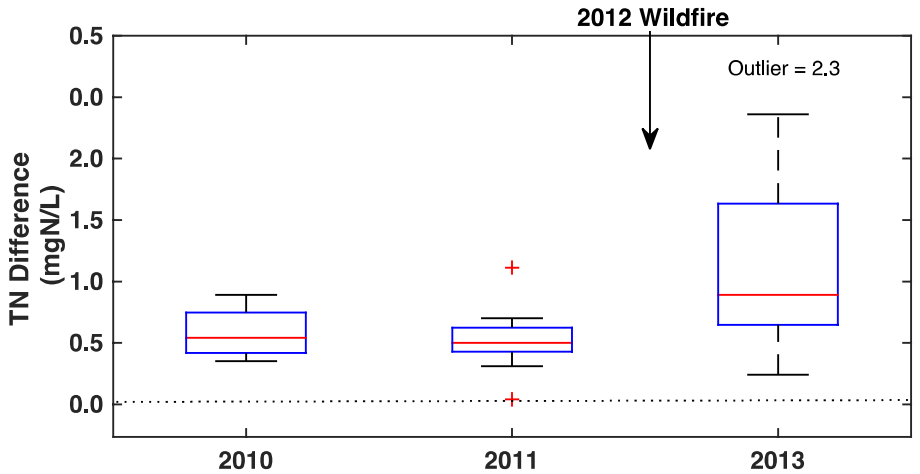
- Monitored bi-weekly during baseflow and snowmelt
- Post-rainstorm samples collected from intake

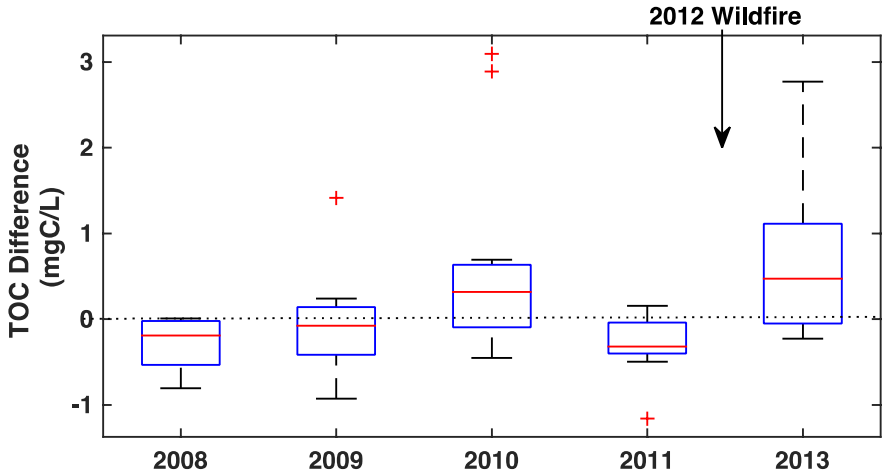
Pre- and Post-fire Water Quality

Hohner et al., 2016, Water Research



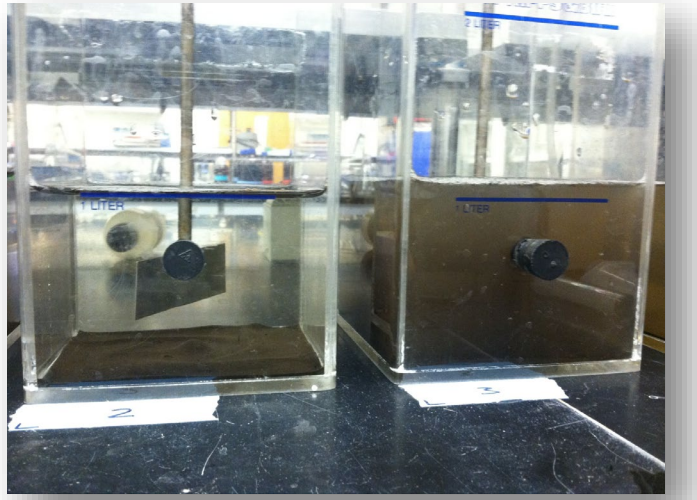




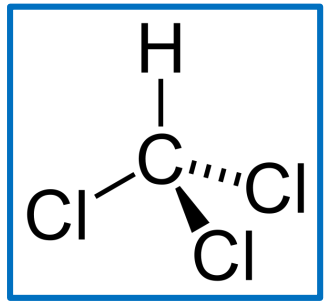


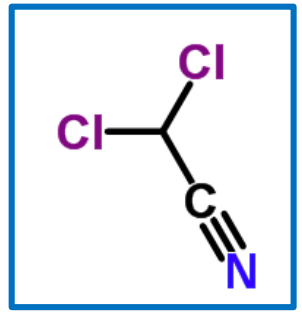
- Paired differences in water quality (intake – reference site)
- Dashed line (difference = 0)
- *Post-rainstorm samples were not included

Treatability Evaluation



- Conventional treatment with aluminum sulfate
- Coagulant dose selected based on optimal DOC removal
- Raw and treated water samples were chlorinated and analyzed for disinfection byproduct formation (DBPs)
  - Carbonaceous DBPs
    - Total trihalomethanes (TTHMs)
    - Five haloacetic acids (HAA5s)
  - Nitrogenous DBPs
    - Haloacetonitriles (HANs)
    - Chloropicrin



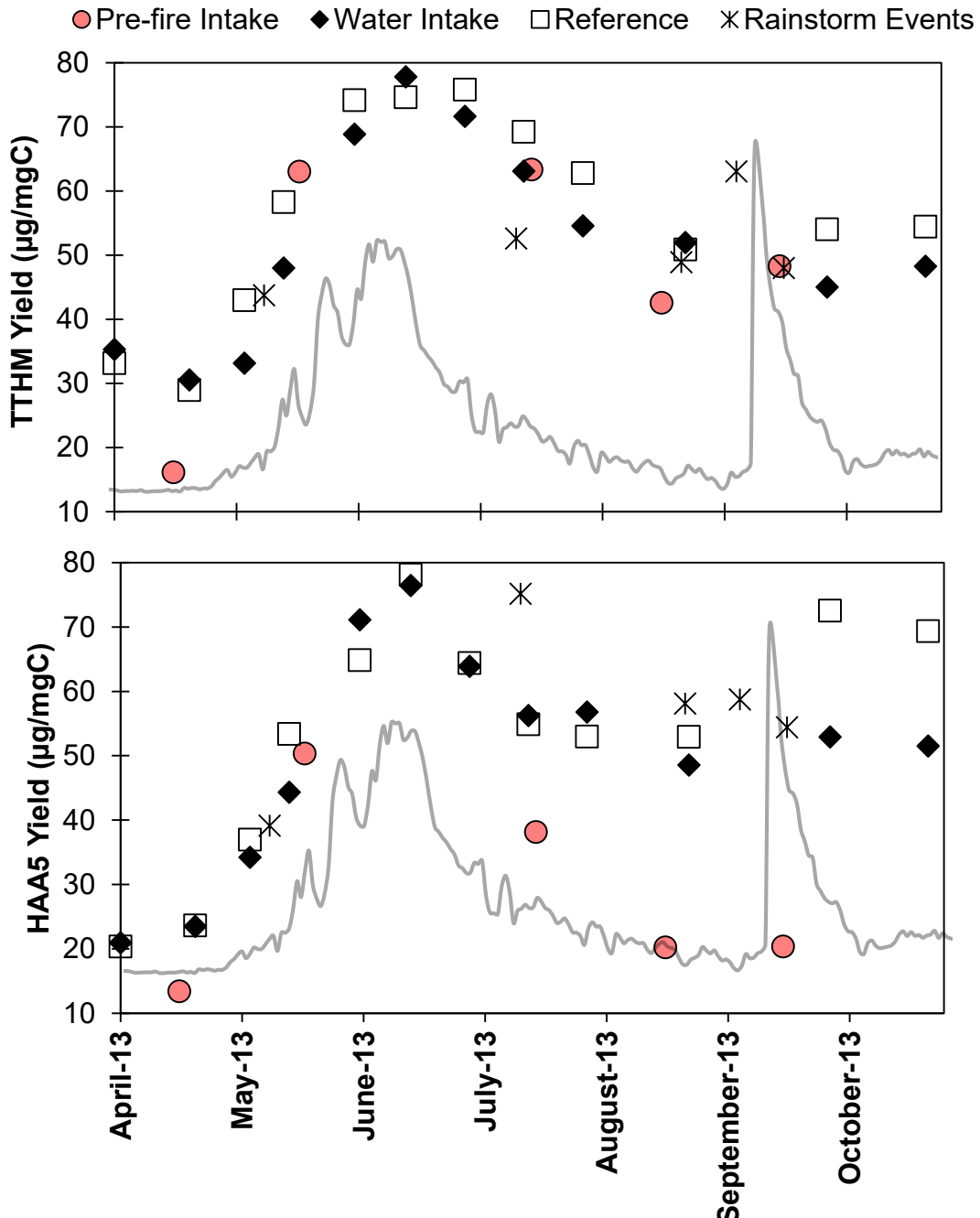


Watershed Monitoring: Raw Water C-DBPs

- TTHM *formation* (µg/L) was significantly higher at the water intake

Watershed Monitoring: Raw Water C-DBPs

- TTHM *formation* (µg/L) was significantly higher at the water intake
- C-DBP *yields* peaked with snowmelt
- C-DBP *yields* were not significantly different following the wildfire
- Post-rainstorm C-DBP *yields* were similar to baseflow & snowmelt samples, BUT DBP formation was elevated due to higher TOC

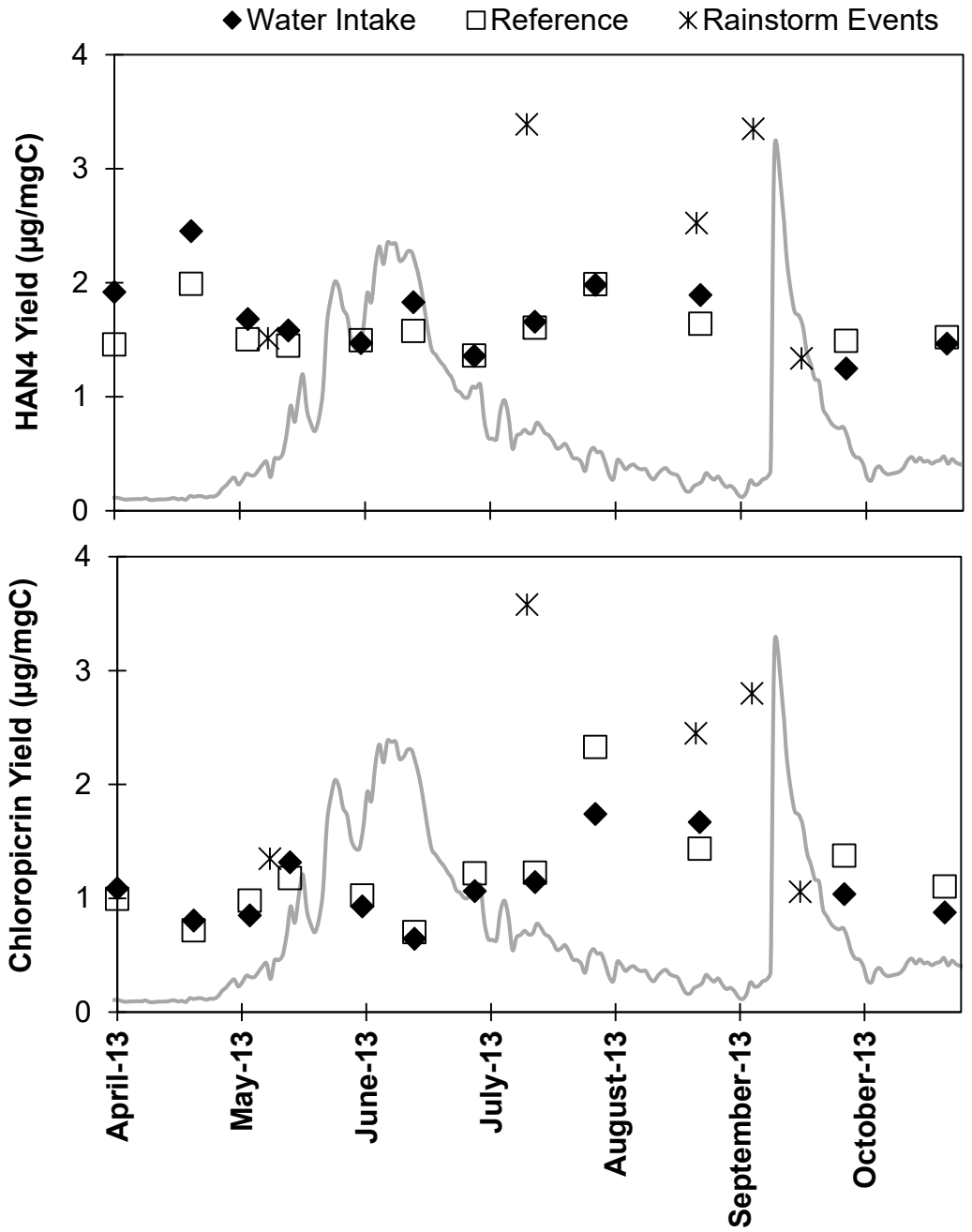


Watershed Monitoring: Raw Water N-DBPs

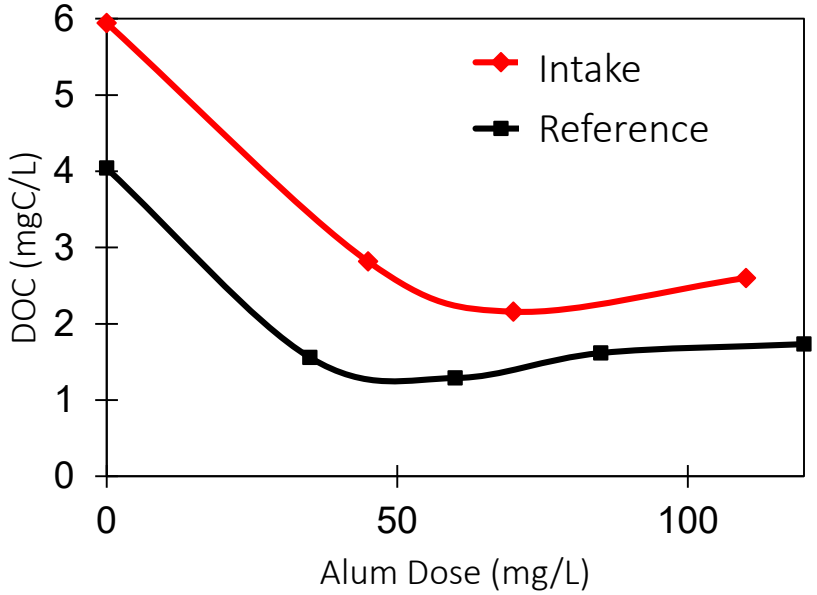
- HAN4 formation (µg/L) was significantly higher at the water intake

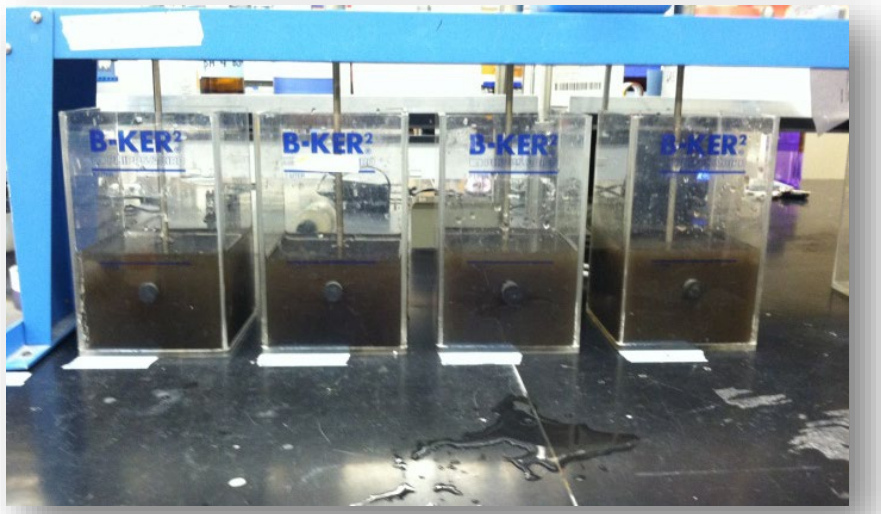
Watershed Monitoring: Raw Water N-DBPs

- HAN4 formation (µg/L) was significantly higher at the water intake
- N-DBP yields did not follow the same seasonal trend as C-DBPs
- N-DBP yields were similar for the water intake and reference site
- Post-rainstorm N-DBP formation and yields were elevated



Watershed Monitoring: Treatment Response





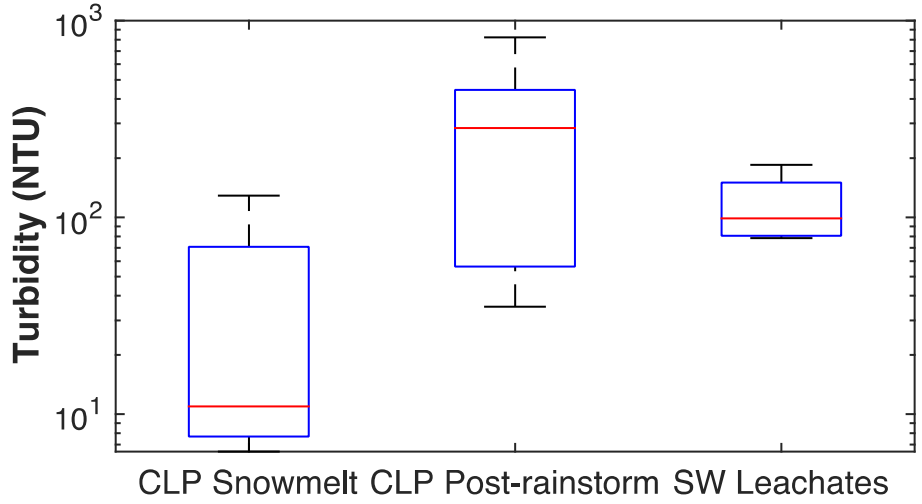
- During baseflow and snowmelt significantly higher alum dose (10 mg/L) required for water intake
- Post-rainstorm samples presented treatment challenges, and even at high alum doses (>65 mg/L) showed minimal DOC removal (< 10%)
- Post-fire samples had high initial turbidity (>200 ntu) and high DOC
- Five post-rainstorm samples exceeded DBP MCLs

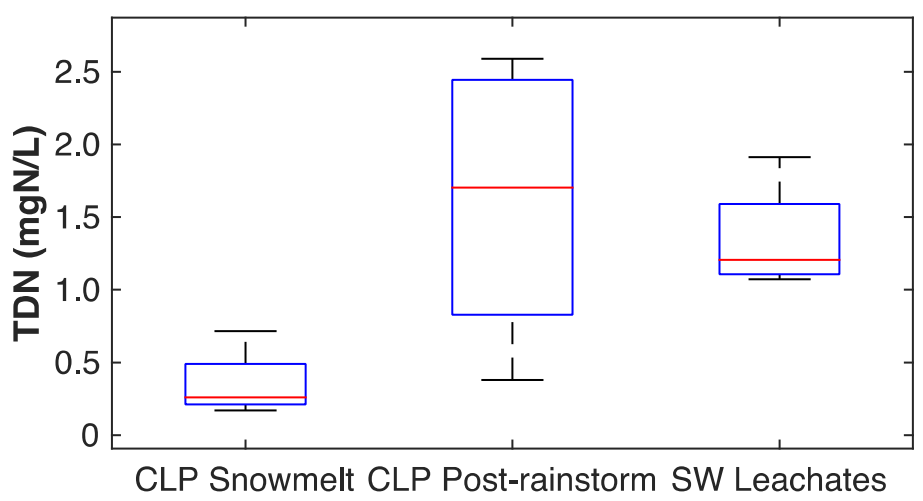
Study 2. Wildfire-affected Sediment Leaching

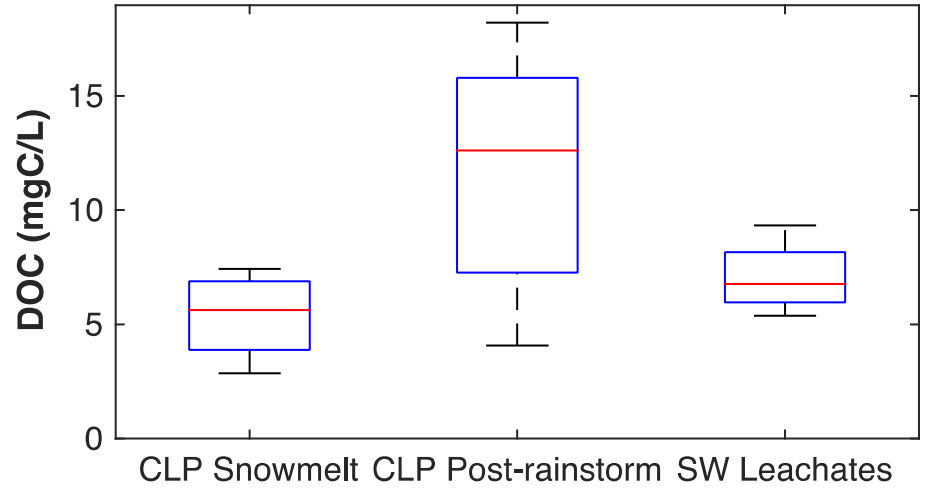
- **Source Water Leachates:**
  - Sediments added to source waters for two utilities
    - Fort Collins (baseline)
    - Denver Water (baseline)
- **LCT Leachates:**
  - Sediments added to low-carbon tap-water (LCT)

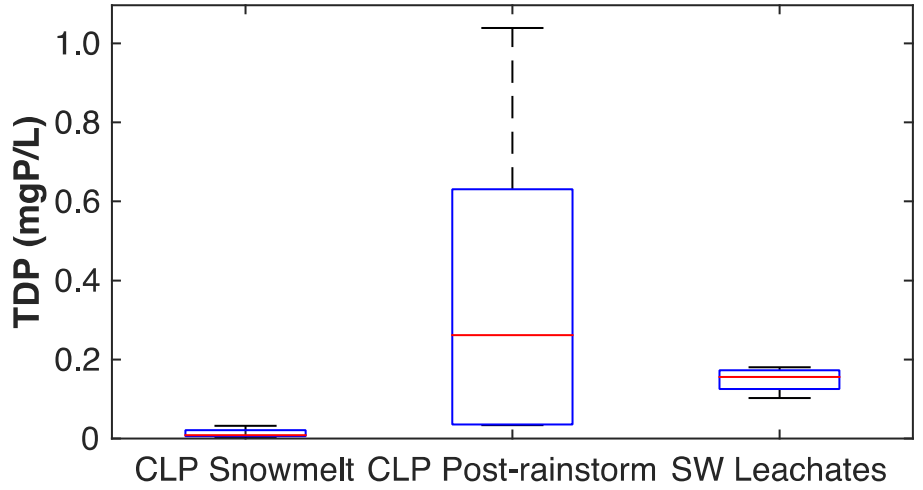
- **Treatment process evaluation:**
  - Coagulation
  - Pre-oxidation/Coagulation
  - Powdered activated carbon (PAC) + Coagulation
  - Biofiltration/Coagulation
  - Ozonation/Coagulation/Biofiltration

CLP River Water and Sediment Leachate Comparison

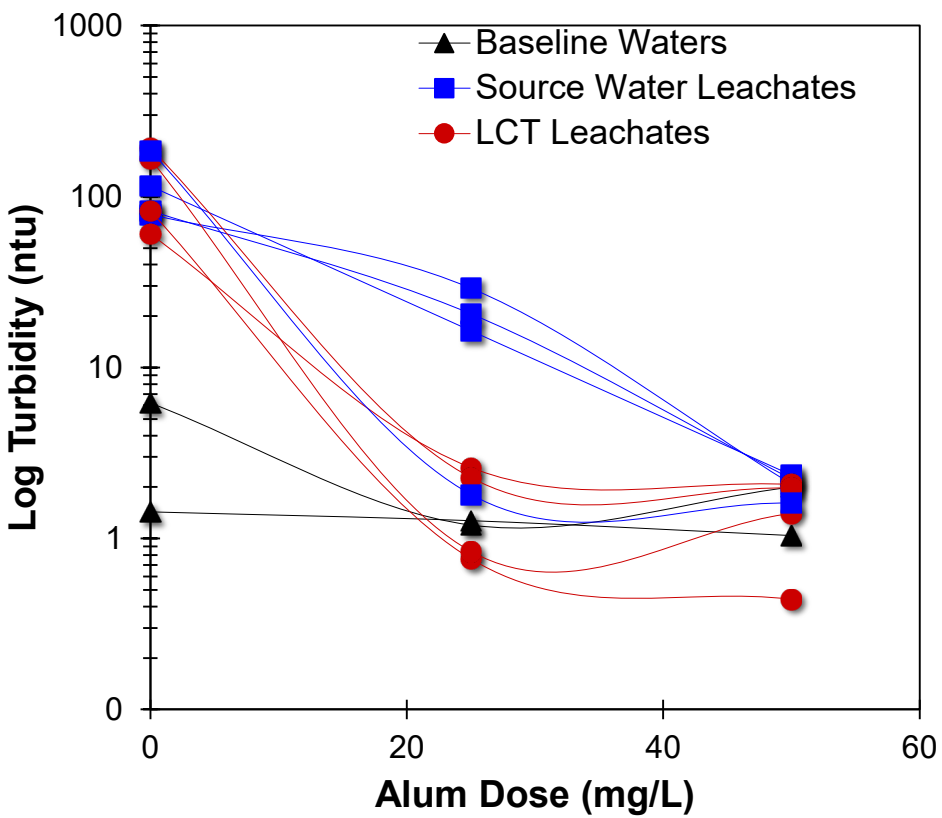


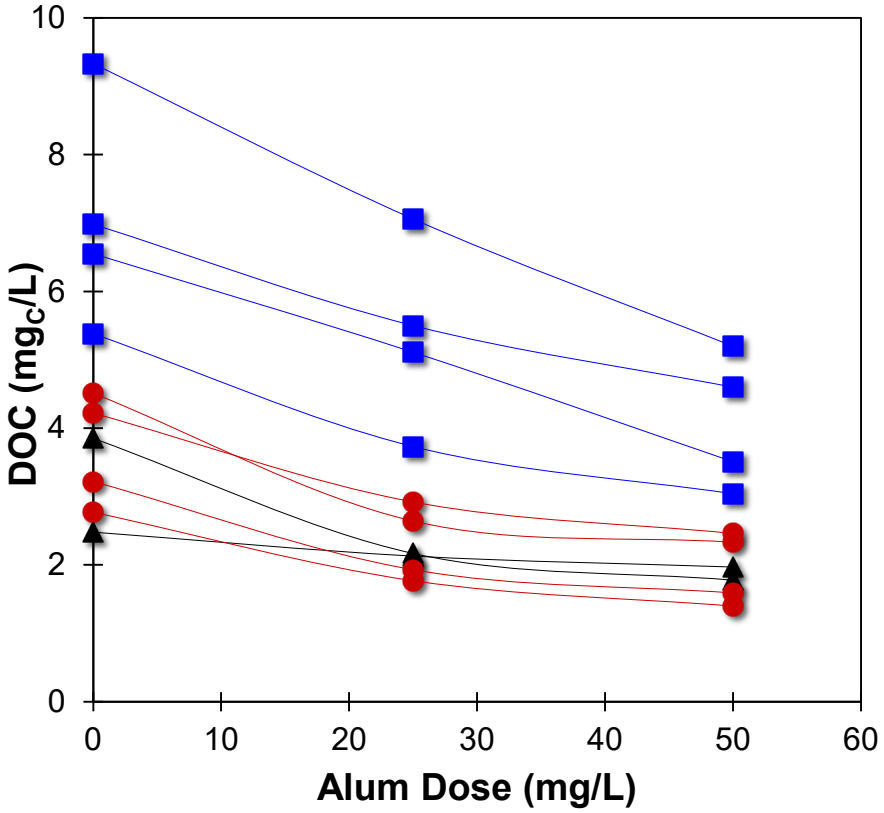






Sediment Leachates: Coagulation Response





Hohner et al., 2017, Environmental Science: Water Research & Technology

1. DBP MCLs were used to assess treatability of the sediment leachates

$$\boldsymbol{TTHM\ MCL} = 80\frac{\mu g}{L} \qquad \boldsymbol{HAA5\ MCL} = 60\frac{\mu g}{L}$$

2. DBP Yields were used for comparison of samples with varying DOC

$$\boldsymbol{DBP\ Yield} = \frac{DBP\ concentration\ \frac{\mu g}{L}}{DOC\ concentration\ \frac{mgC}{L}}$$

3. Required DOC threshold values for the point of chlorination were determined

$$\boldsymbol{DOC\ Threshold} = \frac{DBP\ MCL\ \frac{\mu g}{L}}{DBP\ Yield\ \frac{\mu g}{mgC}}$$

4. The more restrictive DOC threshold was chosen (TTHM or HAA5)- lower required treated water DOC concentration for meeting MCLs

Sample Name		DOC Threshold (mg_C/L)							Best Treatment Option
		Conventional Treatment	Enhanced Coagulation	PAC	Chlorine Dioxide	Pre-ozonation	Biofiltration	Pre-ozonation/ Biofiltration	
Baseline Waters	Fort Collins (FC)	2.6	2.8	2.3	2.6	2.7	2.6	3.0	Pre-ozonation/ Biofiltration
	Denver Water (DW)	3.1	3.3	2.8	4.8	3.0	2.7	3.3	Chlorine Dioxide
Average increase in DOC threshold			0.2	-0.3	0.8	0.0	-0.2	0.3	
Source Water Leachates	A- FC	2.0	2.0	1.8	1.8	2.4	1.4	2.2	Pre-ozonation
	B- DW	1.7	2.1	1.8	1.8	3.0	1.6	2.6	Pre-ozonation
	C- DW	2.1	2.8	2.1	2.1	2.8	2.4	2.1	Enhanced Coag & Pre-ozonation
	D- FC	1.8	2.4	1.3	2.0	2.4	1.8	2.3	Enhanced Coag & Pre-ozonation
LCT Leachates	A- LCT	2.0	2.3	1.8	2.1	2.6	1.6	2.4	Pre-ozonation
	B- LCT	1.6	2.1	2.0	2.0	1.7	1.7	2.1	Enhanced Coag & Pre-ozonation/Bio
	C- LCT	1.4	1.9	2.1	1.7	3.0	1.5	2.1	Pre-ozonation
	D- LCT	2.1	2.0	1.8	2.2	2.7	1.6	2.5	Pre-ozonation
Average Increase in DOC threshold			**0.4**	**0.0**	**0.1**	**0.7**	**-0.1**	**0.5**	**Pre-ozonation**

Research Summary

- A small wildfire may impact water quality and treatment
- Post-rainstorm samples presented the greatest treatment challenges
- Additional treatment may be required to meet DBP MCLs
  - Enhanced coagulation
  - Pre-ozonation
- Attention should be given to post-fire N-DBP precursors
- DOM character may be altered by wildfire heating

Recommendations

- Capital Investment Considerations
  - Expanding water storage capacity
  - Exploring additional supplies
  - Increasing monitoring
  - Constructing pre-sedimentation basins

- Treatment Operations
  - Increase coagulant dose to account for higher turbidity and DOM
  - Increased solids loading, greater costs, shorter filter runs
  - Difficulty meeting DBP regulations

- *Small, single source water treatment systems may be at greatest risk*

Acknowledgments

- Water Research Foundation
- Colorado Department of Public Health & Environment
- Hazen & Sawyer
- Water Utilities
  - City of Fort Collins (Jill Oropeza), Denver Water, NYC Department of Environmental Protection, City of Westminster, San Francisco Public Utilities Commission, Truckee Meadows Water Authority, Metropolitan Water District of Southern California
- University of Colorado
  - Fernando L. Rosario-Ortiz, R. Scott Summers, Jeffrey Writer, Dorothy Noble, Kaelin Cawley, Jack Webster, Leigh Gilmore, Eli Townsend, Ariel Retuta, Garrett McKay, Andrew Moscovich, Wade Godman

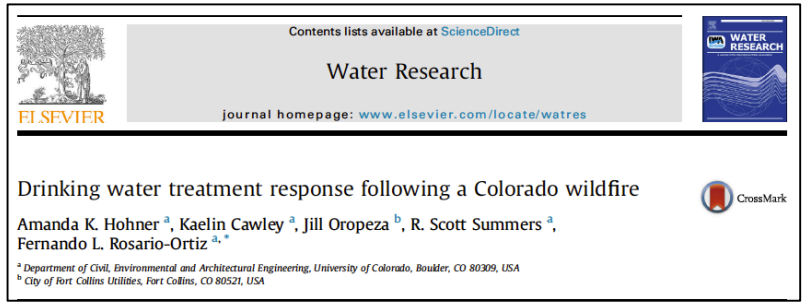
Additional Resources

- Becker et al., 2018, Journal AWWA
- Hohner et al., 2016, Water Research
- Hohner et al., 2017, ESWRT
- WRF 4590 Report, 2018
- Writer et al., 2014, Journal AWWA

Amanda Hohner
Washington State University
ahohner@wsu.edu

PROJECT NO. 4590

Wildfire Impacts on Drinking Water Treatment Process Performance: Development of Evaluation Protocols and Management Practices



Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

Drinking water treatment response following a Colorado wildfire

Amanda K. Hohner, Kaelin Cawley, Jill Oropeza, R. Scott Summers, Fernando L. Rosario-Ortiz

Environmental Science Water Research & Technology

PAPER

WILLIAM C. BECKER, AMANDA HOHNER, FERNANDO ROSARIO-ORTIZ, AND JAMES DEWOLFE

Preparing for Wildfires and Extreme Weather: Plant Design and Operation Recommendations