Post-fire Impacts to Drinking Water Treatment

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Agenda

• Case Study: High Park Fire in northern Colorado
• Utility Response
• Overview of three AWWA-WRF Wildfire projects
  • Post-fire Monitoring of a Water Intake
  • Leaching of Wildfire-Affected Sediments
  • Laboratory Heating of Soil and Litter
• Summary and Recommendations
<table>
<thead>
<tr>
<th>Watershed Response</th>
<th>Treatment Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased particle loads</td>
<td>• Infrastructure problems</td>
</tr>
<tr>
<td></td>
<td>• Coagulation, filtration, &amp; disinfection challenges</td>
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<tr>
<td>Elevated nutrient levels</td>
<td>• Algal blooms</td>
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<tr>
<td></td>
<td>• Algal organic matter</td>
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<tr>
<td>Altered dissolved organic matter</td>
<td>• Coagulation challenges</td>
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<td>• DBP formation &amp; speciation</td>
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**Goal:** connect post-fire water quality changes directly to impacts on treatment process performance and finished water quality
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

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

- Monitored bi-weekly during baseflow and snowmelt
- Post-rainstorm samples collected from intake
• 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
- 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
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 processes evaluation:**
  - Coagulation
  - Pre-oxidation/Coagulation
  - Powdered activated carbon (PAC) + Coagulation
  - Biofiltration/Coagulation
  - Ozonation/Coagulation/Biofiltration
CLP River Water and Sediment Leachate Comparison

- **Turbidity (NTU)**
  - CLP Snowmelt
  - CLP Post-rainstorm
  - SW Leachates

- **TDN (mgN/L)**
  - CLP Snowmelt
  - CLP Post-rainstorm
  - SW Leachates

- **DOC (mgC/L)**
  - CLP Snowmelt
  - CLP Post-rainstorm
  - SW Leachates

- **TDP (mgP/L)**
  - CLP Snowmelt
  - CLP Post-rainstorm
  - SW Leachates
Sediment Leachates: Coagulation Response

Hohner et al., 2017, Environmental Science: Water Research & Technology
### Sediment Leachates: C-DBP Formation

- Solid symbols represent raw samples and open symbols show treated samples.
- Trends were significant for all sample groups ($p < 0.001$).
- Slopes for different sample groups were not significantly different ($p > 0.05$).
Sediment Leachates: N-DBP Formation

- HAN4 trend was significant ($p < 0.001$) for the LCT leachates
- Slopes for the different sample groups were significantly different ($p > 0.05$)
- Sediment leachates appear enriched in N-DBP precursors
1. DBP MCLs were used to assess treatability of the sediment leachates

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

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

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

\[ TTHM\ MCL = 80 \frac{\mu g}{L} \quad HAA5\ MCL = 60 \frac{\mu g}{L} \]

\[ DBP\ Yield = \frac{DBP\ concentration\ \frac{\mu g}{L}}{DOC\ concentration\ \frac{mgC}{L}} \]

\[ DOC\ Threshold = \frac{DBP\ MCL\ \frac{\mu g}{L}}{DBP\ Yield\ \frac{\mu g}{mgC}} \]
<table>
<thead>
<tr>
<th>Sample Name</th>
<th>DOC Threshold (mgC/L)</th>
<th>Best Treatment Option</th>
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<tbody>
<tr>
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<td>Conventional Treatment</td>
<td>Enhanced Coagulation</td>
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<td>Baseline Waters</td>
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<td>Fort Collins (FC)</td>
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<td>2.8</td>
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<tr>
<td>Denver Water (DW)</td>
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<td>Average increase in DOC threshold</td>
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<td>-0.3</td>
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<td>Source Water Leachates</td>
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<td>A- FC</td>
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<tr>
<td>B- DW</td>
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<tr>
<td>C- DW</td>
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<tr>
<td>D- FC</td>
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<td>LCT Leachates</td>
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<td>C- LCT</td>
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<td>D- LCT</td>
<td>2.1</td>
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<tr>
<td>Average Increase in DOC threshold</td>
<td>0.4</td>
<td>0.0</td>
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Study 3: Controlled Heating

- **Objective:** Understand the effects of a low-moderate severity wildfire on dissolved organic matter and treatability

- Surface litter and soil samples were collected from three source watersheds
Controlled Laboratory Heating

- Materials were heated in a furnace at 225°C for two hours
- Soil and litter were composited
- Unheated (control) and heated materials were leached for 24 hours in LCT water
- Leachates were diluted to a DOC concentration = 5.0 ± 1.0 mgC/L
Controlled Heating: Dissolved Organic Matter (DOM)

- Heating altered the DOM character:
  - Nitrogen enriched: DOC:DON ↓
  - More aromatic: SUVA$_{254}$ ↑
  - Lower molecular weight compounds
Controlled Heating: Jar Test Response

- WM Control
- WM Heated
- DW Control
- DW Heated
- NY Control
- NY Heated

Log Turbidity (ntu) vs. Alum Dose (mg/L)

DOC (mg C/L) vs. Alum Dose (mg/L)
Controlled Heating: Treated Water DBP Levels

- TTHM Formation (μg/L)
- HAA5 Formation (μg/L)
- HAN4 Formation (μg/L)
- Chloropicrin Formation (μg/L)

[Graphs showing the relationship between DOC (mgC/L) and DBP levels for Control and Heated conditions, with MCL levels indicated.]

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<th>DOC (mgC/L)</th>
<th>TTHM Formation (μg/L)</th>
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<table>
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<th>HAA5 Formation (μg/L)</th>
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<thead>
<tr>
<th>DOC (mgC/L)</th>
<th>HAN4 Formation (μg/L)</th>
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<table>
<thead>
<tr>
<th>DOC (mgC/L)</th>
<th>Chloropicrin Formation (μg/L)</th>
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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
• 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
  - 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, City of Fort Collins
- University of Colorado
  - Jeffrey Writer, Dorothy Noble, Kaelin Cawley, Jack Webster, Leigh Gilmore, Eli Townsend, Ariel Retuta, Garrett McKay, Andrew Moscovich, Wade Godman
Additional Resources

- Becket 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

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