Removal of 1,4-Dioxane from Groundwater Using Advanced Oxidation

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2018 TACOMA PNWS-AWWA

Presentation Roadmap

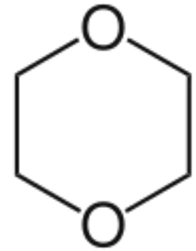
What's 1,4-Dioxane?

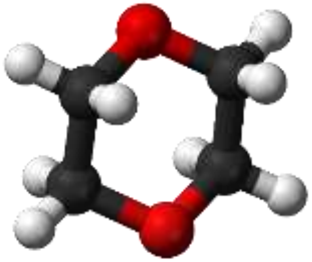
Project Introduction

Bench-scale and Pilot-scale testing

Findings and Next steps

What is 1,4-Dioxane?





- $C_4H_8O_2$
- Classified as an ether
- Solvent, found at many federal facilities
- Widespread use as a stabilizer in certain chlorinated solvents, paint strippers, greases and waxes
- A likely contaminant with certain chlorinated solvents, such as TCE or TCA

Where is 1,4-Dioxane?

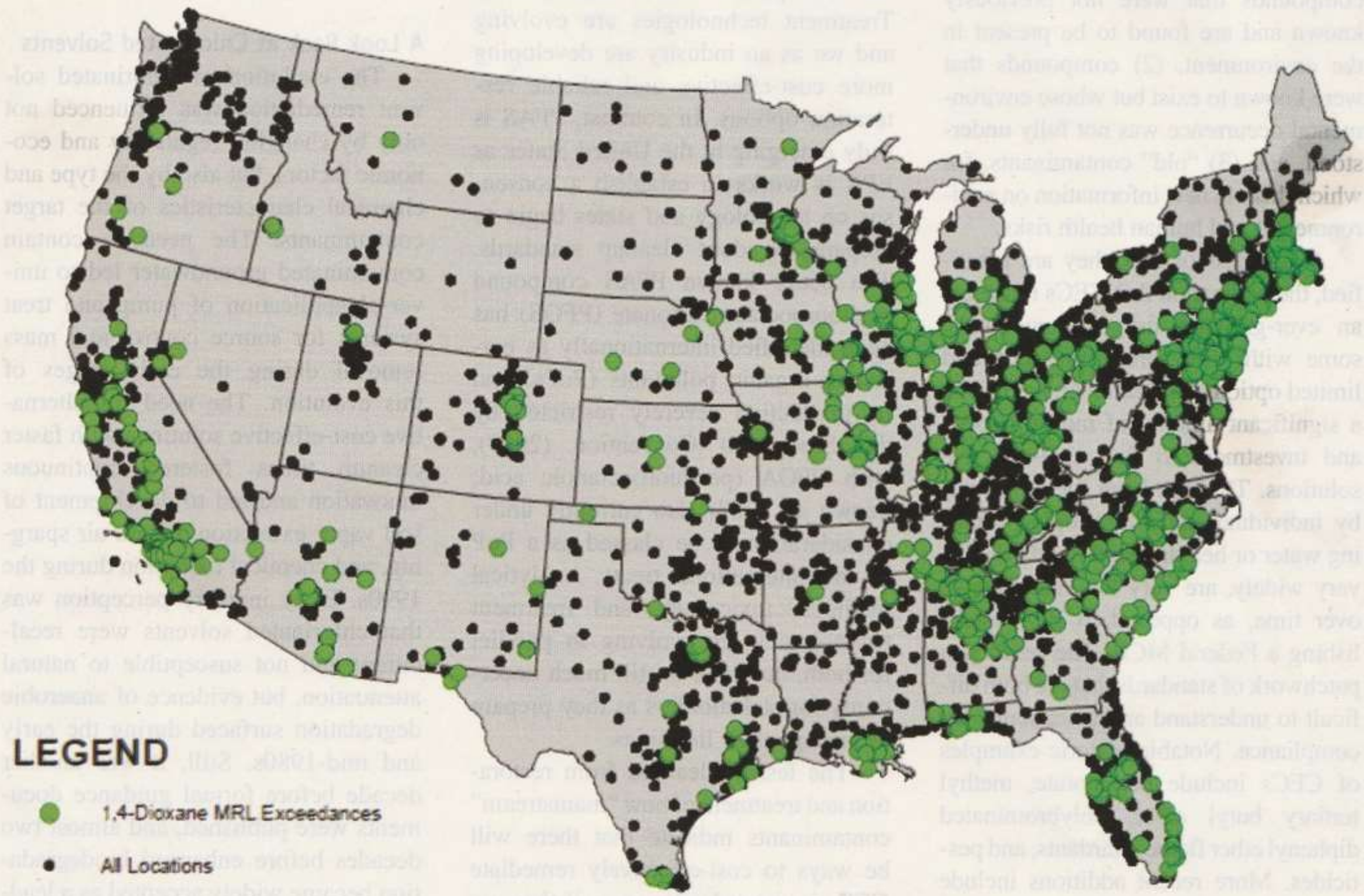


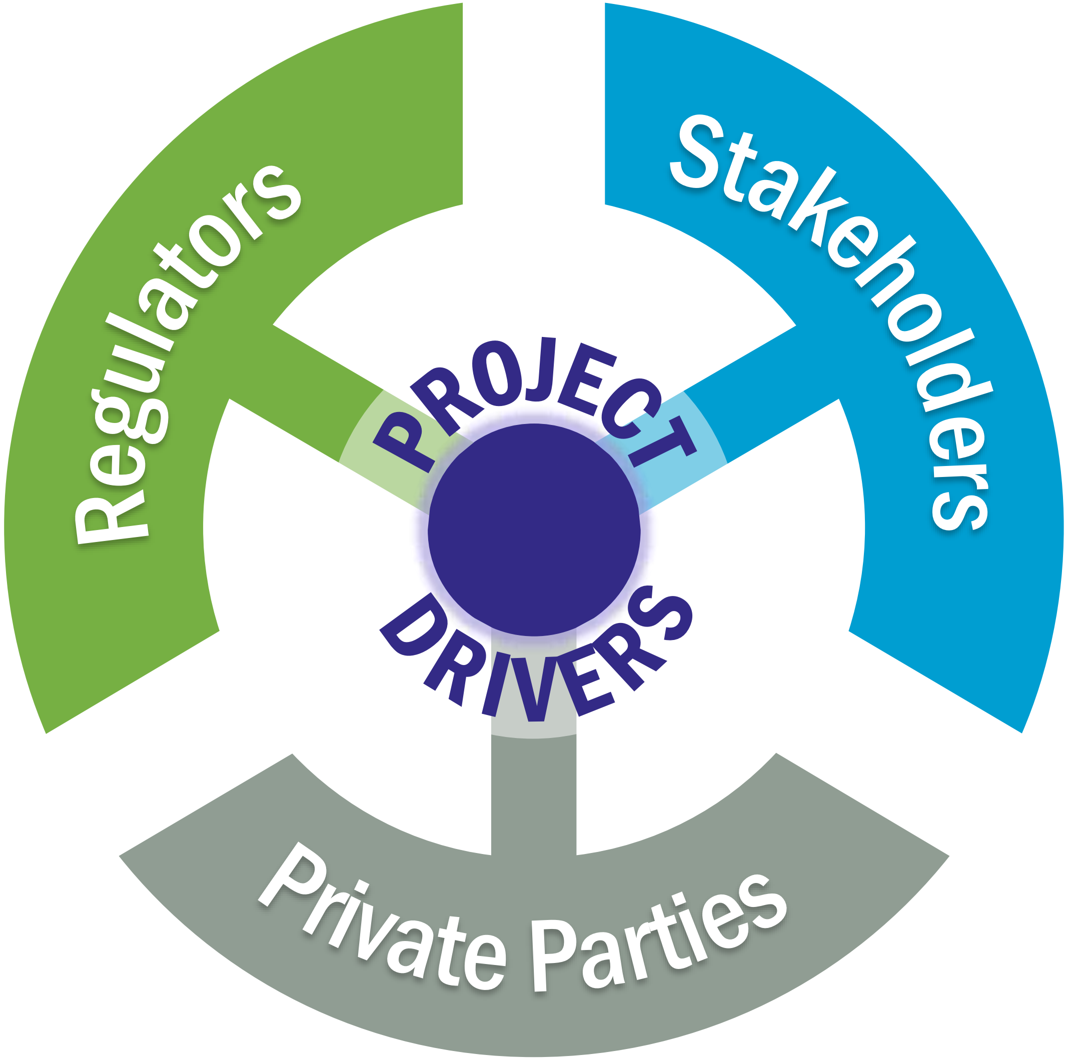
Figure 1. 1,4-dioxane public water supply sampling results from USEPA Unregulated Contaminant Monitoring Rule 3 (UCMR 3) (EPA 2015). Based on results reported through June 2015, nearly 7% of public water supplies tested showed exceedances of the health advisory levels for 1,4-dioxane.

Why do we care?

- Increasingly regulated because it is carcinogenic
  - Found to have fetal effects on rats
  - Chronic exposure may result in dermatitis, eczema, drying and cracking of skin and liver and kidney damage
- Various states adopting regulations
  - California: notification level of 1 µg/L for drinking water
  - Colorado: interim groundwater quality cleanup standard of 0.35 µg/L
  - Florida: health advisory goal of 0.35 µg/L
  - Massachusetts: drinking water guideline level of 0.3 µg/L
  - New Hampshire: reporting limit of 0.25 µg/L for all public water supplies

Key Project Goals

- Design a treatment system that reliably treats 1,4-Dioxane and meets regulations
- Treat what the City currently pumps
- Develop a system that can be managed/ operated by City WTP staff after training



Key Design Criteria

Design Flow	7,500 gallons per minute (gpm), expandable to 10,000 gpm
Avg. Daily Flow	3 million gallons per day (mgd) ~2000 gpm
Meet Primary and Secondary Drinking Water Standards	

Raw Water

1,4-Dioxane max.	10 µg/L
1,4-Dioxane avg.	1 µg/L
Bromide	20 to 108 µg/L
Total Organic Carbon (TOC)	~1 mg/L

Finished Water Goals

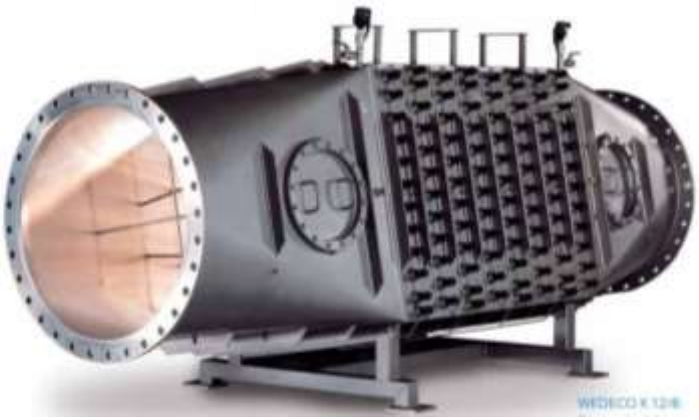
1,4-Dioxane HAL	0.35 µg/L
1,4-Dioxane target	0.20 µg/L
Bromate	< 7 µg/L
TTHMs HAA5	≤60 µg/L ≤40 µg/L

Raw Water Quality Data

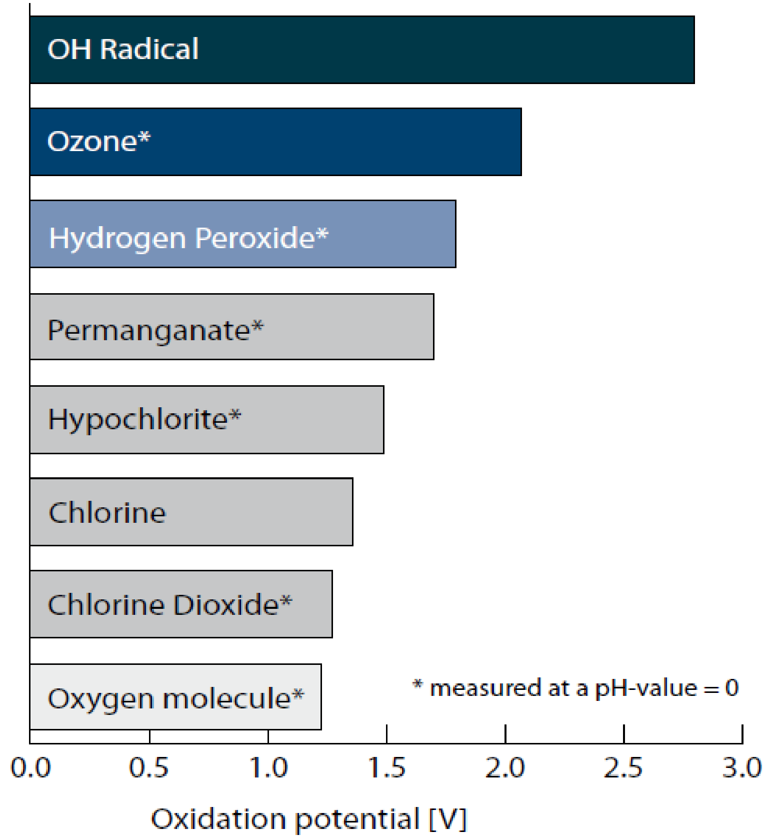
Wellfield/WTP Raw Water Quality Average (Range)					
Parameter	1	2	4	5	6
Capacity (gpm)	1,285	1,540	1,900	2,750	2,525
1,4-D (µg/L)	0.11 (0.11–0.16)	0.89 (0.54–1.38)	1.38 (1.00–1.70)	7.1 (5.60–8.70)	0.29 (0.11–0.68)
TOC (mg/L)	1.33	0.79	0.53	0.66	1.00
Bromide (µg/L)	38.3	37.6	102	41.8	40.3
UV absorbance at 254 nm (cm-1)	0.044	0.0260	0.014	0.028	0.034

Feasibility Study Overview

- Studied the connectivity of aquifer within and around the City wellfield
- Examined the feasibility of potential new well locations and supporting test data
- Evaluated impact of bringing new well online
- Analyzed effectiveness of advanced oxidation process (AOP)
- Reviewed potential byproduct formation by AOP treatment



Advanced Oxidation Process (AOP)



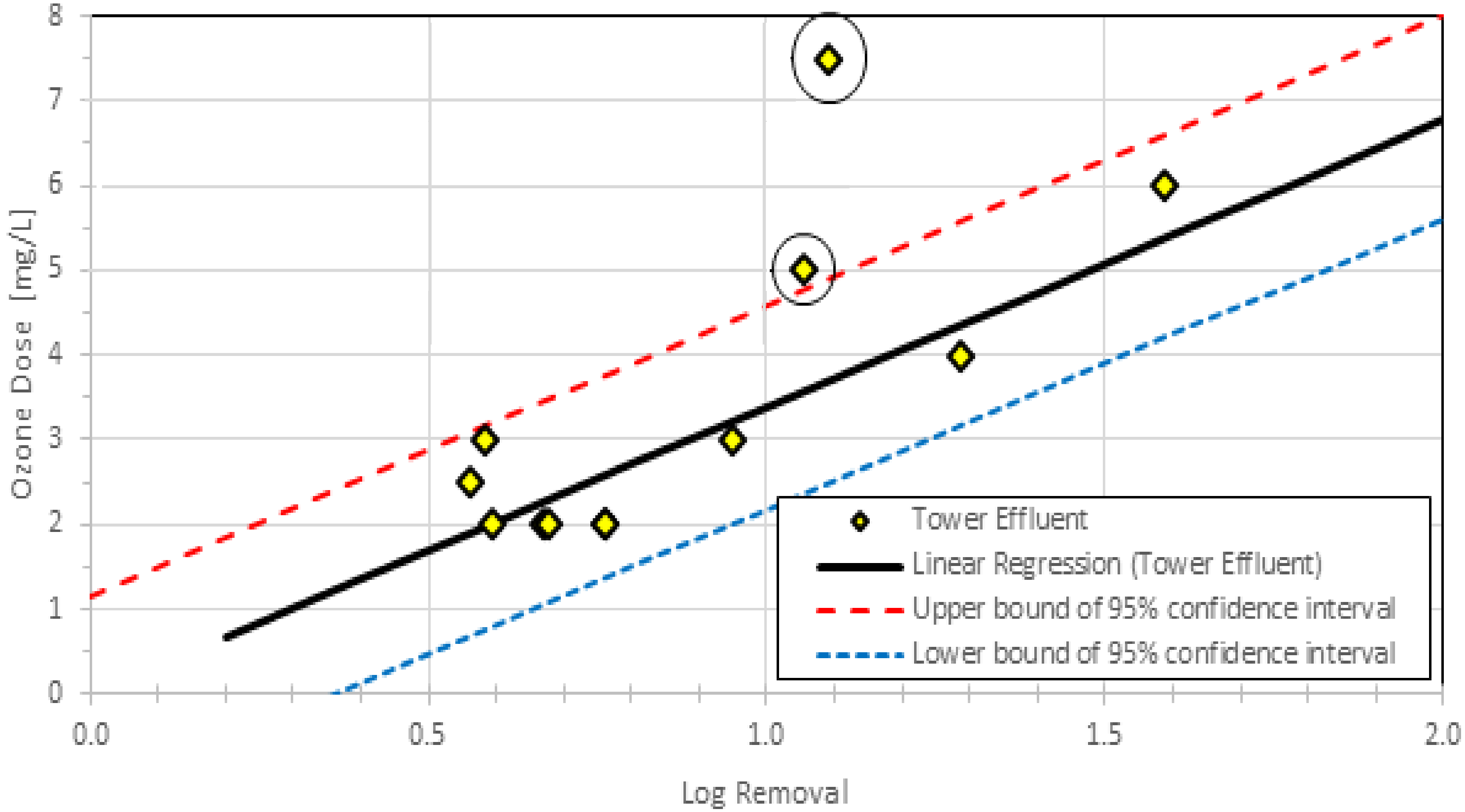
Compared to other oxidants, OH radicals have a considerably higher oxidation potential

Source: Xylem, Wedeco MiPro brochure

Bench Test Summary

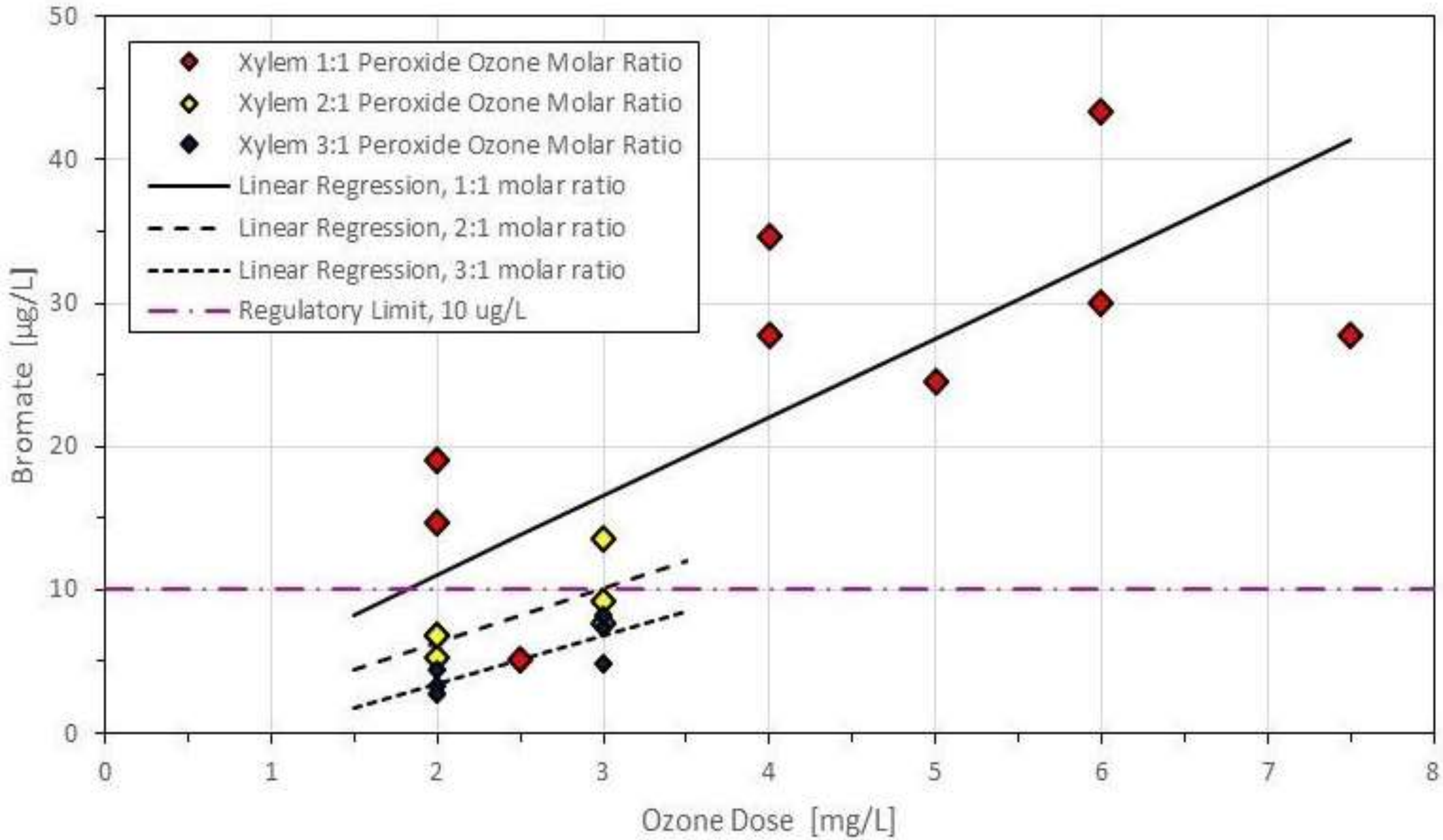
Confirmed ozone/peroxide efficacy and narrowed the pilot testing dose range

Ozone/Peroxide only without UV



Bromate formation is related to ozone dose and can be managed with a higher peroxide to ozone molar ratio

Ozone/Peroxide only without UV



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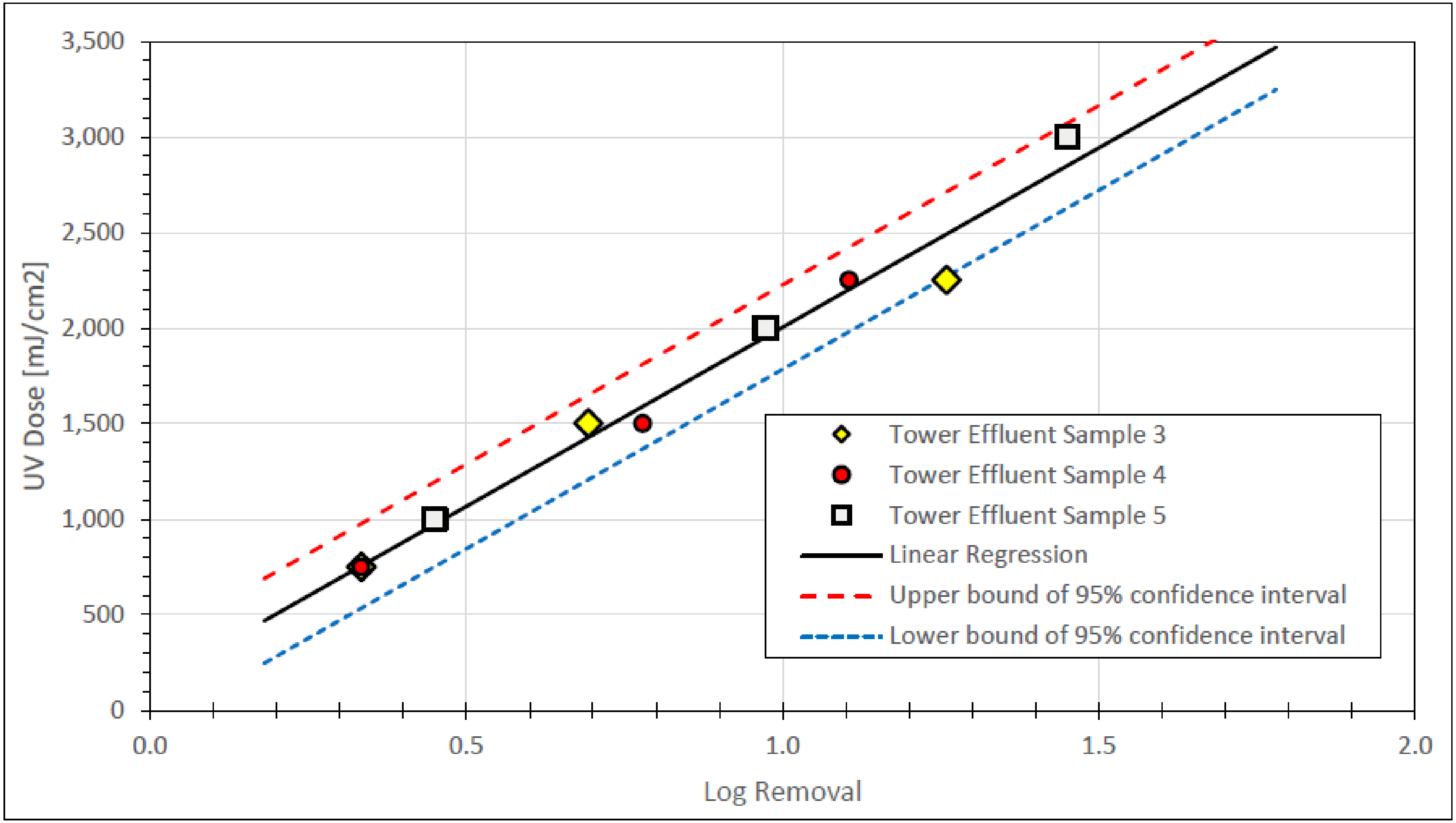
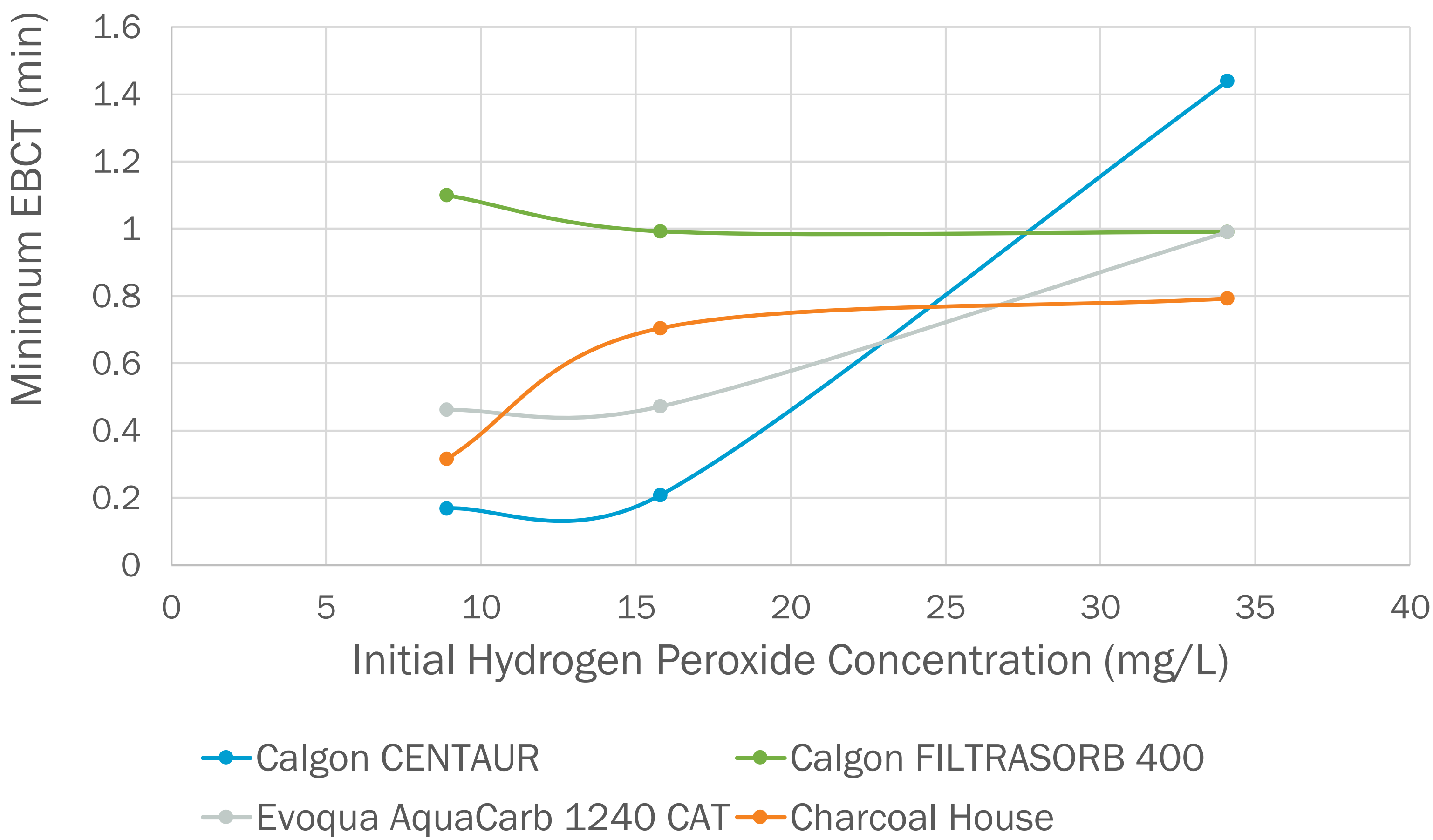


GAC bench-scale testing demonstrated efficient quenching at low EBCTs

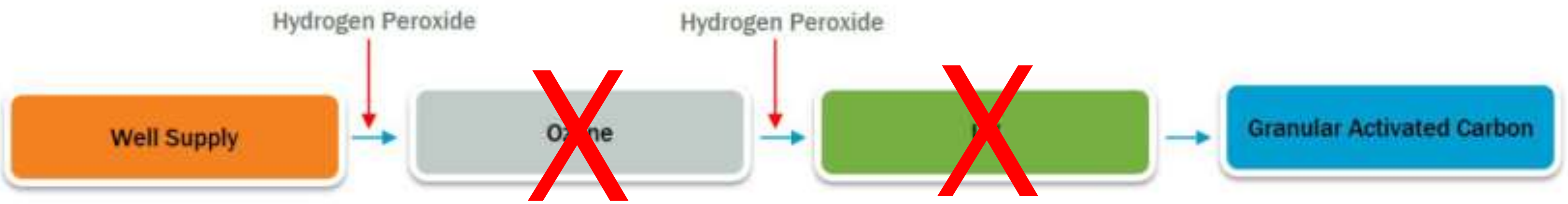


Pilot Testing

Pilot Test Objectives

- Refine understanding of source water treatability by hybrid O_3/H_2O_2 + UV/H_2O_2 process
- Evaluate all typical well combinations
- Confirm ability to control DBP formation for the range of expected operating conditions
- Refine GAC empty bed contact time (EBCT)
- Confirm peroxide quenching and DOC removal

Pilot Configuration



MiPRO™ System

Figure 4: MiPRO™ (UV, Ozone, AOP) pilot interior.

Figure 2: MiPRO™ (UV, Ozone, AOP) pilot delivered to site.

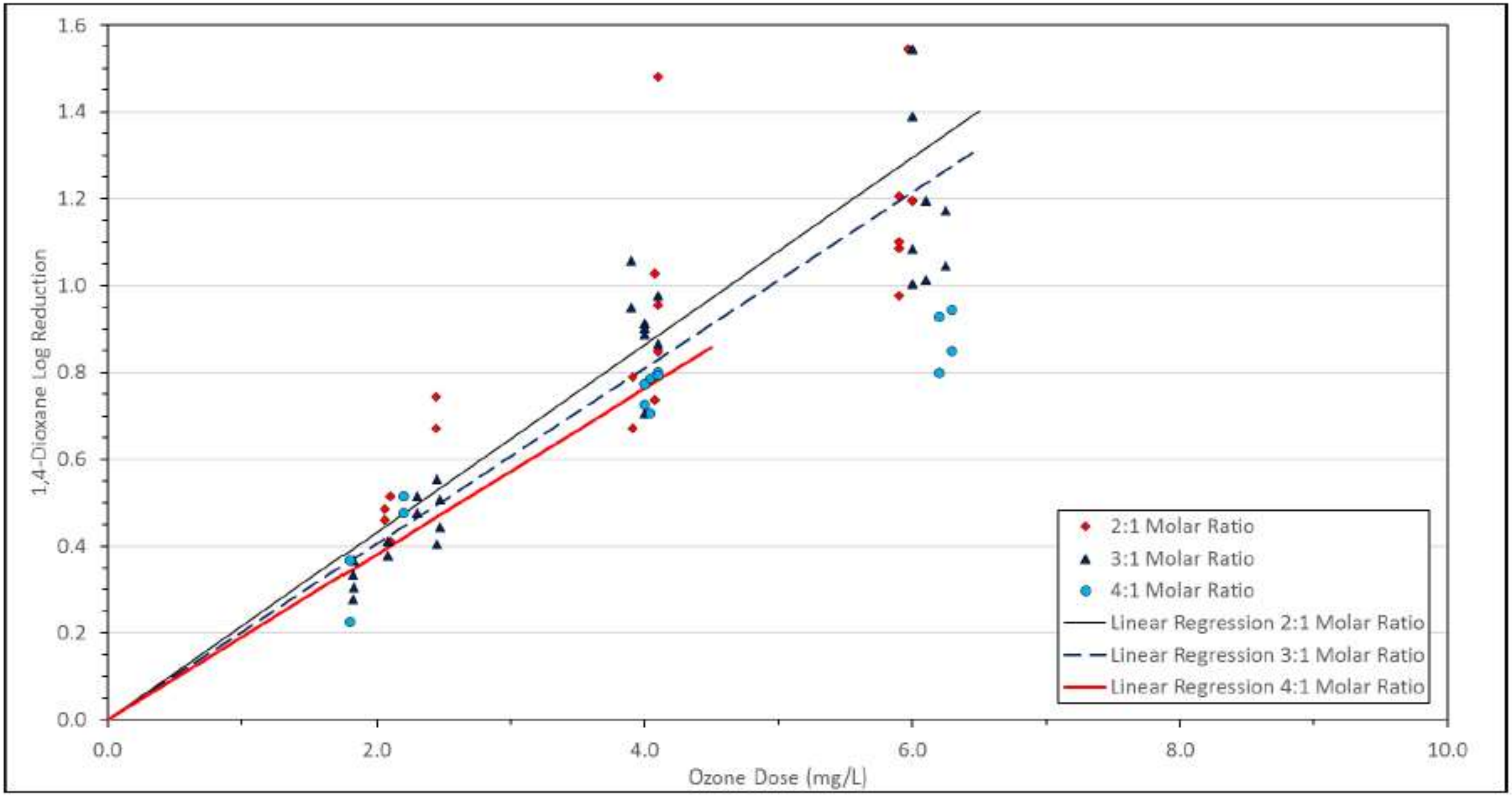
Figure 3: MiPRO™ (UV, Ozone, AOP) pilot installed at site.

- O_3 generated from air
- All internal controls tied into a PLC
- Flow range = 8 – 25 gpm

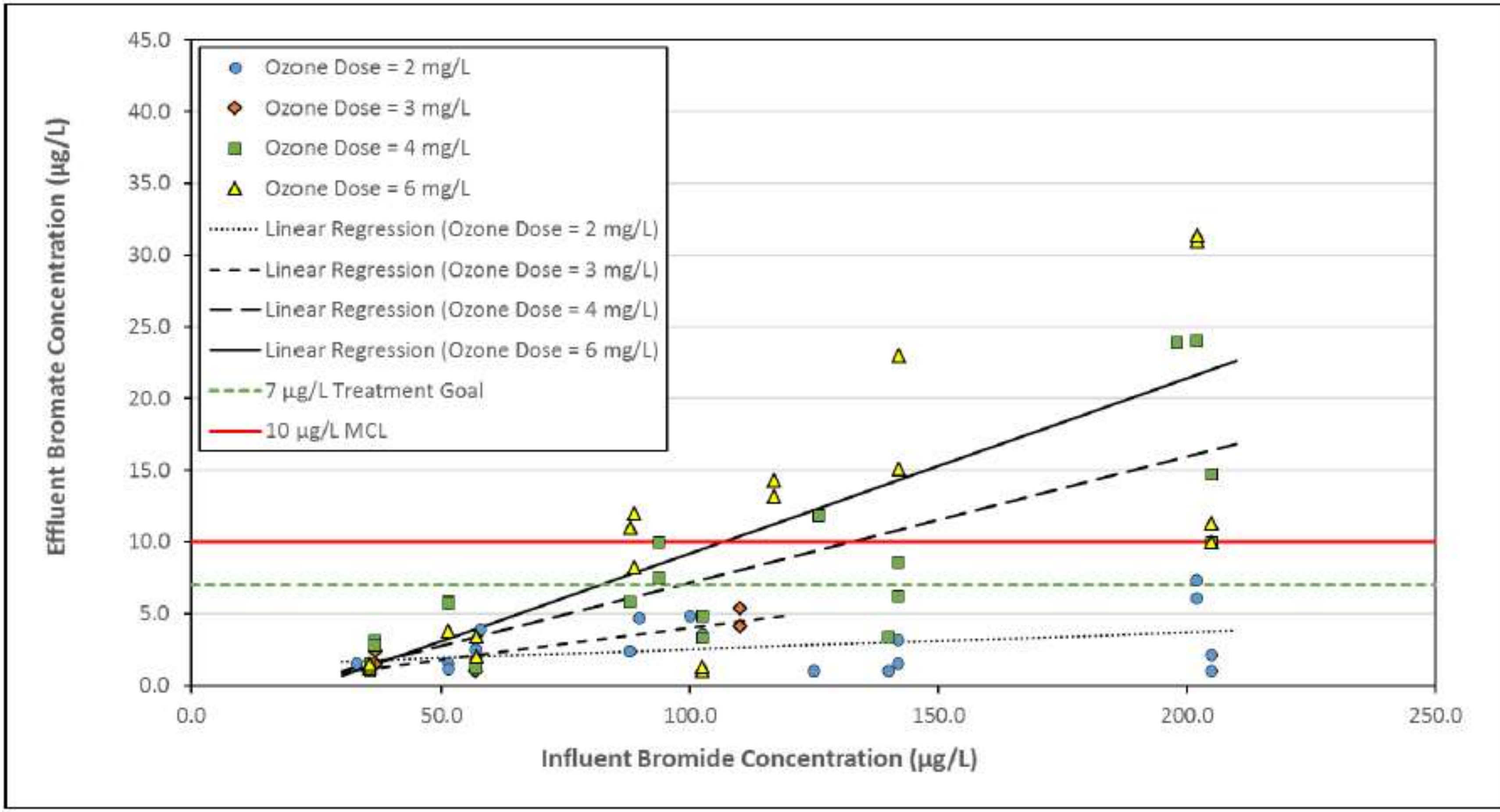
GAC Testing

- Calgon preconstructed system
- Three GAC types

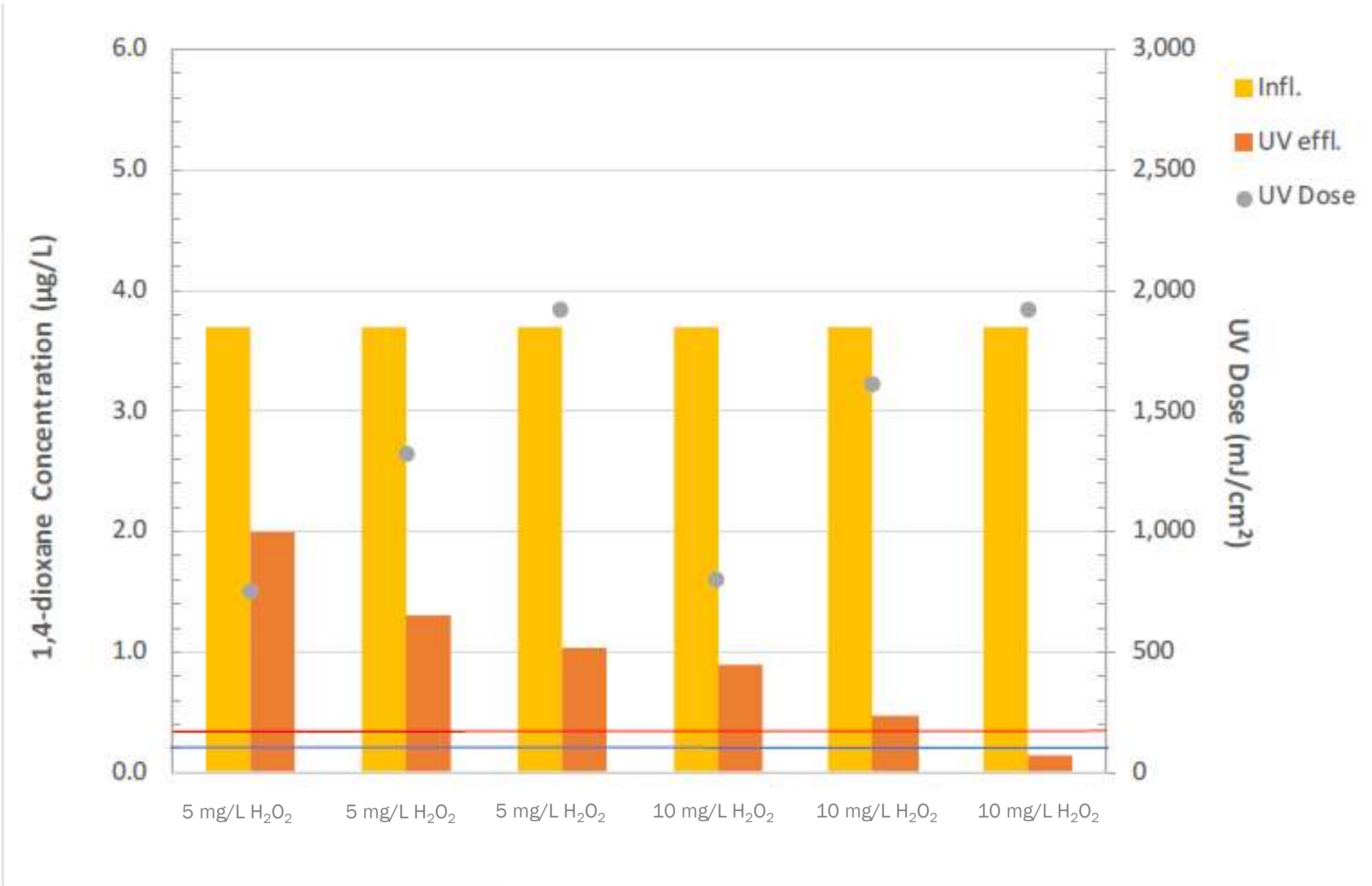
More variability in log removal at higher ozone dosages



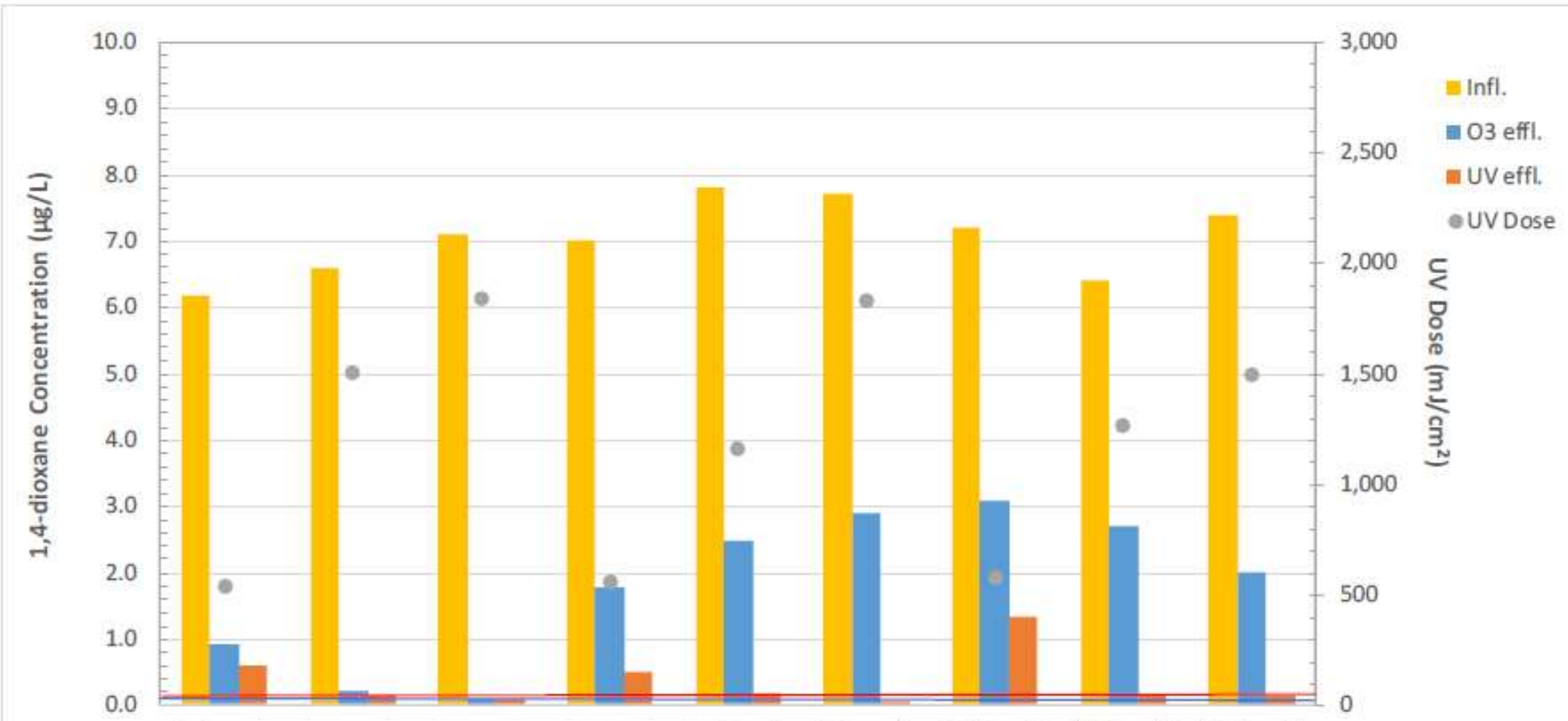
Bromate formation can be controlled if ozone dosages remain below 4 mg/L



UV-AOP can reduce 1,4-D if dose is high enough



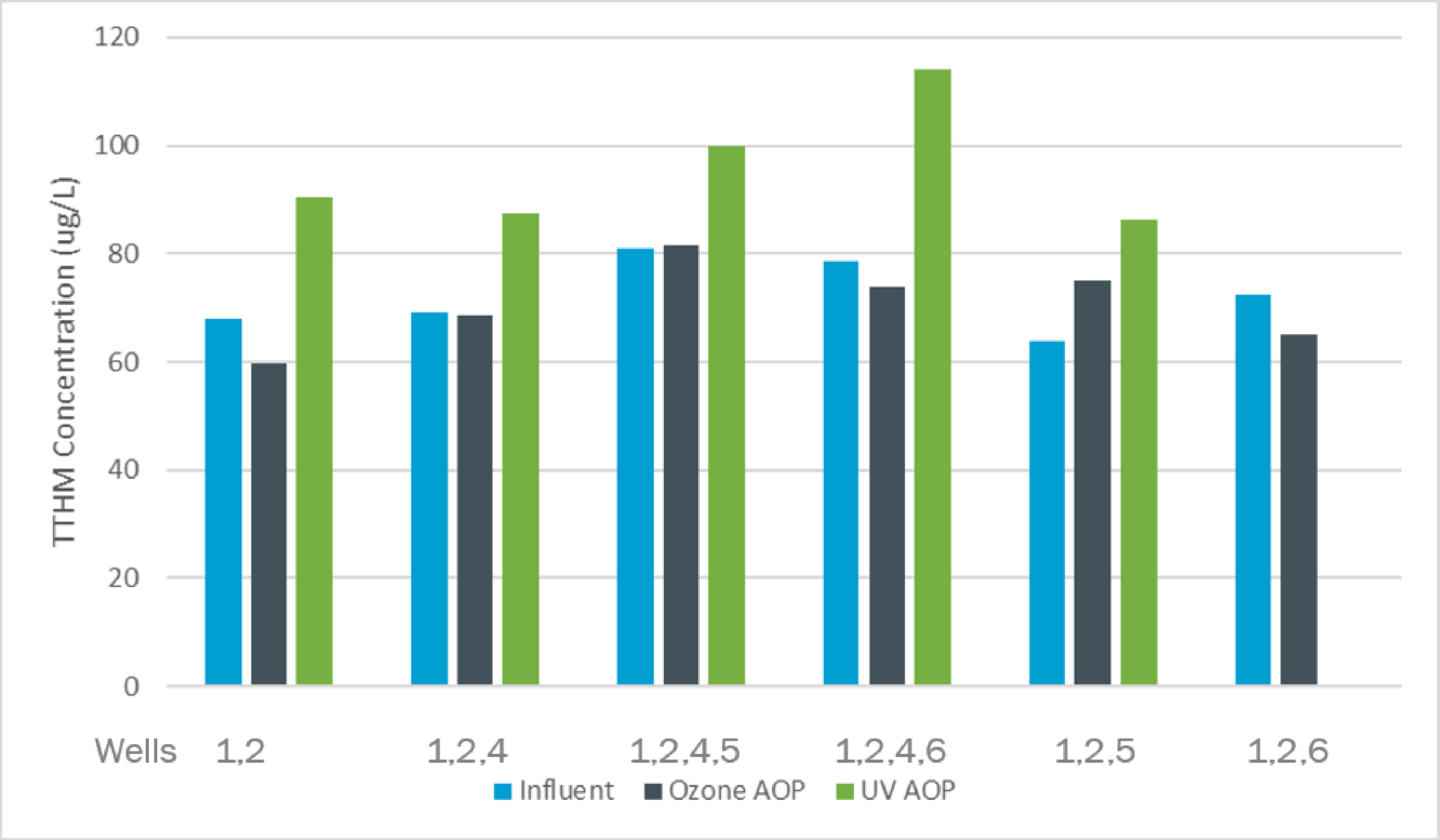
S-AOP worked well to reduce 1,4-D



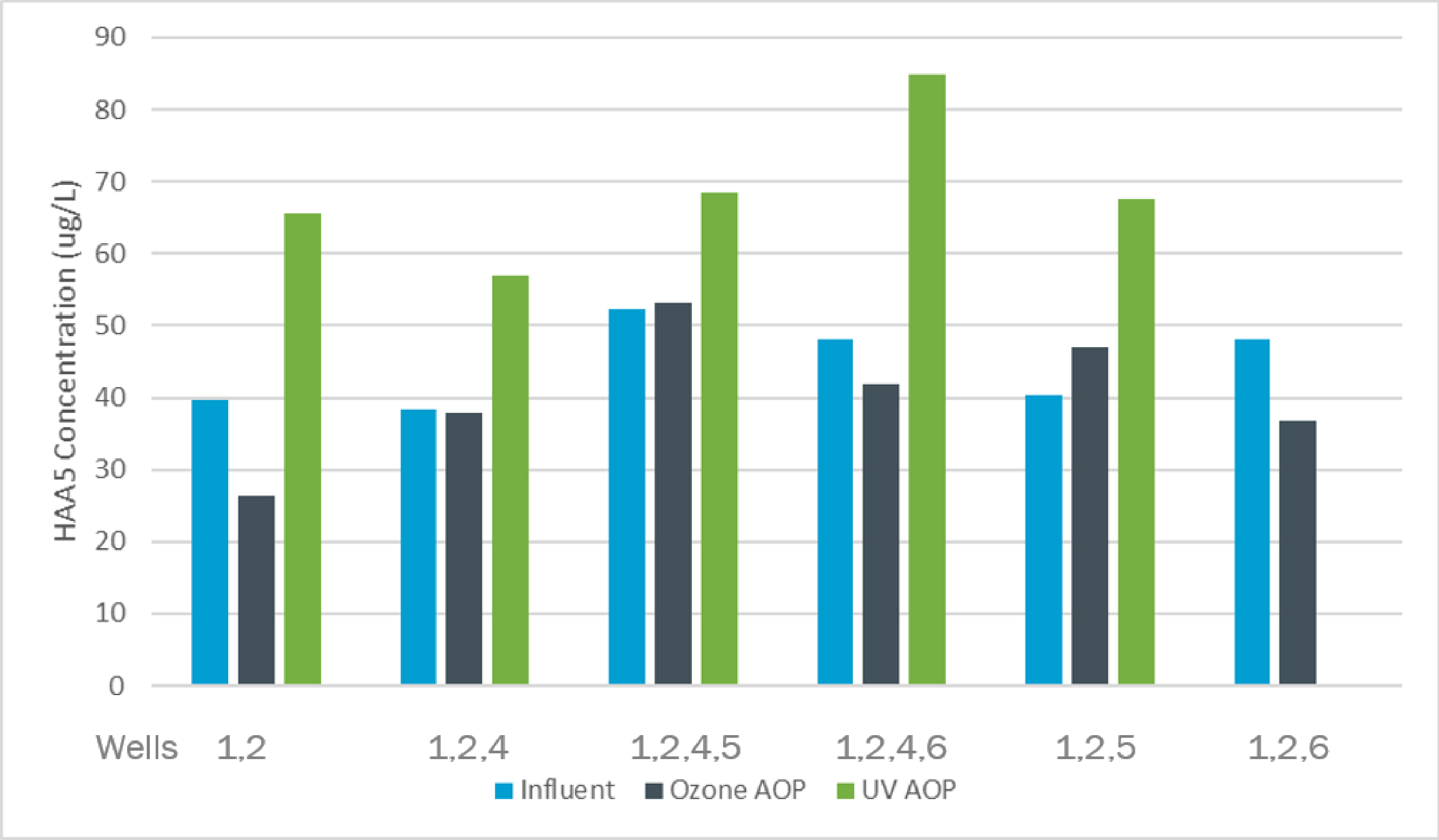
O_3, molar ratio
H_2O_2 + UV

O_3, molar ratio	6 mg/L, 3:1	4 mg/L, 5:1	6 mg/L, 3:1	4 mg/L, 4:1	6 mg/L, 4:1	6 mg/L, 4:1	6 mg/L, 5:1	6 mg/L, 5:1	4 mg/L, 6:1
H_2O_2 + UV	10 mg/L	10 mg/L	10 mg/L	14 mg/L	14 mg/L	14 mg/L	18 mg/L	18 mg/L	18 mg/L

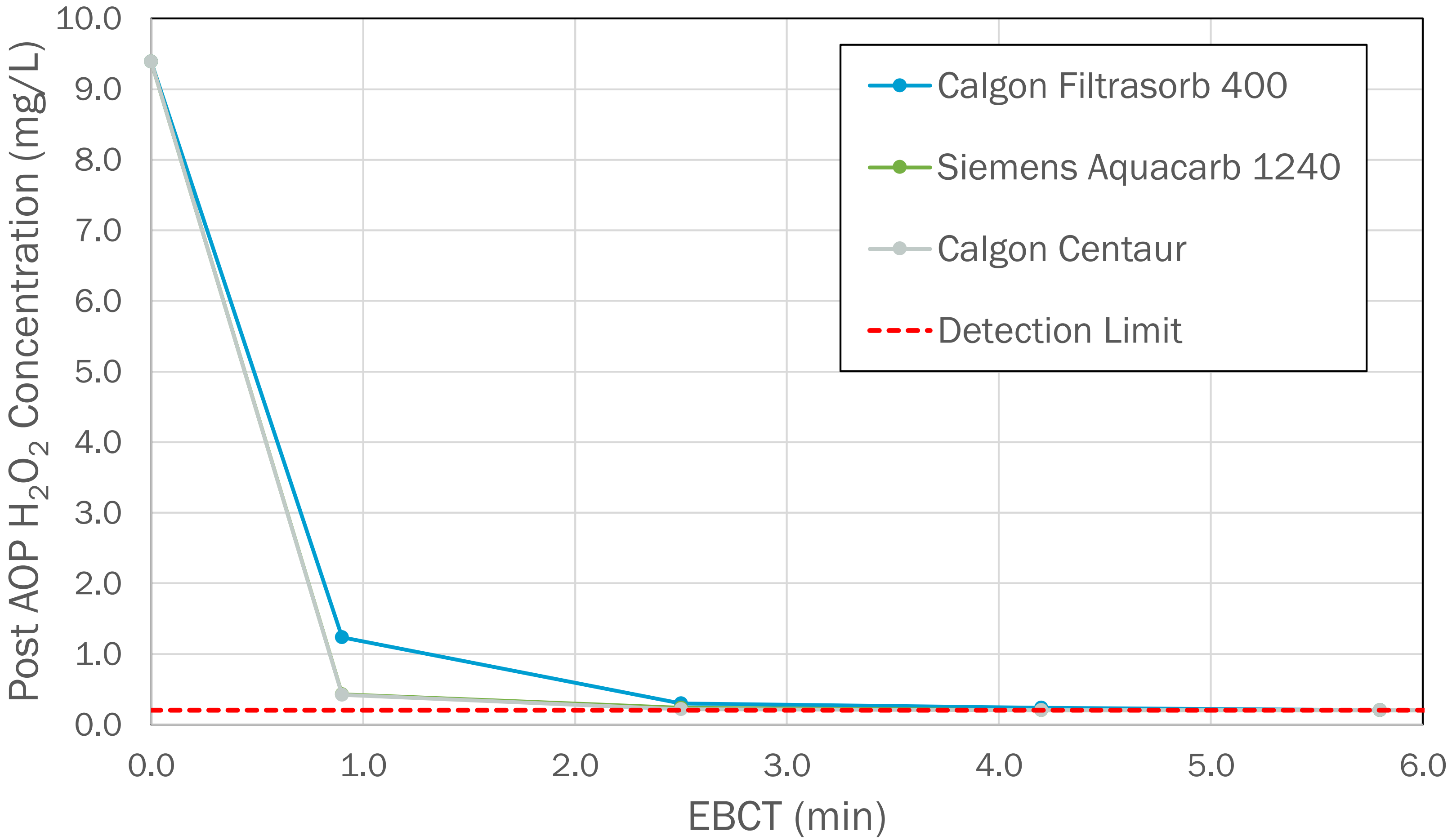
Average total trihalomethanes formation potentials increased through UV-AOP



Average haloacetic acids formation potentials had a dramatic increase through UV-AOP



Catalytic GAC reacted quicker to hydrogen peroxide concentrations



Conclusions

- Removal of 1,4-D to below 0.2 µg/L target concentration
- Ozone-AOP alone could not meet treatment goal due to bromate production
- Sequential AOP vs. UV-only AOP is still being evaluated
- Peroxide quenched by all three GACs tested
  - Two catalytic carbons consistently produced water with peroxide below detection limits at EBCTs of 2.5 minutes.
  - Non-catalytic carbon peroxide quenching rates were slightly less relative to the catalytic carbons, and were below the detection limit at EBCTs of up to 4.2 minutes
- No increase in DBPs with ozone-AOP, increase in DBPs from UV-AOP, especially with higher UV dosages

Just Add Water
2018 TACOMA PNWS-AWWA

Thank you. Questions?

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Brown AND Caldwell