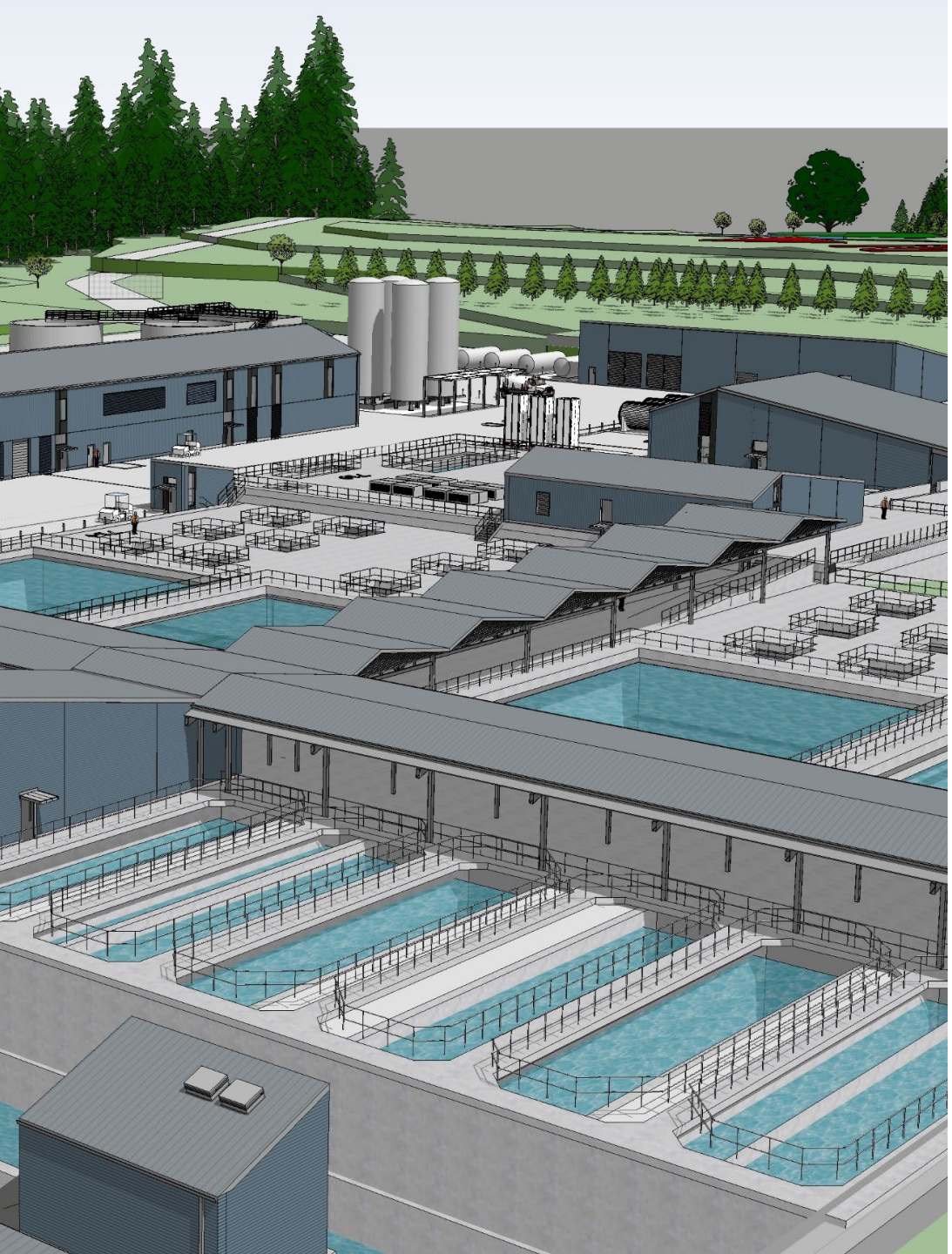


Bull Run TREATMENT PROJECTS

Our water: Safe and abundant for generations to come

PORTLAND WATER BUREAU

Bull Run Treatment Projects

Evaluation of Pre-Oxidation and Secondary Disinfection Approaches on DBP Formation and Taste & Odor Using Simulated Distribution System Testing

April 28, 2022

Anna Vosa, PE

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

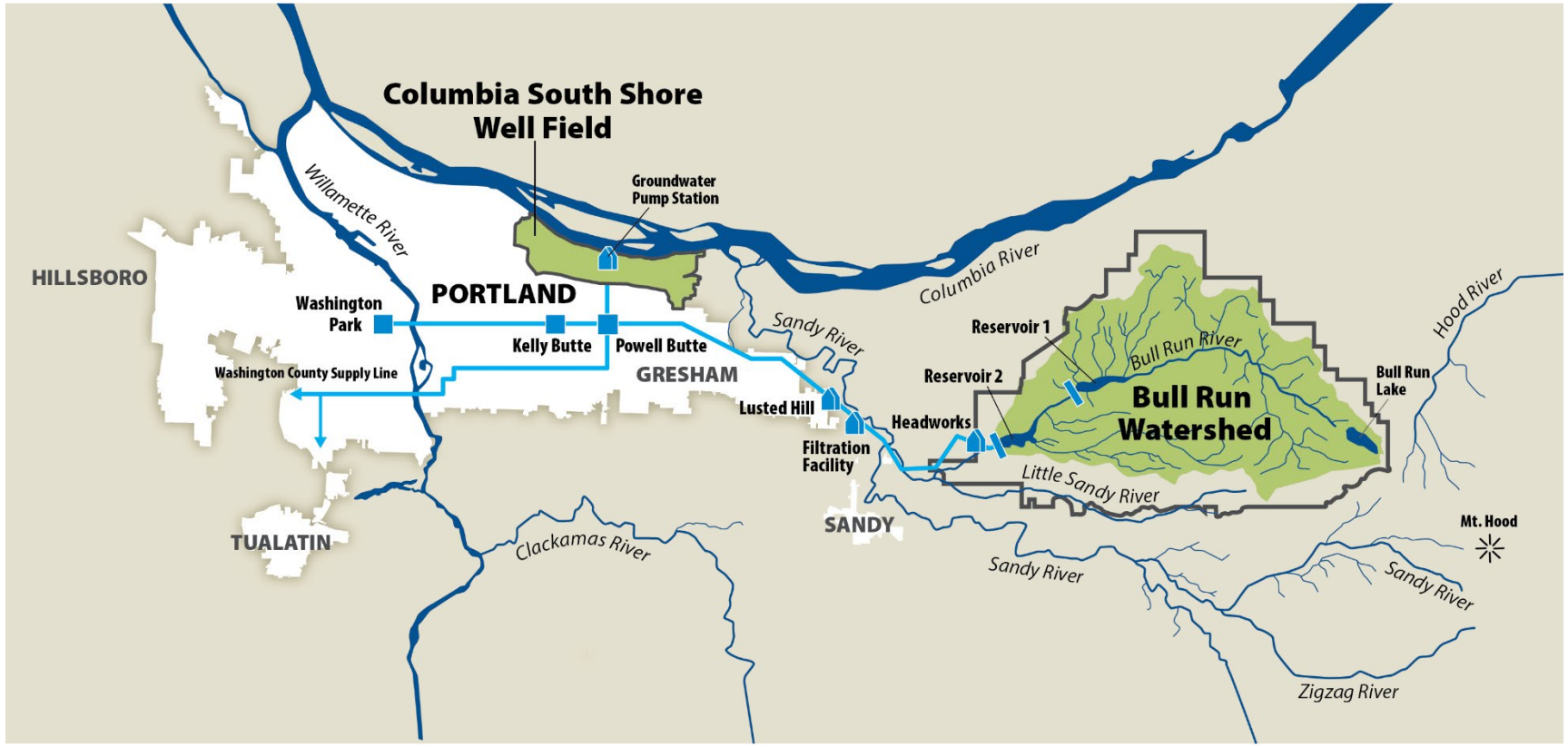
CITY OF PORTLAND, OREGON 1851

PNWS-AWWA
Water 2022
Tacoma, WA • April 27-29

Agenda

1. Background – Portland's Bull Run Filtration Facility Project
2. Methods for Assessing Treatment Alternatives for DBPs and T&O
3. Test Results
   - Pre-oxidant comparison
   - Secondary residual (chlorine vs chloramines)
4. Summary

Thanks to thoughtful planning, Bull Run has been a source of **excellent water since 1895**

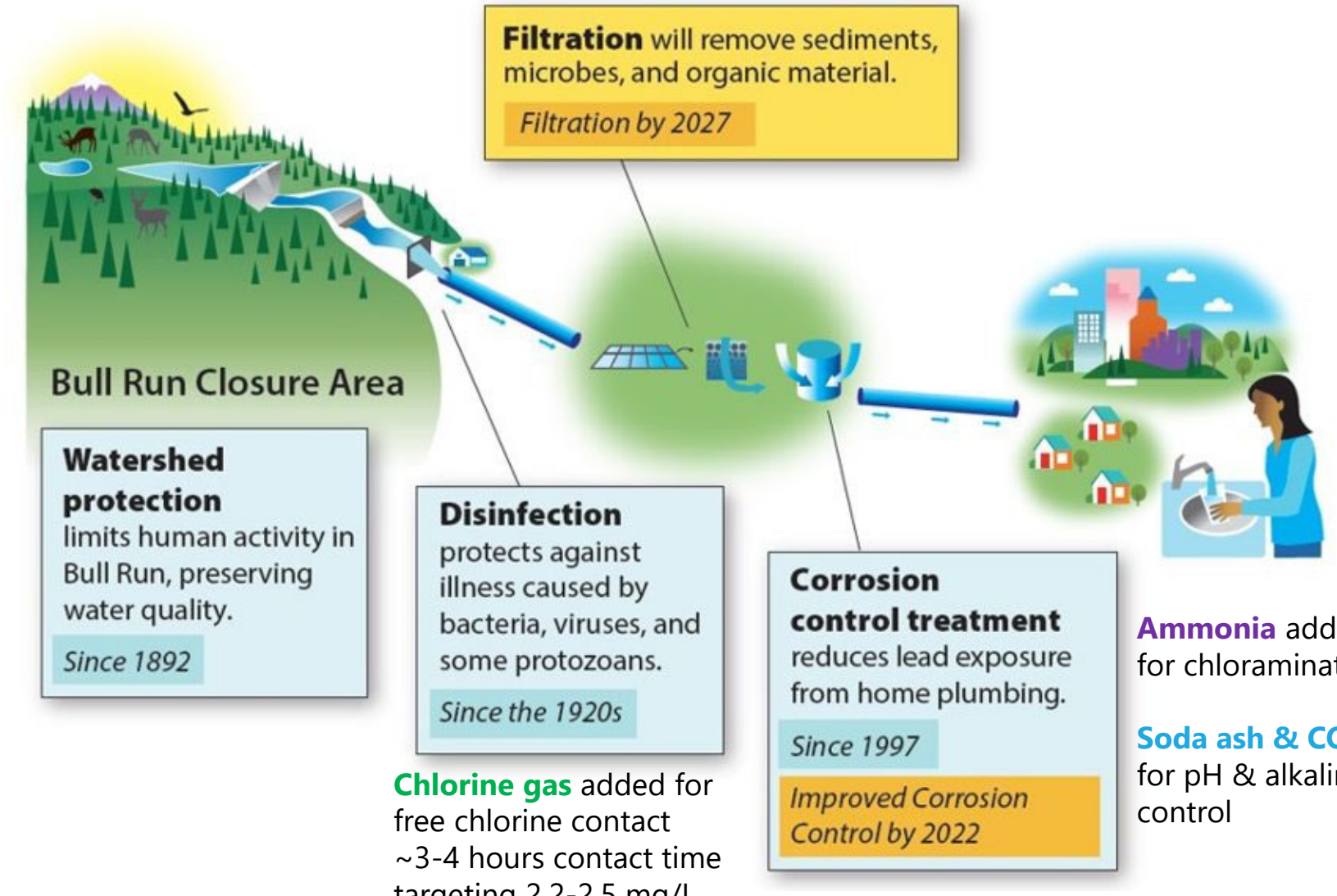


- Serves almost 1 million people
- Serves the City of Portland and 19 wholesale customers
- Uses 100 million gallons of water on an average day

Bull Run
TREATMENT
PROJECTS

Our water: Safe and abundant for generations to come

Improvements to our system are needed to meet national drinking water standards



Chlorine gas added for free chlorine contact ~3-4 hours contact time targeting 2.2-2.5 mg/L

Ammonia addition for chloramination

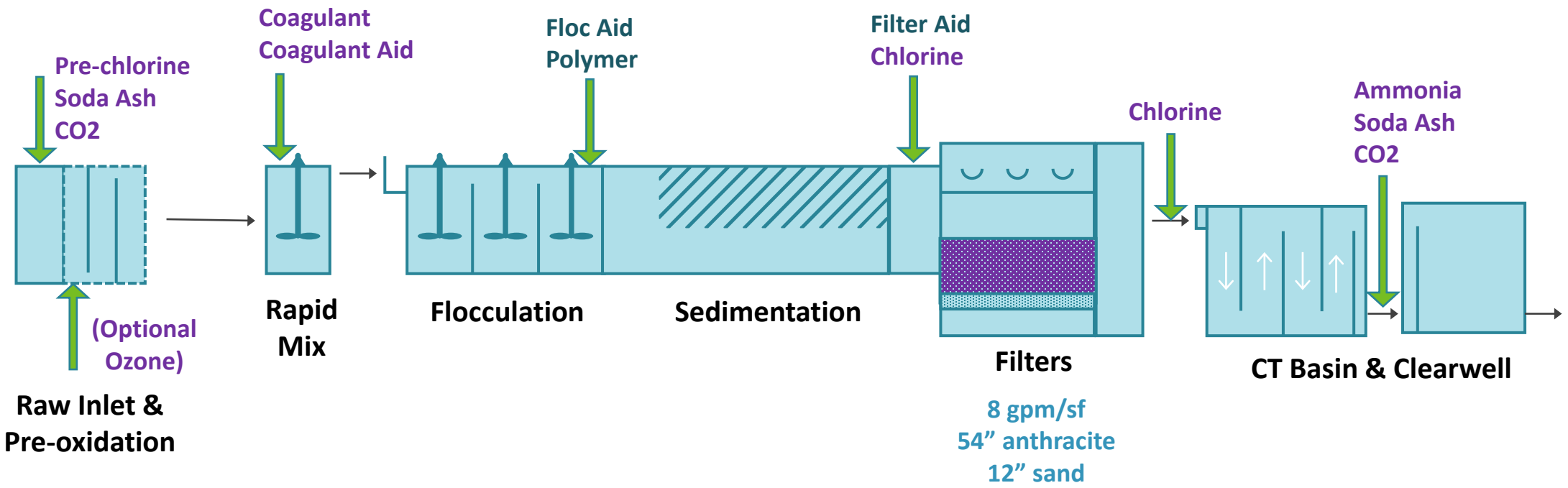
Soda ash & CO2 for pH & alkalinity control

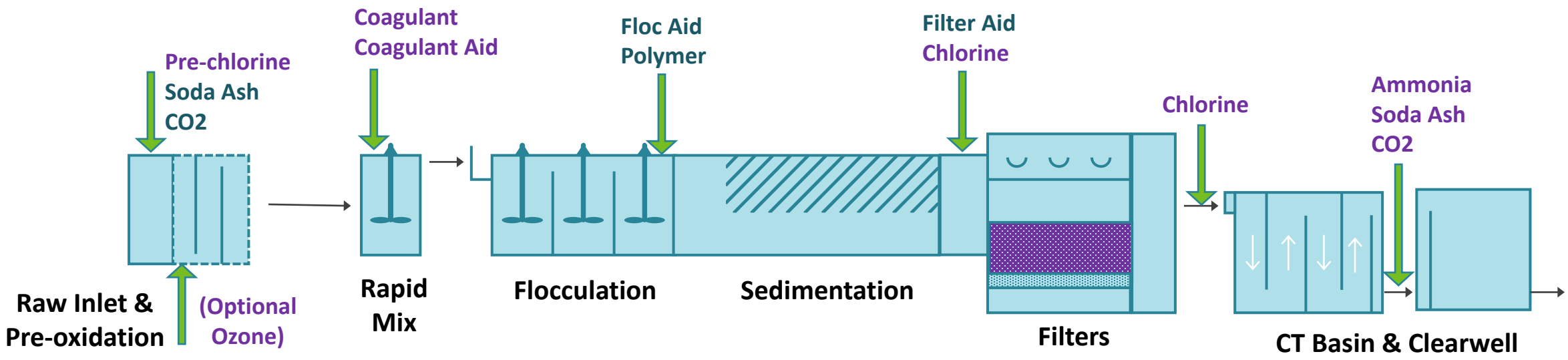
Existing Water Quality and BRFF Treatment Goals

	Current Unfiltered Finished Water Quality Average and (Range)	BRFF Project Goal	Notes
Turbidity (NTU)	0.4 (0.2 – 3.3)	<0.1 NTU	AWOP & PSW optimization goal
TOC (mg/L)	1.0 (0.7 – 2.0)	-	Organics reduction needed to reduce DBPs
Total Chlorine Residual (mg/L)	2.2 – 2.5 mg/L at entry point >1.0 mg/L in tanks >0.5 mg/L in DS	no change	
Total Trihalomethanes (TTHM) (ug/L)	27 (16 – 48)	LRAA <40 ug/L	<50% of MCL (MCL = 80 ug/L)
Haloacetic Acids (HAA5) (ug/L)	32 (11 – 55)	LRAA <30 ug/L	<50% of MCL (MCL = 60 ug/L)

AWOP = Area Wide Optimization Program
PSW = Partnership for Safe Water
MCL = Maximum Contaminant Level
LRAA = Locational Running Annual Average
DS = distribution system

Proposed Treatment Process





Pre-oxidation	Flocculation & Sedimentation	Filtration	Post-Treatment & Finished Distribution
• Pre-oxidant vs no pre-oxidant • Pre-oxidant type: ozone vs chlorine • Pre-oxidant dose strategy	• Coagulant type: PACl, alum, ferric sulfate • Flocculation type and time • Benefit of sedimentation	• Filter loading rate • Filter media types (anthracite vs GAC), sizes/depths	• Primary disinfection – chlorine concentration and contact time • Secondary Disinfectant – chloramines vs free chlorine • Corrosion Control

Purple = Treatment decisions with potential to impact DBPs, chlorine stability, and taste/odor of water in the distribution system

Bench testing approaches for evaluating DBP formation

	Formation Potential "FP"	Uniform Formation Conditions "UFC"	Simulated Distribution System "SDS"
Incubation Time	7 days	24 hours	Match max water age
Chlorine Residual Target	3-5 mg/L after 7 days	1.0±0.4 mg/L after 24 hours	Match DS residual target
Incubation Temperature	25.0±2.0°C	20.0±1.0°C	System-specific
pH	7.0±0.2	8.0±0.2	System-specific (i.e., corrosion control target)
Secondary disinfectant	n/a (free chlorine)	n/a (free chlorine)	System-specific (chlorine or chloramines)

Standard Method
Most comparable
across multiple sites

System-specific
Least comparable
across multiple sites

Why Simulated Distribution System (SDS) Testing?

- Benefits of SDS Tests:
  - Most representative of expected water quality
  - Opportunity to incorporate more than THMs and HAAs:
    - Chlorine stability in bulk water over time
    - Taste testing (flavor profile analysis and flavor rating assessment)
    - Unregulated DBPs (e.g., NDMA formed during chloramination)
- Limitations of SDS testing:
  - Only considers bulk water reactions
    - ✗ Nitrification
    - ✗ Pipe wall effects from unlined cast iron
  - Results cannot be extended to or compared with other supplies

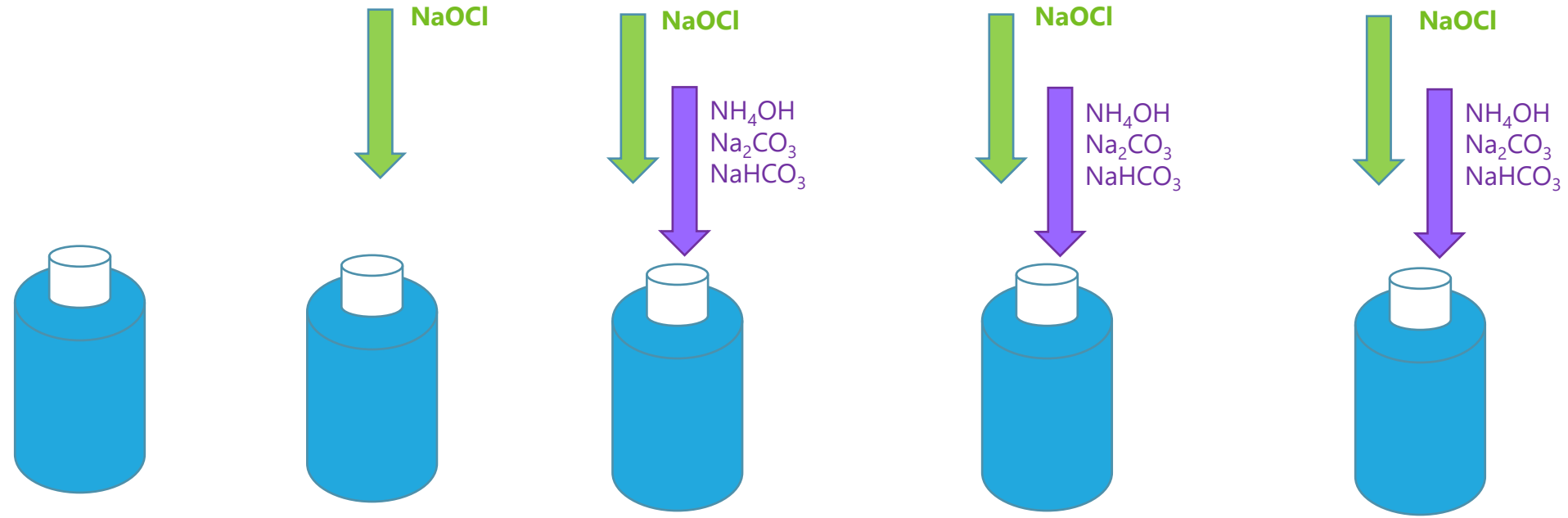
SDS Conditions for BRFF Pilot Study

	Secondary Residual: Chloramines	Secondary Residual: Free Chlorine
Free Chlorine Contact Period:	60 minutes	
Chlorine Residual Target after Free Chlorine Contact Period:	2.5 mg/L	2.0 mg/L
pH/Alkalinity* Target:	9.0/30	8.5/30
Treatment Chemicals	Chlorine: HASA sodium hypochlorite, 12% (NaOCl) Corrosion Control: Soda Ash (Na_2CO_3) and Sodium Bicarbonate ($NaHCO_3$) Chloramination: Ammonium hydroxide (NH_4OH)	
Simulated Distribution Incubation Period	14 days (WQ sampling at beginning, middle, and end)	
Incubation Temperature	Match seasonal terminal reservoir temp (11 – 20°C)	

*Alkalinity as $CaCO_3$

Bull Run Pilot Plant Filter Columns

SDS Testing Approach



Initial Water (IW)

Disinfected Water (DW)

Entry Point (T0)

7-day (T7)

14-day (T14)

Sample:
- **Turbidity**
- **UV254 & Color**
- **TOC**
- **Temperature**
- **pH & alkalinity**

Sample after 60 mins:
- **Free & total Chlorine**
- **Temperature**
- **pH & alkalinity**

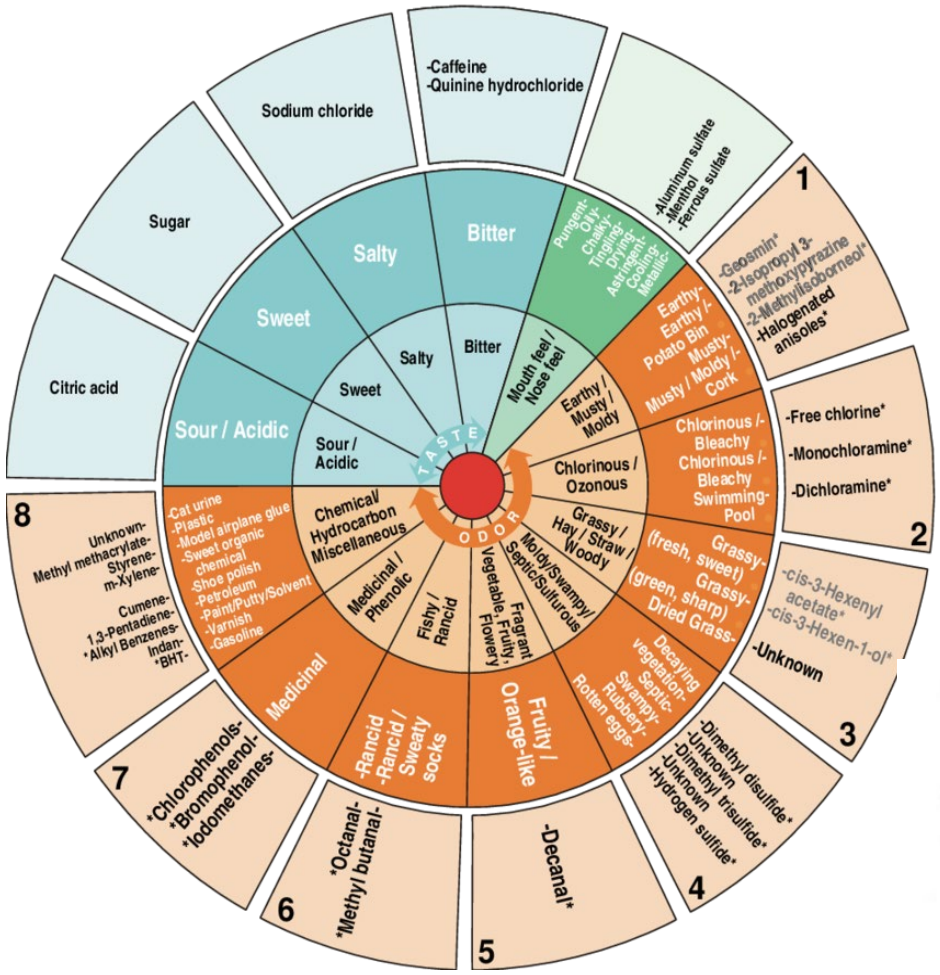
Sample after 10 mins:
- **Total chlorine, monochloramine, free/total NH3**
- **Temperature**
- **pH & alkalinity**
- **TTHM & HAA5**
- Color*

Sample after 7 days:
- **Total chlorine, monochloramine, free/total NH3**
- **Temperature**
- **pH**
- Color*
- TTHM & HAA5*
- FPA/FRA*

Sample after 14 days:
- **Total chlorine, monochloramine, free/total NH3**
- **Temperature**
- **pH**
- **TTHM & HAA5**
- Color*
- Nitrosamines*

*Optional

Flavor Profile Analysis (FPA) and Flavor Rating Assessment (FRA)

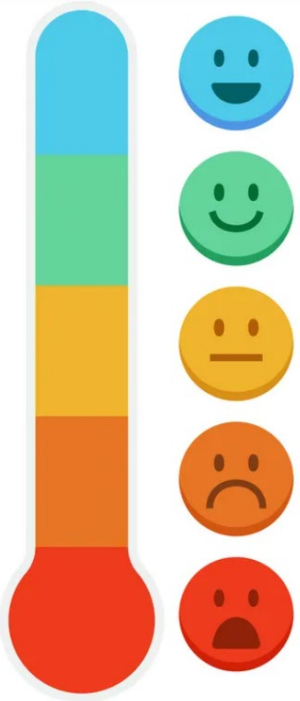


T&O Wheel of Descriptors

FPA rates the intensity of specific characteristics – taste/aftertaste, odor, mouthfeel – identified by the taster on a scale of 0-12 (SM 2170)

FPA Scale

—	(odor-free)
T	(threshold)
2	(very weak)
4	(weak)
6	
8	(moderate)
10	
12	(strong)

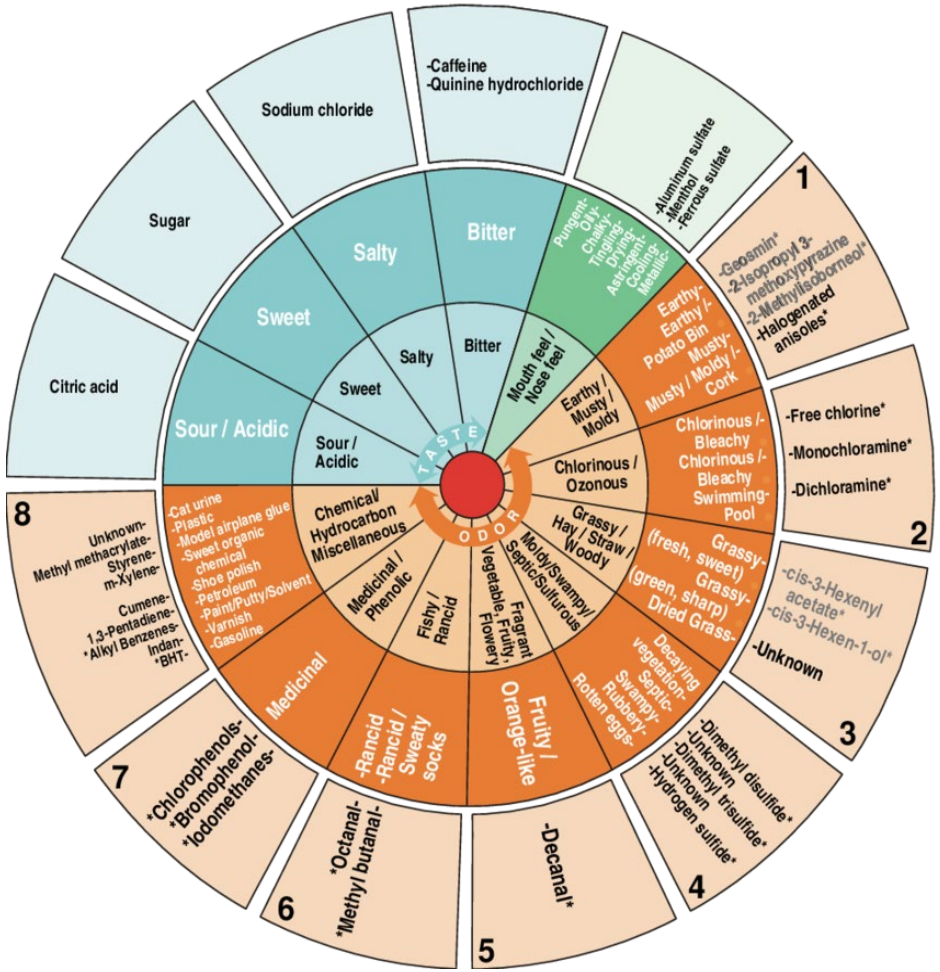


FRA rates the acceptability of the water on a scale of 1-9 (SM 2160)

FRA scale

1. I would be very happy to accept this water as my everyday drinking water.
2. I would be happy to accept this water as my everyday drinking water.
3. I am sure that I could accept this water as my everyday drinking water.
4. I could accept this water as my everyday drinking water.
5. Maybe I could accept this water as my everyday drinking water.
6. I don't think I could accept this water as my everyday drinking water.
7. I could not accept this water as my everyday drinking water.
8. I could never drink this water.
9. I can't stand this water in my mouth and I could never drink it.

Flavor Profile Analysis and Flavor Rating Assessment



FPA/FRA Scoring Sheet for Drinking Water Samples

Initials AV Date 5/18/21

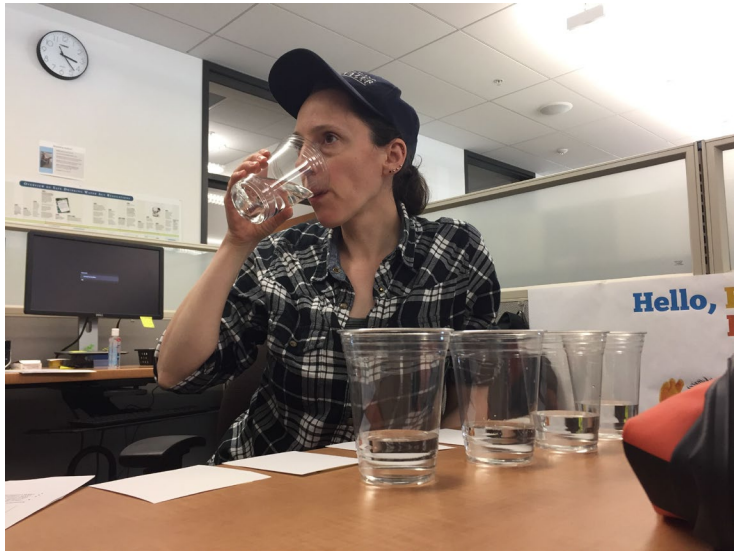
Sample ID	Odor		Mouthfeel		Taste and Aftertaste		FRA (1-9)	Comments
	Descriptor	FPA (0-12)	Descriptor	FPA (0-12)	Descriptor	FPA (0-12)		
1	none	0	smooth	0	chlorine chlorine	3 3	5	
2	none	0	smooth	0	none Metallic aftertaste	1	1	no taste
3	none	0	smooth soft	0	earthy chlorine Metallic aftertaste	1 1	3	
4	none	0	smooth	0	chlorine	1	2	

Samples include the following full treated drinking water samples (not necessarily provided in this order):

- Pilot-filtered water, coagulated with alum, pre-oxidation via pre-chlorination. Adjusted to pH 9 and containing 2.0-2.5 mg/L total chlorine residual.
- Pilot-filtered water, coagulated with alum, pre-oxidation via pre-ozonation. Adjusted to pH 9 and containing 2.0-2.5 mg/L total chlorine residual.
- PWB unfiltered tap water collected from C3LO (Lusted Outlet entry point)
- PWB unfiltered tap water collected from WQSS 71 outside Interstate

Tips for taste testing and considerations for using "simulated" water

- **All samples must be treated to drinking water standards**
- **Treatment chemicals NSF 60 or high-quality reagent-grade**
- Glassware cleaned and "chlorine-demand free"
- Consider screening taste testers beforehand
- Avoid eating/drinking 30 minutes beforehand
- Samples numbered but randomized
- Clean plastic or glass cups, no paper cups
- T&O free water and salt-free crackers in between samples



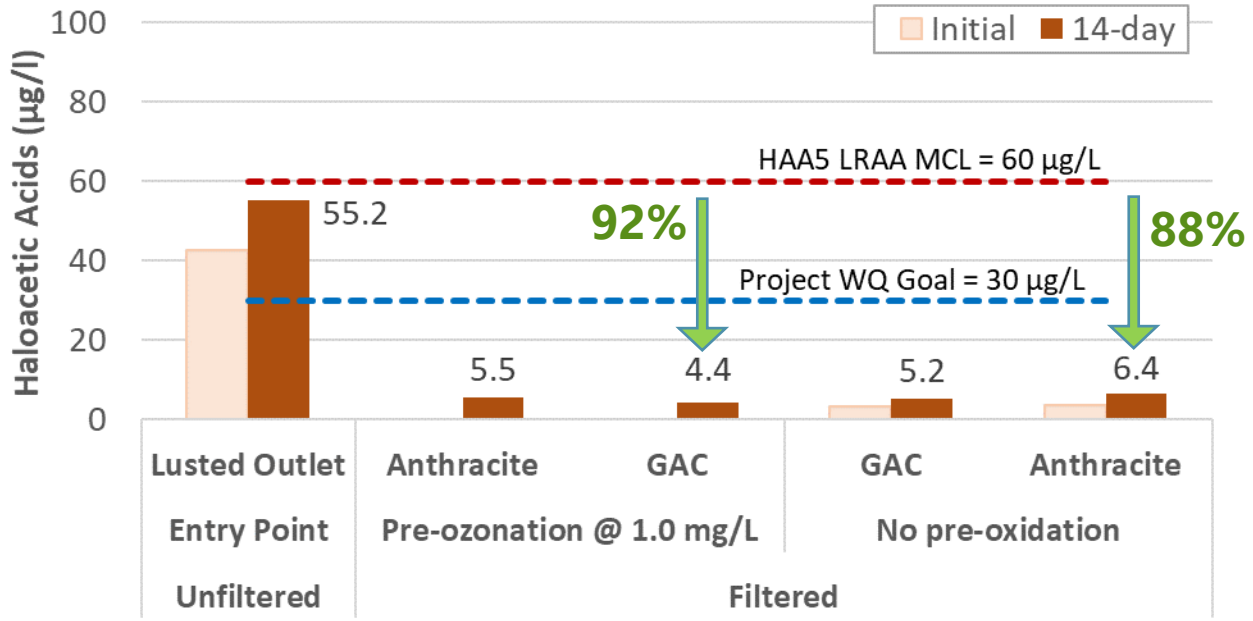
Portland WQ staff Lillian and Nick bravely tasting water samples

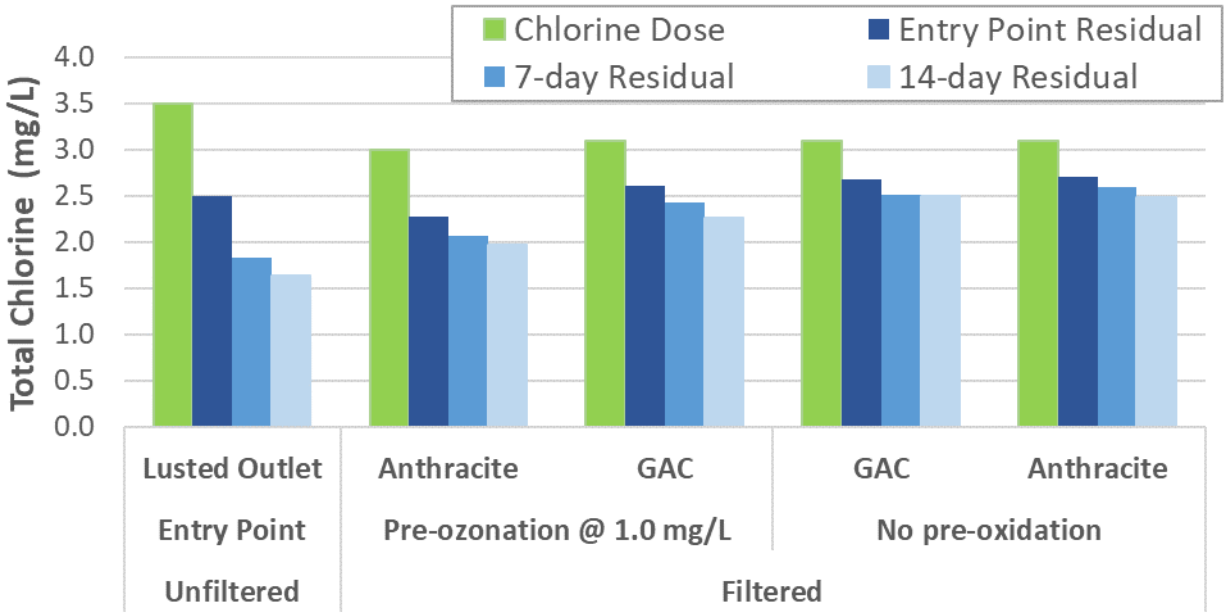
Results

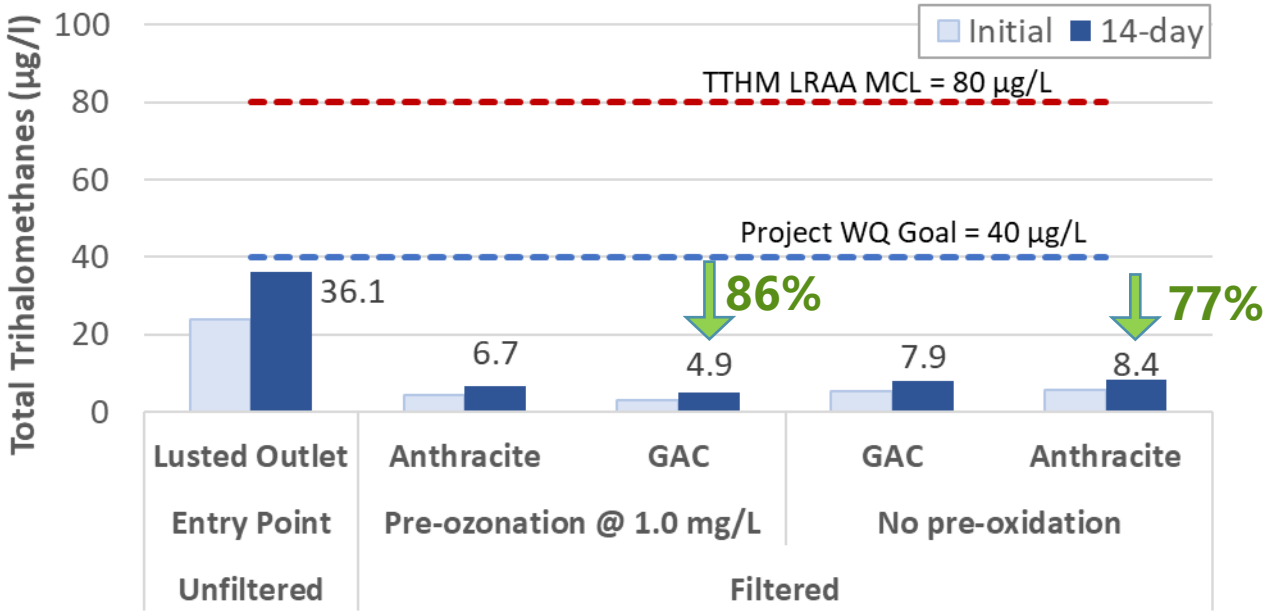
SDS Test*	Objective	Raw (unfiltered) WQ	Filtered WQ	Incubation Temp (°C)
Test 1 (fall 2019)	• Pre-ozone vs no pre-oxidant • Anthracite vs GAC	0.3 NTU 1.3 mg/L TOC	<0.05 NTU 0.4 – 0.6 mg/L TOC	9-13
Test 2 (spring 2021)	• Pre-ozone vs pre-chlorine	0.4 NTU 0.8 mg/L TOC	0.01 NTU 0.3 mg/L TOC	20
Test 3 (fall 2020)	• Two pre-ozone doses (0.6 vs 1.2 mg/L) • Secondary residual impact (chloramines vs free chlorine)	0.5 NTU 1.7 mg/L TOC	0.01 NTU 0.6 - 0.7 mg/L TOC	20

*Coagulation with PACl for Tests 1 and 3. Coagulation with alum for Test 2.

Test 1: Pre-ozone vs no pre-oxidant (fall 2019)







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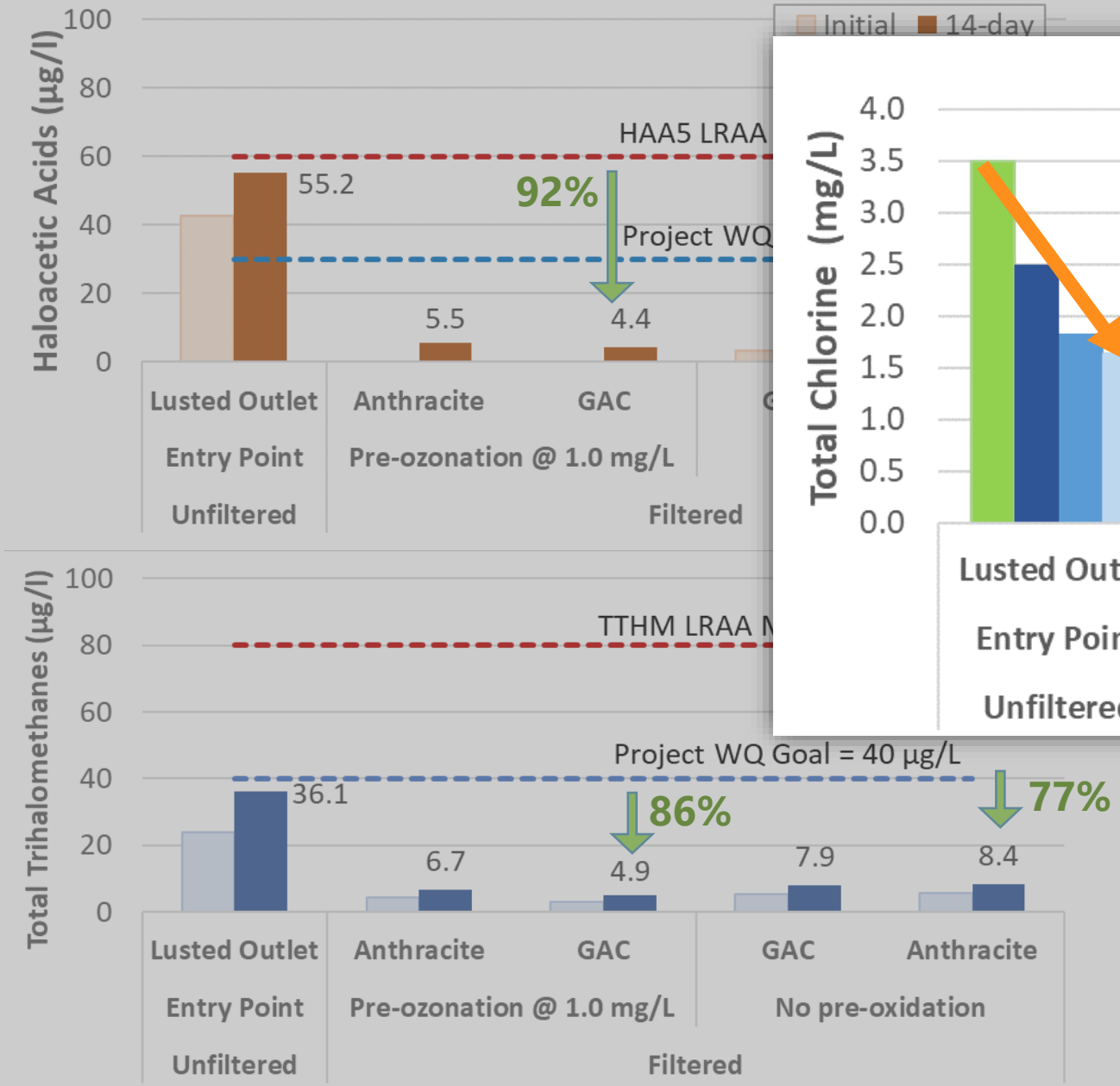

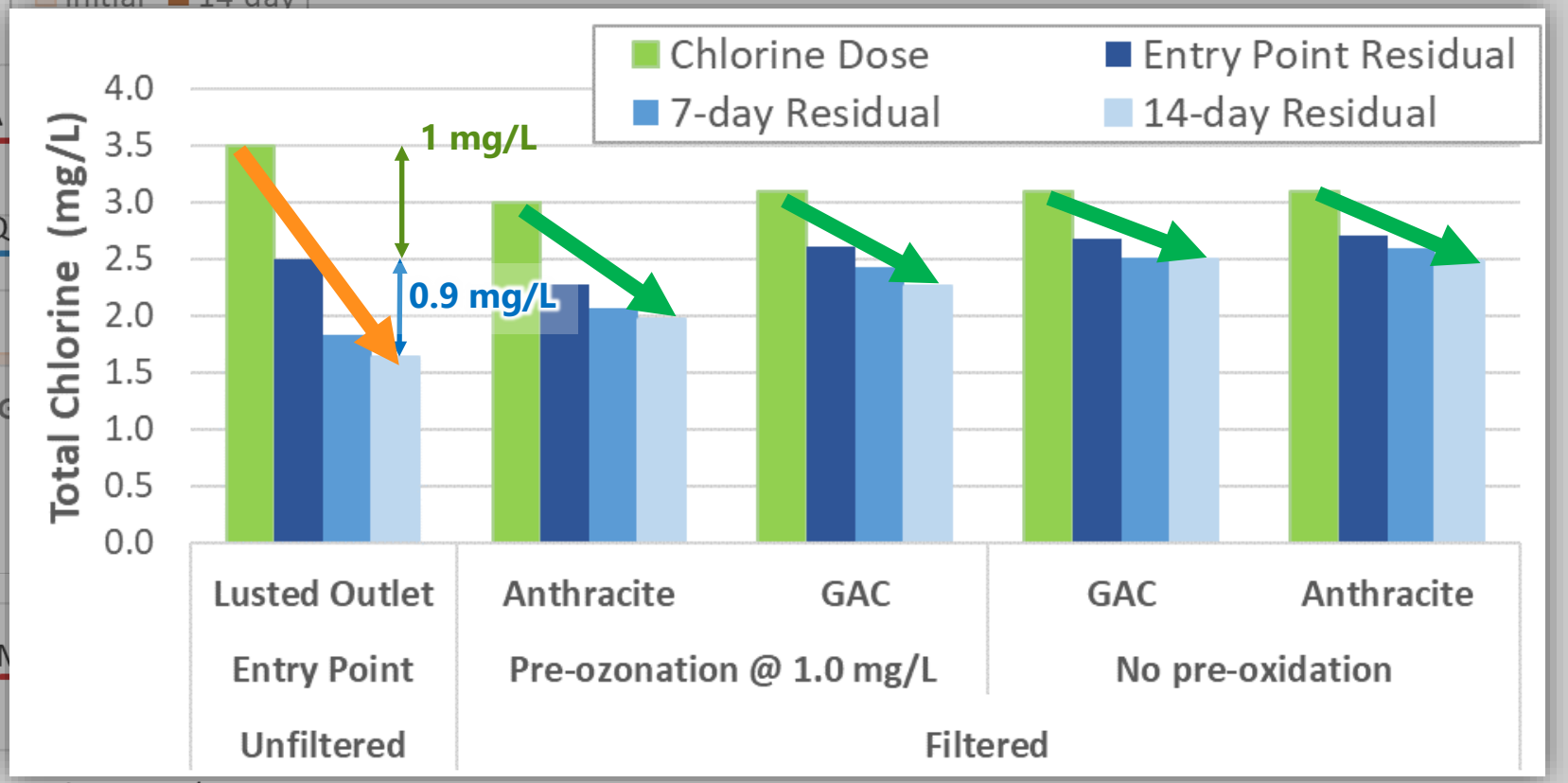

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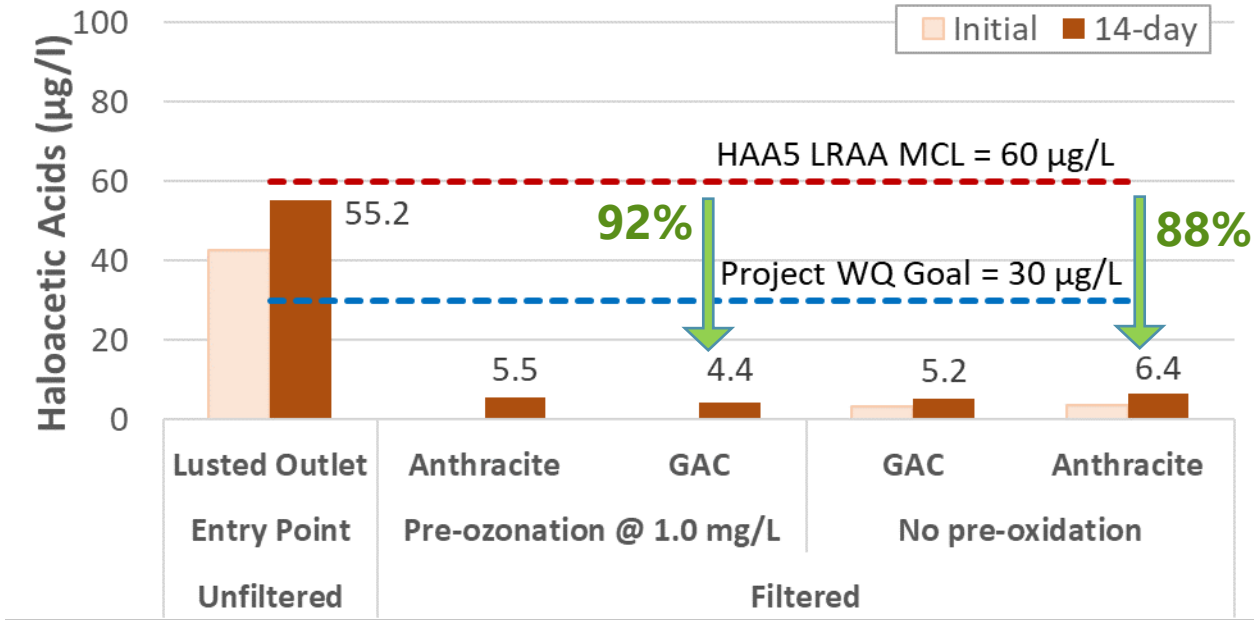

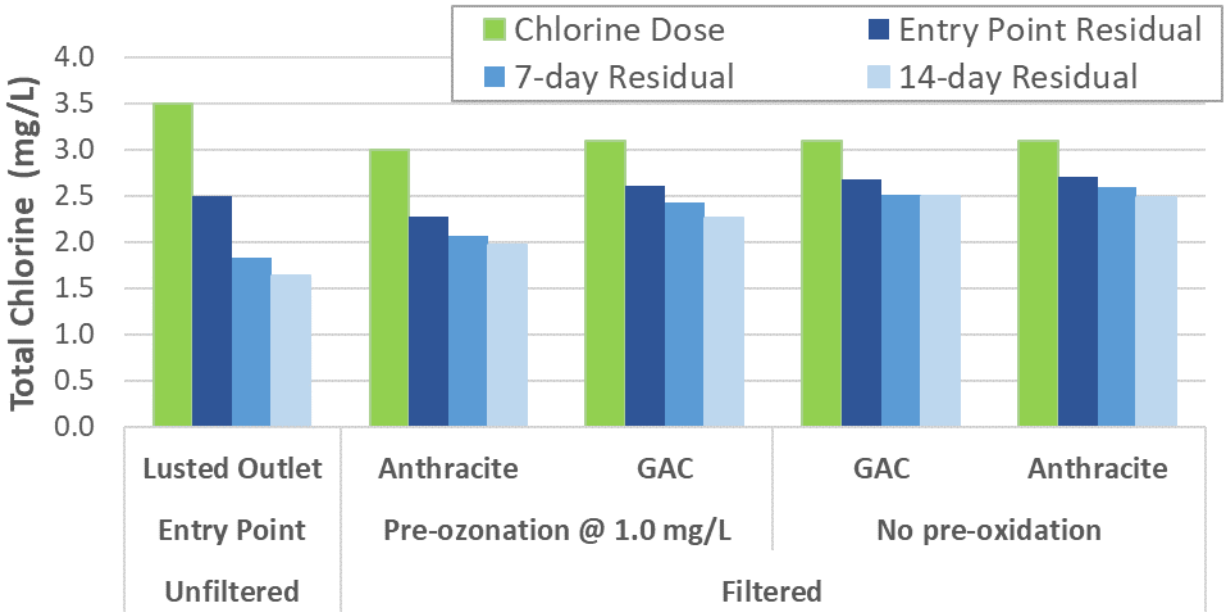

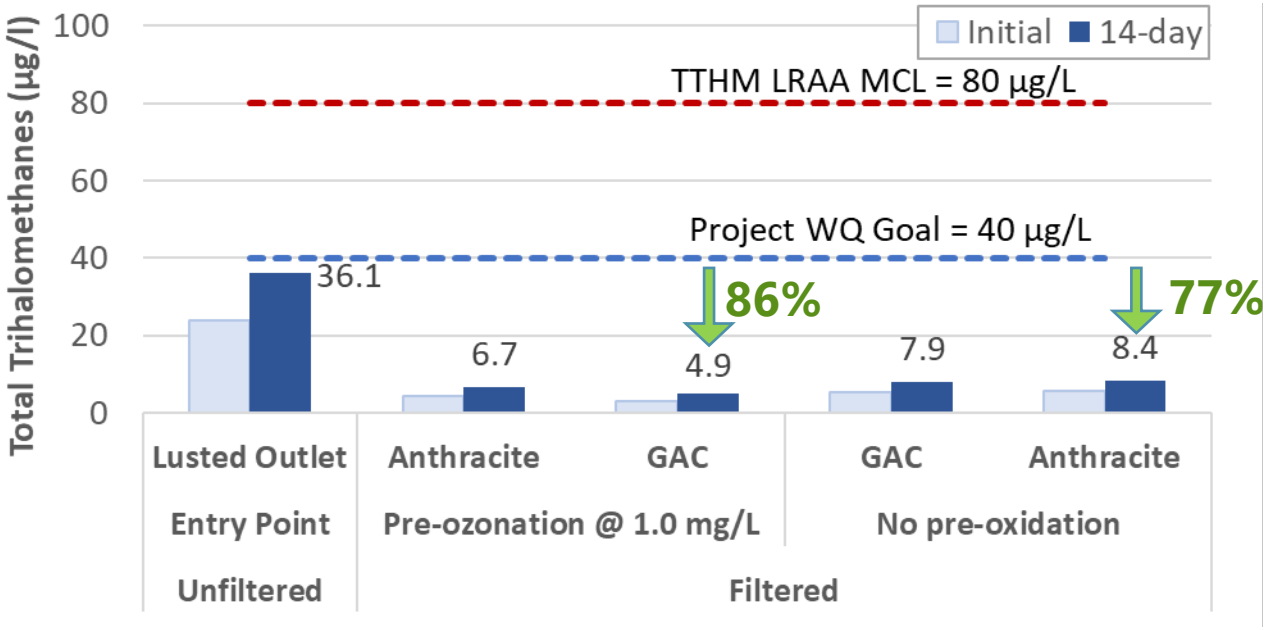

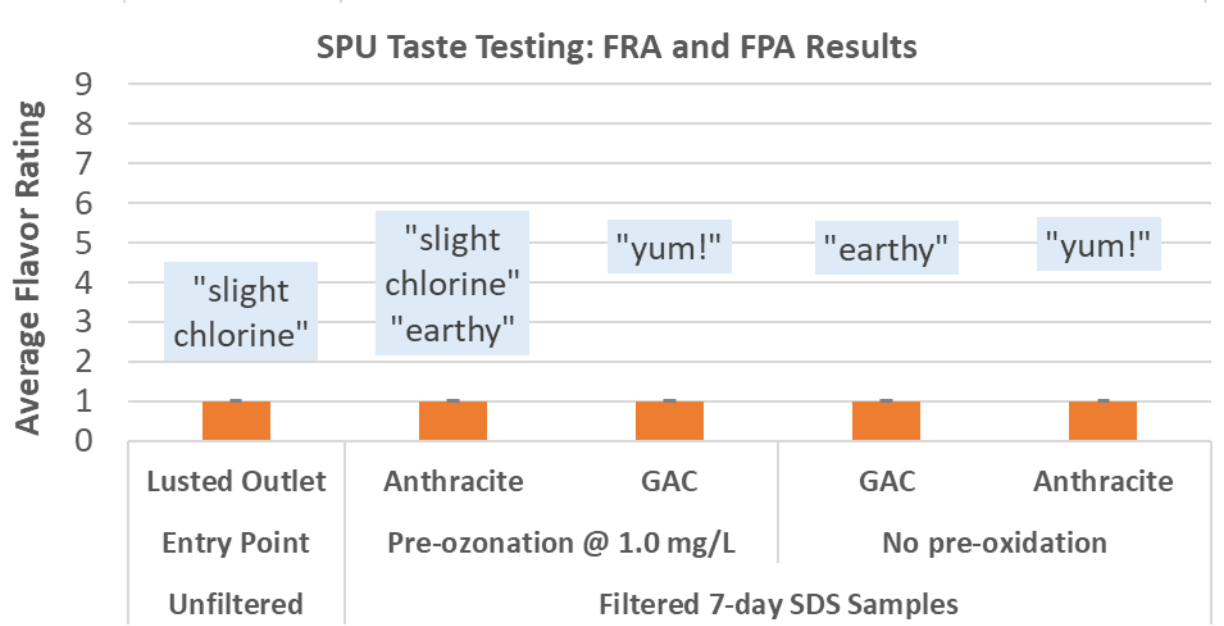

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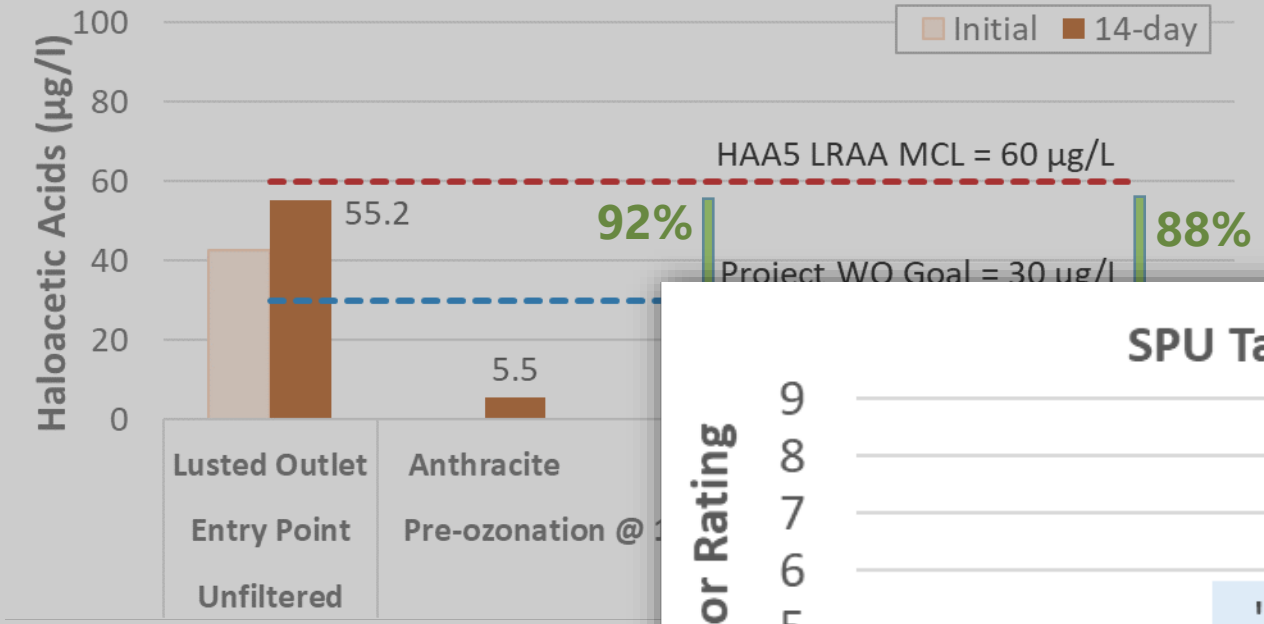

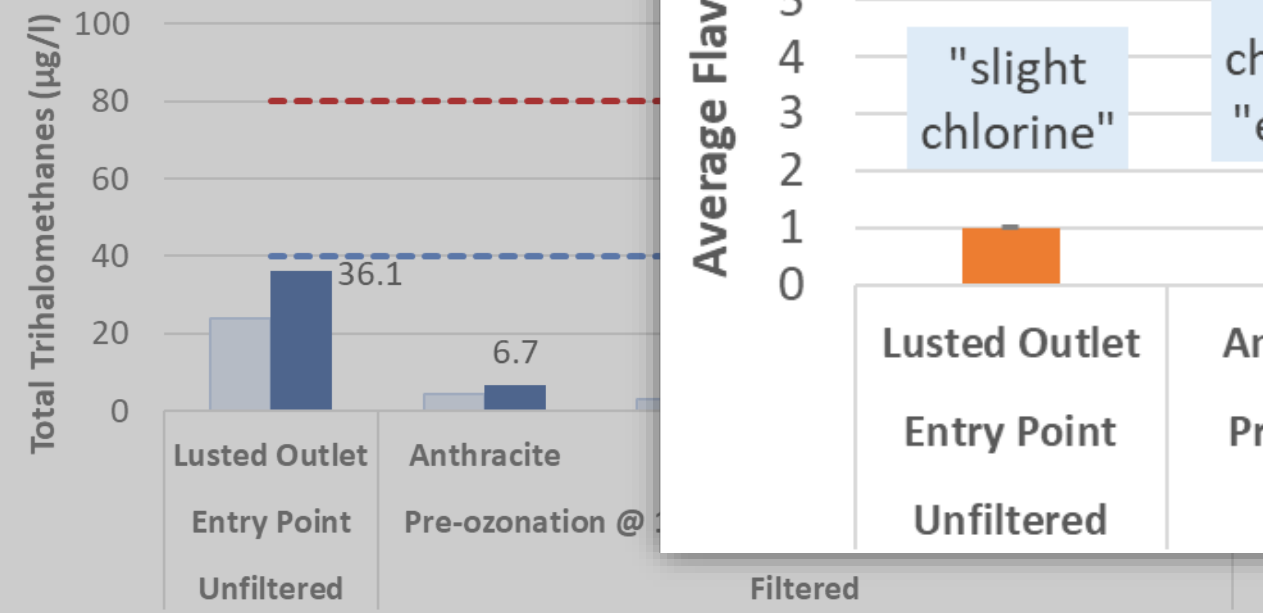

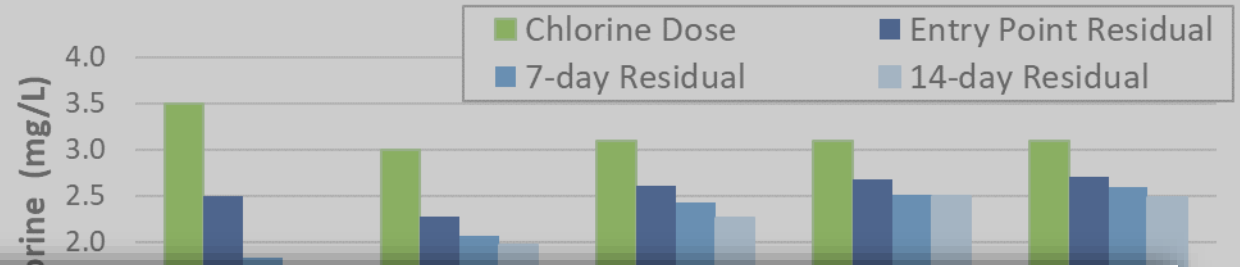

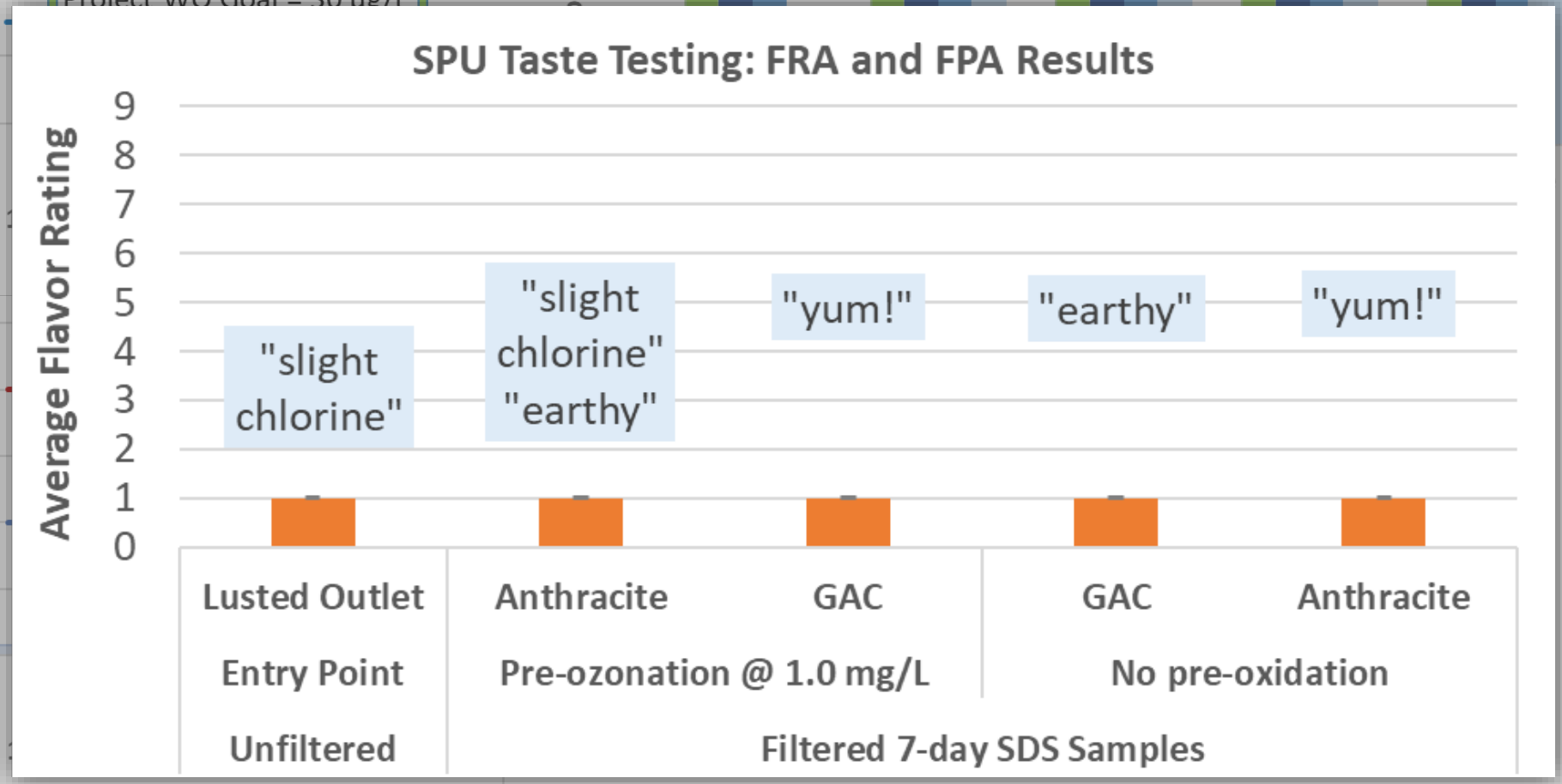

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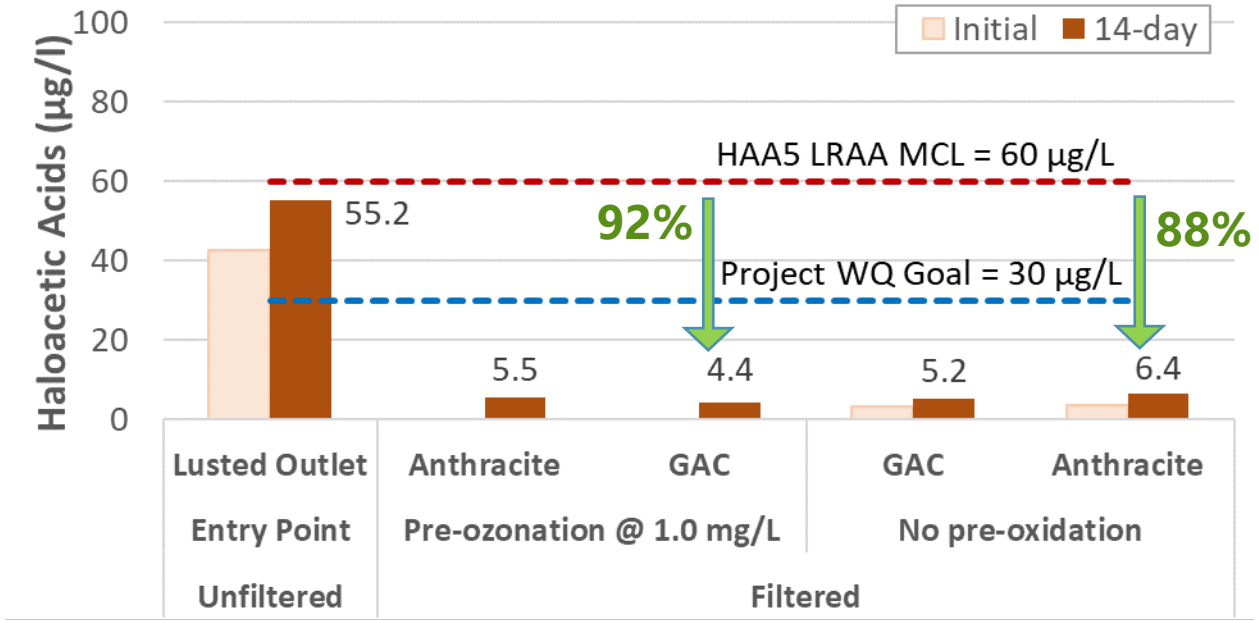
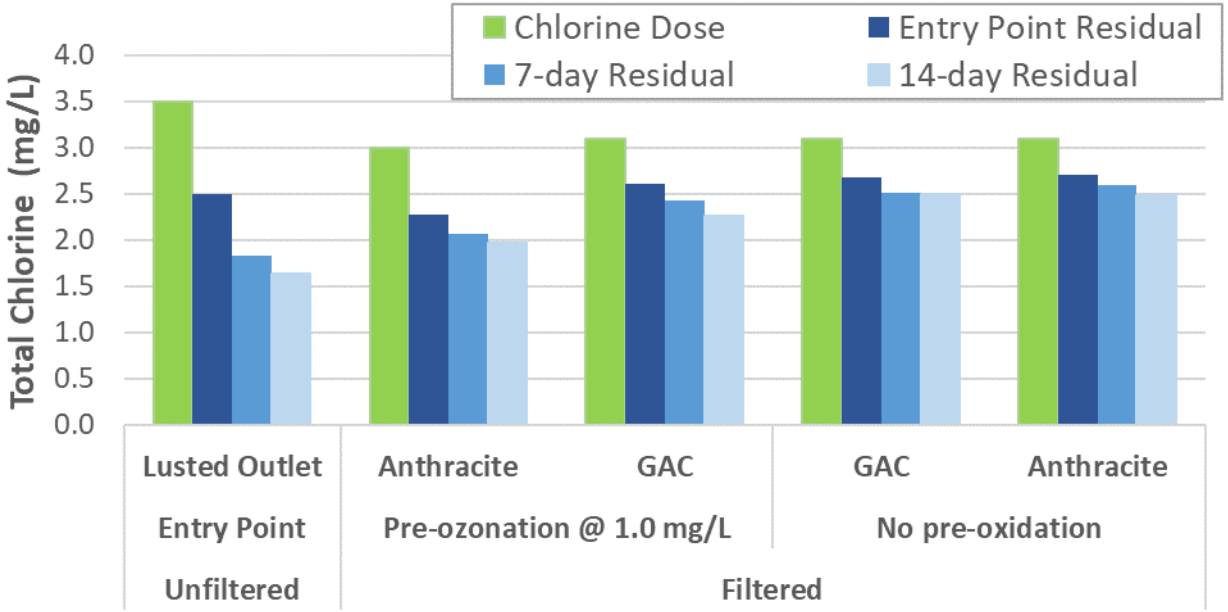
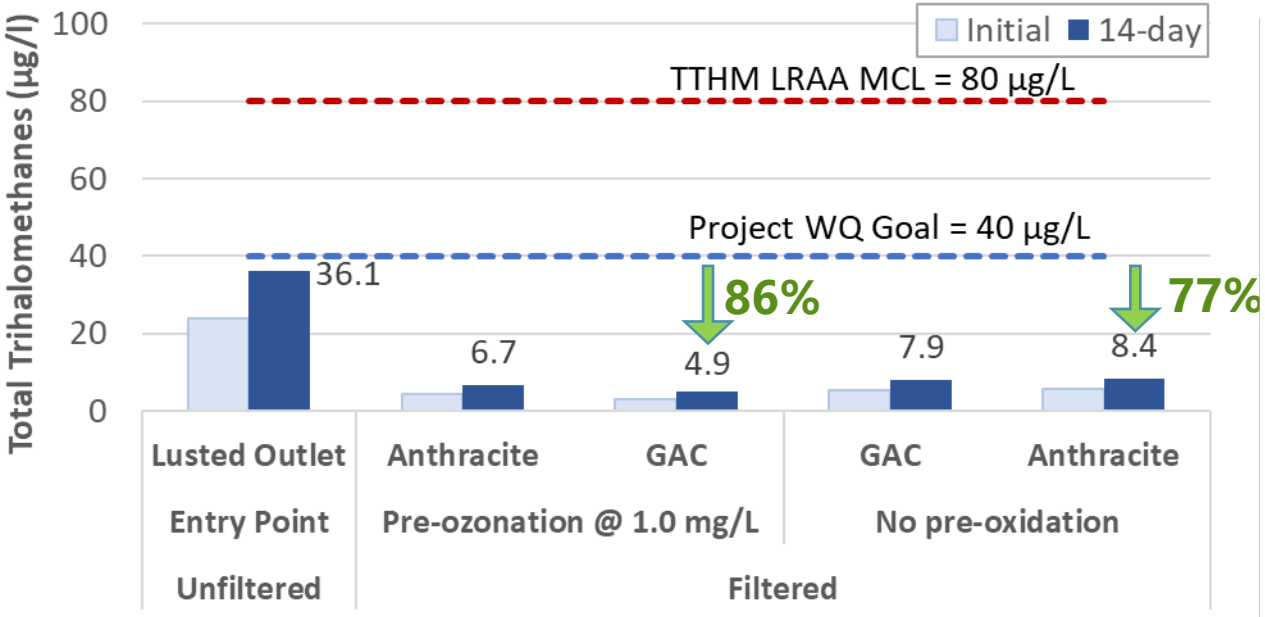
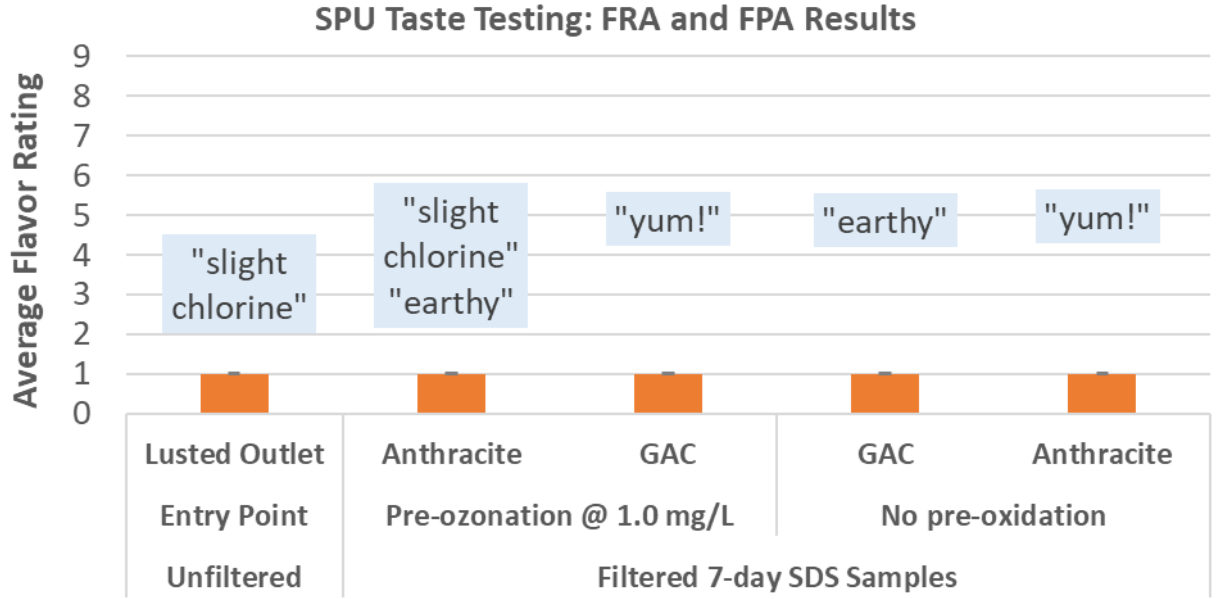
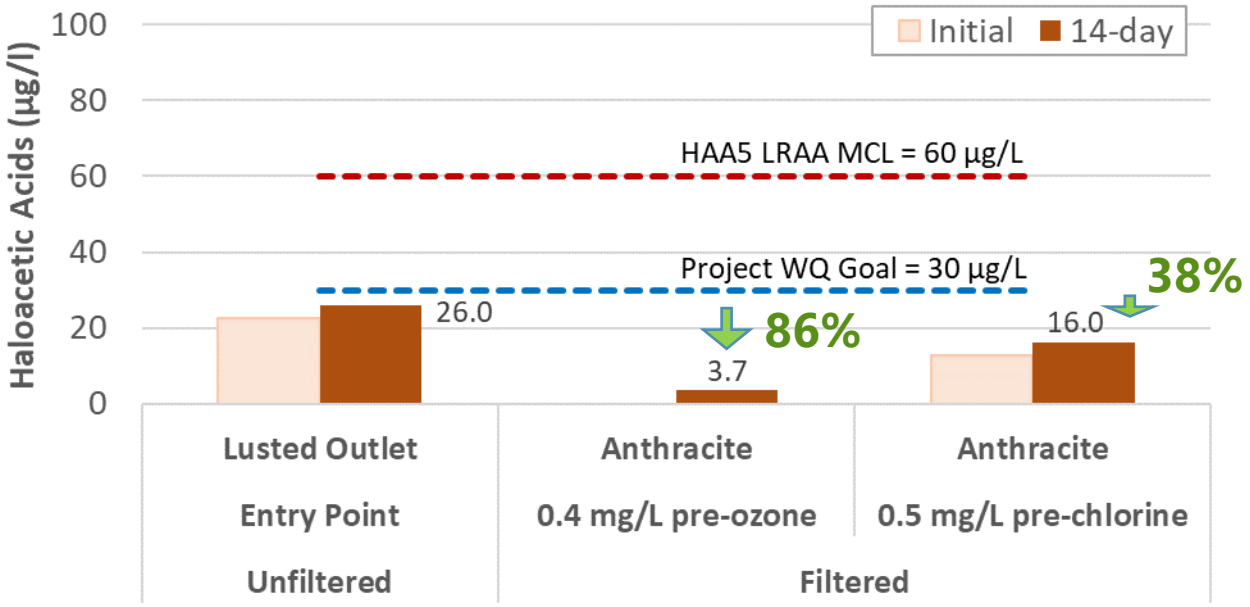


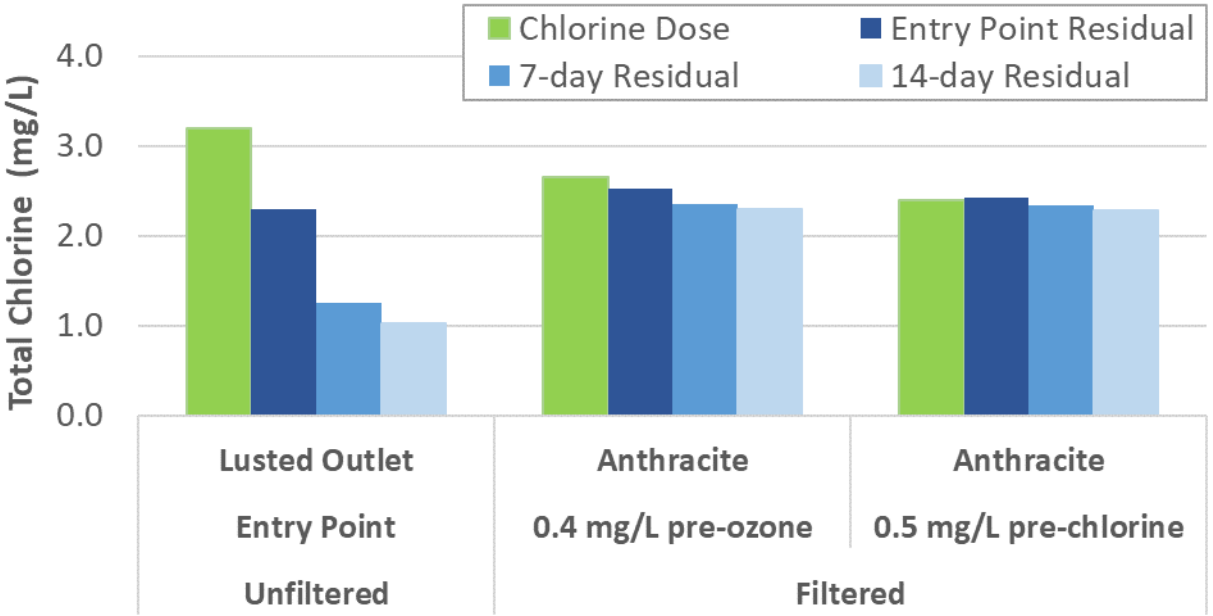


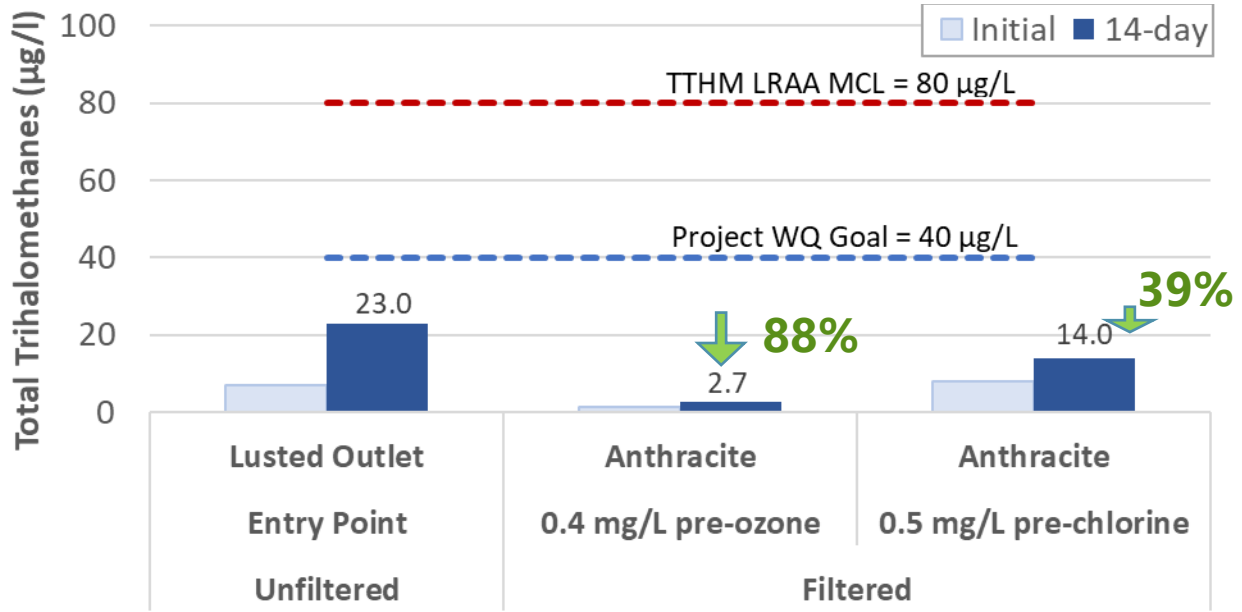




Test 2: pre-ozone vs pre-chlorine (spring 2021)







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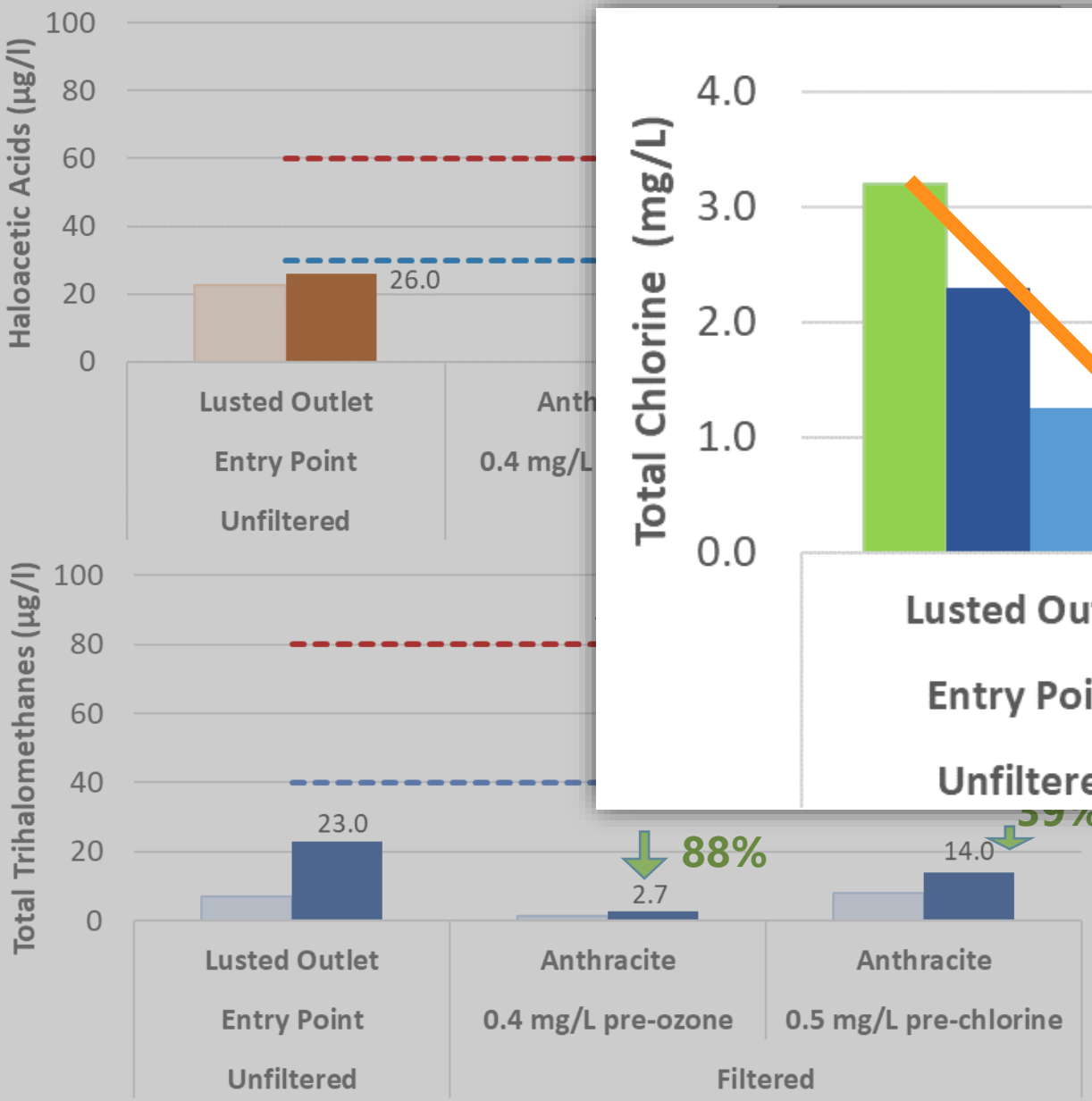

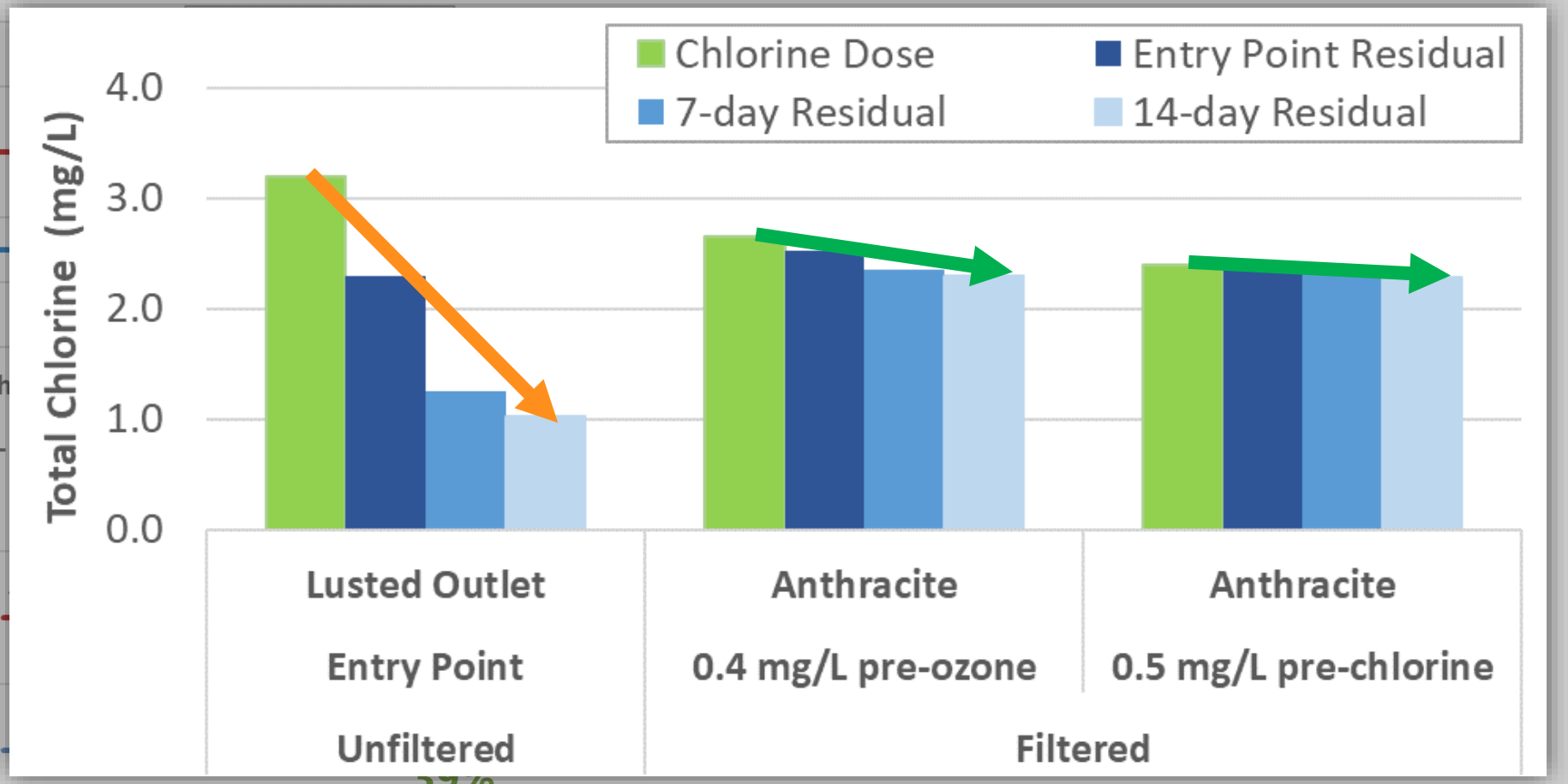

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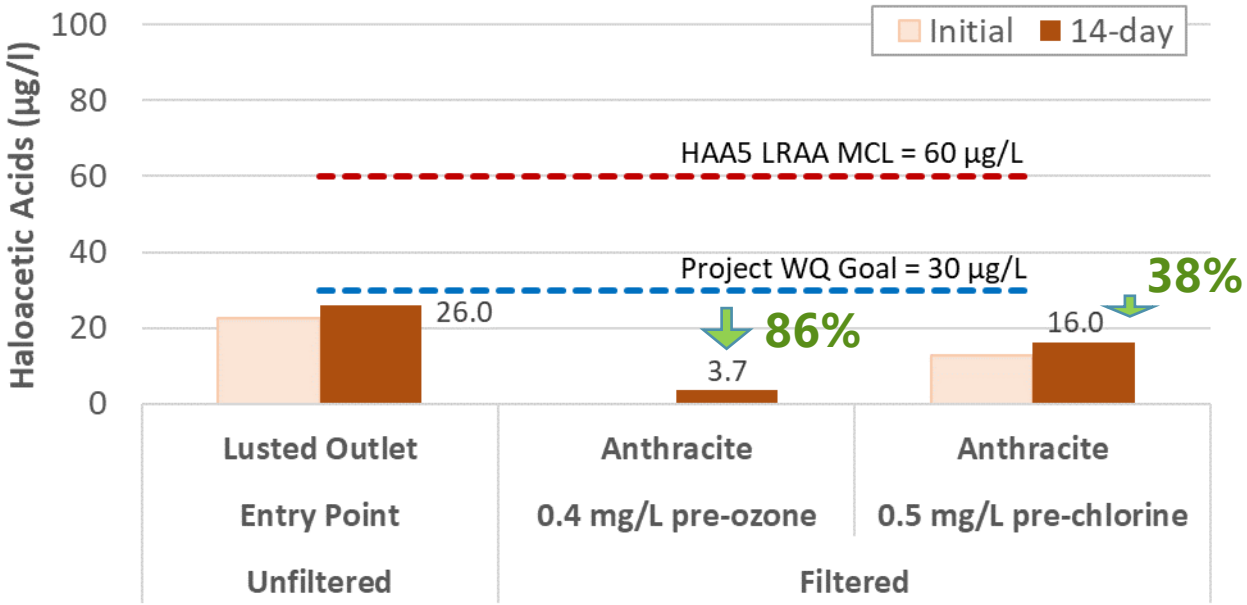

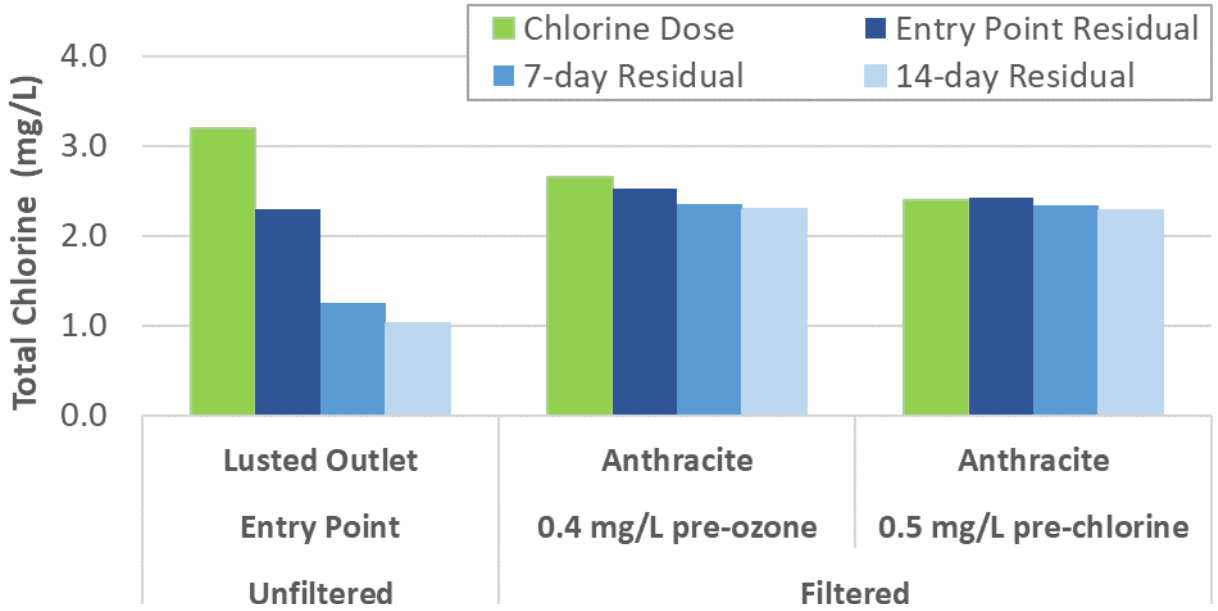

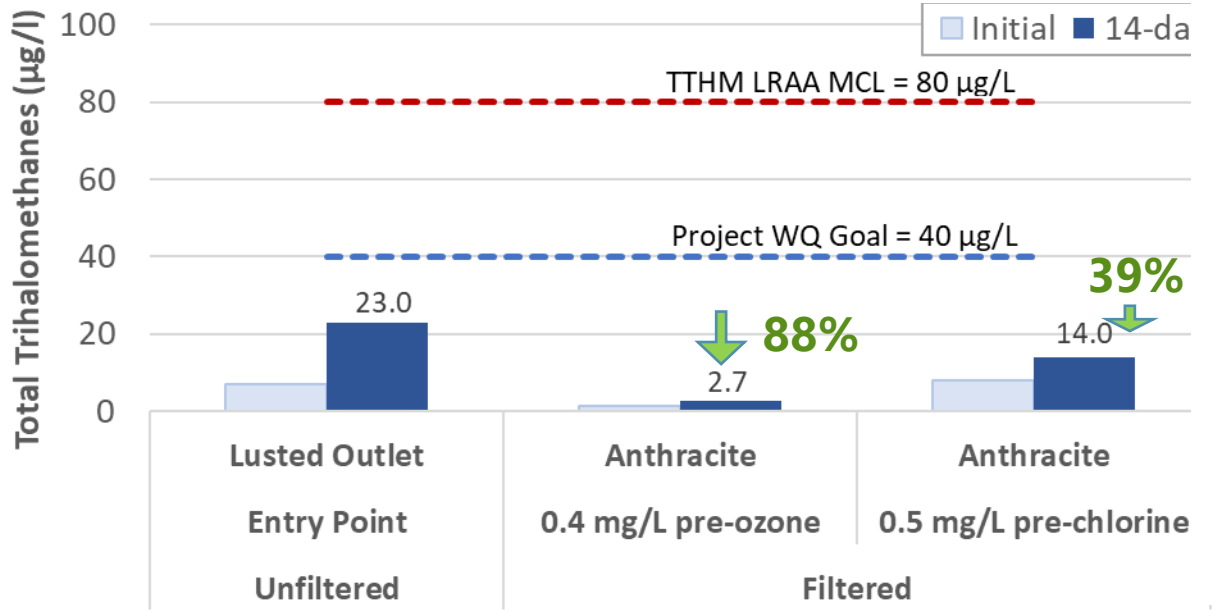

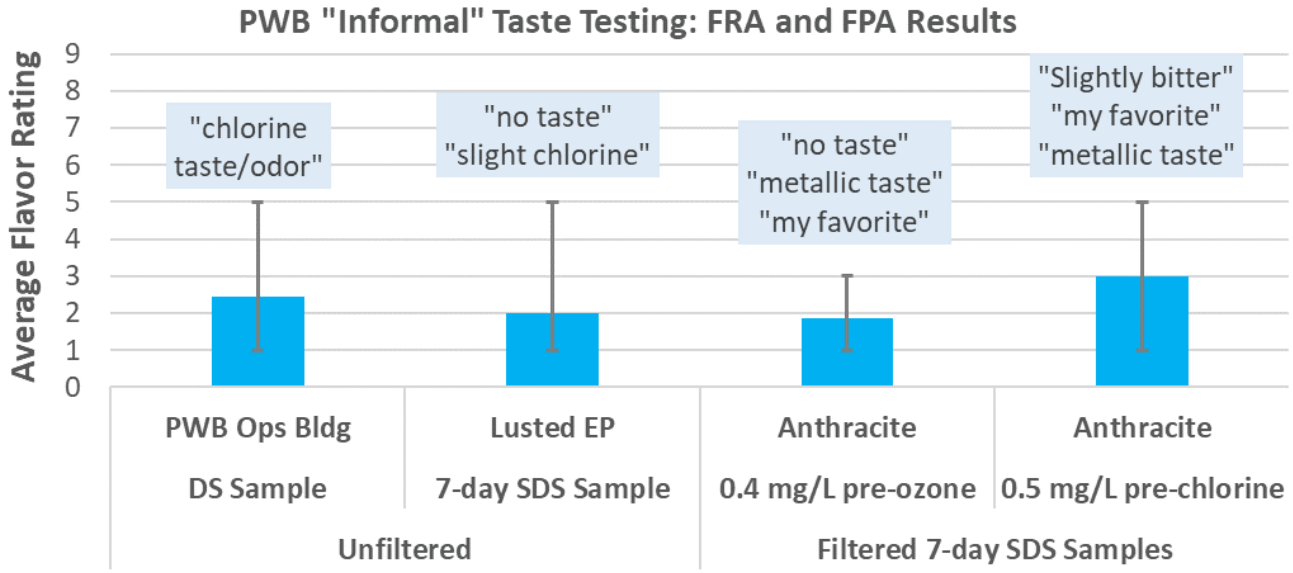

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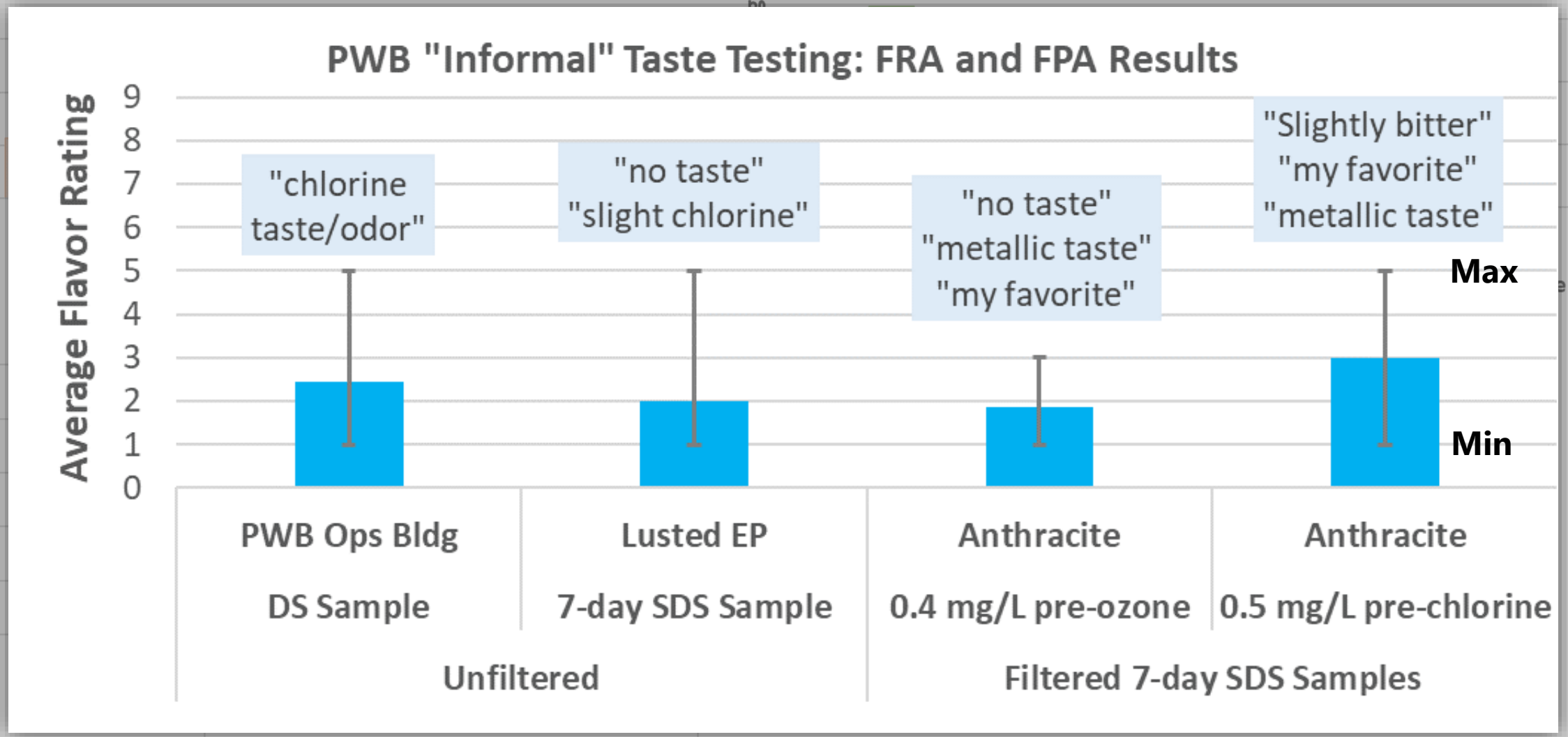

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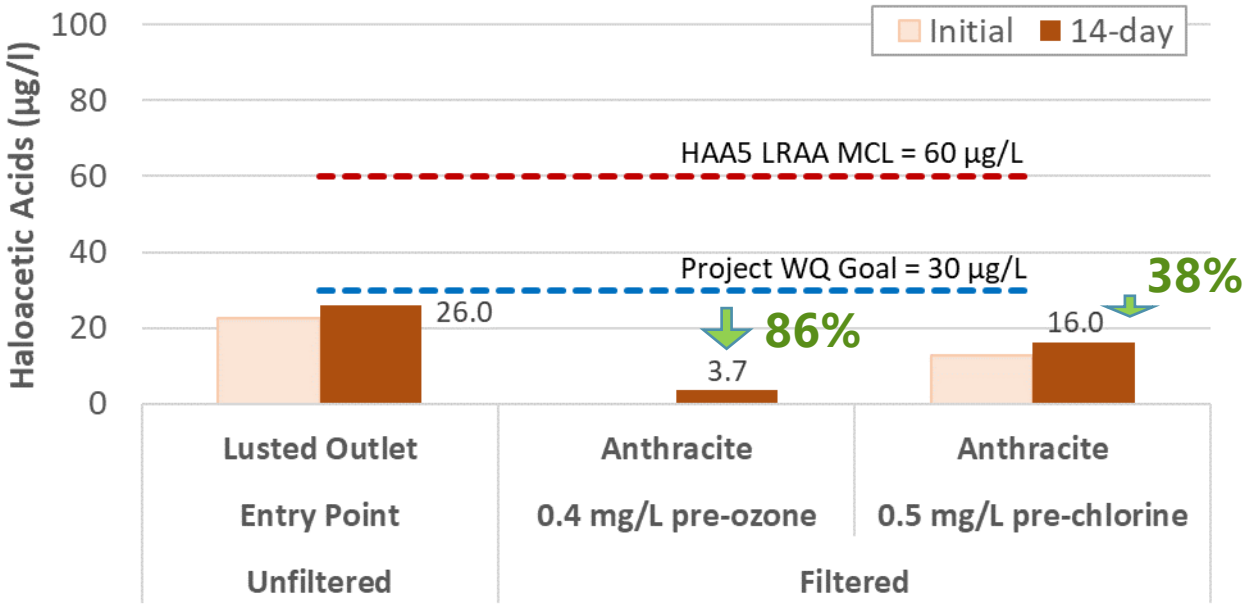
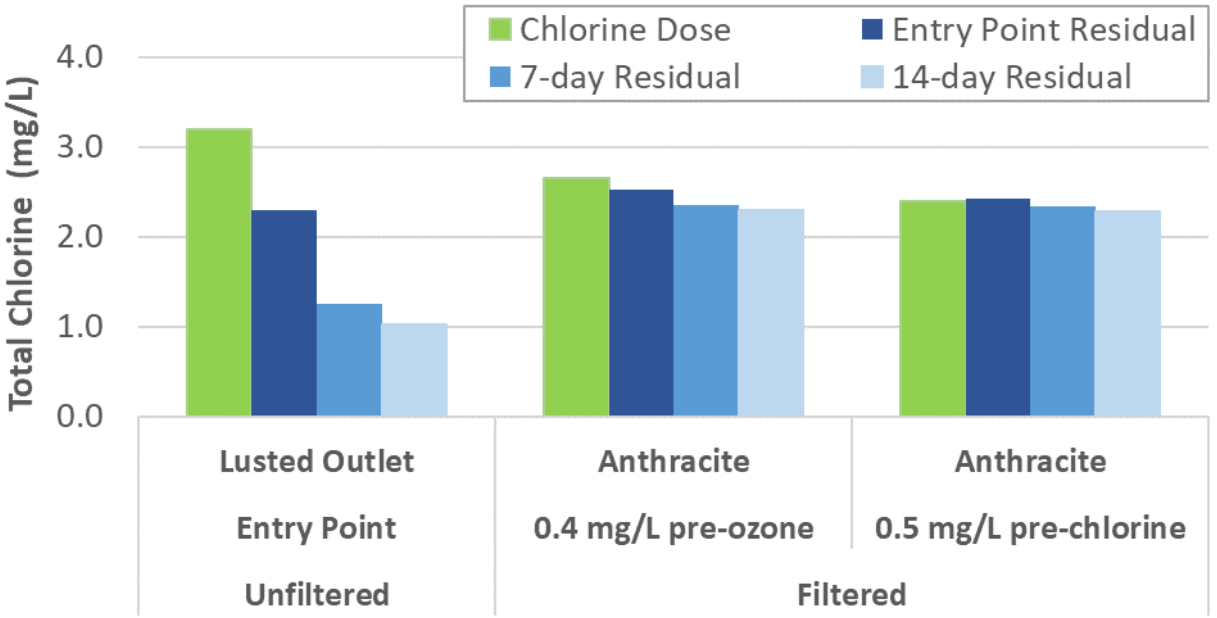
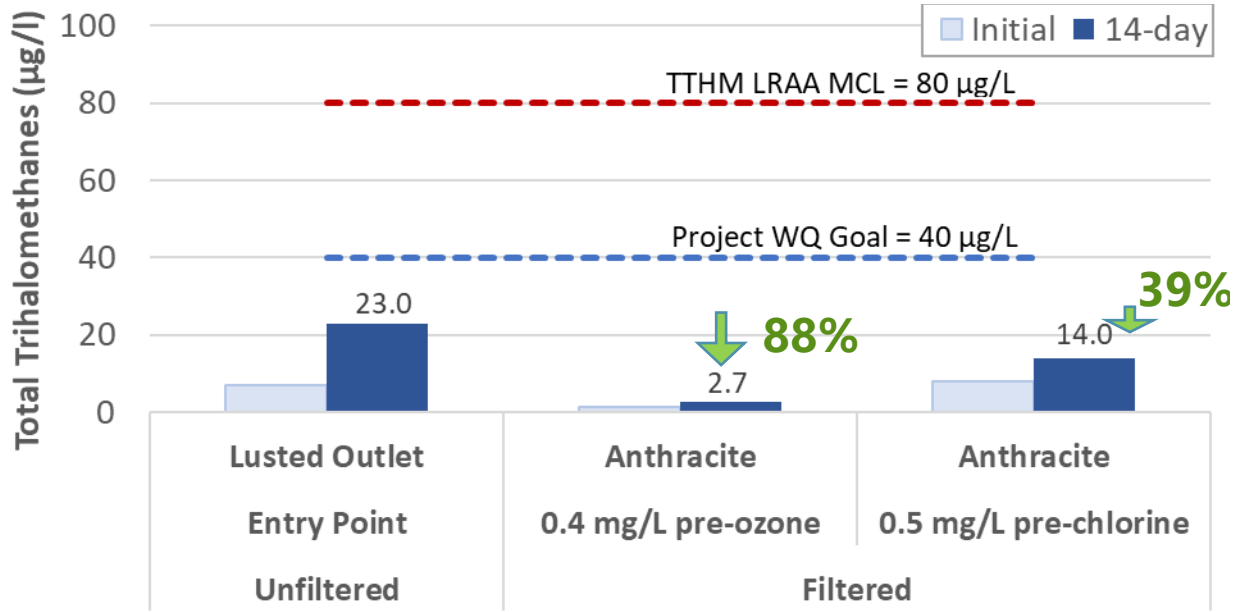
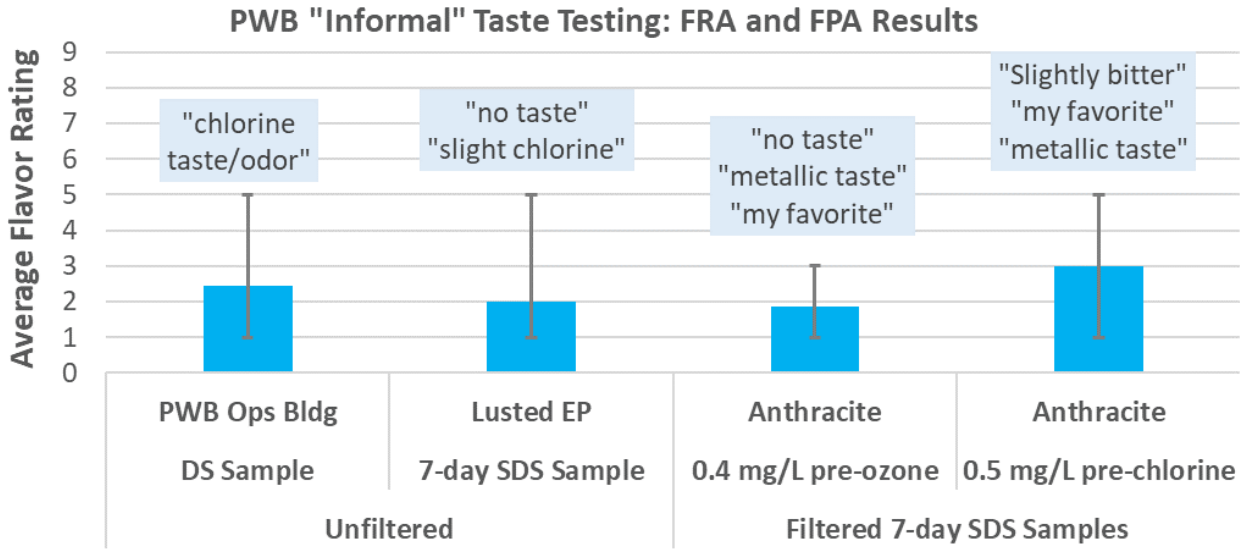
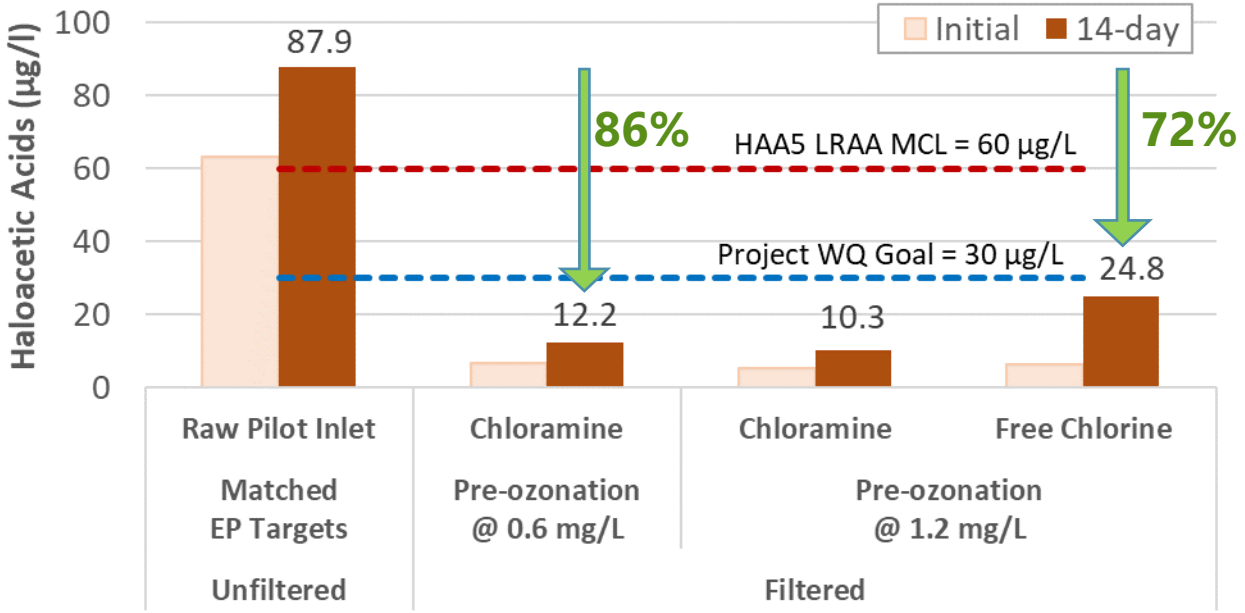


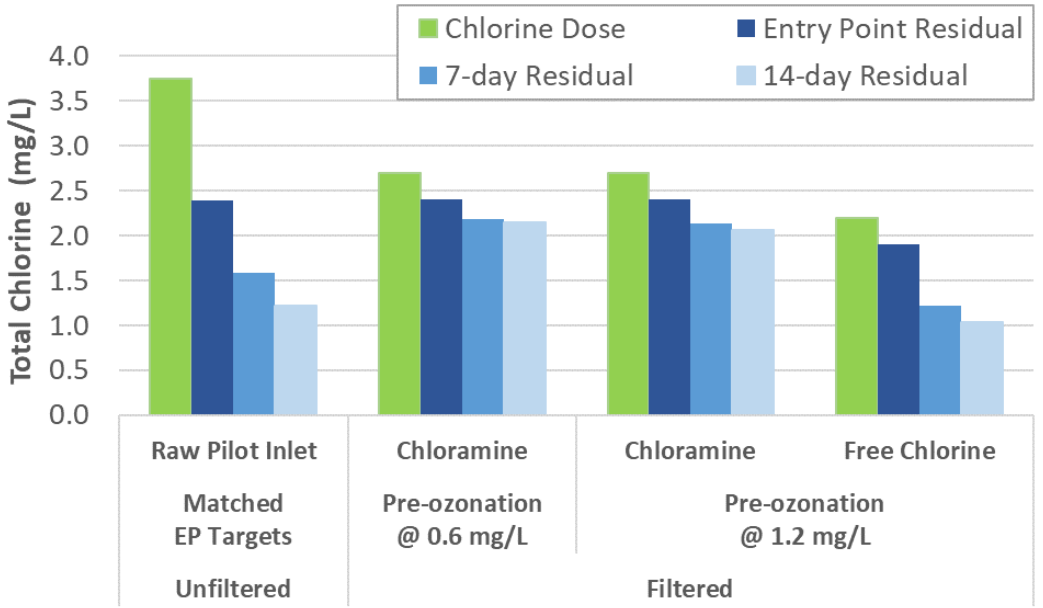


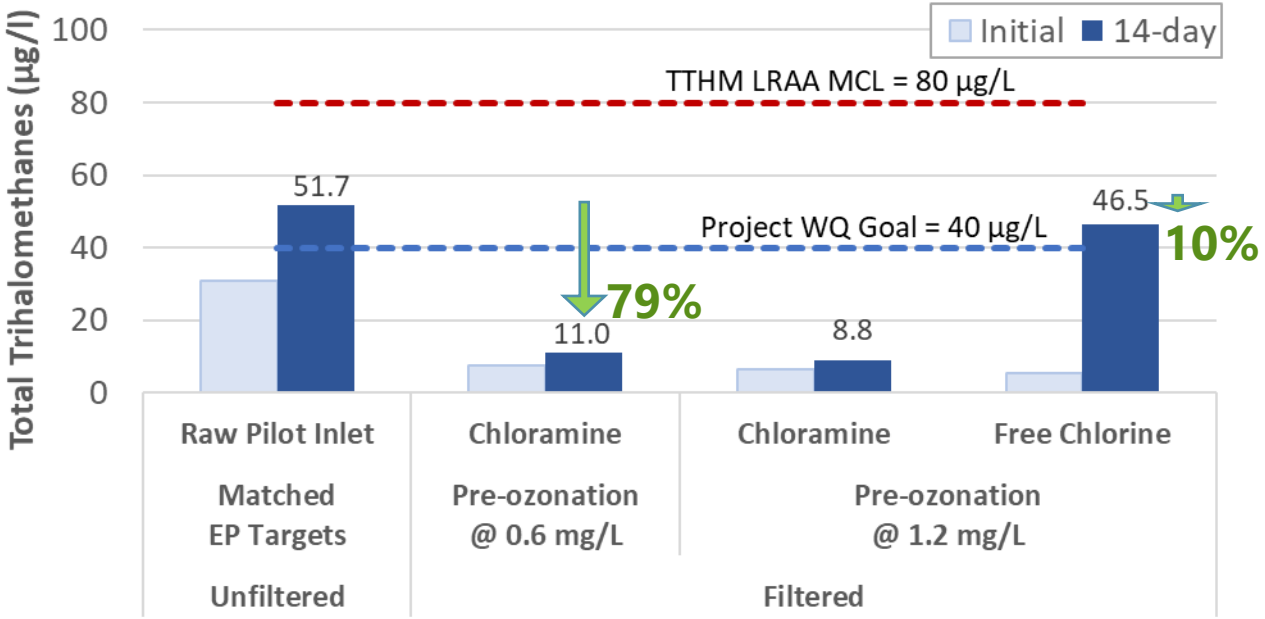




Test 3: ozone dose & secondary residual (fall 2020)







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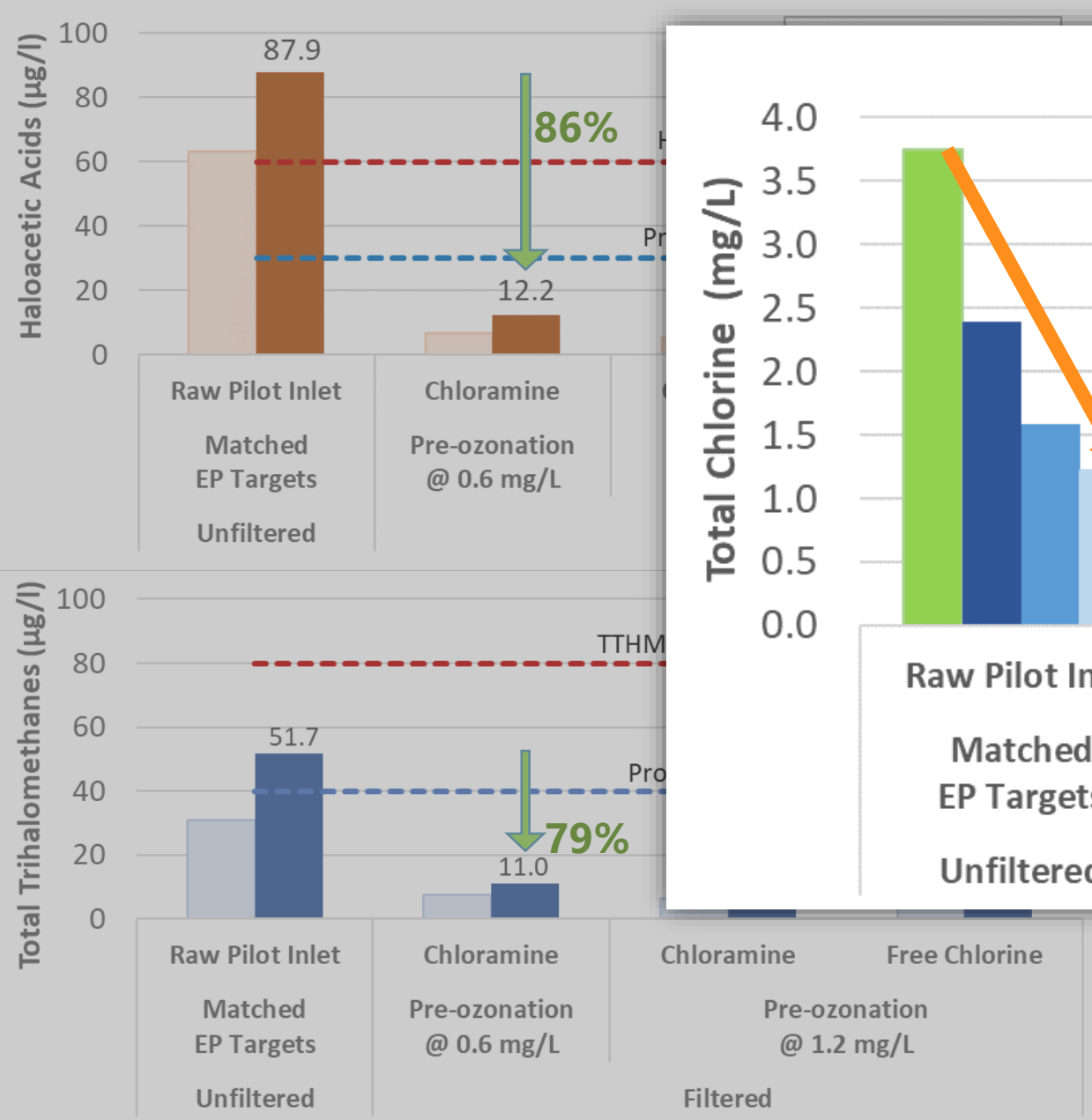

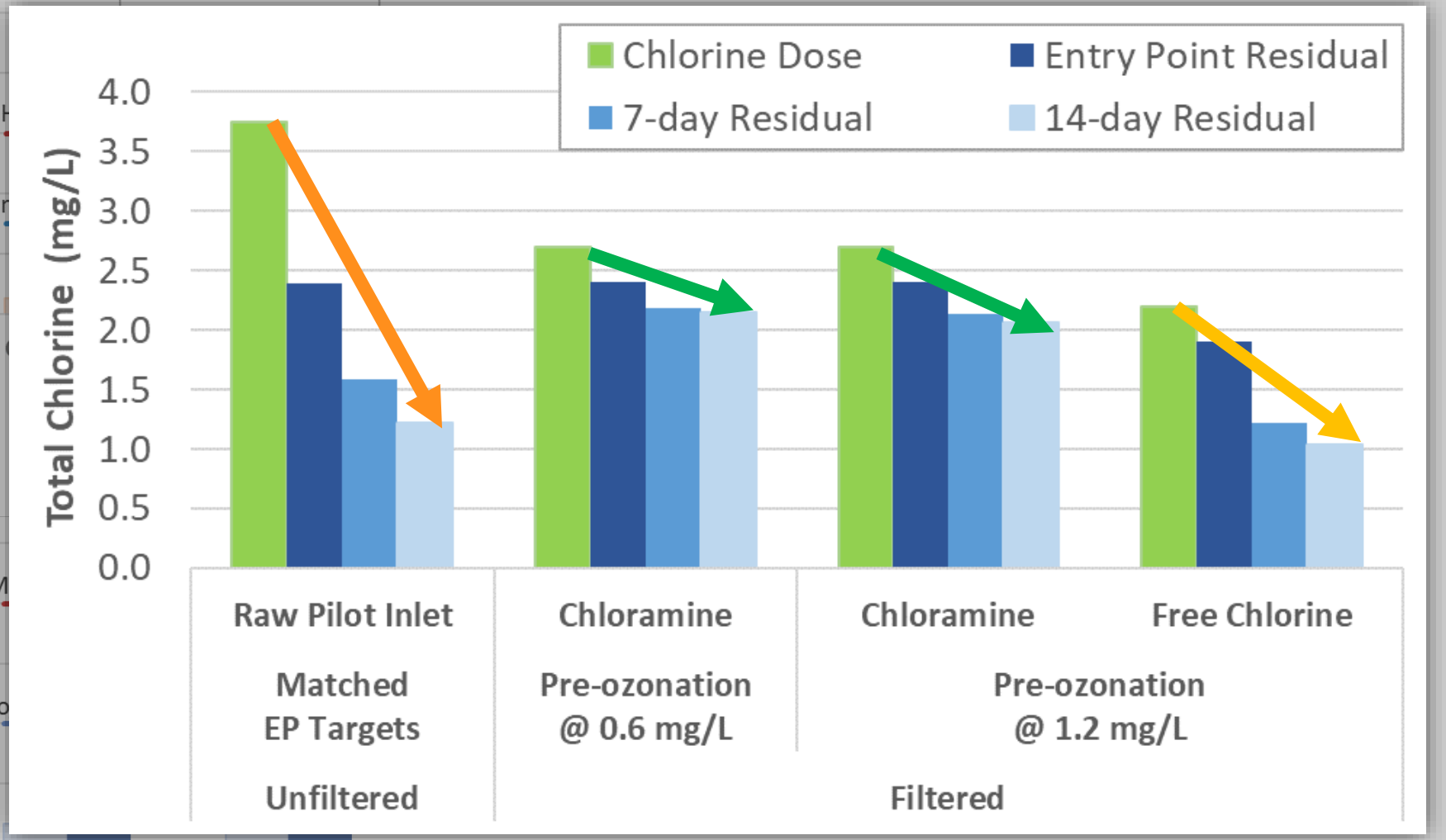

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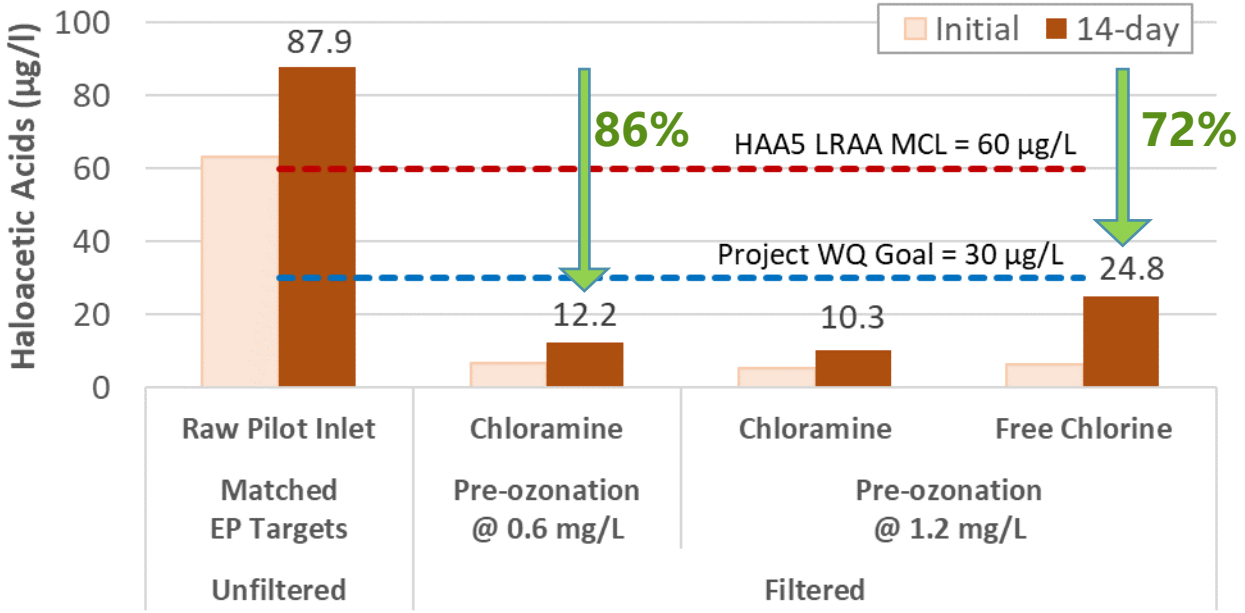

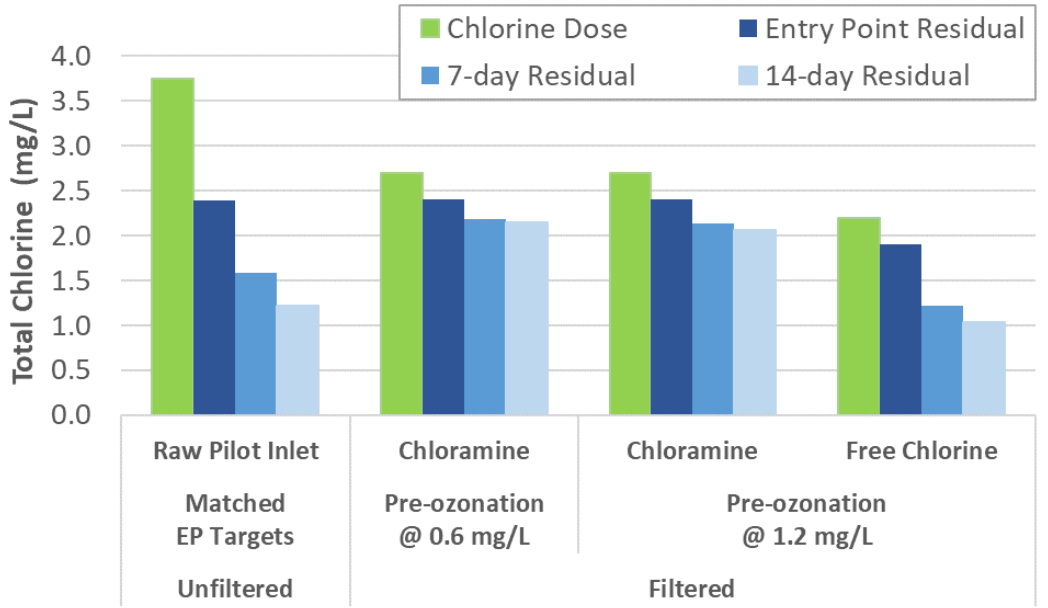

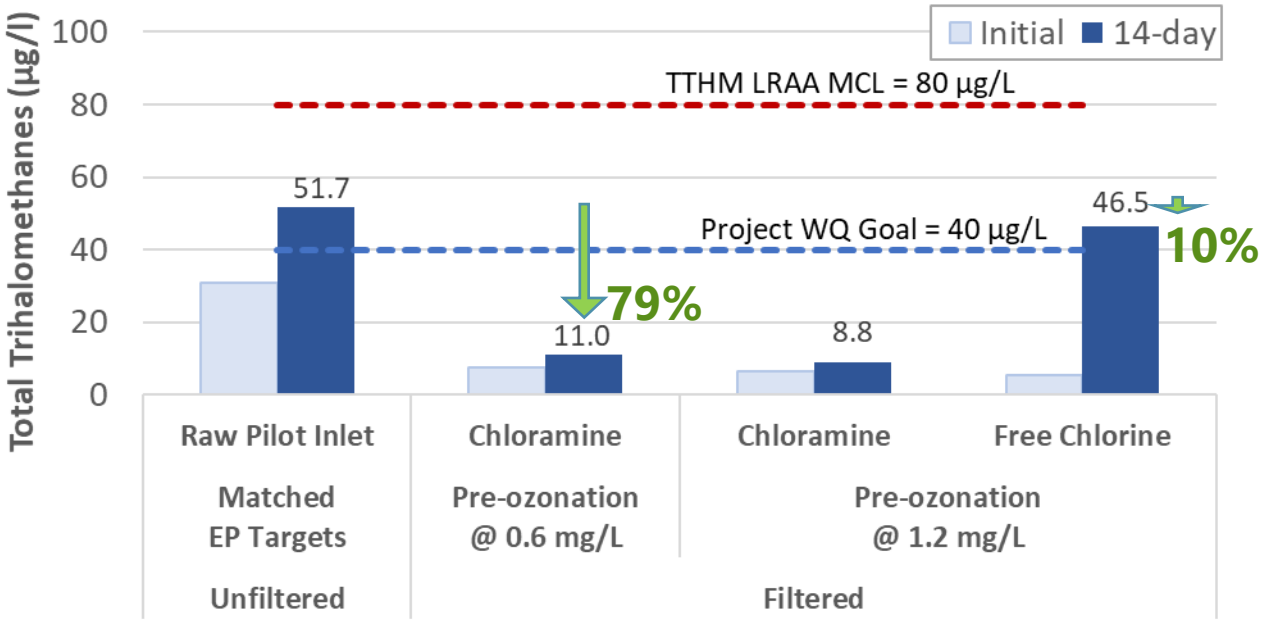

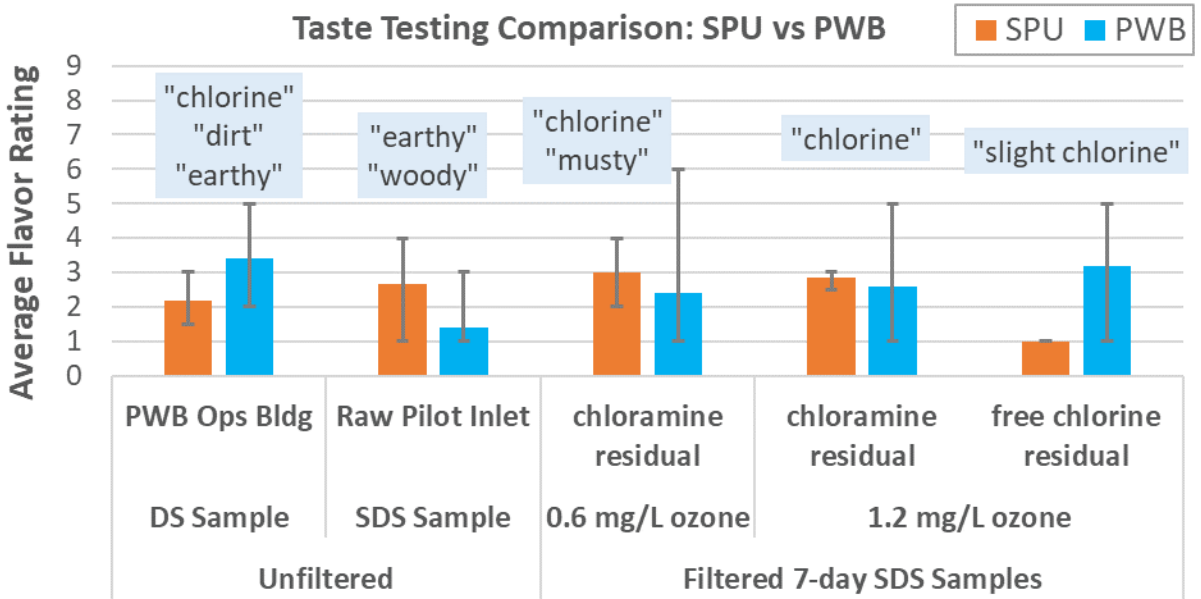

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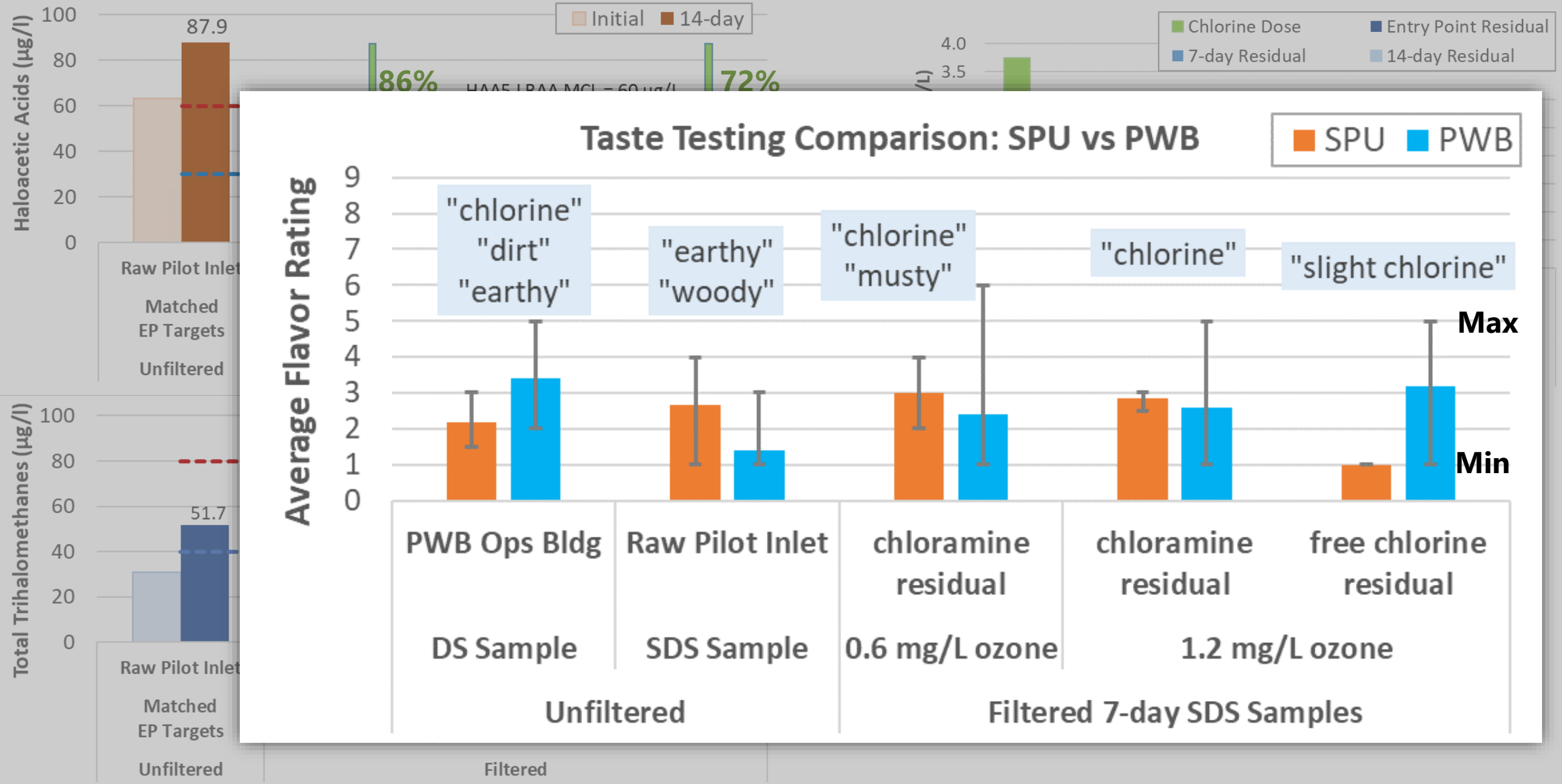

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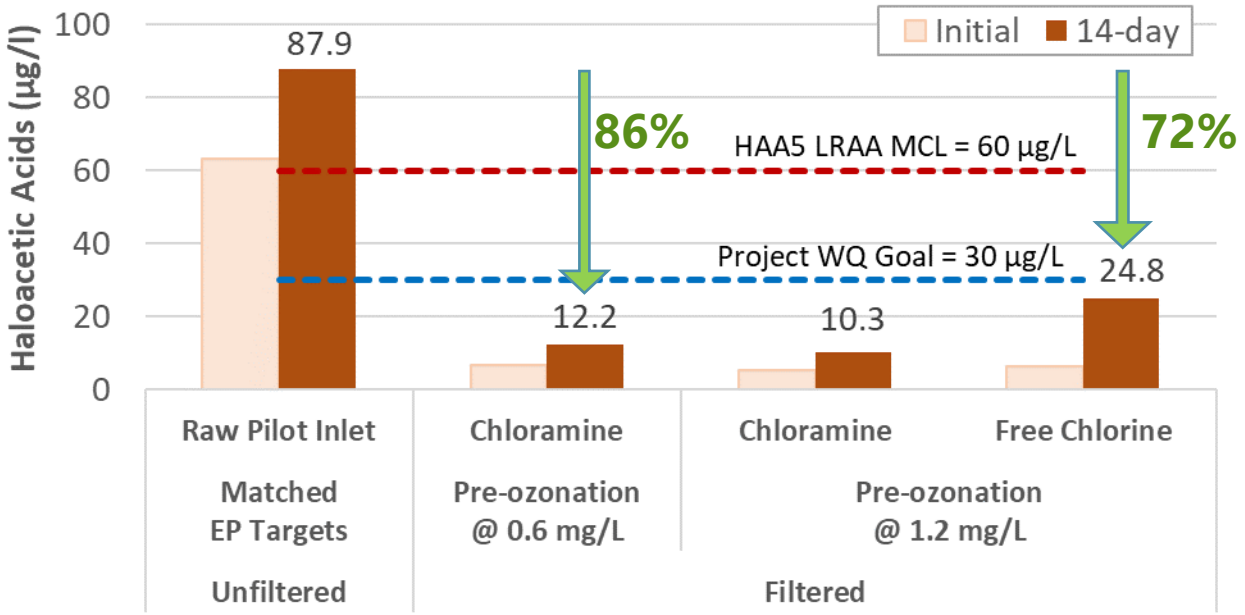
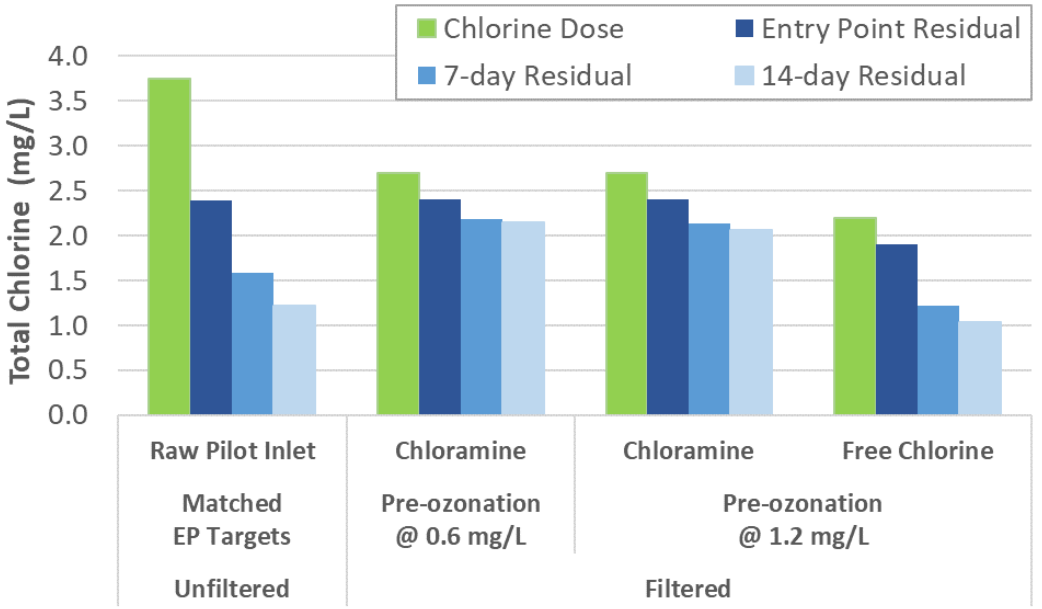
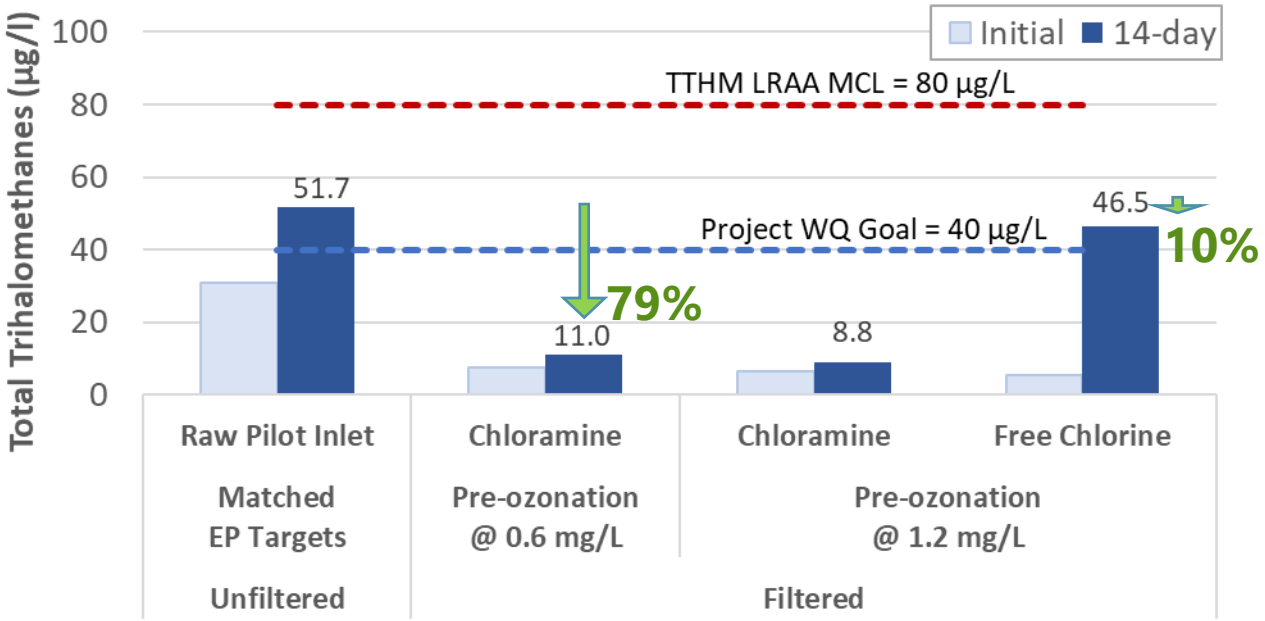
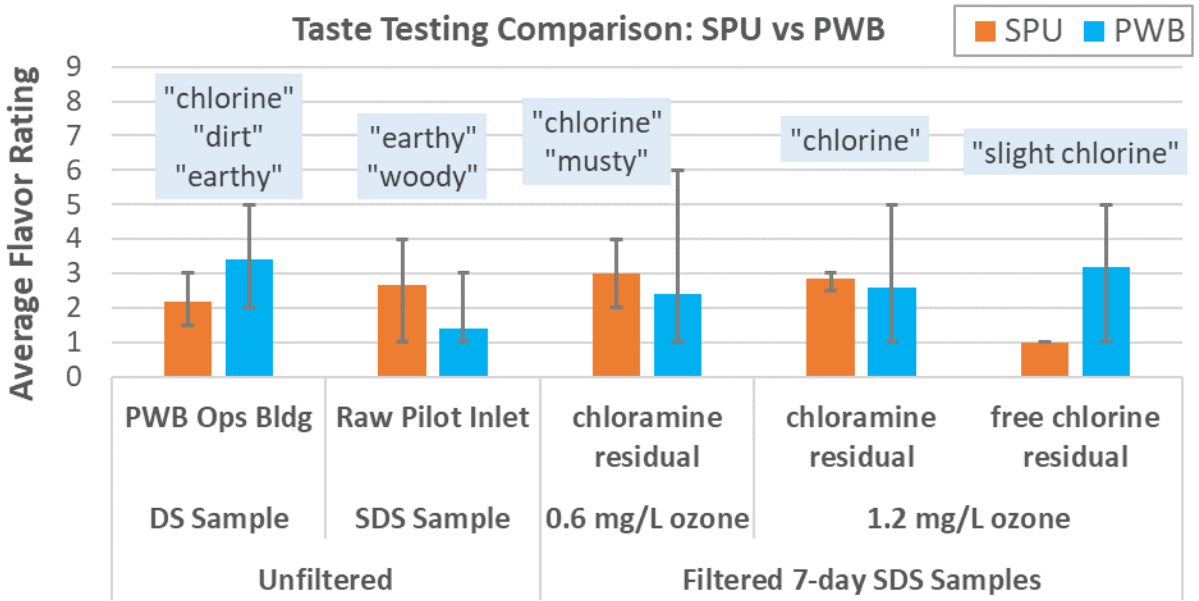


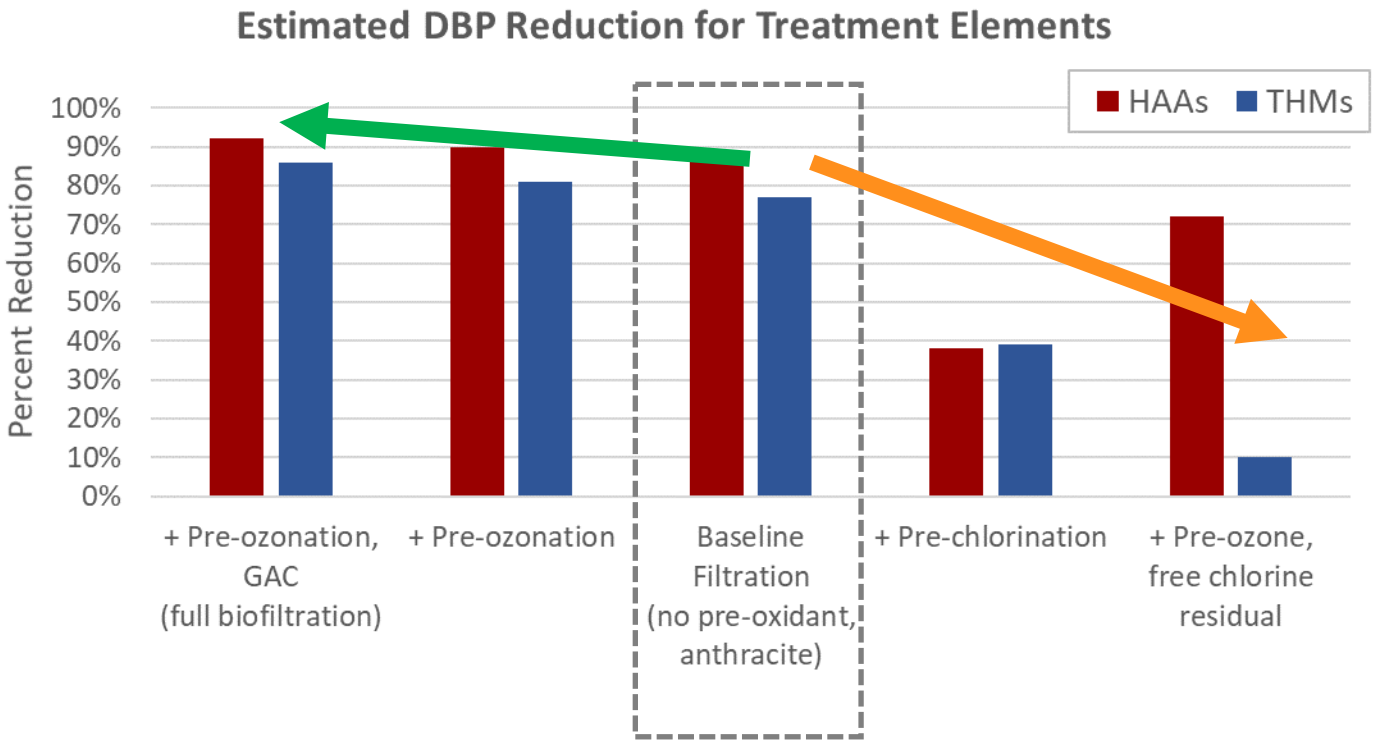






Summary

- Tasters generally rated water highly
  - no major improvements or drawbacks to taste/odor associated with treatment
- Filtration greatly improved total chlorine stability
- DBP goals met with any pre-oxidant approach
  - Project includes 0.75 mg/L ozone system, but may be deferred
  - Pre-chlorination, depending on dose, may not be able to meet DBP reduction goals following a wildfire or other event that degrades raw water quality



Acknowledgements - Pilot Study Project Team

Portland Water Bureau

- **Yone Akagi** – Water Quality Group Manager
- **Kimberly Gupta** – Bull Run Supply & Treatment Manager
- **Anna Vosa** – SDS Testing Lead
- **Mac Gifford** – Pilot Operations Lead
- **Pilot Ops:** Thomas Krause, Mojtaba Azadi Aghdam, Humberto Piedra-Ruiz, Lillian Gehres, Melanie Roy
- **PWB Lab** – Christina Cotnam, Marsha Farooqui, Otilia Plesiu

Pilot Technical Advisors

BRFF TAC

- **Issam Najm,** WQTS
- **Mark LeChevallier,** Dr. Water Consulting

Brown and Caldwell

- **Lynn Stephens**, Pilot Study Lead
- **Damon Roth**, Pilot Study and Corrosion Control
- **Mia Vijanderan**

Seattle Public Utilities WQ Lab

- **Elizabeth Cruise**
- **David Chong**

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Thank you!

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