Bull Run
TREATMENT
PROJECTS

Our water: Safe and abundant for generations to come

PORTLAND WATER BUREAU

Bull Run Treatment Projects

Using Bench Scale Coupon Testing to Assess Lead Reduction Performance in Portland's Water Supply Across a Range of Coagulants and Corrosion Control Treatment Methods

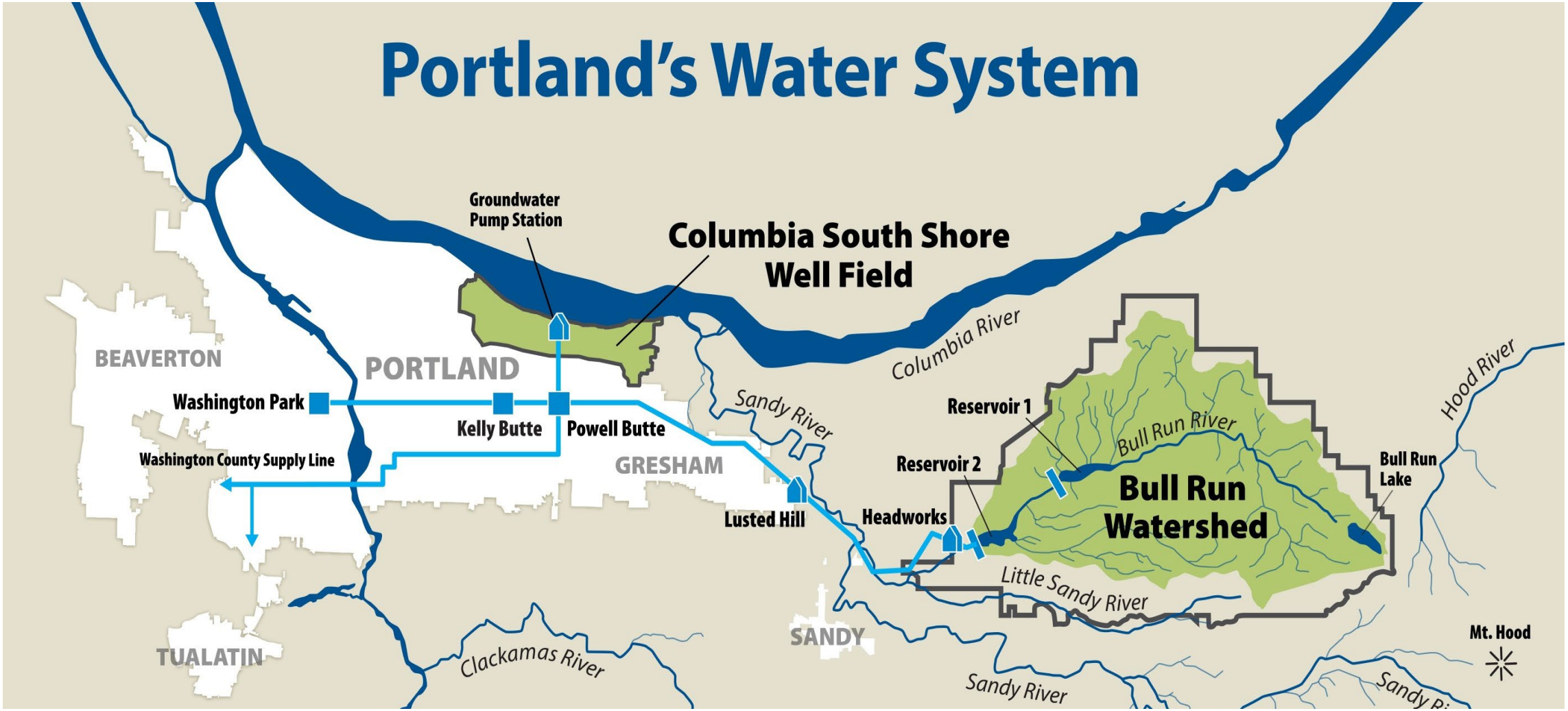
Anna Vosa, P.E., Portland Water Bureau
Alex Mofidi, P.E., Confluence Engineering Group

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

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

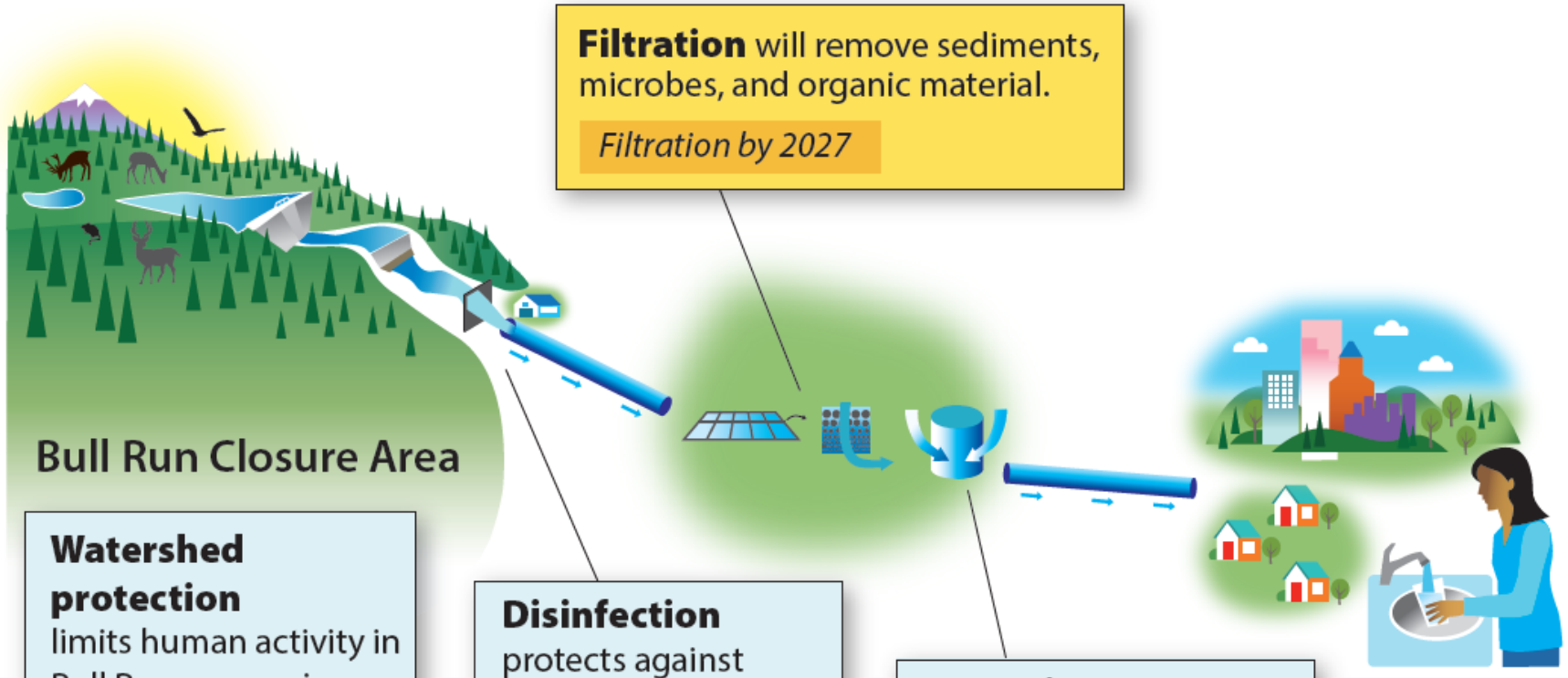
CITY OF PORTLAND, OREGON 1851

confluence
ENGINEERING GROUP LLC



- Serves approximately 970,000 people
- 19 wholesale water districts
- 101 million gallons per day average (80 – 160 mgd)

Current Treatment and Planned Improvements



Filtration will remove sediments, microbes, and organic material.

Filtration by 2027

Watershed protection limits human activity in Bull Run, preserving water quality.

Since 1892

Disinfection protects against illness caused by bacteria, viruses, and some protozoans.

Since the 1920s

Residual Target: 2.2-2.5 mg/L (gaseous chlorine + aqua ammonia)

Corrosion control treatment reduces lead exposure from home plumbing.

Since 1997

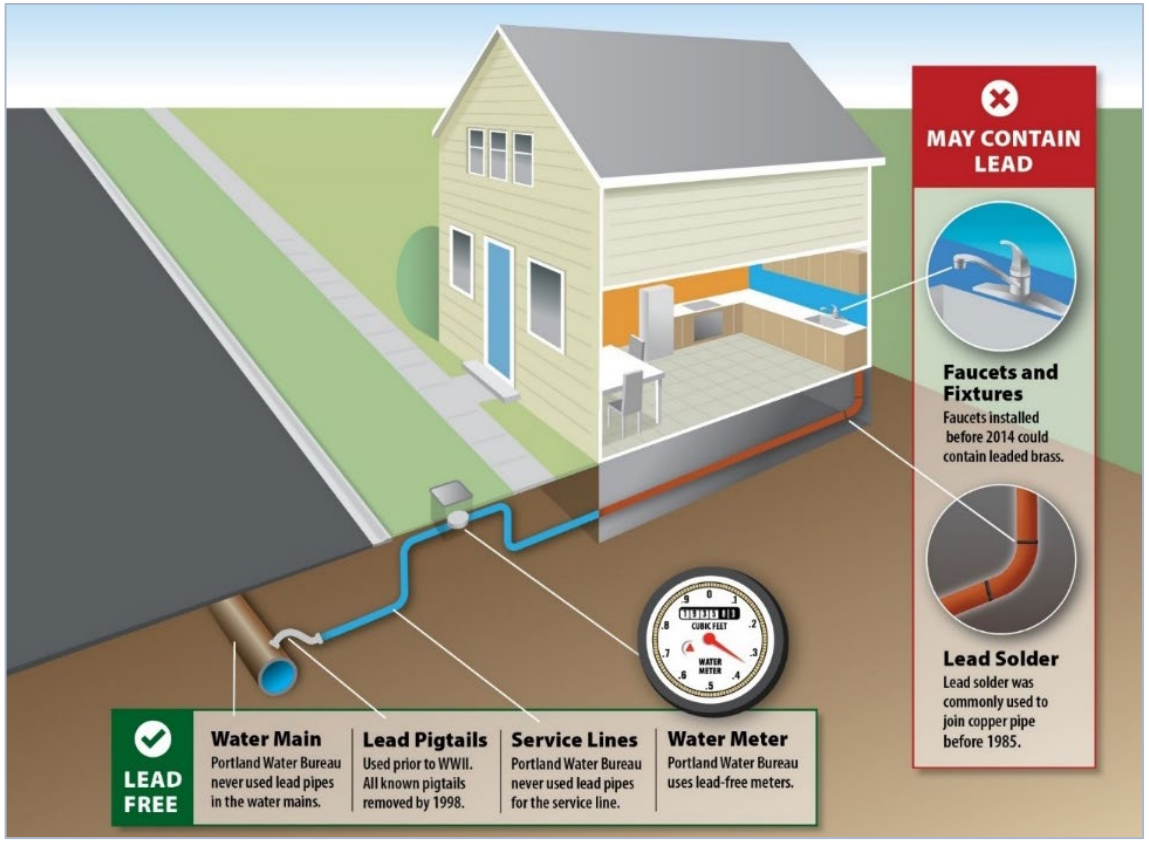
Improved Corrosion Control by 2022

Current pH Target: 8.3 (w/caustic soda)

ICCT Targets:
pH >8.5, alkalinity > 25 mg/L as $CaCO_3$ (w/soda ash and carbon dioxide)

Sources of Lead in Portland

- Portland never used lead service lines
- Copper pipes with lead solder is the main concern for Portland's water
  - Most common in homes plumbed or built from 1970-1985 – less than 10% of homes in Portland
- Home plumbing fixtures containing lead can also contribute to lead in water



Coupon Study Testing Approach

Questions Informing the Study Design

- How do CCT methods compare across a range of premise plumbing materials, including copper w/lead-tin solder (CLS), brass, and pure lead?
- How does CCT performance in filtered water compare with unfiltered water?
- How does the choice of coagulant affect CCT effectiveness?
- How does pH/alkalinity adjustment compare with orthophosphate inhibitor treatment?
- How does the choice in secondary disinfectant residual affect CCT performance?
- What is the overall best CCT approach for filtered water?

Chloride:Sulfate Mass Ratio (CSMR) of Unfiltered and Filtered Water

Water Source		Avg. Chloride (mg/L)	Avg. Sulfate (mg/L)	CSMR Range
Bull Run Raw Water		0.9	0.4	2.2 – 2.9
Unfiltered Finished Water		3.7	0.4	8.0 – 10.3
Filtered Finished Water, Coagulated with:	PACl	4.7	0.4	10.1 – 17.4
	Alum. Sulfate	2.9	3.0	0.7 – 1.0
	Ferric Sulfate	2.7	6.3	0.4 – 0.5

Testing Matrix

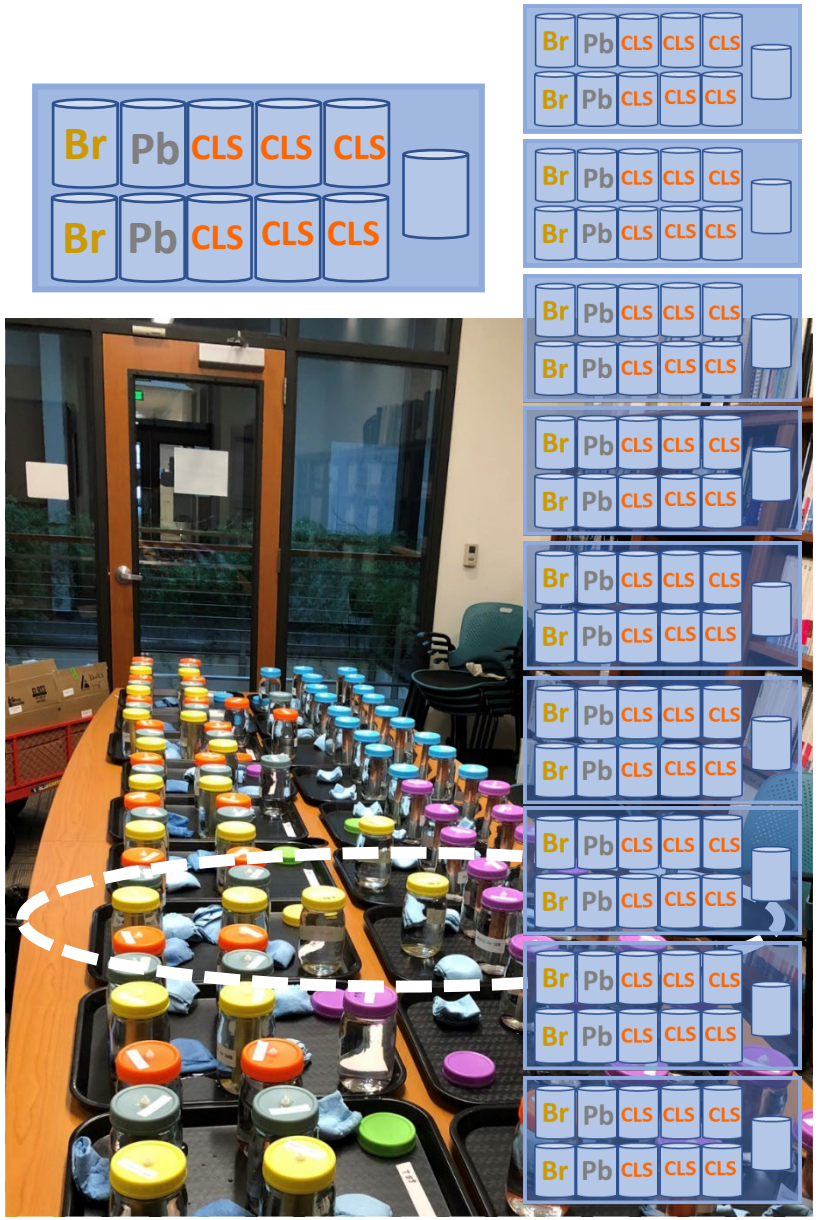
Source		Unfiltered Water Controls			Filtered Water from Pilot					
Test Condition		C85	C90	C95	T85	T90	T95	TO1	TO3	TCL
CCT Targets[1]		pH 8.5	pH 9.0	pH 9.5	pH 8.5	pH 9.0	pH 9.5	1 mg/L PO_4, pH 7.8	3 mg/L PO_4, pH 7.8	pH 8.5, free chlorine
Acclimation (PACl)	**19 weeks** (8/18/20 – 12/31/20)	2 **Brass** 2 **Lead** 6 **CLS**	2 **Brass** 2 **Lead** 6 **CLS**	2 **Brass** 2 **Lead** 6 **CLS**	2 **Brass** 2 **Lead** 6 **CLS**	2 **Brass** 2 **Lead** 6 **CLS**	2 **Brass** 2 **Lead** 6 **CLS**	2 **Brass** 2 **Lead** 6 **CLS**	2 **Brass** 2 **Lead** 6 **CLS**	2 **Brass** 2 **Lead** 6 **CLS**
Phase 1 – PACl	**10 weeks** (1/1/21 – 3/10/21)	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**
Phase 2 – Alum	**13 weeks** (3/11/21 – 6/9/21)	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	Discontinued	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**
Phase 3 - Ferric Sulfate	**10 weeks** (6/10/21 – 8/23/21)	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	Discontinued	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**	2 **Brass** 2 **Lead** 4 **CLS**

[1]All unfiltered and filtered test waters were treated to target a finished chlorine residual (total or free) of 2.5 mg/L and adjusted to 30 mg/L-$CaCO_3$ alkalinity

Testing Approach –
Test Water Preparation and Incubated Water Analysis

- Tests waters were prepared and transferred to the coupon jars Mondays and Thursdays.
- Filtered water was harvested from the pilot ~monthly. Treatment included pre-ozonation and conventional treatment (coagulation, flocculation, sedimentation, and granular media filtration).
- Unfiltered water was collected from the distribution system every Monday and Thursday.
- Replaced water was sampled for field parameters (chlorine, pH, ORP, turbidity, and PO_4). Lead and copper were sampled every Monday (4-day stagnation).

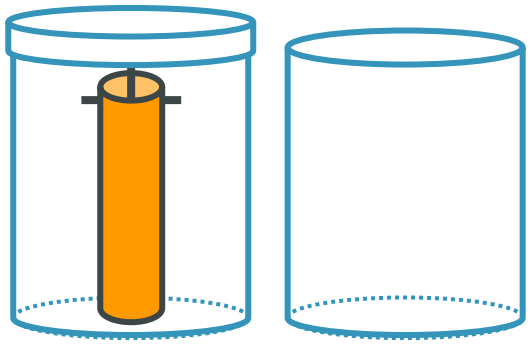
Cubitainers of filtered water harvested from the Bull Run Filtration Pilot Plant



99 jars incubating on our conference room table

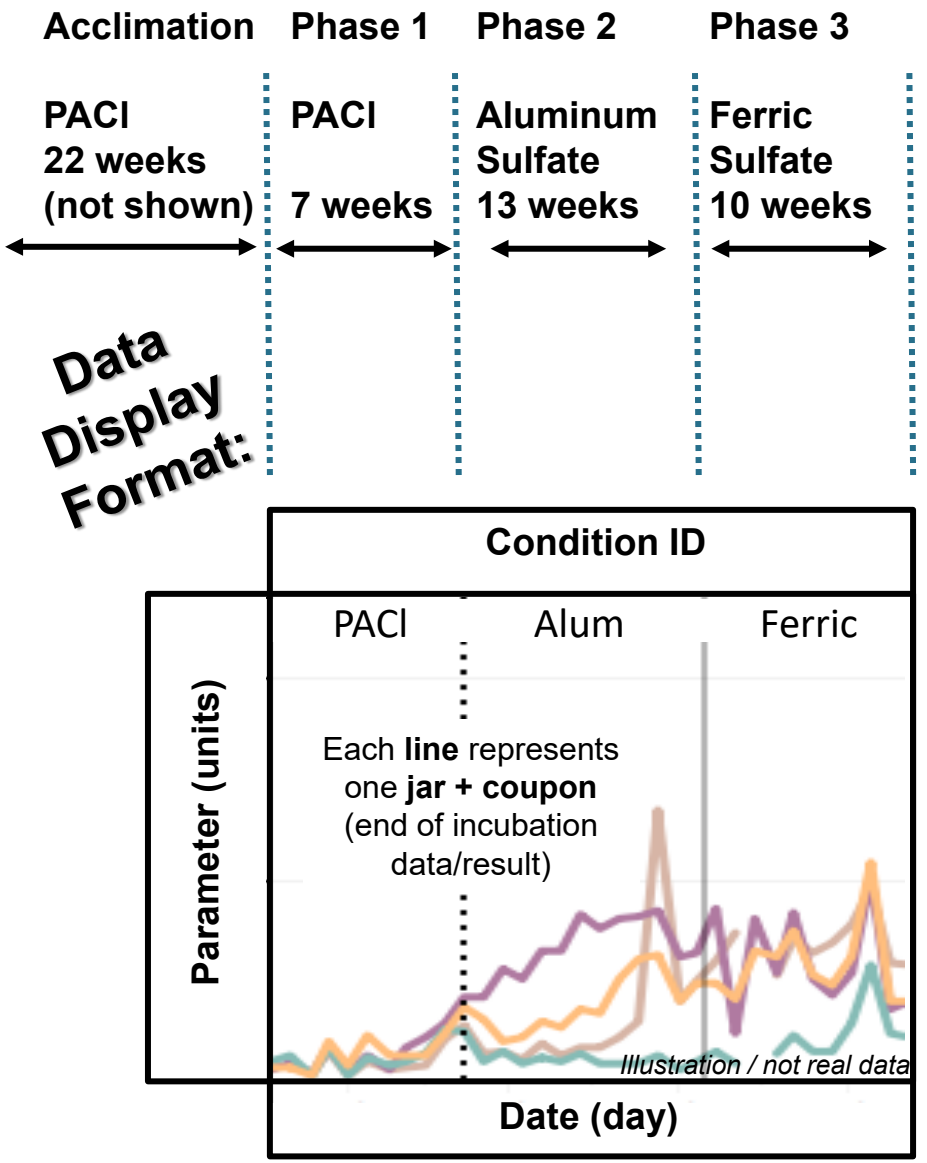
Novel Test Design

- **Varied Bench-Scale Testing Procedures** (No industry-wide protocol, variable coupon & sampling practices)
- **This Study**
  - 500 mL, headspace free, 10-cm pipe coupons
  - Maximized surface area to volume ratio to allow good lead signals



Testing Results

- **Reminders**
  - Unfiltered = From Distribution System
  - Approx. 1 year of data with 3 coagulants
  - BENCH TEST DATA
- **Key Issues to Understand:**
  - Unfiltered vs. Filtered Performance
  - CSMR Impacts from Coagulants
  - Orthophosphate vs. pH/alkalinity
  - Free Chlorine vs. Chloramines



Database and Graphics Software
Tableau Version 2021.1.2, 64 bit
(Seattle, Washington)

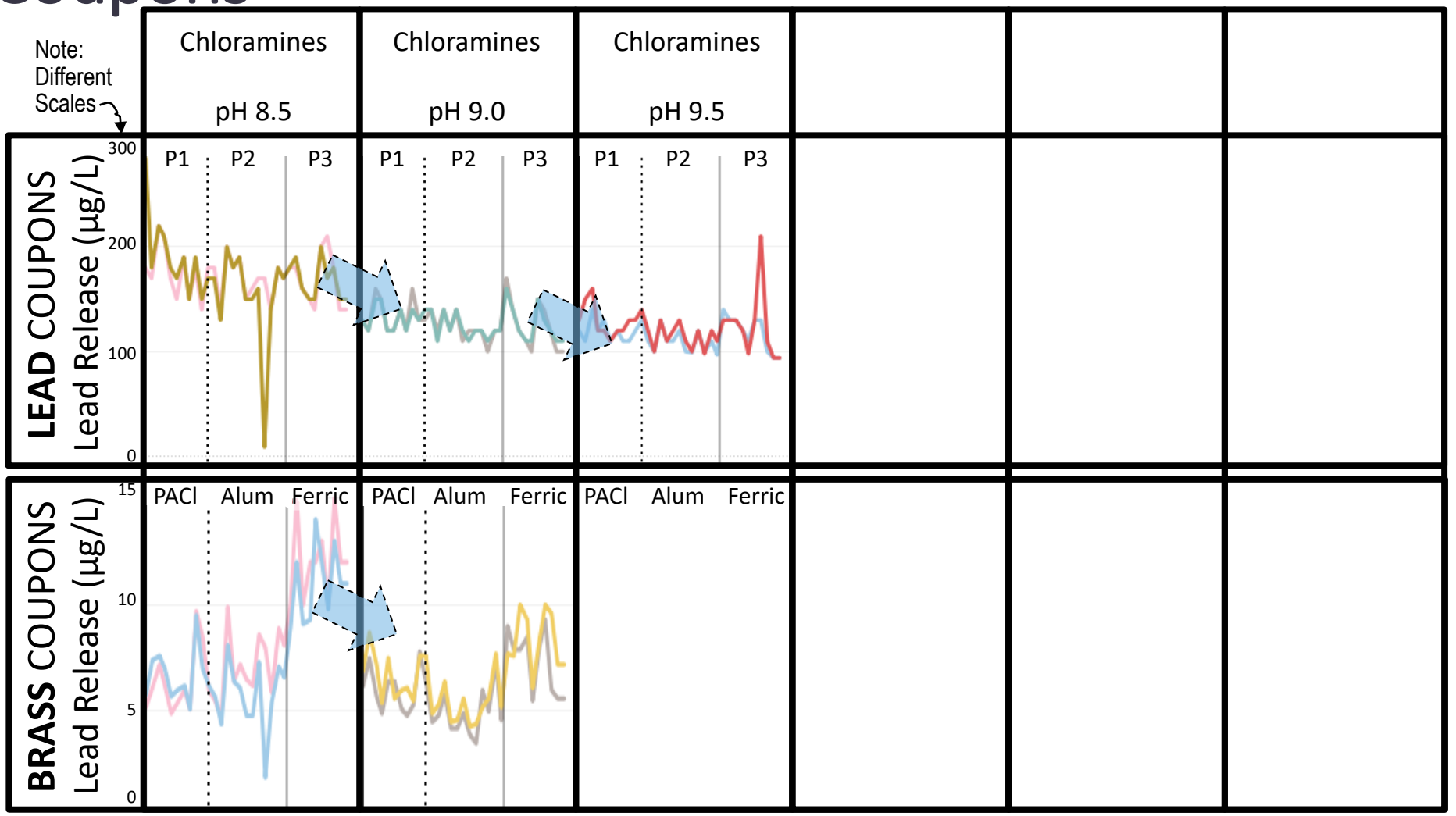
CSMR = Chloride to sulfate mass ratio

Lead and Brass Coupons

Lead and Brass Coupons

ALL CONDITIONS ARE WITH FILTERED WATER

- **As pH ↑, Lead ↓**



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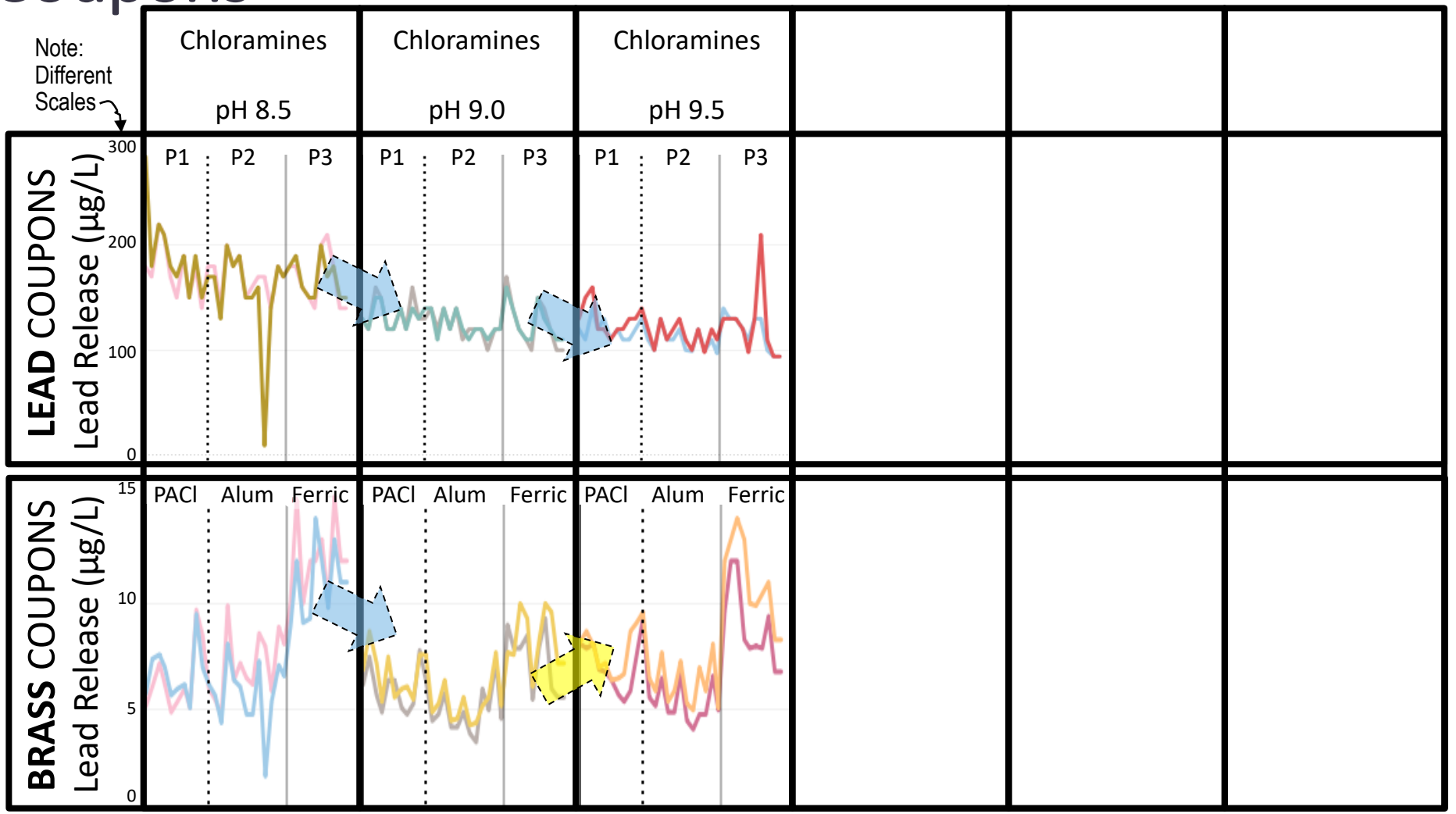
- As pH ↑, Lead ↓
- For Brass, pH 9.5 = ↑Lead & Ferric = ↑Lead
- Minimal CSMR Impact



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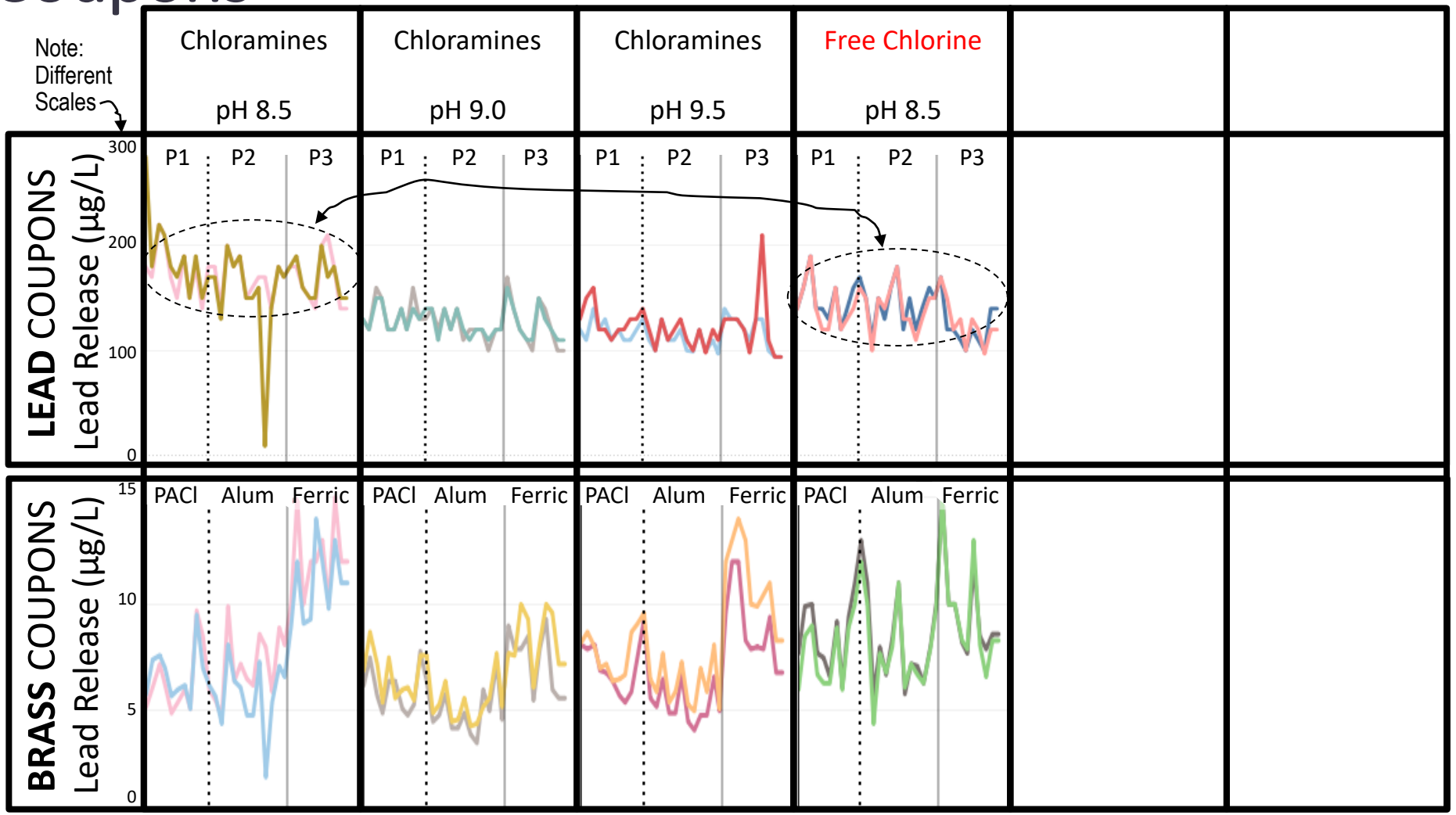
- Minimal Benefit with Free Cl2



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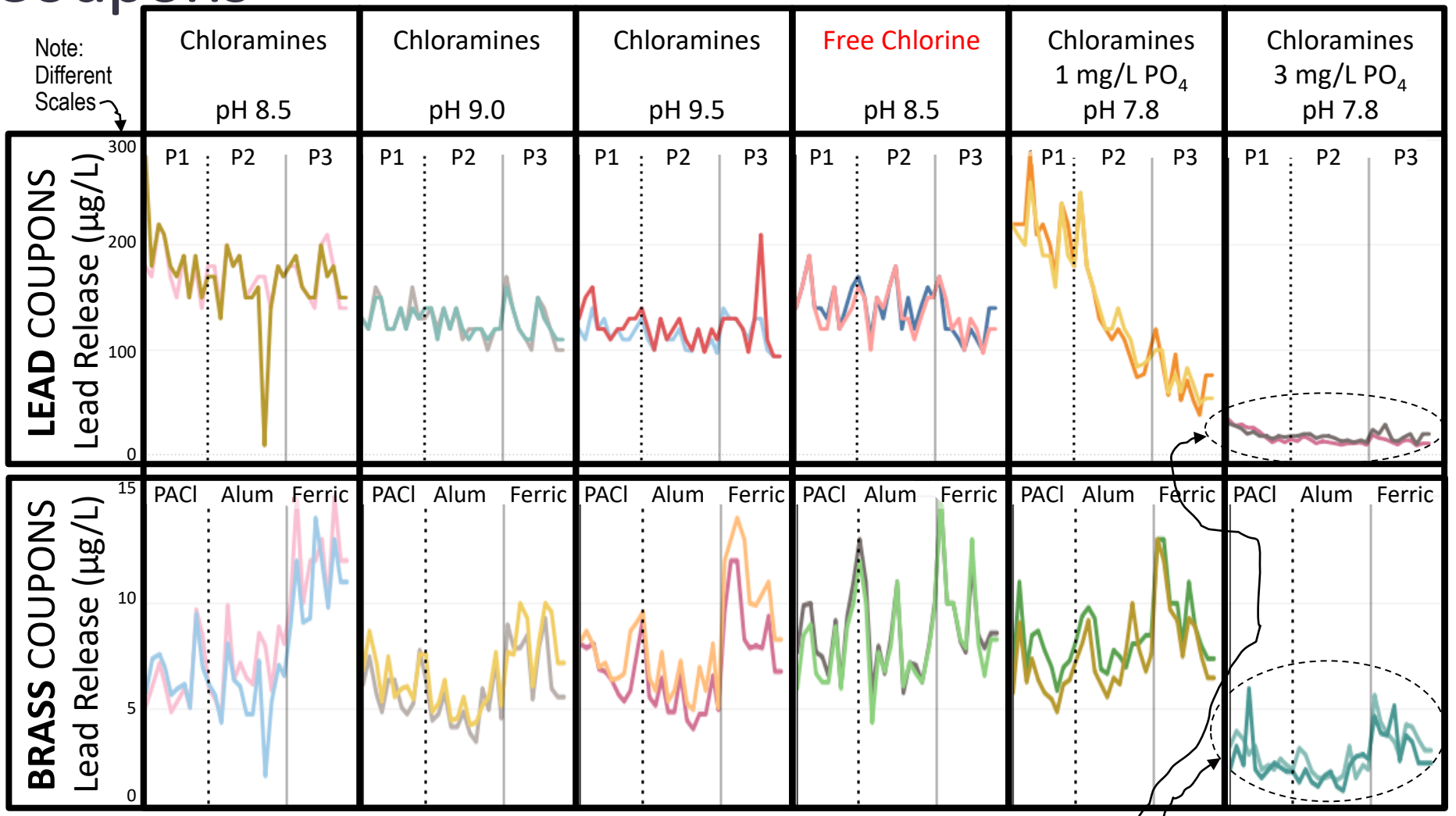
Lead and Brass Coupons

ALL CONDITIONS ARE WITH FILTERED WATER

- As pH ↑, Lead ↓
- For Brass, pH 9.5 = ↑Lead & Ferric = ↑Lead
- Minimal CSMR Impact
- Minimal Benefit Free Cl2
- 3 mg/L PO_4 = Best
- Treatment = ↓ Corrosivity (unfiltered data not shown here)



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Copper + Solder (CLS)

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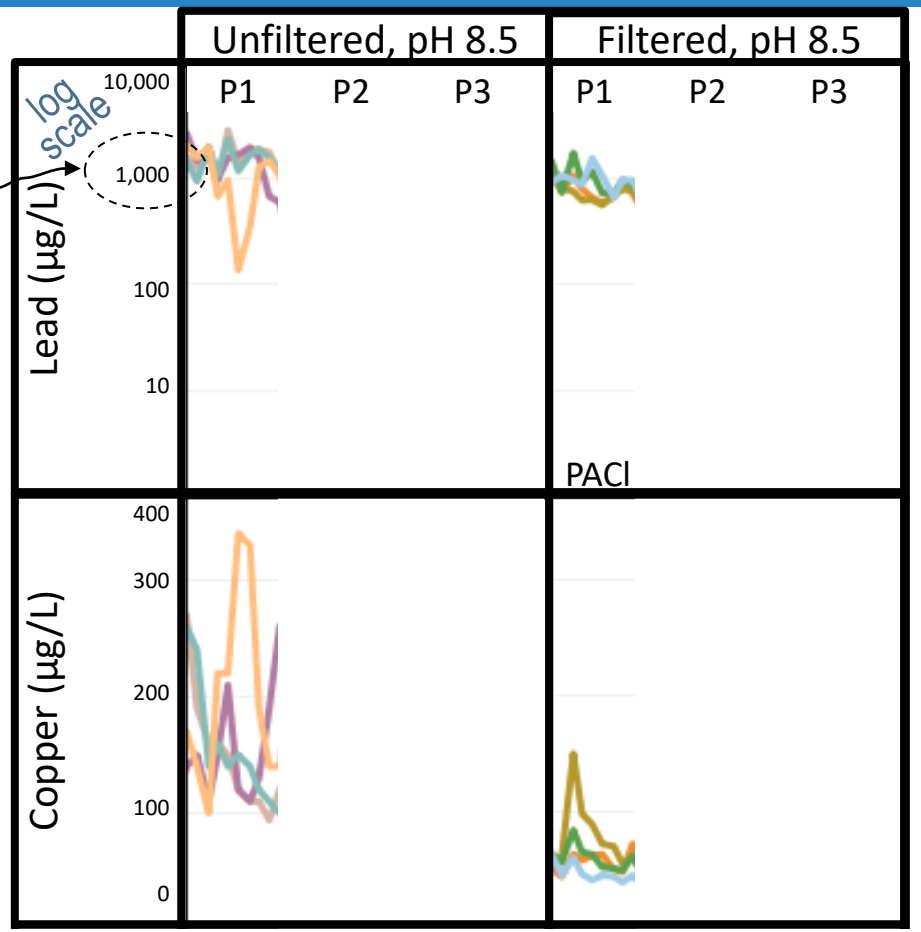
- **CLS = Greatest Lead Release** (compared to lead and brass)
  - Highest w/ PACl



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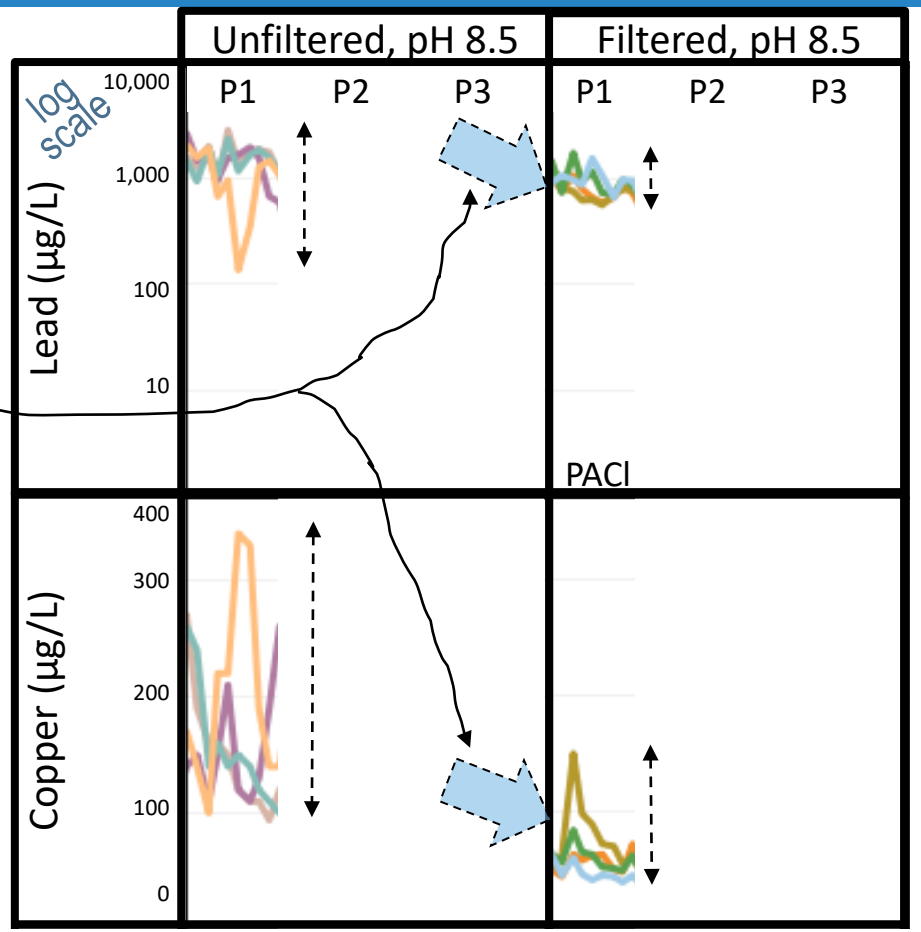

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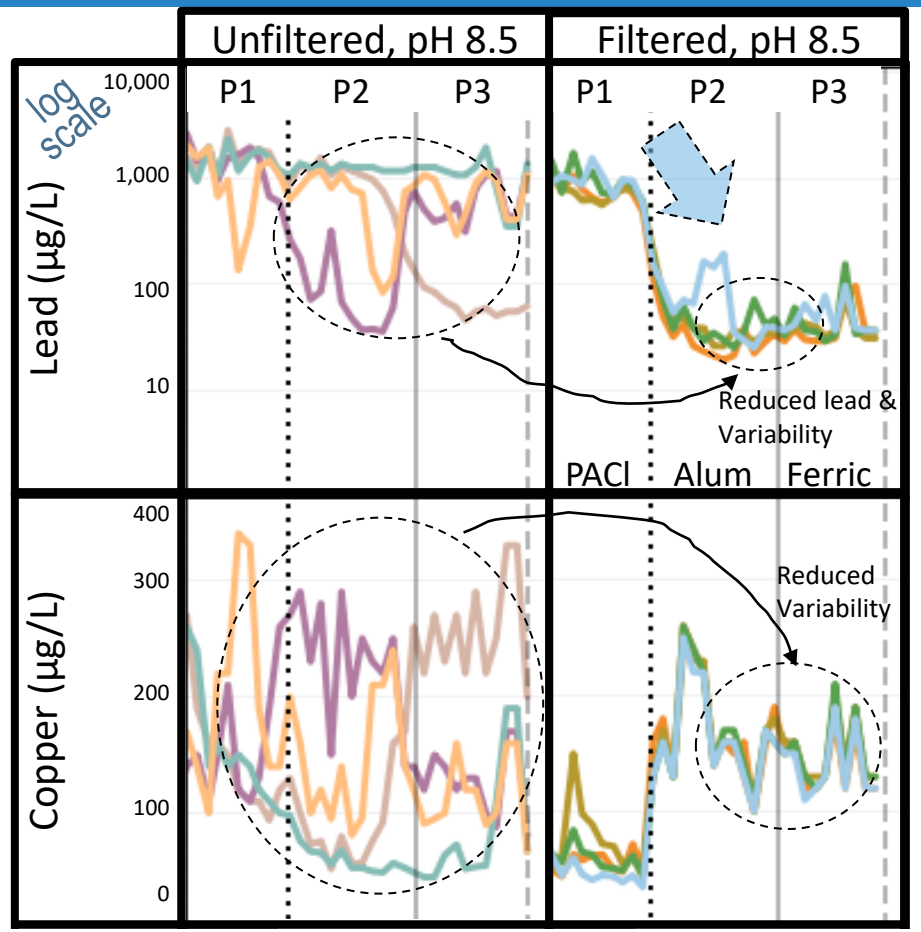
- **Coagulant Impacts:** Lower CSMR ↓lead release



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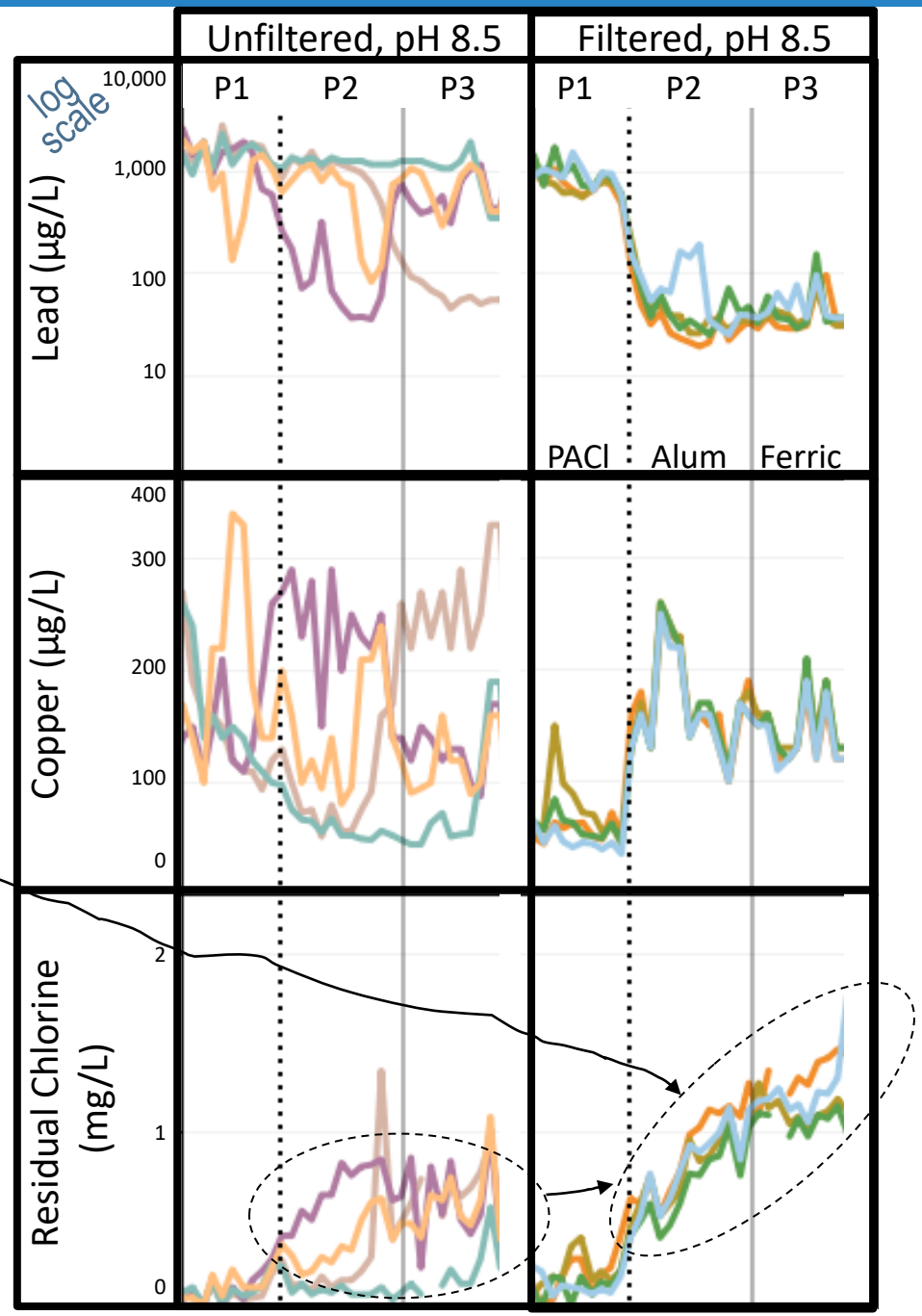

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Copper + Solder (CLS)

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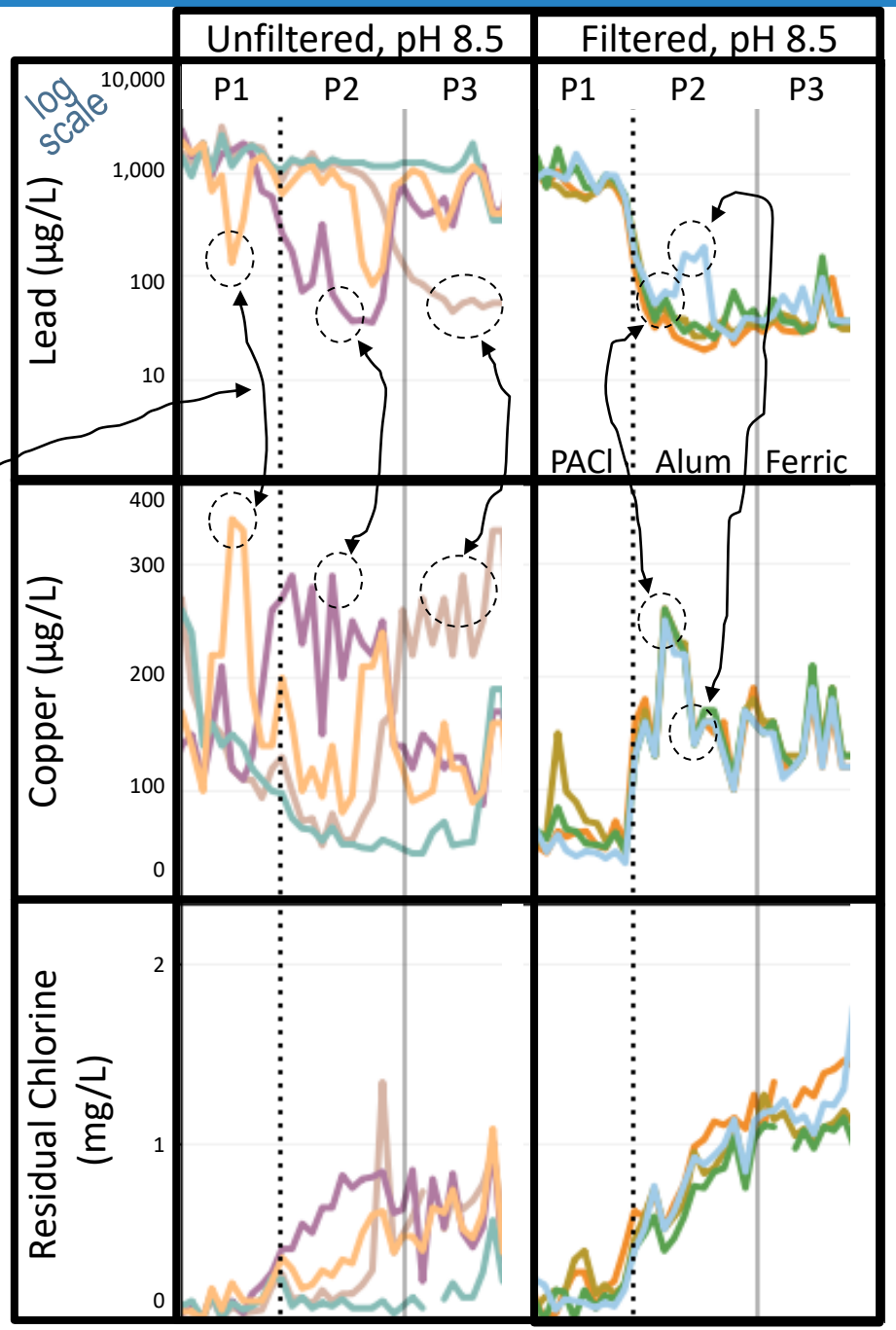
  - Highest w/ PACl
  - Filtration ↓lead/copper & variability
- **Coagulant Impacts:** Lower CSMR ↓lead release, ↑ chloramine stability
- **Switching of anodic corrosion** from lead to copper



CSMR = Chloride to sulfate mass ratio

Copper + Solder (CLS)

- **Continued results……**

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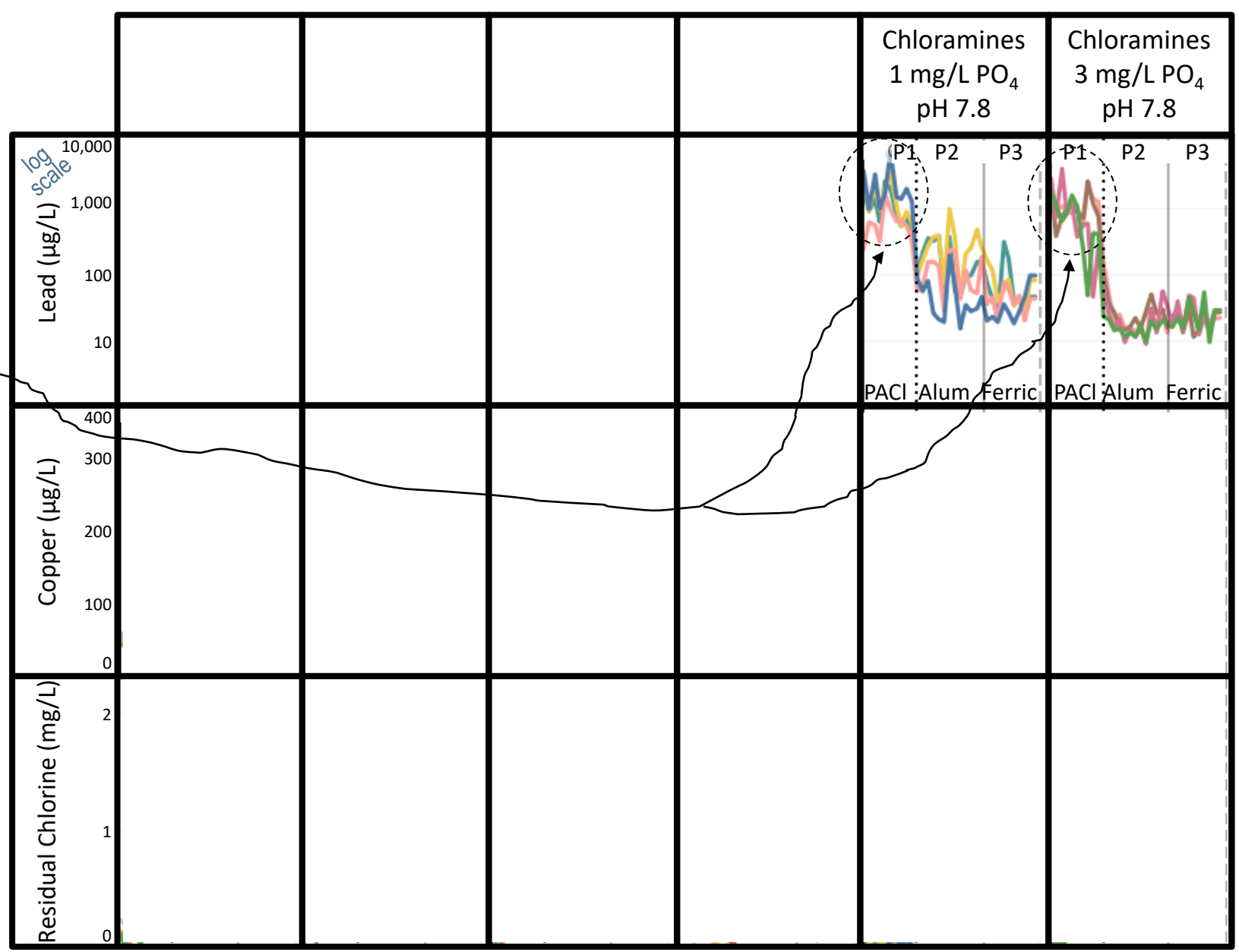
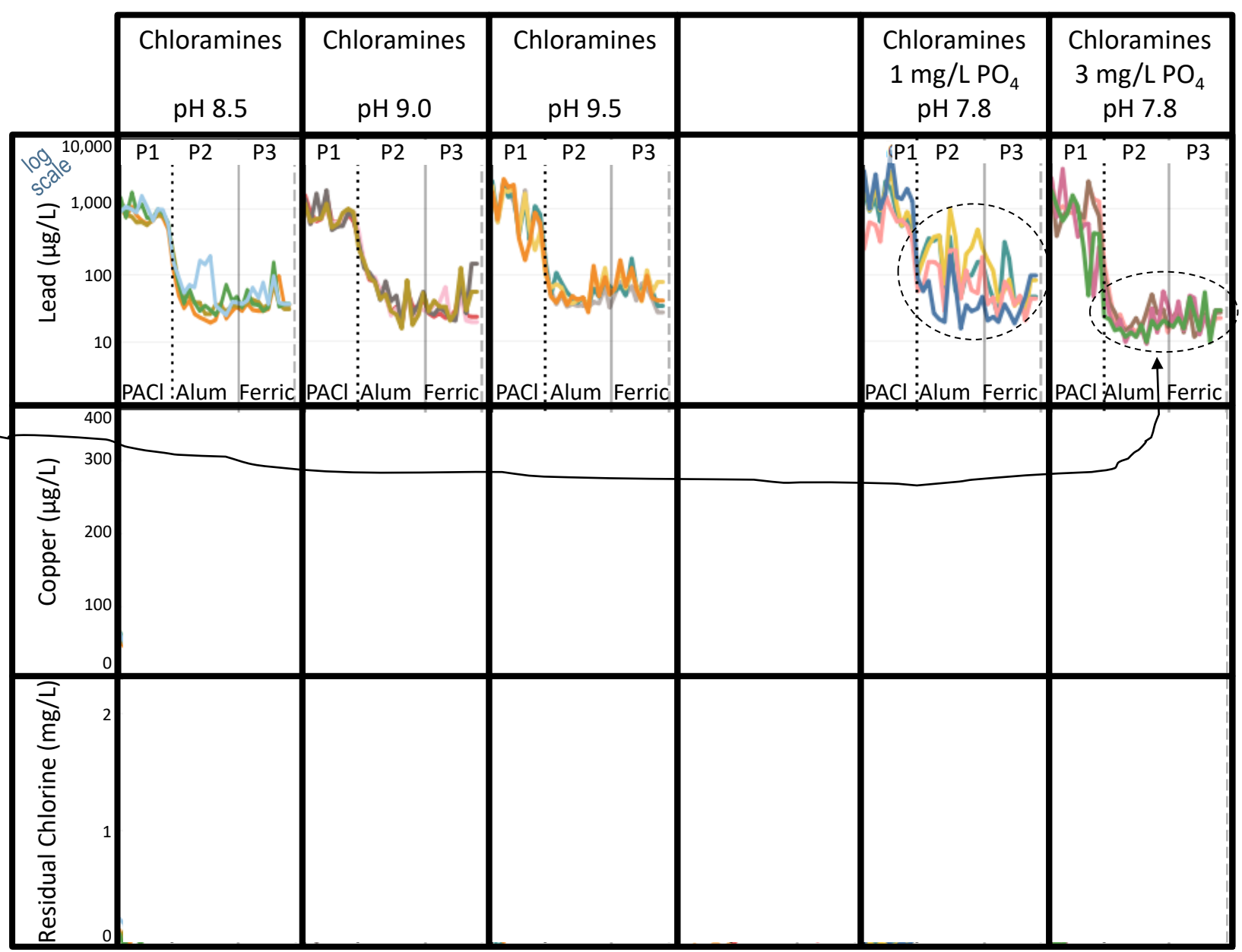
- **PACl + Ortho:** Highest lead (higher than unfiltered)



Copper + Solder (CLS)

- **Continued results……**

- **PACl + Ortho:** Highest lead (higher than unfiltered)
- **3 mg/L PO_4, ↓CSMR:** ↓ lead



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- **Continued results……**

- **PACl + Ortho:** Highest lead (higher than unfiltered)
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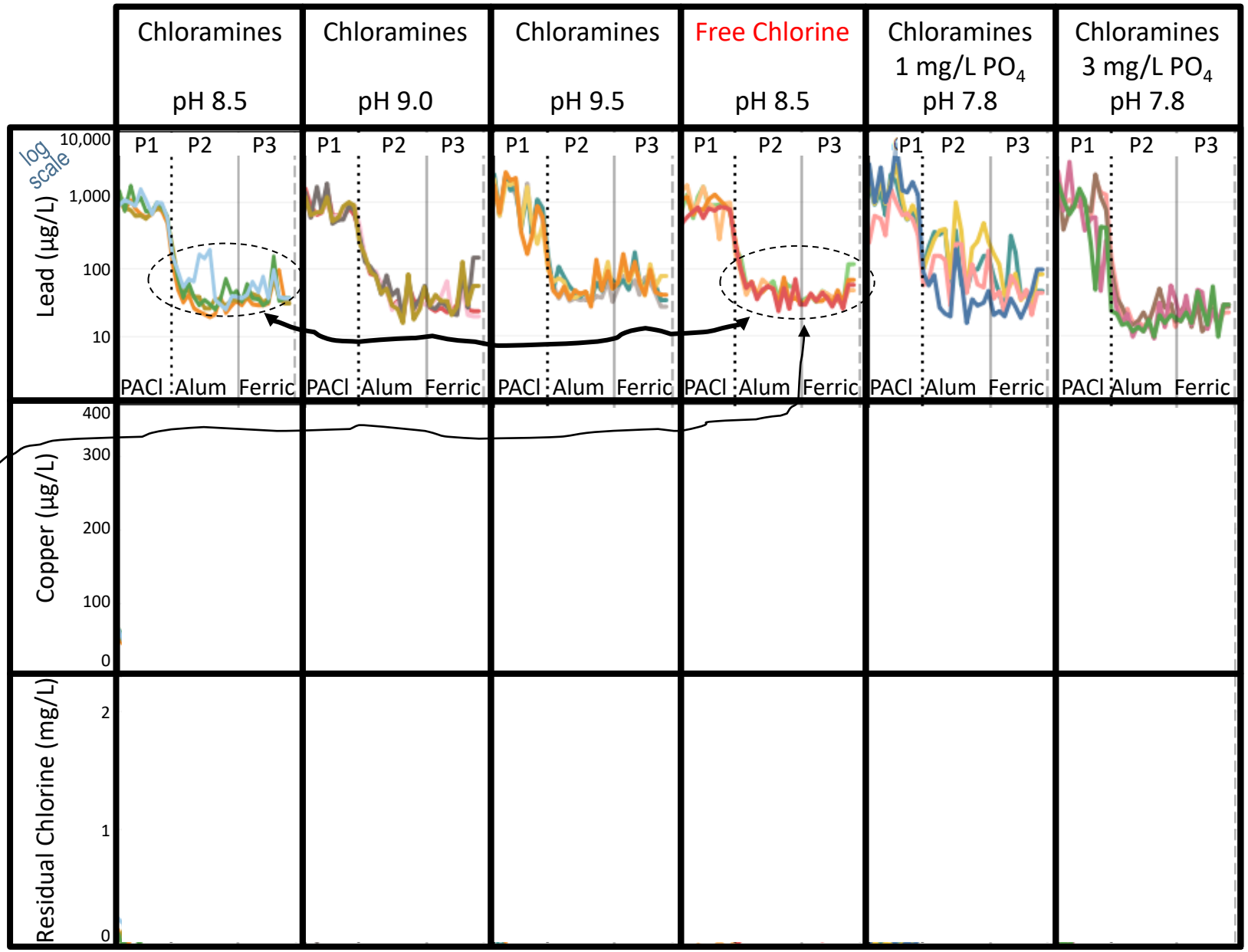
- **Free Cl2:** No benefit

ALL CONDITIONS ARE WITH FILTERED WATER

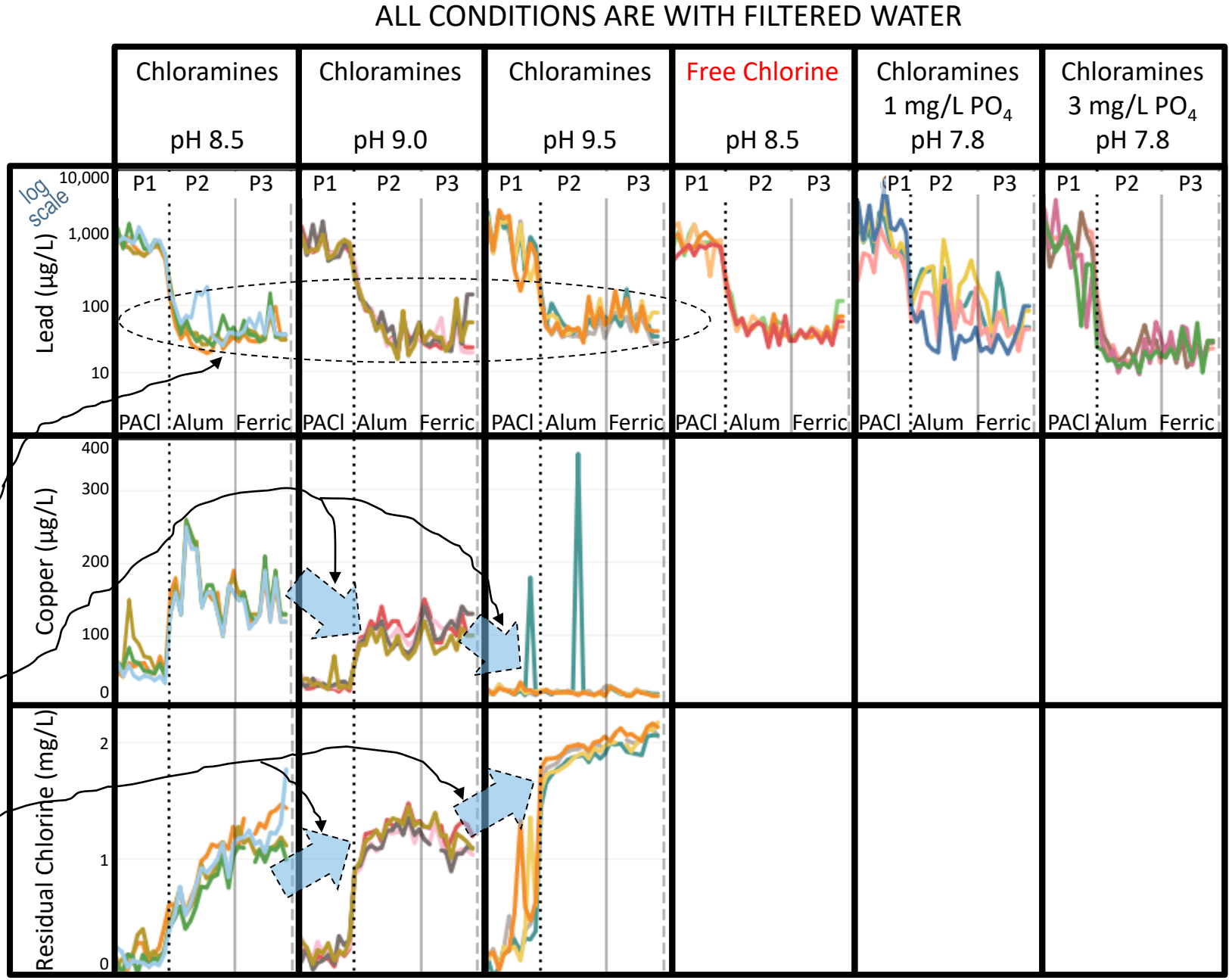


CSMR = Chloride to sulfate mass ratio

Copper + Solder (CLS)

- **Continued results……**

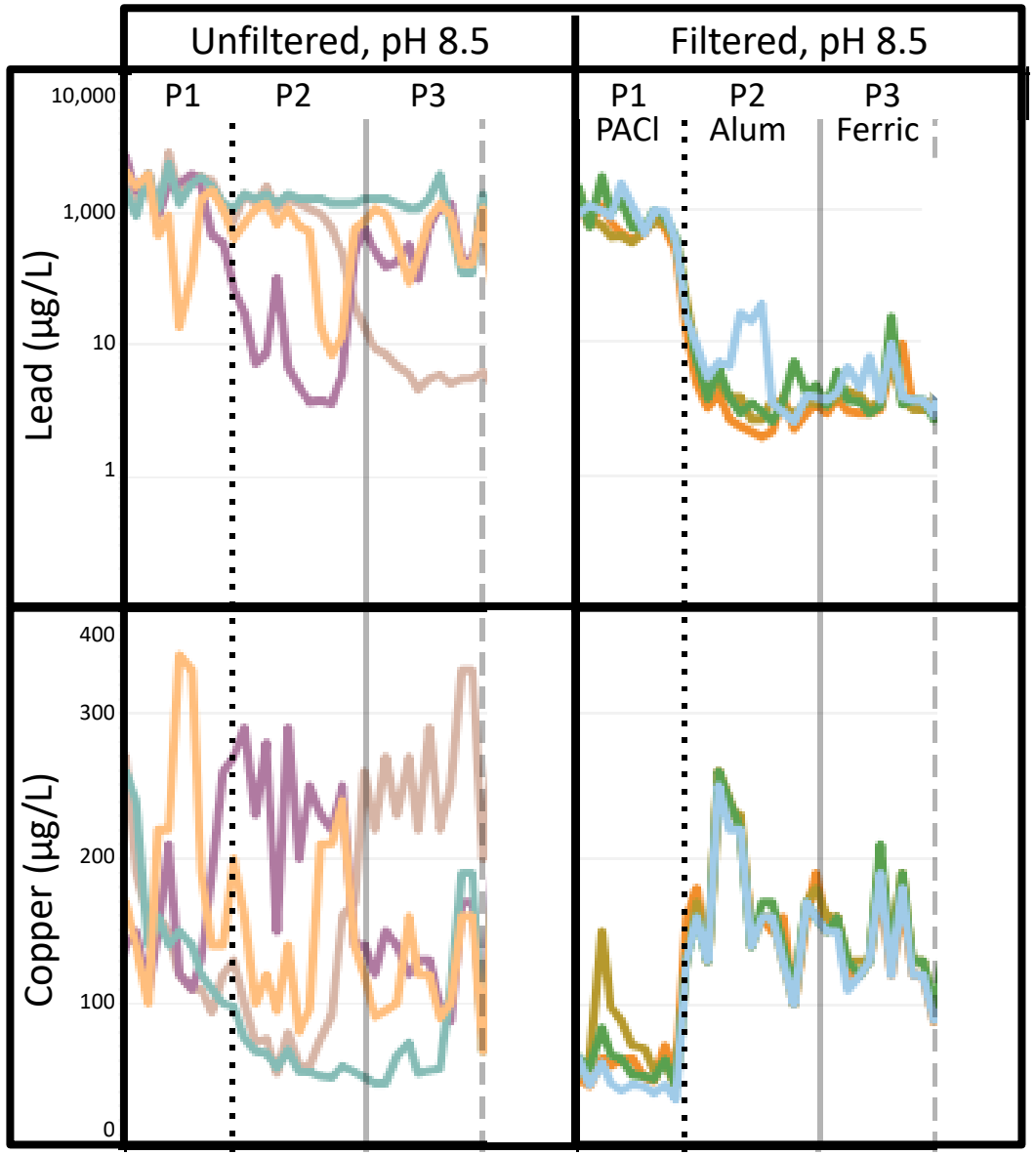
- **PACl + Ortho:** Highest lead (higher than unfiltered)
- **3 mg/L PO_4, ↓CSMR:** ↓ lead
- **Free Cl2:** No benefit
- **↑pH:**
  - Lead is similar
  - ↓copper
  - ↑chloramine stability



CSMR = Chloride to sulfate mass ratio

Copper + Solder: Changing Ammonia for Chloramines

- **Switched back to PACl after Ferric and Evaluated Ammonia Alternatives for Chloramines Formation**
  - First 3 Phases: All used AH



AH = Ammonium Hydroxide **AS** = Ammonium Sulfate

Copper + Solder: Changing Ammonia for Chloramines

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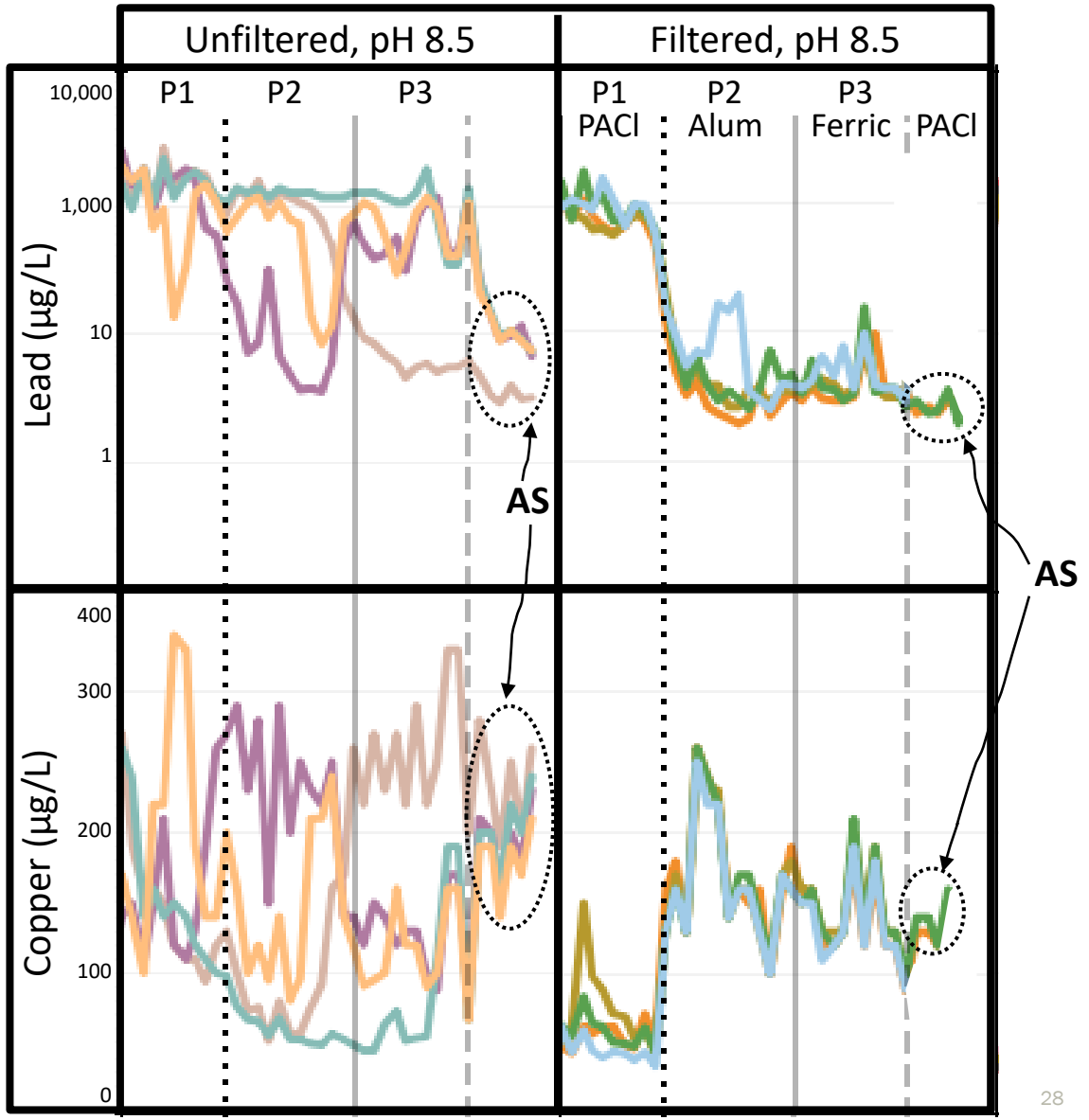
- **AS in Unfiltered & Filtered+PACl:**
  - AS lowered CSMR & kept lead low (i.e., release similar to ferric test phase)



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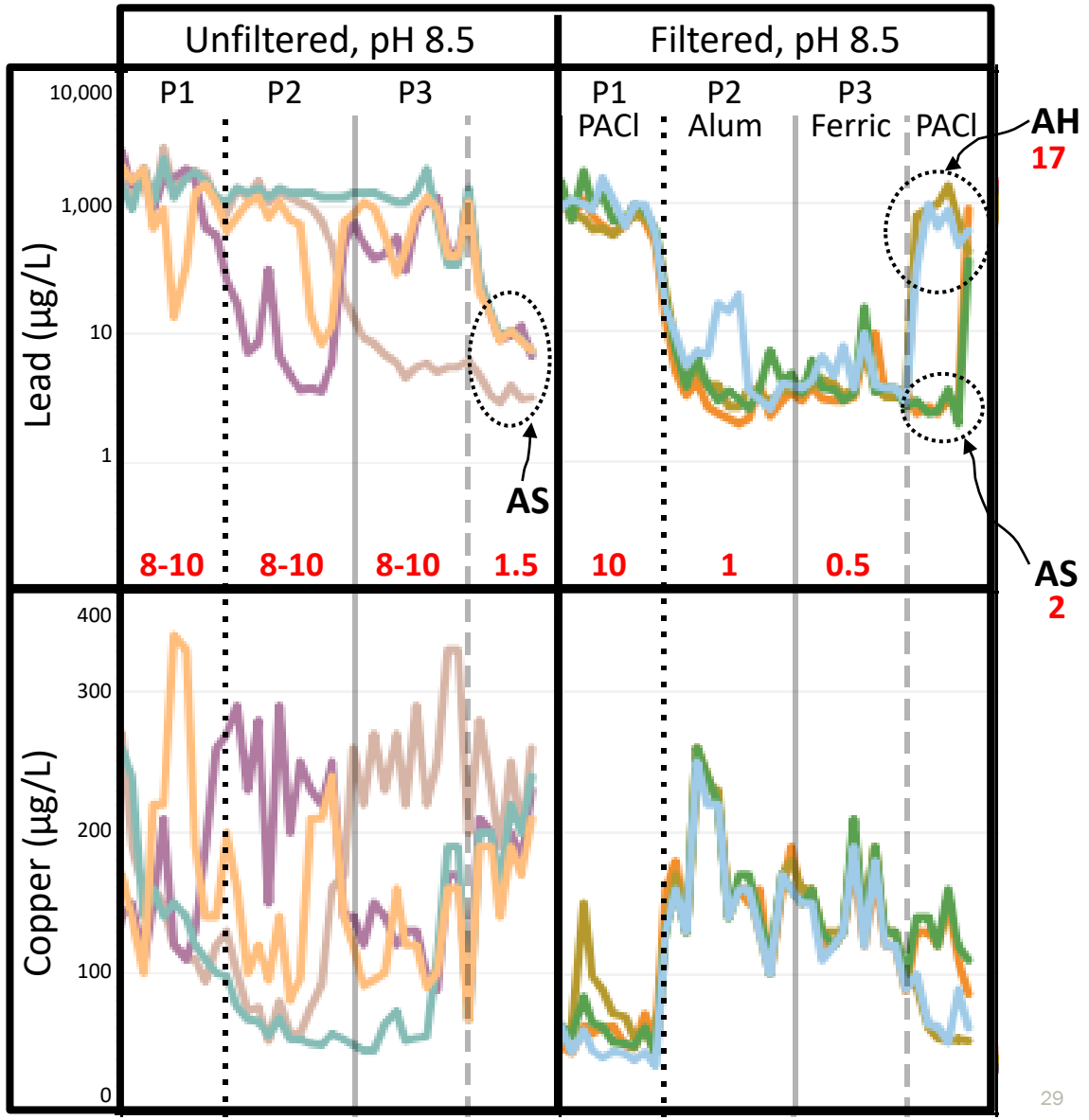
Copper + Solder: Changing Ammonia for Chloramines

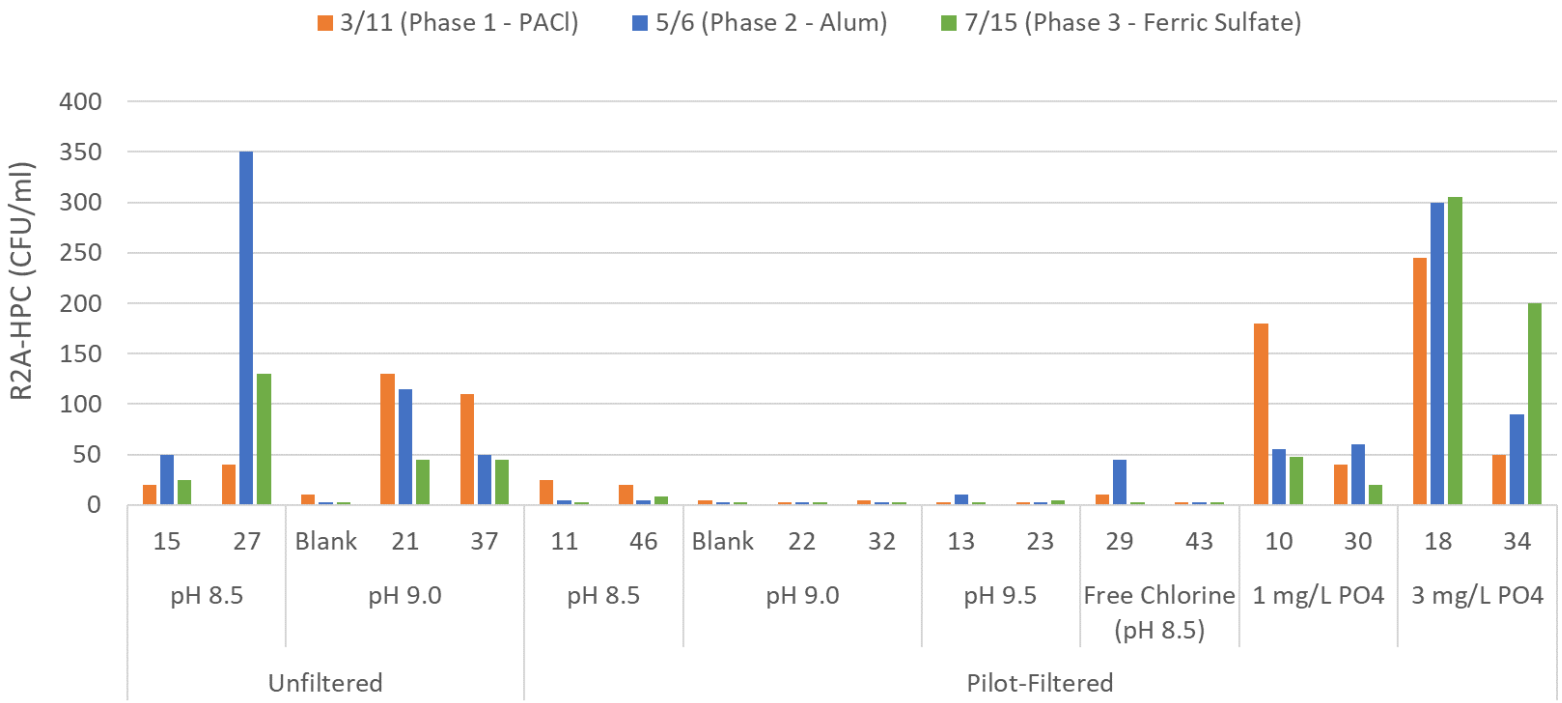
- **Switched back to PACl after Ferric and Evaluated Ammonia Alternatives for Chloramines Formation**
  - First 3 Phases: All used AH
- **AS in Unfiltered & Filtered+PACl:**
  - AS lowered CSMR & kept lead low (i.e., release similar to ferric test phase)
  - Keeping AH repeated high lead release (i.e., similar to first PACl test phase)
  - NOTE: Last green/orange data (high lead): Switched back to AH; lead increased again



AH = Ammonium Hydroxide **AS** = Ammonium Sulfate
CSMR values shown in **RED**

Study Results – Microbial Activity in CLS Coupon Jars

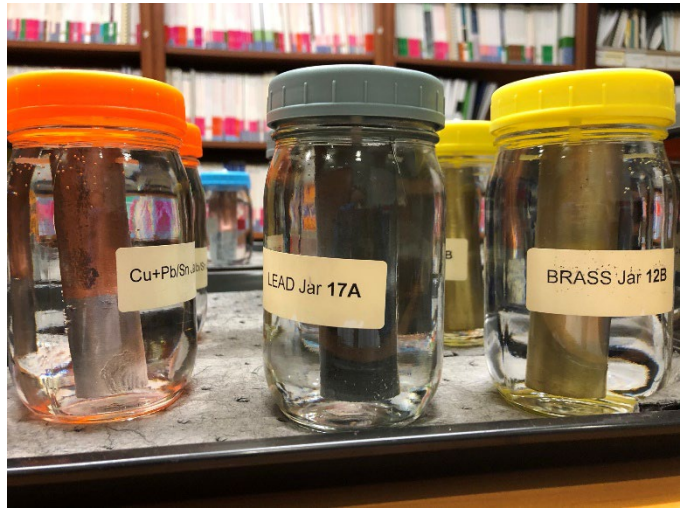
- Samples were collected from CLS jars during each project phase and analyzed for indicators of nitrification (nitrogen species) and R2A-HPC
- No evidence of nitrification observed in any of the sampled jars
- R2A-HPC at or below detection in filtered water treated using pH corrosion control
- R2A-HPC elevated in unfiltered samples and in filtered samples that contained orthophosphate



Summary

- For all materials tested, filtered water treated to the same pH targets as unfiltered water was less corrosive to lead
- Lead release in jars containing copper w/lead solder coupons was substantially higher when the water had a high CSMR (i.e., when unfiltered water or filtered water using PACl was used)
  - PACl + ammonium sulfate provided similar lead control as water coagulated with alum or ferric sulfate
  - Lengthy stagnation periods may have exacerbated conditions for galvanic corrosion
- Orthophosphate provided good lead control across all materials, but had several water quality trade-offs compared with pH control.

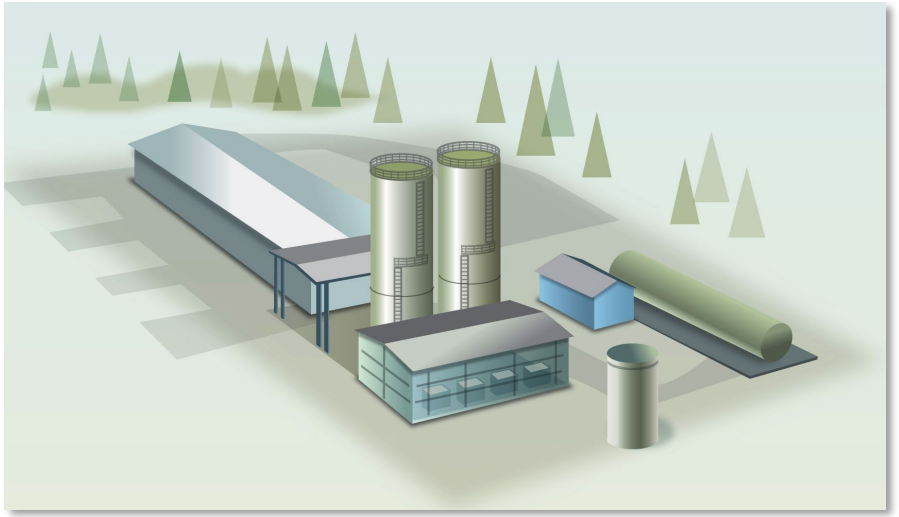
Tom Krause carefully moving copper coupon to freshly prepared water



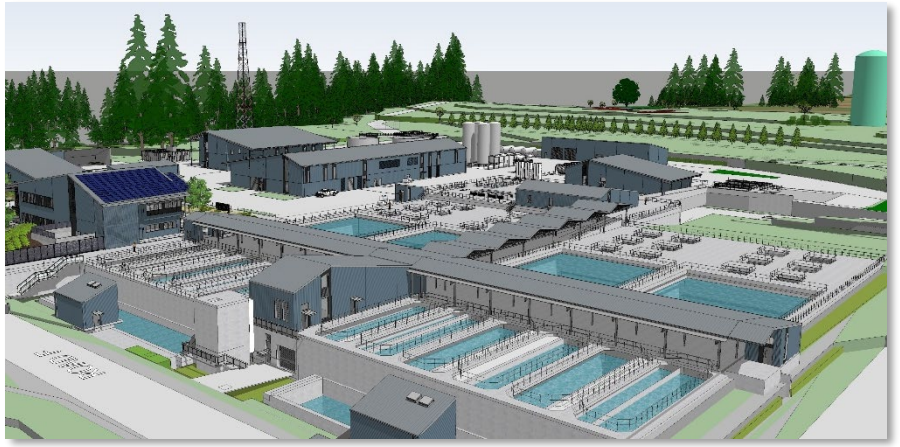
Copper, lead, and brass coupon jars about 6 weeks into acclimation in pH 8.5 test water.

Next Steps

- Confluence and PWB are finalizing study report
- BRFF 90% design submittal due in August
  - Chemical systems will include soda ash/CO_2 for pH control and liquid ammonium sulfate
- ICCT start-up and monitoring:
  - Increase pH (>8.5) and alkalinity (>25 mg/L as $CaCO_3$)
  - Expanded monitoring, including monthly customer sampling and PRS station sampling
  - Transition to LCRR
- Continuation of pilot studies and coagulant/pre-treatment comparisons
- Optimize corrosion control before and after filtration – goal is to reduce 90th percentile in system to <5 ppb



Rendering of ICCT improvements at Lusted Hill Treatment Facility



Rendering of Bull Run Filtration Facility

Filtration Corrosion Control Treatment Study Project Team

PWB

- **Yone Akagi** – Water Quality Group Manager
- **Kimberly Gupta** – Bull Run Supply & Treatment Manager
- **Anna Vosa** – FCCCS Lead
- **Mac Gifford** – Pilot Operations Lead
- **Tom Krause** – Pilot & FCCCS Testing
- **Scott Bradway** – LHRP Manager
- **Contributing Team Members: Lucas Allen, Brooke Stebbins, Lillian Gehres, Allie Molen**, Melanie Roy, Mojtaba Azadi Aghdam, Humberto Piedra-Ruiz, PWB Lab

Confluence

- **Melinda Friedman**, President and Project Advisor
- **Alex Mofidi**, Project Manager
- **Contributing Team Members**: Danbi Won, Al Vetrovs, Michael Hallett, Virpi Salo-Zieman

Brown and Caldwell

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

Bull Run Treatment Projects will help keep our water **safe and abundant** for the next century and beyond

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