Phosphorus in the Circle of Life - A Holistic Approach to Corrosion Control and Water Quality

November 2022 – Atlantic City, NJ

OUR MISSION

Everyone deserves clean water.


Ancient Rome invented plumbing
and had the same problems.
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The UK can provide a glimpse into our future problems.

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Cause & Effect

https://www.nbcnews.com/think/opinion/rampage-suggests-humans-who-mess-nature-are-real-monsters-too-ncna865226

Revised US Lead & Copper Rule…

“The water system must evaluate the effect of the chemicals used for corrosion control treatment on other drinking water quality treatment processes.”

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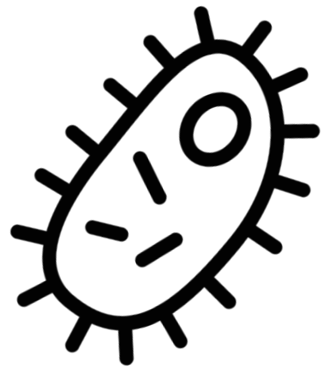
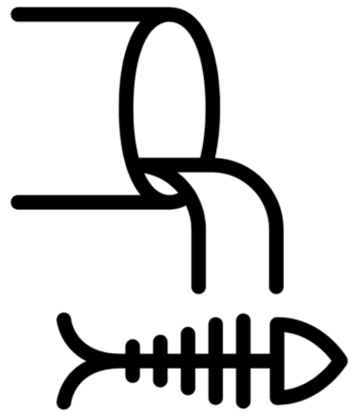
https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-141/subpart-I/section-141.82#p-141.82(c)(2)(v)

Corrosion of infrastructure leads to iron in the water, which reacts with chlorine resulting in lower residuals



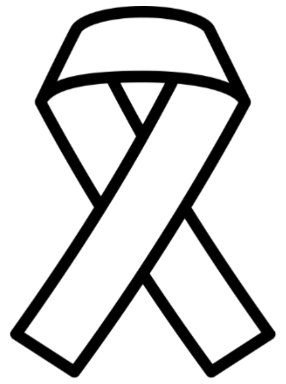
Low Chlorine Residuals



Phosphorus Discharge

A study cited by EPA concluded as much as 35% of the phosphorus load on wastewater plants comes from corrosion control products for drinking water

When low residuals are encountered, more chlorine is added which leads to oxidizing more organics, which leads to excess disinfection byproducts

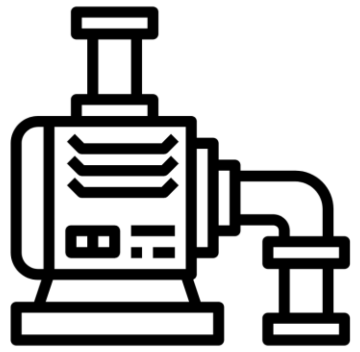


Disinfection Byproducts

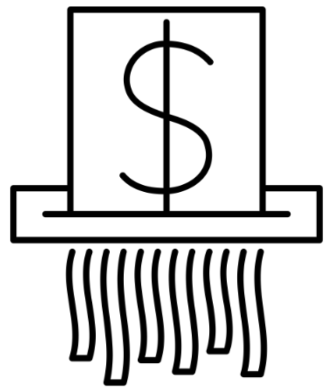
Dangerous Chemicals

Utilities should minimize use and potential exposure to dangerous chemicals, such as phosphoric acid, sodium hydroxide & calcium hydroxide

When pipe wall aren't clean, it takes more energy to pump the same amount of water, leading to excess cost and premature equipment failure



Extra Pumping & Electrical Cost



Expensive Chemicals

"In cases where more than one treatment option can meet OCCT, systems may want to consider cost factors."
-EPA, 2018

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Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems (epa.gov)

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Drinking Water Treatment

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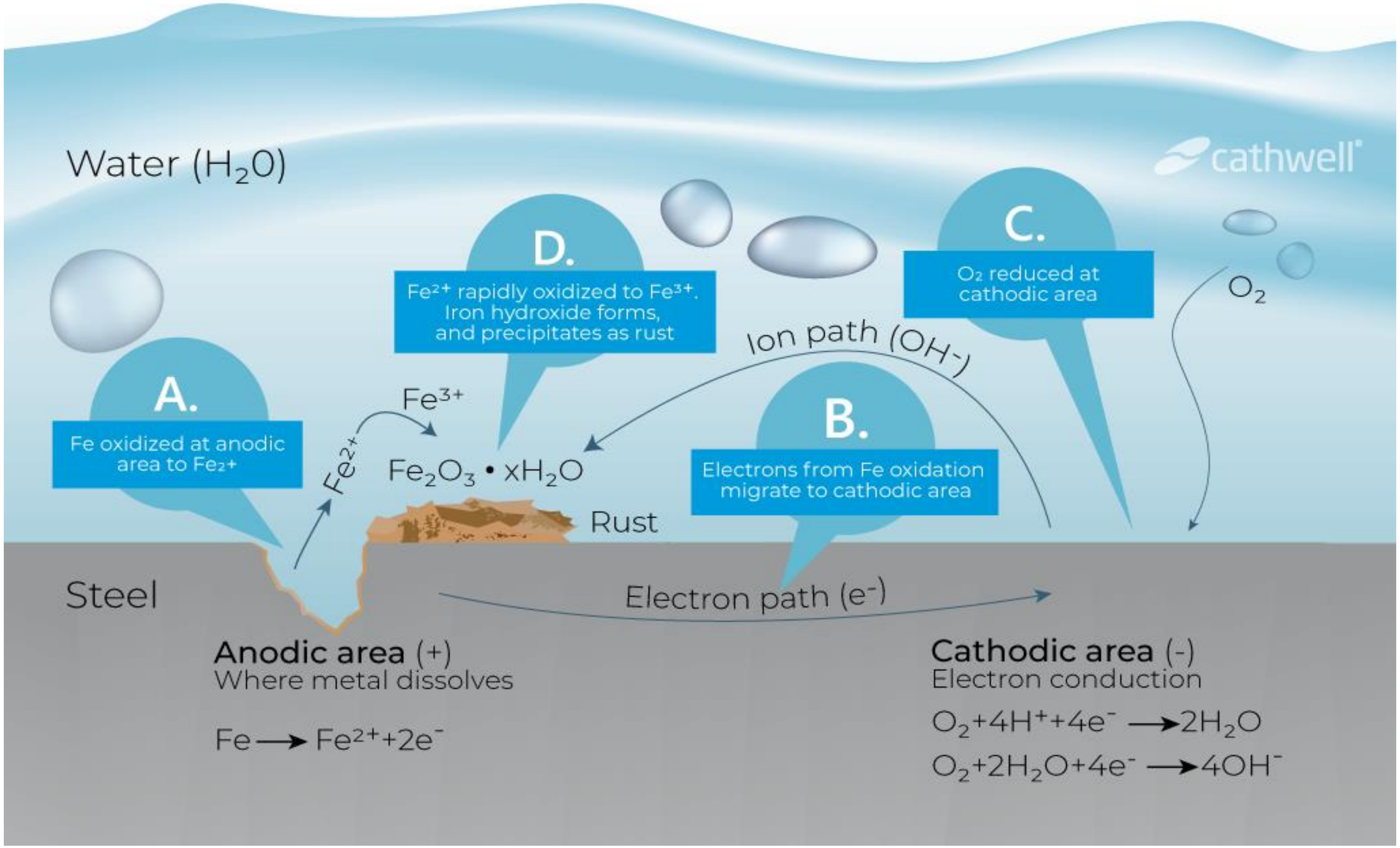
Why is there Corrosion?



https://en.wikipedia.org/wiki/Cathodic_protection

Cathodic Protection?

Anodic Protection?

Oxygen Barriers?

Coatings?

Sac. Anodes?

Charge?

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Building Mineral Scale is the Answer! ….

Pictured from left to right are a lead pipe, a corroded steel pipe, and a lead pipe treated with protective orthophosphate. Orthophospate creates a film coating inside of lead pipes that can act as a barrier, reducing at least somewhat the amount of lead that gets into tap water.

pH Control = Carbonate Scale

Ortho/Zinc Phosphate = Phosphate Scale

Blended Phosphate = Phosphate Scale

Silica = Silica Scale

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Building mineral scale
is complicated
Effect of pH on HOCl and OCl
Total
Matrix mineralogy
Changes due to remineralization
Potentially Leachable
Cl-complexation
DOC complexation
Actual leaching
Sorption
Reducing
Solution chemistry
pH
Eh (volts)
Buffer Intensity (mmol/pH)
25°C
Pyrolusite
Bixbyite
Hausmannite
Platinerite
Cerussite
Hydrocerussite
Galena
Fe(OH)3
Fe 3+
Fe 2+
Fe
Total Alkalinity
OCCT Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems
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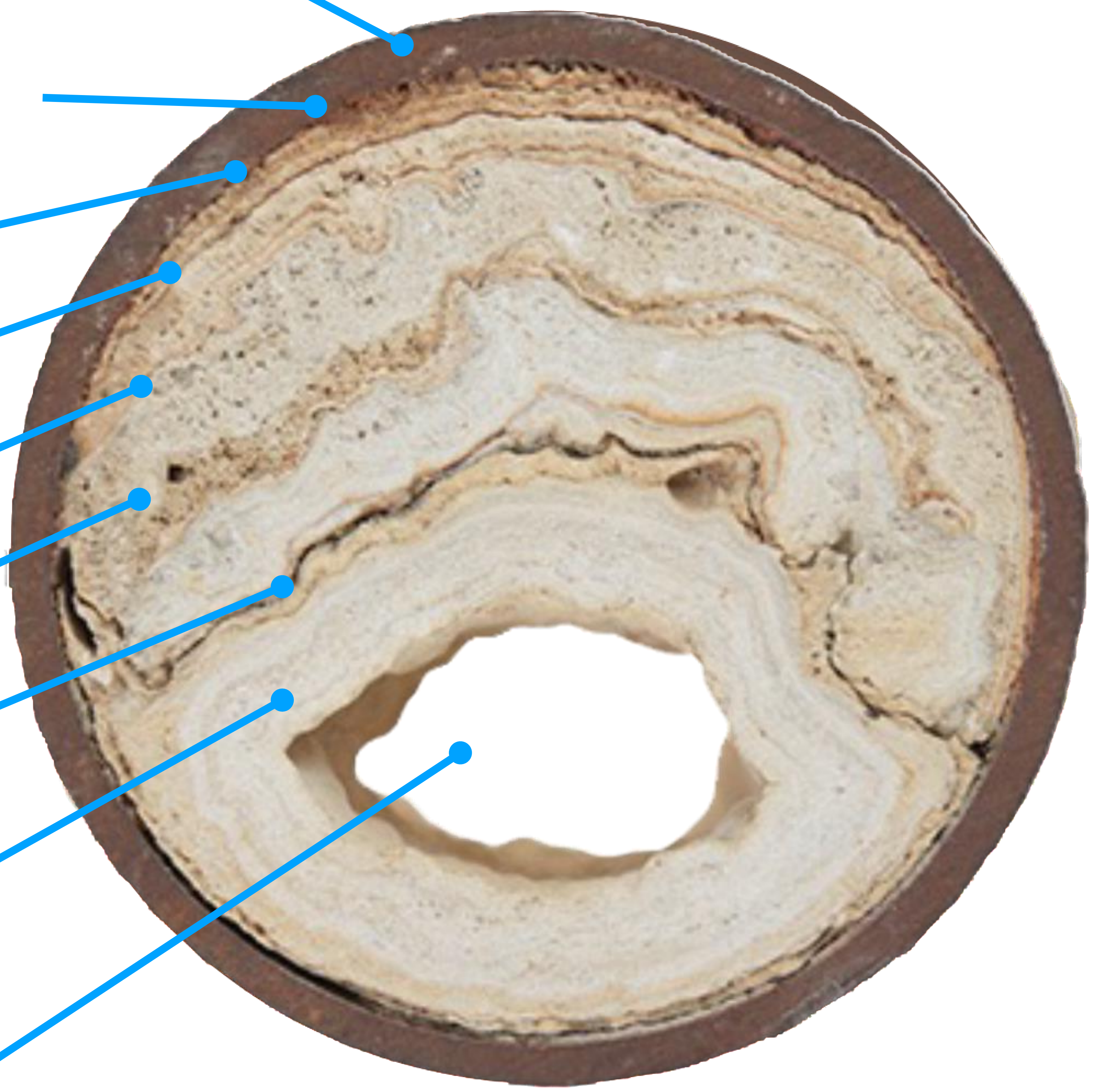
✖ Conditions continuously change



Scale must *continuously* change to keep up with environmental factors

(such as flow, temperature, pH, chlorine, minerals, electrochemical potential...)

Hint: all of this was invented for industrial water treatment where conditions can be controlled

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✖ Corrosion happens underneath

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You can’t stop cavities
by adding more plaque.

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Wastewater Treatment

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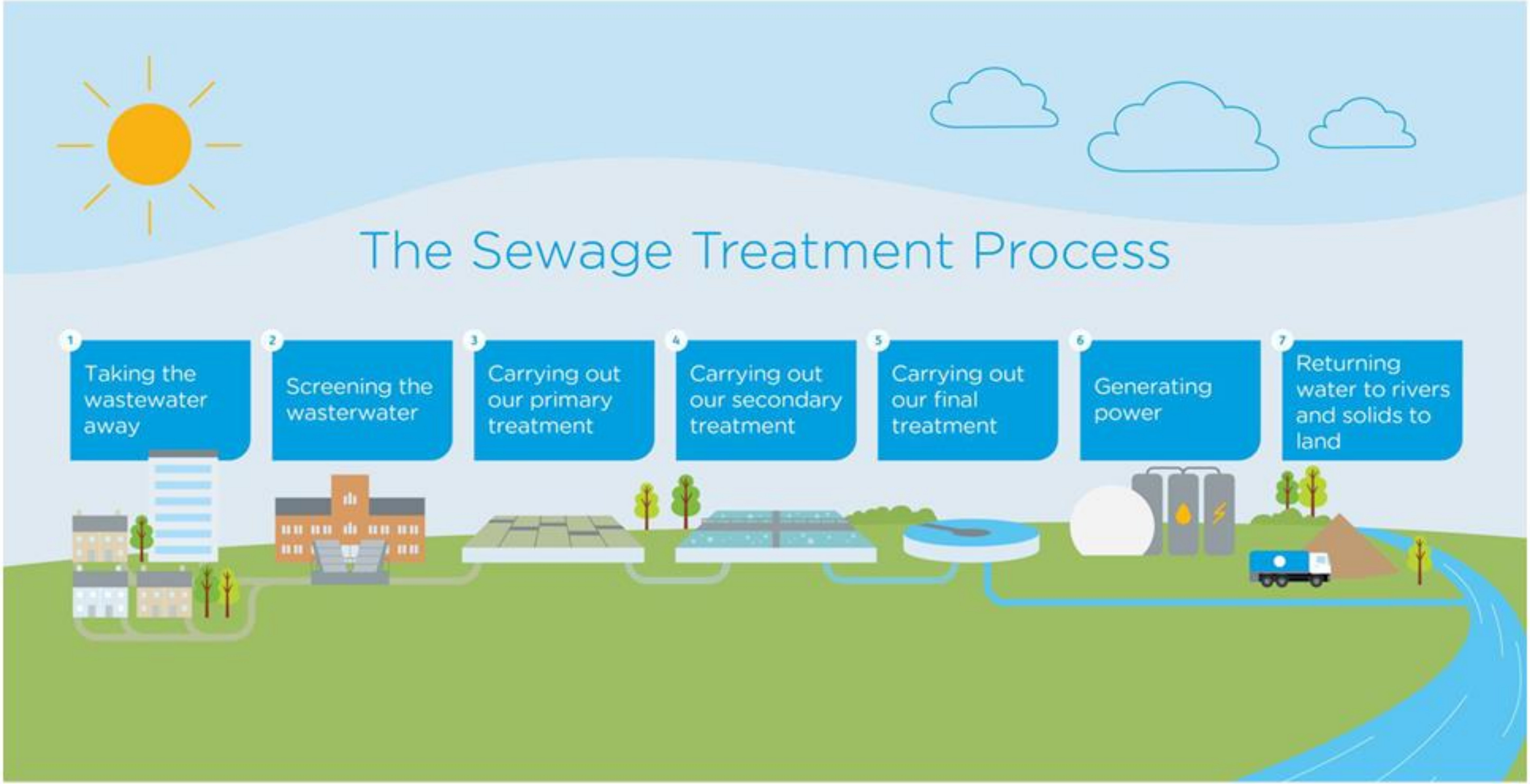

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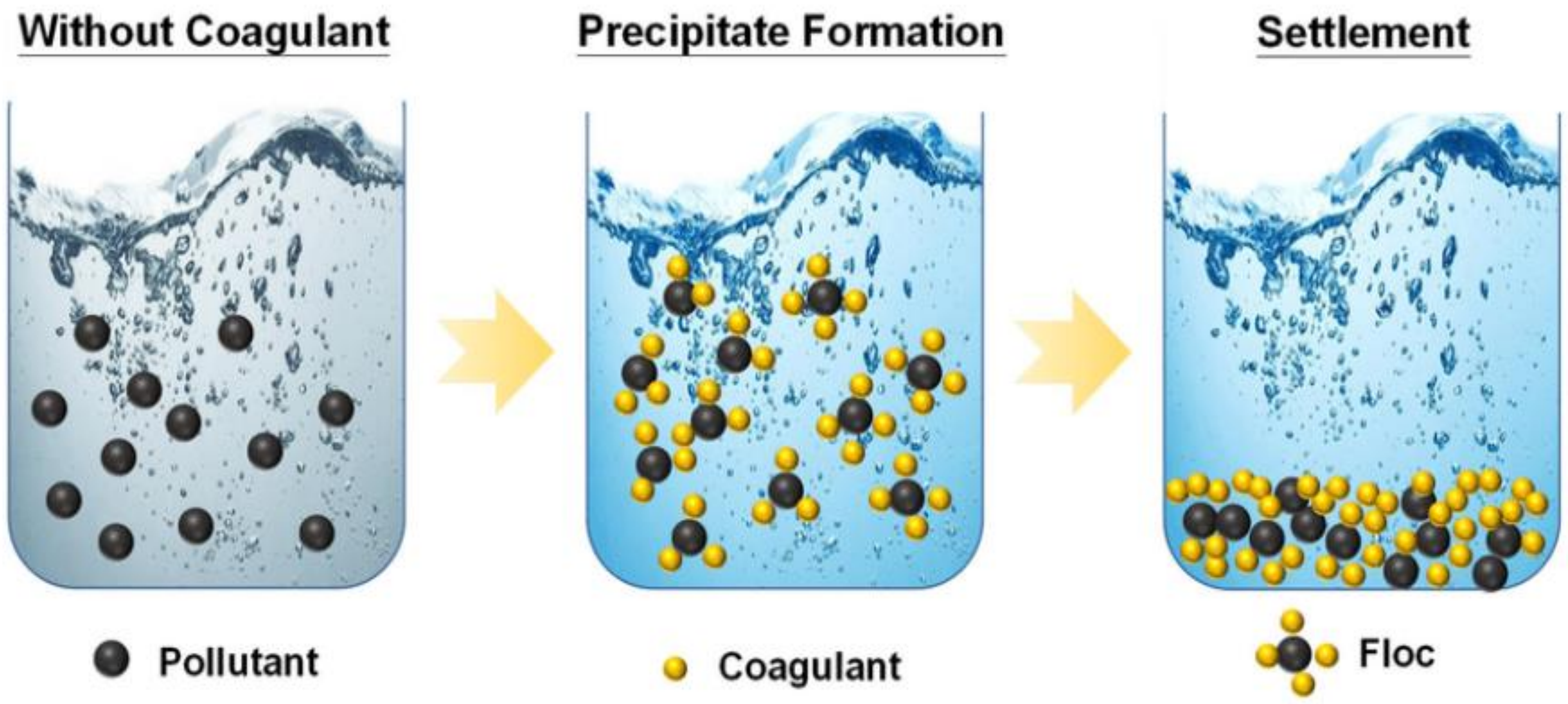
https://www.thameswater.co.uk/media-library/home/about-us/responsibility/education/the-sewage-treatment-process/the-sewage-treatment-process.pdf

How does Coagulation Work?



Primary coagulants neutralize the charge of pollutants so they can bind together easier

Coagulation aides (flocculants) add density (particle agglomeration) so the sludge survives downstream and settles more rapidly

About Coagulants…

Charge:

Different types of pollutants carry many different attributes, which govern the selection and use of treatment process and additives. Coagulants are available with the following charges so the appropriate match to corresponding pollutant charge can be made:

- Cationic (positive)
- Anionic (negative)
- Nonionic (neutral)

Type:

Coagulants are either metallic salts or polymers. In some cases (typically industrial use) blends are utilized. The most common coagulants used in municipal wastewater treatment are:

- $Al_2(SO_4)_3$ – aluminum sulfate (alum)
- $FeSO_4$ – ferrous sulfate
- $Fe_2(SO_4)_3$ – ferric sulfate
- $FeCl_3$ – ferric chloride
- $Al_n(OH)_mCl(3_{n-m})_x$ – polyaluminum chloride (PAC, PACl, ACH, PACH)

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Alum

- Alum was one of the earliest coagulants developed, and is typically produced as a 8.3% active liquid or 17% active solid
- Alum readily dissolves with water and does not produce staining in chemical feed equipment
- Alum is typically effective only at specific pH range 5.8-6.5
- In some waters it can be difficult to achieve proper flocculation, often leading to a significant over-use of alum
- As an inorganic coagulant with zero basicity, use will decrease alkalinity of the water (pH will decrease)

$$\underbrace{Al_2(SO_4)_3}_{\text{Alum}} + \underbrace{3Ca(OH)_2}_{\text{Lime}} \rightarrow \underbrace{2Al(OH)_3}_{\text{Floc}} + 3CaSO_4$$

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Ferric

- Because ferric hydroxide is formed at low pH values, it is possible to use as low as pH 4.0
- Ferric floc is typically heaver and settles faster than alum floc
- Because ferric hydroxide floc does not redissolve at higher pH values, ferric is often used for color removal when oxidizers are used (such as potassium permanganate typically associated with iron and manganese)
- As an inorganic coagulant with zero basicity, use will decrease alkalinity of the water (pH will decrease)

$$\underset{\text{Ferric sulfate}}{Fe_2(SO_4)_3} + 3Ca(OH)_2 \rightarrow \underset{\text{Floc}}{2Fe(OH)_3} + 3CaSO_4$$

PAC and Engineered Coagulants

- The length of the polymerized chain, type (PACl, ACH, PACH), molecular weight and basicity is determined by the manufacturing process and degree of polymerization
- In many cases the lower basicity products (25-45%) are used for phosphorus removal
- In most cases the use of PACs consume less alkalinity than inorganic coagulants such as ferric and alum, which creates a broader pH working range and less reduction of finished water pH
- Less sludge is typically created using PACs since effective dosages are typically lower

$$Al_2(OH)_5Cl \rightarrow Al_2(OH)_5^{+} + Cl^{-} + H_2O \rightarrow 2Al(OH)_3 + H^{+} + Cl^{-}$$

$$Al_2(OH)_3Cl_3 \rightarrow Al_2(OH)_3^{3+} + 3Cl^{-} + 3H_2O \rightarrow 2Al(OH)_3 + 3H^{+} + 3Cl^{-}$$

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Cool Things to Know

- There are other organic coagulants (such as polyDADMAC, polyamine, Tannins) which do not depress pH and generate very little sludge, however they are typically not used in municipal water treatment because they underperform metallic coagulants in removing color and organic materal
- Disinfection with sodium hypochlorite typically raises the pH of the finished water, and in some cases where PACs are used this is enough to eliminate post-coagulant lime feed
- Basicity is a measure of the number of hydroxyl ions included in the structure of a metallic coagulant. The higher the basicity the less impact on finished water pH. (alum has zero basicity since there are no OH-)
- Flocculants can be used for rapid settling or to add strength to the sludge. Typical flocculants:

  -Bentonite

  -Calcium Carbonate

  -Sodium Silicate

  -Anionic Polymers (various molecular weights)

  -Nonionic Polymers (various molecular weights)

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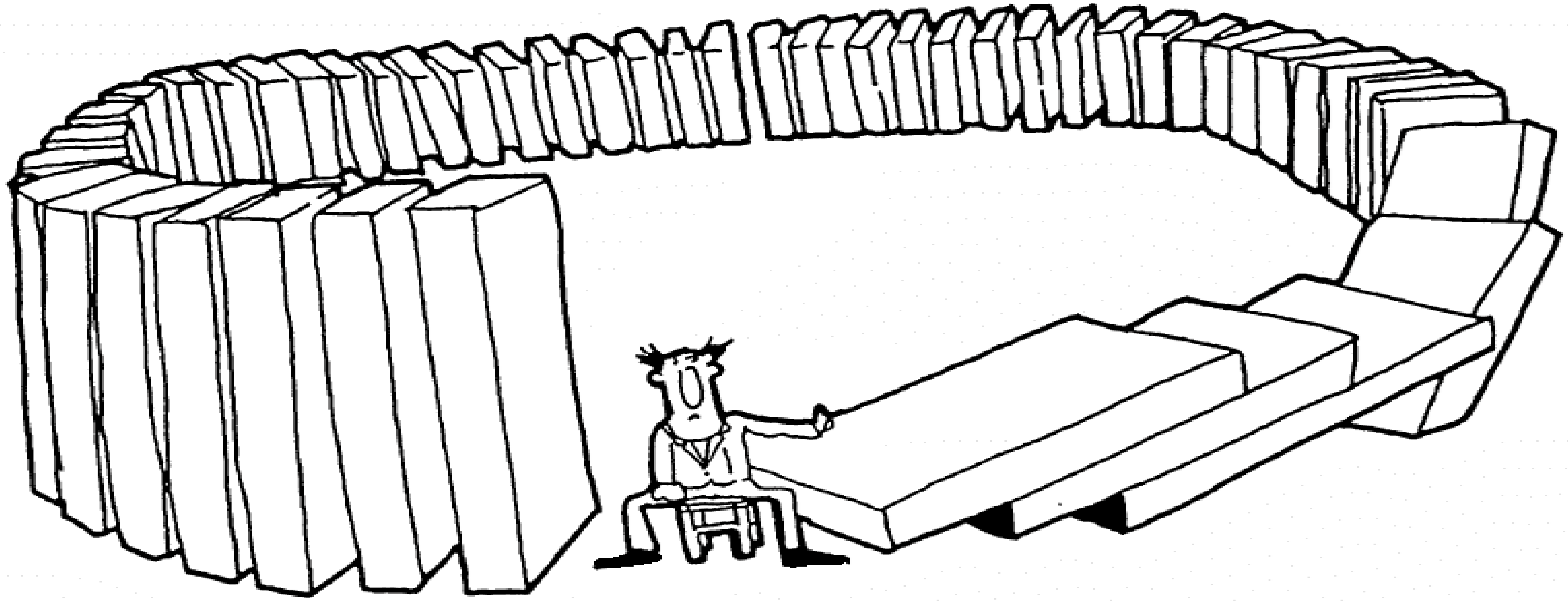

.....an example of unintended consequences and what we can learn from the UK

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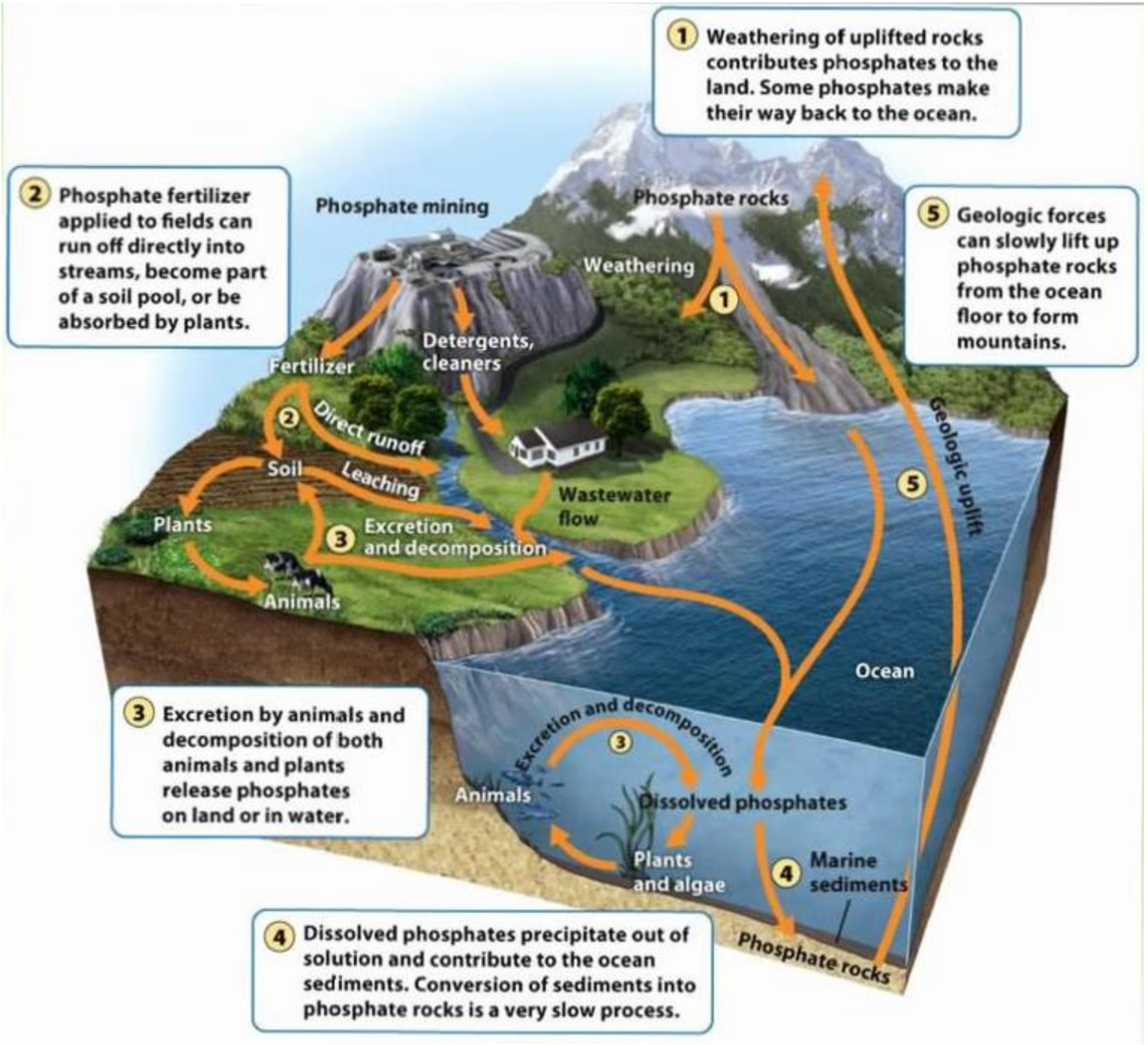

https://quizlet.com/246086779/apes-phosphorus-cycle-diagram/

Phosphorus

- Cannot be manufactured and there is no substitute for it
- Is essential for all living matter
- Equilibrium cause / effects from too much in the waste water supply
- Discharge from waste treatment plants is regulated
- As much as 35% of waste water flow can be due to corrosion control in drinking water (Rogers, 2014)

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Predicting the Future (Part 1)

2014:

"Implications of Phosphorus Treatment of Drinking Water for Significant Wastewater Treatment Plants in the Chesapeake Bay Watershed Portion of Virginia". –Clayton Cope, Lovettsville, VA thesis presented to University of Virginia

- "Phosphorus, in the form of orthophosphate, is added to drinking water in approximately 40% of United States (U.S.) public water systems as a lead corrosion control inhibitor. Typical phosphorus residuals are approximately 0.2 - 1.0 mg/L as P. However, in other countries, such as the United Kingdom, roughly 90% of drinking water systems utilize phosphorus corrosion control inhibitors; with residuals nearly double those of the United States. Discussion has arisen over whether the U.S. should adopt corrosion control polices that mirror those of the United Kingdom (i.e., more drinking water systems adding phosphate and residual levels doubling). However, little is known about the effects this change would have on wastewater treatment plants (WWTPs) treating the amended drinking water."

- "As natural water bodies have deteriorated in quality, the U.S. Environmental Protection Agency (USEPA) has restricted phosphorus discharge from WWTPs. This is especially apparent within the Chesapeake Bay watershed, where WWTPs follow some of the most stringent nutrient control policies under the 2010 Chesapeake Bay total maximum daily load (TMDL)."

- "A survey of significant WWTPs within the Virginia portion of the Chesapeake Bay Watershed was conducted to investigate the effects increased phosphorus loading to drinking water residuals of 2 mg/L as P from phosphorus corrosion control inhibitors would have on WWTP treatment and total solids disposal practices."

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Predicting the Future (Part 2)

2014:

Anticipated impacts from increasing corrosion control phosphorus use in the US in line with current UK use:

- "The most common change to advanced treatment resulting from increased phosphorus loading was an increased addition of aluminum sulfate (88%), and the two most common changes to total solids disposal were an increase in the amount of total solids being disposed (83%) and an increase in the phosphorus concentration of the total solids being disposed (33%)."
- "The average annual cost increase resulting from phosphorus loading was $22,867/million gallons a day (MGD) for changes to advanced treatment and $17,164/MGD for changes to total solids disposal."
- "While results showed that WWTPs can treat a phosphorus increase to 2 mg/L as P without violating TMDL permit levels, there will be a cost that every WWTP must determine and find a way to fund."

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In 2020, wastewater phosphorus discharge levels in the UK were reduced to 0.25 mg/l…

The full impact of this change on how wastewater treatment plants are managed is only now becoming apparent

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https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-141/subpart-I/section-141.82#p-141.82(c)(2)(v)

The number of sites in the UK requiring phosphorus treatment is increasing by 70%

More Sites Require Treatment

Increase in Sludge Output

A significant increase in sludge production is creating cost and complexity to manage

Most of the new sites requiring treatment are small, requiring more complex logistics

Complex Logistics

Dangerous Chemicals

Increased use and handling of coagulants and excess sodium hydroxide for pH control

Coagulant use is increasing by >75% requiring additional UK manufacturing capacity

Increased Chemical Use

Expensive Chemicals

The overall use, and direct raw material cost of chemical continues to increase

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Wessex Water

Highlighted 24 small wastewater treatment sites impacted by increased costs linked to these regulations. Costs include:

- Equipment (pumps, dosing plant, etc.)
- Storage of raw materials
- Emergency showers and other safety requirements
- Site upgrades and improved access for chemical deliveries
- Costs for managing increased sludge production

These costs were concluded to be "disproportionately expensive"

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“The anticipated UK demand by regulated water companies for ferric and ferrous salts needed for phosphate removal in wastewater is expected to grow significantly in the next five to ten years and could exceed the current levels of UK production”

-Water Industry Journal 2021

“Water companies face chemical supply disruption”

-BBC Sept 7th 2021

“Water treatment rules eased due to chemical supply failures”

-CIPD Sept 2021

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Predicting the Future (Part 3)

- In the UK, technologies to control corrosion using less phosphorus, and technologies to remove phosphorus using less chemicals (generating less sludge) are being explored
- In the US, many states are interpreting the revised lead copper rule as a mandate to use larger amounts of phosphorus to control lead
- Wastewater phosphorus limits continue to be reduced, and available supply of chemicals continues to be challenging (phosphorus use for water treatment is the second least valuable market for phosphorus producers)

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SEAQUEST

A Holistic Approach to Water Quality

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Traditional Selection Criteria

	Lead Release	Copper Release	Steel Corrosion	Color / Appearance	Typical Dose	Product Cost
SeaQuest	💧💧💧	💧💧💧	💧💧💧	💧💧💧	💧💧💧	💧💧
pH Control	💧💧💧	💧💧💧	💧	💧	💧	💧💧💧
Silica	💧💧	💧💧	💧💧💧	💧	💧	💧💧💧
Ortho Phosphate	💧💧💧	💧💧	💧💧	💧	💧	💧💧💧
Blended Phosphates	💧💧	💧💧	💧💧	💧💧	💧💧	💧💧

💧 Poor Performance
💧💧 Acceptable Performance
💧💧💧 Excellent Performance

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Holistic Approach Selection Criteria

	Phosphorus Discharge	Chlorine Residuals	Disinfection Byproducts	Electricity / Water Flow	Workplace EHS	Total Use Cost
SeaQuest	💧💧	💧💧💧	💧💧💧	💧💧💧	💧💧💧	💧💧💧
pH Control	💧💧💧	💧	💧	💧	💧	💧💧
Silica	💧💧💧	💧	💧	💧	💧	💧
Ortho Phosphate	💧	💧	💧	💧	💧	💧
Blended Phosphates	💧	💧💧	💧💧	💧💧	💧💧💧	💧💧

💧 Poor Performance

💧💧 Acceptable Performance

💧💧💧 Excellent Performance

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Lead / Copper

Rogue Water Loss

Biofilm

Dirty Water

Low Chlorine

Disinfection Byproducts

Excess Flushing

Clogged Pipes

SeaQuest addresses every issue.

Well Productivity

Dangerous Chemicals

Expensive Chemicals

Hard-to-Feed Chemicals

Hard-to-Control Chemicals

Low Bill Rates

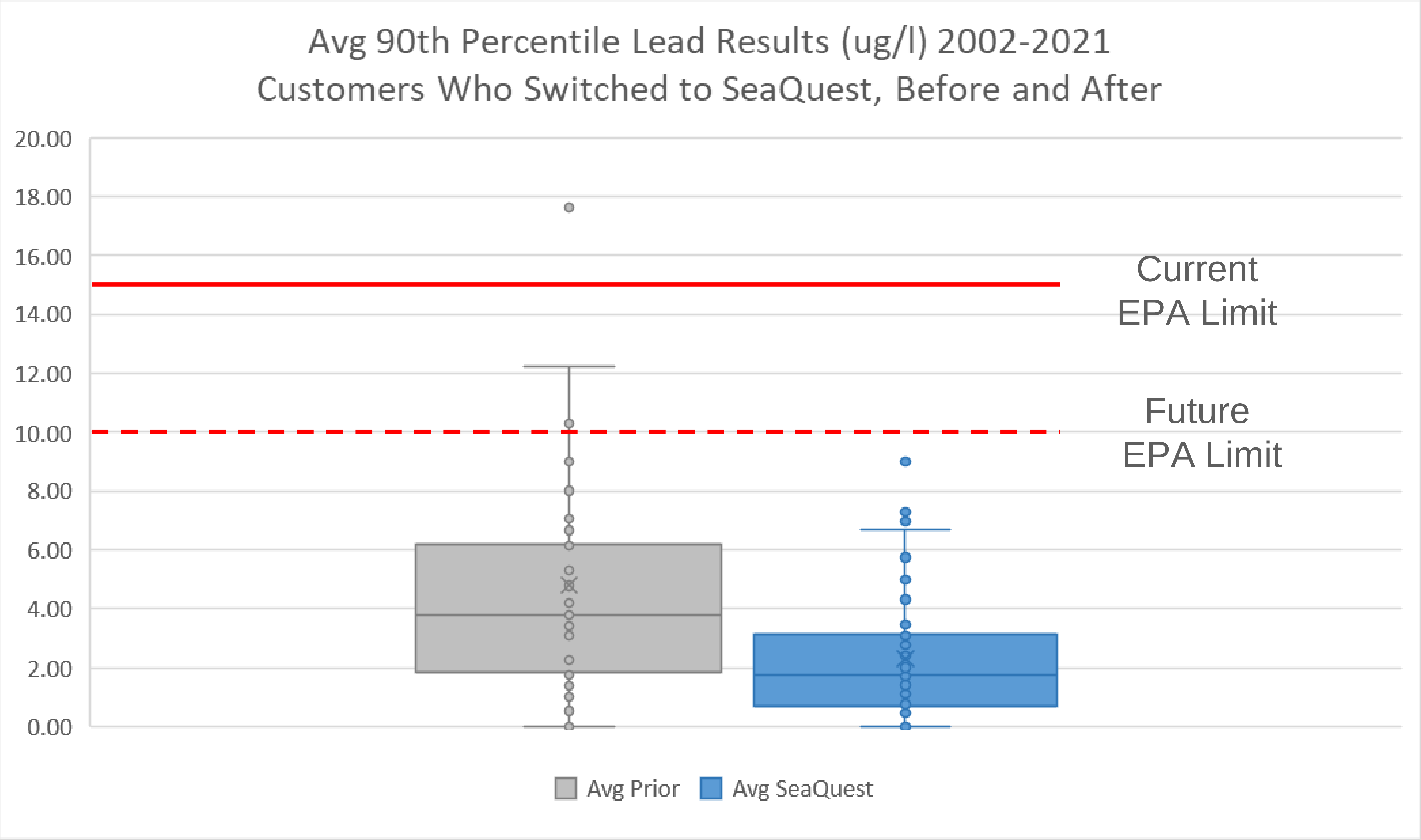
Low Pressure

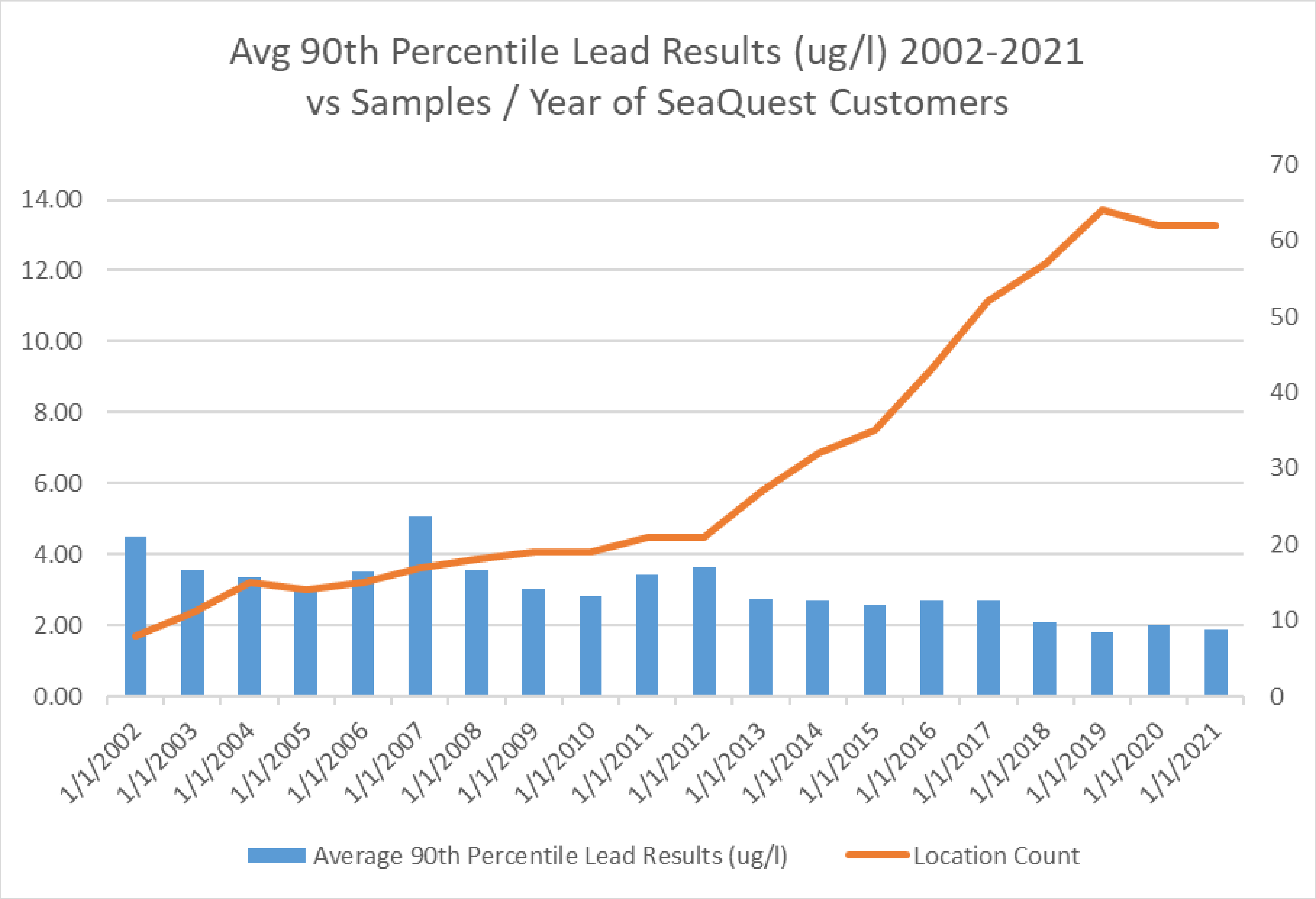
Regulatory Compliance

SeaQuest has treated
more than **8 trillion** gallons of water.


Love Letters
"I WISH ALL WATER TREATMENT PROBLEMS WERE AS QUICKLY AND EFFECTIVELY SOLVED."
"MAKING MY LIFE A LITTLE EASIER BY ELIMINATING THE MAJORITY OF CUSTOMER COMPLAINTS."
NY
"THANK YOU! WE ARE IN COMPLIANCE FOR THE FIRST TIME IN FIVE YEARS."
CO
"DON'T EVER CHANGE THE PRODUCT."
WV
KY
CA
"RED WATER CALLS DROPPED TO ZERO."
"THE FLOW STAYED THE SAME BUT NOW THE PUMP WORKS HALF AS HARD!"
"BEFORE SEAQUEST OUR WATER WAS PLUM FRIGGIN HORRID."
OK
MS
AL
GA
"NOW THE NURSE UNIFORMS DON'T GET RED."
"RED WATER COMPLAINTS STOPPED OVERNIGHT."

Lead Results of SeaQuest in the US 2002-2021





63 customers were sampled who switched to SeaQuest from a different corrosion inhibitor since 2002:

- Average 90th percentile lead concentrations were reduced from 4.8 ug/l to 2.3 ug/l

87 customers were sampled who used SeaQuest since 2002:

- Average 90th percentile lead concentrations remain compliant and are continuously reduced

SeaQuest **continuously** disrupts corrosion

Consuming free radicals at the pipe wall

SeaQuest **continuously** sequesters minerals

Keeping the water clear & the pipe walls clean

SeaQuest **continuously** protects the pipe

Forming an ionic film at the pipe wall

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Back…….To the UK!

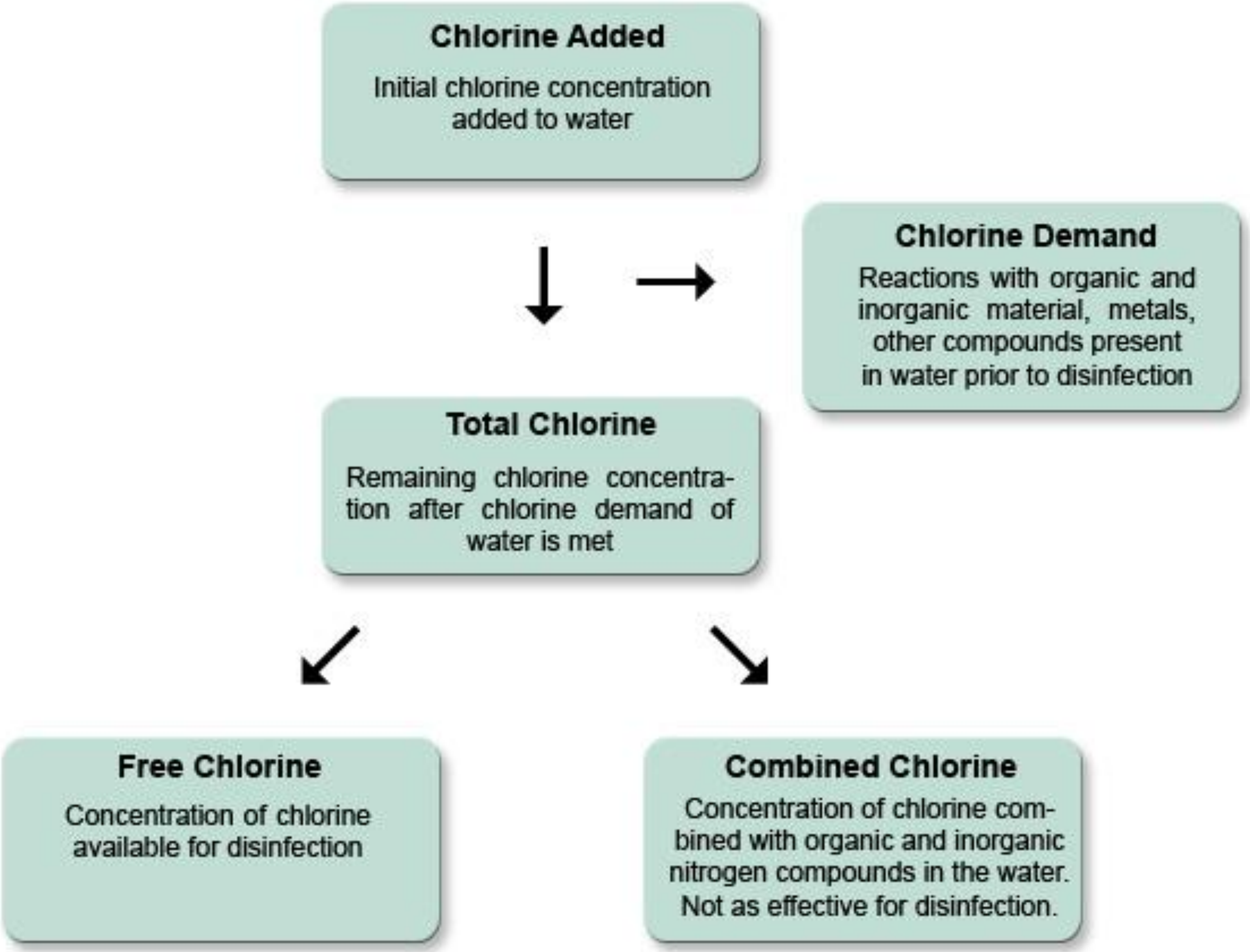
	Total Cost (GBP/Yr)	Total Phosphorus Generation (KG/Yr)	Total Carbon Footprint (KG CO2e/Yr)
Ortho-Phosphate	£3,371,540	146,267	3,844,292
SeaQuest	£2,449,577	32,449	3,270,632
SeaQuest + Eliminate Lime	£1,237,122	32,449	537,640

While:

- Eliminating red water complaints
- Increasing chlorine residuals
- Reducing EHS risk

APPENDIX

Chlorine Residuals & Selection



Corrosion of infrastructure

↓

Contribute metals (typically iron) into the water

↓

Oxidizer consumption

↓

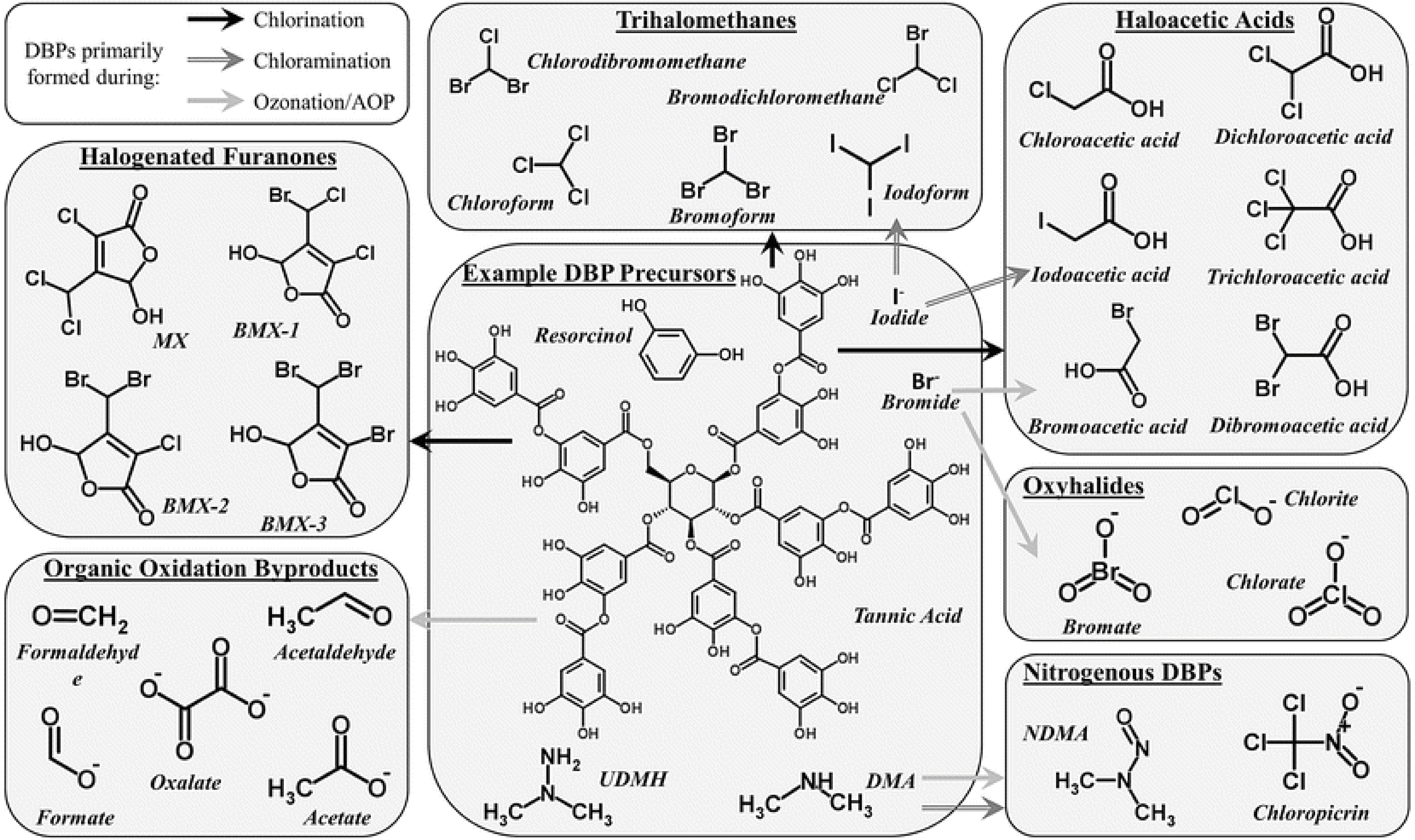
Reduced chlorine residuals

↓

Change in pH / Change in Oxidizer

SOURCE: Chlorine Residual Testing | The Safe Water System | CDC

Disinfection Byproducts



Corrosion of infrastructure

↓

Contribute metals (typically iron) into the water

↓

Oxidizer consumption

↓

Reduced chlorine residuals

↓

Increased oxidizer use

↓

Increased THMs

Mayer, B.K., Ryan, D.R. (2017). Impact on Disinfection Byproducts Using Advanced Oxidation Processes for Drinking Water Treatment. In: Gil, A., Galeano, L., Vicente, M. (eds) Applications of Advanced Oxidation Processes (AOPs) in Drinking Water Treatment. The Handbook of Environmental Chemistry, vol 67. Springer, Cham. https://doi.org/10.1007/698_2017_82

Phosphorus & Zinc Discharge

"Because of problems with nutrient enrichment of surface waters, there has been concern about adding phosphate-based corrosion inhibitors to drinking water because it will increase the phosphorus loading to the wastewater treatment plant. Some wastewater utilities have stringent limits on the amount of phosphorus that can be discharged to receiving waters and remove it at the plant using biological and/or chemical treatment. Survey findings from 14 utilities showed that adding a phosphate-based corrosion inhibitor increased the phosphorus load to the wastewater treatment plant by 10 to 35 percent, with a median of 20 percent (Rodgers, 2014).

"Prior to selecting a phosphate-based corrosion inhibitor, water systems and primacy agencies should work with wastewater utility personnel to estimate the additional phosphorus load to the WWTP and assess if the load could cause the plant to exceed permit limits or cause other operational problems"

Use of a zinc orthophosphate corrosion inhibitor can increase zinc loading to the WWTP. Schneider et al. (2011) noted that, based on three case studies, most of the zinc in zinc orthophosphate makes its way into the wastewater treatment stream. Although many systems have successfully used zinc orthophosphate for corrosion control, zinc can inhibit biological wastewater treatment processes, particularly nitrification and denitrification. Moreover, EPA has set limits for zinc in processed sludge that is land applied (USEPA, 2004b).

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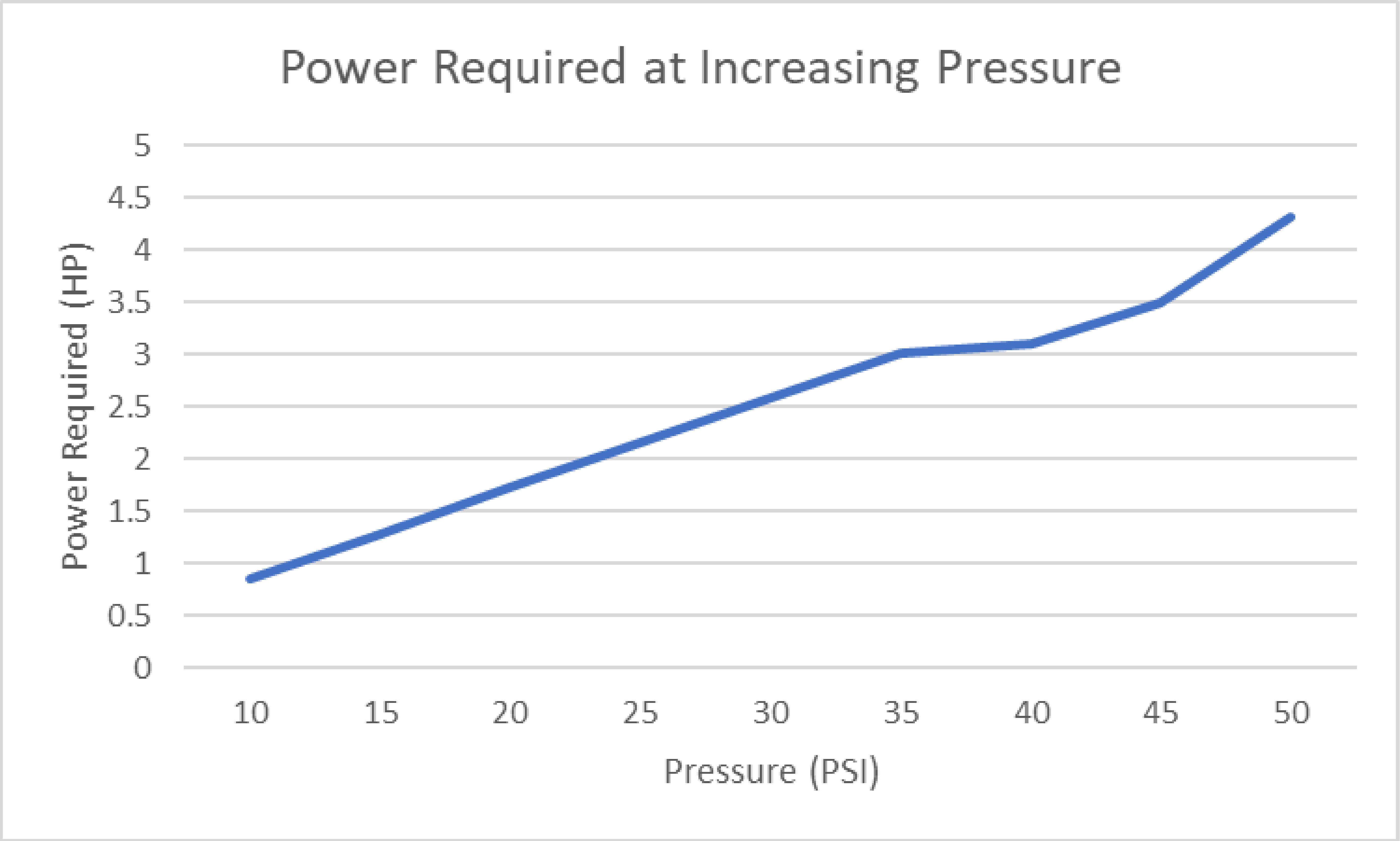
[Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems (epa.gov)]

Electricity / Flow



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Workplace EHS

“**Phosphoric acid can be very hazardous** in the case of skin contact, eye contact, and ingestion. It can also cause irritation if vapors are inhaled. This chemical can cause damage to the skin, eyes, mouth, and respiratory tract. Because of the potential hazards posed by this chemical, it is important to use care when handling it.”

Sodium hydroxide is highly caustic… and **can cause serious damage** when not handled safely.

The two most common ways to become injured by sodium hydroxide is either by contact (skin or eyes), or by inhaling a vapor containing high levels of the compound. The following injuries can occur when coming into direct contact with undiluted sodium hydroxide:

•Ulceration of the nasal passages
•Irritation of the skin, eyes, lungs or nasal passages
•Eye and skin burns, sometimes severe
•Esophageal burns if swallowed
•Blindness

https://www.sciencedirect.com/science/article/pii/B9780323476614000393

https://www.ehs.com/2014/04/sodium-hydroxide-lye-safety/

https://www.ehs.com/2015/06/phosphoric-acid-safety-tips/

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Total Cost

"Systems should consider operability, reliability, system configuration, and other site-specific factors when evaluating CCT alternatives. In cases where more than one treatment option can meet the OCCT definition of the rule, systems may want to consider cost factors including costs for **capital equipment, operations, and maintenance**."

DIRECT COST

-Corrosion inhibitor use cost

INDIRECT COST

-Oxidizer efficiency

-Oxidizer selection

-Operating pH window selection

-Capital feed equipment lifecycle / capex

-Flushing man hours

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Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems (epa.gov)

SEAQUEST

Case Histories

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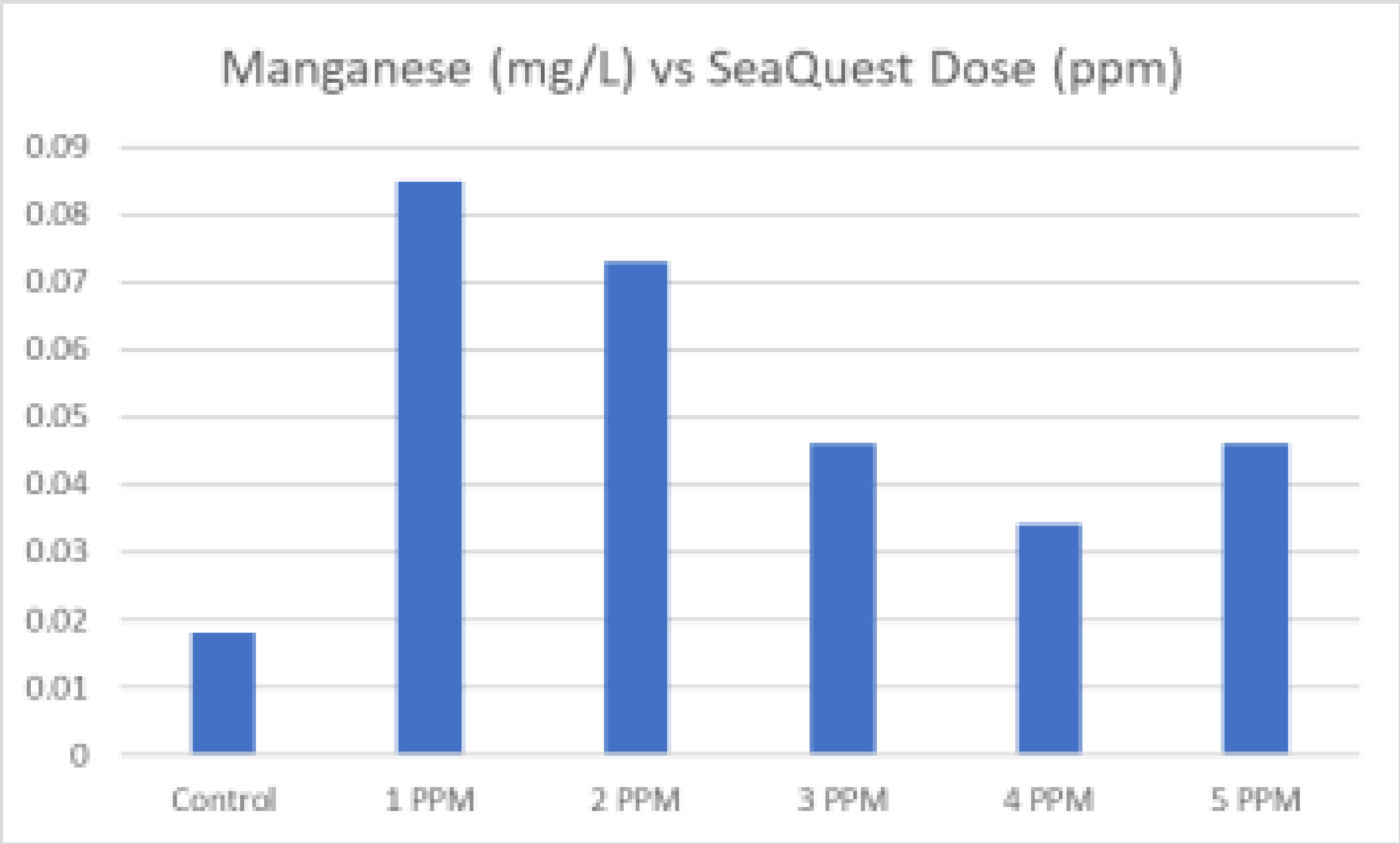
Desoto Parrish Louisiana

Desoto Parrish, Louisiana experiences periods of manganese release when the bayou turns over twice per year. The system is all PVC, but the treatment plant was designed for 0.5 MGD with a demand of 1.2 MGD. As a result, the potassium permanganate used for manganese removal does not achieve complete removal due to minimal residence time.



Control	1 ppm SQ	2 ppm SQ	3 ppm SQ	4 ppm SQ	5 ppm SQ

To reduce black water complaints an experiment was performed to identify the dose of SeaQuest required to remove existing manganese deposits from the PVC, while keeping the manganese soluble and eliminating complaints.

After the success of the experiment a field trial was performed in Q4 2021, using 3.0 ppm of SeaQuest.

During the spring bayou changeover black water complaints were eliminated, and now the SeaQuest dose is being further reduced to optimize economically.

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Augusta, GA

The Problem:

Other phosphate-based chemicals were used, resulting in inconsistent chlorine residuals and finished water pH. Bids were awarded based on price / pound rather than performance. As a result, excess chemicals (and cost) were observed, along with substantial red water complaints due to system wide corrosion.

The Solution:

The City of Augusta moved to a performance-based specification with a dose rate guarantee and switched to SeaQuest. $14,000 per year was saved in the ground water plant, and $55,000 per year was saved in the surface water plant.

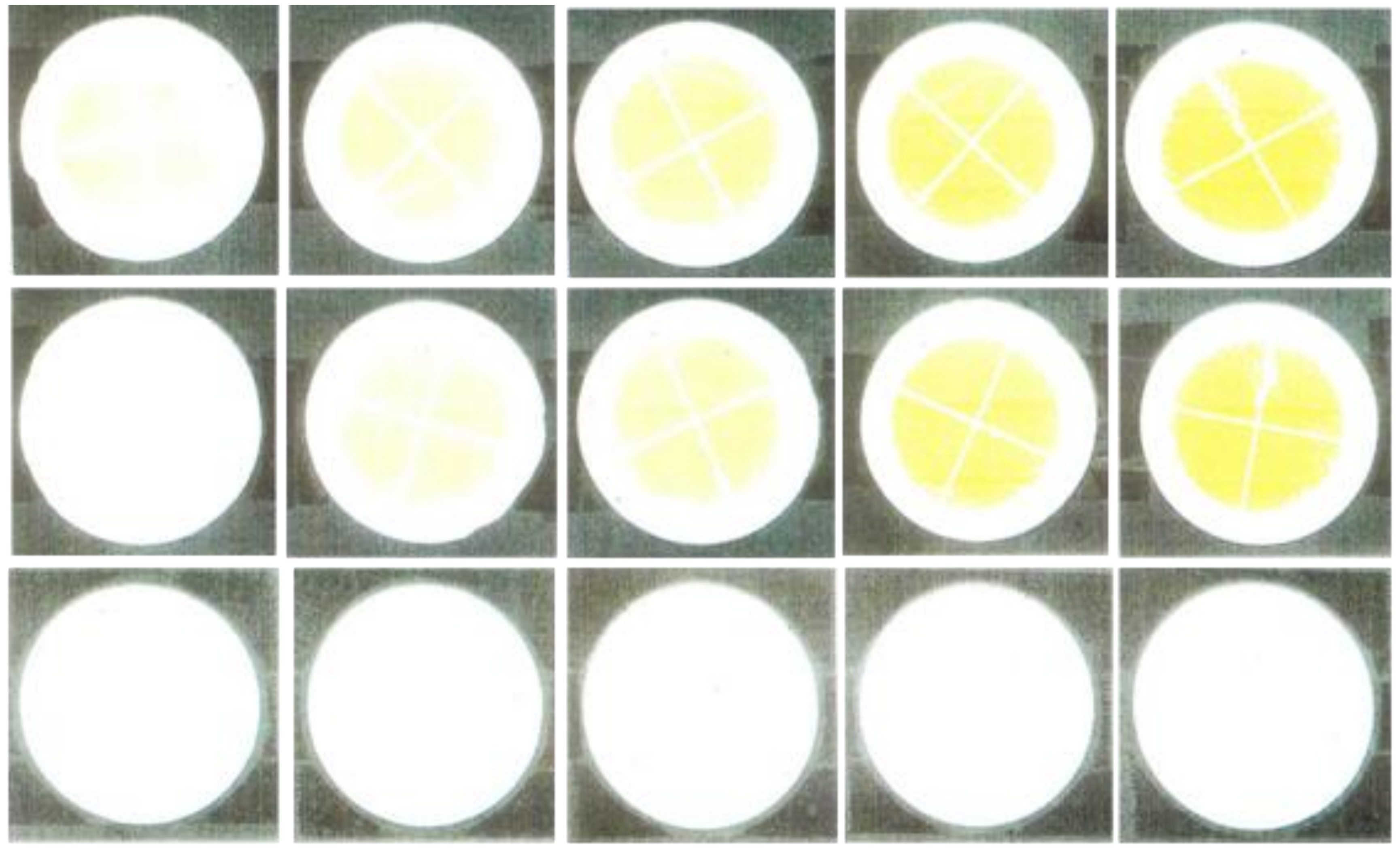
- All copper and lead tests remain in compliance
- Less pH adjustment was required since the distribution water was more stable
- Less chlorine was used
- Customer complaints were reduced dramatically

Las Cruces, NM

The Problem:

Due to the high levels if iron / manganese in their source water, the City of Las Cruces, NM routinely suffered from dirty water complaints, costing ~$120,000 / year.

Various phosphates were sourced through a traditional bidding process, but often resulted in over-use and excess cost without reducing the complaints.



Filter pads from 1hr to 5 hrs showing iron oxidation and sequestration

The Solution:

To be able to accurately mimic field performance, a new chemical evaluation protocol was developed. Raw water containing iron and manganese was oxidized before and after the addition of phosphate. The samples were stored to simulate water aging, and then filtered at 0.45 micron. Failure occurred when a visible amount of iron was observed on the filter pad, indicating a loss of sequestration. SeaQuest passed and was selected for system wide use based on highest performance and lowest use cost. As a result:

- Within one year complaints were reduced from ~800 to ~75
- The amount of SeaQuest needed did not increase from the original dose
- ~10,000 less man hours were spent flushing

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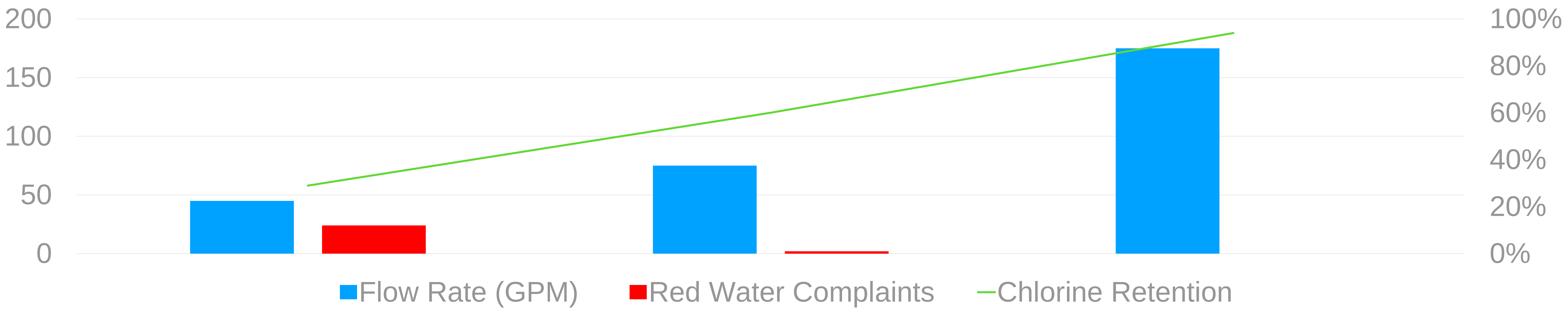
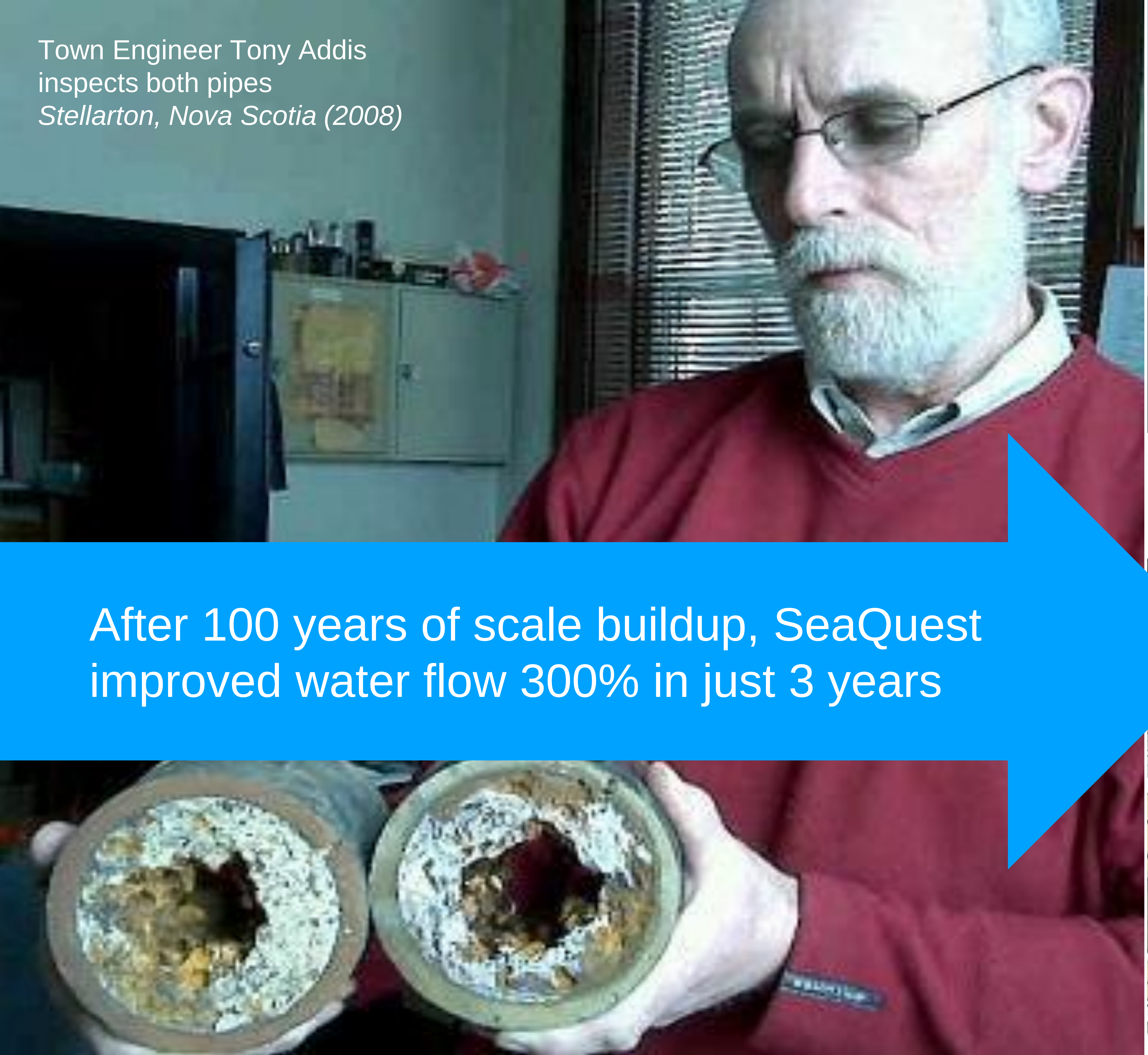
Brunswick, GA

2009	2010	2011
		



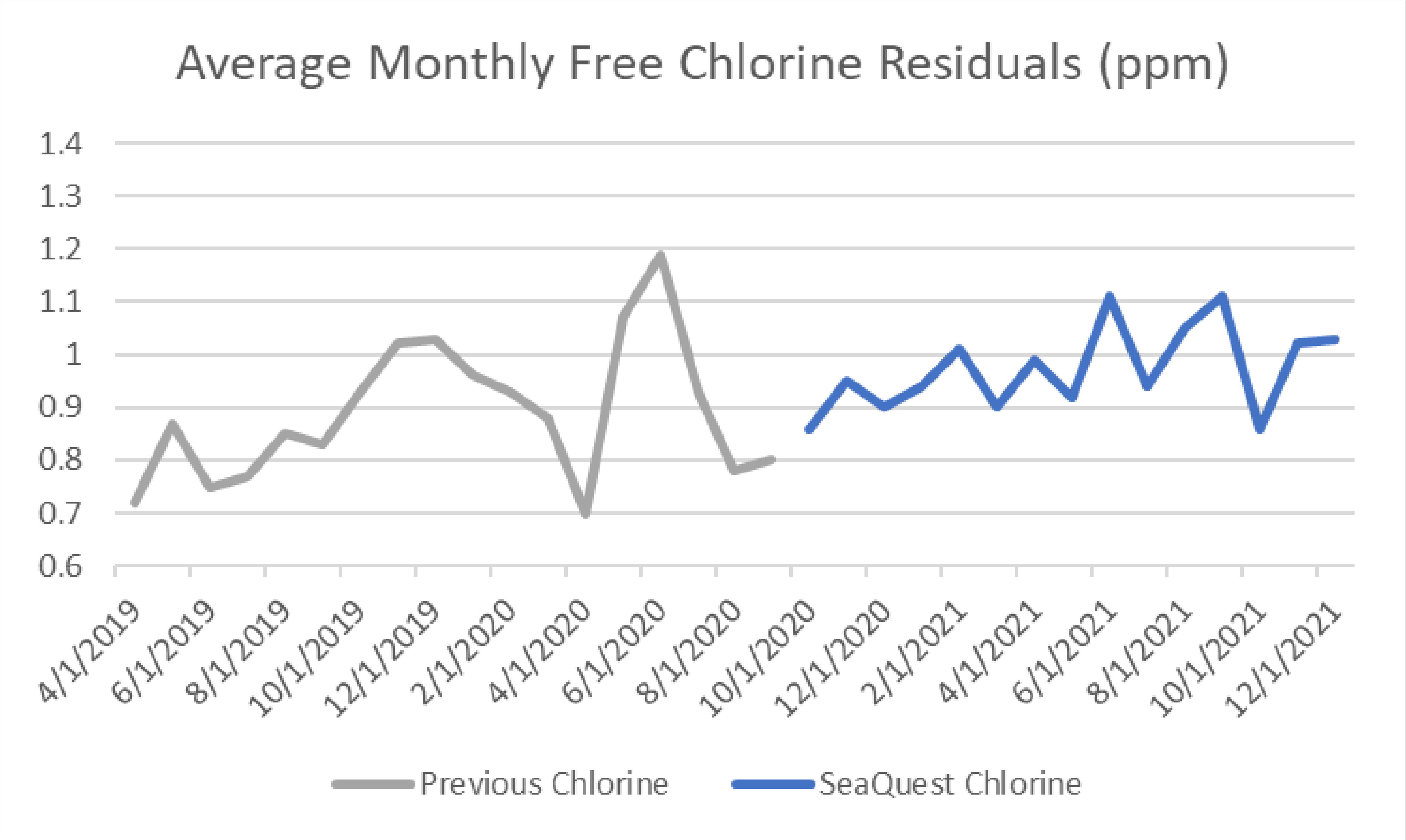
Town Engineer Tony Addis
inspects both pipes
Stellarton, Nova Scotia (2008)

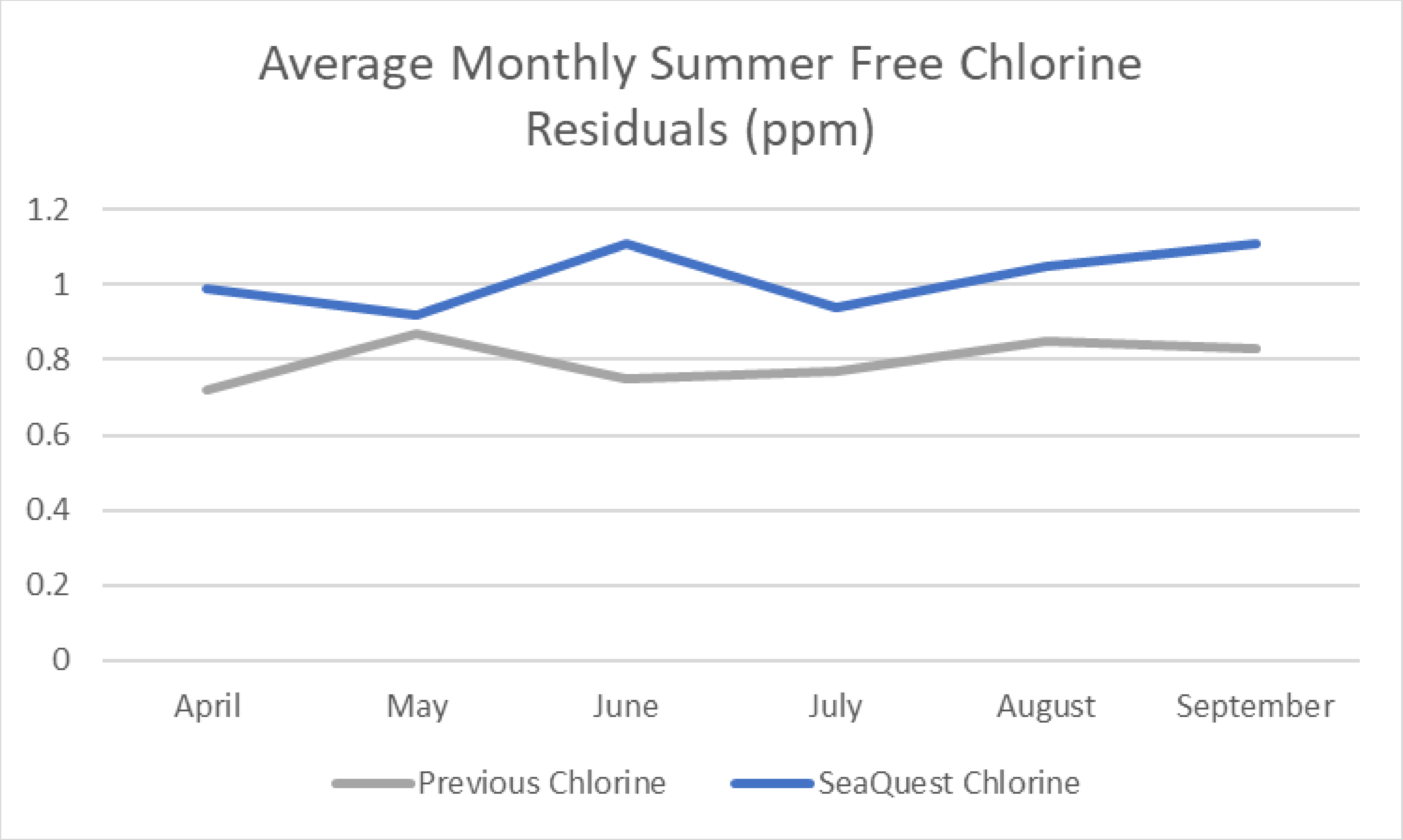


After 100 years of scale buildup, SeaQuest improved water flow 300% in just 3 years

Spartanburg, SC

The City of Spartanburg, SC switched from a traditional blended phosphate to SeaQuest at the Landrum Plant in October 2020. The Landrum plant is a surface water treatment plant averaging 0.4 MGD of production. The finished water pH is 7.3.





As a result, the following results were achieved:

- An overall 10% increase in average free chlorine residuals in the distribution system
- An overall 16% increase in average free chlorine residuals in the distribution system in the summer months from April to September
- A 74% improvement in the consistency of product quality

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Opflow Vol 29, No 1: Chlorine Efficiency

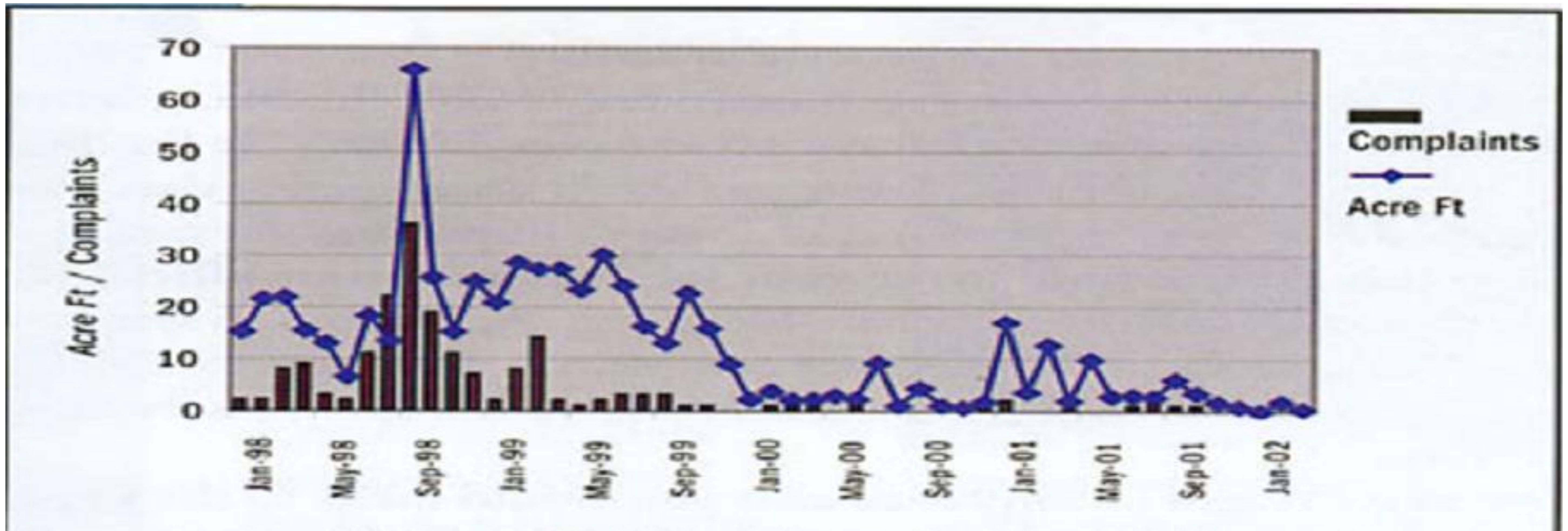


Figure 1. Flushing volume vs. complaints

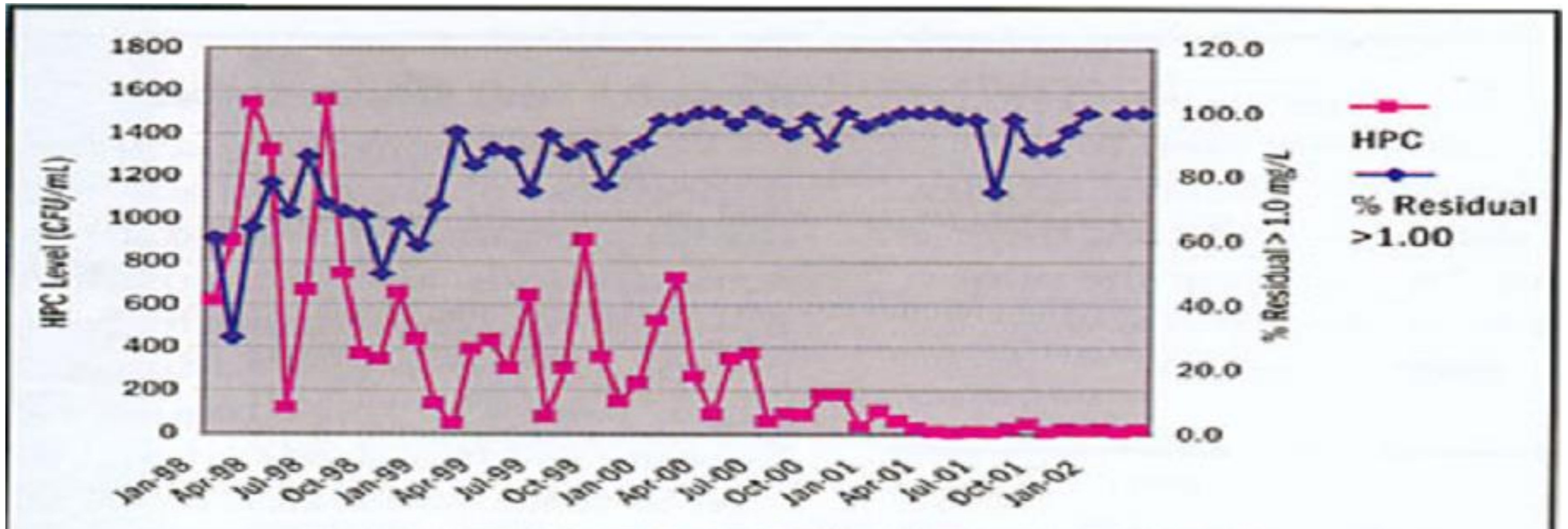


Figure 2. HPC vs. total chlorine residual level

<u>Summary:</u>

A large utility in California was facing significant biofouling complaints and had to flush extensively.

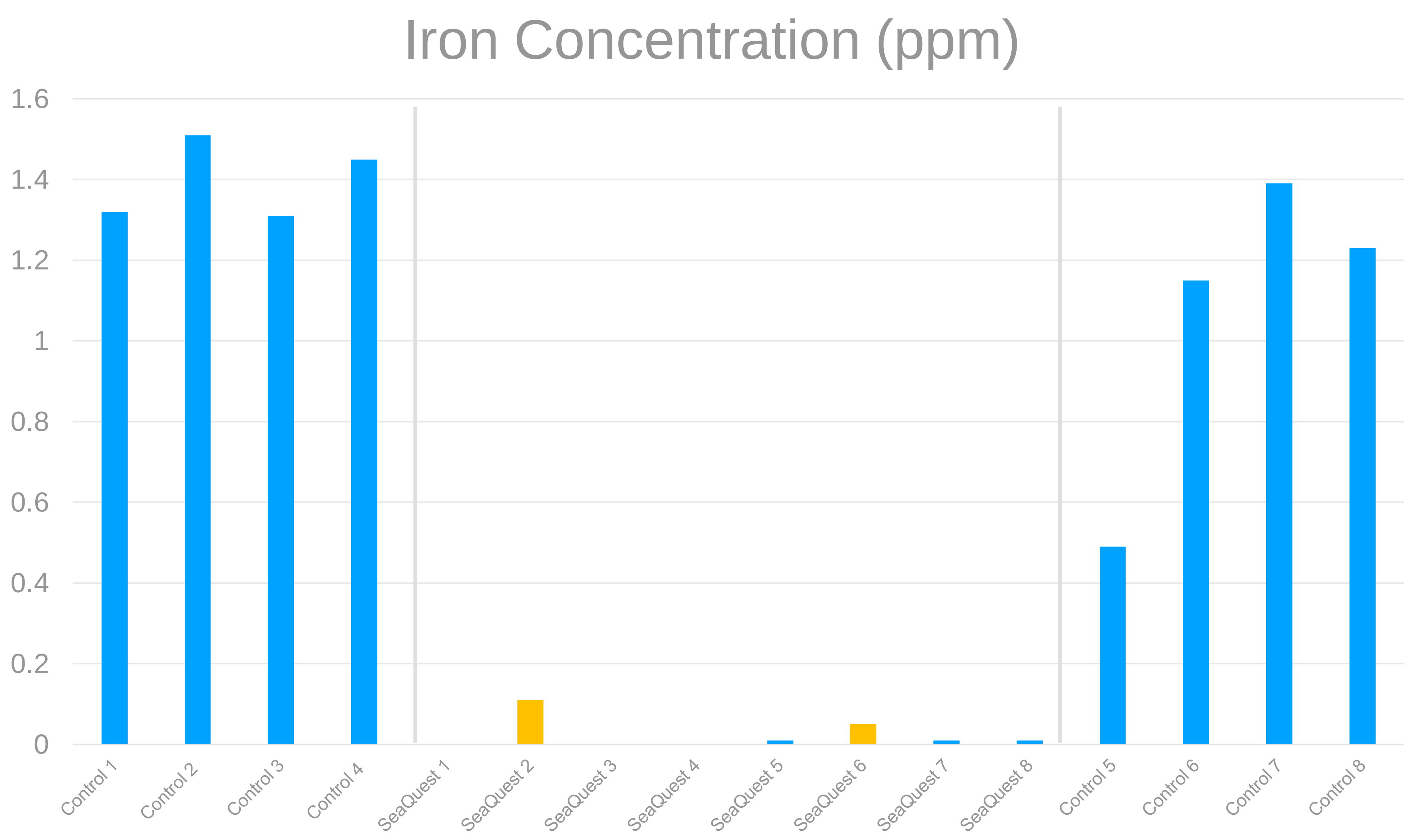
They switched to SeaQuest, and both the flushing program and complaints were reduced.

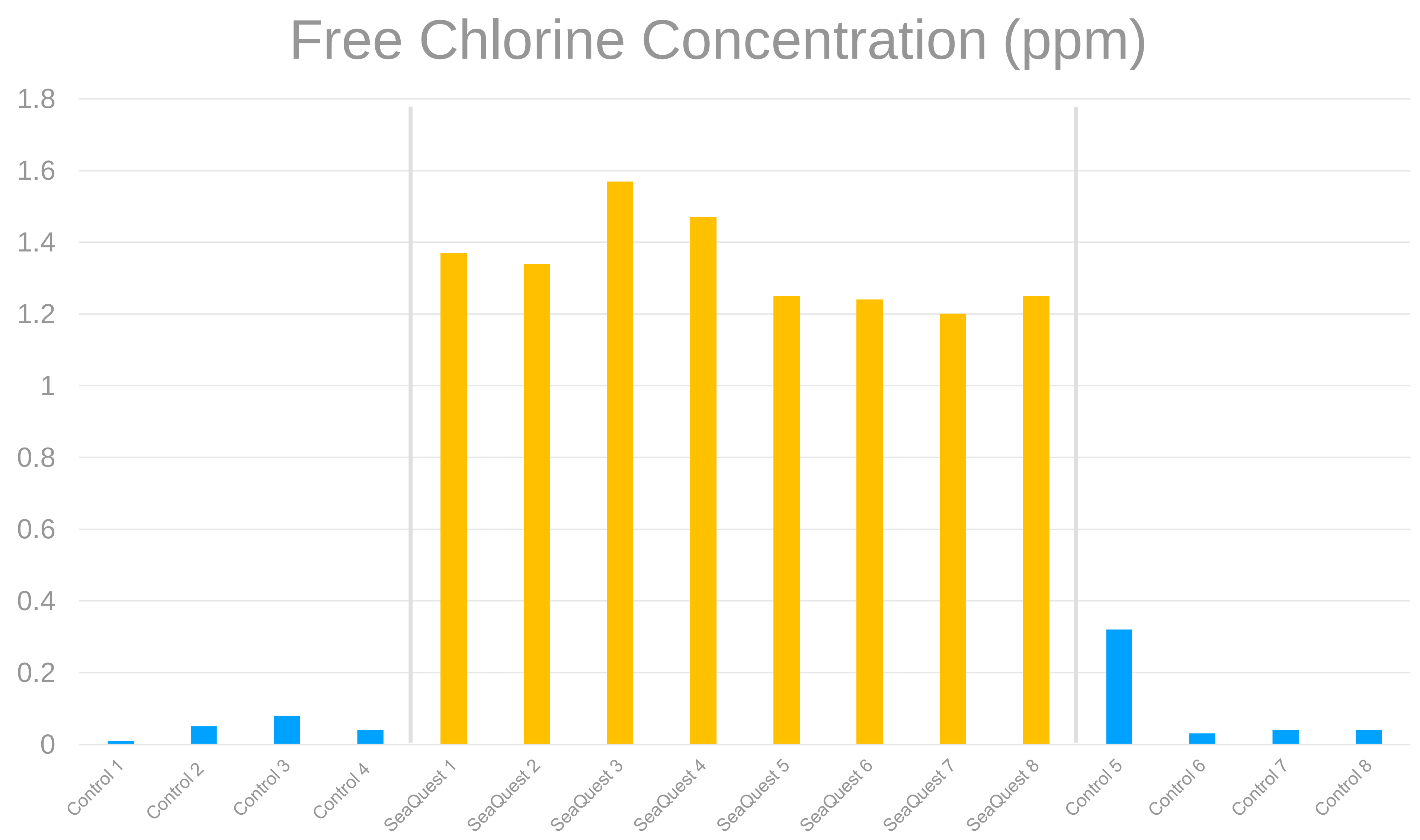
With SeaQuest, chlorine residual in distribution was able to build consistently, which reduced HPCs, biofouling and black water.

Nassau, Bahamas: Red Water, Chlorine Residual

SeaQuest was used to prevent red water and build a chlorine residual in an extremely corrosive environment (LSI: -0.9)

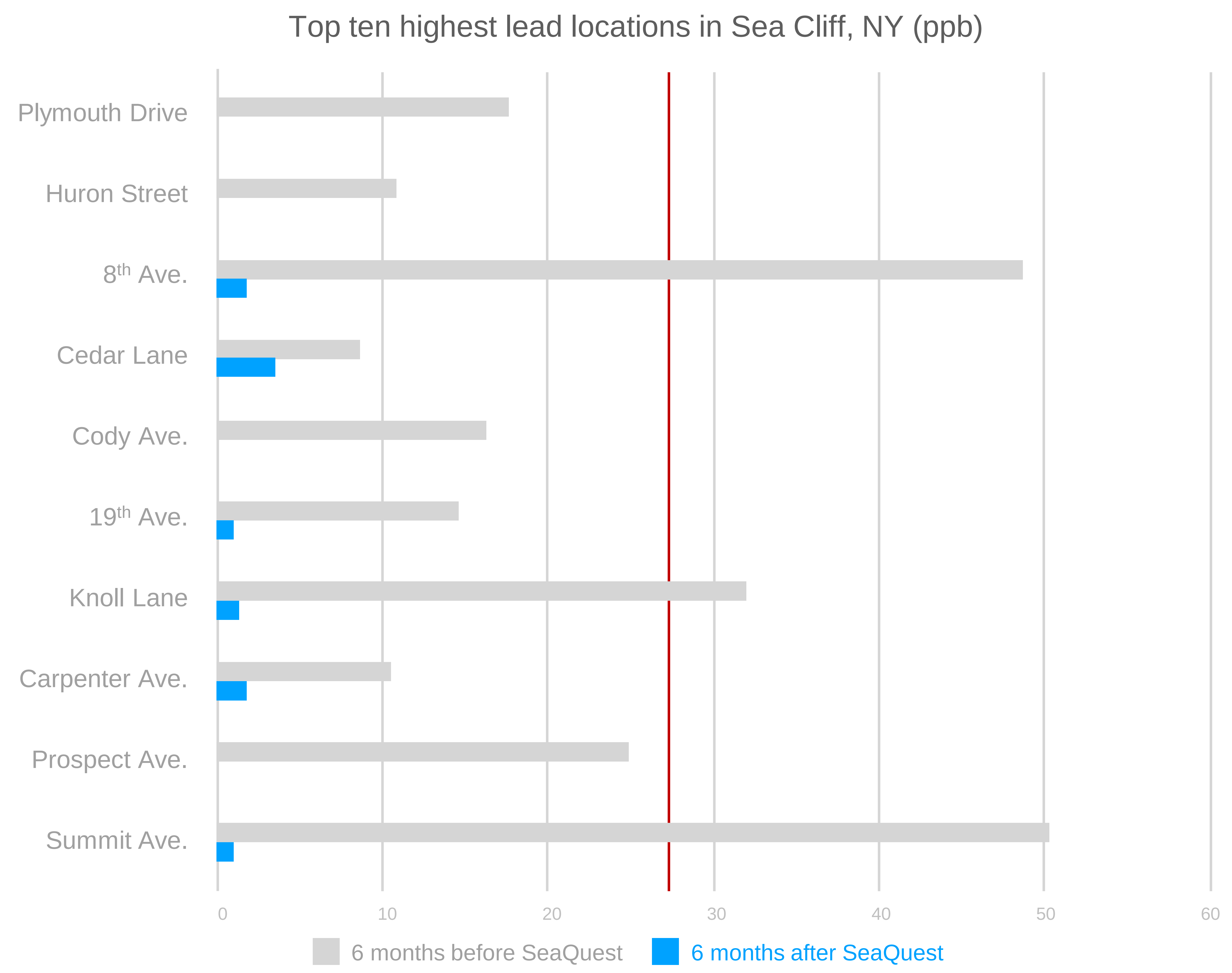
LSI of -0.8 to -0.9	
pH	7.05
Alkalinity	46
Chloride	405
Calcium	16
Sodium	178





24 hours
after SeaQuest treatment

Sea Cliff, NY



Background:

- Compliance issues resulted in NY DEP forcing a review and change to CCT
- (previous treatment 1.1 ppm shmp + pH increase)
- Reviewed top 10 highest lead locations before and after SeaQuest
- 2 locations had lead service lines which were not replaced
- 90th percentile lead reduced from 14.7 to 1.2 ppb

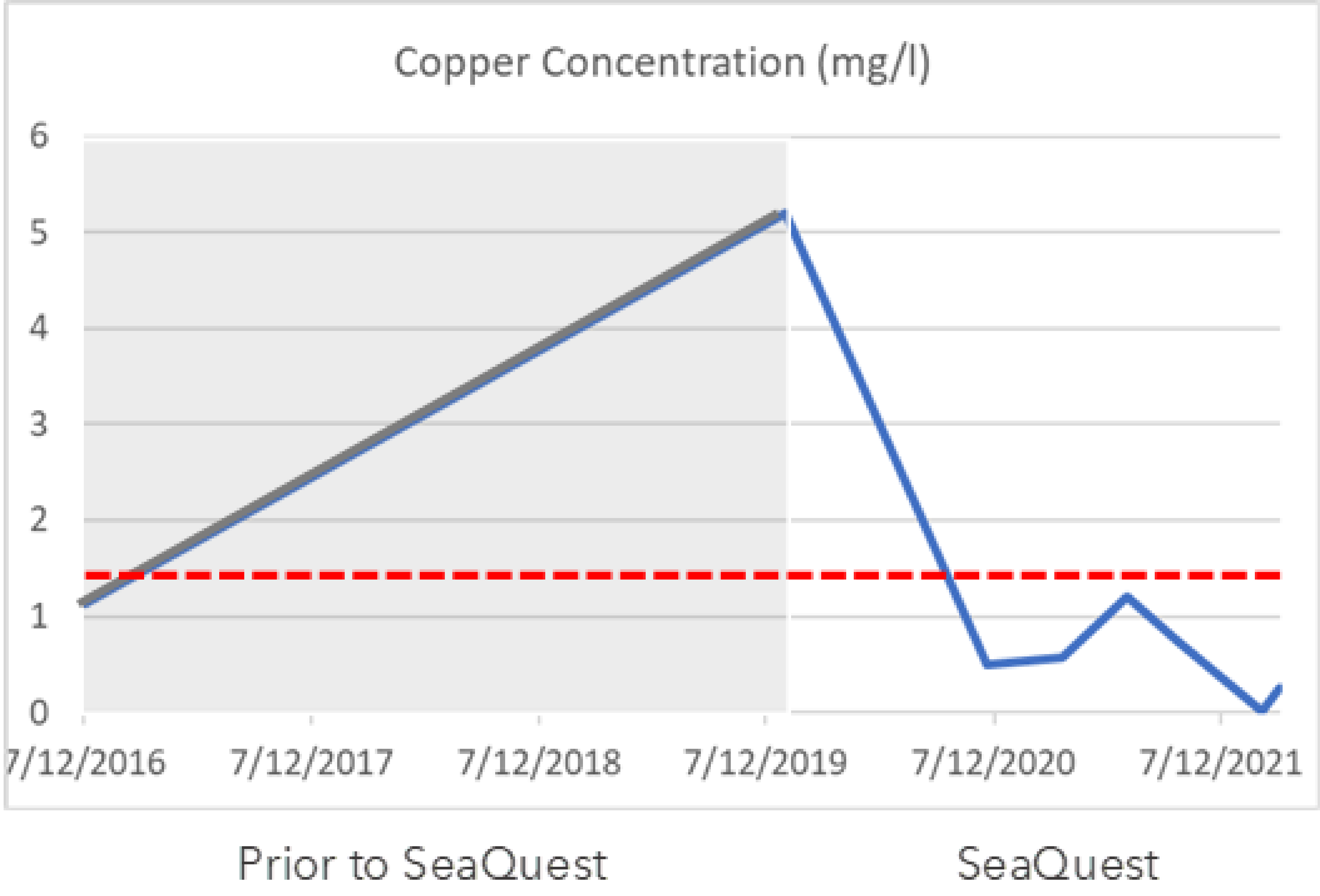
Pike County, GA

The Problem:

A former orphanage was repurposed to a DFACS shelter for families fleeing violence. The facility experienced periods of neglect which resulted in inconsistent water treatment. Several lead and copper exceedances occurred from 1995-2016.

In 2019 the 90th percentile copper measured 5.2 mg/l and lead measured 15 ug/l.

During an inspection DFACS noted the blue/green staining of sinks and bathtubs.



The Solution:

A new contract operator took over the facility to gain control of the water, repairing and installing capabilities as needed. Chlorine was stabilized and SeaQuest was installed for corrosion control. Because the system is very small, installing liquid caustic was deemed too dangerous. As a result the pH of the water ranged from 6.7-7.1.

After installing SeaQuest:

- Copper corrosion was immediately controlled, and copper levels were reduced from 5.2 mg/l to 0.5 mg/l.
- Lead levels were reduced from 15 ug/l to 0 ug/l
- The facility is now fully compliant with all regulations

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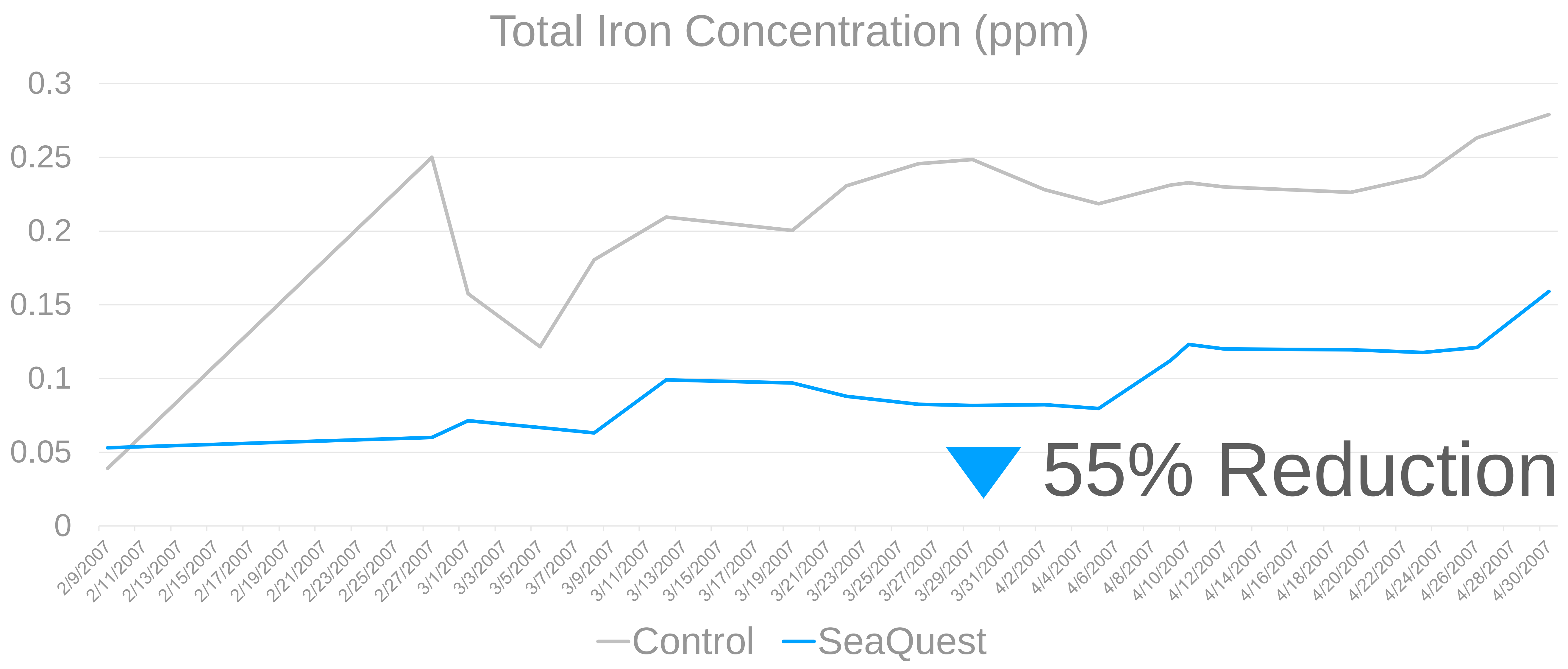
Houston, TX

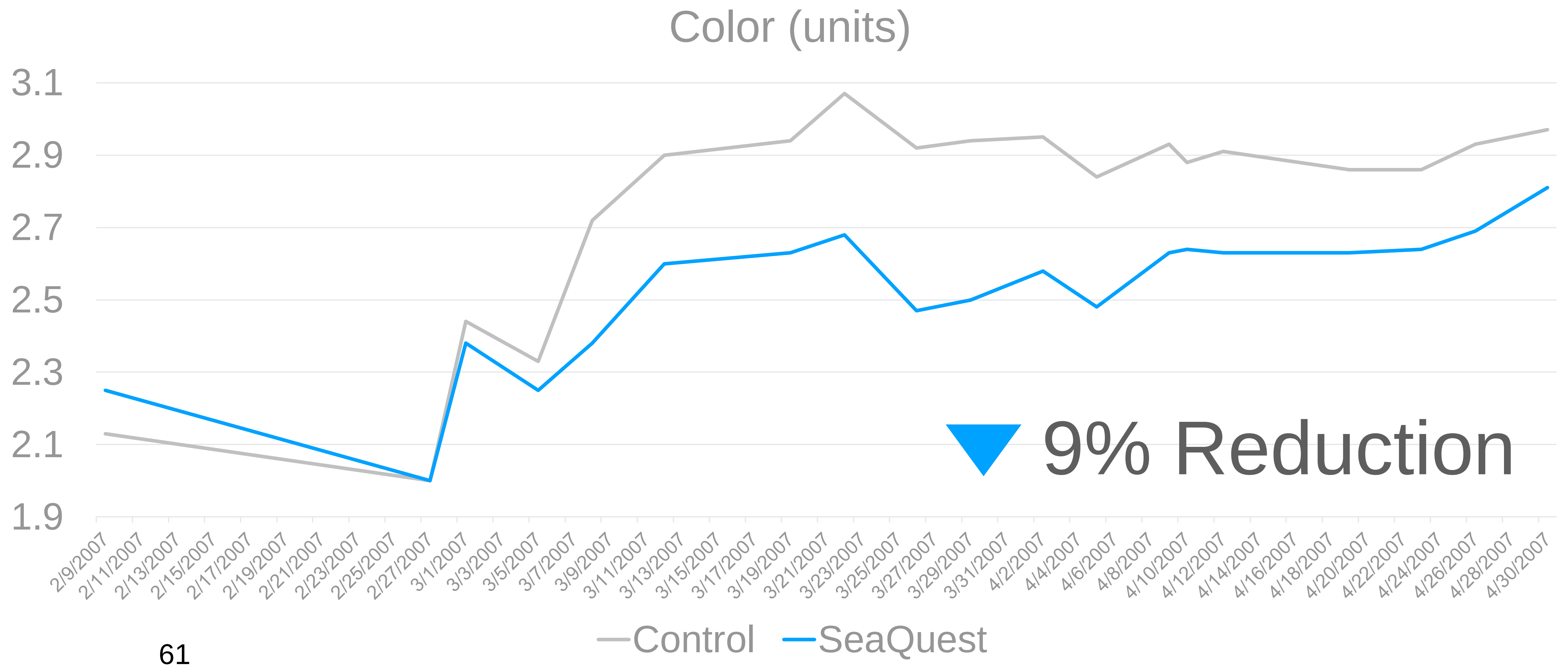
Summary:

The City of Houston was receiving red water complaints, so they performed a 60-day trial by isolating two areas of their distribution system and treating one with SeaQuest.

KPIs for both the control and SeaQuest systems were monitored:

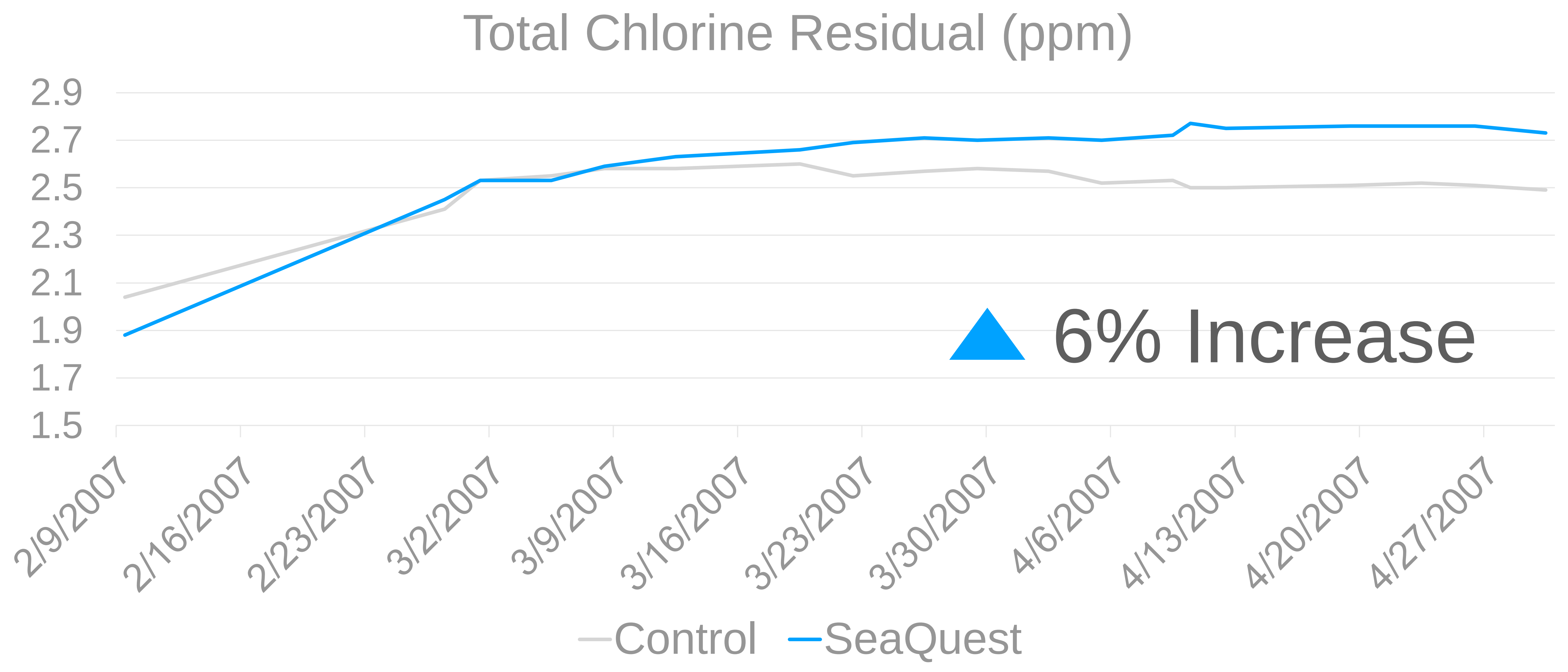
- Iron
- Total Chlorine
- Color
- HPCs



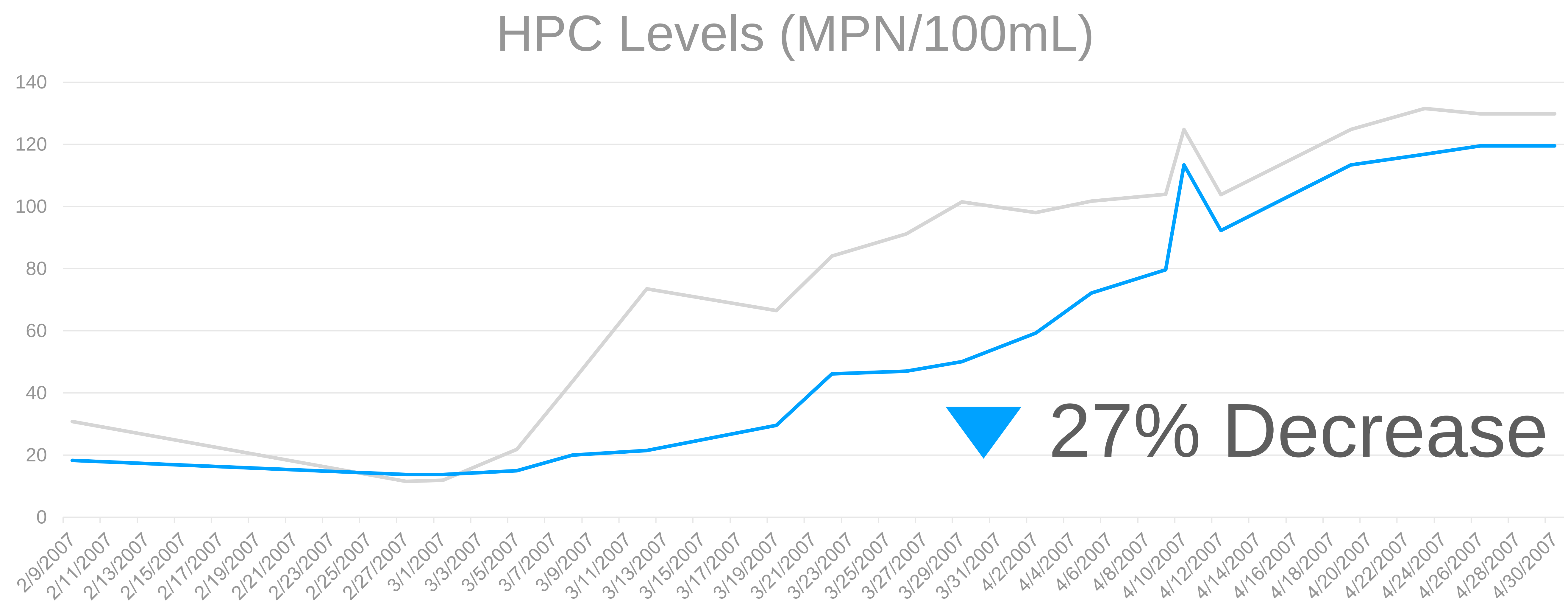


Houston, TX

09/06/2007 01:49 pm
OUSTON
PUBLIC
WORKS

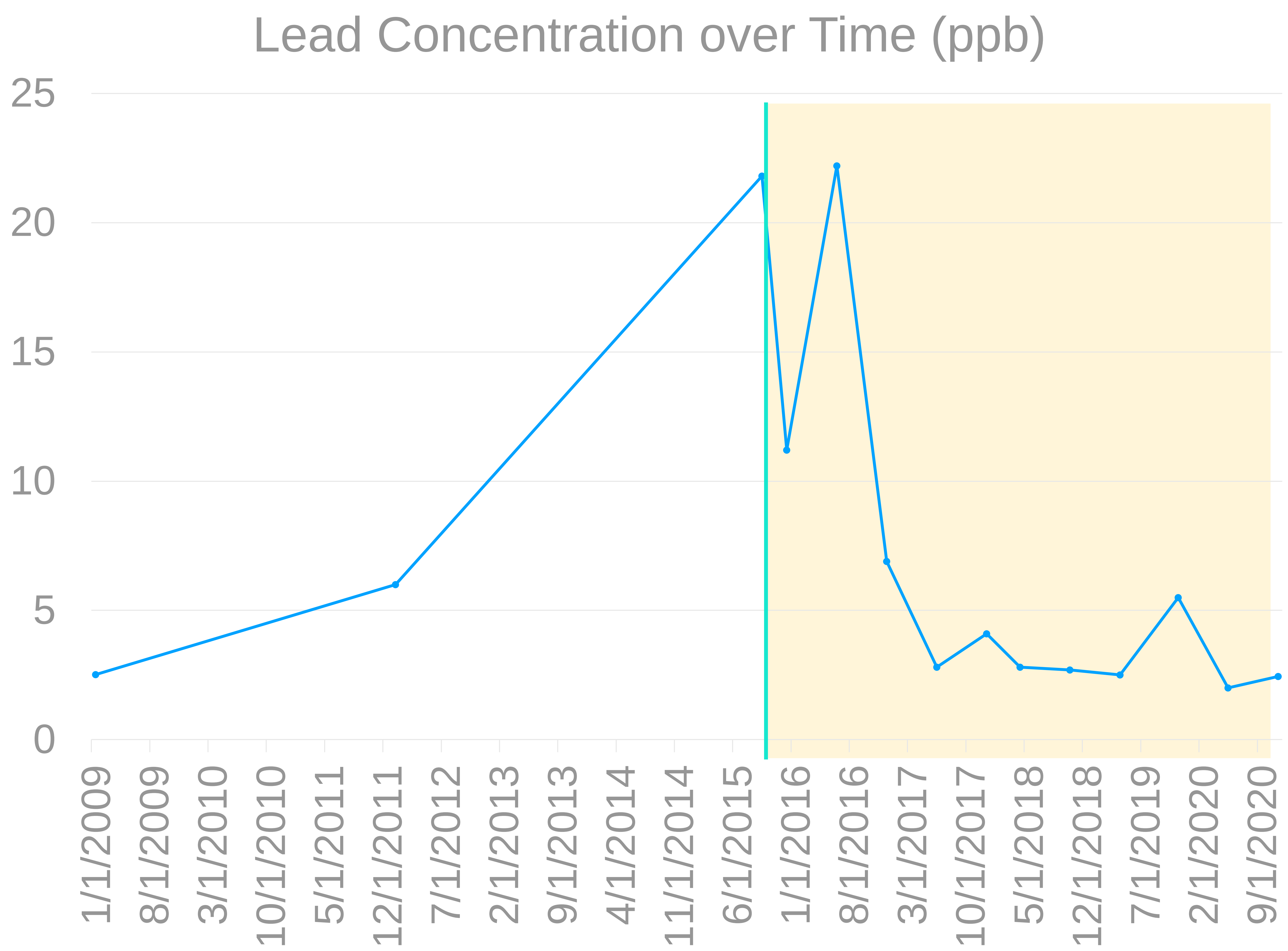


Total Chlorine Residual (ppm)
2.9
2.7
2.5
2.3
2.1
1.9
1.7
1.5
2/9/2007
2/16/2007
2/23/2007
3/2/2007
3/9/2007
3/16/2007
3/23/2007
3/30/2007
4/6/2007
4/13/2007
4/20/2007
4/27/2007
Control
SeaQuest
6% Increase



HPC Levels (MPN/100mL)
140
120
100
80
60
40
20
0
2/9/2007
2/11/2007
2/13/2007
2/15/2007
2/17/2007
2/19/2007
2/21/2007
2/23/2007
2/25/2007
2/27/2007
3/1/2007
3/3/2007
3/5/2007
3/7/2007
3/9/2007
3/11/2007
3/13/2007
3/15/2007
3/17/2007
3/19/2007
3/21/2007
3/23/2007
3/25/2007
3/27/2007
3/29/2007
3/31/2007
4/2/2007
4/4/2007
4/6/2007
4/8/2007
4/10/2007
4/12/2007
4/14/2007
4/16/2007
4/18/2007
4/20/2007
4/22/2007
4/24/2007
4/26/2007
4/28/2007
4/30/2007
Control
SeaQuest
27% Decrease

Firestone, CO was on track to be the next Flint, MI



*"In Firestone **SeaQuest was added to the town's water supply** to prevent the breakdown of water pipes. **Lead levels there are now down**."*
- USA Today (2016)

In Firestone, CO, 40 homes that were built before 1986 were tested for lead in the water:

- July 2015: 11 tested > 15 ppb
- December 2015: 6 tested > 15 ppb
- **January 2019: Zero (0) tested > 15 ppb**

"You know Flint was a disaster all the way around. There's many other ways to deal with that issue in a safe and proactive way. And our water providers in our region are doing that."
- Tom Cech,
M.S.U Denver One World One Water Center

SECTION 2

Revised Lead / Copper Rule

Lead / Copper Rule Scope

Scope. The regulations in this subpart establish a treatment technique that includes requirements for corrosion control treatment, source water treatment, lead service line inventory, lead service line replacement, public notice, monitoring for lead in schools and child care facilities, and public education. Several of the requirements in this subpart are prompted by the lead and copper action levels or the lead trigger level, specified in paragraph (c) of this section, as measured in samples collected at consumers' taps.

Corrosion control requirements.

- (1) All water systems shall install and operate corrosion control treatment in accordance with §§ 141.81 and 141.82, and that meets the definition of *optimal corrosion control treatment* at § 141.2.
  - Optimum Corrosion Control Treatment
    - *Optimal corrosion control treatment,* for the purpose of subpart I of this part only, means the corrosion control treatment that minimizes the lead and copper concentrations at users' taps while ensuring that the treatment does not cause the water system to violate any national primary drinking water regulations

Lead / Copper Rule Scope

Any water system that complies with the applicable corrosion control treatment requirements specified by the State under §§ 141.81 and 141.82 shall be deemed in compliance with the treatment requirement contained in paragraph (d)(1) of this section.

141.81:
eCFR :: 40 CFR 141.81 -- Applicability of corrosion control treatment steps to small, medium, and large water systems.

141.82:
eCFR :: 40 CFR 141.82 -- Description of corrosion control treatment requirements.

Compliance is variable based on lead inventory, lead results relative to population served, and current use of corrosion control treatment.

The majority of systems are in compliance and are not expected to be triggered into corrosion control optimization / reoptimization…

Out of compliance (simple version):
Large, no corrosion, lead > 0.005
Any size, lead > 0.010

Lead / Copper Rule Monitoring – Site Selection

A water system must use the information on lead, copper, and galvanized iron or steel that is required to be identified under § 141.42(d) when conducting a materials evaluation and the information on lead service lines that is required to be collected under § 141.84(a) to identify potential lead service line sampling sites.

A water system whose distribution system contains lead service lines must collect all samples for monitoring under this section from sites served by a lead service line. A water system that cannot identify a sufficient number of sampling sites served by lead service lines must still collect samples from every site served by a lead service line, and collect the remaining samples in accordance with tiering requirements under paragraphs (a)(5) through (7) or paragraphs (a)(9) through (10) of this section.

eCFR :: 40 CFR 141.86 -- Monitoring requirements for lead and copper in tap water.

Lead / Copper Rule Monitoring – Sampling 1

All tap samples for lead and copper collected in accordance with this subpart, with the exception of fifth liter samples collected under paragraph (b)(3) of this section, and samples collected under paragraphs (b)(5) and (h) of this section, must be first draw samples. The first draw sample shall be analyzed for lead and copper in tap sampling periods where both contaminants are required to be monitored. In tap sampling periods where only lead is required to be monitored, the first draw sample may be analyzed for lead only.

Each first draw tap sample for lead and copper must be one liter in volume and have stood motionless in the plumbing system of each sampling site for at least six hours. Bottles used to collect first draw samples must be wide-mouth one-liter sample bottles. First draw samples from residential housing must be collected from the cold-water kitchen or bathroom sink tap. First draw samples from a nonresidential building must be one liter in volume and collected at a tap from which water is typically drawn for consumption. State-approved non-first-draw samples collected in lieu of first draw samples pursuant to paragraph (b)(5) of this section must be one liter in volume and shall be collected at an interior tap from which water is typically drawn for First draw samples may be collected by the system or the system may allow residents to collect first draw samples after instructing the residents of the sampling procedures specified in this paragraph (b)(2). Sampling instructions provided to residents must not include instructions for aerator removal and cleaning or flushing of taps prior to the start of the minimum six-hour stagnation period. To avoid problems of residents handling nitric acid, acidification of first draw samples may be done up to 14 days after the sample is collected. After acidification to resolubilize the metals, the sample must stand in the original container for the time specified in the approved EPA method before the sample can be analyzed. If a system allows residents to perform sampling, the system may not challenge, based on alleged errors in sample collection, the accuracy of sampling results.

https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-141/subpart-I/section-141.86#p-141.86(b).

Lead / Copper Rule Monitoring – Sampling 2

Systems must collect tap water in five consecutively numbered one-liter sample bottles after the water has stood motionless in the plumbing of each sampling site for at least six hours without flushing the tap prior to sample collection. Systems must analyze first draw samples for copper, when applicable, and fifth liter samples for lead. Bottles used to collect these samples must be wide-mouth one-liter sample bottles. Systems must collect first draw samples in the first sample bottle with each subsequently numbered bottle being filled until the final bottle is filled with the water running constantly during sample collection. Fifth liter sample is the final sample collected in this sequence. System must collect first draw and fifth liter samples from residential housing from the cold-water kitchen or bathroom sink tap First draw and fifth liter samples from a nonresidential building must be one liter in volume and collected at an interior cold water tap from which water is typically drawn for consumption. First draw and fifth liter samples may be collected by the system or the system may allow residents to collect first draw samples and fifth liter samples after instructing the residents on the sampling procedures specified in this paragraph (b)(3)(ii). Sampling instructions provided to customers must not direct the customer to remove the aerator or clean or flush the taps prior to the start of the minimum six-hour stagnation period. To avoid problems of residents handling nitric acid, the system may acidify first draw samples up to 14 days after the sample is collected. After acidification to resolubilize the metals, the sample must stand in the original container for the time specified in the approved EPA method before the sample can be analyzed. If a system allows residents to perform sampling, the system may not challenge, based on alleged errors in sample collection, the accuracy of sampling results.

https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-141/subpart-I/section-141.86#p-141.86(b).

Lead / Copper Rule Monitoring – Childcare

eCFR :: 40 CFR 141.92 -- Monitoring for lead in schools and child care facilities.

Five samples per school and two samples per child care facility at outlets typically used for consumption shall be collected. Except as provided in paragraphs (b)(1)(i) through (vi) of this section, the outlets shall not have point-of-use (POU) devices.

Water systems must collect the samples from the cold water tap subject to the following additional requirements:

(A) Each sample for lead shall be a first draw sample;

(B) The sample must be 250 ml in volume;

(C) The water must have remained stationary in the plumbing system of the sampling site (building) for at least 8 but no more than 18 hours; and

(D) Samples must be analyzed using acidification and the corresponding analytical methods in § 141.89.

Water systems shall collect samples from at least 20 percent of elementary schools served by the system and 20 percent of child care facilities served by the system per year, or according to a schedule approved by the State, until all schools and child care facilities identified under paragraph (a)(1) of this section have been sampled or have declined to participate.

All elementary schools and child care facilities must be sampled at least once in the five years following the compliance date in § 141.80(a)(3).

Testing If Triggered into CCT Optimization

The water system must evaluate each of the corrosion control treatments using either pipe rig/loop tests, metal coupon tests, partial-system tests, or analyses based on documented analogous treatments with other systems of similar size, water chemistry, and distribution system configurations.

Large and medium systems and small community water systems and non-transient non-community water systems that select the corrosion control treatment option under § 141.93 with lead service lines that exceed the lead action level must conduct pipe rig/loop studies using harvested lead service lines from their distribution systems to assess the effectiveness of corrosion control treatment options on the existing pipe scale. For these systems, metal coupon tests can be used as a screen to reduce the number of options that are evaluated using pipe rig/loops to the current conditions and two options.

There are levels of compliance and what needs to happen based on a lot of factors once lead > 0.010 , but CCT testing is almost always the first thing required

Testing guidance (2016):
Optimal Corrosion Control Treatment Evaluation Technical Recommendations | US EPA
Different checklist for population < > 50,000
Some states may be using this incorrectly. It is meant for testing guidance if there is a trigger. Some states are using it to justify change when there is no trigger

Testing, Continued…

If a corrosion inhibitor is used, a minimum orthophosphate or silicate concentration measured in all tap samples that the State determines is necessary to form a passivating film on the interior walls of the pipes of the distribution system. When orthophosphate is used, such an orthophosphate concentration shall be equal to or greater than 0.5 mg/L (asPO_4) for *OCCT* designations under paragraph (d)(1) of this section and 1.0 mg/L for *OCCT* designations under paragraph (d)(2) of this section, unless the State determines that meeting the applicable minimum orthophosphate residual is not technologically feasible **or is not necessary for *optimal corrosion control treatment*.**

- The water system must evaluate the effectiveness of the following treatments, and if appropriate, combinations of the following treatments to identify the optimized / re-optimized *optimal corrosion control treatment* for the system:
- (A) Alkalinity and/or pH adjustment, or re-adjustment;
- (B) The addition of an orthophosphate- or silicate-based corrosion inhibitor at a concentration sufficient to maintain an effective corrosion inhibitor residual concentration in all test samples if no such inhibitor is utilized;
- (C) The addition of an orthophosphate-based corrosion inhibitor at a concentration sufficient to maintain an orthophosphate residual concentration of 1 mg/L (PO_4) in all test samples unless the current inhibitor process already meets this residual; and
- (D) The addition of an orthophosphate-based corrosion inhibitor at a concentration sufficient to maintain an orthophosphate residual concentration of 3 mg/L (PO_4) in all test samples unless the current inhibitor process already meets this residual.

NOTE: this is a minimum list of items that must be tested, not a list of approved treatments.

Switching Corrosion Treatment without Trigger

Any water system shall notify the State in writing pursuant to § 141.90(a)(3) of any upcoming long-term change in treatment or addition of a new source as described in § 141.90(a)(3). The State must review and approve the addition of a new source or long-term change in water treatment before it is implemented by the water system. The State may require any such water system to conduct additional monitoring or to take other action the State deems appropriate to ensure that such water system maintains minimal levels of corrosion control in its distribution system.

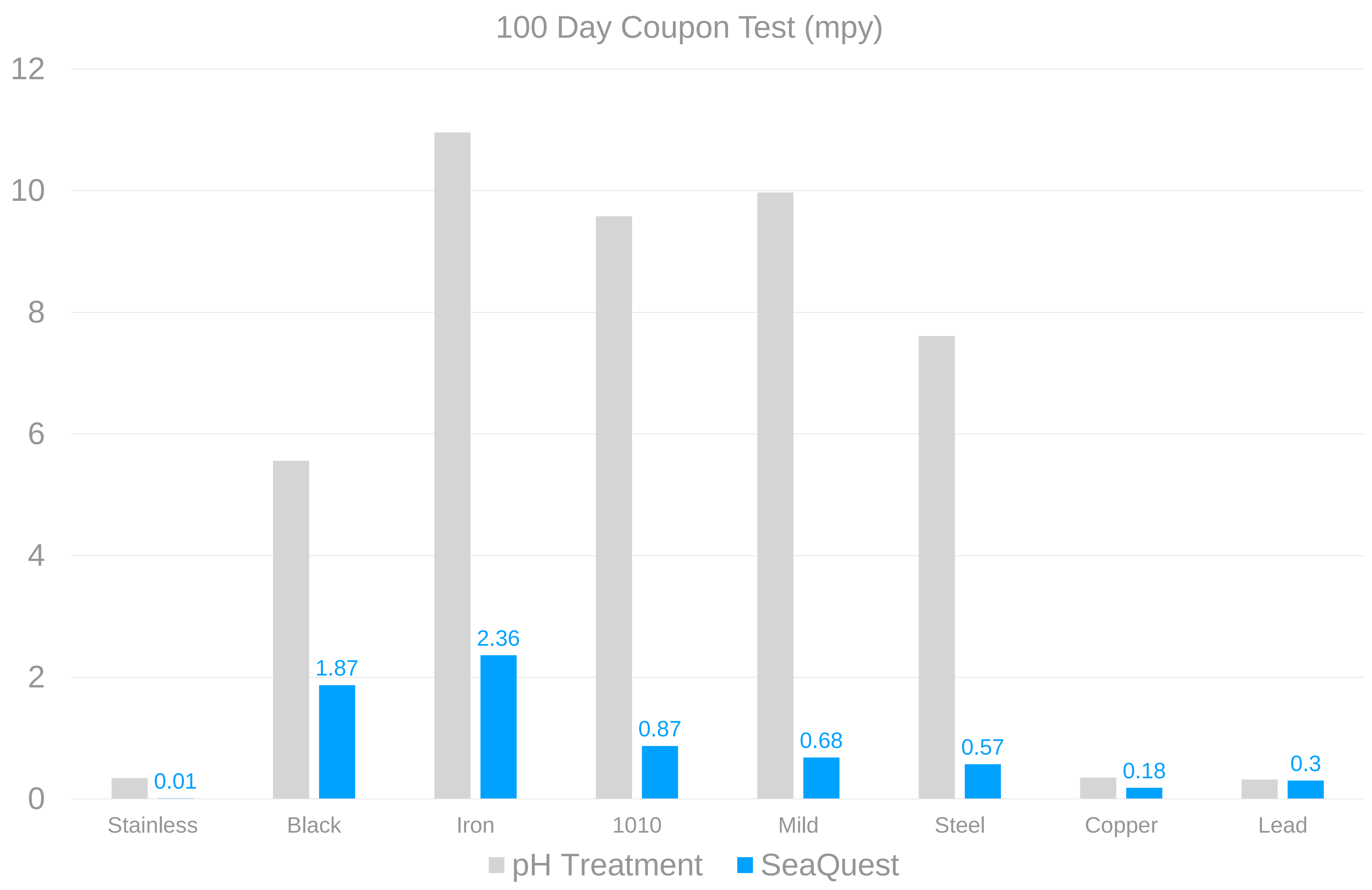
If a water system has notified the State in writing in accordance with § 141.90(a)(3) of an upcoming addition of a new source or long term change in treatment, the water system shall monitor every six months at the standard number of sites listed under paragraph (c) of this section until the system is at or below the lead and copper action levels for two consecutive six-month monitoring periods, unless the State determines that the addition of the new source or long term change in treatment is not significant and, therefore, does not warrant more frequent monitoring. Systems that do not exceed the lead and copper action levels, and/or the lead trigger level for two consecutive six-month monitoring periods may reduce monitoring in accordance with paragraph (d)(4) of this section.

SEAQUEST

Lead Data

AQUASMART INC

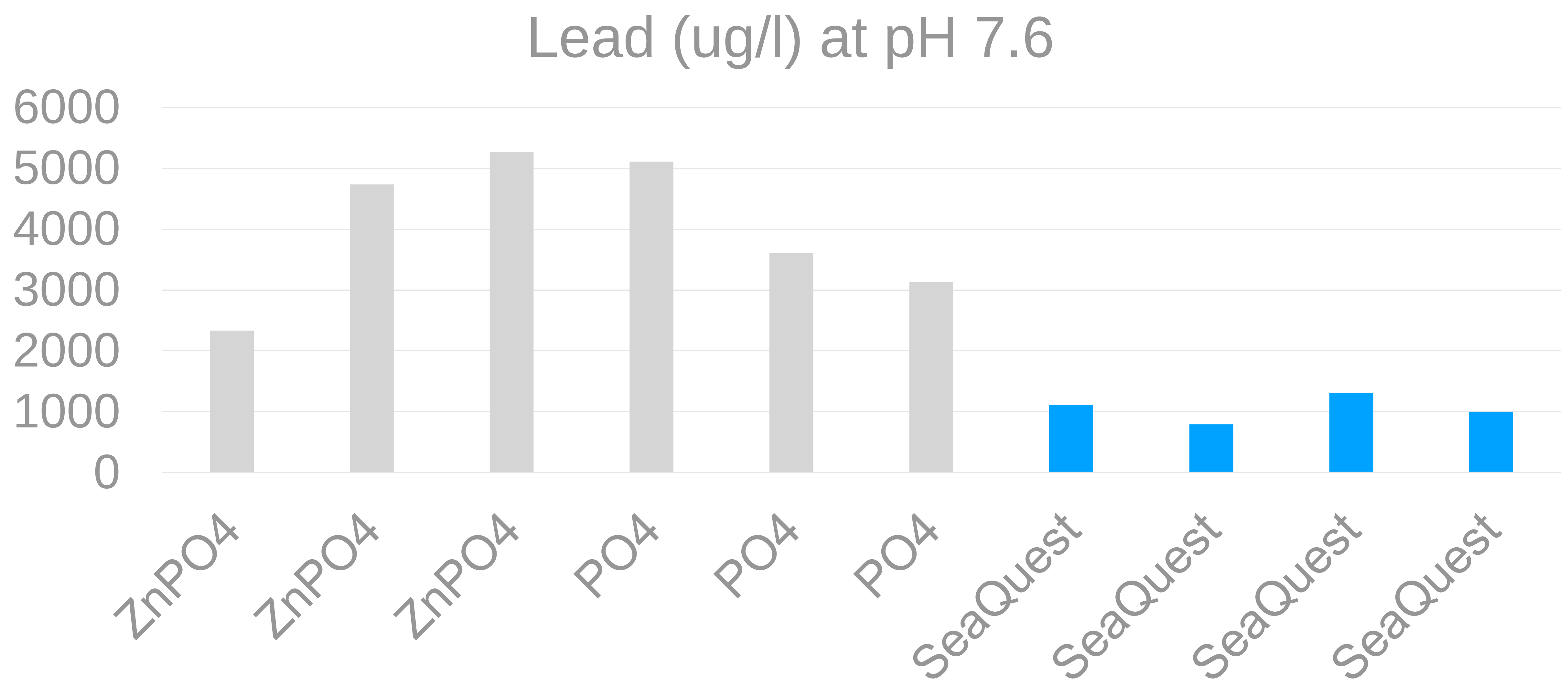
Example Corrosion Coupon Study

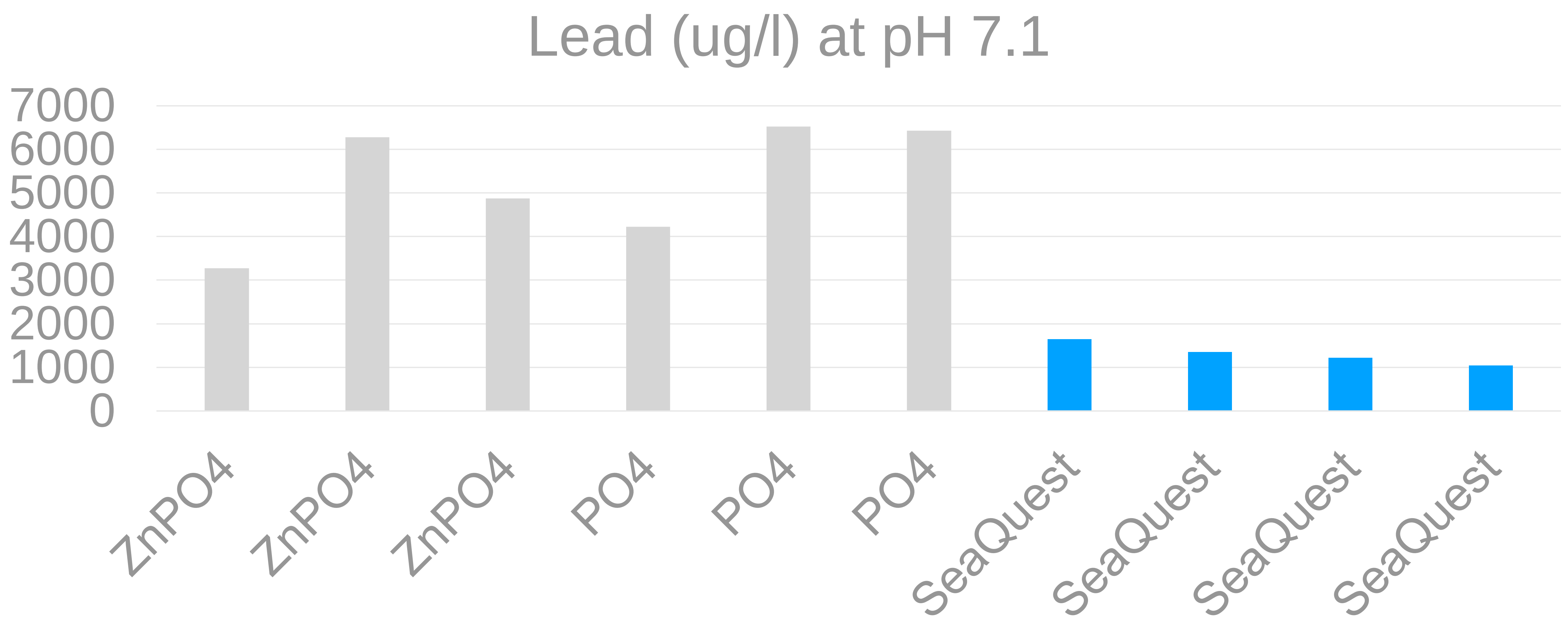


SeaQuest performs well in corrosion coupon studies.

In the proposed lead/copper rule, these studies can be used instead of a full pipe loop in certain areas to justify CCT changes.

17 Day Coupon Soak Test





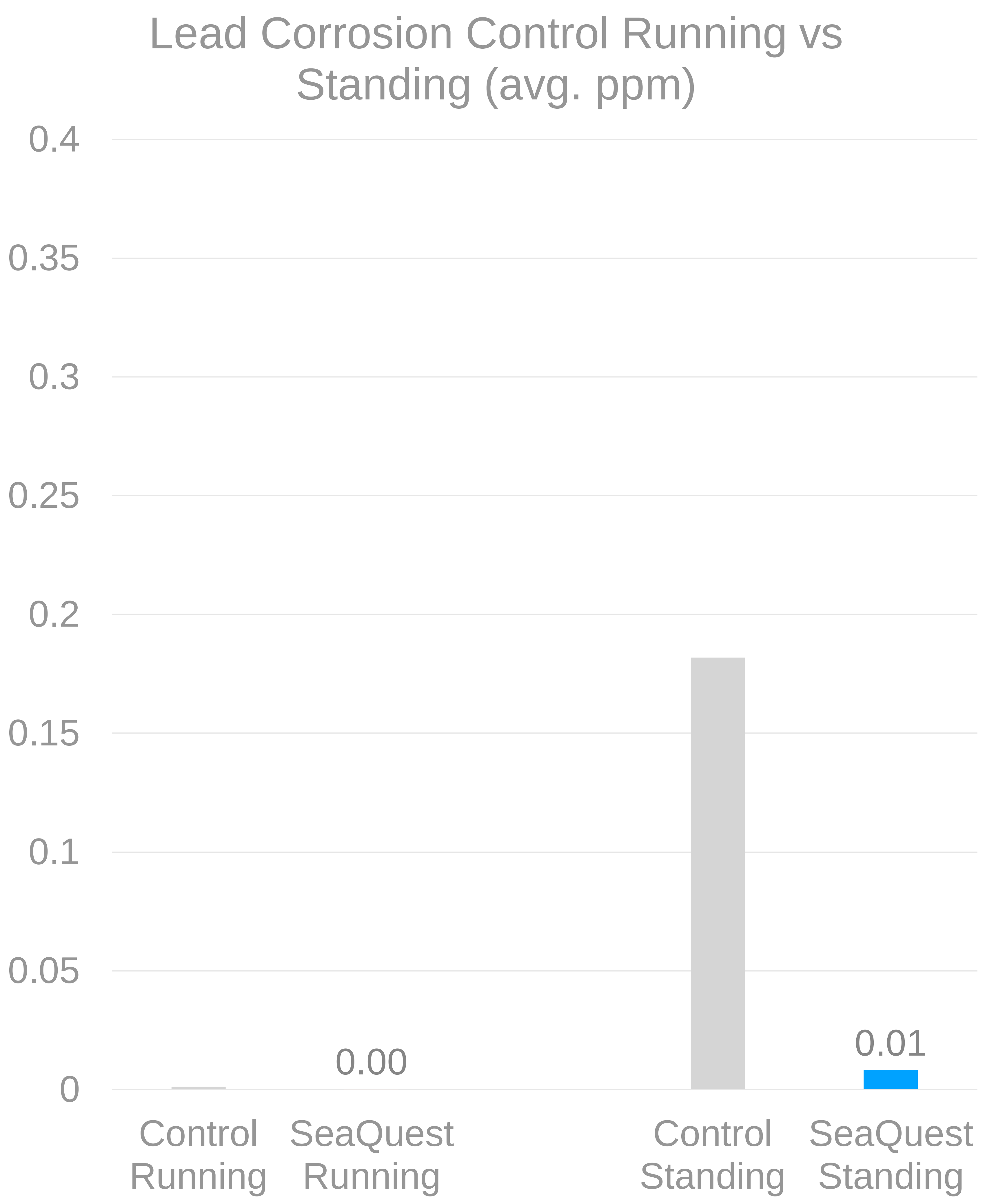
SeaQuest performs well in soaked coupon tests, which are more aggressive than standard coupon tests.

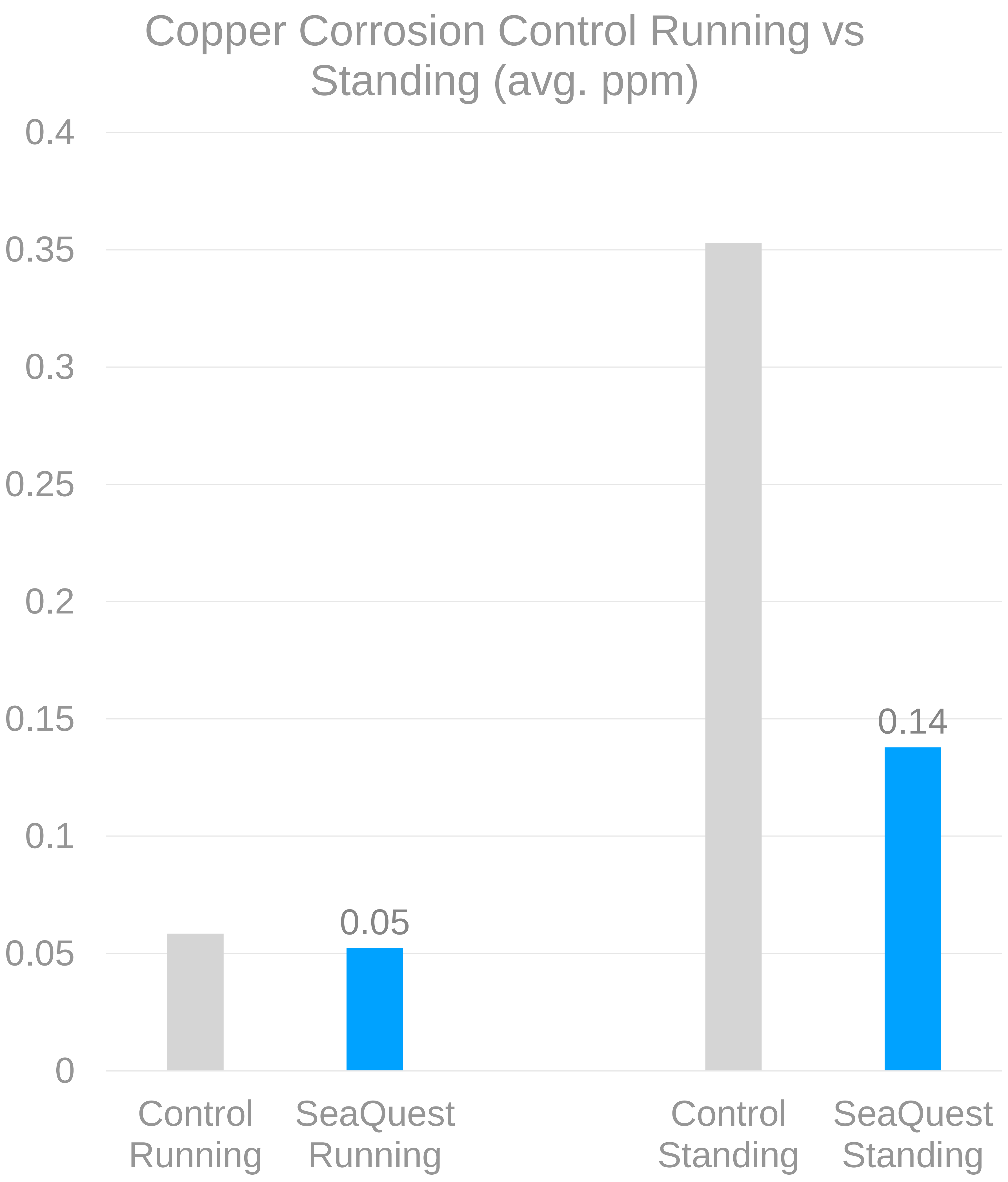
In this test, the SeaQuest shows better control of lead leaching than orthophosphate and zinc phosphate.

The doses range from 0.5-2.0 mg/l for the phosphate and 0.5-5.0 mg/l for the SeaQuest.

The SeaQuest outperforms all doses of both phosphates at both pH conditions, even at a low dose of 0.5 mg/l.

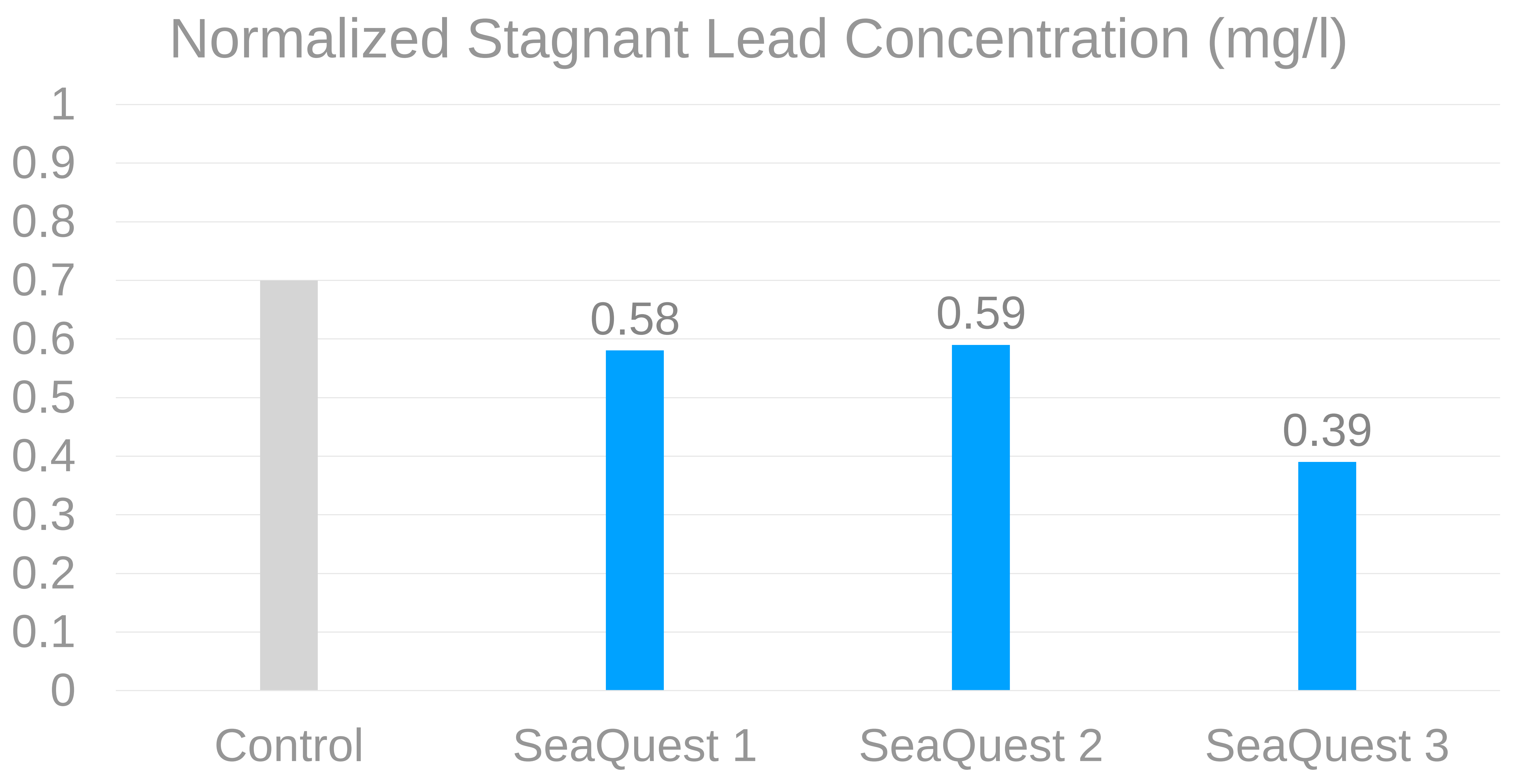
Standing vs Running Pipe Loop Testing





This test shows the difference between a standing and running pipe loop test, and how SeaQuest (dosed at 0.5 mg /l) controls both copper and lead better than zinc ortho phosphate (control dosed at 2.0 mg/l)

Lead Solder Pipe Loop Testing

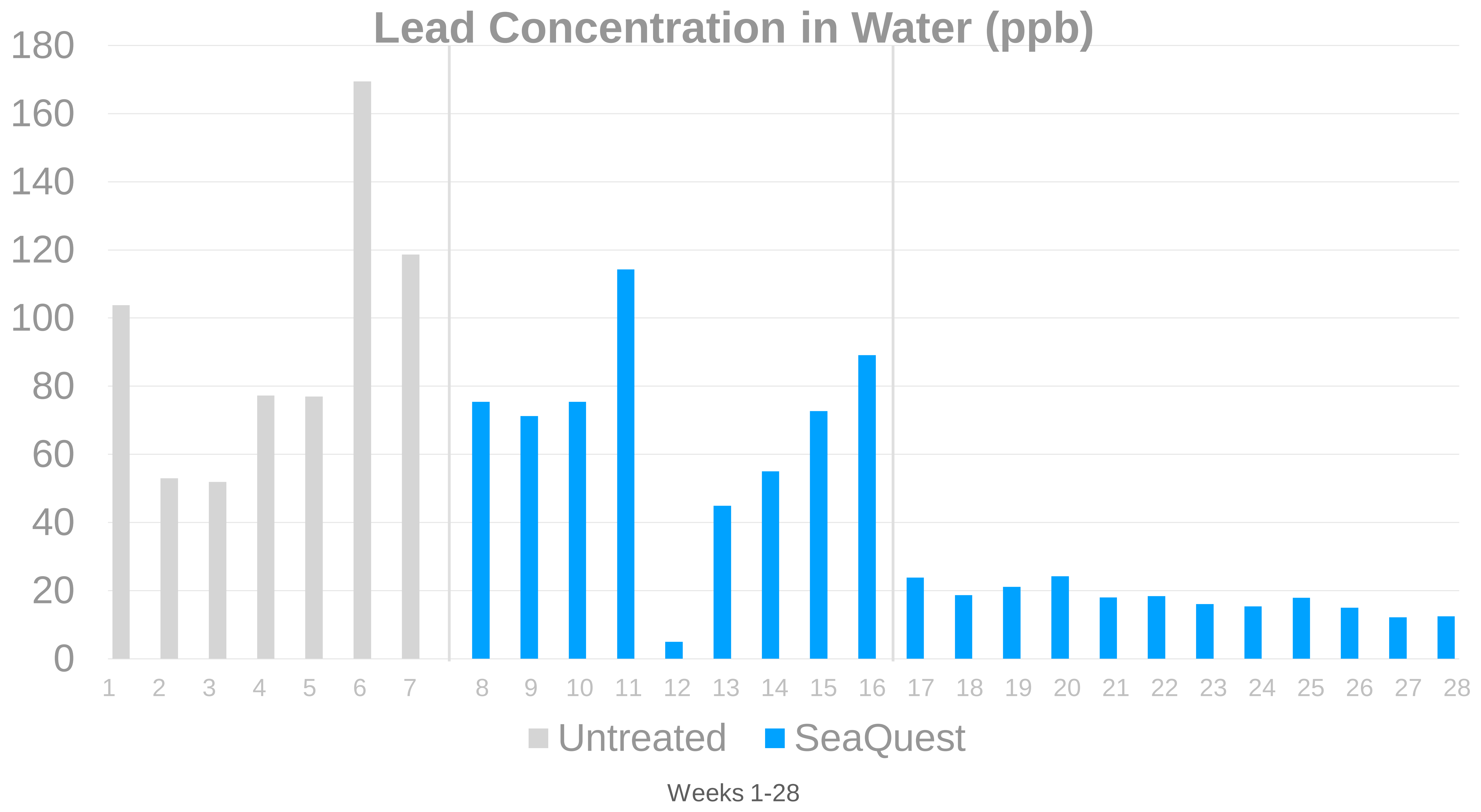


This test shows the effect of SeaQuest vs orthophosphate at controlling lead release from lead solder, typically found in homes.

SeaQuest loop 3 shows effectiveness at low dose and at natural pH.

Conditions	Procedure
Loop 1 = 2 ppm Ortho, pH 7.2-7.4	a. 2 Weeks conditioning at pH 7.2-7.4
Loop 2 = 0.6 ppm SeaQuest, pH 7.2-7.4	b. 30 Days treatment at baseline current conditions (2 ppm ortho, pH 7.2-7.4)
Loop 3 = 0.6 ppm SeaQuest, pH 7.2-7.4	c. Lead analyzed during conditions for baseline to normalize data
Loop 4 = 0.6 ppm SeaQuest, pH 6.8	d. Stagnant for 6- and 24-hour periods to simulate home use for 90 days ; 23 24hr samples, 6 6hr samples

Harvested Lead Pipe Single Pass

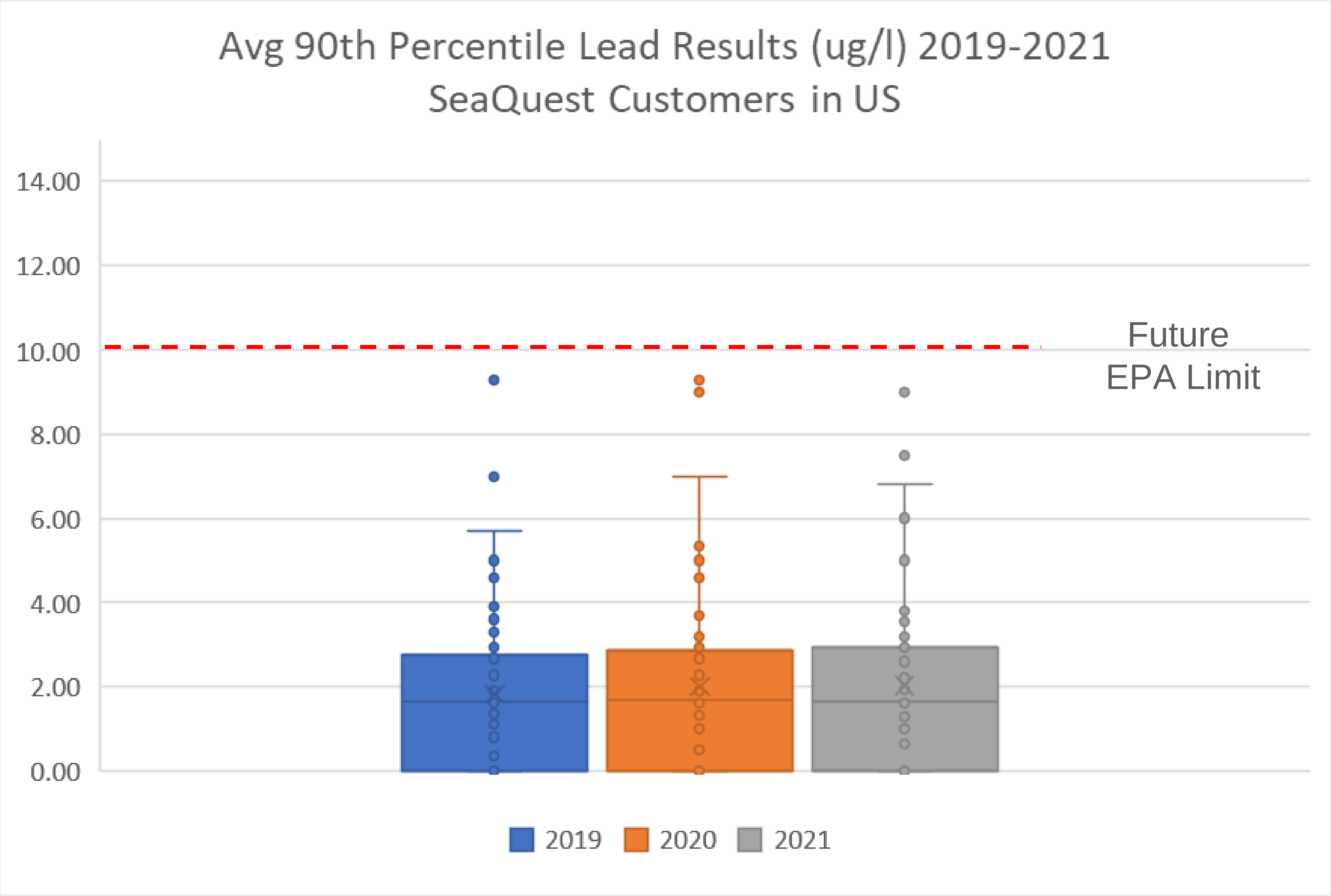


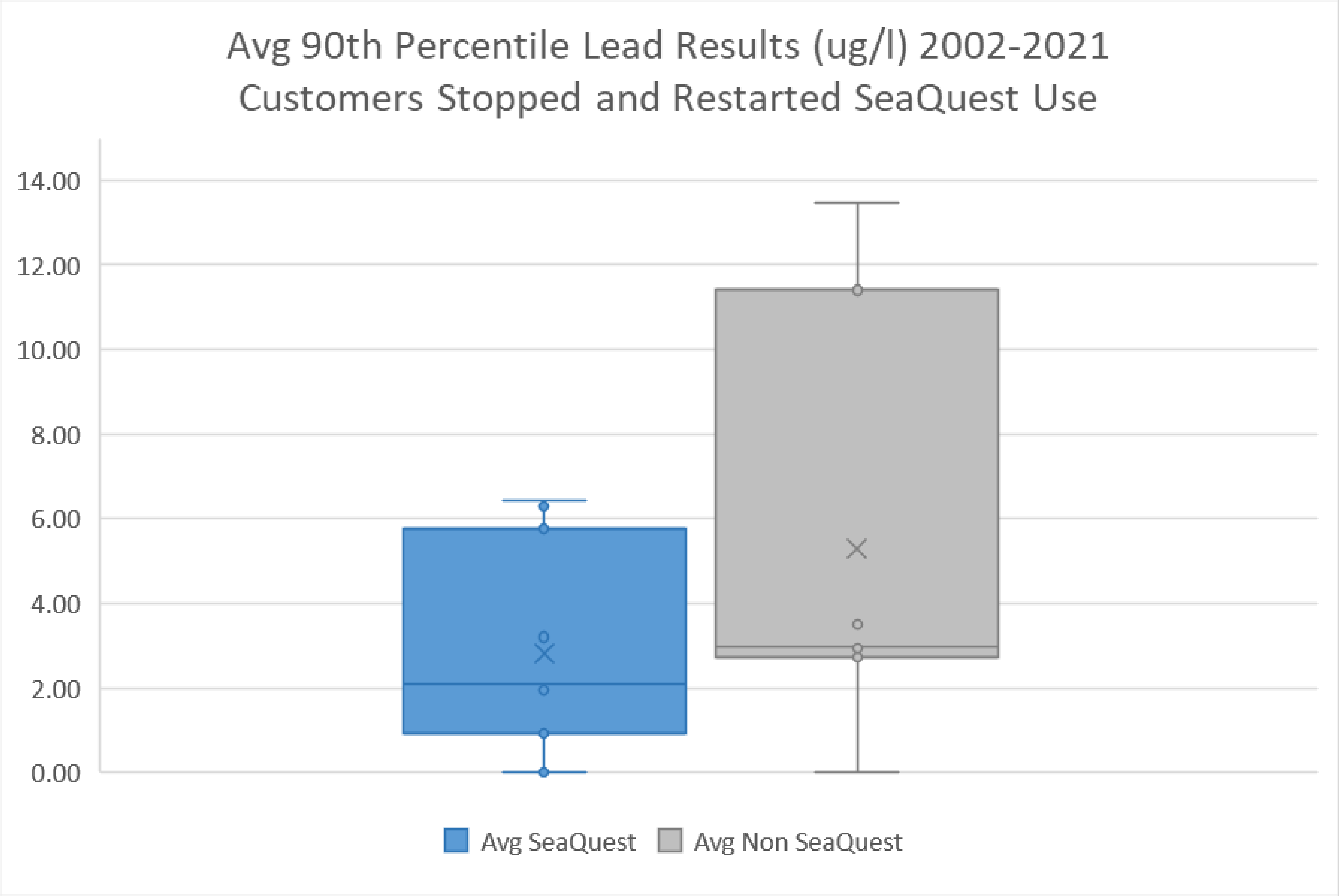
A lead pipe previously treated with orthophosphate was harvested from the field and run through a single pass pipe loop.

- The first 7 weeks untreated water averaged 91 ppb
- The next 9 weeks SeaQuest treated water averaged 67 ppb
- The final 12 weeks SeaQuest treated water averaged 18 ppb

What this test shows is the effect SeaQuest can have in establishing control over a lead pipe, and that during the changeover from ortho-phosphate to SeaQuest there is not significant lead release.

Lead Results of SeaQuest in the US 2002-2021

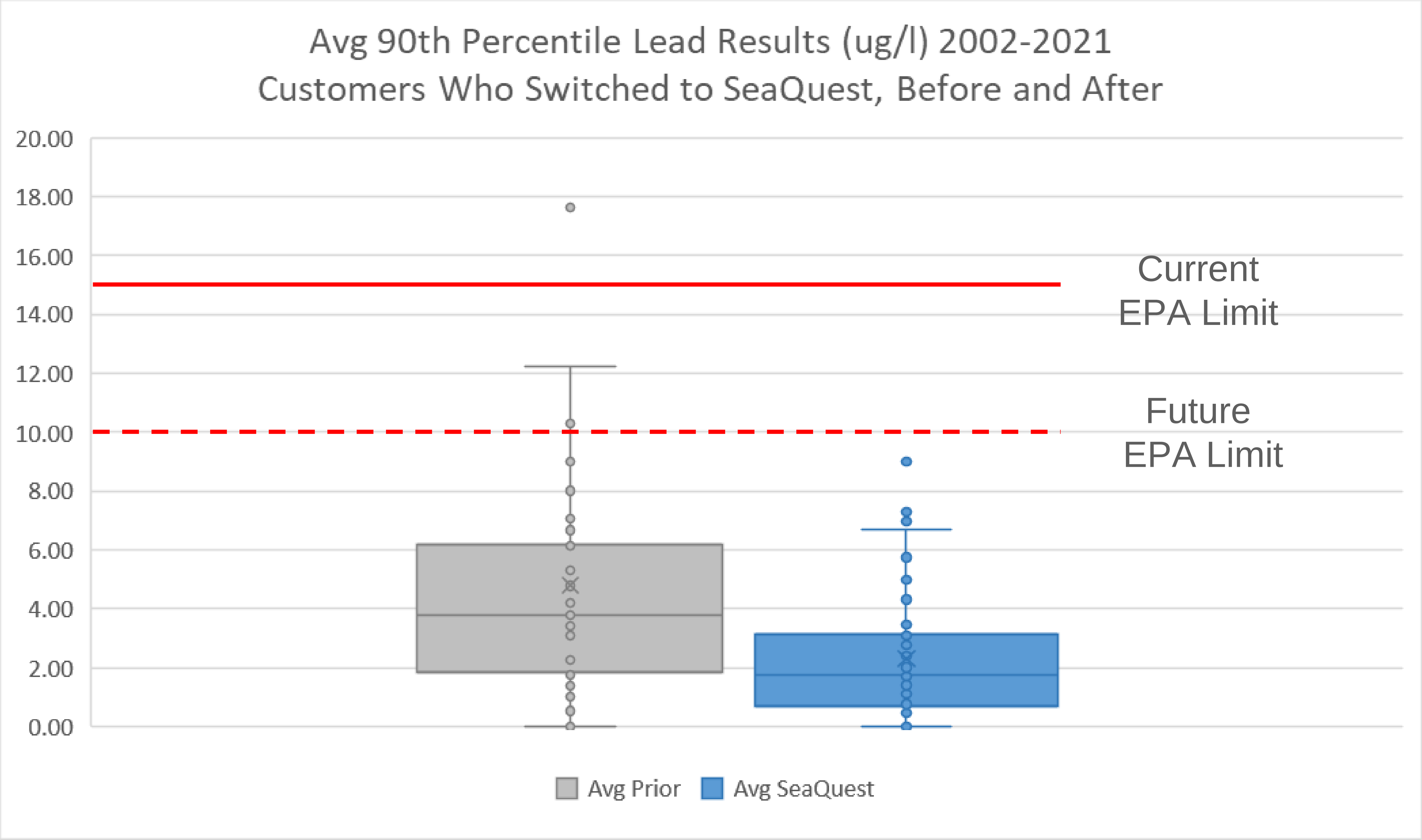


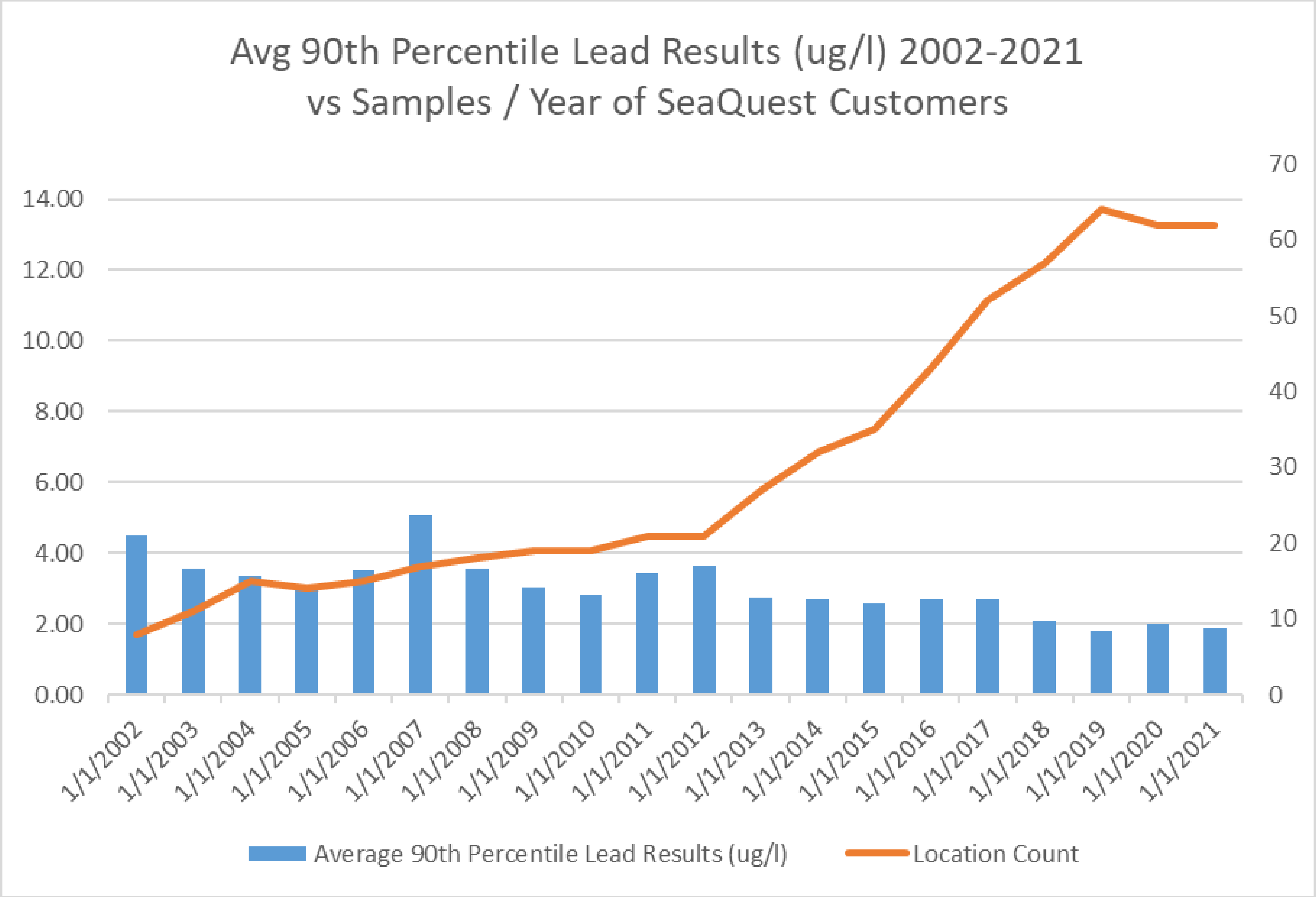


Current users of SeaQuest are all in compliance with future lead & copper rule requirements

Customers who stopped using SeaQuest were able to regain performance after starting again

Lead Results of SeaQuest in the US 2002-2021





63 customers were sampled who switched to SeaQuest from a different corrosion inhibitor since 2002:

- Average 90th percentile lead concentrations were reduced from 4.8 ug/l to 2.3 ug/l

87 customers were sampled who used SeaQuest since 2002:

- Average 90th percentile lead concentrations remain compliant and are continuously reduced