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CONTAMINANTS OF CONCERN:
Managing Lead and Manganese

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Corrosion Control

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Webinar Moderator

Kimberly Gupta

Water Supply and Treatment Manager

Portland Water Bureau

Kimberly is the Water Supply and Treatment Manager for the Portland Water Bureau where she has worked for the past 9 years. She has approximately 18 years of experience in the drinking water industry working for large utilities on projects related to drinking water treatment, DBP formation, emerging contaminants, and distribution system issues such as nitrification and water age management. Kimberly has a master's degree in Civil/Environmental Engineering and is a licensed professional civil engineer in both Oregon and California. Kimberly is the Chair of AWWA's Inorganic Contaminants Research Committee and an active member of AWWA's distribution system committee.

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Panel of Experts

France Lemieux
Head of the Materials and Treatment Section
Health Canada's Water and Air Quality Bureau

Bofu Li

Dalhousie University

Melinda Friedman
President
Confluence Engineering Group, LLC

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Agenda

I. **Considerations in Updating the Corrosion Control Guidance Document**
France Lemieux, Health Canada Water and Air Quality Bureau

II. **Evaluation of Phosphate- and Silicate-Based Corrosion Inhibitors using a Pilot-Scale Distribution System**
Bofu Li, Dalhousie University

III. **Impacts of Changing from Surface Water to Groundwater on Lead Behavior – A Desk-Top and Pipe Rig Case Study**
Melinda Friedman, Confluence Engineering

Time Permitting – Q&A

Enter your **question** into the **question pane** at the lower right-hand side of the screen.

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Health Canada Santé Canada

Canada

Considerations in Updating Corrosion Control Guidance

France Lemieux
Water and Air Quality Bureau
Health Canada
International Symposium on Inorganics
Webinar
May 22, 2020

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Presentation Outline

- History
- Current guidance document
- Driver for change
- Revised lead guideline
- Focus of Corrosion Control update
- What's new and being considered
- Lead variability and total lead exposure*
- What's next?

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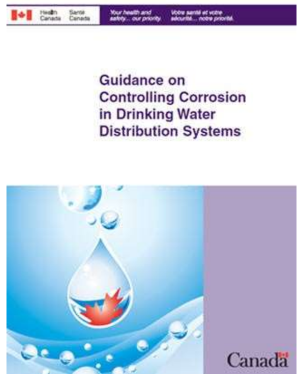
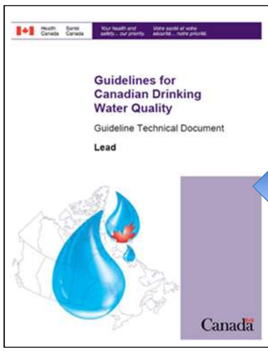
A little bit of history….

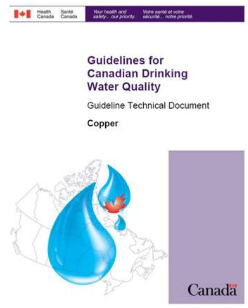
Consultation on corrosion control guidance document began in 2007; Final document published in 2009





Lead guideline published in March 2019

Copper guideline published in June 2019



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2009 Guidance on Corrosion Control

- Guidance
  - Corrosion control programs and protocols (residential and non-residential buildings)
  - Supporting information
- Principles of corrosion
  - Main contaminants (lead, copper, iron)
  - Sources (materials)
  - Factors that affect lead levels at the tap i.e., pH, alkalinity, stagnation, flushing, materials
- Methods for measuring corrosion
- Treatment/control measures for Pb, Cu and Fe

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2009 Corrosion Control Guidance (2)

- Identifies that contaminants could accumulate in and be released from the distribution system from changes in:
  - treatment processes
  - hydraulic regime and/or
  - water quality (i.e., pH, alkalinity and ORP)

- Action Levels and sampling protocols intended to reduce exposure to lead through corrosion control
- Intended to complement lead guideline, not replace it

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What's driving the need for change?

- Corrosion guidance based on previous MAC for lead (10 ppb) developed in 1992
  - Revised lead guideline published in March, 2019
- New information on corrosion control sampling and strategies
- Distribution system impacts recognized in guidelines for other metals
- New copper guideline published in June, 2019

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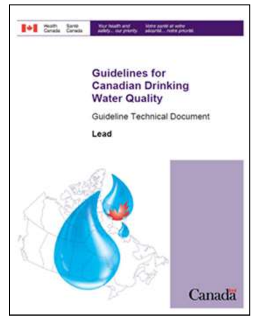
Revised guideline for lead

- Maximum acceptable concentration (MAC) of 0.005 mg/L (5 ppb)
- Sampling for typical exposure
  - At population level
- Includes:
  - Factors affecting exposure
  - Sampling considerations
  - Lead variability (particulate/dissolved)
  - Monitoring considerations



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Refresher -Health Effects

- Lead internationally accepted as non-threshold toxicant by many agencies (Health Canada, U.S. EPA, CDC)
  - no safe level established for Pb in children's blood

  Lead exposure is associated with many health effects but decreased IQ is considered the critical effect:
  - Strongest evidence for a causal effect
  - Children were affected at the lowest blood lead levels studied

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Refresher - Exposure

- Lead in drinking water needs to be measured at the tap
- Lead service lines can contribute at least 50–75% of lead in drinking water
  - Leaded brass and lead solder can also be important sources of lead in drinking water, especially in buildings
- Lead levels can be highly variable

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Sampling considerations

- Different sampling protocols will achieve different objectives
  - Some may achieve more than one objective
- Sampling protocol depends on objective
  - Exposure
  - Investigative/diagnostic
  - Treatment performance
  - Compliance

- Sampling protocol should capture
  - Variability → because exposure varies
  - Total lead → dissolved and particulate fractions

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Factors affecting lead release

- Many factors affect lead release but typically differ for particulate vs. dissolved
- Dissolved lead release
  - Water quality
  - Surface area of lead surface (pipe length, diameter)
  - Stagnation time of water
  - Release of dissolved lead is reasonably well characterized
- Particulate lead release
  - Physical disturbances (hydrant flushing, road work, etc.)
  - LSL replacement (full or partial)
  - Galvanic corrosion
  - Hydraulic disturbances and transport of particles

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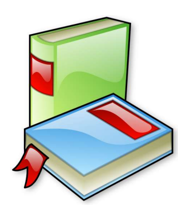
Focus of Update to Corrosion Guidance

- Protocols for assessing corrosion control
  - primary focus on Pb
- Re-evaluate document in light of revised Pb MAC
  - complementary approach
- Update information on optimizing and implementing corrosion control
- Include newest available information on orthophosphate, silicates, etc.
- Update information on monitoring



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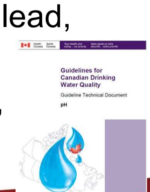
Focus of Update (2)

- Evaluate if 90th percentile/action levels still appropriate
- Update information on sampling for different objectives
  – expand RDT sampling information and UK experience
- Update information for lead, copper and iron
- Address impacts of accumulation and release in distribution system

What’s new since 2009?

- Included accumulation/release of metals in guideline documents on:
  - cadmium
  - chromium
  - lead
  - manganese
  - strontium
  - uranium
- Revised pH document (pH 7-10.5) in recognition of corrosion impacts and treatment effectiveness
- Clearly identified need to monitor at the tap for lead, copper and other metals
- Identified role of nitrification on pH in ammonia, nitrite/nitrate and chloramines documents



Correlation between particulate lead and metals

- Metals can accumulate on top of iron and lead in distribution system
- Iron (Fe) and manganese (Mn) scales accumulate lead
  - Fe and Mn scales can be released after full or partial LSL replacement

- Increased release of particulate lead
- Red water/discolouration events result in release of metals such as lead
  - Need to monitor these events as they are not innocuous!

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What else will be included in the revision?

- Reinforcing the need for monitoring in the distributed water
- Emphasis on the need to address discolouration events
  - indicator for the potential release of contaminants (radiological and metal)
- Strengthen information on issues impacting water quality:
  - Impacts of pH on distribution system water quality
  - Importance of pH in corrosion control
  - Role of nitrification on pH
  - Role of NOM on distribution water quality

Holistic approach needed - integrating and addressing key related issues identified in other documents!

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Monitoring

- Address residential sites
  - Single family homes
  - Multi-dwelling residences
- Needs to consider practicality/customer acceptability
- Should include buildings and schools
  - Capture vulnerable population
  - Different challenges (fittings, faucets, bubblers)
- Should address variability, building type, seasonal differences, occupancy/water use
- Target high risk areas/zones

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Monitoring considerations

- Sampling type, locations and number
  - Identify priority sites & locations
  - Homes with LSLs (full or partial) should be prioritized
  - Guidance on site selection when can't sample homes with LSLs
- Protocol for large buildings and schools
  - Difficult to assess 'representative' sample
  - Needs be practical/realistic for large buildings and schools

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Sampling results

- What does a sample result tells you depends on how it was taken
- 6 hours first and second draw
- 30 minutes first and second draw
- 5 minutes fully flushed samples
- Random daytime
- Profiling sampling after 30 min and 6 hour stagnation

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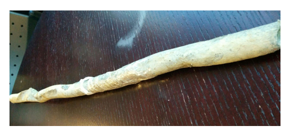
Strategies to reduce lead



- Full lead service line replacement is best approach
- Partial lead service line replacement reduces lead
  - May cause release of lead for several months
  - Reduction may not mirror percentage of line removal
- Corrosion control
  - May not be sufficient to reduce lead concentrations when water is supplied through a lead service line

Lead

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Strategies to reduce lead (2)

- Use low lead materials that comply with NSF 372 and NSF 61 for plumbing and distribution systems
  - May be difficult and costly
- Filters work well but are a temporary measure
  - Should be certified by third party as meeting the appropriate NSF standard for reducing lead
  - NSF standard now includes reduction to 5 ppb of lead or less
  - Maintenance is essential

Lead

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What's Next?

- Public consultation document expected in early 2021
- Work on revision of iron guideline expected to begin in late 2021

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Questions?

Contact:

France.Lemieux@canada.ca

Stay tuned…. join our email list:

http://www.hc-sc.gc.ca/ewh-semt/water-eau/water_list-liste_eau-eng.php

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Thank you!

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DALHOUSIE UNIVERSITY

Evaluation of silicate- and phosphate- based corrosion inhibitors using a pilot-scale distribution system

Bofu Li, Benjamin Trueman and Graham Gagnon

Civil and Resource Engineering
Dalhousie University

Date 2/10/2020

waterstudies
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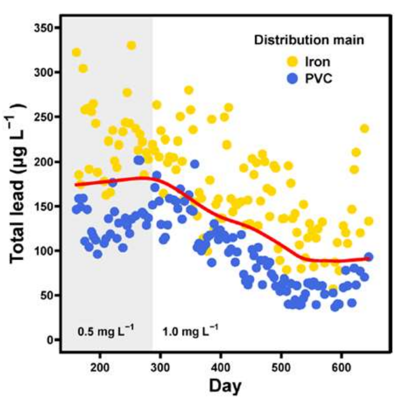
Phosphates in drinking water



(Trueman and Gagnon, 2016)

- **Phosphates are commonly used to control lead release to drinking water**
- **Formation of passive corrosion scales can mitigate lead release**

Trueman, B. F., & Gagnon, G. A. (2016). Understanding the role of particulate iron in lead release to drinking water. *Environmental science & technology*, *50*(17), 9053-9060.

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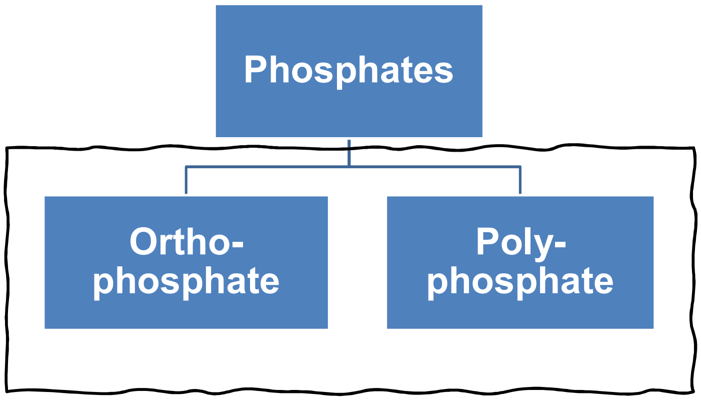
Phosphate classes



Blended phosphates

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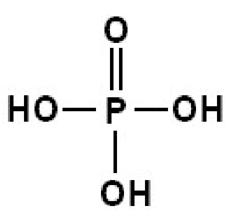
Ortho-phosphate



orthophosphoric acid

- **Contains one PO_4^{3-} unit**
- **Used for corrosion control (e.g., lead)**

(CBC news, 2017)

Figure source: https://en.wikipedia.org/wiki/Phosphoric_acids_and_phosphates
https://www.cbc.ca/news/canada/nova-scotia/how-to-tell-if-there-s-a-lead-pipe-under-your-property-1.4259585

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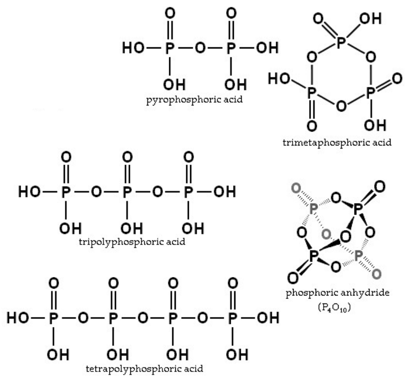
Poly-phosphate

- Contains several PO_4^{3-} units
- Used for sequestration (e.g., Fe and Mn)
- May <u>increase lead release</u>



(Source: www.corrosionguru.com)

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Figure source: https://en.wikipedia.org/wiki/Phosphoric_acids_and_phosphates
https://www.corrosionguru.com/corrosion-and-red-water-in-portable-water-distribution-system/

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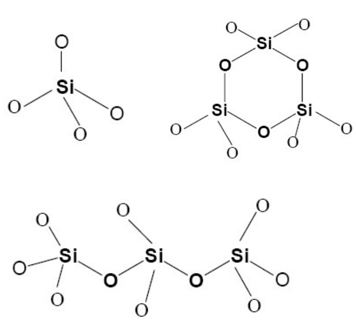
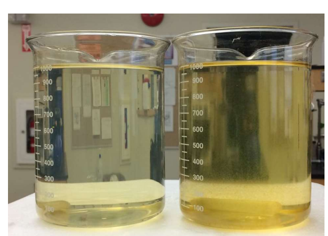
Sodium silicates

- Used for sequestration (e.g., Fe and Mn)
- Occasionally used for lead corrosion control



(Figure source: National Silicates)



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Alternative additives-sodium silicate

Pros

- Decrease in lead release by 55-95%
  (Schock et al., 2005)
- Decrease lead release to below 15 µg/L
  (Lintereur et al. 2010)

Cons

- No effective decrease in lead release
  (Kogo et al., 2017)
- Phosphate yielded significantly lower lead release than sodium silicate
  (Woszczynski et al., 2015)

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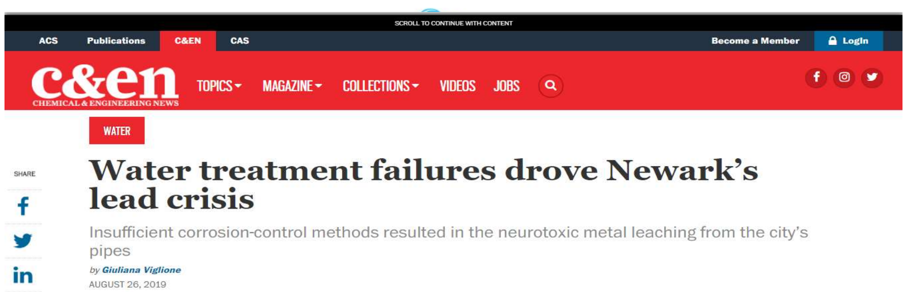

"The Pequannock Water Treatment Plant, which provides more than half of the city's water, had been using sodium silicate as a corrosion inhibitor since the mid-1990s. The exact mechanism of how sodium silicate works as a corrosion inhibitor is still unknown."

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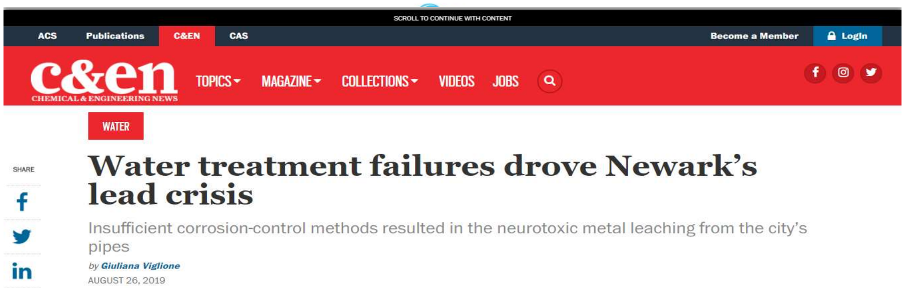
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Water treatment failures drove Newark's lead crisis
Insufficient corrosion-control methods resulted in the neurotoxic metal leaching from the city's pipes
by Giuliana Viglione
AUGUST 26, 2019

"…experts think it is two-fold.

First, some water experts propose it forms a thin, gel-like layer on the inside of pipes, which prevents corrosion.

The compound also raises the water's pH, making it less corrosive and promoting the formation of insoluble lead-carbonate minerals that end up lining pipes instead of flowing out faucets."

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Objectives

- **Evaluate the effect of sodium silicate on lead release, compared with orthophosphate treatment**
- **Investigate silicates' impact on distribution systems as a whole**

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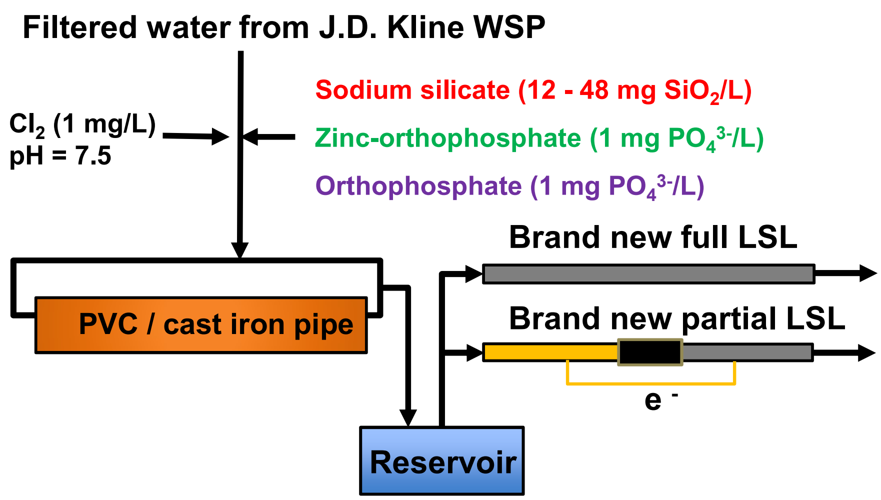
Pilot-scale test at Pockwock lake (Halifax , Canada)



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Experimental design

Distribution main	Corrosion inhibitor	LSL configuration
Cast iron	Sodium silicate	Partial LSL
Cast iron	Orthophosphate	Partial LSL
Cast iron	Zinc orthophosphate	Partial LSL
PVC	Sodium silicate	Partial LSL
PVC	Orthophosphate	Partial LSL
PVC	Zinc orthophosphate	Partial LSL
Cast iron	Sodium silicate	Full LSL
Cast iron	Orthophosphate	Full LSL
Cast iron	Zinc orthophosphate	Full LSL
PVC	Sodium silicate	Full LSL
PVC	Orthophosphate	Full LSL
PVC	Zinc orthophosphate	Full LSL

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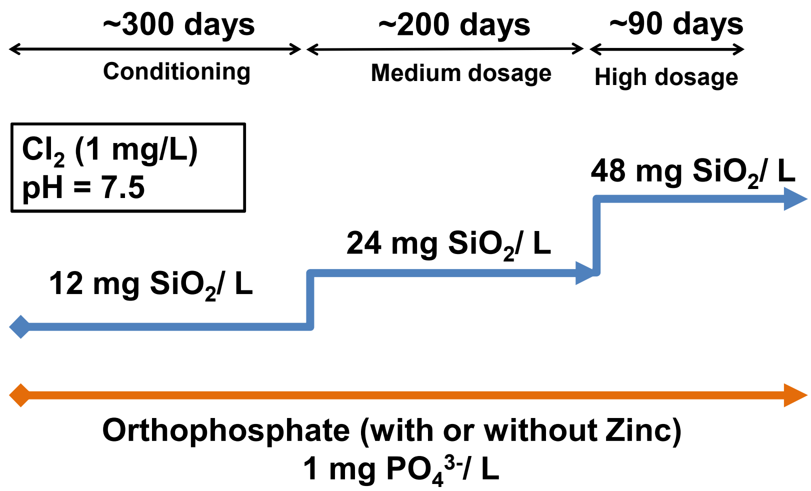
Timeline



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Pilot-scale test results

	Full LSLs (Avg. µg Pb/L)	Partial LSLs (Avg. µg Pb/L)
Sodium silicate* (n >50)	439	630
Zinc-orthophosphate (n >50)	69	88
Orthophosphate (n >50)	80	88

* 24 mg SiO_2/L
Sampling every week

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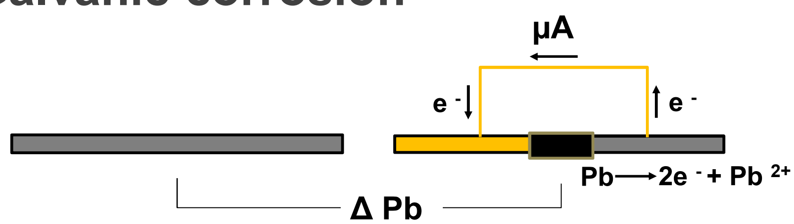
Galvanic corrosion



	Δ Pb (μg Pb/L)	Pb release per μA
Sodium silicate*	191	~100
Zinc-orthophosphate	19	~10
Orthophosphate	8	~10

* 24 mg SiO_2/L

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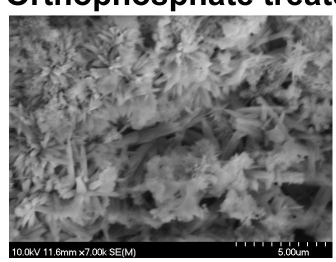
Corrosion scale analysis (SEM & XRD)

Sodium silicate treated

Hydrocerussite
$Pb_3(CO_3)_2(OH)_2$

Orthophosphate treated



Hydroxypryromorphite
$Pb_5(PO_4)_3(OH)$

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WATER

Water treatment failures drove Newark's lead crisis

Insufficient corrosion-control methods resulted in the neurotoxic metal leaching from the city's pipes

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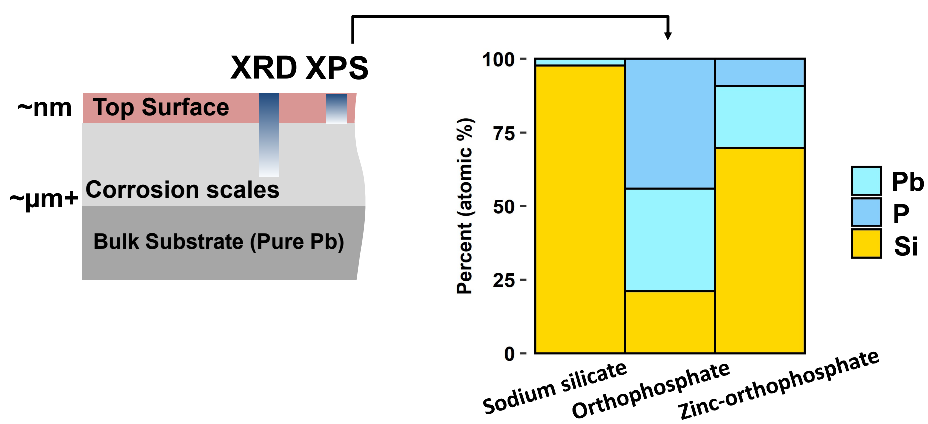
Surface chemistry (XPS)



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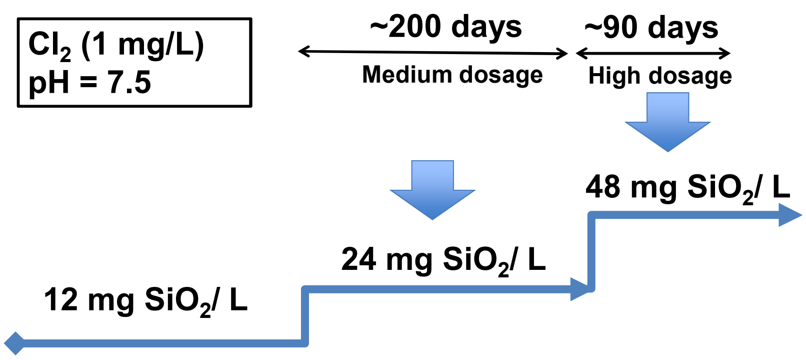
High dosage of sodium silicate



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High dosage of sodium silicate

		24 mg SiO_2 /L	48 mg SiO_2 /L	Δ Pb or Fe
Cast iron	Pb	1003	1508	+505
	Fe	74	155	+81
PVC	Pb	353	456	+103
	Fe	22	45	+23

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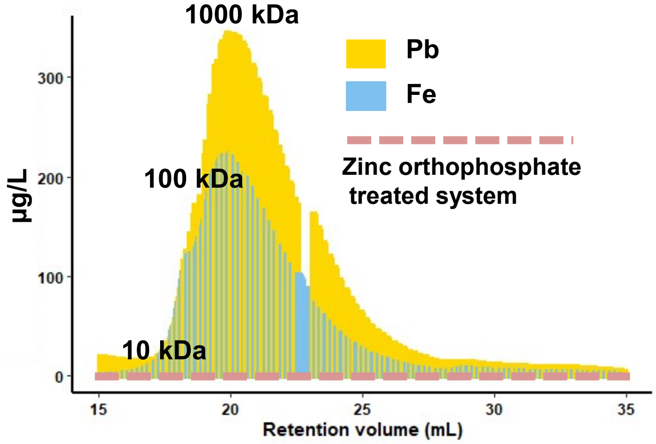
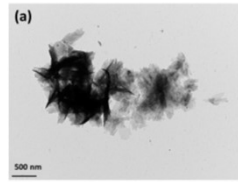
Colloidal Fe and Pb detected by field flow fractionation

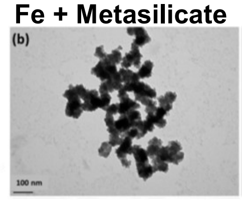


Colloidal Fe and Pb in effluent from silicate or zinc orthophosphate systems supplied by cast iron

Fe



Fe + Metasilicate



(Li et al., 2019)

Li, B., Trueman, B. F., Rahman, M. S., Gao, Y., Park, Y., & Gagnon, G. A. (2019). Understanding the impacts of sodium silicate on water quality and iron oxide particles. Environmental Science: Water Research & Technology, 5(8), 1360-1370.

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Summary

- Independent of pH, sodium silicate cannot maintain lead at an acceptable concentration (compared with orthophosphate treatment)
- We observed a thin silicon-rich coating (~nm), but sodium silicate does not appear to form protective corrosion scale (~µm + depth) with lead directly
- High dosage of sodium silicate may increase colloidal Fe and Pb, especially in systems containing unlined cast iron pipes
- It is worth investigating silicates' impact on recovered lead pipes which are rich in non-lead species (i.e., Al, Ca and Mg)

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Acknowledgments

The research team acknowledges the support from the NSERC / Halifax Water Industrial Research Chair program and its member partners; funding from NSERC Collaborative Research & Development Grant with National Silicates and ColdBlock Technologies; and the scholarship support from the Killam Trusts

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Impacts of Changing from Surface Water to Groundwater on Lead Behavior – A Desk-Top and Pipe Rig Case Study

Melinda Friedman, P.E.
Confluence Engineering Group, LLC
melinda@confluence-engineering.com

AWWA Inorganics Symposium May 22, 2020

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Acknowledgments

- City of Tacoma (Tacoma Water)
  - Kim Defolo
  - Craig Downs
  - Scott Hallenberg
  - Jeremy Banks
  - Mike Gorenson
  - Celine Mina
  - Craig Carrara
  - Mike Shoblom
- HDR Engineering Inc.
  - Pierre Kwan
  - Beth Mende
- Confluence Engineering Group, LLC
  - Anna Vosa (now with Portland Water Bureau)
- University of Washington, Seattle
  - Dr. Gregory Korshin
  - Manjie Li
  - Siqi Liu
- ReiCorr Consulting
  - Dr. Steve Reiber

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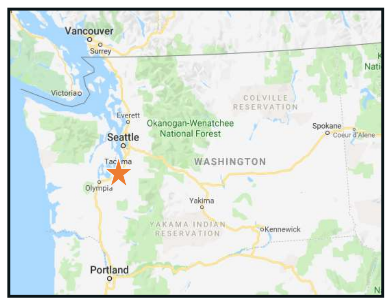
Overview of Tacoma Water System

- 320,000 direct service population, plus 200,000 served through regional partnerships and wholesale customers
- 167 MGD peak treatment capacity from the Green River Supply –
  - Protected 235 mi^2 watershed
  - Conventional Filtration added 2014 (GRFF)
- ~45 MGD supplemental supply from urban groundwater supplies



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Tacoma Water Corrosion Assessment (2016-2018)

- Study Objectives
  - Evaluate current distribution system water quality and corrosion control effectiveness
  - Although considered optimized for decades, identify possible opportunities to further reduce lead levels

Specifically, to assess impact of switching and blending surface water and groundwater on different materials

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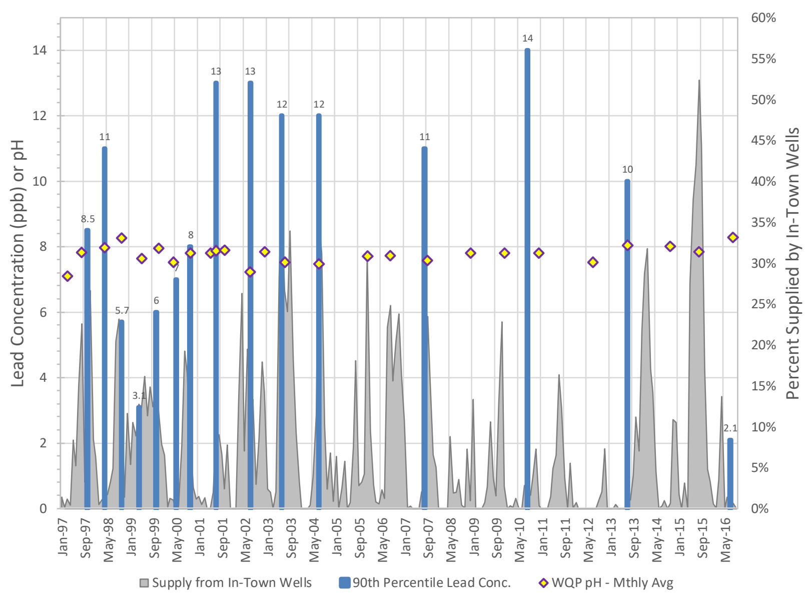
In-Town Well Supply and Lead Levels (1997 – 2016)

- Several factors likely contributed to historically low levels in 2016
  - Covering open reservoirs
  - Filtration of GRFF in 2014
  - Increased pH and chlorine throughout DS
- LCR samples not collected during period of significant GW use since 2007



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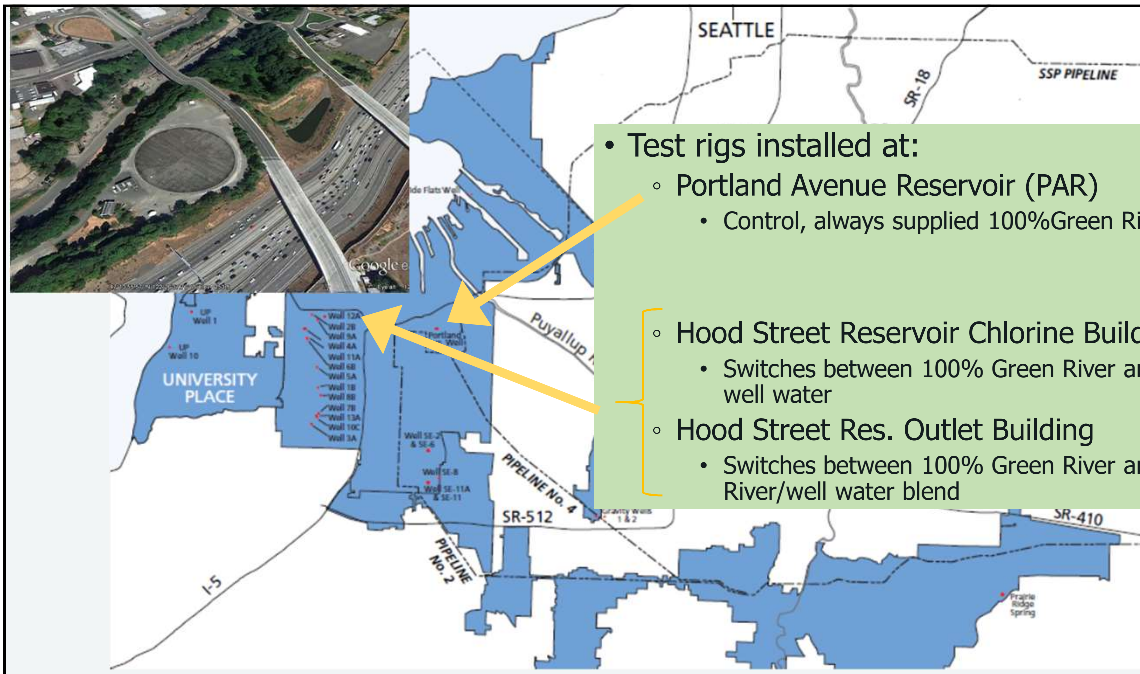

- Test rigs installed at:
  - Portland Avenue Reservoir (PAR)
    - Control, always supplied 100%Green River water
  - Hood Street Reservoir Chlorine Building
    - Switches between 100% Green River and 100% well water
  - Hood Street Res. Outlet Building
    - Switches between 100% Green River and Green River/well water blend

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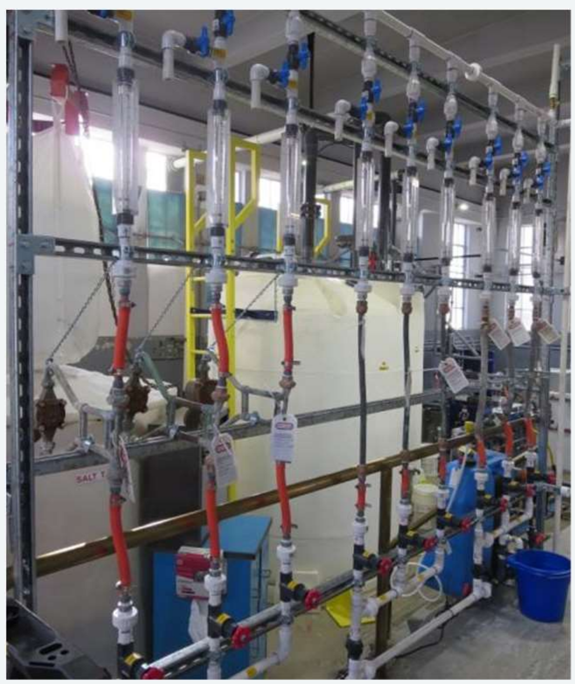
Tacoma Water Pilot Rigs

- Materials
  - Brass meters
  - Copper pipe
  - Lead goosenecks
- Phase 1 – Surface Water (pH ~8.1)
- Phase 2 – Groundwater (pH ~7.4)
- Phase 3 – Surface Water (pH ~8.2)
- Phase 4 – Blends
- Phase 5 – Treated GW (pH ~7.8)



Source: Tacoma Water and HDR Engineering, Inc.

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Water Quality Comparison Summary at Hood Street

Parameter	Surface Water	Groundwater
Free Chlorine (mg/L)	0.7 - 1.1	0.9 - 2.2
pH	8.1 - 8.2	7.4 - 7.8
Alkalinity (mg/L CaCO3)	20 - 27	42 - 98
DIC (mg/L C)	4 - 5	22 - 24
Conductivity (µs/cm)	29 - 45	58 - 125
Chloride (mg/L)	2 - 2.9	3.5 - 9.1
Sulfate (mg/L)	1.7 - 8.3	5.1 - 12.3
Iron (mg/L)	<0.005 - 0.04	<0.005 - 0.03
Manganese (mg/L)	<0.0009 - 0.07	<0.0009 - 0.06

Source: Tacoma Water

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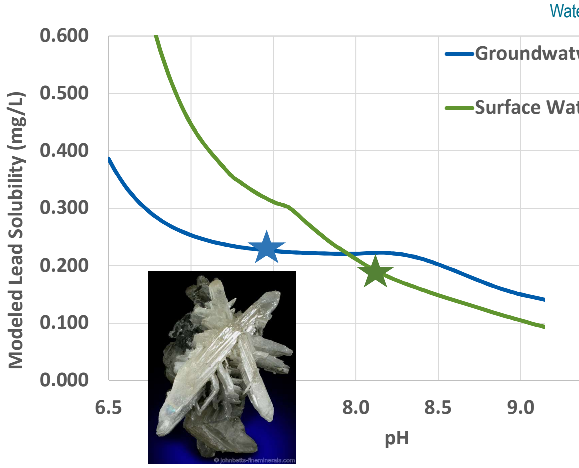
Theoretical Pb Solubility of Surface Water (SW) and Groundwater (GW) Supplies

Source: Confluence project files
WaterPro! 25°C



Cerussite – $PbCO_3$

Source: minerals.net

Hydrocerussite – $Pb_3(CO_3)_2(OH)_2$

Source: gettyimages.net

- GW less corrosive below pH 8
- SW less corrosive above pH 8
- Because of DIC, forming different dominant lead species
  - GW dominated by cerussite
  - SW dominated by hydrocerussite

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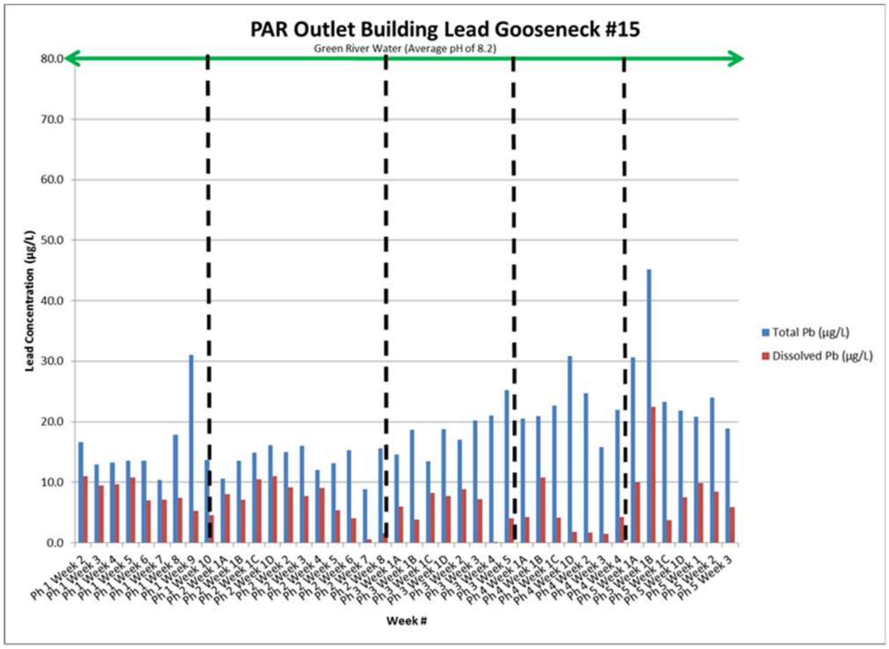
Control Rig:
100% Surface Water



Source: Tacoma Water and HDR Engineering, Inc.

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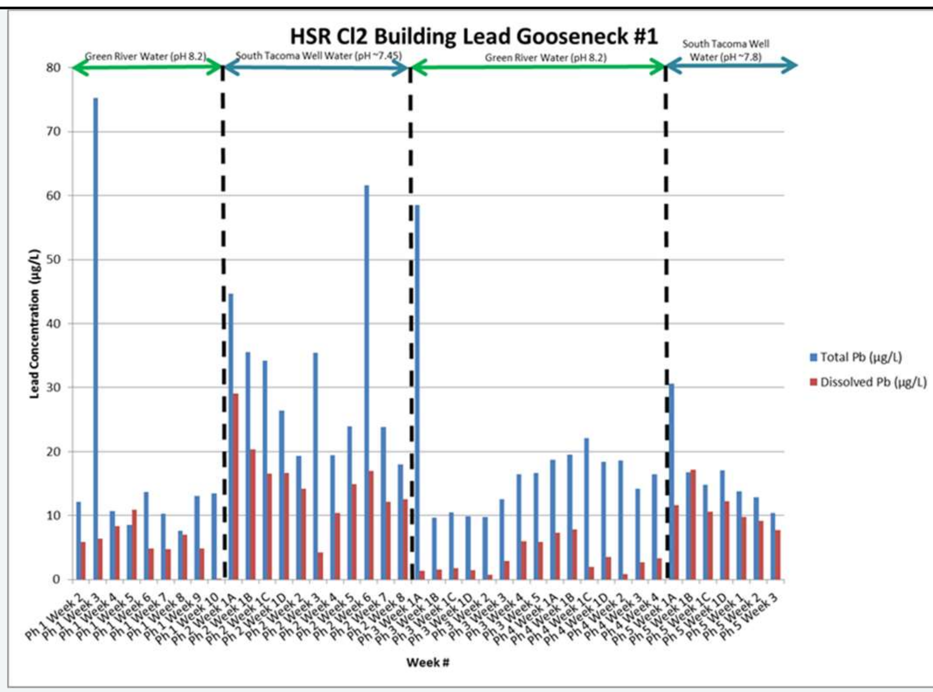
Test Rig:
Alternating SW and GW



Source: Tacoma Water and HDR Engineering, Inc.

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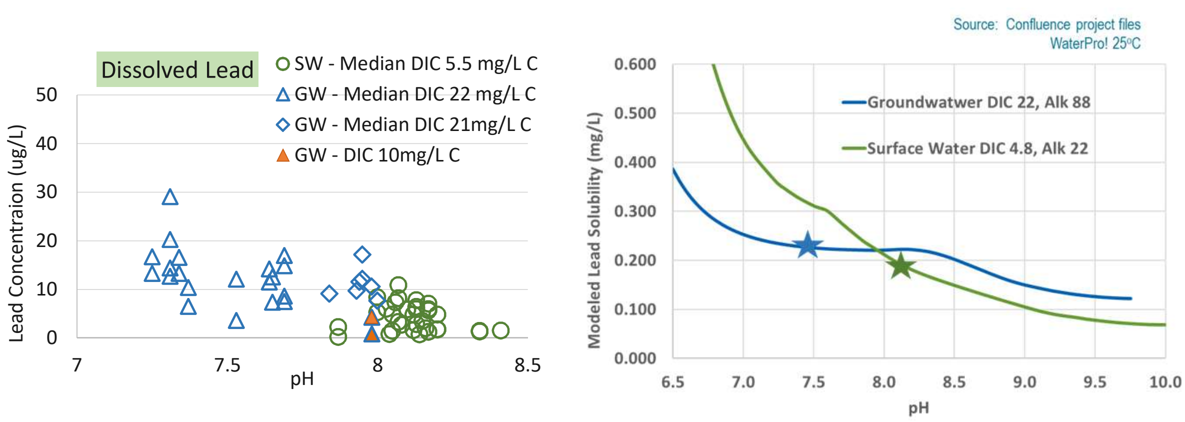
Lead vs. pH – HSR Chlorine Building Rig (GN #1 & #2)



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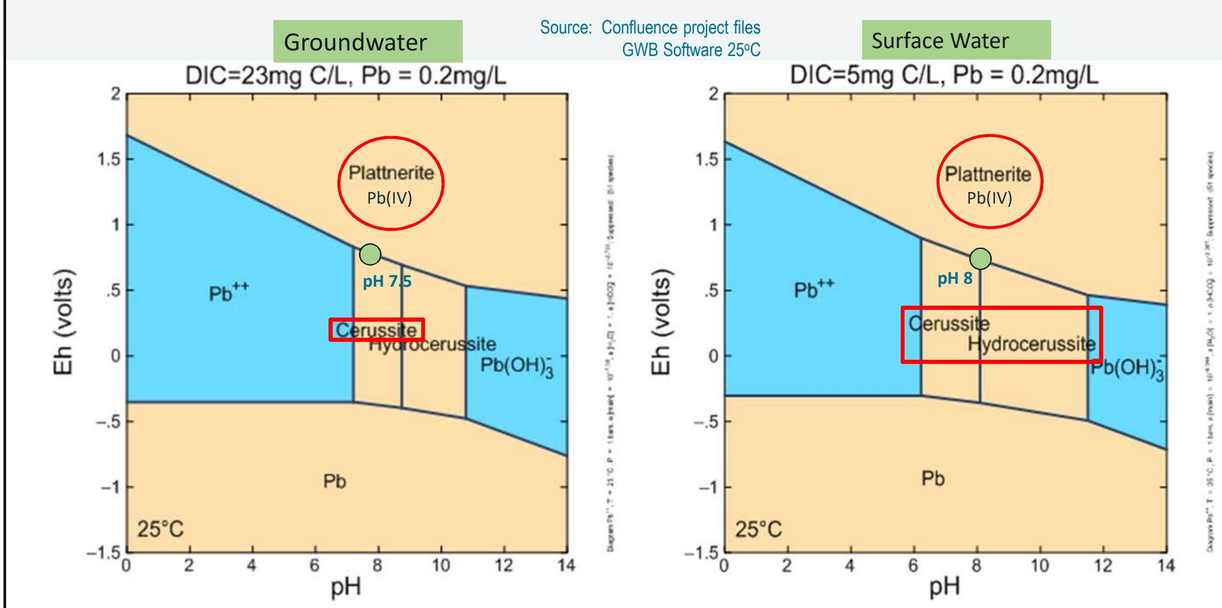
Pourbaix Diagram - Lead Speciation as a Function of ORP, DIC, and pH



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Scale Analysis Procedures

Led by Dr. Gregory Korshin, University of Washington

- Visual examination of internal surfaces of materials exposed to varying water qualities
- Scanning Electron Microscopy (SEM) of pipe coupons sections representing characteristic types of the observed corrosion scales
- Energy Dispersive X-Ray (EDX) analyses performed in some cases simultaneously with SEM
  - EDX can be used to determine the elemental composition of surface scales and map the distribution of representative elements on exposed surfaces

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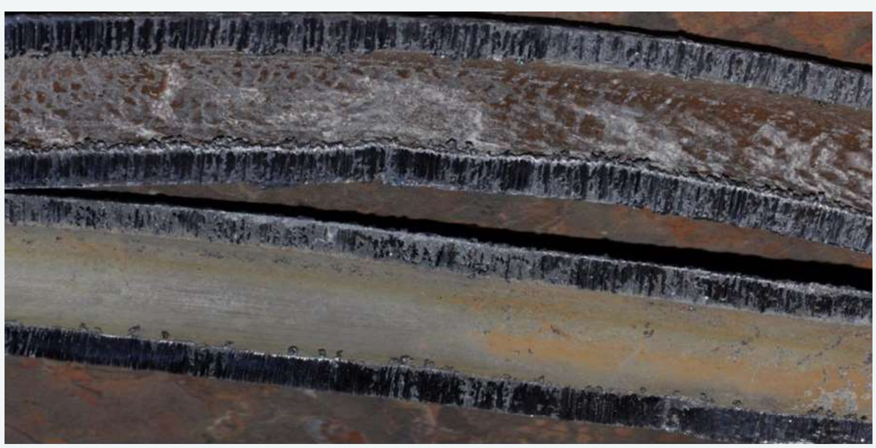
Visual examination of lead gooseneck

Phase 1 – Surface Water

Phase 2 – Ground Water



Source: G. Korshin, U. Washington

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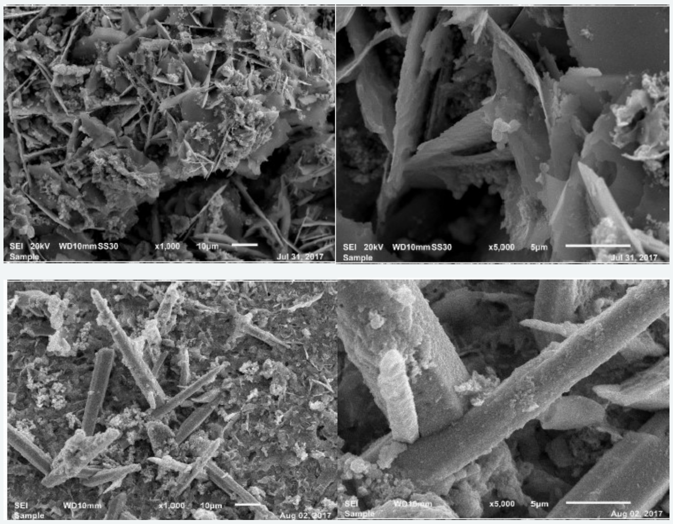
Comparison of Scale Characteristics – SW vs. GW HSR Inlet Cl2 Building



Lead Gooseneck Phase 1 – Surface Water
Scale dominated by Pb(II) hydrocerussite with some Pb(IV)

Lead Gooseneck Phase 2 - Groundwater
Scale dominated by Pb(II) cerussite with some Pb(IV)

Source: G. Korshin, U. Washington

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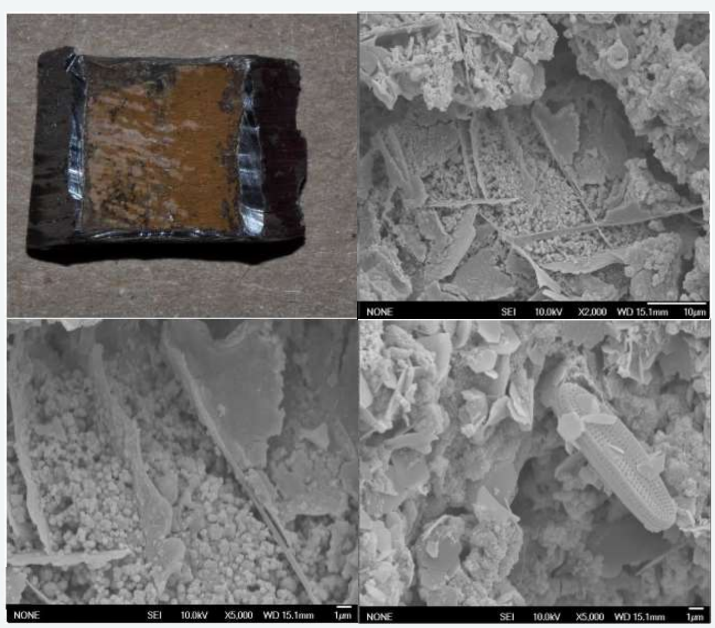
Views of 100% Surface Water Exposed Lead Scale – PAR Outlet Building Control Site



Source: Korshin, U. Washington

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Update – 2019 Lead Results

- Since this study, Tacoma Water has targeted:
  - SW pH ~8.4, Alkalinity ~24 mg/L $CaCO_3$
  - Chlorine residual target 0.8 mg/L throughout DS
  - GW pH ~7.8

- 2019 90th Percentiles for both lead and copper were NON-DETECT!
  - < 1 ppb for lead
  - <0.02 mg/L for copper
- Of 51 samples, only 4 lead detections, highest value was 4.8 ppb
- No groundwater on-line at time of sampling

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Key Findings and Recommendations

- Switching between SW and GW can impact lead release
  - Impacts lead speciation
  - Can increase particulate release
  - Can be very difficult to reach an equilibrium when switching often
- Not enough, or even necessarily appropriate, to just match pH
  - GW and SW will form different species, depending also on DIC and ORP
  - However, stable pH still very important for many distribution system reactions
- Alkalinity/DIC play major role
  - Beyond just buffering capacity
  - DIC key factor in dominant species
- Chlorine residual can play a major role
  - Form some Pb(IV) – much lower solubility compared to Pb(II)
  - Difficult to control or know chlorine levels within premises, therefore, must also optimize for Pb(II)
  - Must balance with DBPs and customer acceptance
- Multiple tools used in this study – all have value
  - Desk-top/Theoretical modeling
  - Pilot rigs to assess lead release from harvested materials
  - Scanning Electron Microscopy (SEM) to look at scale structures
  - Energy Dispersive X-Ray (EDX) also used to determine and map elemental composition
- Theory matched reality in this study
  - Very "well-behaved" system, often seen in Pacific Northwest Waters
  - Not necessarily the case elsewhere

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THANK YOU

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Ask the Experts

France Lemieux
Health Canada's Water and Air Quality Bureau

Bofu Li
Dalhousie University

Melinda Friedman
Confluence Engineering Group, LLC

Enter your **question** into the **question pane** at the lower right-hand side of the screen.

Please specify to whom you are addressing the question.

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- As part of your registration, you are entitled to an additional 30-day archive access of today's program.
- Until next time, keep the water safe and secure.

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Presenter Biography Information

- France Lemieux is the Head of the Materials and Treatment Section in Health Canada's Water and Air Quality Bureau and holds a Bachelor's degree in Biochemistry and a Masters' degree in Civil Engineering -Water Resources. France's 32+ year career at Health Canada is multi-disciplinary and varied in nature. She has worked in drinking water for 22 years, primarily as a drinking water treatment specialist. Although she has covered a wide variety of areas including PFAS, *Legionella* and DBPs, her main focus is corrosion control and inorganics such as lead and copper. She has integrated information on distribution system and small systems challenges into her work at Health Canada. She is a member of various U.S. and Canadian committees on health-based standards for drinking water, treatment units and plumbing standards; Chair of the NSF Additives Joint Committee, a member of the NSF Council for Public Health Consultant and Chair of the Water Quality Association's Public Health Review Board as well as sitting on the Board of Directors of RESEAU Centre for Mobilizing Innovation (RESEAU). Her passion is working with industry, users and regulators to collaboratively achieve positive public health impacts from safe drinking water.
- Bofu Li is a PhD candidate and Killam scholar at Dalhousie University, Canada. He received his master's degree at the same university. His research focuses on the corrosion control of distribution systems and biological treatments.
- Melinda Friedman is President of Confluence Engineering Group, LLC, in Seattle, Washington. Melinda has decades of experience providing services related to source water and distribution system water quality evaluation, source water changeovers and new source introductions, regulatory compliance, comprehensive planning, and optimized distribution system and treatment practices. As a recognized leader in distribution system water quality assessments, she has participated in numerous research and training efforts, and has helped to prepare many prominent industry Guidance Manuals published by the American Water Works Association and the Water Research Foundation.

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