## Lead Corrosion & Control

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**Acknowledgement**
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## Water Lead/LSLs Correlated to Blood Lead: Europe

- Lead in water > 5 ppb significantly increased blood lead ($p > 0.001$) in young women, and intervention excluding tap water a few months dropped blood lead 37% (Fertmann et al., 2004)
- Children in France (6 months-6 years) had 50% higher blood lead if they consumed tap water and had an LSL, and the 95%'ile blood lead level for this group was increased by 256% (Etchevers et al., 2014)

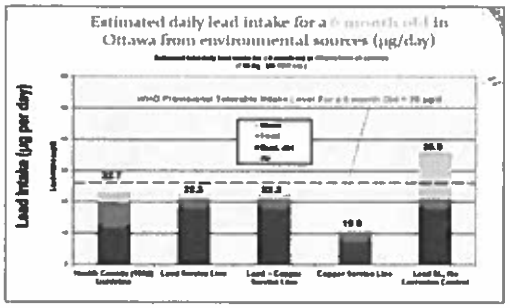
## Presentation Outline

- Background
- Corrosion chemistry in drinking water
- Corrosion control methods
- Bench-top corrosion research tools
- Long-Term LCR Revisions and impacts
- Take home messages
- LCR monitoring case study -LWC

## Historical Corrosion Management

- Iron corrosion
  - Prevent Tuberculation
  - Prevent pipe loss
  - Prevent red water
- Controlled by
  - Ferric oxides & calcium carbonate films at pH >8
  - Polyphosphate addition –NOT orthophosphate

## Daily Lead Intake: Water vs Other Sources

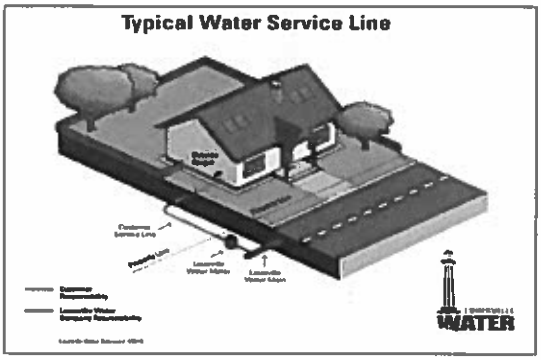



Drinking water normally is not a major source of lead exposure. It can be a significant source under the condition of lead service line with no corrosion control.

## Historical Corrosion Management

- Copper corrosion
  - Prevent pitting corrosion
  - Prevent uniform (general) corrosion
- Controlled by
  - Prevent microbiological growth
  - Maintaining low DIC/high pH
  - Allowing time for films to form
  - Orthophosphate – ongoing treatment but must be maintained

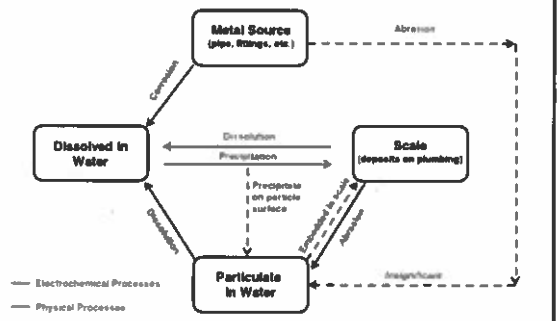
## Lead Sources from Water Service Connections




## Abrasion

- Physical disturbances
  - Meter installation/replacement or damaged
  - Service line repair or partial replacement
  - External shut-off valve repair/replacement
  - Street excavation or construction near the house
  - Any part of home plumbing system disturbance
- Hydraulic factors
  - Significant flow changes
  - Flow reversals
  - Pressure transients

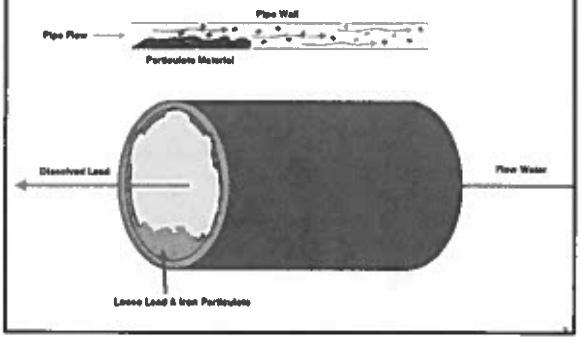
## Lead in Drinking Water




## Corrosion Basics

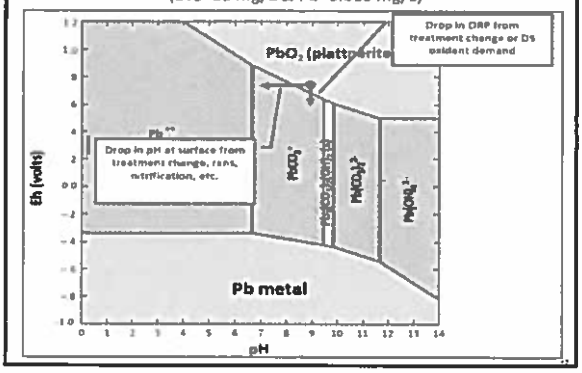
- Corrosion in drinking water: An electrochemical interaction between metal surface and water, resulting in metal release into water
  - Reduction @ Cathode: $2e^- + 1/2O_2 + H_2O = 2OH^-$
  - Oxidation @ Anode: $Me = 2e^- + Me^{2+}$
- Types of corrosion
  - General or uniform
  - Non-uniform: galvanic, pitting, microbial
- Complex processes
  - Pipe material and plumbing practice
  - Water quality factors (pH, DIC, ORP, $PO_4^{3-}$, Cl and $SO_4^{2-}$, ...)
  - Hydraulic conditions

## Water with Dissolved Lead and Lead Particulate

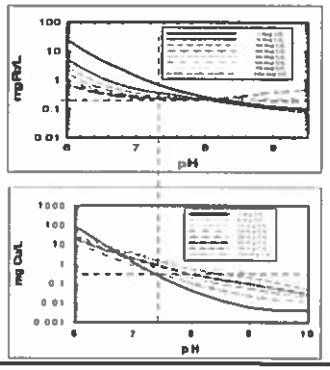



## Lead Eh-pH Diagram in Water

(DIC=18 mg/L & Pb=0.010 mg/L)

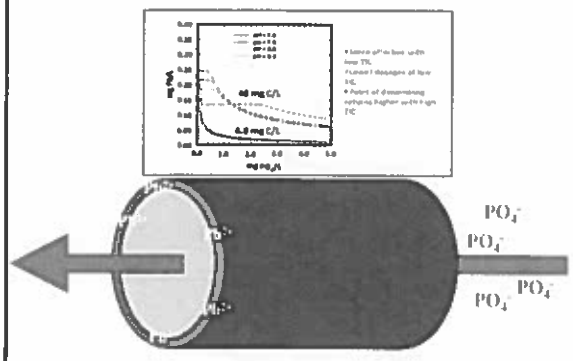


## Impact of pH and DIC on Pb and Cu




- Higher pH better for both
- Optimal DIC for Pb depends on pH
- Lower DIC better for Cu at all pH > ~7.2 and for Pb at pH >~8.2

## Orthophosphate Application

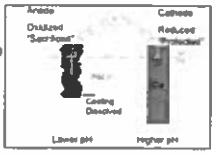



## How to Minimize Corrosion

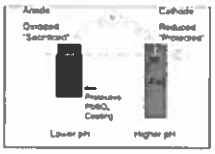
- pH/alkalinity/DIC
  - High pH and low DIC
- Orthophosphate ($PO_4$)
  - Best at pH 7.2 to 7.8
  - Issues: microbial? wastewater P?
- *Form insoluble Pb(IV) scale*
  - *High oxidation state, e.g., via maintenance of free chlorine residual*
- Cl/SO4 Ratio
  - Higher chloride-to-sulfate mass ratio (CSMR) tends to increase lead release under the conditions of galvanic corrosion
  - CSMR<0.5

## Effect of CSMR

- Higher chloride-to-sulfate mass ratio (CSMR) tends to increase lead release under the conditions of galvanic corrosion

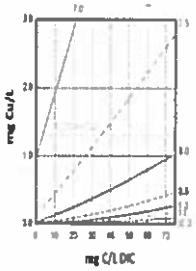



- A threshold CSMR of 0.5 was reported. Significant lead leaching may occur when CSMR > 0.5




## pH Adjustment

- Pb and Cu release generally decreases with pH increase from solubility point of view under most conditions. Raise pH in 0.3 unit increments towards 9-9.5 is recommended by EPA as a Pb control strategy if current pH is >7.8 and DIC >5 mg C/L
- pH adjustment may not always work when
  - pH not high enough throughout DS and need buffering (water blending, nitrification, CO2 exchange in tanks)
  - Dissimilar material on pipe surface or other corrosion mechanisms

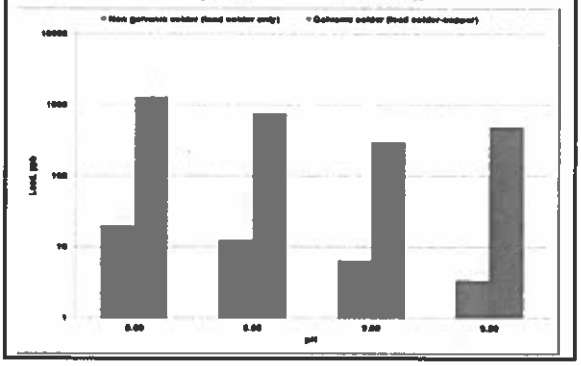



## Bench Scale Research Tools

- Two Types of coupons can be used
  - Non-galvanic solder (NGS) coupon – 50:50 Pb:Sn solder, 1" /1/8" (L/D), epoxied to the bottom of a 120 mL glass jar
  - Galvanic solder (GS) coupon -50:50 Pb:Sn solder placed inside copper coupling (right picture)
    - 50:50 Pb:Sn solder - 1"/1/2" (L/D)
    - Cu coupling – 1.2"/5/8" (L/D)

## pH Effect on Pb Release

(Average lead levels over 2 month study)

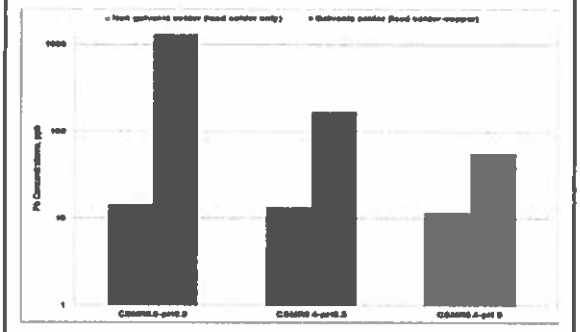


## Long-Term LCR

- Long-Term LCR (LT-LCR)
  - Scheduled to be proposed by USEPA sometime in ~~2013~~ ~~2014~~ ~~2015~~ 2017?
  - Likely promulgated two years later
  - May include
    - Revisions to sampling
    - New or re-emphasized OCCT
    - PLSLR and other LSL issues
    - AL?

## CSMR and pH Effect on Pb Release

(Average lead levels over 2 month study)



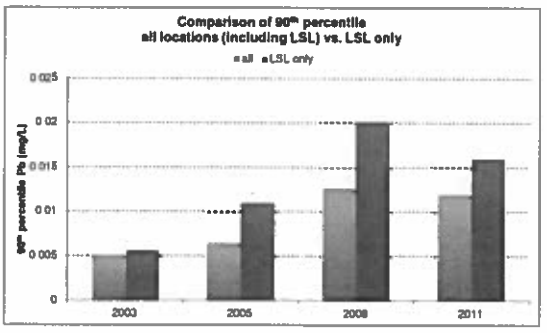
## LTLCR – Potential Impact of Revisions

- Some systems currently in compliance need to
  - Re-assess current OCCT
  - Change OCCT
- Change LSL replacement activities
- Repeat OCCT studies (pipe loops)
- Separate Cu and Pb
- Only or More LSLs as Tier 1 sites
- Change sampling protocol
- Lower AL
- More WQP
  - More sites
  - Higher frequency
  - Use control charts
- Public Education

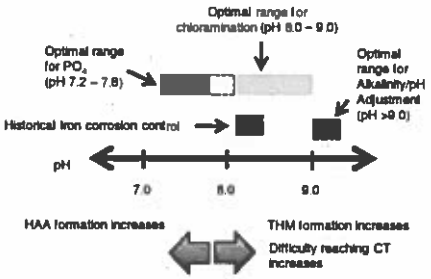
## Lead and Copper Rule (LCR)

- Promulgated 1991
- Sample "first flush" in selected homes with great likelihood of high Pb levels (LSLs or Pb solder)
- Number of locations depends on system size
- Action Level (AL)
  - 0.015 mg/L for Pb, 1.3 mg/L for Cu
  - Exceedance of is NOT an MCL violation, but can trigger other actions (TT)
    - Optimized Corrosion Control Treatment (OCCT)
    - Water quality parameter (WQP) monitoring
    - public education, and
    - lead service line replacement (LSLR)
- 2000 & 2007
  - Minor revisions – rule framework basically unchanged

## 90th Percentile Lead Levels: All vs LSL Only



## Balancing Multiple Regulations: DBP Example




## LCR-Year Monitoring Case Study

- Develop strategy to improve site representativeness and sample integrity – *Noise Reduction*
- Establish team involving all key departments
- Historical data review
- Identify factors that may inadvertently alter sample representativeness – *False Signal*
- Irregular/abnormal distribution and/or residential disturbances
- Customer performs the sampling

## Take Home Messages

- Personal involvement from top management
- A WQ team from across the company
- A WQ surveillance team with internal and external customers
- Be proactive: 5Cs (character, comprehensiveness, communication, commitment, and creativity)
- Define WQ signal from noise
- Review historical data to calculate 90th percentile using only LSL locations
- Profile (ten 1L samples) at selected homes
- Investigate high velocity flushing after LSL replacement
- If close to AL or ~8 ppb, look at Pb control alternatives (PO4)

## LCR-Year Monitoring Case Study

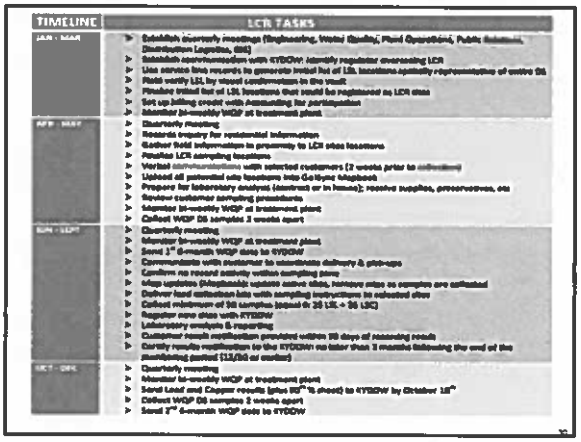
**3C's Required For Success:**

**Communication + Commitment + Collaboration**

| Quarter | LCR Tasks |
|---|---|
| Q1 | ➢ Form team with support from executive leadership<br>➢ Establish communications with team members & state regulators<br>➢ Initiate surveying of LCR sample sites |
| Q2 | ➢ Collect field & residential information to finalize sample list<br>➢ Verbal & written communications with customers<br>➢ Upload all LCR sample sites into GoSync mapping tool for field users<br>➢ Begin sample collection: coordinate delivery & pick-ups of samples |
| Q3 | ➢ Continue sample collections through September<br>➢ Laboratory analysis and reporting<br>➢ Customer result notifications |
| Q4 | ➢ Calculate 90th percentiles, finalize all reporting |

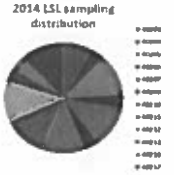
## Take Home Message

- **Three levels of WQ issues (Result-code)**
  - System-wide: treatment plant related (water source or and/or source WQ changes, treatment changes/loss of treatment control, unstable water leaving the plant(s)
  - Area-wide/Zip code: distribution tanks/reservoirs, major water-main breaks, downstream low demand, nitrification, etc.
  - Individual customers: low water use homes may perpetually have high lead; stagnation can affect protective scales within LSLs; LSL disturbances happen daily
- **Distribution water quality management**
  - Customers drink tap water not finished water in clear wells
  - Water quality can change as it travel from the plant to customer taps: pH drop, nitrification, bio-chemical reactions



## Sample Sites Selection

- Spatial representation of wide DS
- Field verification of LSL
- Identify significant DS impacts in proximity of sample site within a 3 month period prior to collection
- Gather residential information: shut offs, water usage, contact information
- Customer communications: verbal commitment to participate, details about residence, schedule sample collection
- Offer $20 billing credit as incentive




## Customer Incentives Sponsored by Water System (credit card, credit on water bill, other incentive)