Optimized Corrosion Control Treatment

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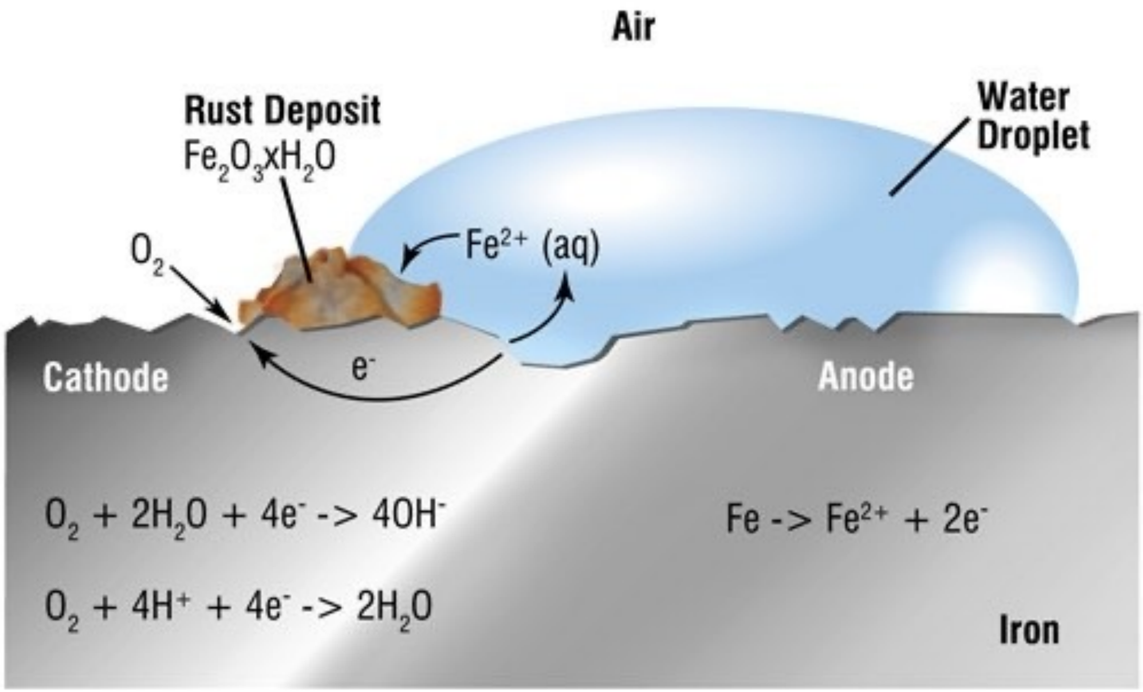
AE2S

Discussion Topics

- Corrosion Fundamentals
- Corrosion Control Treatment Options
- South Dakota Experience
- EPA view of Optimized Corrosion Control
- Future Opportunities

CORROSION

- Corrosion "battery" consists of an anode, cathode, and return current path
- Metal is oxidized at the anode



WHAT MAKES WATER CORROSIVE / STABLE?

WATER QUALITY FACTORS THAT INFLUENCE CORROSIVITY

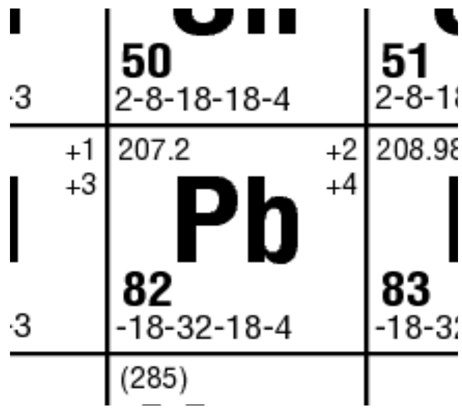
Dissolved oxygen (or other oxidants)	• Enhances corrosion
pH - metals more soluble at lower pH	• Increased corrosion
TDS - higher TDS, the better electrolyte	• Promotes corrosion
Temp	• Inc. Temp. generally increase corrosion rate
Chloride to sulfate ratio	• High values increase corrosion
Presence of an inhibitor	• Can minimize corrosion
Change in oxidation potential (switching from free chlorine to chloramine)	

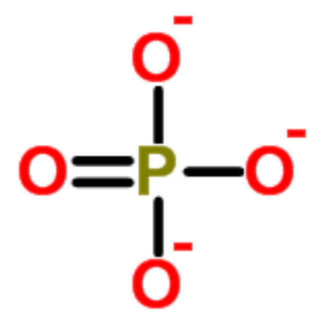
CORROSION

- Deposit of corrosion products (called passivating deposits) at the anode may inhibit further corrosion
- Some deposits are very poor inhibitors
- Pipe “scale” can help inhibit corrosion

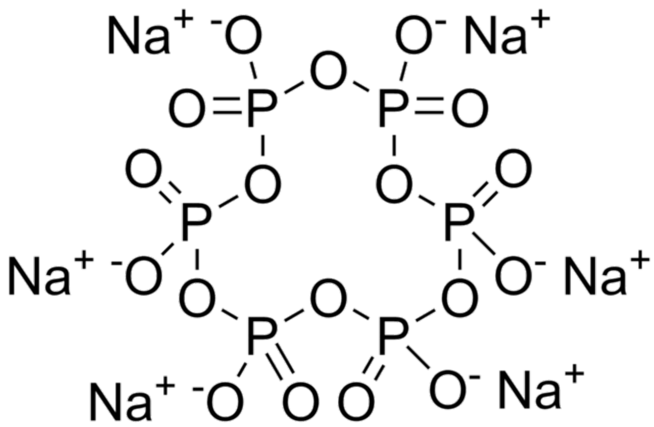
Lead Pipe Scales

- **Depends on water chemistry**
- Carbonate compounds ($PbCO_3$)
- Lead oxides (PbO_2 – in highly oxidative conditions)
- Lead orthophosphates ($Pb_3(PO_4)_2$ – when orthophosphate is used as an inhibitor)

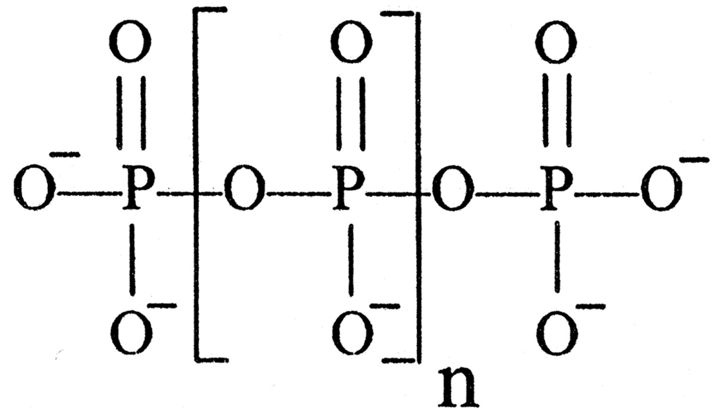




PHOSPHATE COMPLEX COMPOUNDS



Sodium Hexametaphosphate

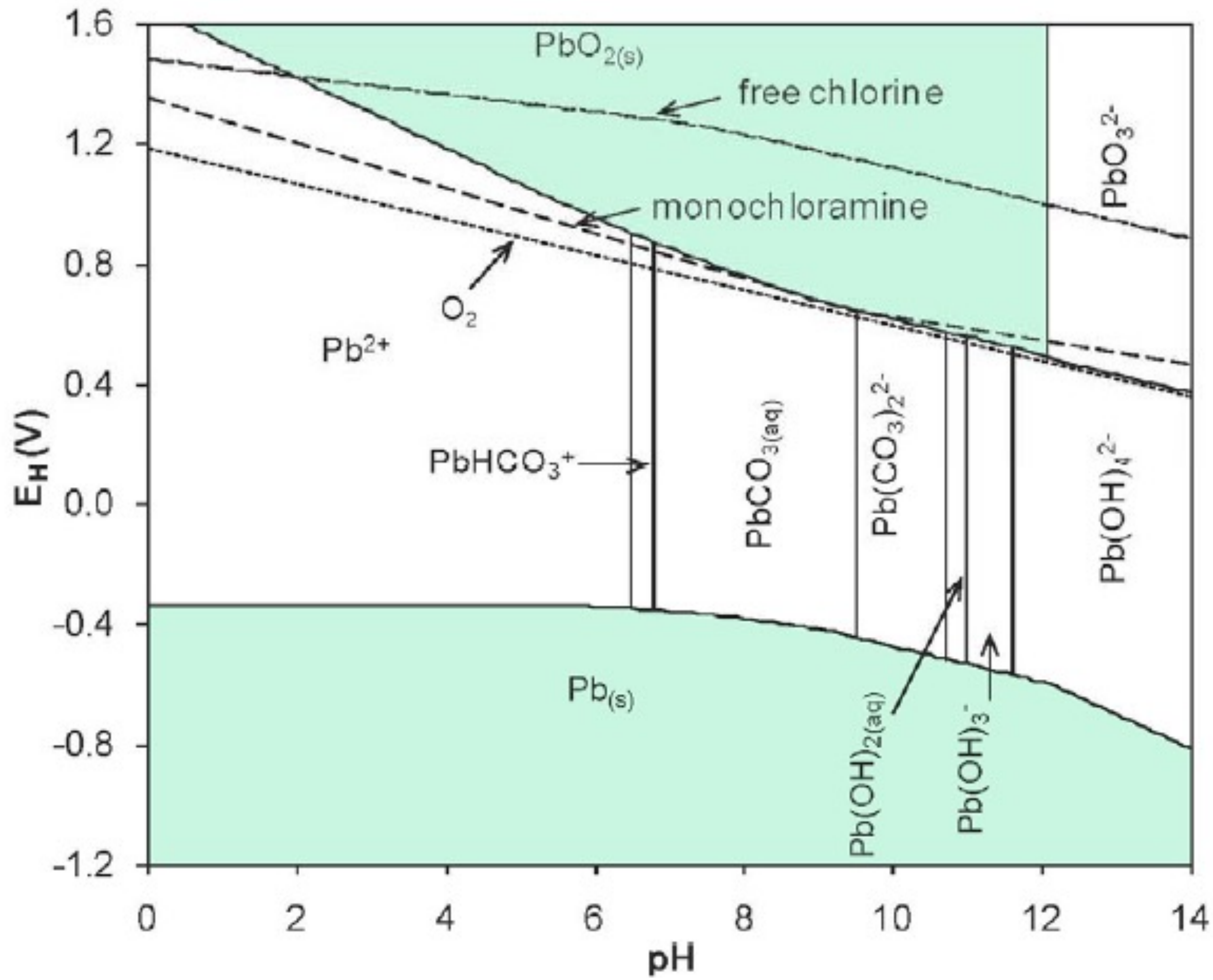


Polyphosphate

- Forms complexes with metal ions – undersaturate the system
- Poisons growth of crystals – threshold effect

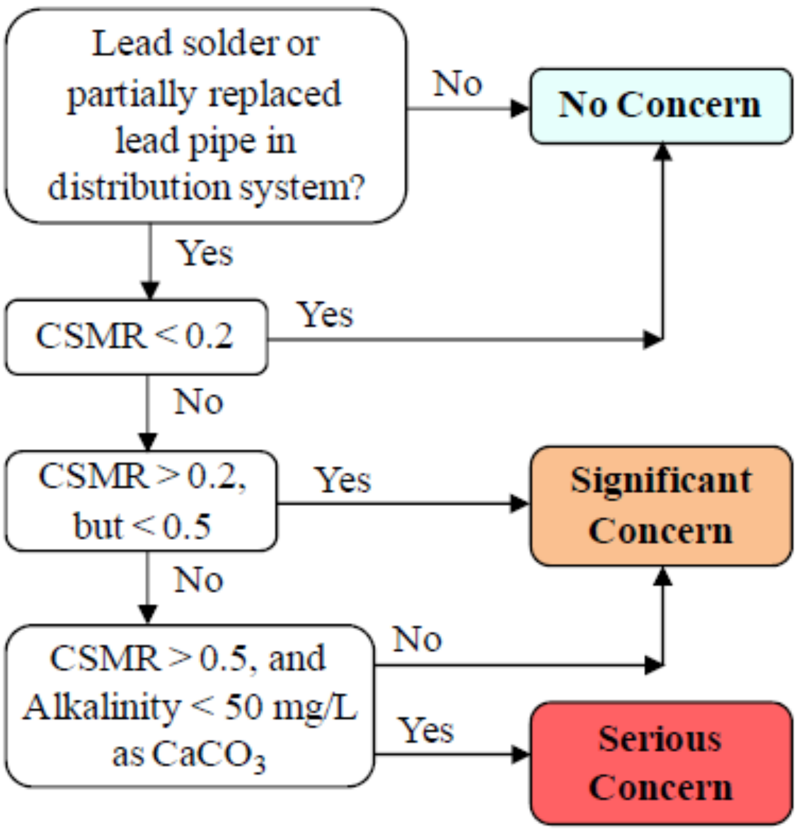
SWITCHING FROM FREE CHLORINE TO MONOCHLORAMINE

- Stable lead species may change to more soluble species, and dissolve the lead oxide (PbO_2) scale



CHLORIDE/SULFATE MASS RATIO

- Greatest impact on lead solder and partially replaced lead pipe (galvanic connection)
- Sulfate forms $PbSO_4$ solids – reduces galvanic current and forms protective layer
- Chloride forms soluble $PbCl^-$ complexes – increases galvanic current and prevents protective layer



MANAGING CORROSIVITY/STABILITY?

- Protective coatings and linings
- Use corrosion resistant materials
- Cathodic protection (makes the metal a cathode)

Treatment to inhibit corrosion by making the metal less soluble or laying down an inhibiting scale

CORROSION CONTROL TREATMENT

Adjust pH (decrease solubility of Pb/Cu)

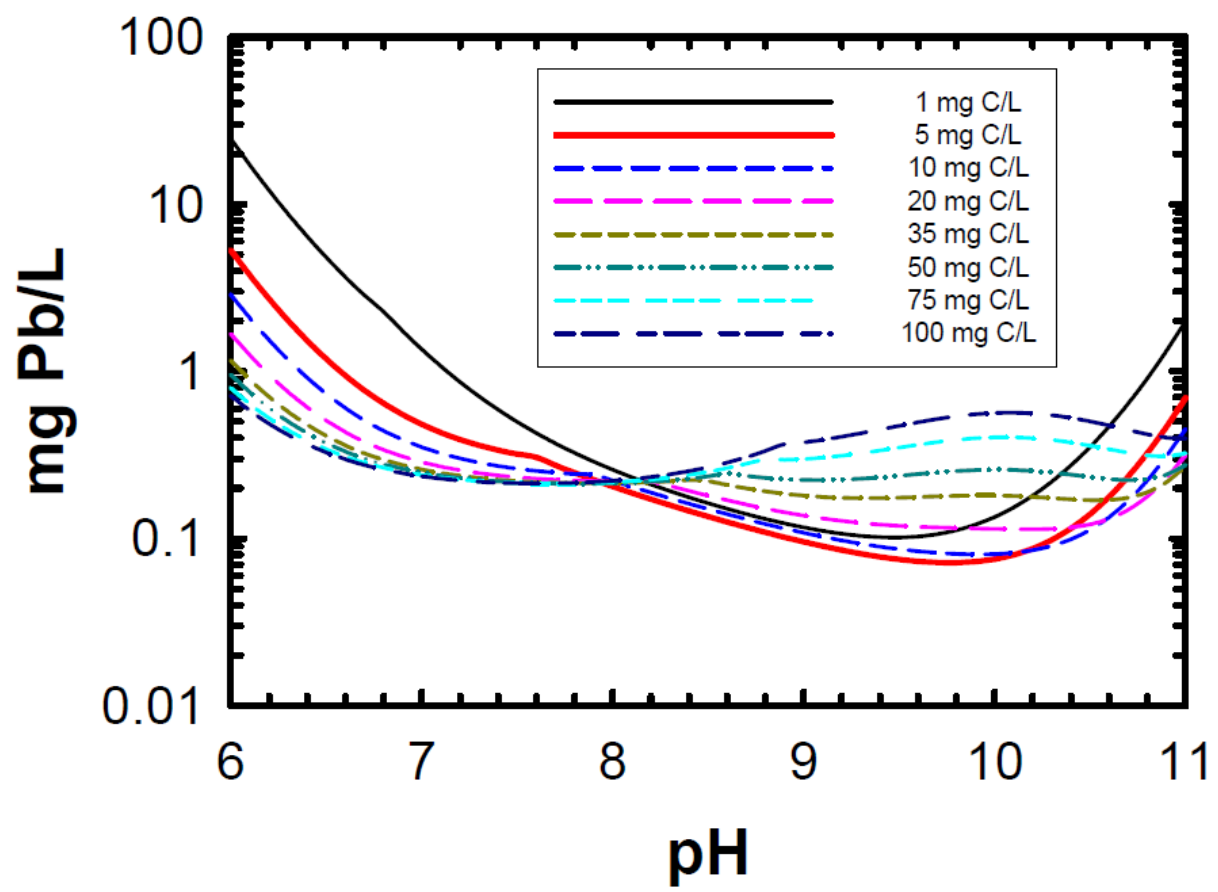
- Lime, soda ash, sodium hydroxide, adjust pH in recarbonation step of lime softening

Add an inhibitor (create an inhibiting layer)

- Orthophosphate (ortho is the best for Pb/Cu)
- Ortho/poly blend
- Silicate

pH and DIC AFFECT LEAD SOLUBILITY

- When DIC is less than 30 mg/ C/L, increasing pH generally decreases lead solubility



pH ADJUSTMENT – IMPACTS ON CALCIUM

- Calcium is precipitated as $CaCO_3$

$$CaCO_3\downarrow \leftrightarrow Ca^{2+} + CO_3^{2-}$$

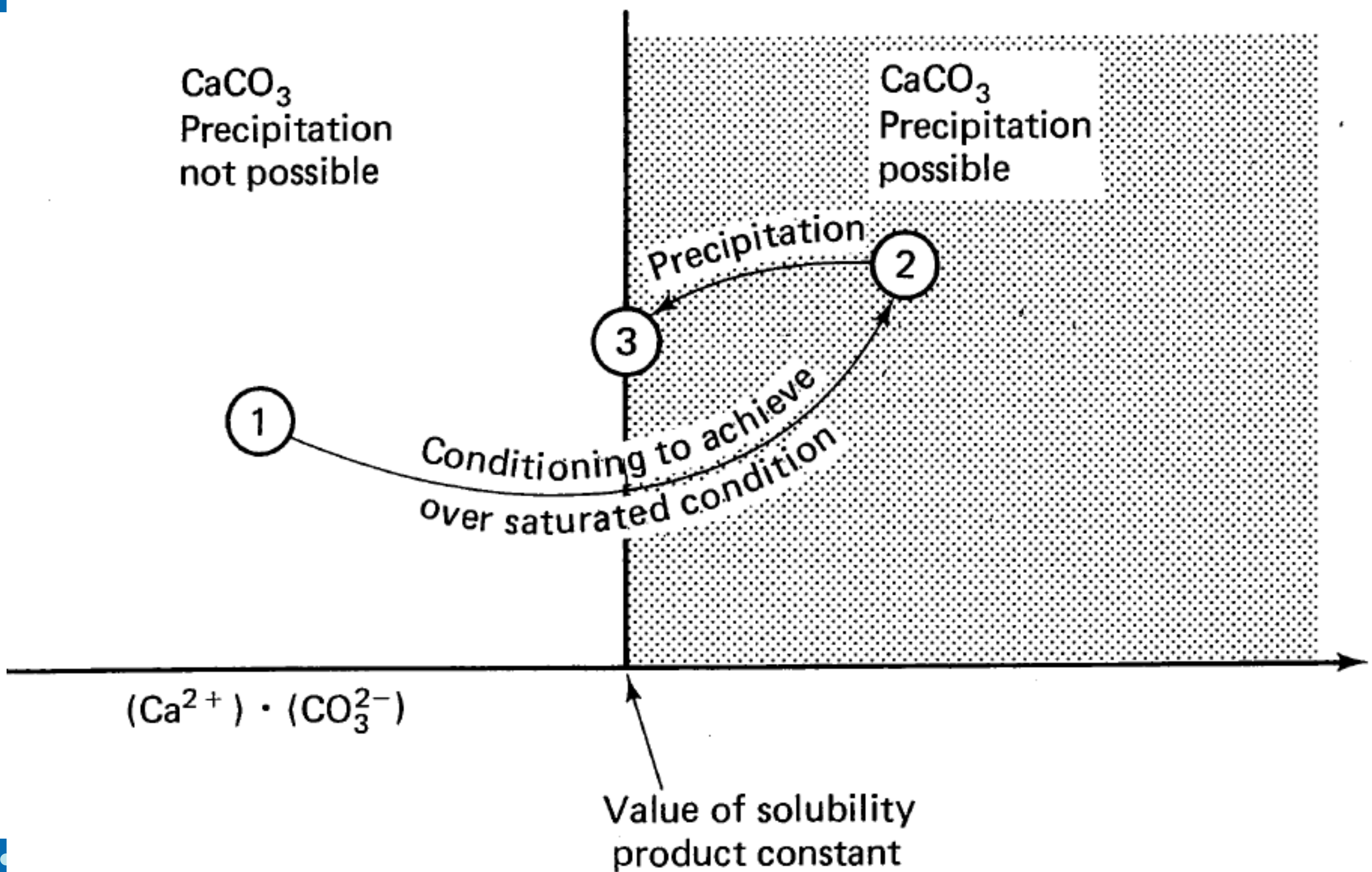
$$K_{sp} = (Ca^{2+})(CO_3^{2-})$$

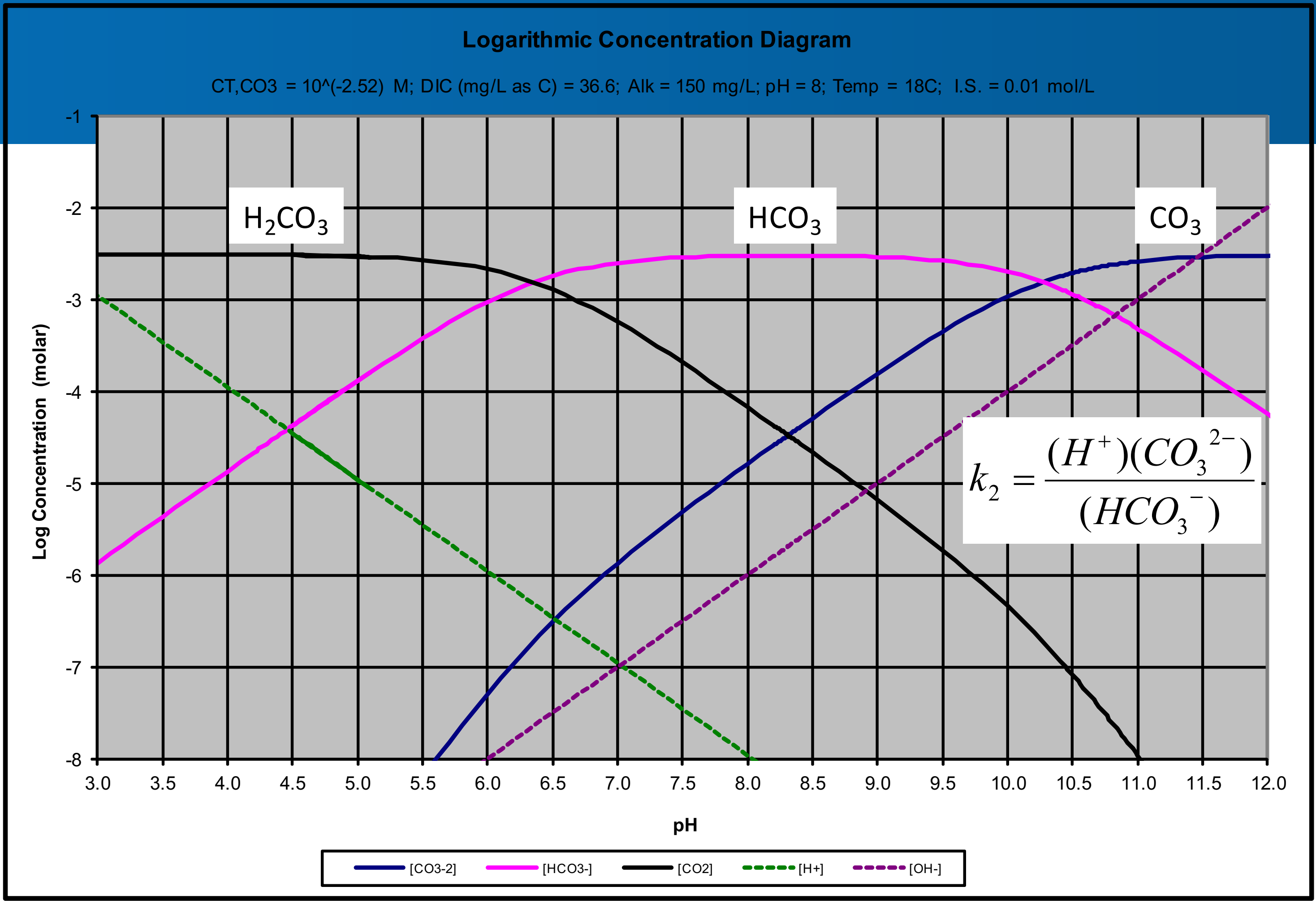
- Natural alkalinity forms, HCO_3^-, CO_3^{2-}
- Form present in water depends on pH

$$HCO_3^- \leftrightarrow H^+ + CO_3^{2-}$$

- Increasing pH creates carbonate, which in turn, precipitates calcium carbonate

WATER STABILIZATION SCHEMATIC





Logarithmic Concentration Diagram
CT,CO3 = 10^(-2.52) M; DIC (mg/L as C) = 36.6; Alk = 150 mg/L; pH = 8; Temp = 18C; I.S. = 0.01 mol/L
Log Concentration (molar)
-1
-2
-3
-4
-5
-6
-7
-8
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.0
pH
H_2CO_3
HCO_3
CO_3
$k_2 = \frac{(H^+)(CO_3^{2-})}{(HCO_3^-)}$
[CO3-2]
[HCO3-]
[CO2]
[H+]
[OH-]

RECARBONATION

- Purposes
  - Reduce the pH
  - Control water **stability** with respect to $CaCO_3$
- pH is based on proper balance between HCO_3^- and CO_3^{2-}

$$CO_2 + CaCO_3 + H_2O \rightarrow Ca(HCO_3)_2$$

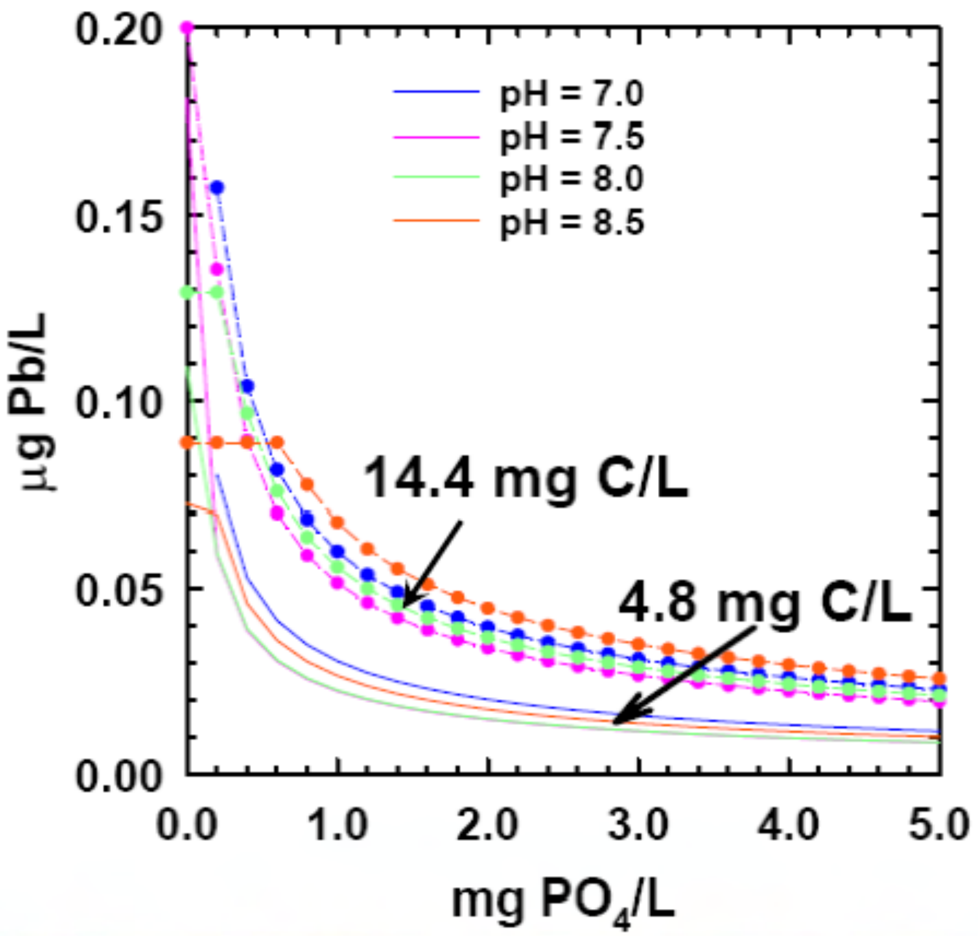
CORROSION CONTROL WITH ORTHOPHOSPHATE

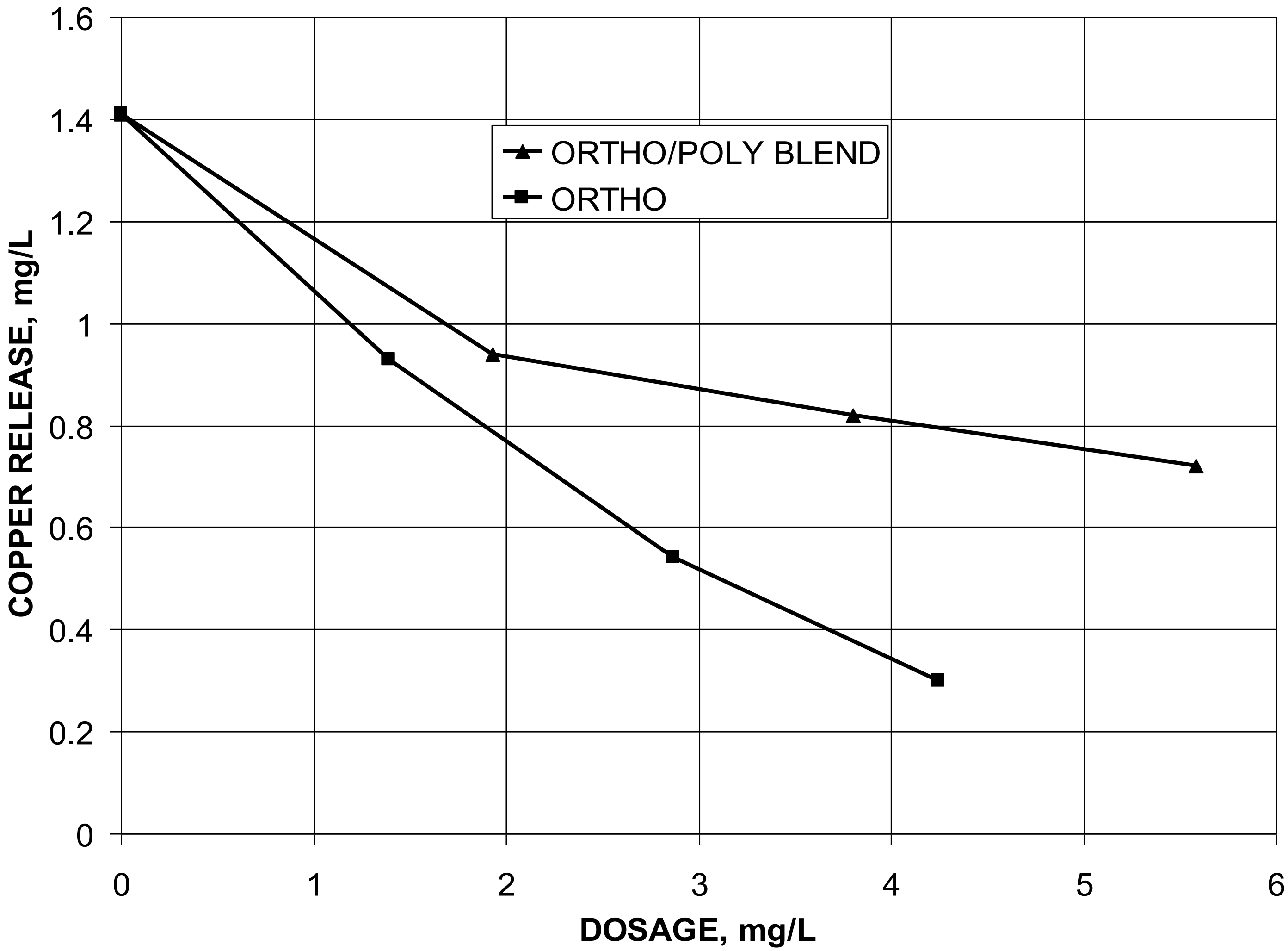
Chemicals

- Zinc Ortho
- Sodium Ortho
- Blended Ortho / Poly

PO_4 decreases Pb Solubility

- As dose increases, reach a point of diminishing returns
- More effective (lower dosages needed) with lower total inorganic C
- pH has less effect at lower total inorganic C



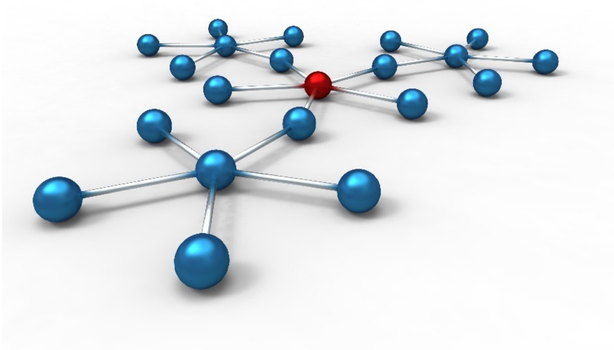


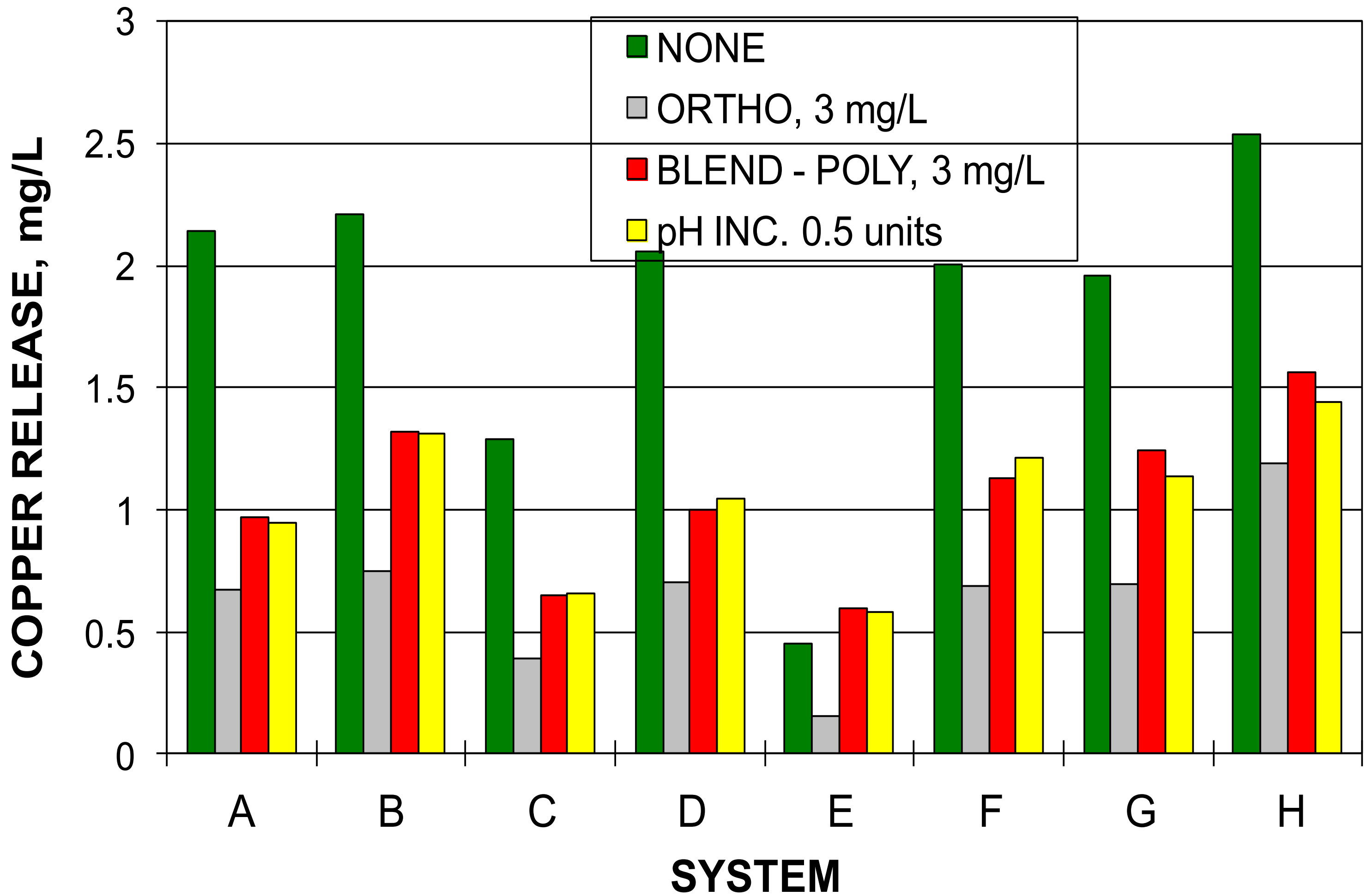
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
ORTHO/POLY BLEND
ORTHO
COPPER RELEASE, mg/L
DOSAGE, mg/L

TYPICAL PRACTICE FOR ORTHO IN SD

Vendor guided

- Water pH 7-8
- Liquid chemical feed system
- Dosage ranges from 0.5 to 3 mg/L





NONE
ORTHO, 3 mg/L
BLEND - POLY, 3 mg/L
pH INC. 0.5 units
COPPER RELEASE, mg/L
SYSTEM
0
0.5
1
1.5
2
2.5
3
A
B
C
D
E
F
G
H

pH Adjustment In SD

4 systems adjusted pH to meet Action Levels

- 2 Pb, (lime softening)
- 2 Cu, (sodium hydroxide)
- All 4 systems meeting current action levels

Parameter	Range	Average
Ca Hardness, mg/L as CaCO3	52-325	133
Alkalinity, mg/L as CaCO3	18-97	53
pH	7.7-9.45	8.54
90%ile Pb, ppb	0.27-10.7	2.36
90%ile Cu, ppm	0.02-0.52	0.09

Lime Softening Systems In SD

- Data from 17 Lime Softening Systems

Parameter	Range	Average
Ca Hardness, mg/L as CaCO3	52-325	133
Alkalinity, mg/L as CaCO3	18-97	53
pH	7.7-9.45	8.54
90%ile Pb, ppb	0.27-10.7	2.36
90%ile Cu, ppm	0.02-0.52	0.09

Orthophosphate Treatment in SD

8 systems

- 2 lead, 6 copper
- 1 system exceeding Cu Action Level

Parameter	Range	Average
Ca Hardness, mg/L as CaCO3	111-605	284
Alkalinity, mg/L as CaCO3	149-367	279
pH	7.28-7.84	7.5
Langlier Index	-0.5-1.0	0.35
90%ile Pb, ppb	1.0-3.9	1.7
90%ile Cu, ppb	0.04-1.5	0.62

Blended Phosphate Treatment in SD

11 systems

- 3 lead, 8 copper
- 7 systems are purchasing water from RWS
- All 1 systems meeting Current Action Levels

Parameter	Range	Average
Ca Hardness, mg/L as CaCO3	74-428	157
Alkalinity, mg/L as CaCO3	34-343	175
pH	7.15-8.75	7.9
Langlier Index	-0.35-1.73	0.3
90%ile Pb, ppb	0.5-9.1	3.0
90%ile Cu, ppb	0.02-1.01	0.43

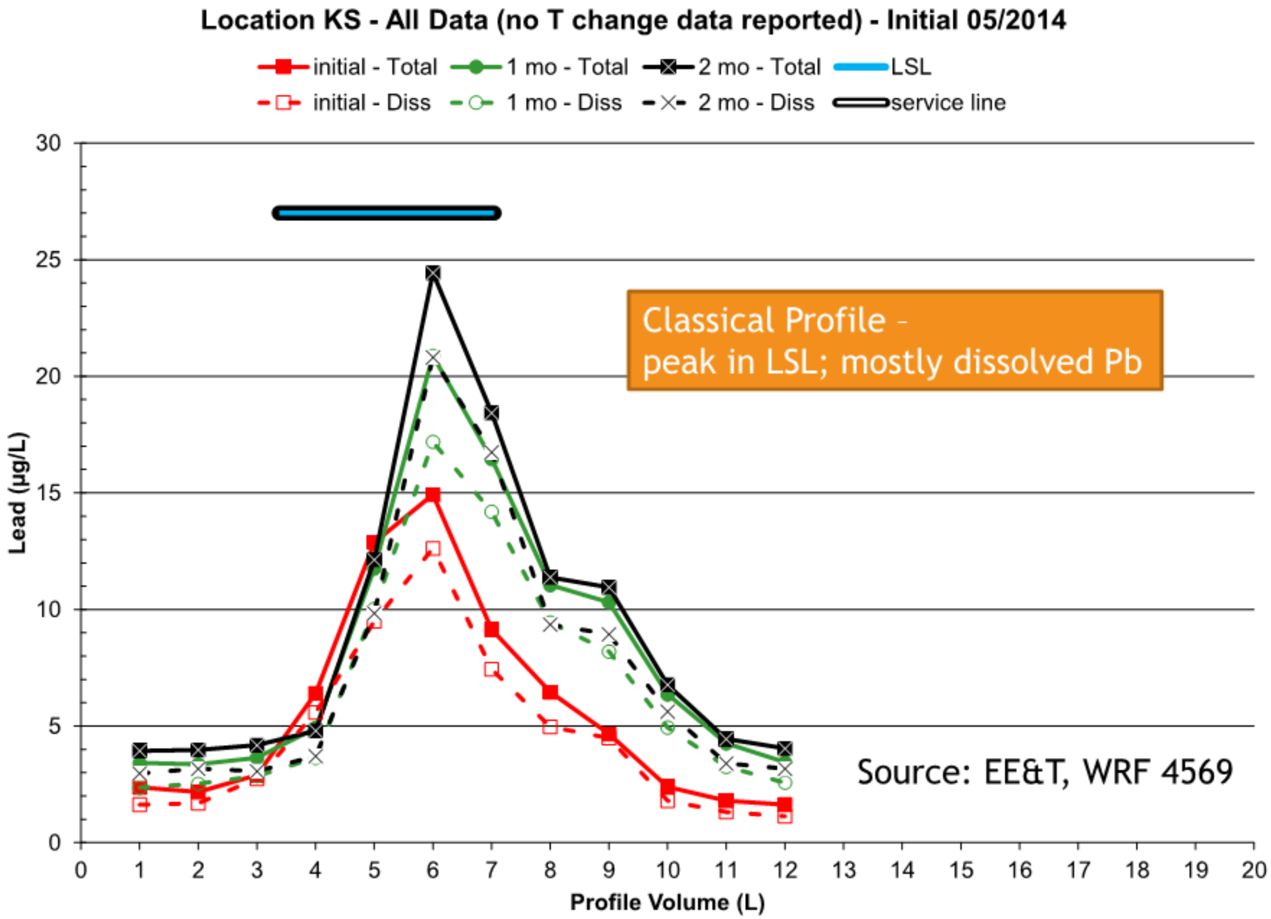
What is Optimized Corrosion Control?

- Basis for regulation
  - Action level addresses health concern, but not an MCL
  - What Action Level is possible with corrosion control treatment??
  - LCR – 15 ppb Lead, 1.3 ppm Copper
  - LCRI – 10 ppb Lead, 1.3 ppm Copper
- EPA says - 10 ppb is supported by past corrosion control treatment performance data as being generally representative of optimized corrosion control treatment (that most systems that have installed OCCT can meet).

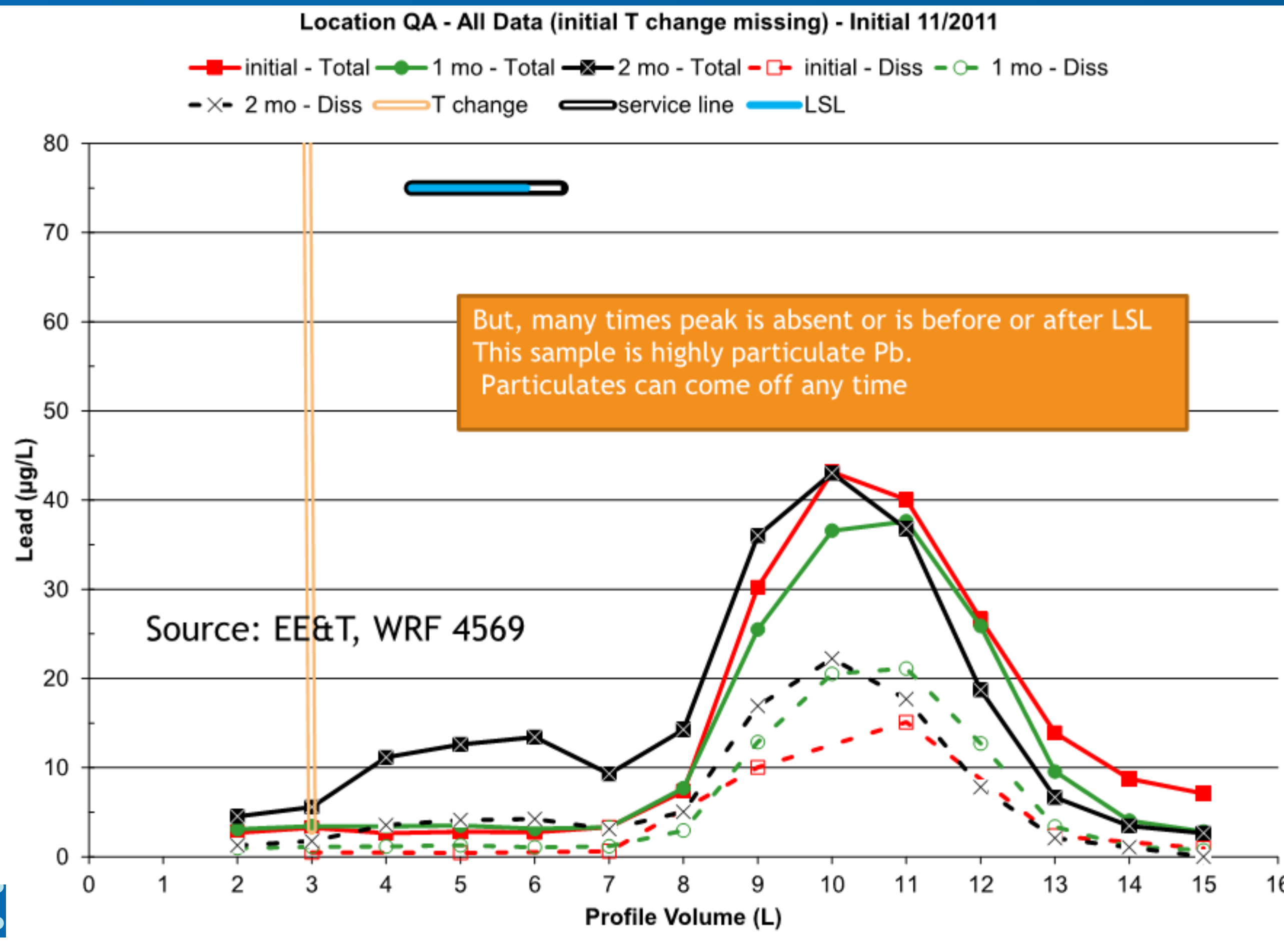
Sampling Protocol

- LCR
  - 1st Draw, 1 Liter
- LCRR and LCRI
  - 1st Draw at all sample sites
  - 5th Liter at lead service line sample sites

PROFILE SAMPLING – Dissolved Lead



PROFILE SAMPLING – Particulate Lead



LEAD RELEASE

- **Hydraulic Release**
  - Shorter term
  - Off-color water – customer noticed
  - Short duration
  - Flush to remediate
  - Particulate metal dominant

- **Chemical Release**
  - Longer term
  - Changes in water chemistry
  - Elevated concentrations of dissolved metal
  - Caught in interval sample at volume equivalent to the lead source

LCRI – Lead Action Level

Lowering the Lead Action Level. EPA is proposing to lower the lead action level from 15 µg/L to 10 µg/L. When a water system's lead sampling exceeds the action level, the system would be required to inform the public and take action to reduce lead exposure while concurrently working to replace all lead pipes. For example, the system would install or adjust corrosion control treatment to reduce lead that leaches into drinking water.

Actions – Individual tap sample exceeding 10 ppb

EPA is proposing to maintain the 2021 LCRR requirement for systems to conduct additional activities when a tap sample exceeds 10 ppb. Systems would conduct the distribution system and site assessment for any sampling site that exceeds 10 ppb. The distribution system and site assessment would involve collecting a water quality sample in the distribution system near the site, collecting a follow-up lead tap sample, and evaluating the results to determine if either a localized or centralized adjustment of the OCCT or other distribution system actions are necessary and submit a recommendation to the State.

South Dakota Impacts

- Current data indicates that 16 systems exceed the 10 ppb action level for lead
  - Likely the number will change with proposed 5th liter sampling protocol
- Courses of action
  - Remove lead service line
  - Optimize treatment

Thank you! **Questions?**

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