Water Quality Impacts on Metal Release and Emerging Research Issues for Service Lines

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Topics Covered

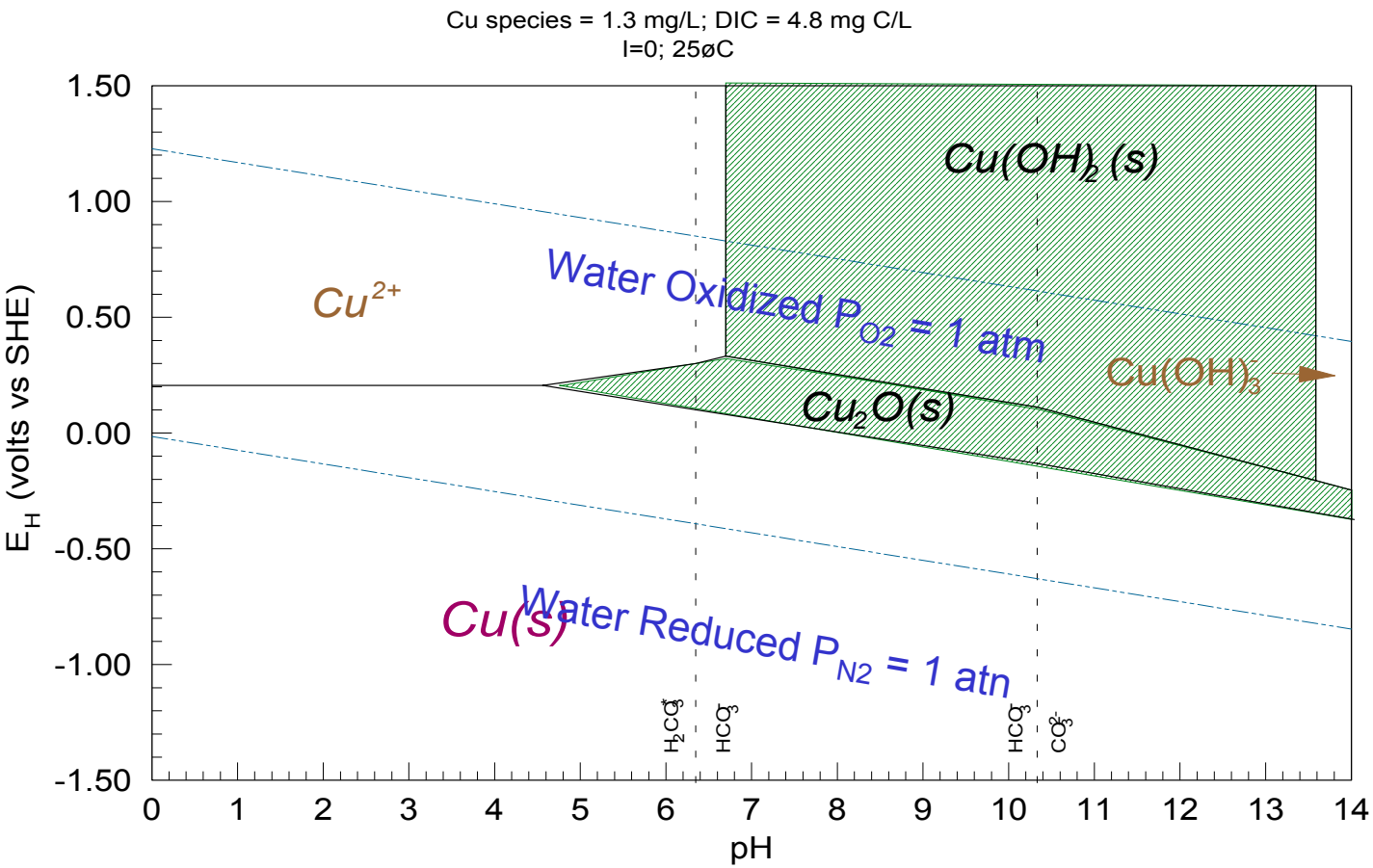
- Basic chemistry factors governing Pb & Cu
- Issues with lead leaching from in-line devices
- Other research issues
  - Partial lead service line replacement
    - Physical disturbance possibility
    - Galvanic corrosion possibility
  - Accumulation of metals in scales
  - Long-term performance of non-Pb brasses

Copper Chemistry Issues

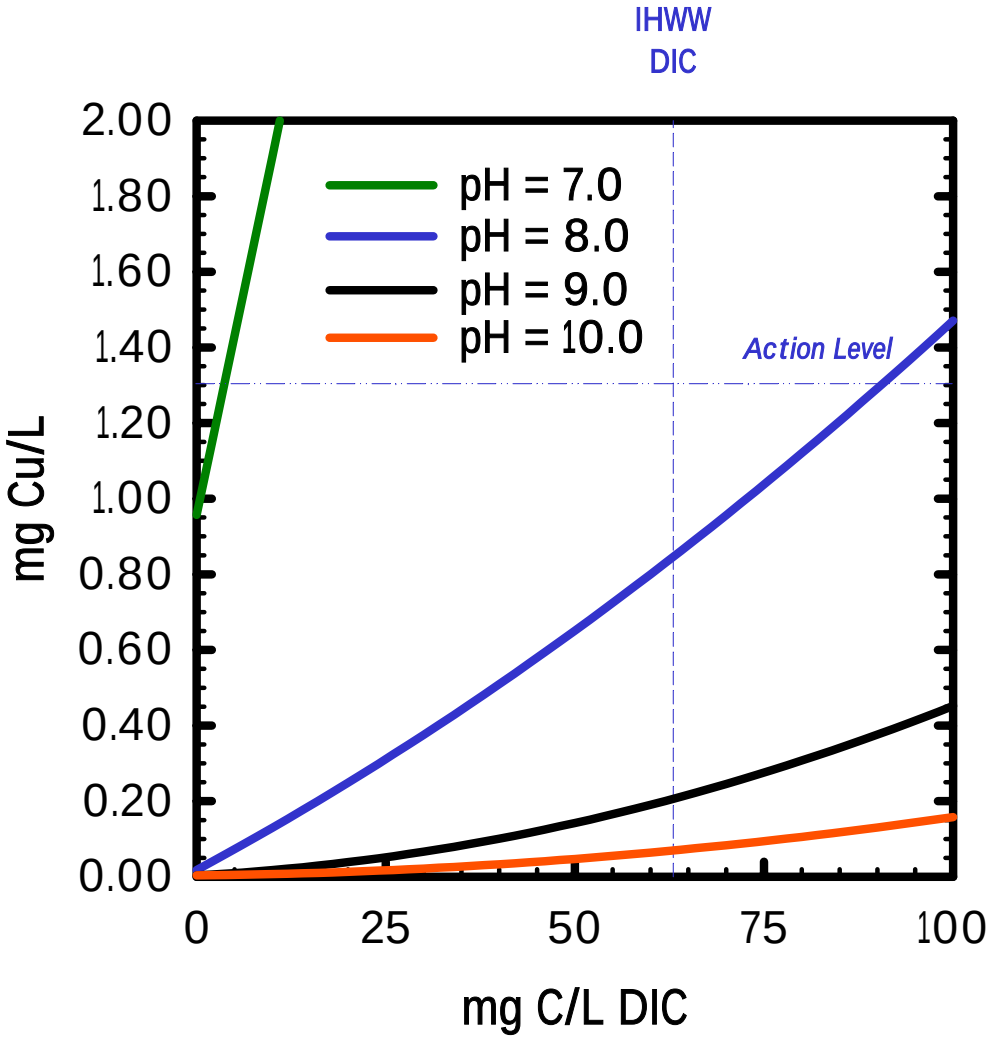
Major Factors for Cuprosolvency

- Low pH
- High alkalinity (DIC >> 25 mg/L as C)
- Fresh pipe
- Presence of persistent oxidants
- Orthophosphate
  - Slows oxidation rate
  - Reduces Cu dissolution, esp. for high alkalinities
  - Retards "aging"

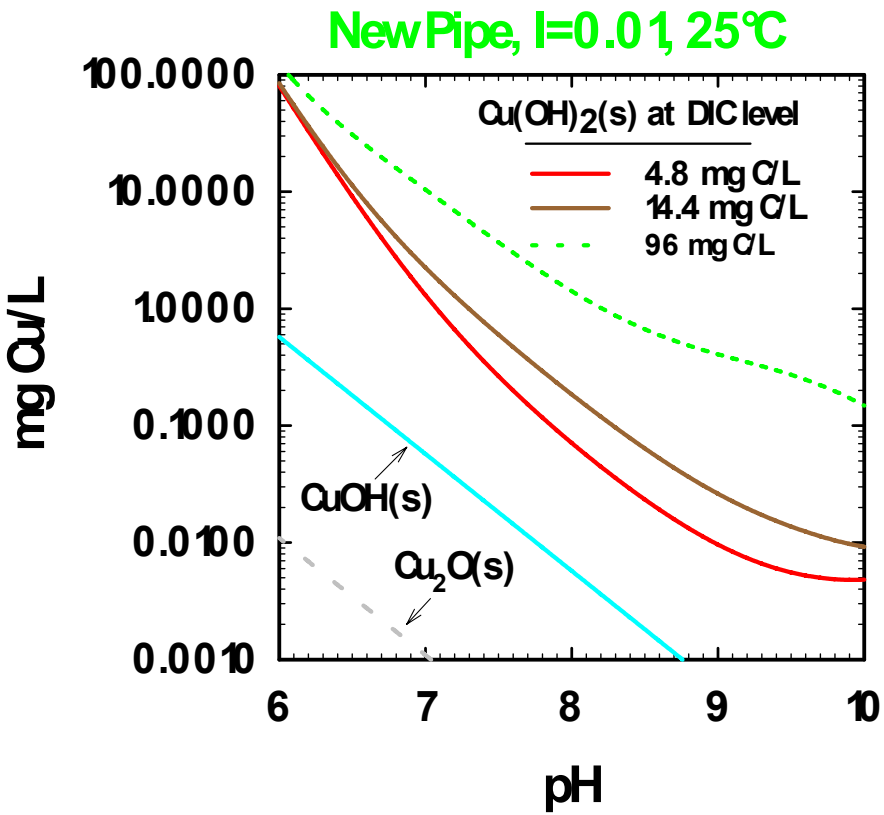
E_H – pH Diagram for Copper



Copper(II) Solubility & pH Adjustment

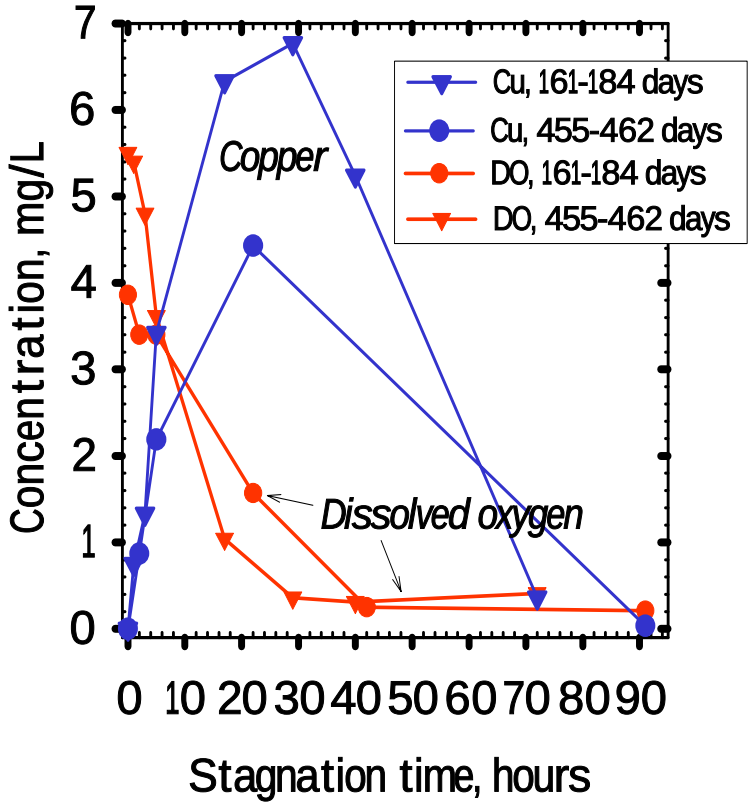


Copper(II) Solubility at Different DIC Levels Compared to Copper(I) Solubility



Oxidant Effects on Stagnation Profile

Copper Tubing: IX Softened Water, DIC=75 mg C/L



Metastable Solid Conversions

(The importance of aging)

$Cu(OH)_2 \Rightarrow CuO$ (high surface area)

high pH

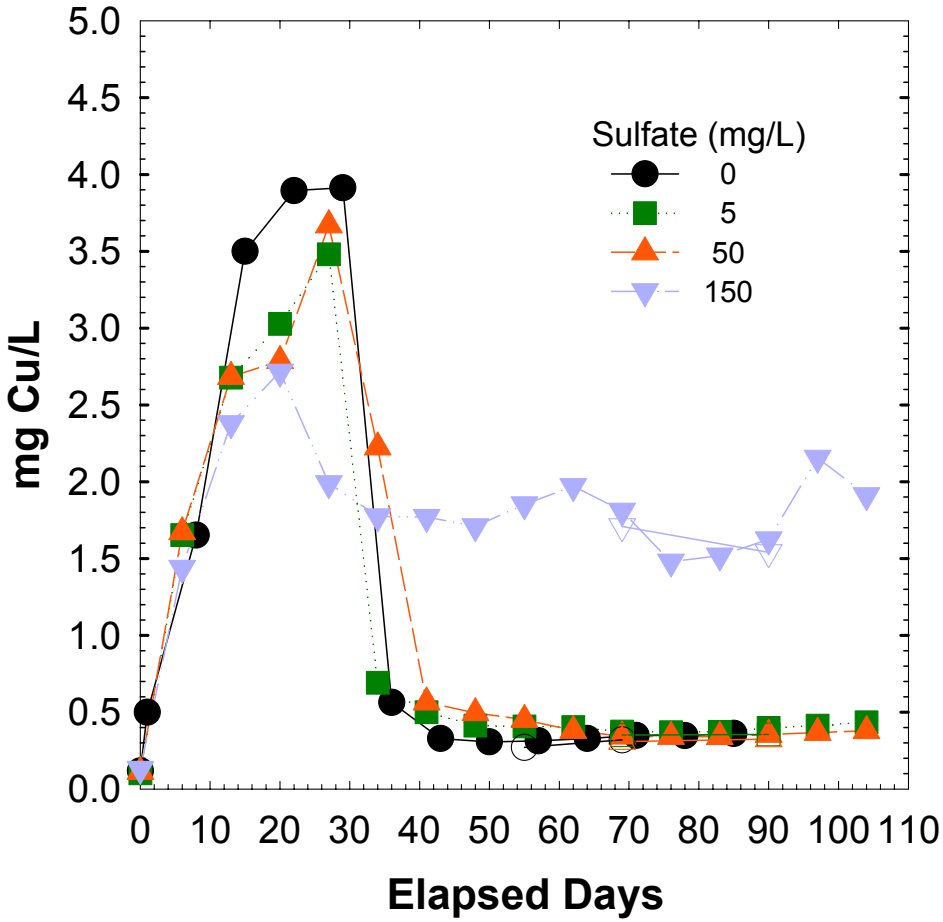
CuO (low s)

low pH

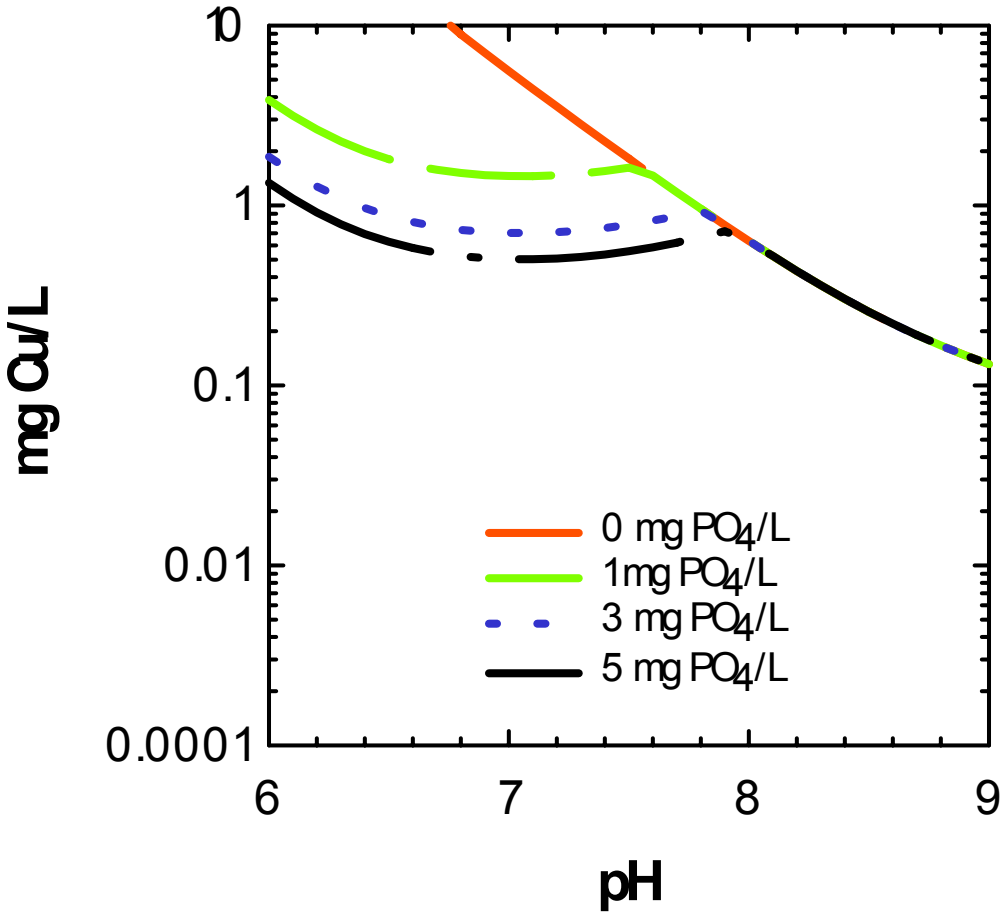
$2\ CuO + 2H^+ + CO_3^{2-} \Rightarrow Cu_2(OH)_2CO_3$

$2Cu(OH)_2 + CO_3^{2-} \Rightarrow Cu_2(OH)_2CO_3$

Effect of Sulfate at pH 7, DIC=10 mgC/L



Effect of Orthophosphate on $Cu(OH)_2$ Solubility at DIC=48 mg C/L



pH

65

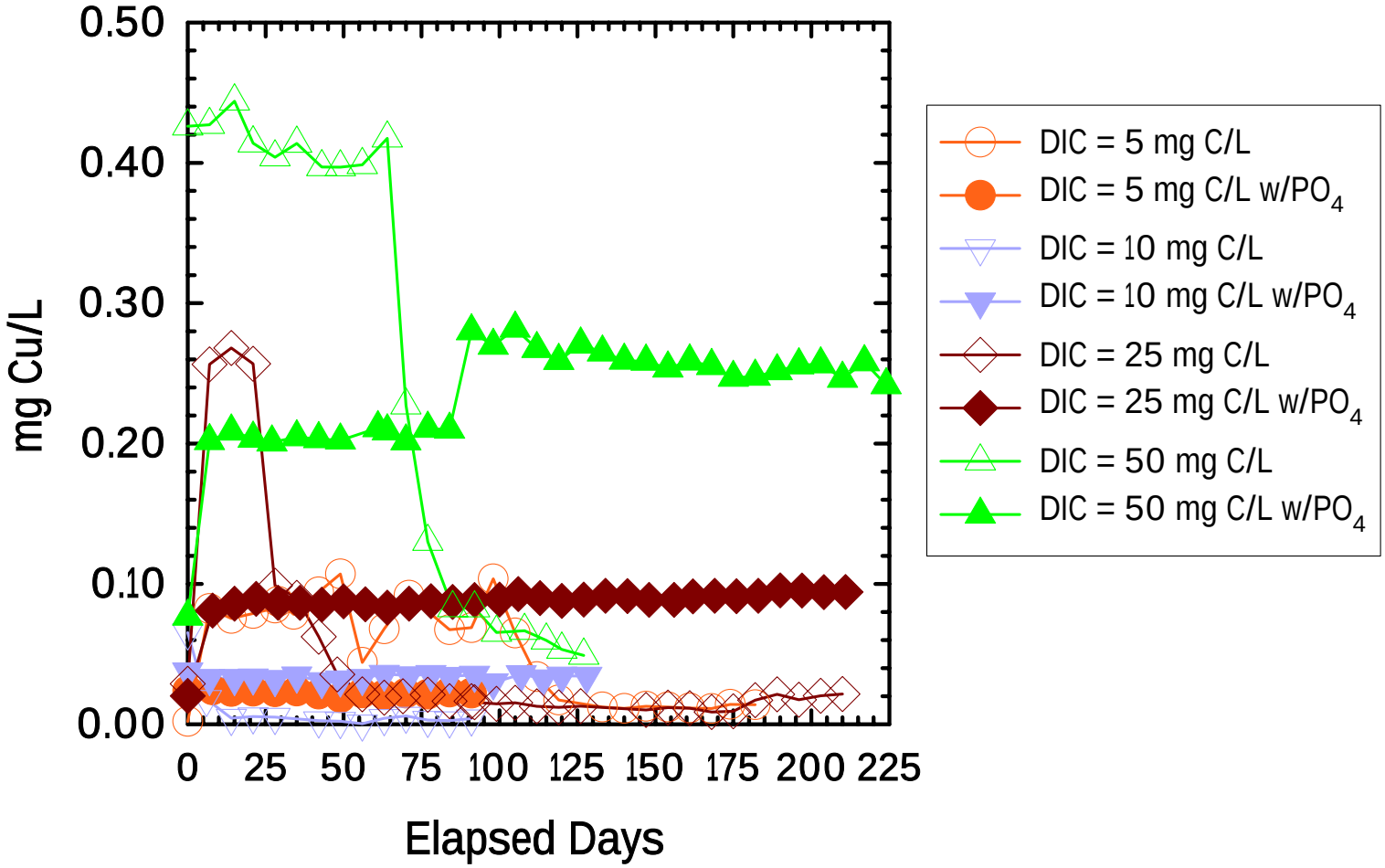
70

80

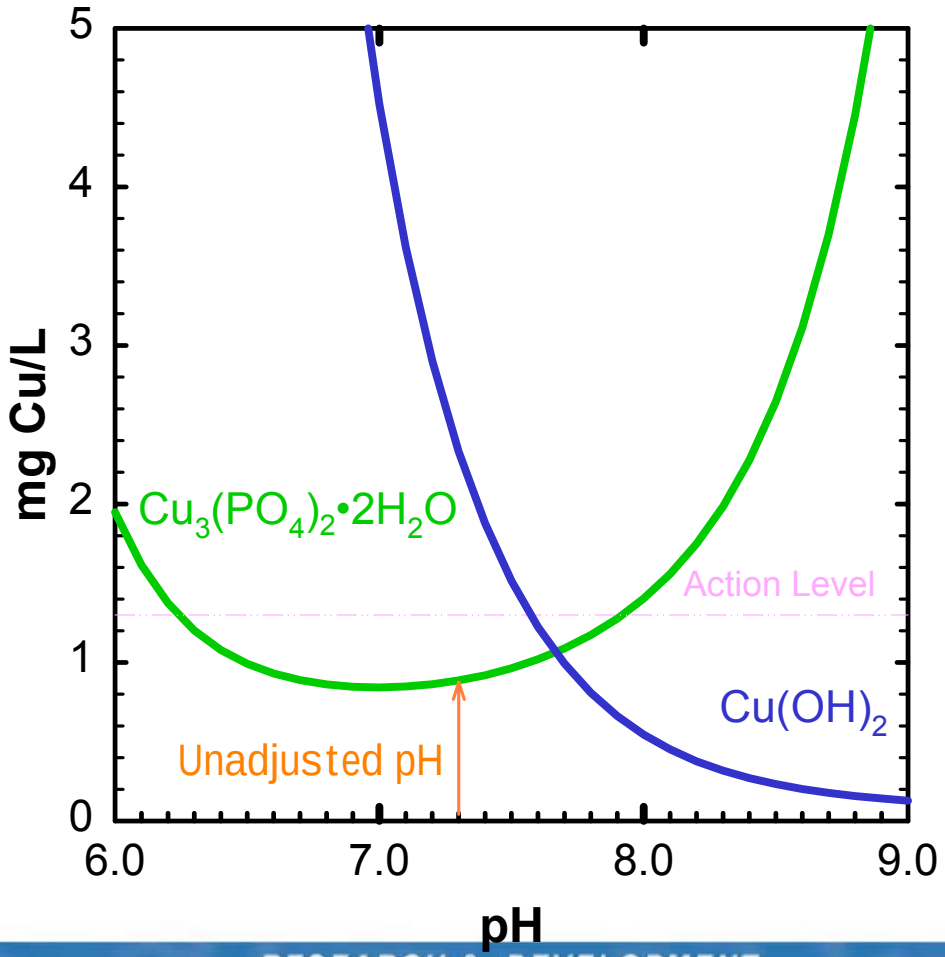
90

Effect of 3 mg/L Orthophosphate

EPA Pipe Experiments at pH 9.0

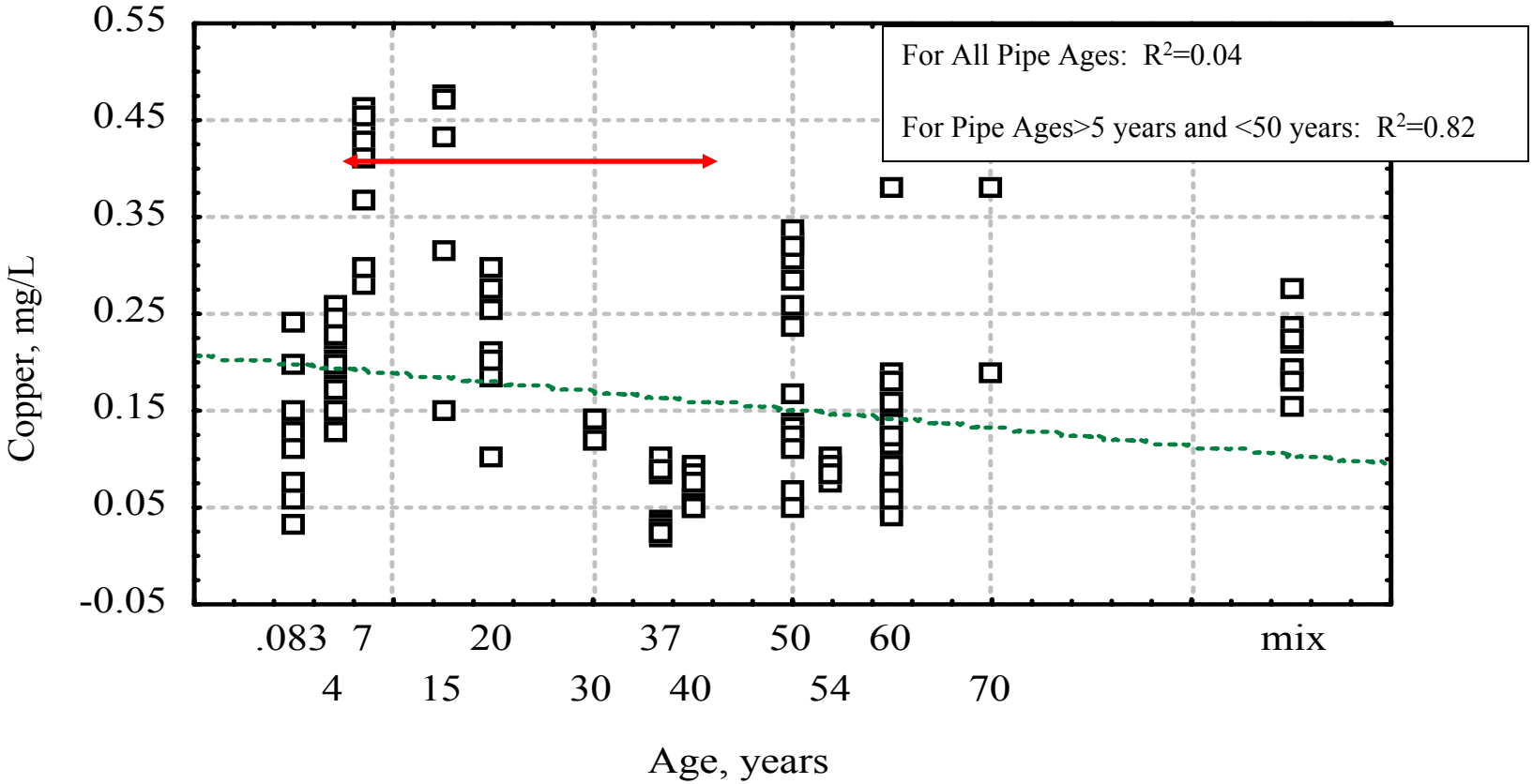


Theoretical Effect on Cu of 3.3 mg PO_4/L at DIC=63 mg C/L



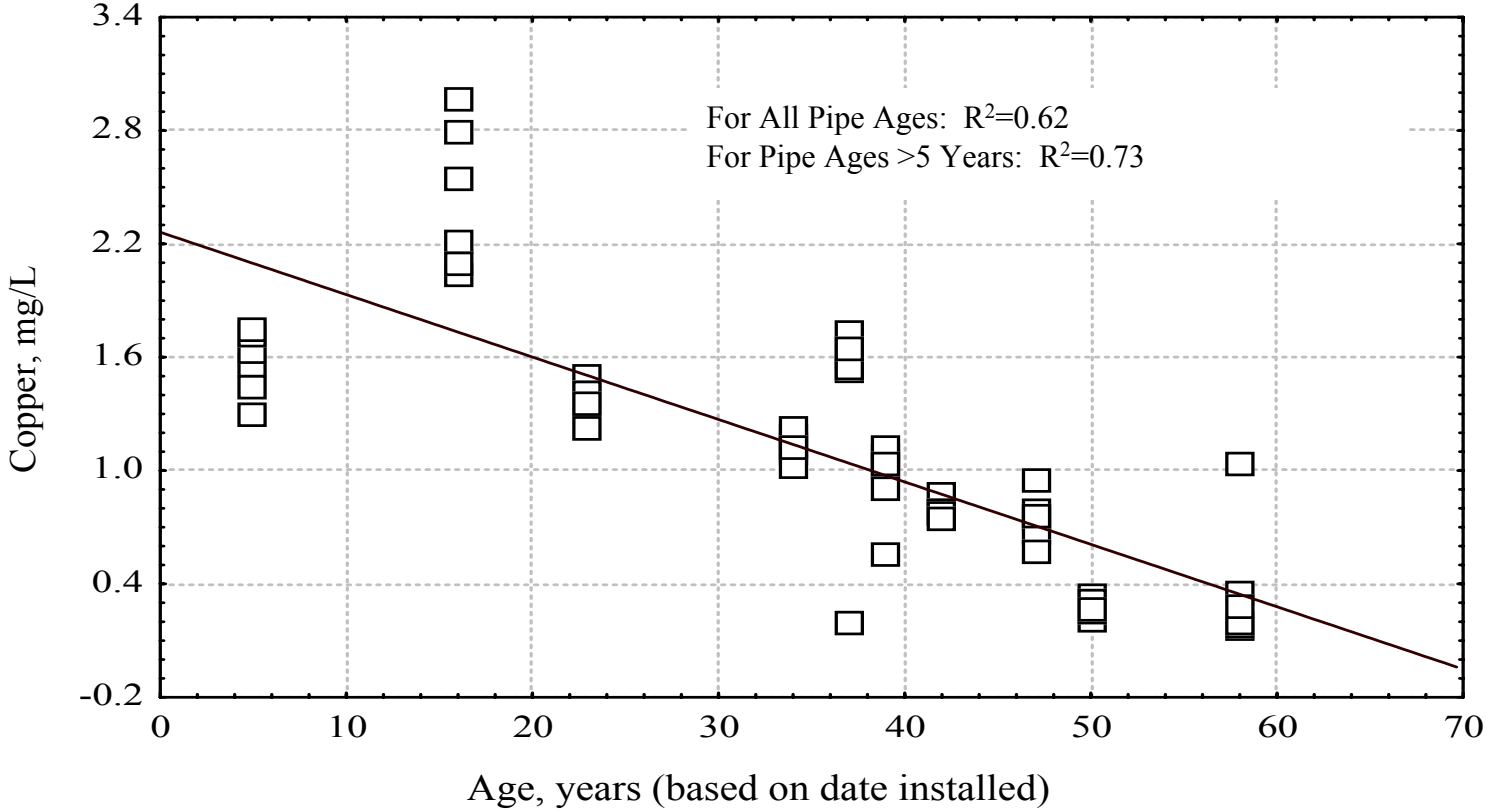
Piping Age vs. Copper Levels

Philadelphia



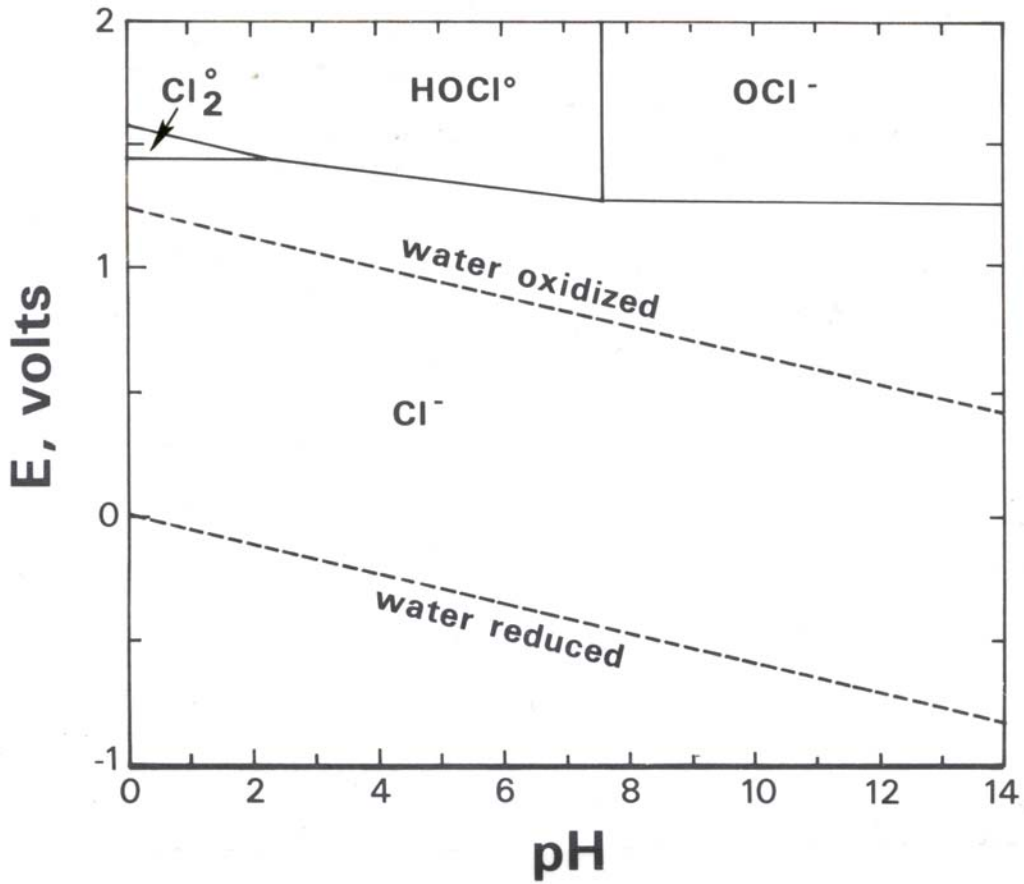
Piping Age vs. Copper Levels

Hastings, NE (high alkalinity)



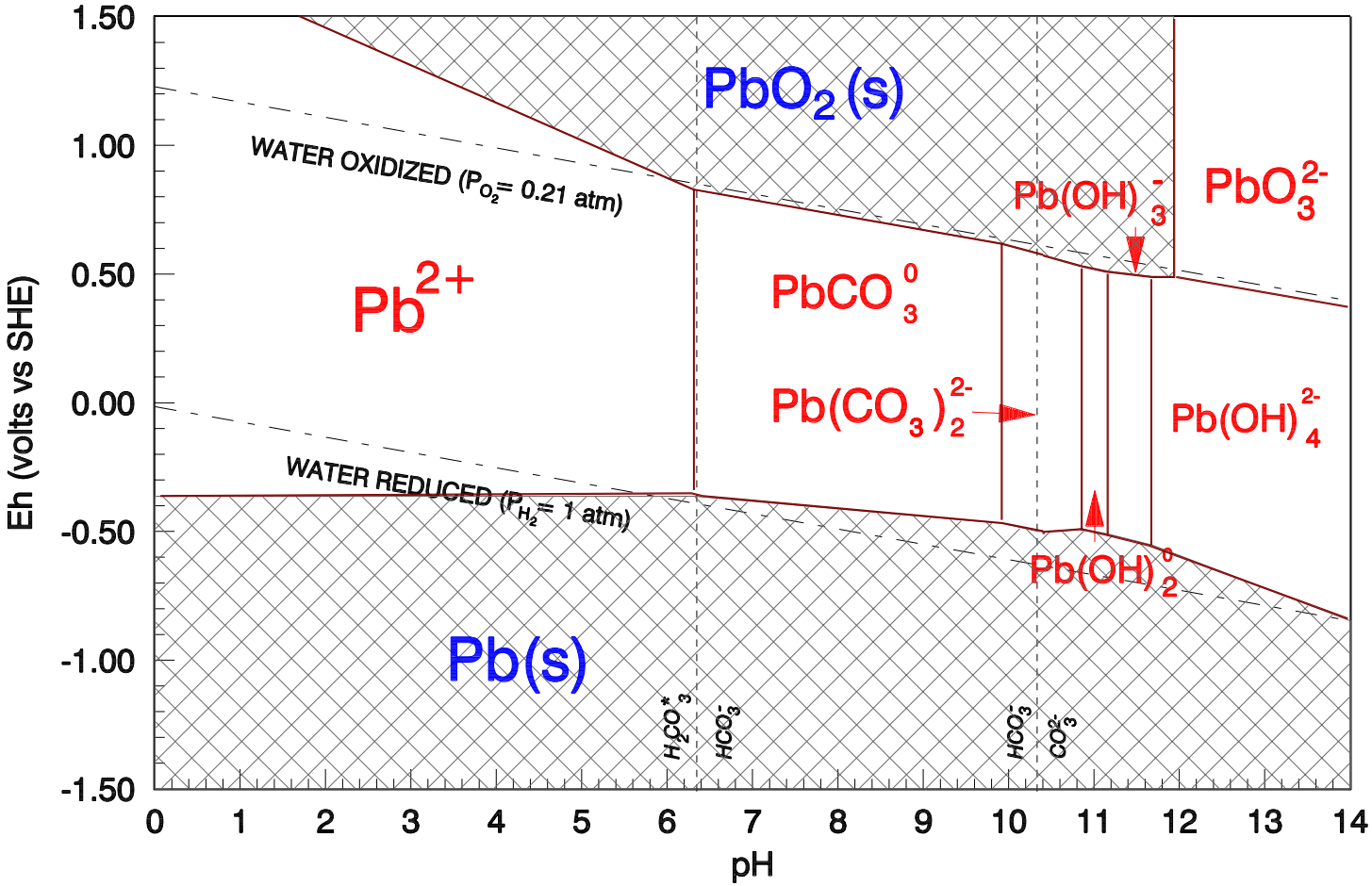
Lead Chemistry Issues

EMF-pH Diagram for Metastable Hypochlorite Species (1 mg/L as Cl_2)



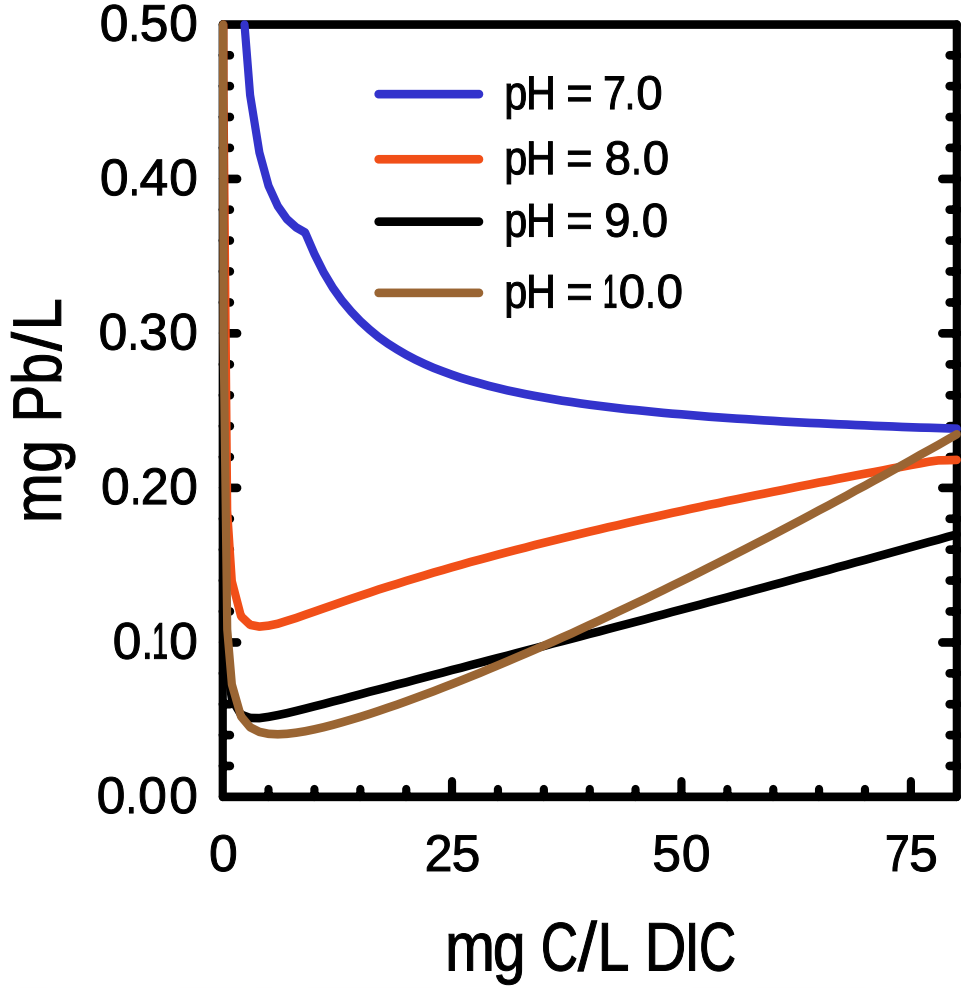
EMF-pH Diagram for Pb - H_2O - CO_2 System

Pb species = 0.015 mg/L; DIC = 18 mg C/L
I=0; 25°C

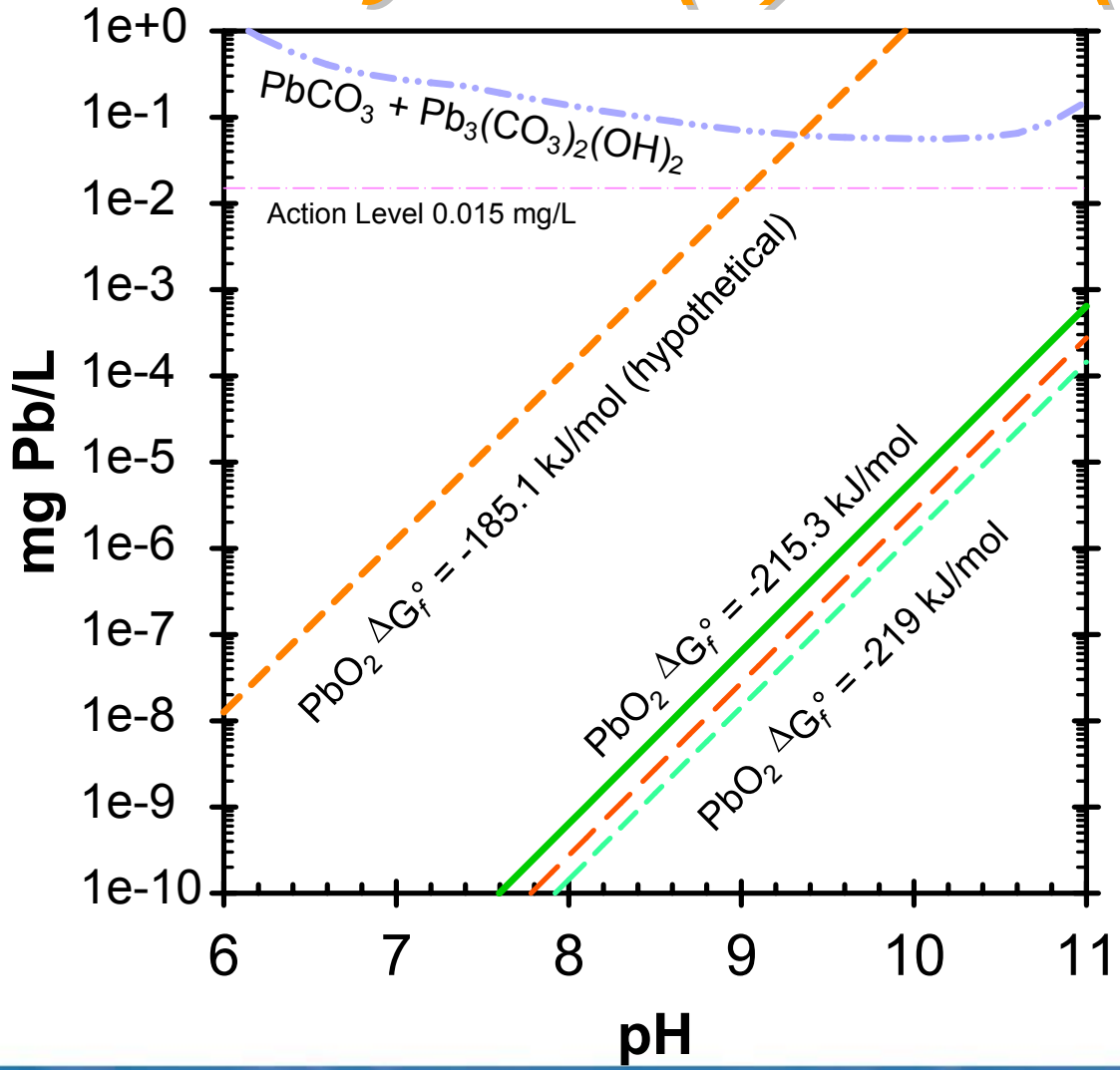


Simple Plumbosolvency Diagram

I=0.02, 25°C



Solubility of Pb(IV) and Pb(II)



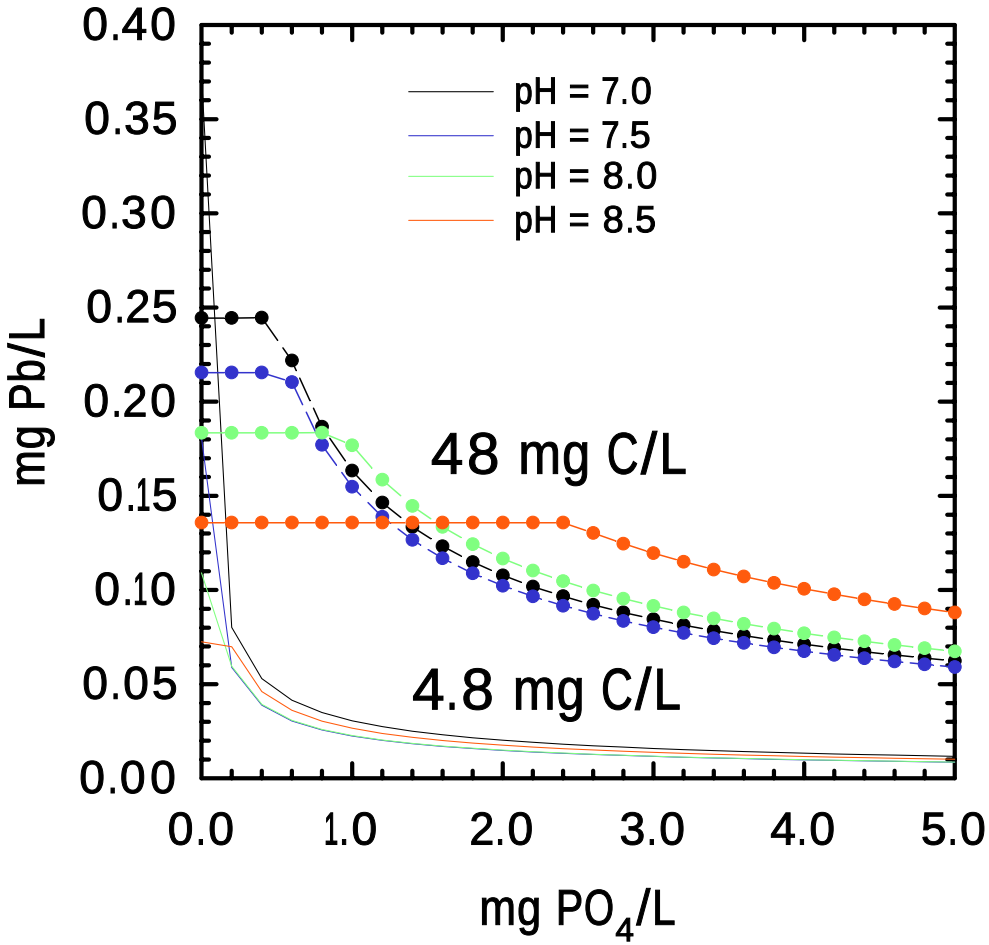
Some "typical" Pb(II) Scales

Four Random LSL Specimens from GCWW

Photographs of Monroe St. Scale

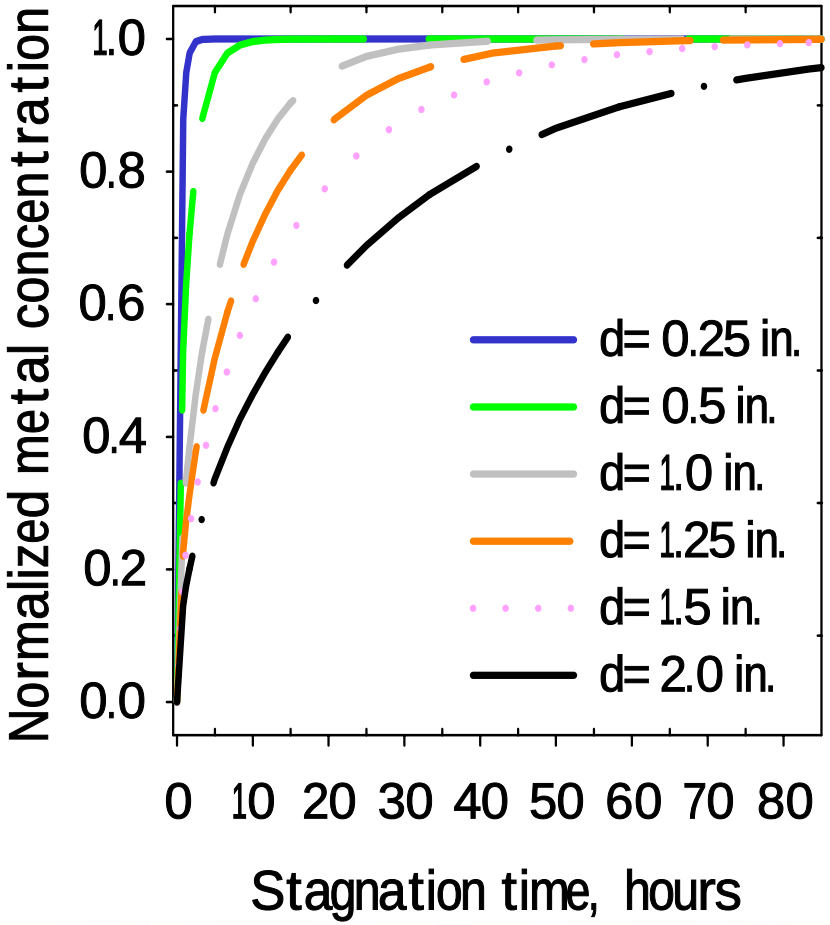
Another PbO_2 Example: Utility X

Effect of pH, PO_4 & DIC on Lead



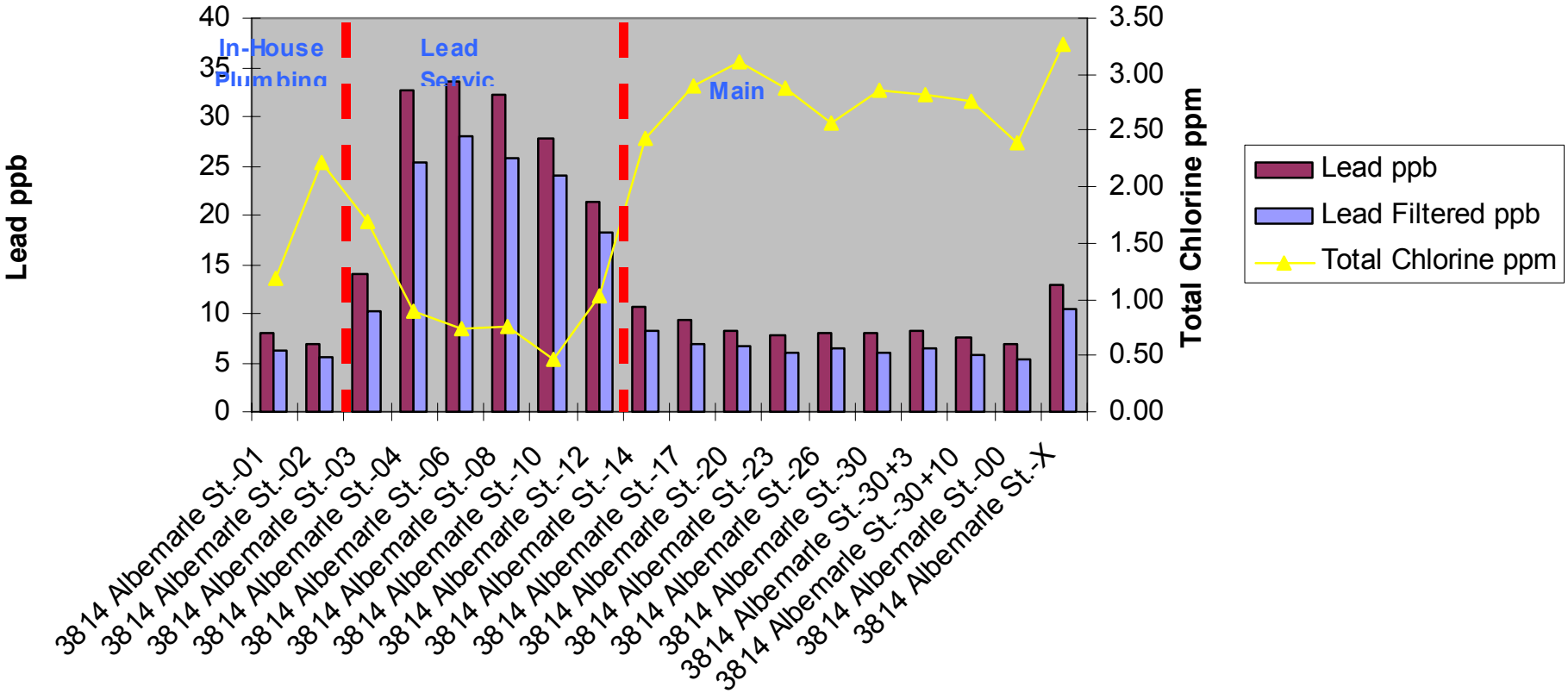
Stagnation Curve: Normalized "Pb" Concentrations

Different Pipe ID's, Radial Diffusion (Kuch & Wagner)



After 4 weeks of Cl_2

3814 Albemarle St



In-line Device Issues

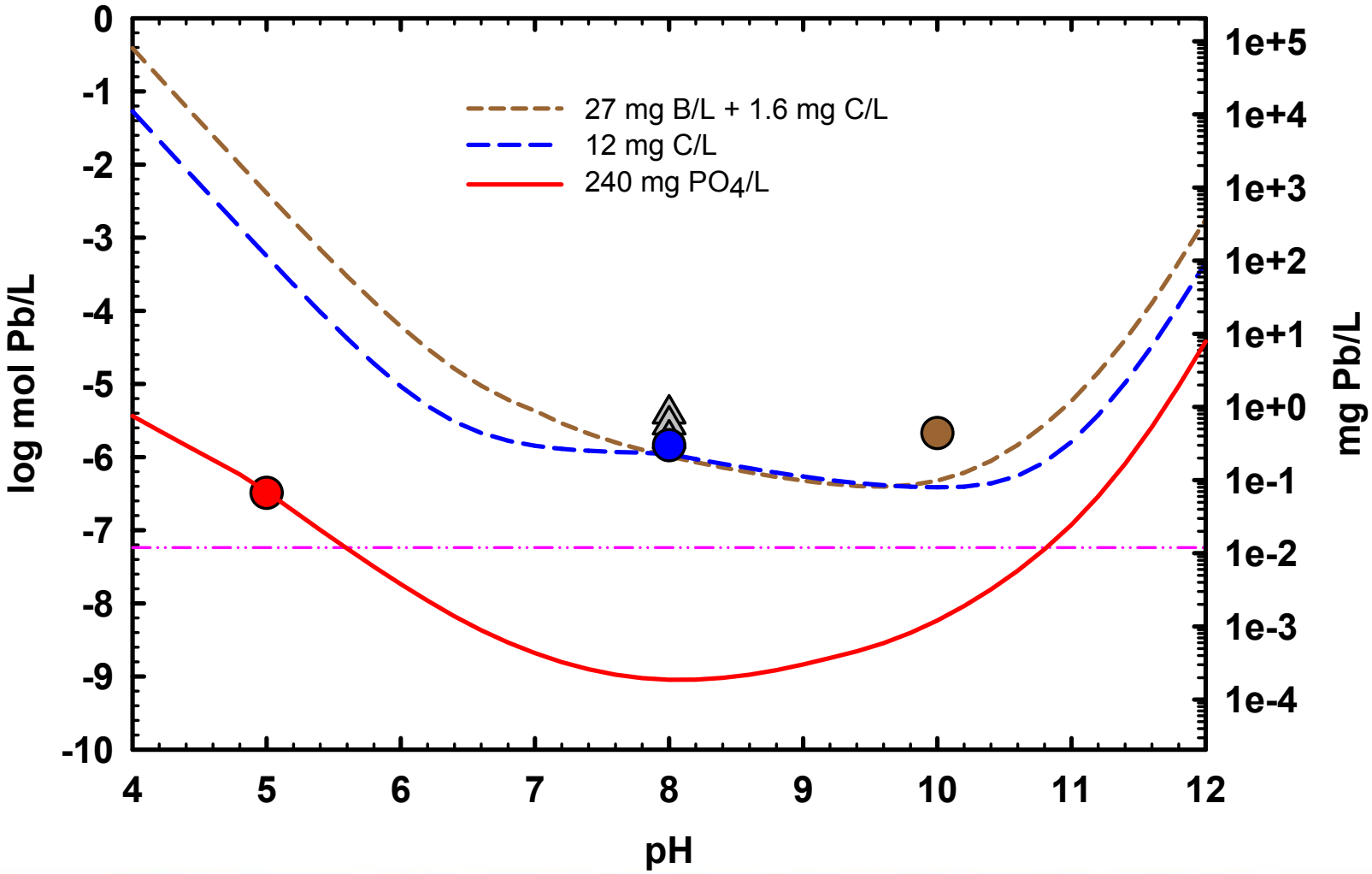
NSF/ANSI 61 Issues

- Section 9 (endpoint devices)
  - Aggressive leach solution (DIC = 122, pH 8)
  - Complicated exposure & computation procedure
  - Large "normalization" factor
- Section 8 (in-line devices)
  - Non-aggressive solutions
  - Simple exposure protocol that is fairly difficult
  - Very large "normalization" factor
  - No limit to number of devices in a line

Section 8 Chemistry Issues

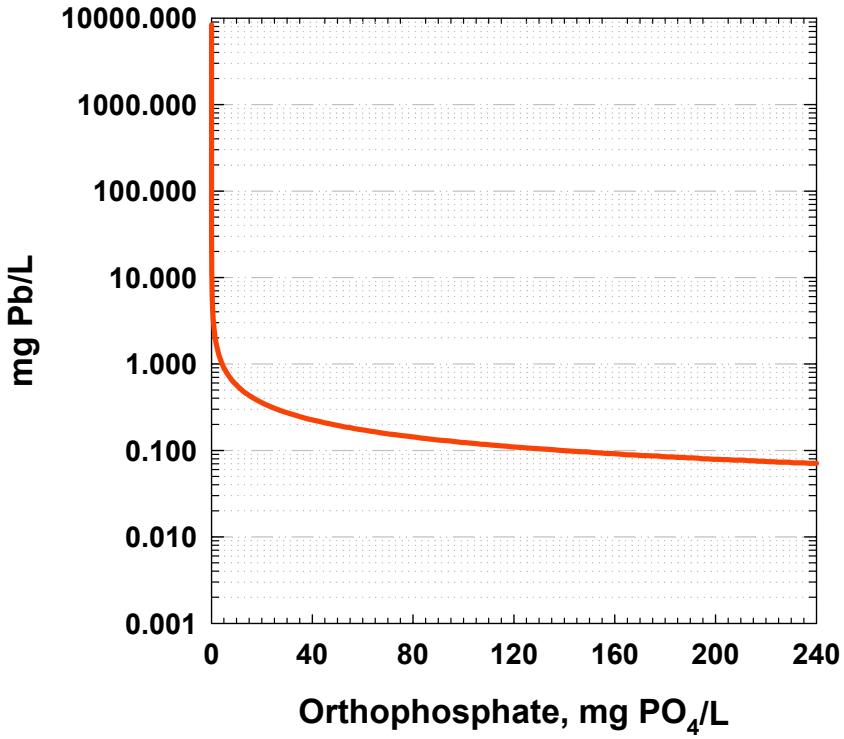
- Two test solutions
  - pH 5, 240 mg/L PO_4
  - pH 10, variable TIC (can passivate), borate buffer
- Strongly inhibitive to Pb & Cu solubility
- Large normalization factor can certify Pb
- NSF will be testing pH 10 reproducibility
- EPA will be evaluating stringency

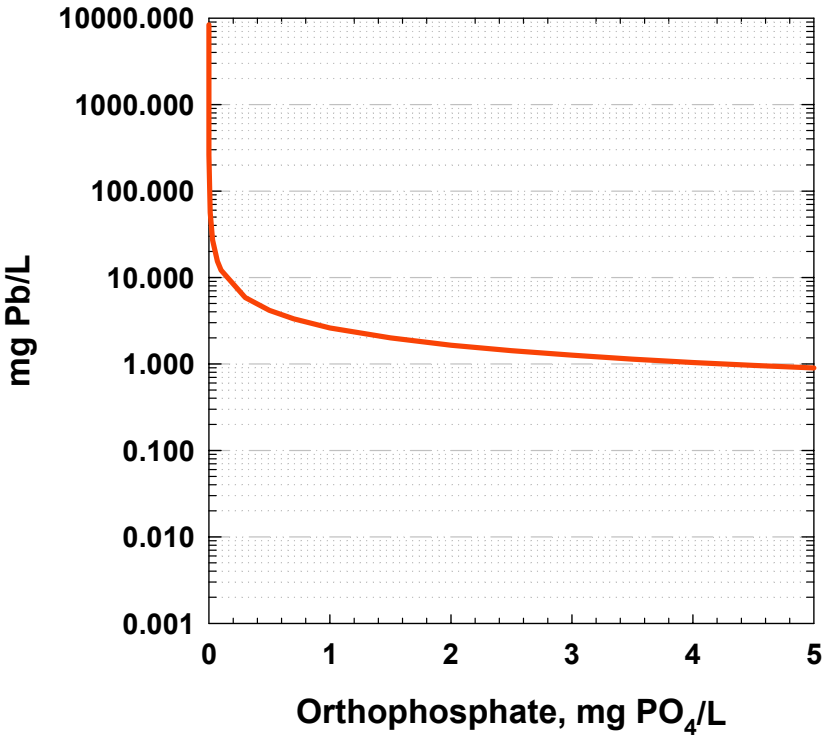
Early Pb Coupon Experiments



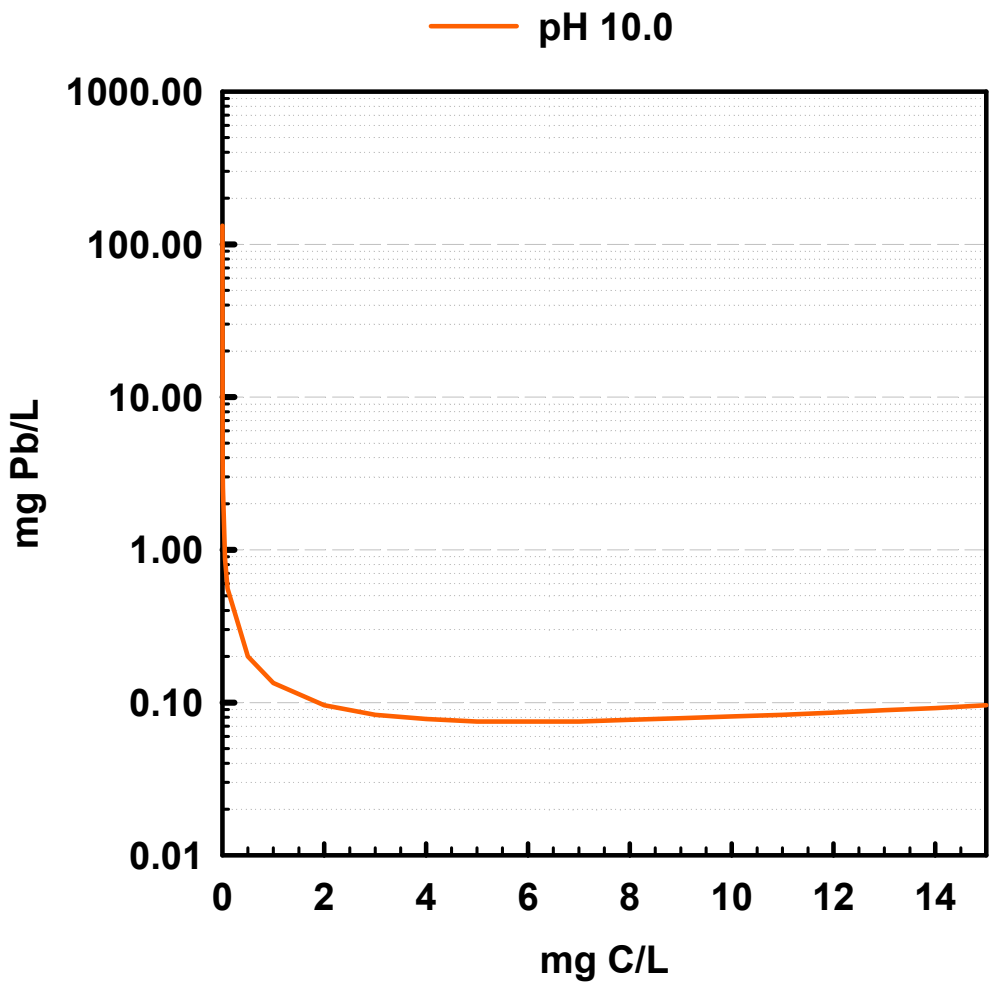
Phosphate Buffer Is Not Inert

Effect of Orthophosphate on Pb Solubility
pH 5.0, DIC = 0.14 (atmospheric equilibrium)





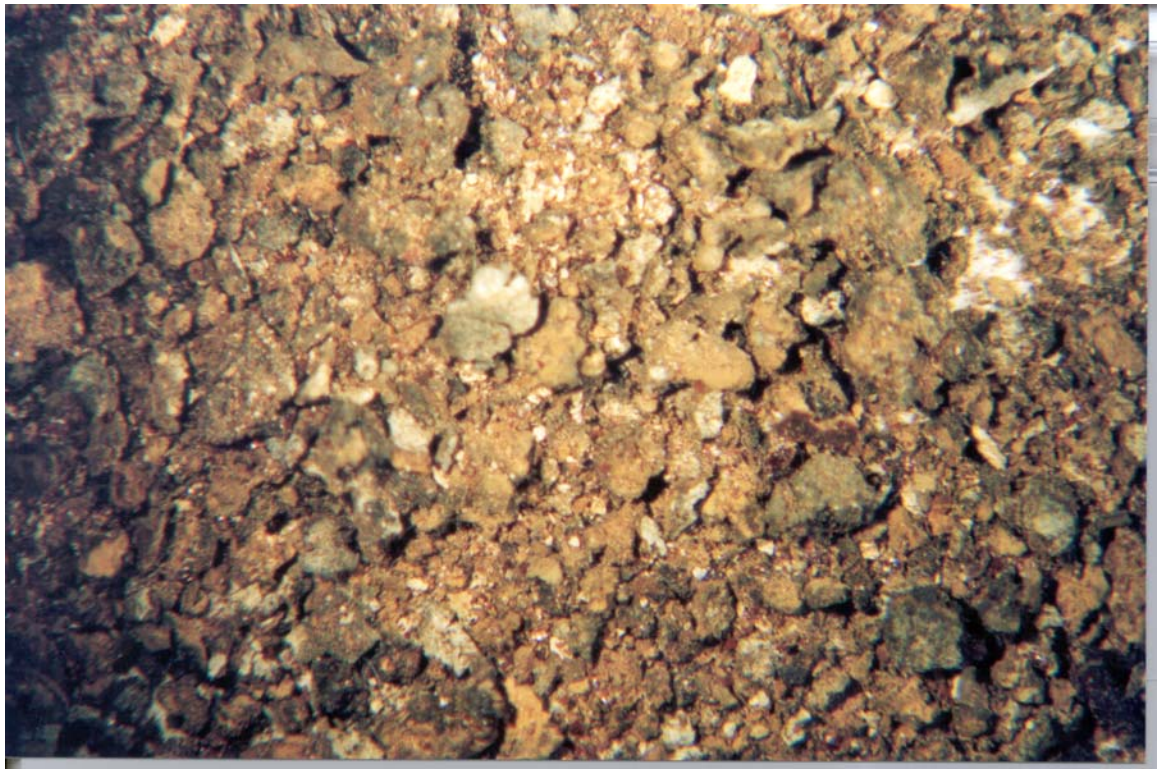
Sensitivity of Pb to DIC from Air



Trace Metal/Radionuclide Accumulation

City "A" Thick Hydrous Scale Layer

City "B", 16x Magnification



Trace Constituents

Element	City "A" (1) mg/kg	City "A" (2) mg/kg	City "B" mg/kg	City "C" mg/kg	City "D" mg/kg	City "E" Fe mg/kg
As	20	31.6	2	10.6	229	21.1
Ba	88	< 0.009	1	< 0.02	< 0.009	< 0.009
Bi	340	5.97	550	1.72	2.54	0.38
Cd	7.4	16.1	0.4	0.59	76.8	0.62
Cr	29	65.4	<1	4.06	6.36	14.2
Cu	350	0.01	1100	0.08	0.09	0.20
Hg	0.26	0.34	0.11	1.24	0.85	0.48
Mn	300000	686000	71	781	6240	0.031
Ni	40	164	15	68.7	21.4	8.48
Sb	100	2.54	85	5.39	27.4	0.78
Sn	100	1.26	210	5.47	105	5.82
Sr	14	81.6	0.4	43.7	69.4	87.7
V	43	68.4	9	182	154	2
Zn	2100	9170	10	36900	687	533

"Unusual" Constituents

Element	City "A" (1) mg/kg	City "A" (2) mg/kg	City "B" mg/kg	City "C" mg/kg	City "D" mg/kg	City "E" Fe mg/kg
Ce	16	8.33	0.7	3.29	2.34	0.28
Co	15	36.2	0.2	2.47	6.83	0.69
Dy	3.5	646	0.09	188	4450	35.9
Gd	4.5	2.7	0.10	14.1	0.957	0.31
La	19	38.9	0.7	1.5	5.62	0.39
Mo	1.3	0.47	< 0.1	8.29	6.48	13.6
Nd	20	32.8	0.5	1.33	6.12	0.38
Pr	4.5	7.35	0.1	0.32	1.38	0.09
Rb	< 0.1	0.23	< 0.1	1.14	2.68	0.45
Se	< 1	0.3	1	0.5	7.81	< 0.2
Sm	4.1	6.22	0.1	0.27	1.28	0.07
Tl	0.6	0.38	0.1	12.7	0.24	<0.06
U	1.1	2.66	1.4	20.4	8.38	1.47
Y	27	41.7	0.5	2.52	6.83	0.36

Aluminum Coatings

- Widespread when silica present, or alum use
- Often amorphous
- Shown in some cases to reduce Pb release
- Some researchers think it aggravates pitting corrosion
- Can impede hydraulics

Emerging Issues

Emerging Issues

- How does partial LSLR affect Pb levels?
  - Disturbance
  - Cutting method
  - Possibility of some galvanic corrosion (next slide)
- How well will non-Pb brass parts work long-term?
- Does leaving LSL in place constitute a hazardous waste problem?

Galvanic Corrosion

- In-line devices with service line
- Partial service line replacement
  - Does it relate to relative segment lengths?
  - To what extent is it dependent on water chemistry?
  - Do certain disinfectants affect it more?

Questions?