Lead Over Time in Chicago

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IWEA

City of Chicago
Department of Water Management
Thomas H. Powers, P.E., Commissioner

Department of Water Management

Water System Overview

Protecting public health & safety

- 2 Cribs
- 2 Water Purification Plants
  - Jardine: 1,457 MGD capacity (1964)
  - South: 720 MGD capacity (1947)
- 12 Water Pumping Stations
- 4,300 Miles of Distribution Mains
- 4,400 Miles of Sewer Mains
- Serves City & 125 suburbs (~41% of IL)
- Serves 5.3 million people

Why lead?

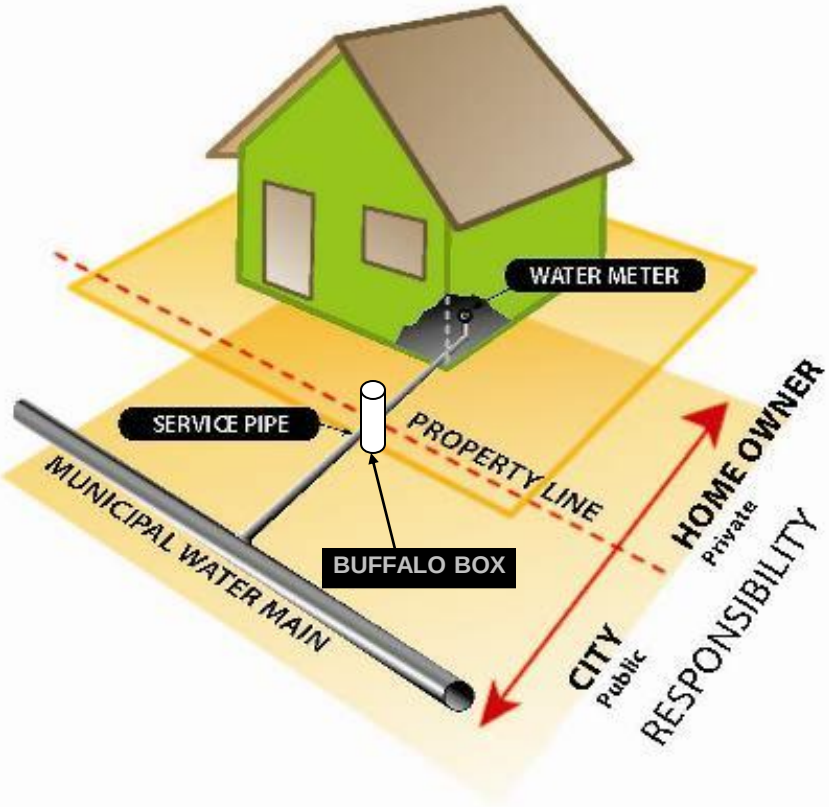
- Lead has been used in pipes for a very long time!
  - Maleable
  - Abundant
  - Low melting point
  - Resistant to corrosion

- But it is toxic
  - Lowers IQ in children
  - Can leach into water
  - Dissolution rate increases with temperature

Lead pipes from Roman Baths

Current lead status in Chicago

- ~500,000 water accounts
- Estimated 78% have lead service lines
  - Installed pre-1986 & ≤ 2" diameter
    ➡ lead (or maybe iron)
  - Installed post-1986 & ≤ 2" diameter
    ➡ copper
  - > 3" diameter
    ➡ cast iron or ductile iron
- Lead used until 1986 amendment to the Safe Drinking Water Act
  - "lead-free" ≤ 8% lead
  - 2014: "lead-free" ≤ 0.25% lead
- Downstream of buffalo box is owner's responsibility



Chicago's Lead Research History

Chicago's Early Lead Research Efforts – 1976 to 1990

- Started with pH control of lead

Blended Phosphate Research, LCR – 1990 to present

- Investigating blended phosphate control of lead
- Investigating addition of orthophosphate upstream

Current Compliance

Early Lead Research

1947 SWPP/1964 JWPP

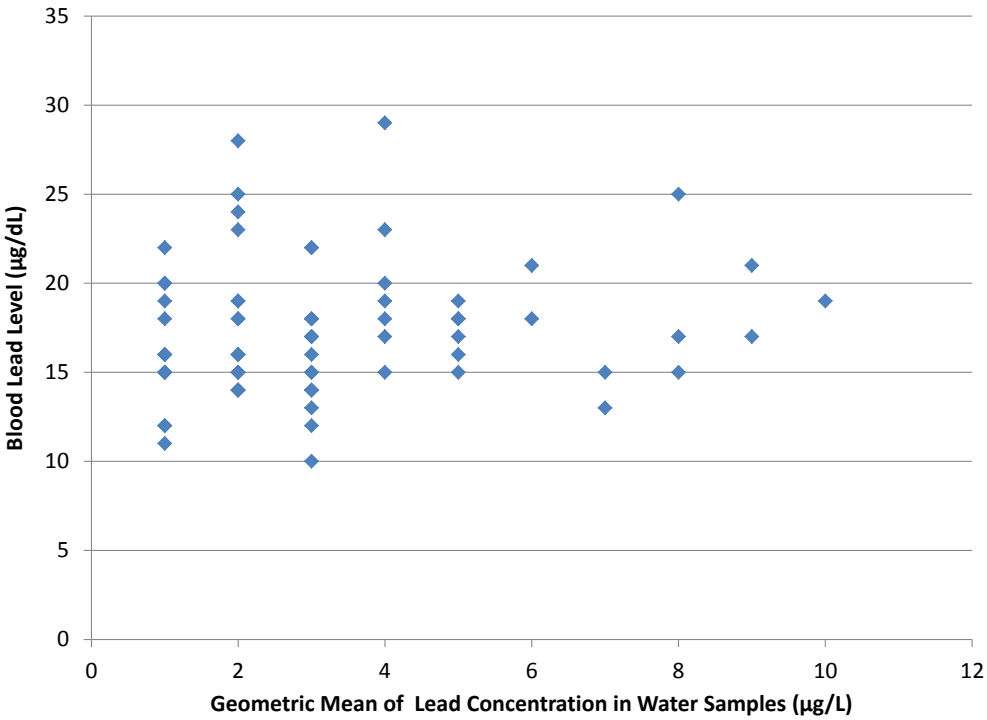
- At plant start-up, Chicago used pH adjustment as corrosion control
  - pH is increased via feeding of lime
  - Maintained Langelier Saturation Index > 0.1 ➡ lead leaching is minimized from scale coating in pipe

1974

- Safe Drinking Water Act is established
  - Lead Maximum Contaminant Level (MCL) = 50 µg/L

1976 – 1977 WHO Study

- World Health Organization, Chicago Departments of Health (DOH) and Water Management (DWM) measure lead in blood samples & home kitchen taps from 99 employees
  - Up to 8 water samples (initial & best estimate of service line water) taken per employee over a year to check seasonal effect
  - All blood lead levels were measured by DOH & ranged 11-29 µg/100 mL (< NIOSH elevated level of 60 µg/100 mL at the time)
  - No correlation was found between blood lead levels & drinking water lead levels



1986 – 1990 New Bldg. Study

- DWM conducts New Building Lead Surveys at kitchen taps of newly built homes (MCL = 50 µg/L)
- Same homes sampled in each survey

	JWPP (# homes = 45)		SWPP (# homes = 96)	
Survey	Avg. Home Age (months)	Avg. Initial Lead Conc. (µg/L)	Avg. Home Age (months)	Avg. Initial Lead Conc. (µg/L)
1	10	43.4	13	38.6
2	30	26.0	26	27.5
3	40	21.0	42	19.4

JWPP = Jardine Water Purification Plant
SWPP = South Water Purification Plant

Took 3 years of scale build up to reduce lead by 50%

Also, high seasonal sensitivity

May 1989 – September 1990

- DWM Employee Sampling Program used to determine lead concentrations at kitchen taps of 30 volunteers

Lead Concentration	Initial	"Service Line"	Final Flush
# data sets	30	30	30
# individual tests	233	233	235
Average (µg/L)	9.0	13.9	8.8
Median (µg/L)	8.2	13.4	7.5
Range (µg/L)	<3 - 118	<3 - 76	<3 - 53
95% Confidence Level	6.8 - 11.2	11.2 - 16.6	6.8 - 10.8

- Avg. home age =49 yrs

Less seasonally sensitive

Average < MCL

DWM concerned about outliers

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Blended Phosphate Research

April 1990 – October 1992

- DWM conducts voluntary, proactive testing of blended phosphate jointly with phosphate manufacturer (Hydronics/Stiles Kem)
  - Test conducted using PVC pipe loop with lead, copper, and steel coupons and JWPP outlet water (either pH-adjusted or treated with 0.7 mg/L total PO_4)
  - Blended phosphate treated water showed decreased lead leaching over time

January 1992

- Lead and Copper Rule is implemented (became law June 7, 1991)
- Lead < 15 µg/L at the 90th percentile of samples
- Copper < 1,300 µg/L at the 90th percentile of samples

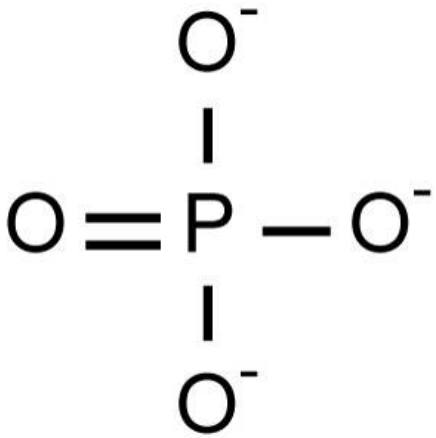
First LCR Compliance Samples

- DWM begins EPA-required, two 6-month monitoring periods (100 first-draw consumer samples)
- Had not yet implemented results from blended phosphate study!

Round	Report Date	Result	No. Sites >15µg/L	$Pb_{90\%}$ (µg/L)	$Cu_{90\%}$ (mg/L)
1	3/92	Pass	3	11	.024
2	12/92	Fail	19	20	.013
3	5/93	Pass	8	14	.012

Full-Scale Blended Phosphate

- With IEPA approval of blended phosphate testing, feeding of Stiles Kem blended phosphate began
  - SWPP – June 1993
  - JWPP – January 1994
  - Dose = 0.8 mg/L total PO_4 (6.7 lbs/MG)



- Didn't stop feeding lime until Dec. 1995
  - pH with lime addition was too high for optimum phosphate-based corrosion control

September 1993 – May 1994

- DWM conducts Optimal Corrosion Control Treatment (OCCT) Study using pipe loop rigs due to Dec. 1992 violation
- 4 types of blended phosphate tested (proprietary blends)
  - JWPP: Kjell
    Calciquest Blended
  - SWPP: Stiles Kem
    Betz Industrial

- All 4 types of blended phosphates provided comparable performance
- Phosphate-treated water reduced lead & copper leaching more than the pH-adjusted water

September 1995 – October 1996

- DWM conducts EPA-required testing of compatibility of other phosphate vendors to an established pipe film of Stiles Kem
  - Phase 1 (9/95 - 4/96): Stiles Kem fed to lead coupons to build up film
  - Phase 2 (4/96 - 10/96): Stiles Kem stopped & either Kjell, Betz, Calciquest, or Stiles Kem (control) phosphate blend was fed

- The control water (no PO_4) caused reversion of Stiles Kem pre-formed phosphate film
- The 4 blended phosphates (Stiles Kem, Kjell, Betz, Calciquest) caused no reversion of Stiles Kem pre-formed phosphate film
- Switched to Carus for economic reasons in early 1997

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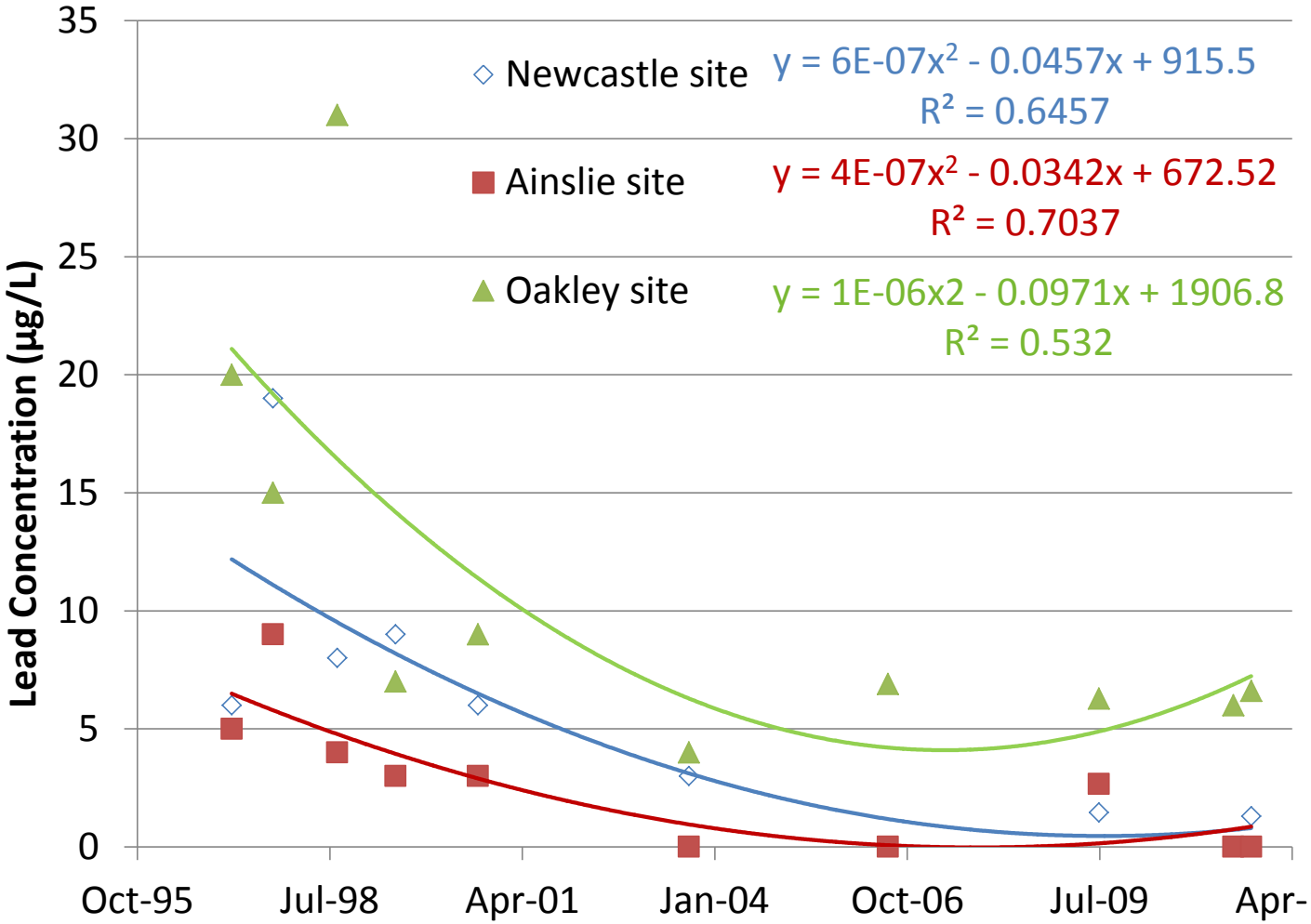
LCR Monitoring Summary

Sampling Date	Result	$Pb_{90\%}$ (µg/L)	$Cu_{90\%}$ (µg/L)	% Satellites whose $Pb_{90\%}$ > 15 µg/L
3/97	Pass	10	23	7
10/97	Pass	11	20	8
9/98	Pass	14	17	2
7/99	Pass	8	35	1
9/00	Pass	7	22	0
9/03	Pass	4	24	0
7/06	Pass	6.1	< 3	0
7/09	Pass	6.07	32	2

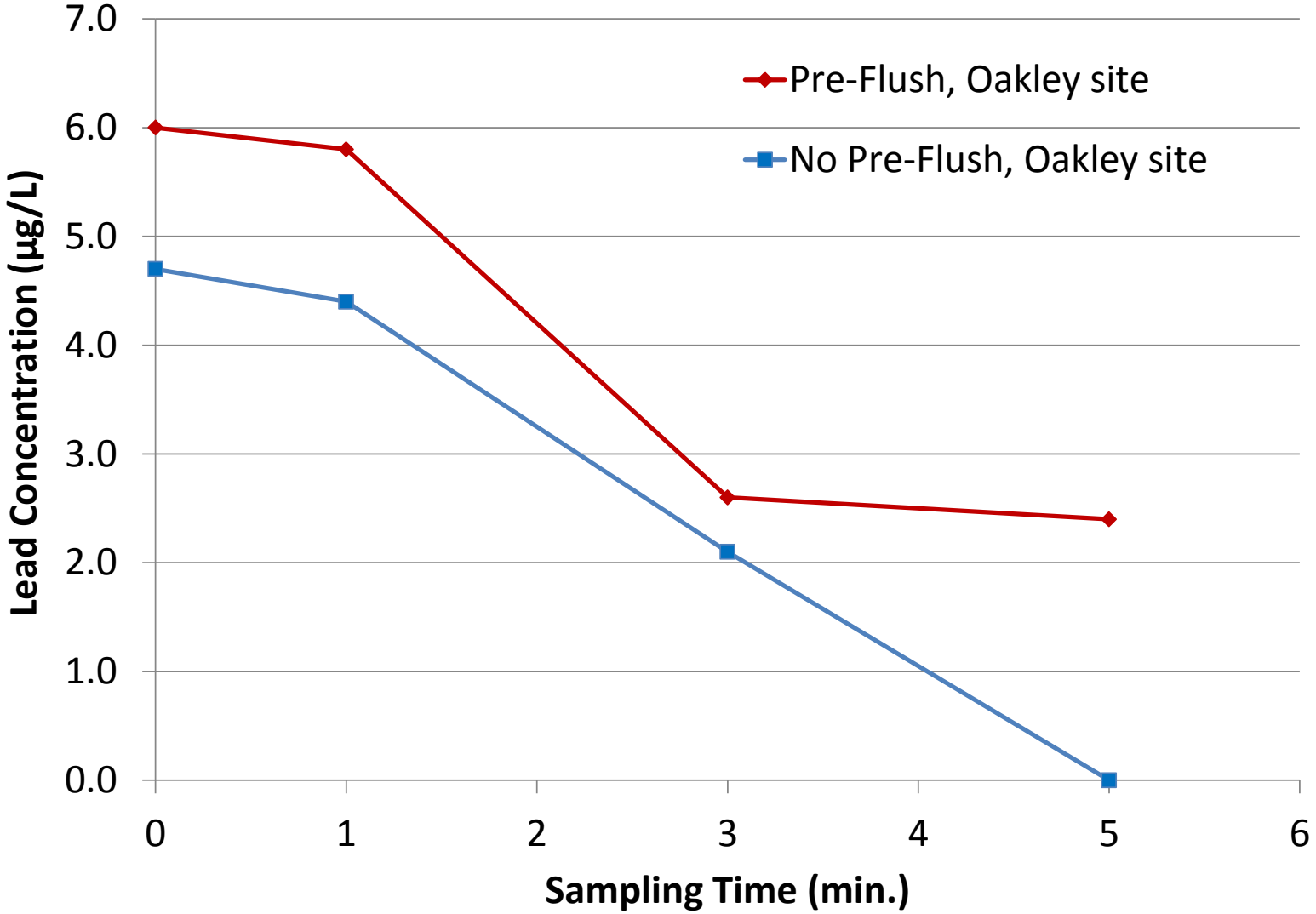
- 1998: corrosion control study to optimize phosphate application
  - Orthophosphate residual ≥ 0.4 mg/L, 7.2 ≥ pH ≥ 7.9 at entry point
  - Successful → reduced sampling schedule

Individual Site Tracking

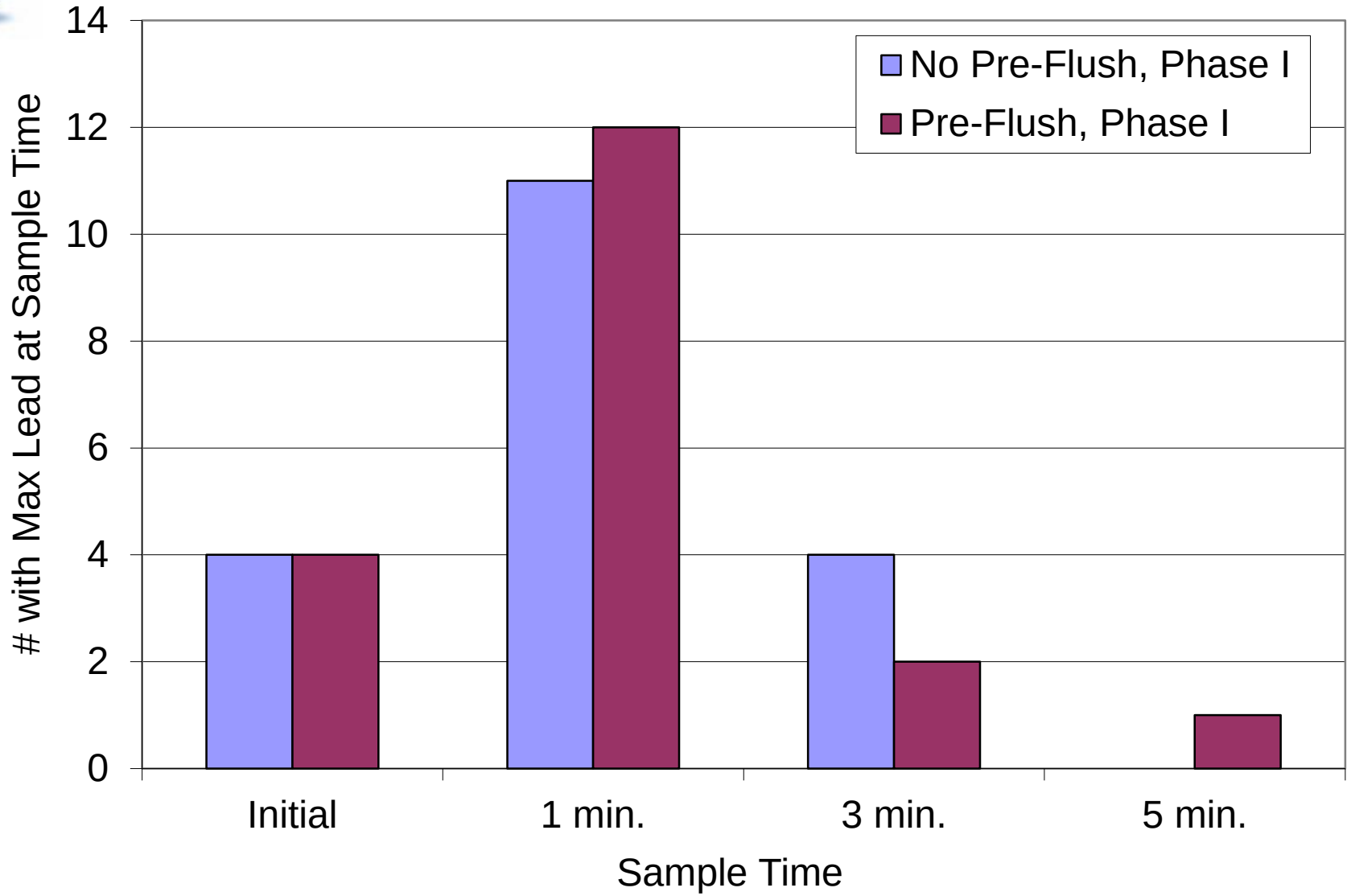
- Individual lead compliance sites have been tracked over time since 1997
- 20/24 sites show decrease in lead concentrations over time
  - Using a linear equation, these 20 slopes range -1.9×10^{-5} to -5.9×10^{-3}
  - Polynomial fits best



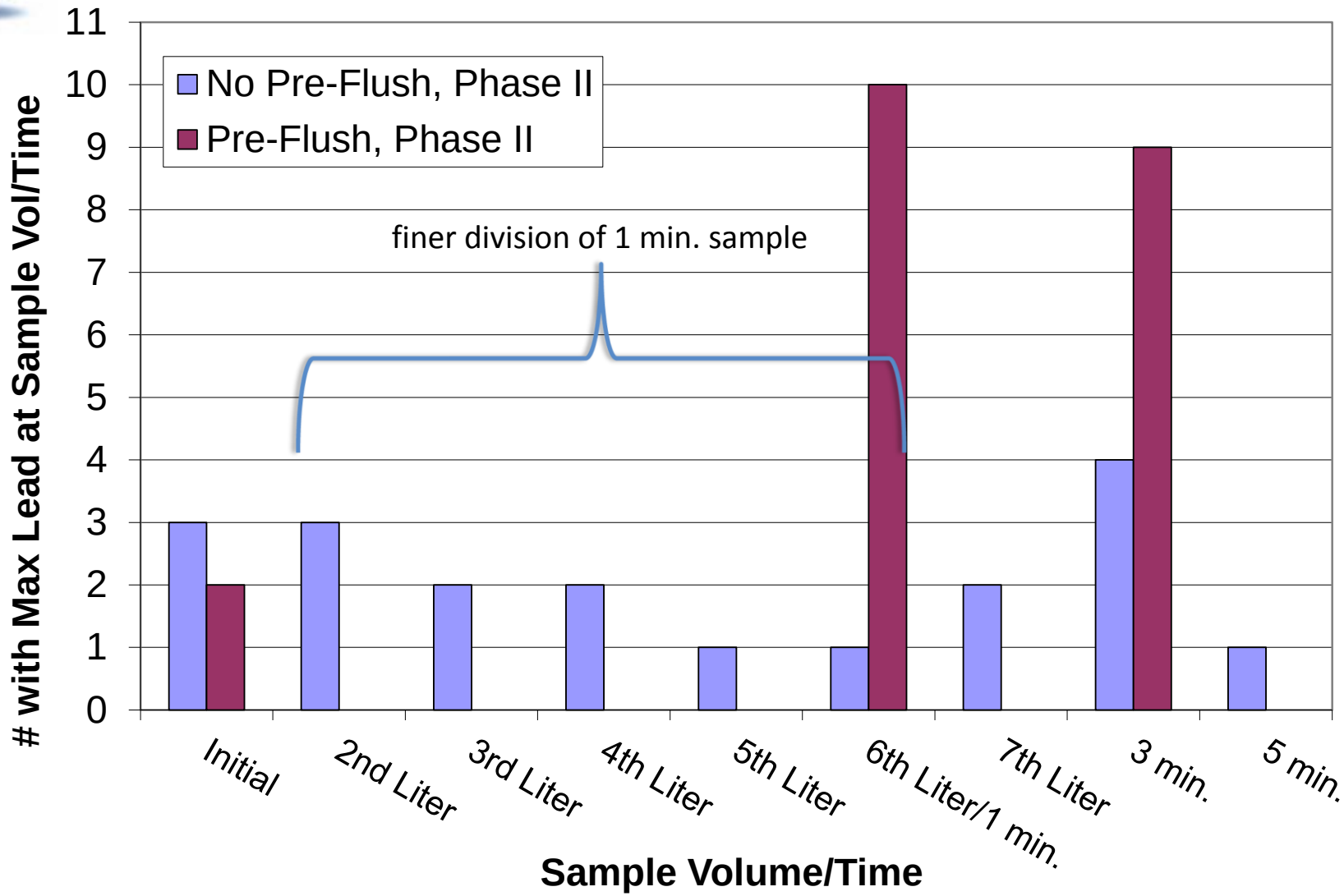
2011 Lead Sampling *Protocol* Study: Pre-Flush vs. No Pre-Flush



2011 Lead Sampling *Protocol* Study: Time Sequential Findings



2011 Lead Sampling *Protocol* Study: Vol. Sequential Findings



2011 Lead Sampling *Protocol* Study

- Findings
  - Entry to home for sequential sampling in early a.m. difficult
  - Practice of grounding electrical wiring to water lines → accelerated leaching of lead
  - Shows high level of variation from home to home
    - Pre-flushing *may* get more of the "worst case scenario" lead then not flushing
    - How to choose the "worst case scenario" lead concentration time if varies by site?

Conclusions & Future Research

- Chicago has been proactive in researching lead in drinking water since the 1970's
- DWM has been in compliance with LCR action levels since 1992, mainly due to successful blended phosphate use
- No "Magic Bullet" to lead sampling protocols

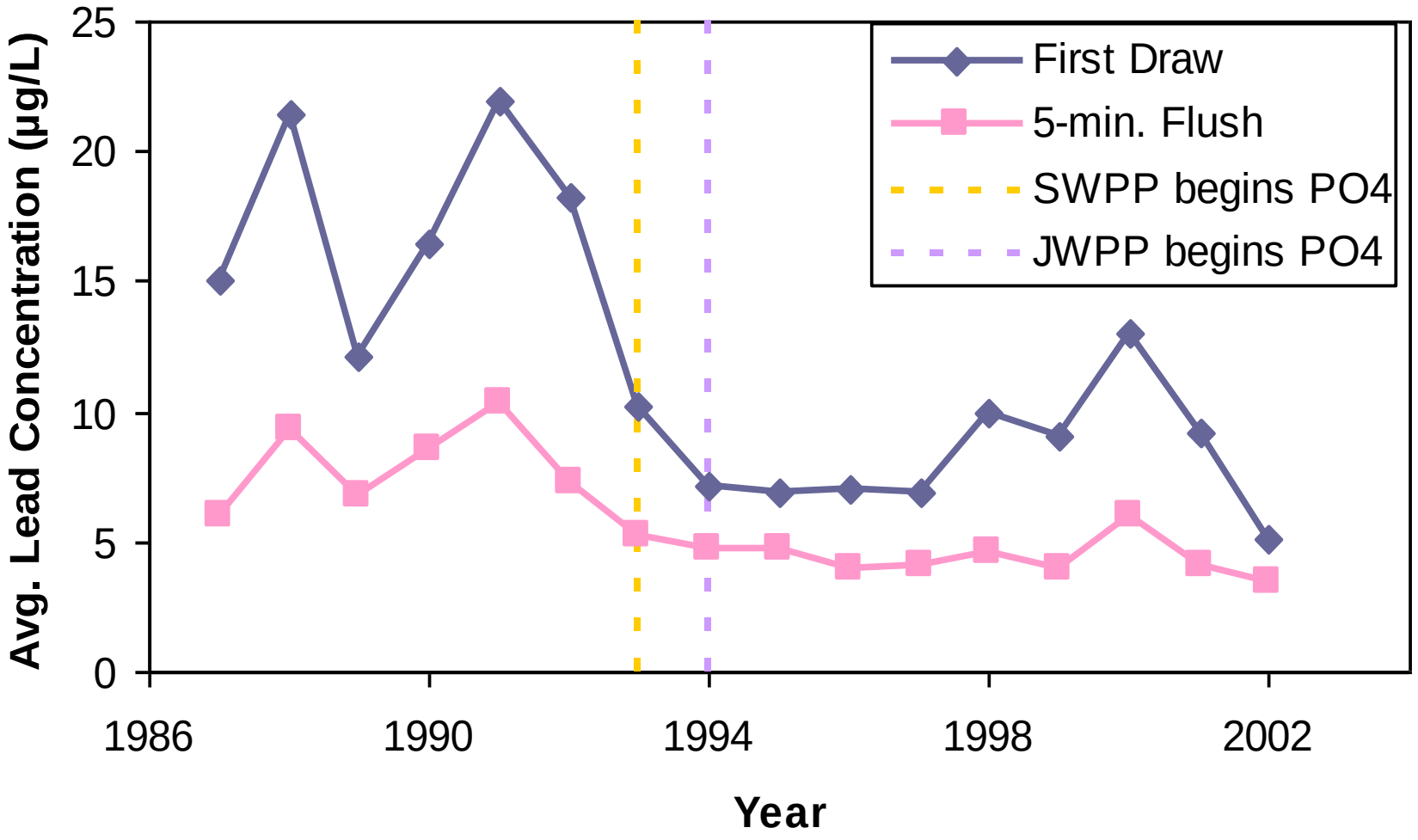
- Future/continuing research:
  - Full-scale SWPP ortho-PO_4 verification study
  - Partner with the USEPA on detailed sequential sampling research
  - Partner with Chicago Dept. of Public Health to sample homes of children with elevated blood lead levels

Questions?

Acknowledgements:

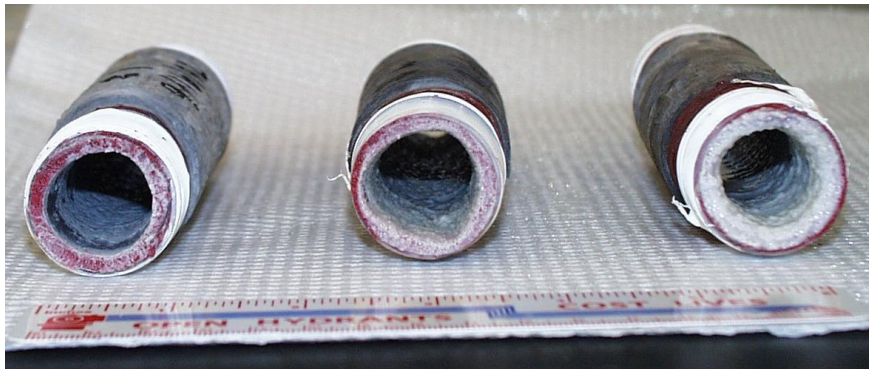
- Amrou Atassi, CDM Smith
- Cuneyt A. Feizoulof, AECOM

Consumer Request Lead Analysis



Unintended Consequence: Phosphate Deposition

- Late 1997 – Suburban customer observed hydraulic losses in transmission & distribution system
- Losses from deposits resulting from phosphate chemical applied for corrosion control. Testing of deposit by Univ. of IL confirmed $AlPO_4$ compound.
  - $AlPO_4$ vs. $Pb_3(PO_4)_2$
- How to minimize/eliminate the $AlPO_4$ deposition without adversely impacting lead?



  - Ortho-PO_4 addition to the rapid mix!
    - 1999-2005: Pipe loop testing, pilot testing, & eventually full-scale testing at JWPP showed up to 60% removal of dissolved Al was realized with 0.75 mg/L of ortho-PO_4
    - 2012: Full scale verification at SWPP to begin