Sequential Water Sampling as Diagnostic Tool for Assessing Lead Sources: Case Studies

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Tap Water Sampling Approaches

- Regulatory/Compliance/Treatment Sampling
- Exposure Assessment Sampling
- Sampling for Lead Sources
- No single universally applicable sampling approach for lead in drinking water exists
- There are many protocols, but each has a specific use answering one of those many questions

Multiple Options Exist for Lead Sampling

	Sampling Purpose	Protocol
First Draw	-Regulatory (US) -Treatment Assessment	-6+ hr stagnation -Collect first liter
Random Daytime Sampling (RDT)	-Regulatory (UK) -Treatment Assessment	-Random sample collection (variable stagnation times) -Collect first liter
Fixed Stagnation Time (30MS)	-Regulatory (Ontario) -Treatment Assessment	-2-5 min. flush -30 min stagnation -Collect first two liters
Fully Flushed	-Lead Source Assessment -Treatment Assessment	-Several piping volumes flushed -Collect first liter
Sequential Sampling (Profile Sampling)	Lead Source Assessment	-Defined stagnation time -Collect 10-20 samples of defined volume (125 mL, 250 mL, 1 L, etc.)
Composite Proportional	Exposure Assessment	-Normal water use patterns -A device collects 5% of every draw from the tap for consumption -Used for 1 week
Particle Stimulation Sampling	-Lead Type Assessment -Exposure Assessment	-5 min stagnation -Collect first liter and maximum flow rate, open and close tap five times, fill rest of bottle at normal flow rate. -Collect second liter at a normal flow rate -Collect third liter the same way as the first
Service Line Sampling (Second Draw)	-Regulatory (US) -Lead Source Assessment	-6+ hr stagnation -Volume between tap and LSL flushed -Collect 1 L
3T's Sampling for Schools	-Lead Source Assessment	-Overnight stagnation -Collect first 250 mL from all taps and fountains -Take follow up sample of overnight stagnation and 30 second flush if first sample> 20 ppb

Sampling Considerations

Protocol Considerations:
- Sample volume
- Number of samples per site
- Number of sites
- Stagnation time
- First draw or flush
- Site choice
- Frequency of sampling

Sampling Variabilities:
- Flow Rate
- Water Temperature
- Time of Year
- Pre-flushing
- Aerator removal
- Particulate release
- Accurate Quantification
- Stagnation time differences

Sampling for Lead Sources
Where is the lead coming from?

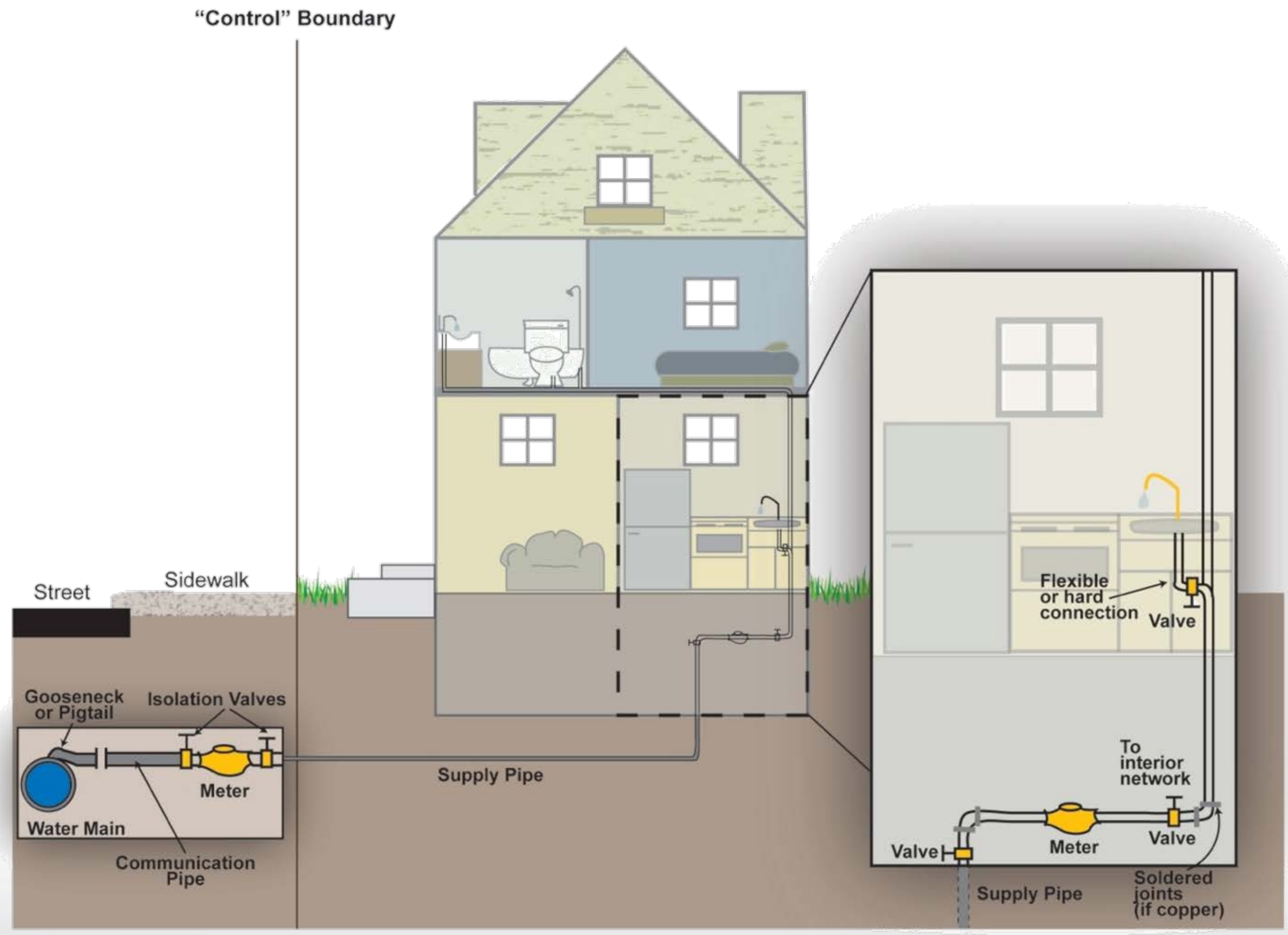
- Sequential Sampling
  - Correspond high Pb and/or Zn, Cu, Sn, Fe samples to plumbing volumes
- LSL Sampling

  Option 1: Fully flushed (+short stagnation, 15-30 minutes) samples above ~3 µg/L can indicate a LSL is present (threshold depends on LSL length)

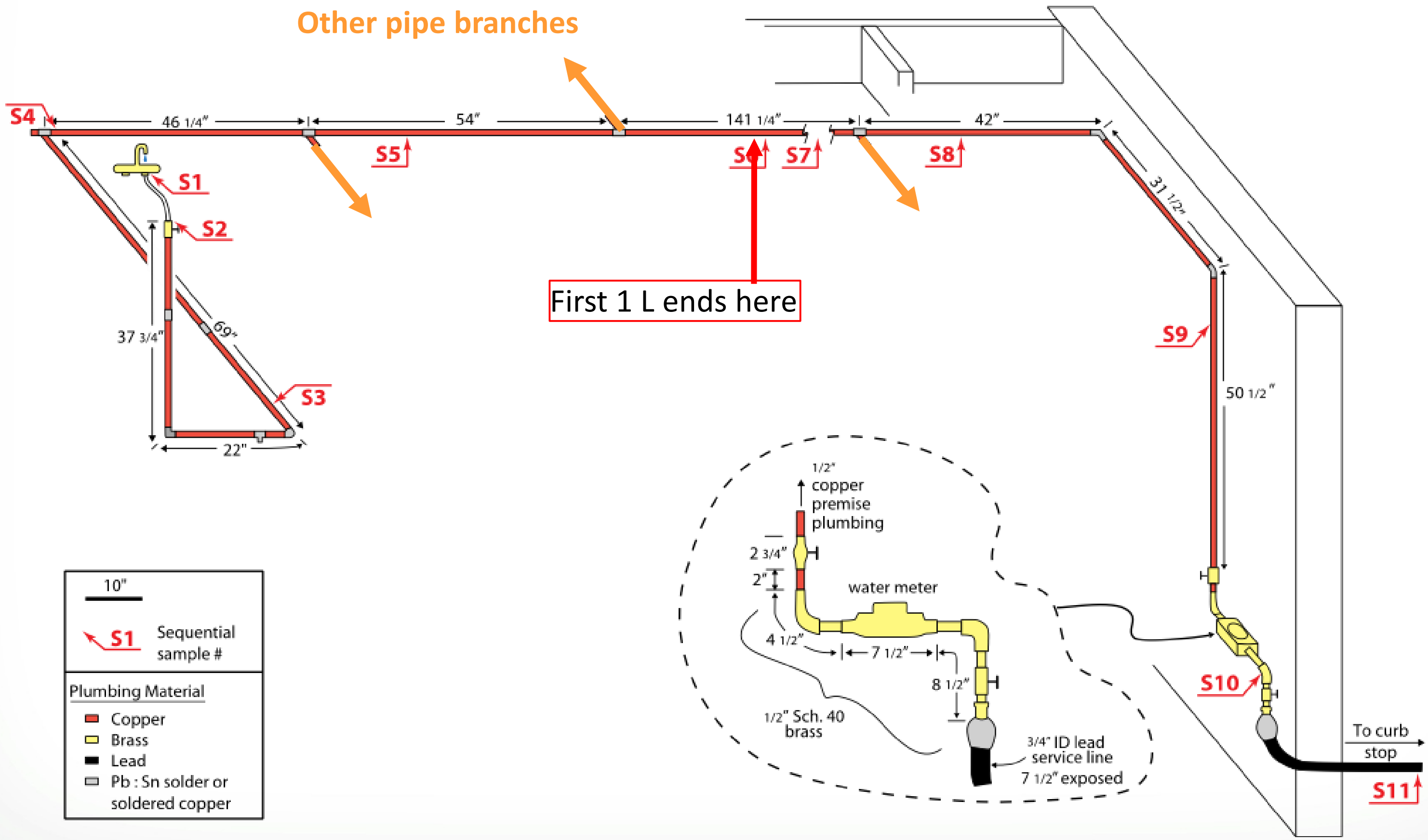
  Option 2: Allow water to sit motionless in the LSL for at least 6 hours, flush premise plumbing volume to sample LSL stagnation contribution (1 L sample)
- 3T's
  - 250 mL sample above 20 ppb after overnight stagnation indicates faucet or bubbler likely contributes lead (brass)

*250 mL is ~4 ft of plumbing at ½ inch ID (inside diameter)

Plumbing Configuration



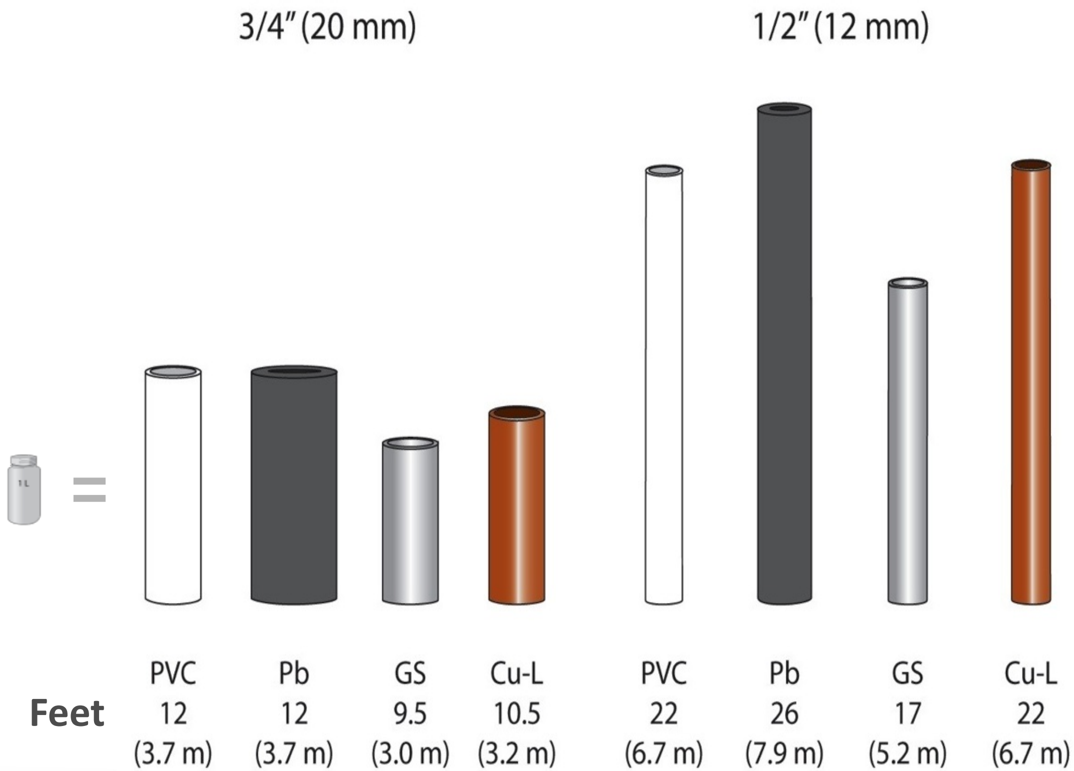
Identifying Pb Sources in a House: Volume as Distance



Tool: Sample Volumes Represent Source Position in Plumbing

Wide-mouth bottles preferable to allow higher flow rate

ID



After: Schock, M. R.; Lytle, D. A. Internal Corrosion and Deposition Control; In *Water Quality and Treatment: A Handbook of Community Water Supplies*; Sixth ed. 2011.

Sample Volume Per Length: Cu

Material	Type	Nominal Size (in)	OD (in)	Thickness (in)	ID (in)	mL/ft	mL/m	ft per L	m per L
Copper tube	K	0.500	0.625	0.049	0.527	43	141	23.3	7.1
Copper tube	L	0.500	0.625	0.04	0.545	46	151	21.8	6.6
Copper tube	M	0.500	0.625	0.028	0.569	50	164	20.0	6.1
Copper tube	K	0.750	0.875	0.065	0.745	86	281	11.7	3.6
Copper tube	L	0.750	0.875	0.045	0.785	95	312	10.5	3.2
Copper tube	M	0.750	0.875	0.032	0.811	102	333	9.8	3.0
Copper tube	K	1.000	1.125	0.065	0.995	153	502	6.5	2.0
Copper tube	L	1.000	1.125	0.05	1.025	162	532	6.2	1.9
Copper tube	M	1.000	1.125	0.035	1.055	172	564	5.8	1.8

Example: ¾-in ID Type L Copper

Material	Type	Nominal Size (in)	OD (in)	Thickness (in)	ID (in)	mL/ft	mL/m	ft per L	m per L
Copper tube	K	0.500	0.625	0.049	0.527	43	141	23.3	7.1
Copper tube	L	0.500	0.625	0.04	0.545	46	151	21.8	6.6
Copper tube	M	0.500	0.625	0.028	0.569	50	164	20.0	6.1
Copper tube	K	0.750	0.875	0.065	0.745	86	281	11.7	3.6
Copper tube	**L**	**0.750**	0.875	0.045	0.785	**95**	**312**	**10.5**	**3.2**
Copper tube	M	0.750	0.875	0.032	0.811	102	333	9.8	3.0
Copper tube	K	1.000	1.125	0.065	0.995	153	502	6.5	2.0
Copper tube	L	1.000	1.125	0.05	1.025	162	532	6.2	1.9
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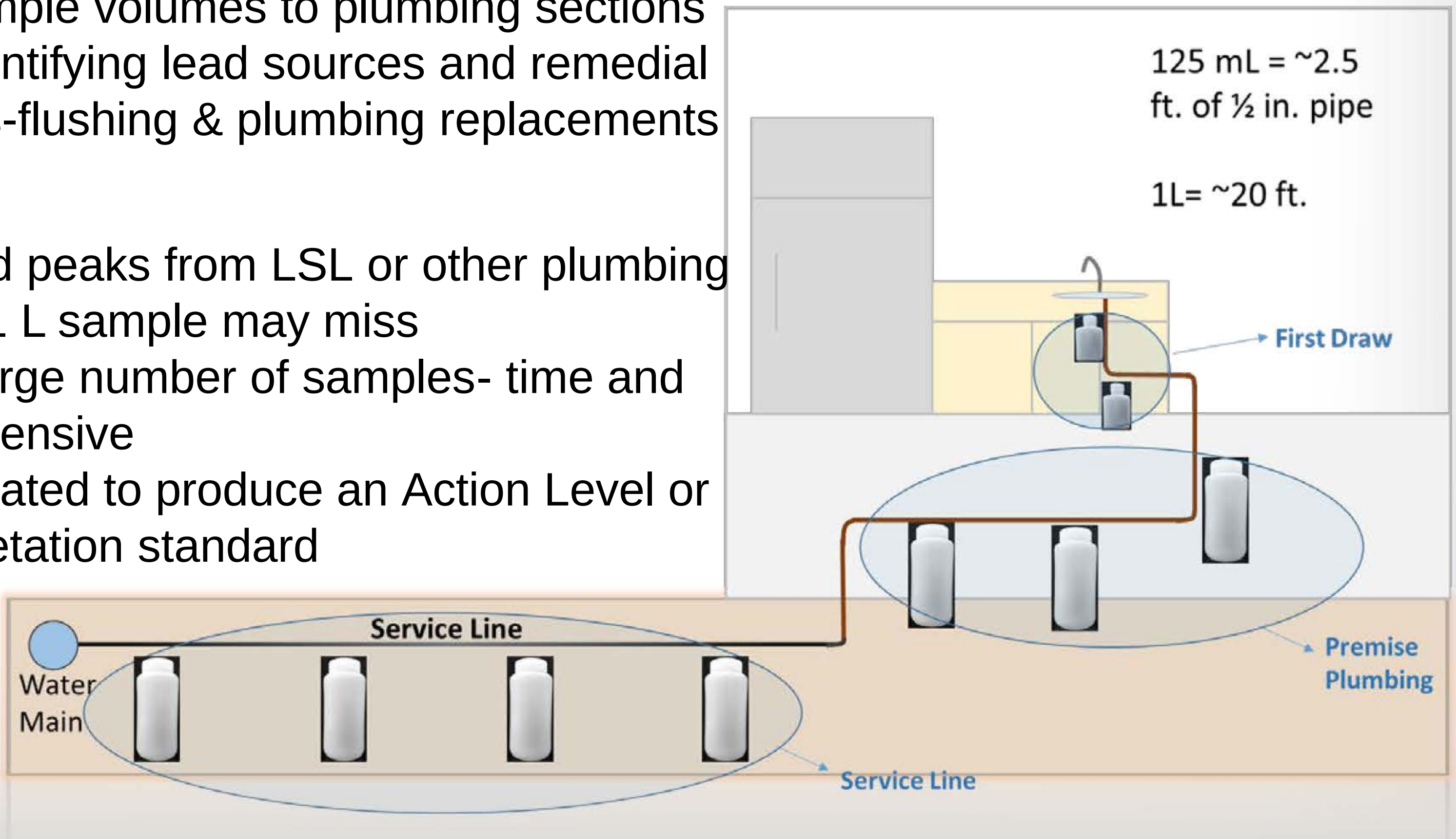
Sample Volume/Length (other)

Material	Type	Nominal Size (in)	OD (in)	Thickness (in)	ID (in)	mL/ft	mL/m	ft per L	m per L
Galvanized steel	Sched 40	0.500	0.840	0.109	0.622	60	196	16.7	5.1
Galvanized steel	Sched 40	0.750	1.050	0.113	0.824	105	344	9.5	2.9
Galvanized steel	Sched 40	1.000	1.315	0.133	1.049	170	558	5.9	1.8
Lead	0.25-in wall	0.500	1.000	0.25	0.500	39	127	25.9	7.9
Lead	0.25-in wall	0.625	1.125	0.25	0.625	60	198	16.6	5.1
Lead	0.25-in wall	0.750	1.250	0.25	0.750	87	285	11.5	3.5
PVC, CPVC	Sched 80	0.500	0.84	0.147	0.546	46	151	21.7	6.6
PVC, CPVC	Sched 80	0.75	1.05	0.154	0.742	85	279	11.8	3.6
PVC, CPVC	Sched 80	1	1.315	0.179	0.957	141	464	7.1	2.2
HDPE	200 psi	1	1.315	0.146	1.023	162	530	6.2	1.9

Sequential Sampling

- Series of samples taken after stagnation
- First samples typically 125-250 mL
- Later samples 1 L (uniform plumbing)
- Correlate sample volumes to plumbing sections
- Useful for identifying lead sources and remedial actions-flushing & plumbing replacements

- Captures lead peaks from LSL or other plumbing that a 1 L sample may miss
- Requires a large number of samples- time and cost intensive
- More complicated to produce an Action Level or interpretation standard

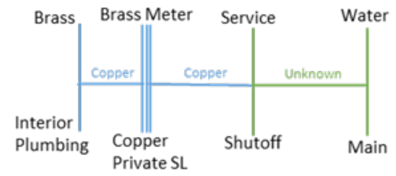


EPA Sequential Sampling Protocol

- Examine plumbing, estimate distance and water volume to main
- Pre-flush water in home (unlike LCR sampling)
- Allow water stagnate for 6+ hours
- Collect series of sequential samples:
  - 2-125 mL samples
  - X-1000 mL samples based on plumbing exam
- Flush line for 10 minutes at max flow then collect 1000 mL sample
- Repeat previous step at 2/3 and 1/3 max flow
- Measure samples for lead, copper, zinc and iron

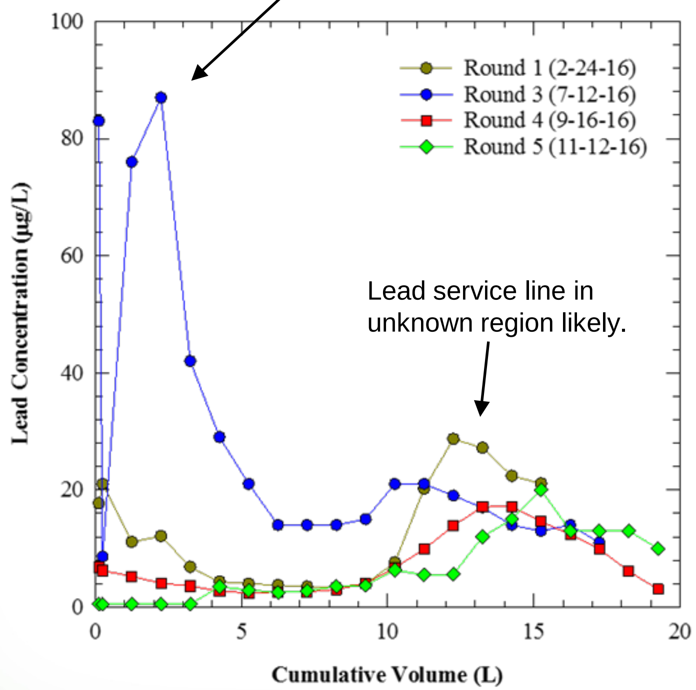
Identification of Lead Contribution and Plumbing Materials (Michigan Case)

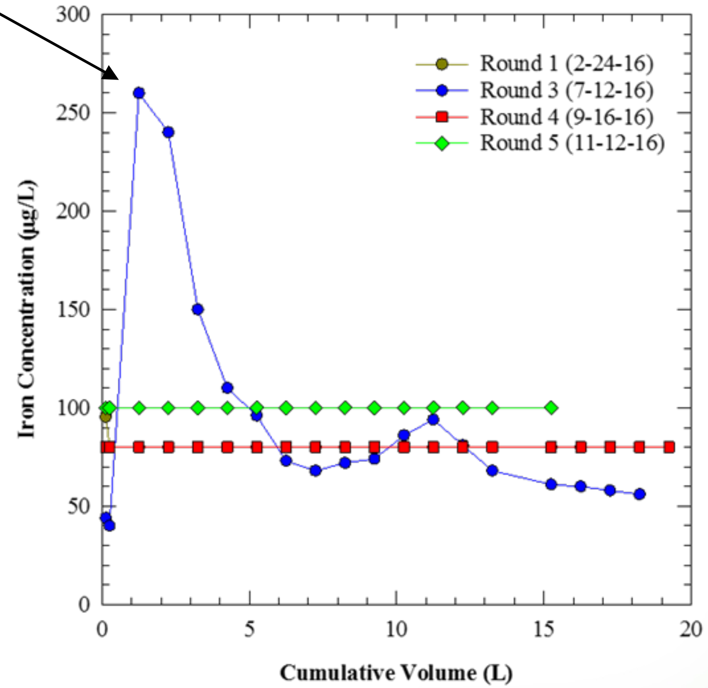
Elevated iron and lead suggests particles.



Plumbing Inspection

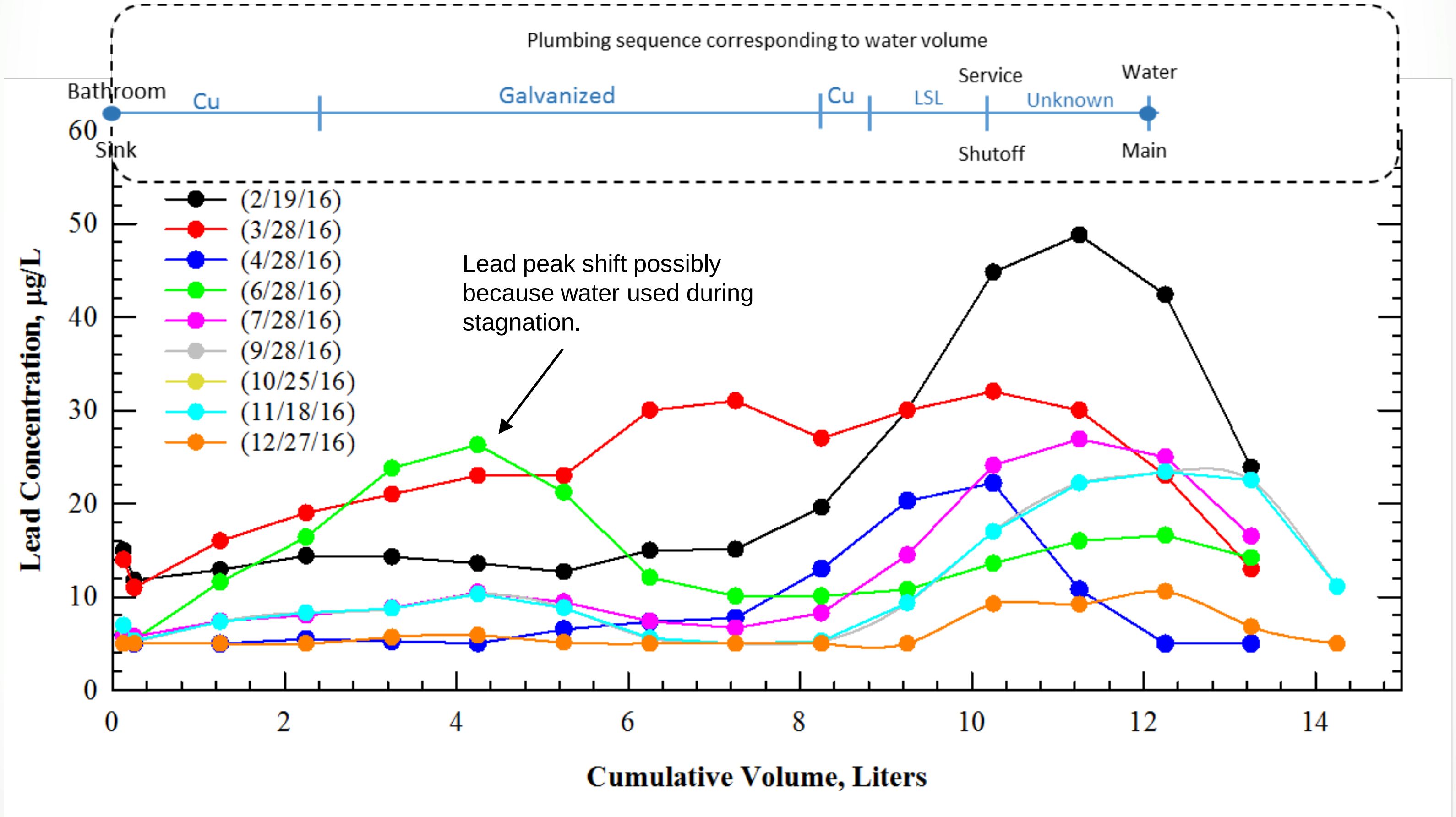
Lead





Iron

Impact of Corrosion Control on Lead Reduction over Time (Ohio Case)



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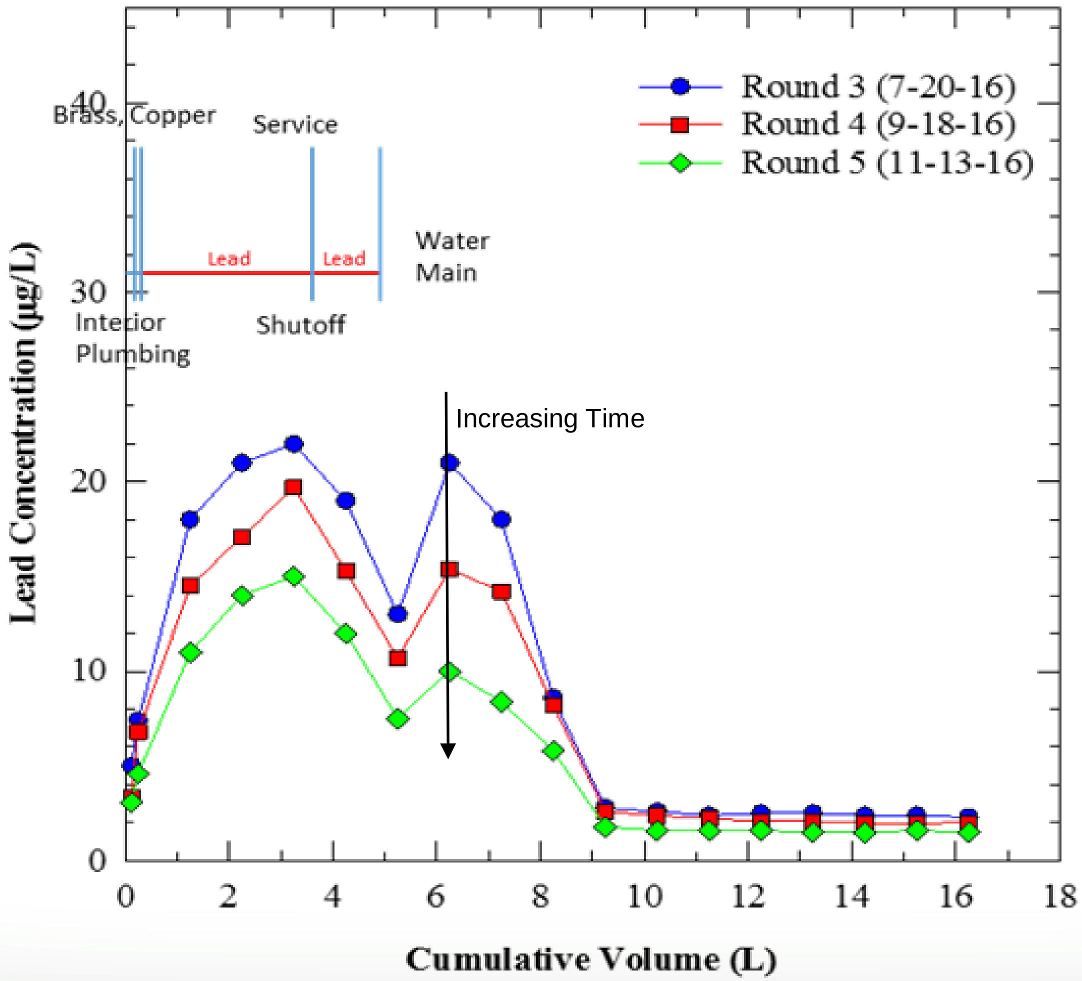
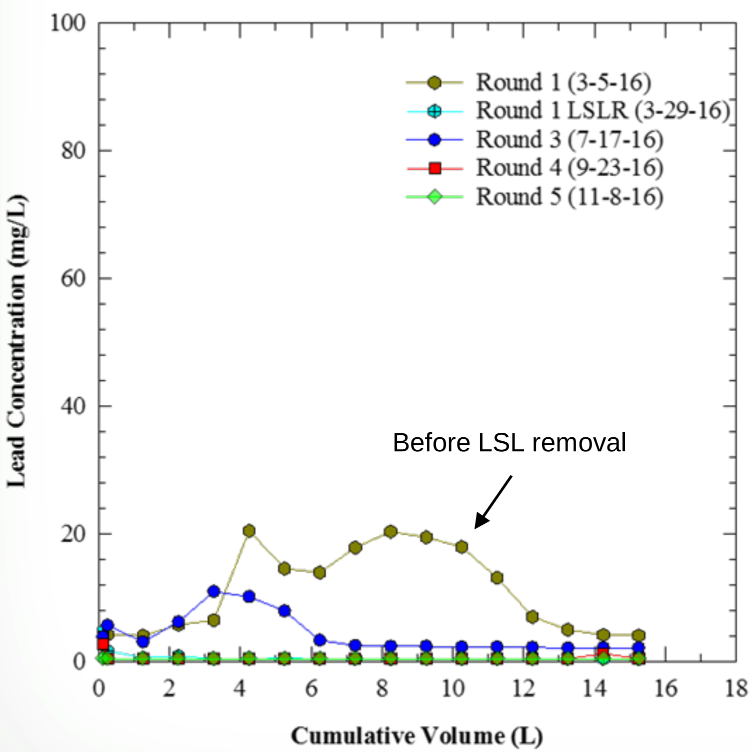
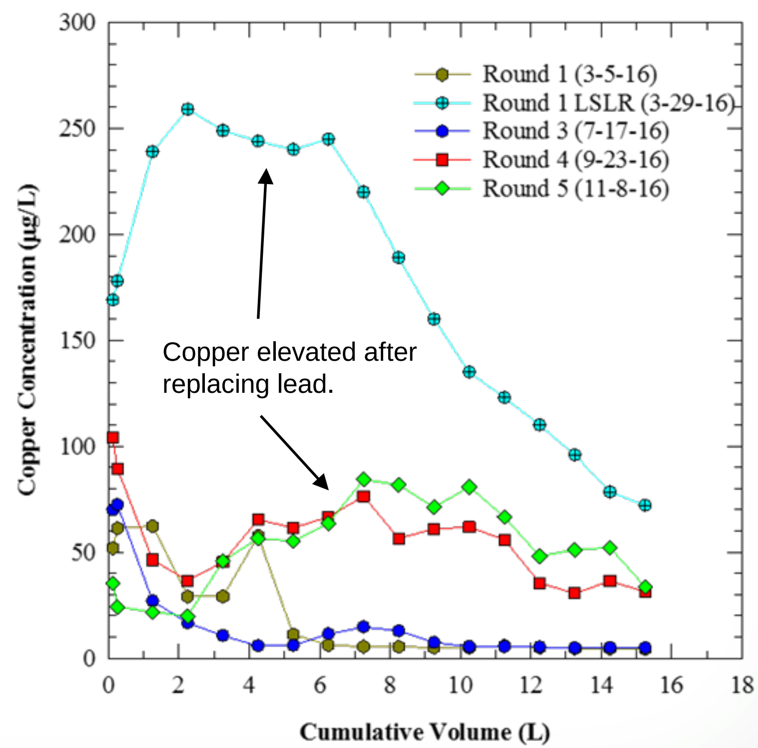
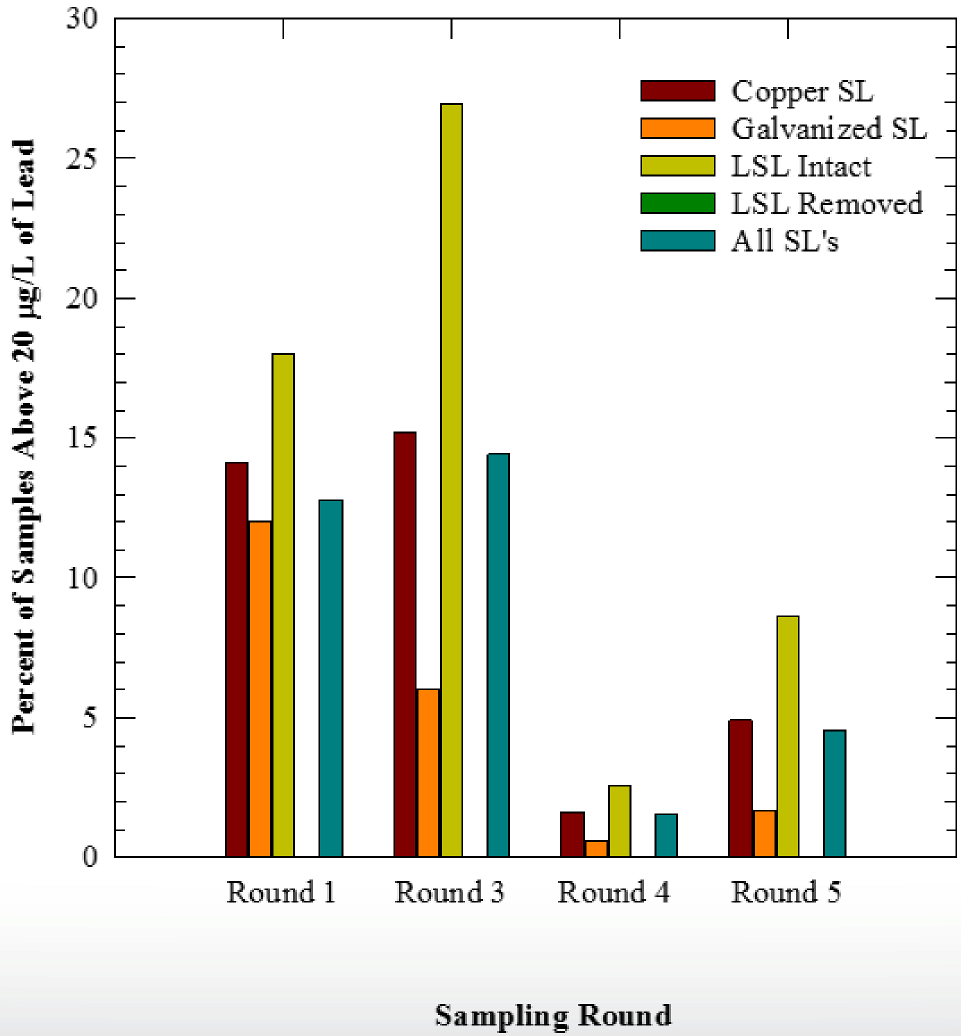


Benefit of Lead Service Line (LSL) Removal (Michigan Case)

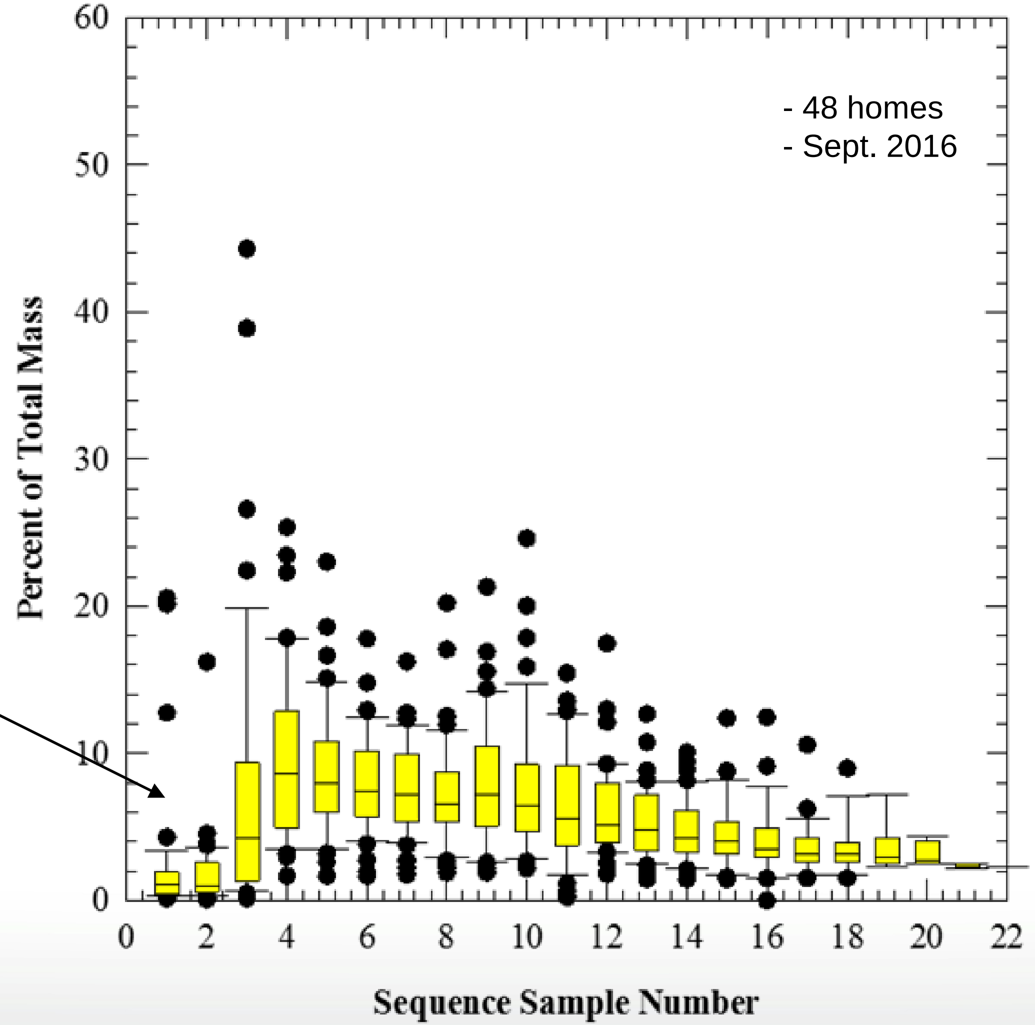




Impact of Treatment on Lead Particles (Michigan Case)



Relative Contribution of Lead Sources (Michigan Case)



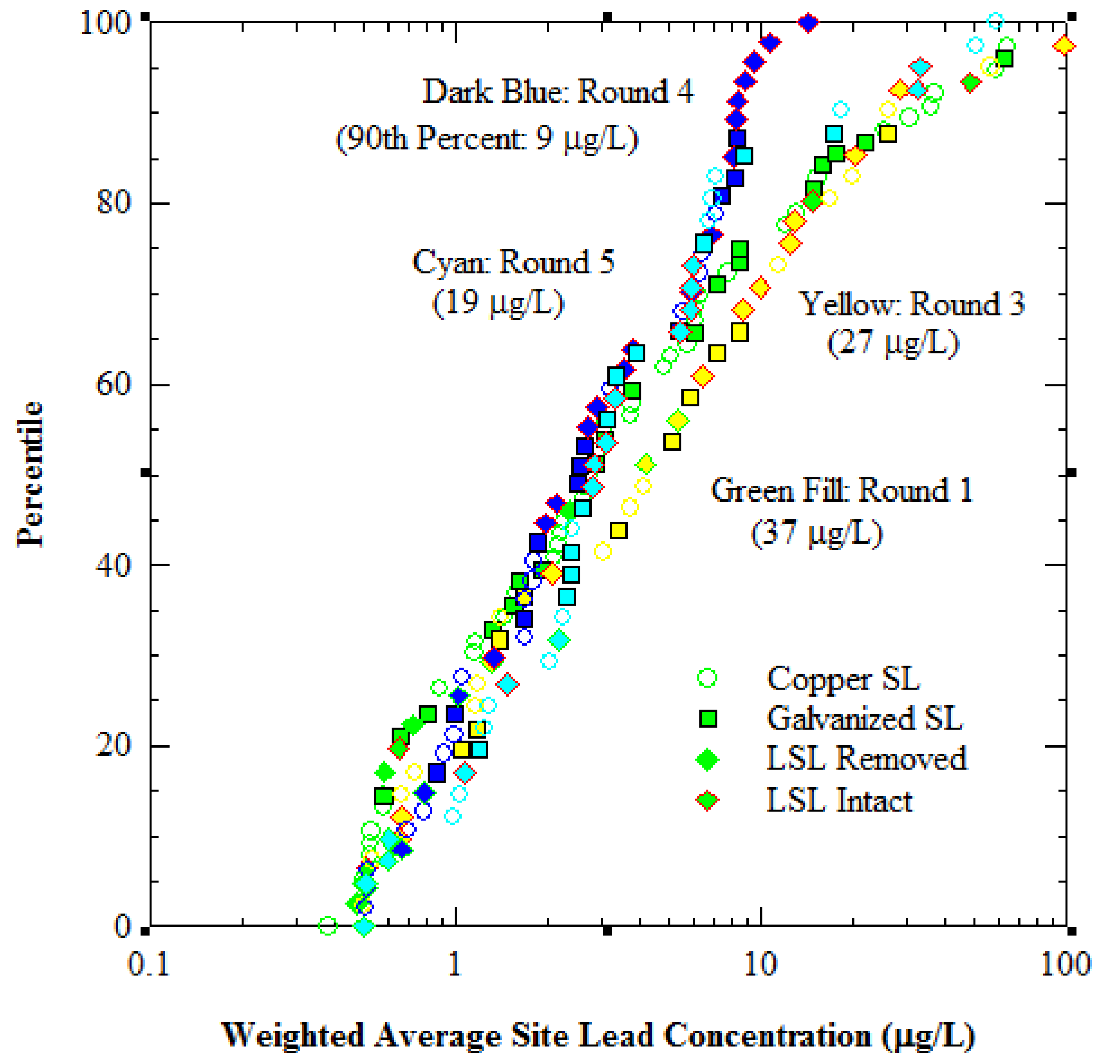
125 mL=~2.5 ft of ½ in diameter pipe

Weighted Average Sequential Lead Concentration (WASLC)

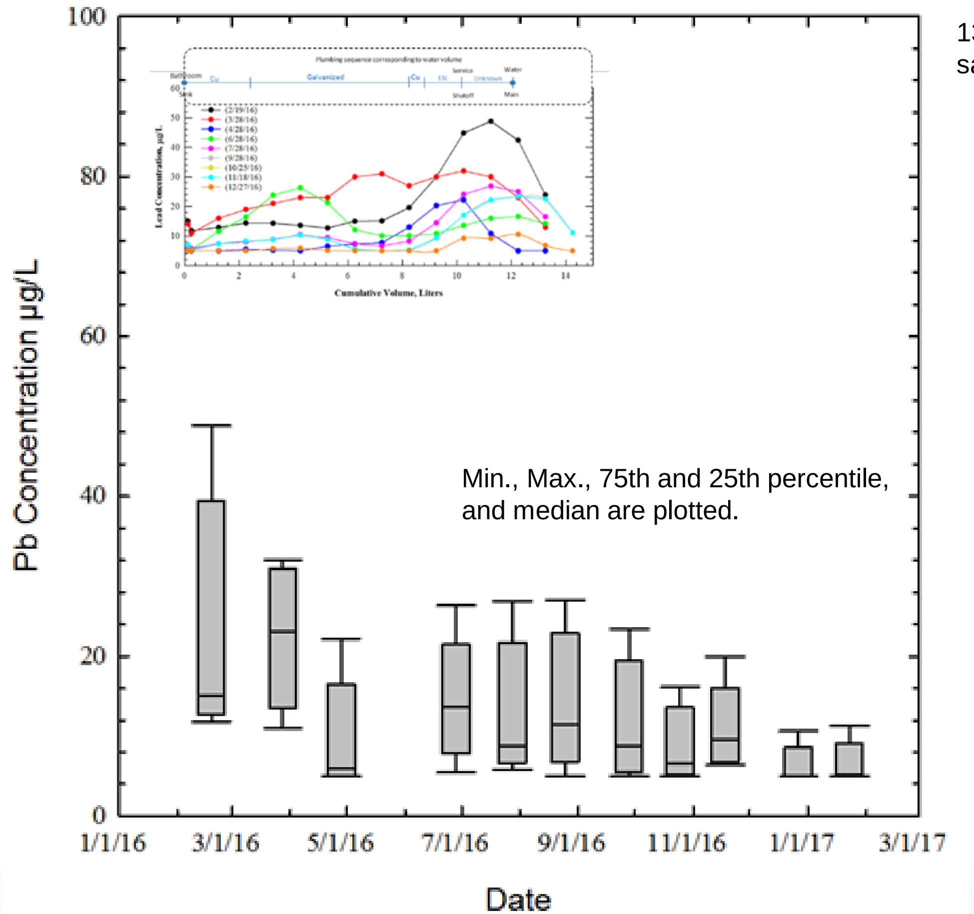
$$WASLC = \frac{\sum_{i=1}^{n}(C_i)(V_i)}{\sum_{i=1}^{n} V_i}$$

,where n is the number of sequential samples, C is the lead concentration (µg/L), and V is the sample volume

Progress of Treatment with Time (Michigan Case)



Impact of Corrosion Control on Lead Reduction over Time Using WASLC (Ohio Case)



13 or 14 sequential samples.

Potential Constraints of Sequential Sampling

- The farther the deviation from plug flow, the less accurate in finding exact location of specific sources
- The longer the distance of the tap from the source, and the more bends, the more mixing that will take place
  - Lowering peak Pb
  - Loss in resolution
  - May displace precise peak positions relative to source locations
- Samples can be biased by water passing through leaded devices on the way to the bottle
- Accurately capturing particulate release highly depends on on-off protocol, flow rate and flow turbulence
- Count on homeowner to not use water

Summary

- Different sampling approaches address different questions
- Sequential sampling is a valuable assessment tool:
  - Identify lead sources
  - Compare relative contributions of lead sources
  - Evaluate long-term effectiveness of CC treatment (soluble and particulate)
  - Evaluate the benefits of LSL removal
- Sequential sampling can be expensive and complicated, and depends on homeowner not using the water

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