Drinking water sampling for protecting human health

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Elevated Blood Lead Levels in Children Associated With the Flint Drinking Water Crisis: A Spatial Analysis of Risk and Public Health Response

Mona Hanna-Attisha, MD, MPH, Jenny LaChance, MS, Richard Casey Sadler, PhD, and Allison Champney Schnepp, MD

Objectives. We analyzed differences in pediatric elevated blood lead level incidence before and after Flint, Michigan, introduced a more corrosive water source into an aging water system without adequate corrosion control.

Methods. We reviewed blood lead levels for children younger than 5 years before (2013) and after (2015) water source change in Greater Flint, Michigan. We assessed the percentage of elevated blood lead levels in both time periods, and identified geographical locations through spatial analysis.

Results. Incidence of elevated blood lead levels increased from 2.4% to 4.9% ($P<.05$) after water source change, and neighborhoods with the highest water lead levels experienced a 6.6% increase. No significant change was seen outside the city. Geospatial analysis identified disadvantaged neighborhoods as having the greatest elevated blood lead level increases and informed response prioritization during the now-declared public health emergency.

Conclusions. The percentage of children with elevated blood lead levels increased after water source change, particularly in socioeconomically disadvantaged neighborhoods. Water is a growing source of childhood lead exposure because of aging infrastructure. (*Am J Public Health.* Published online ahead of print December 21, 2015: e1–e8. doi:10.2105/AJPH.2015.303003)

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Elevated Blood Lead in Young Children Due to Lead-Contaminated Drinking Water: Washington, DC, 2001–2004

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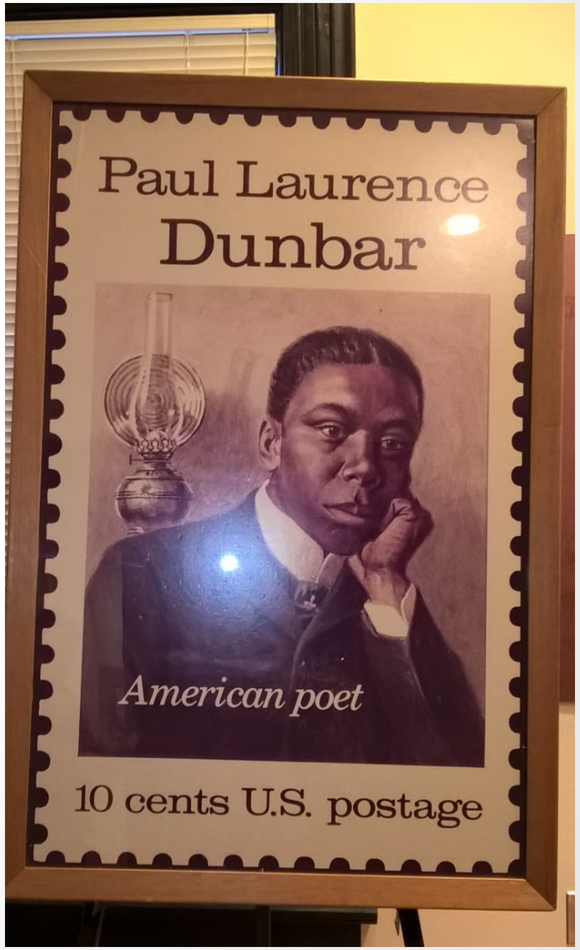
Incidence of EBL (blood lead ≥ 10 μg/dL) for children aged ≤1.3 years in Washington, DC increased more than 4 times comparing 2001–2003 when lead in water was high versus 2000 when lead in water was low. The incidence of EBL was highly correlated (R^2 = 0.81) to 90th percentile lead in water lead levels (WLLs) from 2000 to 2007 for children aged ≤1.3 years. The risk of exposure to high water lead levels varied markedly in different neighborhoods of the city. For children aged ≤30 months there were not strong correlations between WLLs and EBL, when analyzed for the city as a whole. However, the incidence of EBL increased 2.4 times in high-risk neighborhoods, increased 1.12 times in moderate-risk neighborhoods, and decreased in low-risk neighborhoods comparing 2003 to 2000. The incidence of EBL for children aged ≤30 months also deviated from national trends in a manner that was highly correlated with 90th percentile lead in water levels from 2000 to 2007 (R^2 = 0.83) in the high-risk neighborhoods. These effects are consistent with predictions based on biokinetic models and prior research.

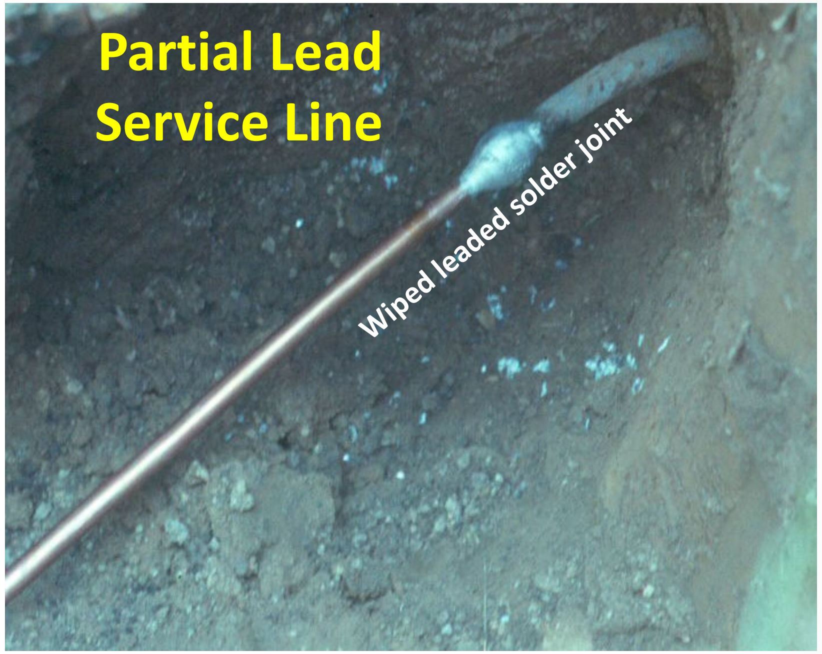

Lead pipes
everywhere in
kitchen

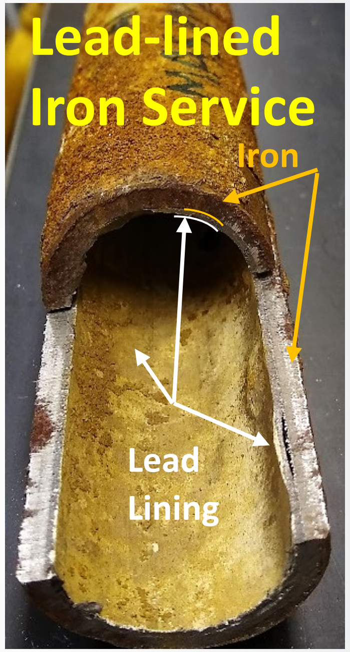

Dayton Aviation Heritage National Historical Park
NATIONAL PARK SERVICE
PAUL LAURENCE
DUNBAR HOUSE
Historic Site
OHIO
HISTORY
CONNECTION


Lead pipes all the
way to kitchen
faucet


Paul Laurence
Dunbar
American poet
10 cents U.S. postage

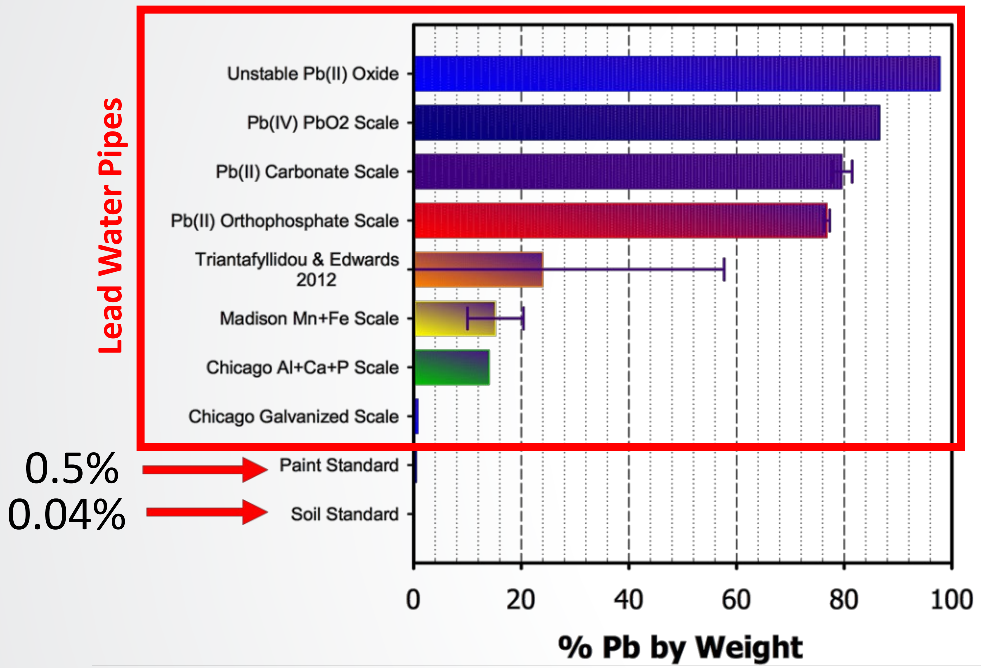
Lead plumbing sources





Triantafyllidou et al., 2021
[Variability and sampling of lead (Pb) in drinking water.]

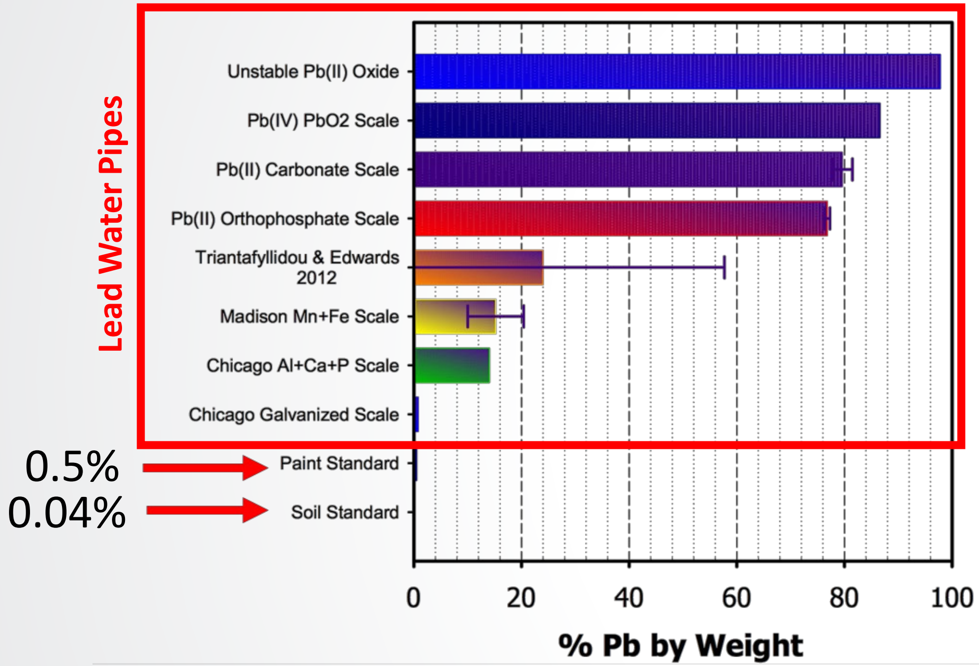
Lead pipe scales



- Pipe scale particles have more lead than paint, soil, or hazardous waste
- Release of small particles may result in greater relative exposure from drinking water than paint or soils

"Hazardous" waste definition (Resource Conservation and Recovery Act-RCRA): ≥ 5 mg/L Pb (or 0.0005 wt %)

Lead pipe scales



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- Drinking through lead-painted straws

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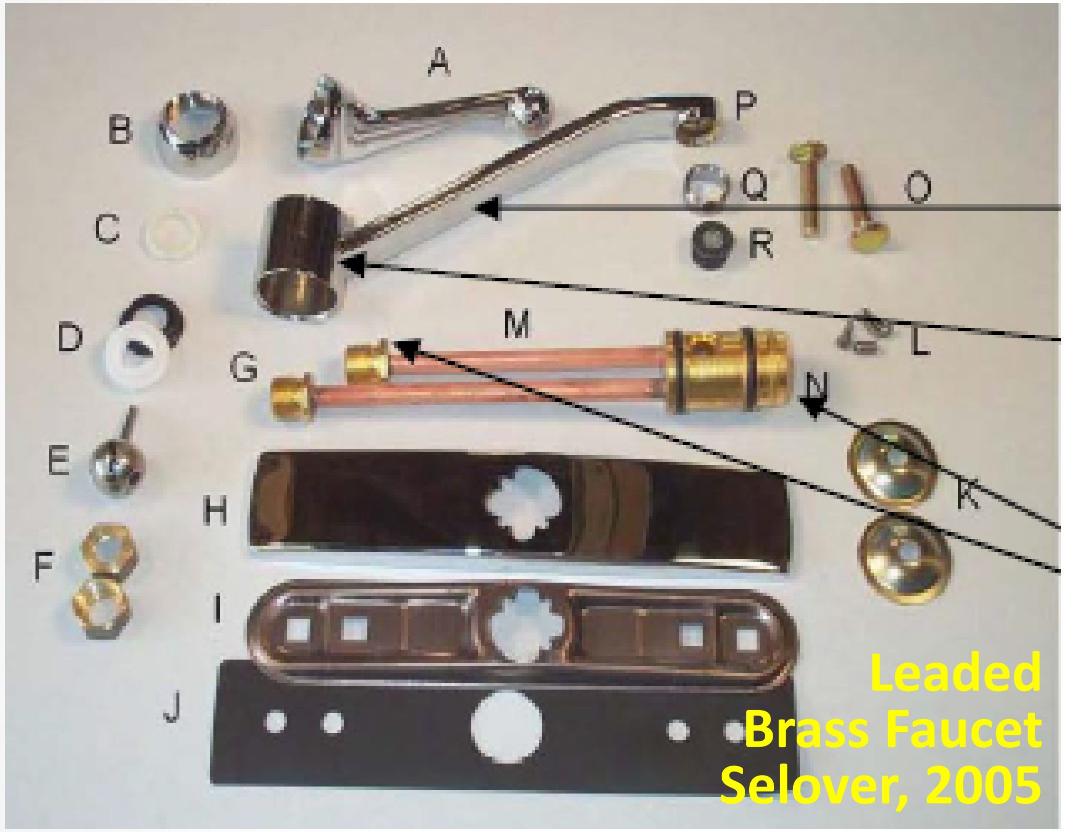
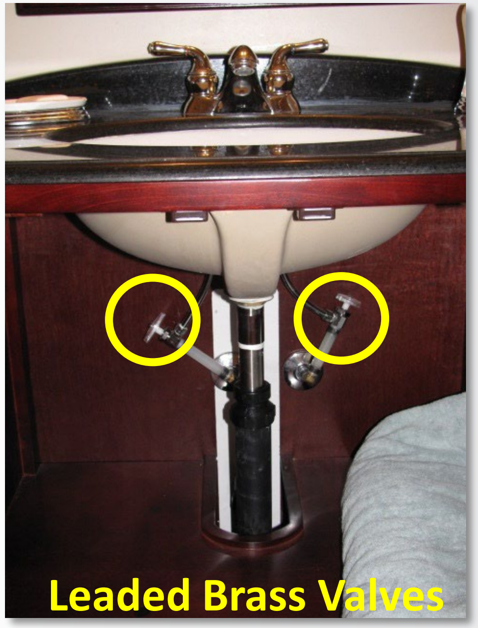
Lead Plumbing Sources



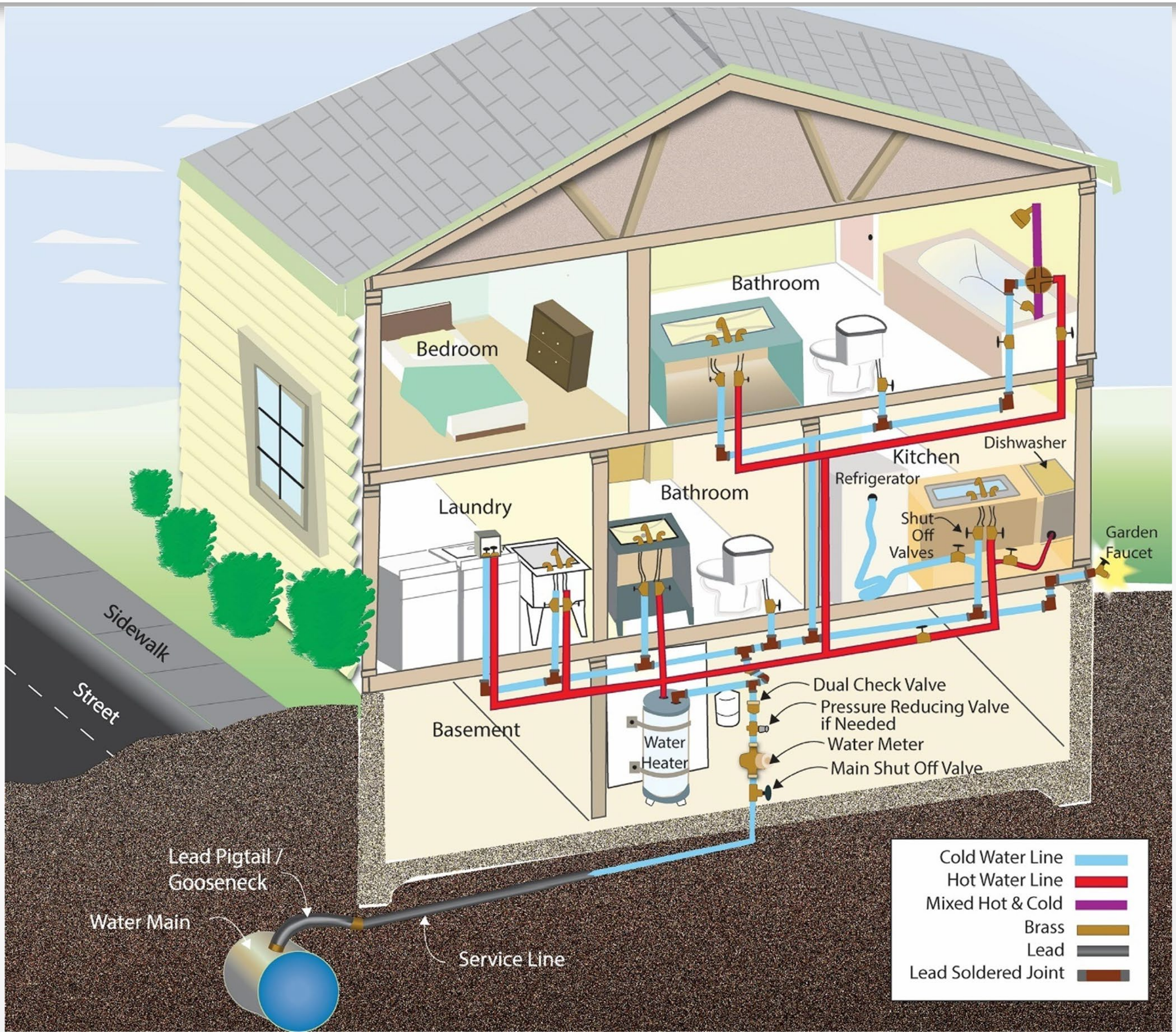
<0.5%Pb

2% Pb

3% Pb



Lead sources are not uniformly distributed



Triantafyllidou et al., 2021 [Variability and sampling of lead (Pb) in drinking water.]

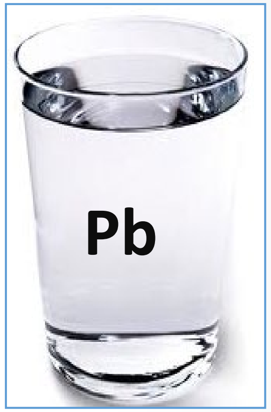
What is a “representative” water sample?

Factors affecting Pb release

- Pb plumbing materials, dimensions, configurations & age
- Water chemistry (corrosivity) and chemical changes
- Hydraulics and hydraulic changes
- Individual water use patterns

Contribute to Pb variability

- Pb Spatial variability
- Pb Temporal variability
- Particulate vs dissolved Pb



water consumed

water sampled

Sampling: What is the question?

- No single universally applicable sampling approach for lead in drinking water exists
- There are many protocols, but each has a specific use answering a specific question
- What question(s) are you trying to answer?

Sampling: What is the question?

QUESTION(S):

- Does the water meet regulatory standards for Pb?
- How effective is the current corrosion control treatment for interior plumbing?

- Where is the Pb coming from?
- What type of Pb is present (dissolved/ particulate)?

- What is the general public's exposure to Pb in water in this residence/ neighborhood/ town/distribution system?

SAMPLE FOR:

1. Lead regulatory compliance

2. Lead plumbing sources determination or
Lead type identification

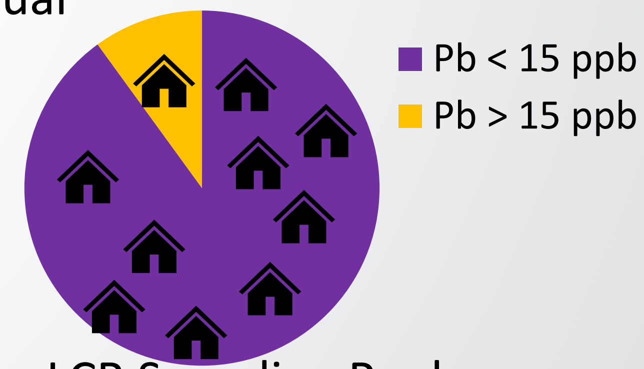
3. Lead exposure assessment

Lead regulatory compliance

Lead and Copper Rule (LCR)*

- LCR sampling pool consists of homes believed to contain major lead plumbing sources
- Homeowners collect 1 L of water from kitchen tap after overnight water stagnation (6+ h)
- 90th %ile lead results compared to Lead Action Level of 15 ug/L
- 90th %ile action level is a trigger for corrosion control treatment rather than an exposure level
- Rule identifies system-wide problems, rather than problems at individual buildings

NOT a Health-Based Value



LCR Sampling Pool

*Revisions to the LCR, known as LCRR, will be enforced in 2024. Additional LCR improvements (LCRI) are also currently underway and may yield additional regulatory changes that are unknown at this point.

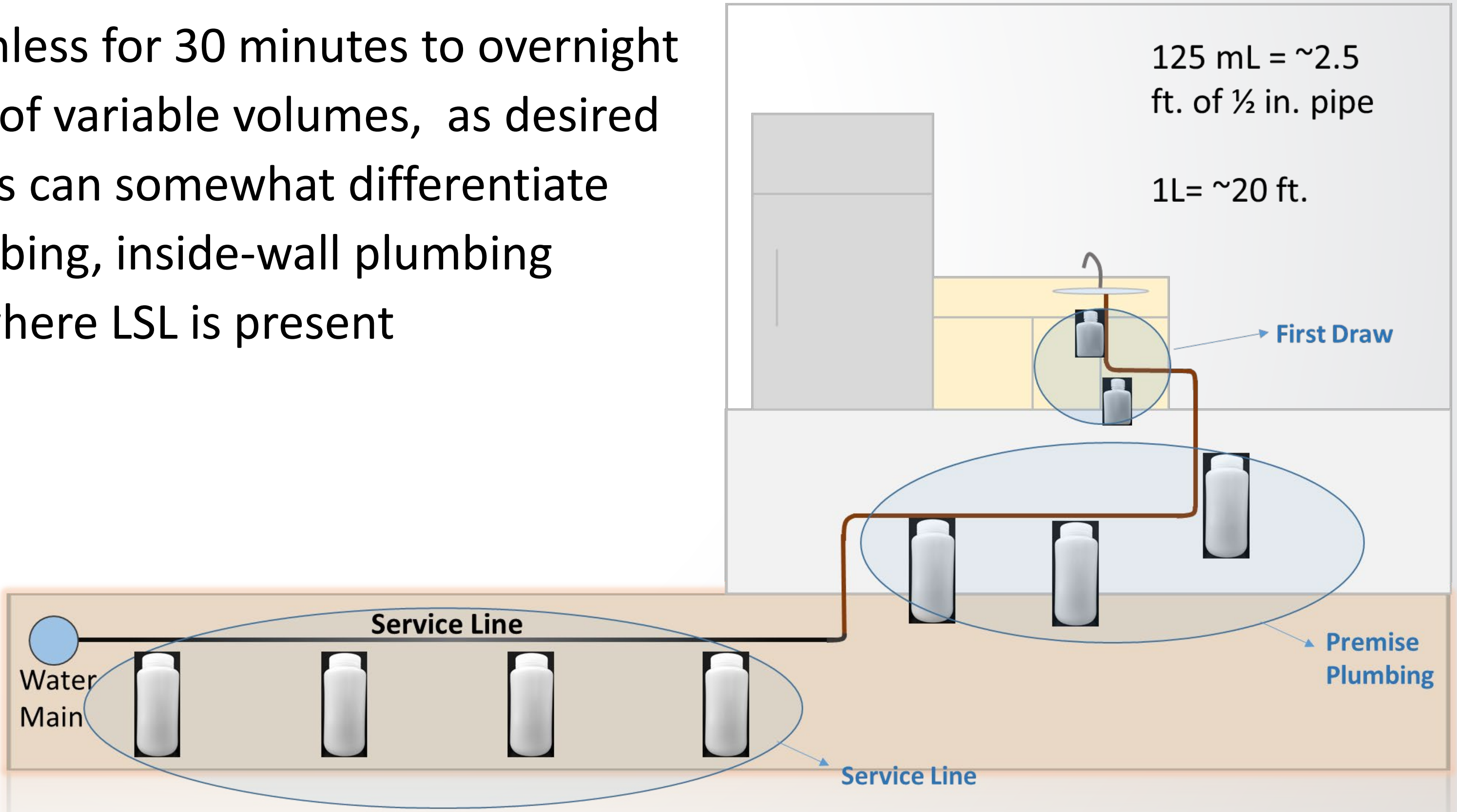
Lead plumbing sources determination

Sequential sampling (profile sampling)

- Map interior plumbing and approximate exterior route to main in terms of lengths, ID and visible materials
- Allow water to sit motionless for 30 minutes to overnight
- Take successive samples of variable volumes, as desired
- Different sample volumes can somewhat differentiate

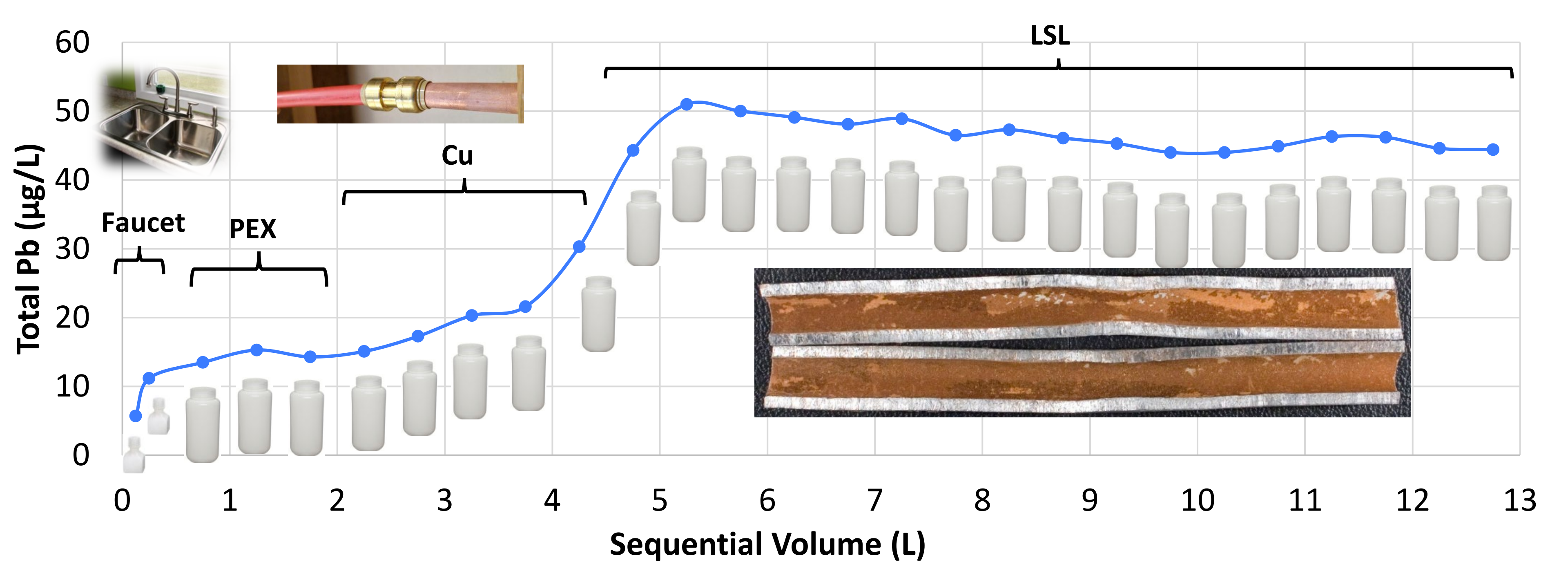
bubbler or faucet, valve, tubing, inside-wall plumbing

- Can help determine if /where LSL is present



Lytle et al., 2018. Identify Plumbing Sources to Protect Public Health

Lead plumbing sources determination



Diagnostic sampling allows identification of lead plumbing sources (lead service lines, lead goosenecks, lead soldered joints, leaded brass faucets, valves, and other leaded brass plumbing fittings) and their locations

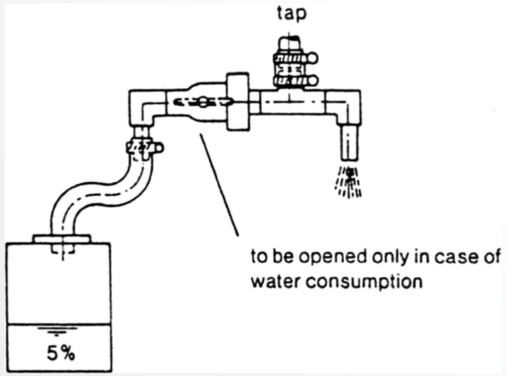
Exposure assessment

Composite (i.e., cumulative) sampling

- collects lead under normal use conditions, capturing a range of flow rates, stagnation times, flow durations, and temperatures
- May be:
  - “Automatic”
  - “Manual”

Automatic Composite Sampling

- Device is affixed to the tap & consumer operated (not entirely automatic)
- 5% of every draw meant for consumption is routed into collection vessel
- Cumulative water sample in collection vessel analyzed for lead



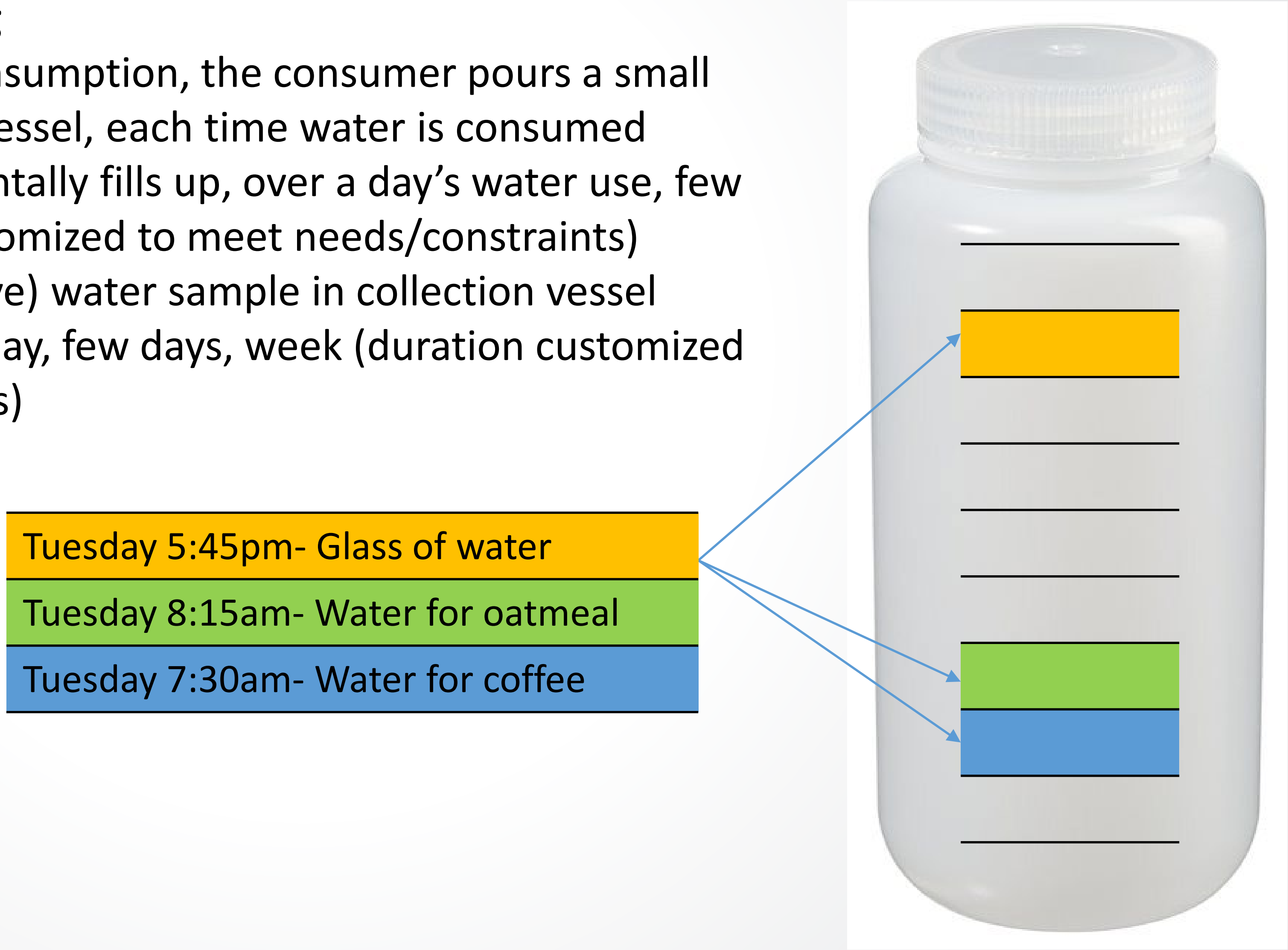
Triantafyllidou et al. 2021 reprint from van den Hoven, 1987

Deshommes et al, 2017

Exposure assessment

Manual Composite Sampling

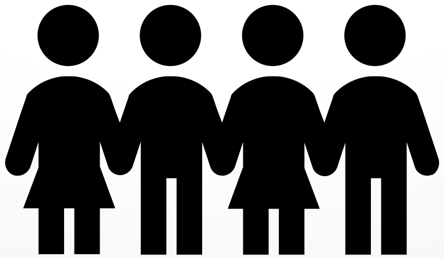
- Of all water drawn for consumption, the consumer pours a small volume into a collecting vessel, each time water is consumed
- Collecting vessel incrementally fills up, over a day's water use, few days, week (duration customized to meet needs/constraints)
- Composite (i.e., cumulative) water sample in collection vessel analyzed for lead after a day, few days, week (duration customized to meet needs/constraints)



Exposure assessment

Environmental assessments of lead-poisoned children by Health Departments:

- Is water tested?
- If yes, what is the sampling protocol?
- What can the sampling protocol tell us?




ASTHO Report

In-depth coverage of leading state and territorial public health issues.

September 2022

Going Beyond Regulatory Compliance for Lead Testing in Drinking Water

This report serves as a primer for state and territorial health agencies (S/THAs) seeking to assess the public health impacts of lead exposure in drinking water. It also offers a public health perspective on current protocols for testing lead in drinking water, and therefore discusses the need for additional sampling protocols (termed diagnostic sampling and exposure sampling herein) to identify levels of lead found in residential facilities that meet the regulatory standards for tap water (termed regulatory sampling herein).

Although this report focuses on sampling protocols for lead in residential facilities, EPA has additional resources that can be helpful when testing for lead in schools. Through engaging in both diagnostic and regulatory sampling, S/THAs can better understand the comprehensive lead risks to a household or those served by schools, daycares, and other facilities.

The Association of State and Territorial Health Officials (ASTHO) published a report in September 2022

ASTHO 2022 report goes over:

- Regulatory sampling for lead in water
- Diagnostic and exposure sampling for lead in water
- Differences among sampling types
- Considerations for adding diagnostic and exposure sampling protocols
- Summary of survey results from fourteen jurisdictions about environmental assessments:
  - Requirements for testing drinking water sources, if any
  - Contaminants tested
  - Partners engaged
- Additional Resources

https://www.astho.org/topic/report/going-beyond-regulatory-compliance-for-lead-testing-in-water/

Is my water safe to drink?

- "Consumers may be unaware that drinking water is another source of lead in the home. To assess water lead exposure of individuals, S/THAs could consider exposure sampling protocols. S/THAs may collect these samples during environmental assessments for cases of known childhood lead exposures."
- "Moving forward, collaboration between S/THAs, drinking water primacy agencies, public water systems, and the public to identify and remove lead service lines and assess this and other water lead exposures will be critical."
- "In all cases, answering the question "is my water safe" should be qualified by an explanation of the specific water sampling protocol used, and the information it can or cannot provide."

ASTHO 2022
https://www.astho.org/topic/report/going-beyond-regulatory-compliance-for-lead-testing-in-water/

Summary

- Elevated lead in tap water can still contribute or even cause elevated lead in children's blood, in cases of sub-optimal corrosion control in the presence of leaded plumbing
- Sampling tap water at homes, schools and other buildings can allow for assessment of lead through water consumption
- Lead in tap water can be highly variable (spatially and temporally)
- Therefore, different tap water sampling protocols may yield different lead concentrations and sample different sources/forms of lead
- Regulatory compliance sampling under the LCR (and upcoming LCRR/LCRI) does not diagnose lead plumbing sources like diagnostic sampling does
- Regulatory compliance sampling under the LCR (and upcoming LCRR/LCRI) does not assess water lead exposure like exposure sampling does

Summary

- Many health departments do not sample drinking water during environmental assessments
- The cost, logistics, timeliness, and consumer participation are all practical considerations. But individuals may be exposed to elevated water lead, even if the drinking water utility meets the federal LCR water lead requirements
- Understanding the differences between sampling protocols (regulatory, diagnostic, exposure) for lead in water can help customize and implement the appropriate sampling protocol to meet specific needs/objectives
- In all cases, answering the question “is my water safe” should be qualified by an explanation of the specific water sampling protocol used, and the information it can or cannot provide

Resources

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Review article

Variability and sampling of lead (Pb) in drinking water: Assessing potential human exposure depends on the sampling protocol

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ABSTRACT

Lead (Pb) in drinking water has re-emerged as a modern public health threat which can vary widely in space and in time (i.e., between homes, within homes and even at the same tap over time). Spatial and temporal water Pb variability in buildings is the combined result of water chemistry, hydraulics, Pb plumbing materials and water use patterns. This makes it challenging to obtain meaningful water Pb data with which to estimate potential exposure to residents. The objectives of this review paper are to describe the root causes of intrinsic Pb variability in drinking water, which in turn impacts the numerous existing water sampling protocols for Pb. Such knowledge can assist the public health community, the drinking water industry, and other interested groups to interpret/compare existing drinking water Pb data, develop appropriate sampling protocols to answer specific questions relating to Pb in water, and understand potential exposure to Pb-contaminated water. Overall, review of the literature indicated that drinking water sampling for Pb assessment can serve many purposes. Regulatory compliance sampling protocols are useful in assessing community-wide compliance with a water Pb regulatory standard by typically employing practical single samples. More complex multi-sample protocols are useful for comprehensive Pb plumbing source determination (e.g., Pb service line, Pb brass faucet, Pb solder joint) or Pb form identification (i.e., particulate Pb release) in buildings. Exposure assessment sampling can employ cumulative water samples that directly capture an approximate average water Pb concentration over a prolonged period of normal household water use. Exposure assessment may conceivably also employ frequent random single samples, but this approach warrants further investigation. Each protocol has a specific use answering one or more questions relevant to Pb in water. In order to establish statistical correlations to blood Pb measurements or to predict blood Pb levels from existing datasets, the suitability of available drinking water Pb datasets in representing water Pb exposure needs to be understood and the uncertainties need to be characterized.

Triantafyllidou et al., 2021 Variability and sampling of lead (Pb) in drinking water.

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Disclaimers

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