Assessing Portable Analyzers for Lead Testing in School Drinking Water

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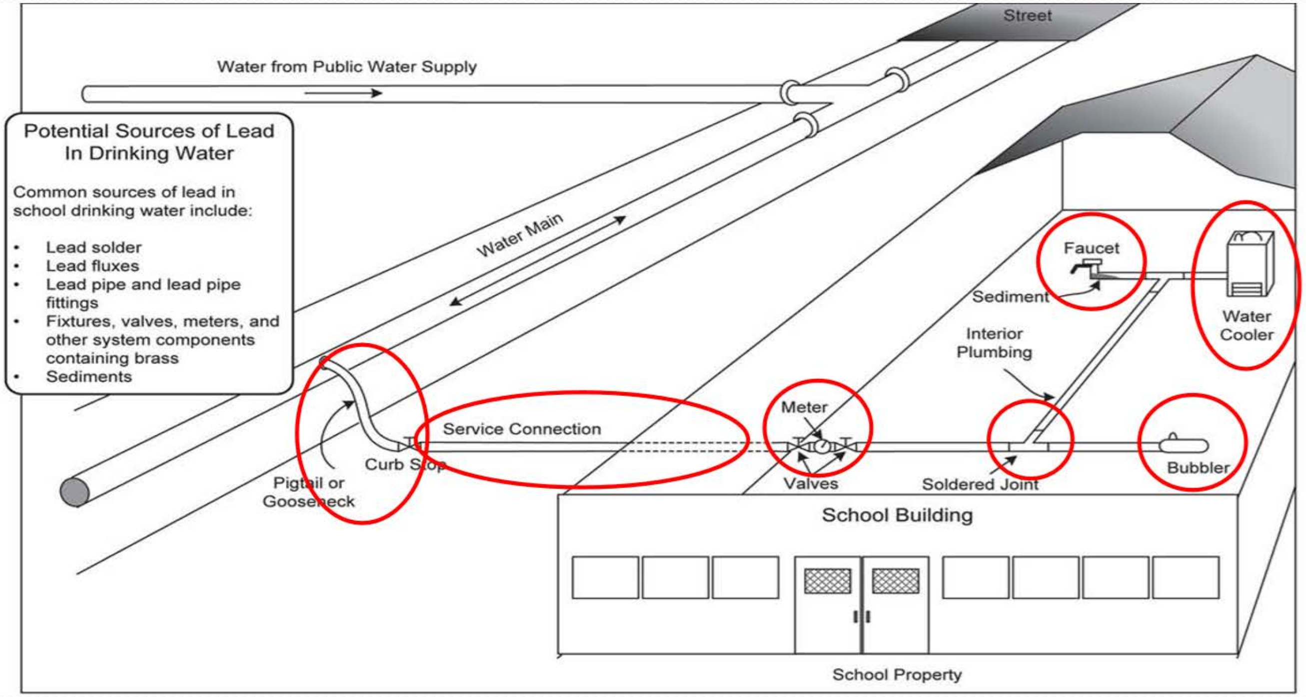
Presentation Outline

- Introduction
- Background and Motivation
- Study Objectives
- Methodology
- Results
- Conclusions

Lead (Pb) in Drinking Water

- Pb enters water from plumbing components (e.g., Pb pipes, fittings and fixtures)
- Adverse health effects from Pb exposure – children most vulnerable, even at low levels



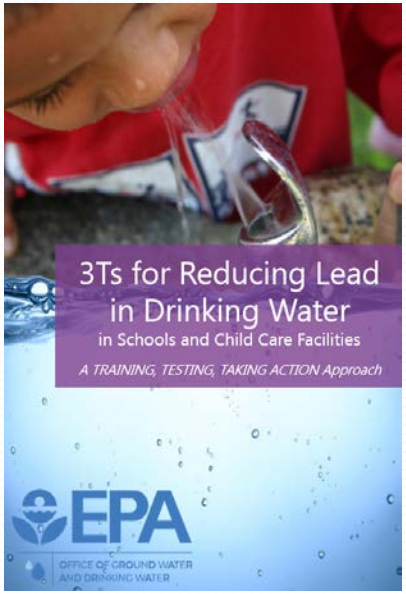
Source: US EPA, 2018, 3Ts for Reducing Pb in Drinking Water in Schools and Child Care Facilities

Regulating Pb in Plumbing Materials

- Safe Drinking Water Act Amendments
  - 1986 – Prohibited use of pipes, solder or flux that were not "Pb-free" (<0.2% for solder and flux and <8% for pipes)
  - 1996 – Required plumbing fittings and fixtures to comply with voluntary Pb leaching standards
- Reduction of Pb in Drinking Water Act, 2011
  - Redefined "Pb-free" by reducing Pb content to a weighted average of <0.25% in the wetted surface material

Guidance for Pb in Schools

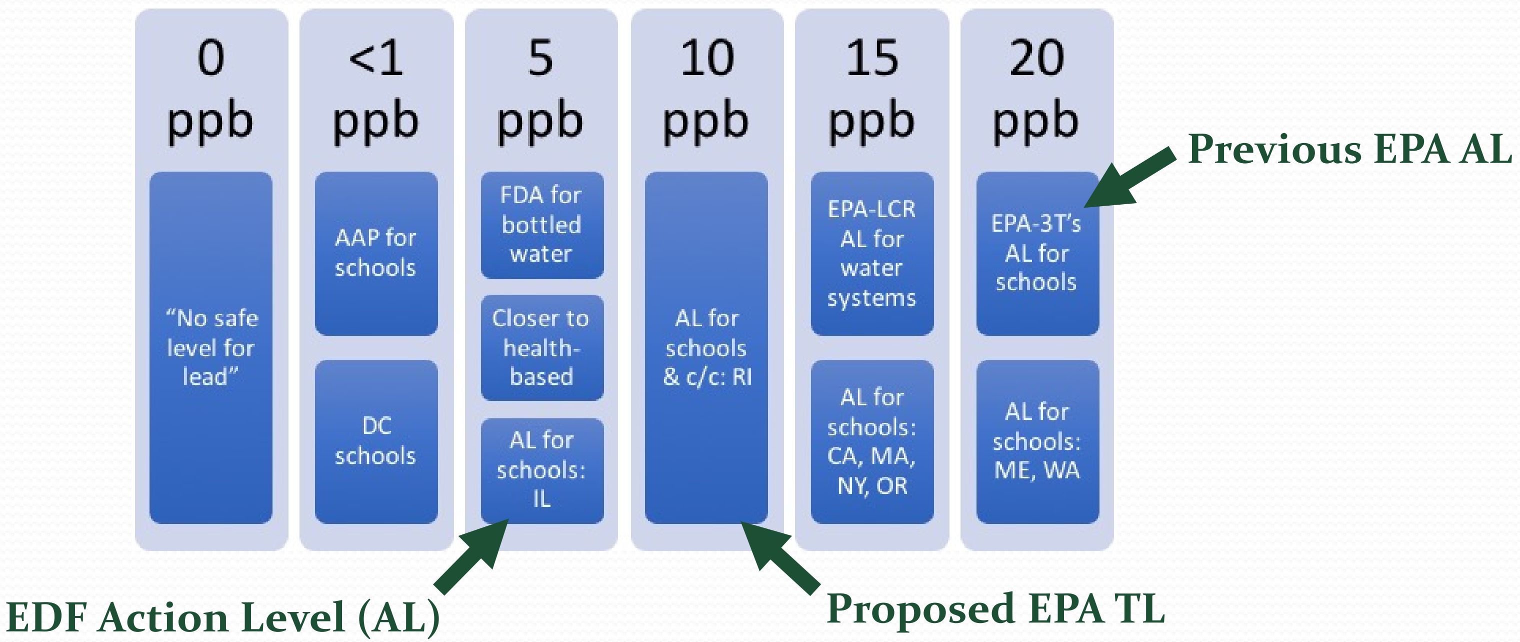
- Pb Contamination Control Act, 1988
  - Established **voluntary program** to reduce Pb levels in drinking water at schools and child care facilities
  - Banned water coolers with Pb lined tanks
  - Created Pb monitoring and reporting guidelines
- 3Ts for Reducing Pb in Drinking Water, revised 2018
  - Provides tools to help schools and child care facilities implement **voluntary** Pb in water testing programs
  - Training, Testing, and Taking Action



Pb Trigger Levels (TL)

- Some states, tribes and local jurisdictions have established regulations for schools and child care facilities
- Testing may be required under proposed Lead and Copper Rule revisions

Variation in Allowable or Recommended Pb Levels



Adapted from Hecht, 2018, Safe Water in Schools: What do we know? What can we do?

Portable Pb Analyzers for School Testing

- Renewed interest in using portable analyzers as a quick method to identify elevated Pb levels at the tap
- Provides simple, rapid, low-cost method compared to standard laboratory testing, but may miss the particulate fraction of Pb resulting in false assurance the water is safe
- Accurate quantification of the total Pb concentration is essential to effectively reduce children's exposure to Pb

Motivation: EDF Pilot Study

- Tested 11 child care facilities across four states
  - Compared Pb levels measured using two portable Pb meters with standard EPA-approved Inductively Coupled Plasma Mass Spectrometry (ICP-MS) Method 200.8
  - Meters tended to underestimate Pb compared to laboratory analysis
- Further research needed to confirm if portable meters can be used to reliably test for Pb in drinking water

Source: edf.org/health/tackling-lead-water-child-care-facilities

Study Objectives

- Determine if two common, commercially-available portable Pb meters can accurately and reliably detect Pb in drinking water compared to standard laboratory analysis
- Determine if sample preservation and analysis methods can improve the accuracy of the portable units, especially when particulate Pb is present
- Assess the practicality of using these units to conduct analyses onsite

Approach

- Compared Pb levels measured using standard EPA-approved ICP-MS Method 200.8 with two portable Pb meters
  - Anodic stripping voltammetry (ASV) – EPA certified method (1001) only if samples are acidified
  - DNA-based fluorescence technology – EPA Environmental Technology Verification Program
- Performed combination of controlled laboratory and field testing
- Evaluated sample preservation and analysis methods to improve the accuracy of the portable units, especially when particulate Pb is present

Study Design

Phase 1

- **Controlled Laboratory Testing**
- Dissolved Pb
- Evaluated preservation/ pretreatment methods

Phase 2

- **School Testing**
- Dissolved & particulate Pb
- Usability of portable units

Phase 3

- **LSLR Samples**
- Dissolved & particulate Pb
- Evaluated preservation/ pretreatment methods

Portable Analyzer Specifications

Parameter	ASV	Fluorescence
Detection Range	2-100 ppb Pb	2-100 ppb Pb
Precision	N/A	±15% or 2 ppb
Calibration	New lot/box of sensors	Onsite with specific water matrix; changes in water matrix, temperature & sensor lot
Sample Temperature	**15-30°C (20-25°C optimal)**	**17-35°C (20-25°C optimal)**
Sample pH	• N/A • **If sample acidified, use neutralization kit**	• **5-8** • **If sample acidified, neutralize with NaOH**
Sample Analysis	• **Freshly collected (optimal)** • Ensure tablet completely dissolved	• **Freshly collected, unpreserved (optimal)** • 1 hr (2 hr max) • Once mixed with buffer, test within 15 min; wait 5 min before testing for most accurate results
Storage Requirements	Sensor: 18-month shelf life at 2-30°C	• Sensor: 1-year shelf life at <23°C, <50% humidity • Buffer: 6-month shelf life at <23°C

GCWW Water Quality

- Surface water supply with stable characteristics
- Conventional water treatment with Granular Activated Carbon
- Pb corrosion control treatment
  - pH adjustment (8.9)
  - 90th percentile Pb = 7.3 µg/L

Finished Water Quality Data[a]

Parameter[b]	Min	Max
Aluminum	0.02	0.08
Calcium	24	43
Chloride	<30	38
Chlorine Residual, Total	1.01	1.60
Iron, Total	<0.04	<0.04
Magnesium	2	18
Phosphate, as PO_4-P	0.04	0.24
Sulfate	49	95
Total Alkalinity, as $CaCO_3$	46	107
Total Hardness, as $CaCO_3$	90	165
Total Organic Carbon	0.36	1.38
Turbidity (NTU)	0.04	0.12

[a]GCWW 2018 Compliance Data
[b]Reported in mg/L except where noted

Phase 1 Laboratory Testing

Phase 1
- **Controlled Laboratory Testing**
- Dissolved Pb
- Evaluated preservation/ pretreatment methods

Phase 2
- **School Testing**
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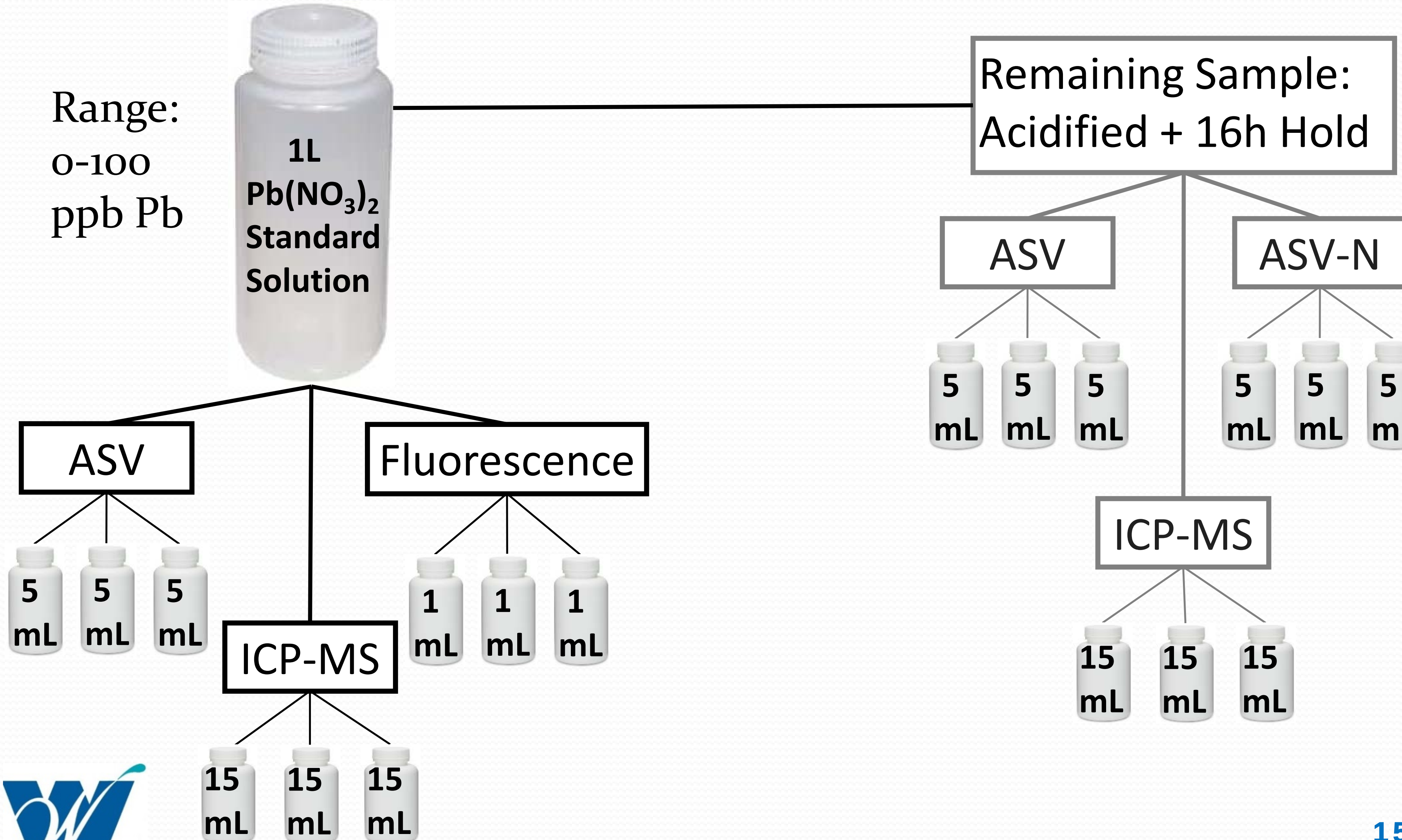
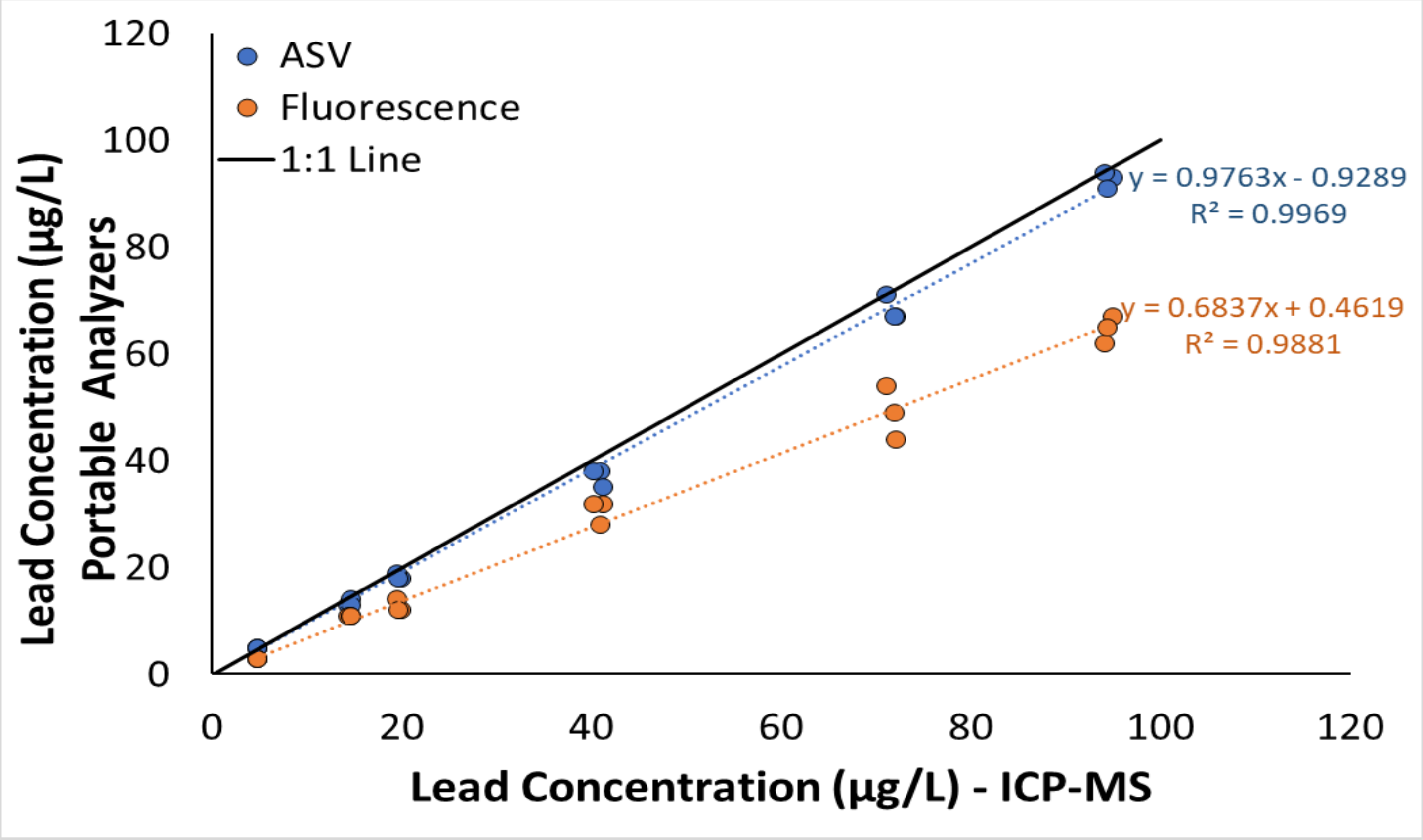
Phase 1 Lab Testing: Sampling Protocol



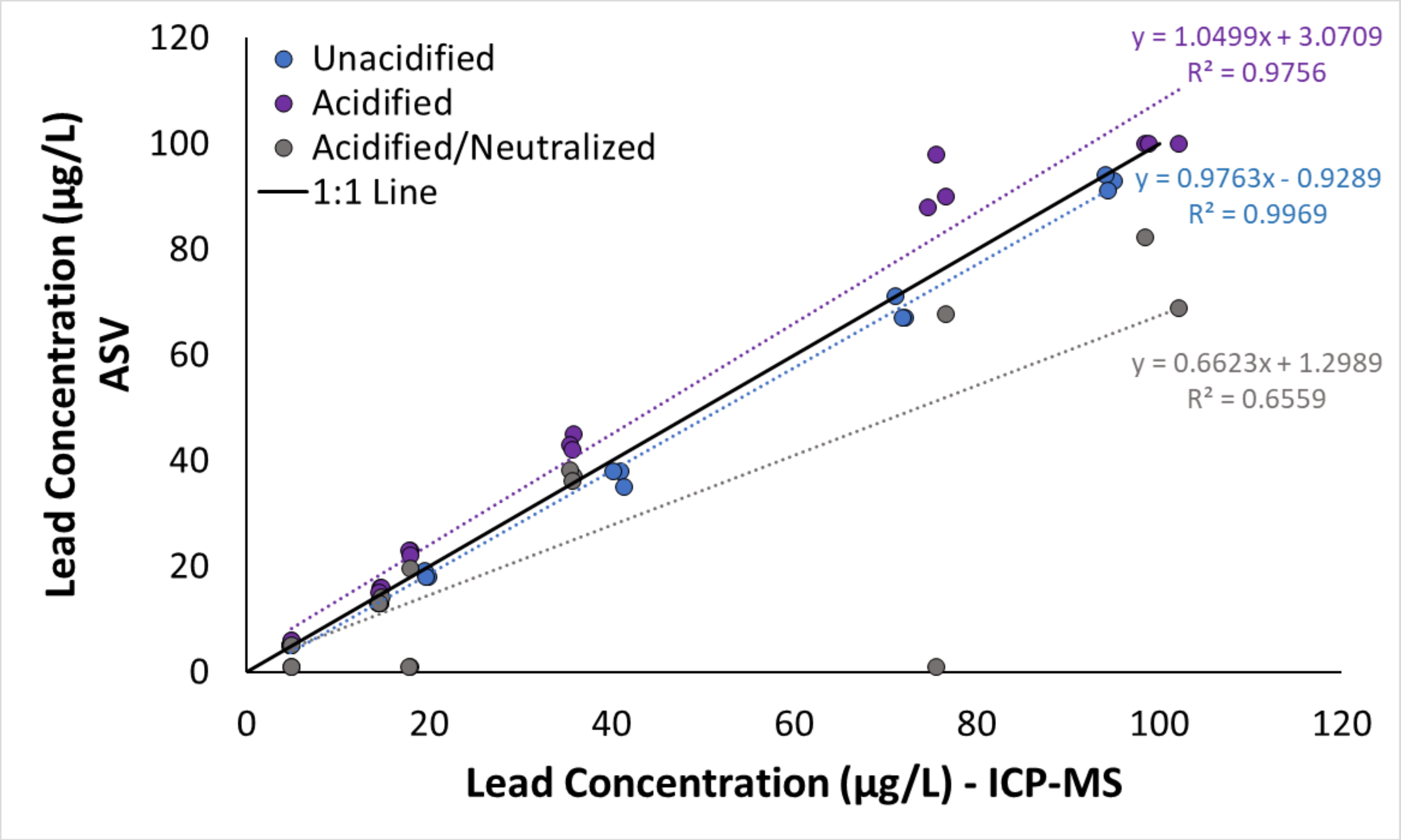
Phase 1 Laboratory Testing – Results

Typical response curve for triplicate analyses using clear well water spiked with Pb nitrate



Phase 1 Laboratory Testing – Results

ASV Pretreatment Method Comparison



Phase 1 Laboratory Testing – Summary

- Fluorescence underestimated Pb levels compared to ICP-MS under controlled laboratory conditions, while accurate results were obtained using ASV
- Sample preservation and pretreatment methods did not improve Pb recovery using ASV

Phase 2 School Testing

Phase 1
- **Controlled Laboratory Testing**
- Dissolved Pb
- Evaluated preservation/ pretreatment methods

Phase 2
- **School Testing**
- Dissolved & particulate Pb
- Usability of portable units

Phase 3
- **LSLR Samples**
- Dissolved & particulate Pb
- Evaluated preservation/ pretreatment methods

Phase 2 School Testing: Samples

Phase 2 School Testing: Sampling Protocol

Field – Optimal Sample Conditions

Laboratory Testing

250mL Sample

ASV — **5 mL**

Fluorescence — **1 mL**

Remaining Sample: Acidified + 16h Hold

ICP-MS

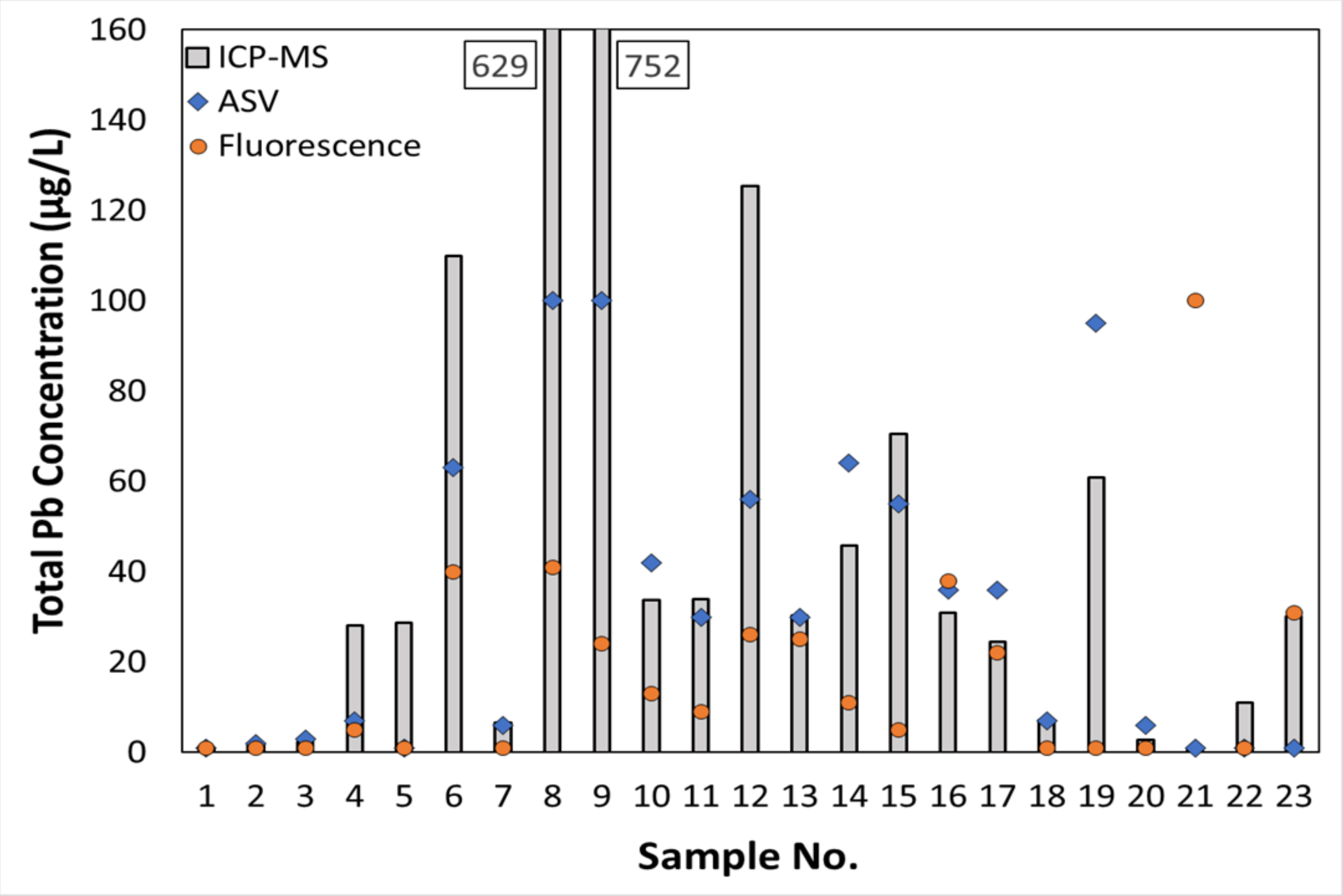
15 mL

15 mL

50mL Sample Aliquot Filtered – Prior to Acidification

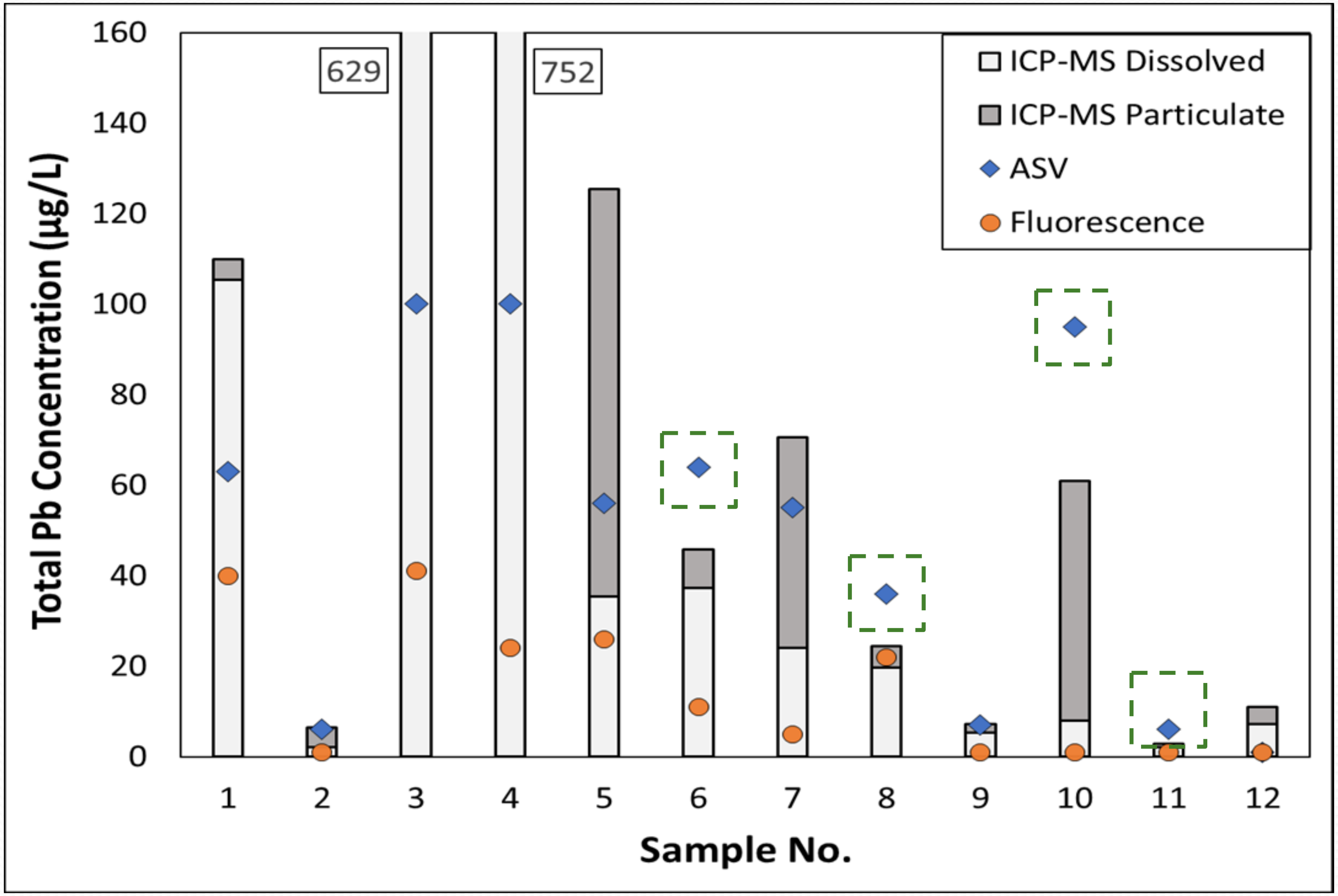
Phase 2 School Testing – Results

School Samples Analyzed Under Optimal Conditions



Phase 2 School Testing – Results

School Samples Analyzed Under Optimal Conditions – Assessing Impact of Particulate Pb



Phase 2 School Testing – Results

	ASV	Fluorescence
Average % Recovery	85	39
Standard Deviation	56	37
False Negatives*	3	7
N =	*23*	*22*

***False Negative** = negative reading (<2 ppb) with portable analyzer, but positive ICP-MS result (≥2 ppb)

Pb Trigger Levels (TL)

0 | <1 | 5 | 10 | 15 | 20

schools: IL

NY, OR

ME, WA

Percentage of School Samples Mischaracterized as <TL

- ASV: 13-17%
- Fluorescence: 26-30%

EDF AL **Proposed EPA TL**

Adapted from Hecht, 2018, Safe Water in Schools: What do we know? What can we do?

Practicality of Using Portable Units

ASV

- Pros
  - EPA-approved field method (1001) if acid preserved
  - User friendly (minimal skill level or training required)
  - Clear instructions
  - Performs mini acidification
- Cons
  - Longer analysis time (3 minutes)
  - Hazardous waste disposal cost
  - Delicate sensors (easily damaged)

Fluorescence

- Pros
  - Faster analysis time (1 minute)
  - No disposal cost/hazardous waste
  - Wider sample temperature range
- Cons
  - More in-depth calibration and sample prep
  - May be challenging for people without science background
  - Sample hold time and pH restrictions

Method Cost Comparison

Parameter	ICP-MS	ASV	Fluorescence
Cost Per Sample	\$20 - 100[a]	\$9.50[b]	\$10[b]
Equipment Cost	N/A	\$1,950[b]	\$2,400[b]
Waste Disposal Cost (Per Sample)	N/A	~\$1[c]	N/A
Labor Considerations	*Shipping*	*Setup, meter calibration, sample analysis and cleanup*	

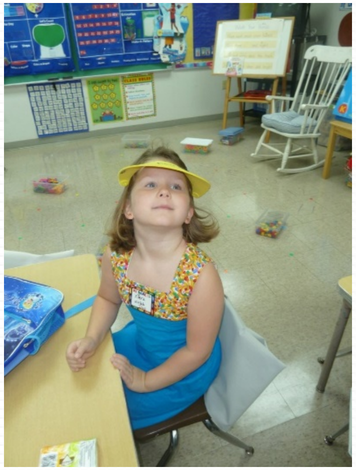
[a]US EPA, 2019, Basic Information about Lead in Drinking Water

[b]Prices do not include shipping or other fees

[c]Based on GCWW hazardous waste disposal cost

Phase 2 School Samples – Summary

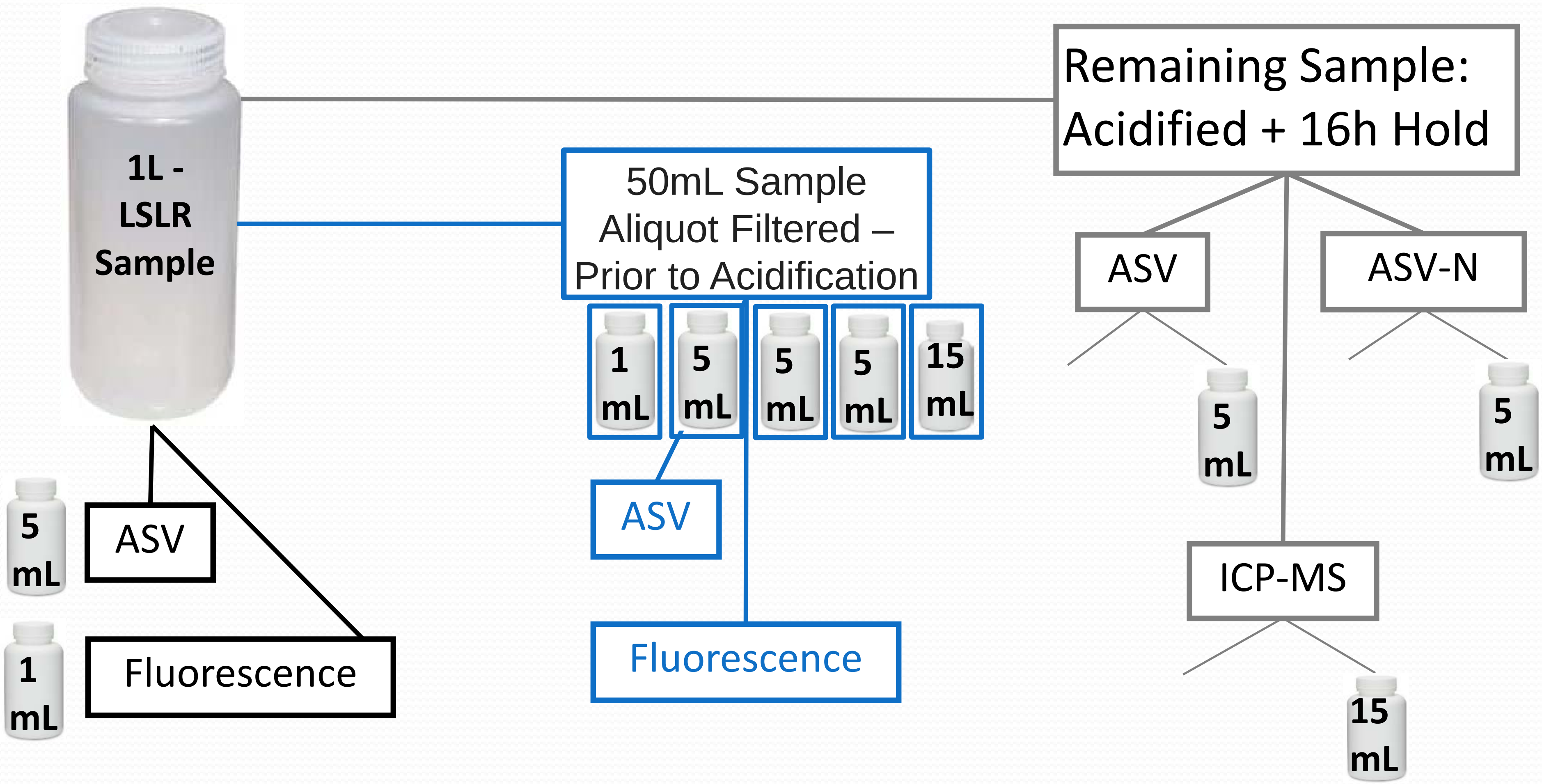
- Minimal specific skill level or training required for ASV, but Fluorescence may be challenging for a non-trained analyst (such as a school administrator or building superintendent)
- Portable analyzers tended to underestimate Pb levels in school samples compared to ICP-MS in the presence of particulate Pb



Phase 3 Lead Service Line Replacement (LSLR) Samples

- **Phase 1**
  - **Controlled Laboratory Testing**
  - Dissolved Pb
  - Evaluated preservation/ pretreatment methods
- **Phase 2**
  - **School Testing**
  - Dissolved & particulate Pb
  - Usability of portable units
- **Phase 3**
  - **LSLR Samples**
  - Dissolved & particulate Pb
  - Evaluated preservation/ pretreatment methods

Phase 3 LSLR Samples: Sampling Protocol



Phase 3 LSLR Samples – Summary

- Preliminarily results comparable to the findings from Phases 1 and 2
- Additional LSLR samples being tested to statistically analyze data

Study Limitations

- Limited number of samples and types
- Bias associated with splitting sample
- Error associated with acidifying sample aliquot rather than acidification of entire sample

Summary

- Overall, results obtained with the handheld units underestimated Pb levels compared to standard laboratory analysis
- Portable meters were more accurate under controlled laboratory testing compared to field testing
- Variable Pb results when particulates present
- Sample preservation and pretreatment methods unable to improve accuracy using Cincinnati tap water

Future Needs

- Impact of interfering constituents and varying water chemistries
- Effect of particle size and chemical composition
- Impact of sample collection (e.g., stagnation time, flow rate and volume)
- Evaluation of operator bias, both for experienced and inexperienced personnel

Acknowledgements

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Questions?

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GREATER CINCINNATI WATER WORKS

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