Assessing Portable Analyzers for Lead Testing in School Drinking Water

Lauren Wasserstrom[1] & James Nelson[1]

Dawn Webb[1], Lindsay McCormick[2], Simoni Triantafyllidou[3], Denise Patrick[1] & Jeff Swertfeger[1]

AWWA Water Quality Technology Conference| Dallas, Texas

November 4, 2019

[1]Greater Cincinnati Water Works | [2]Environmental Defense Fund | [3]U.S. Environmental Protection Agency

GREATER CINCINNATI WATER WORKS

EDF ENVIRONMENTAL DEFENSE FUND® Finding the ways that work

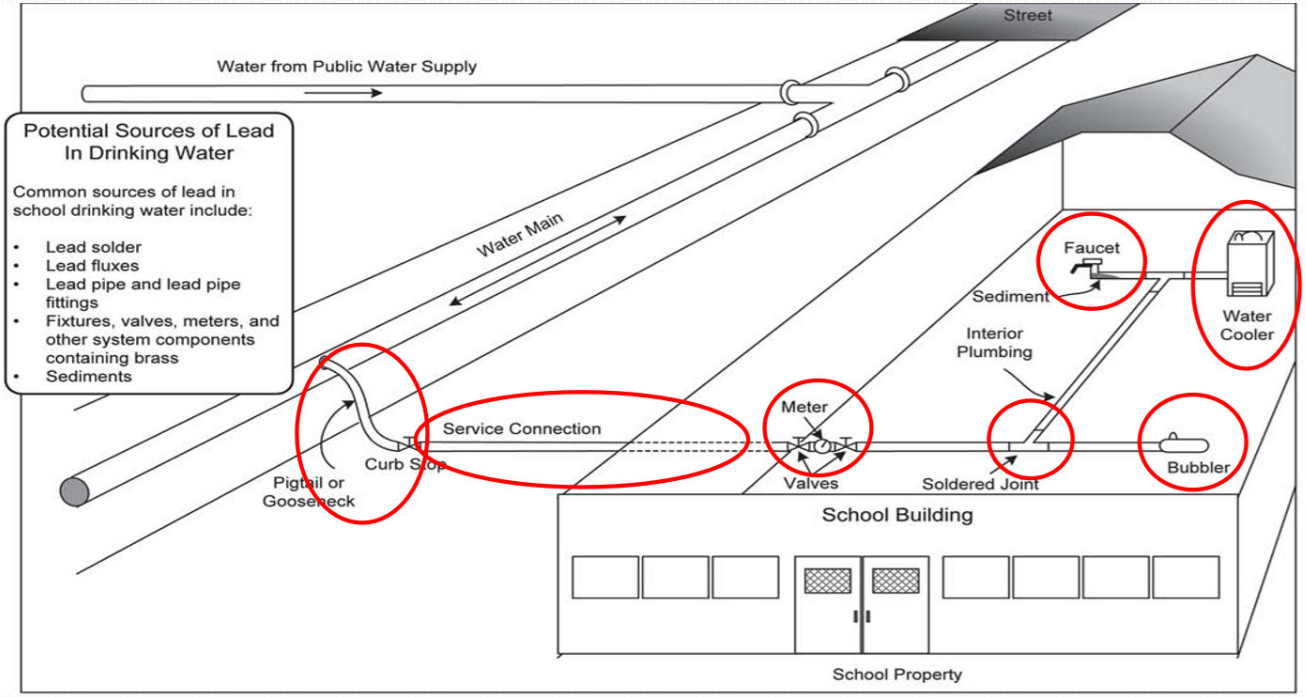
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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



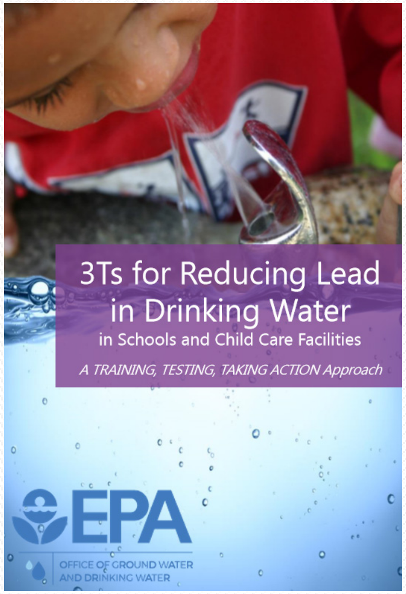
Source: US EPA, 2018, 3Ts for Reducing Pb in Drinking Water in Schools and Child Care Facilities

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

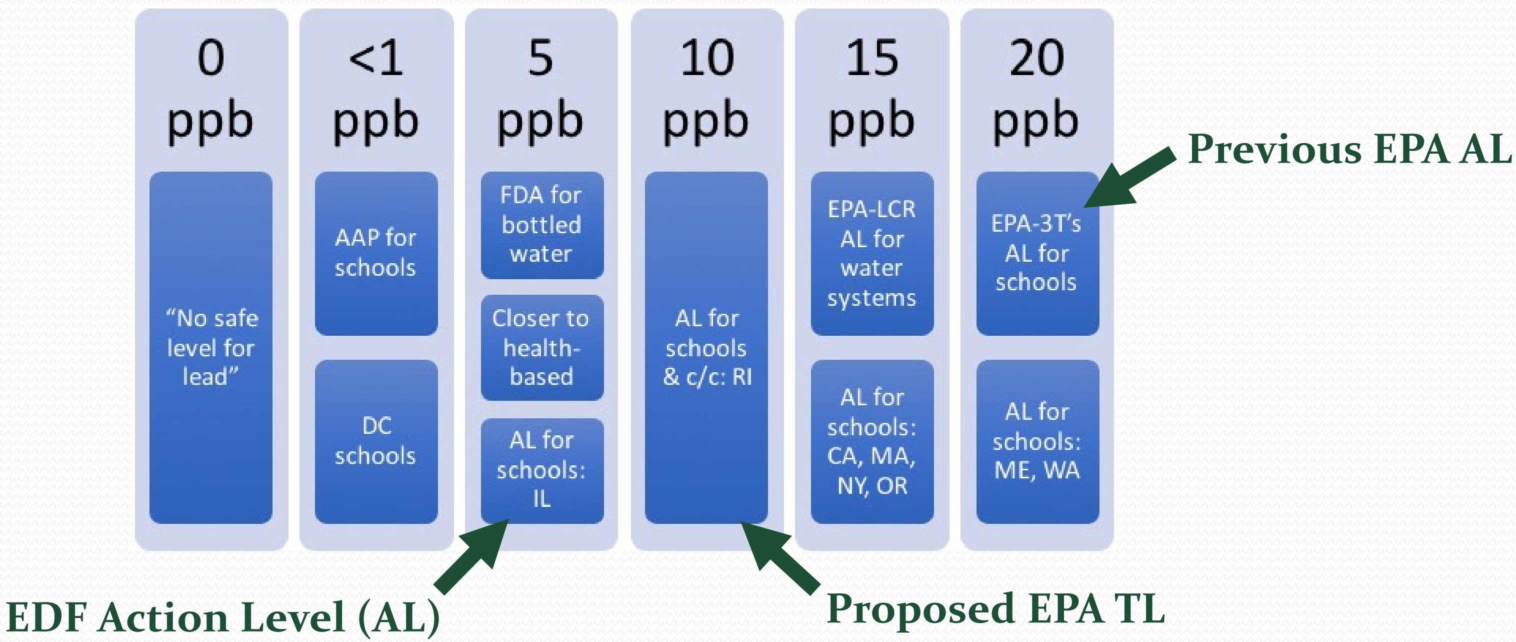
- Pb Contamination Control Act, 1988
  - Established **voluntary program** to reduce Pb levels in drinking water at schools and child care facilities
  - Banned water coolers with Pb lined tanks
  - Created Pb monitoring and reporting guidelines
- 3Ts for Reducing Pb in Drinking Water, revised 2018
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

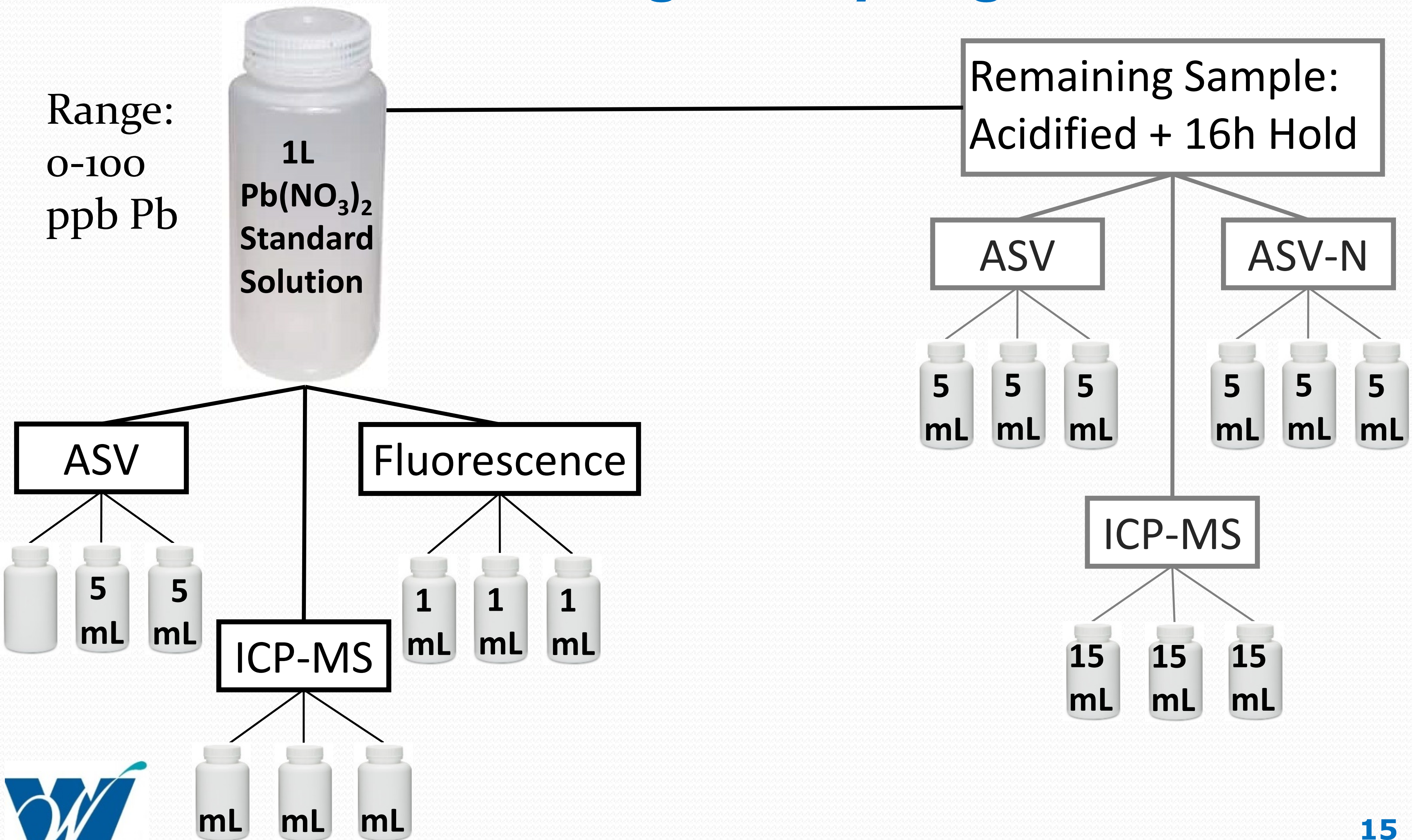
Phase 1 Laboratory Testing

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

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

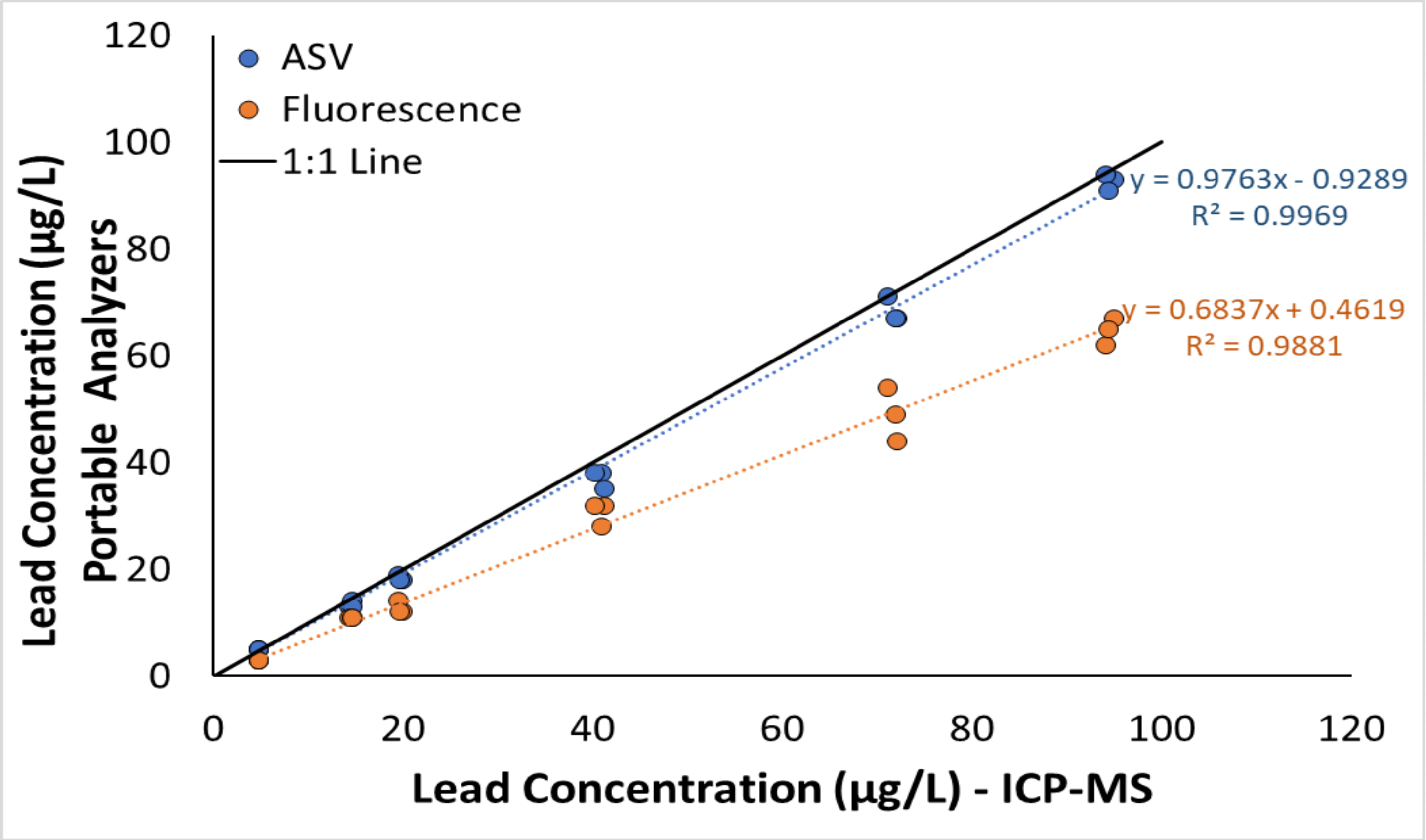
Phase 3
- **LSLR Samples**
- Dissolved & particulate Pb
- Evaluated preservation/ pretreatment methods

Phase 1 Lab Testing: Sampling Protocol



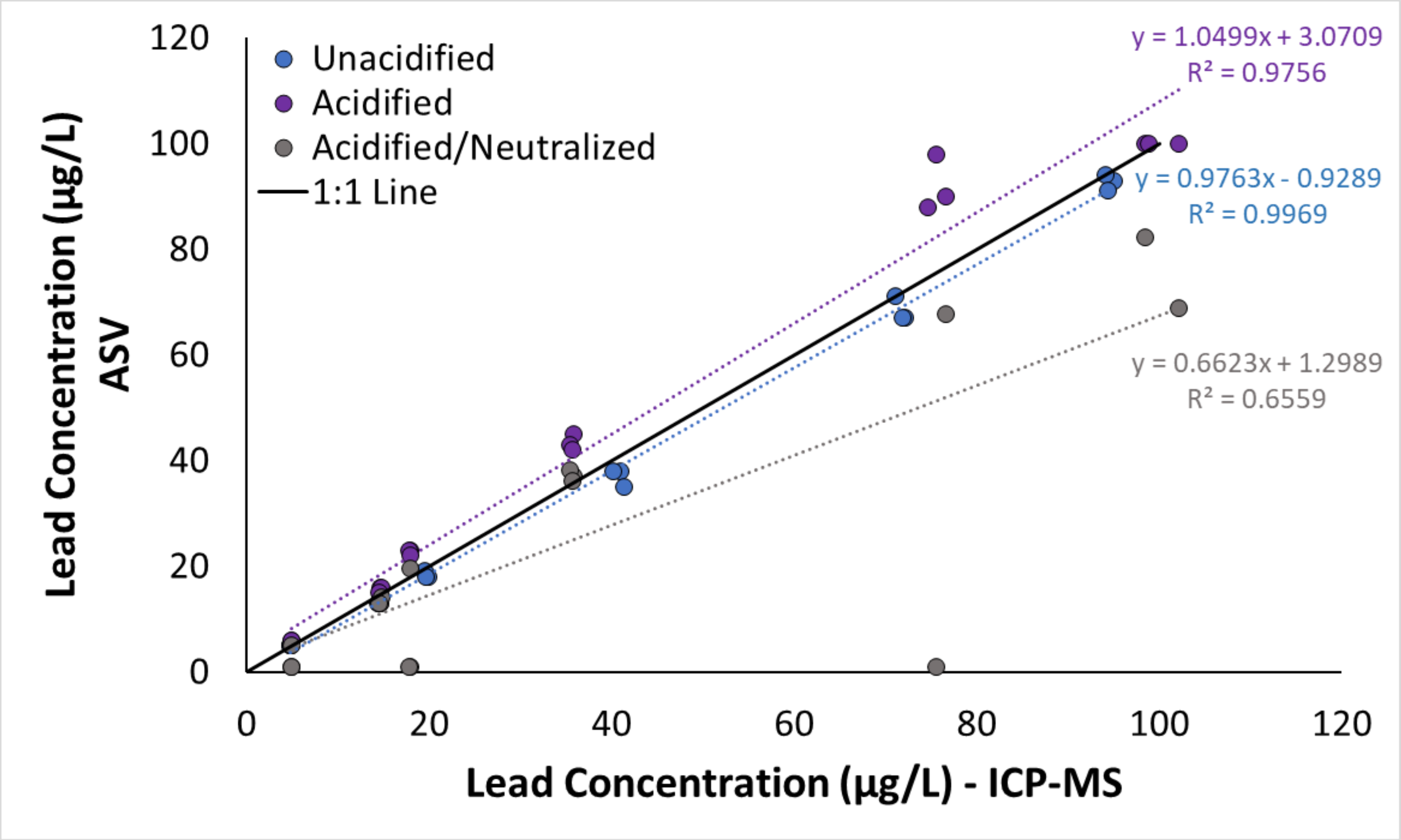
Phase 1 Laboratory Testing – Results

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

250mL Sample

ASV — 5 mL

Fluorescence — 1 mL

Laboratory Testing

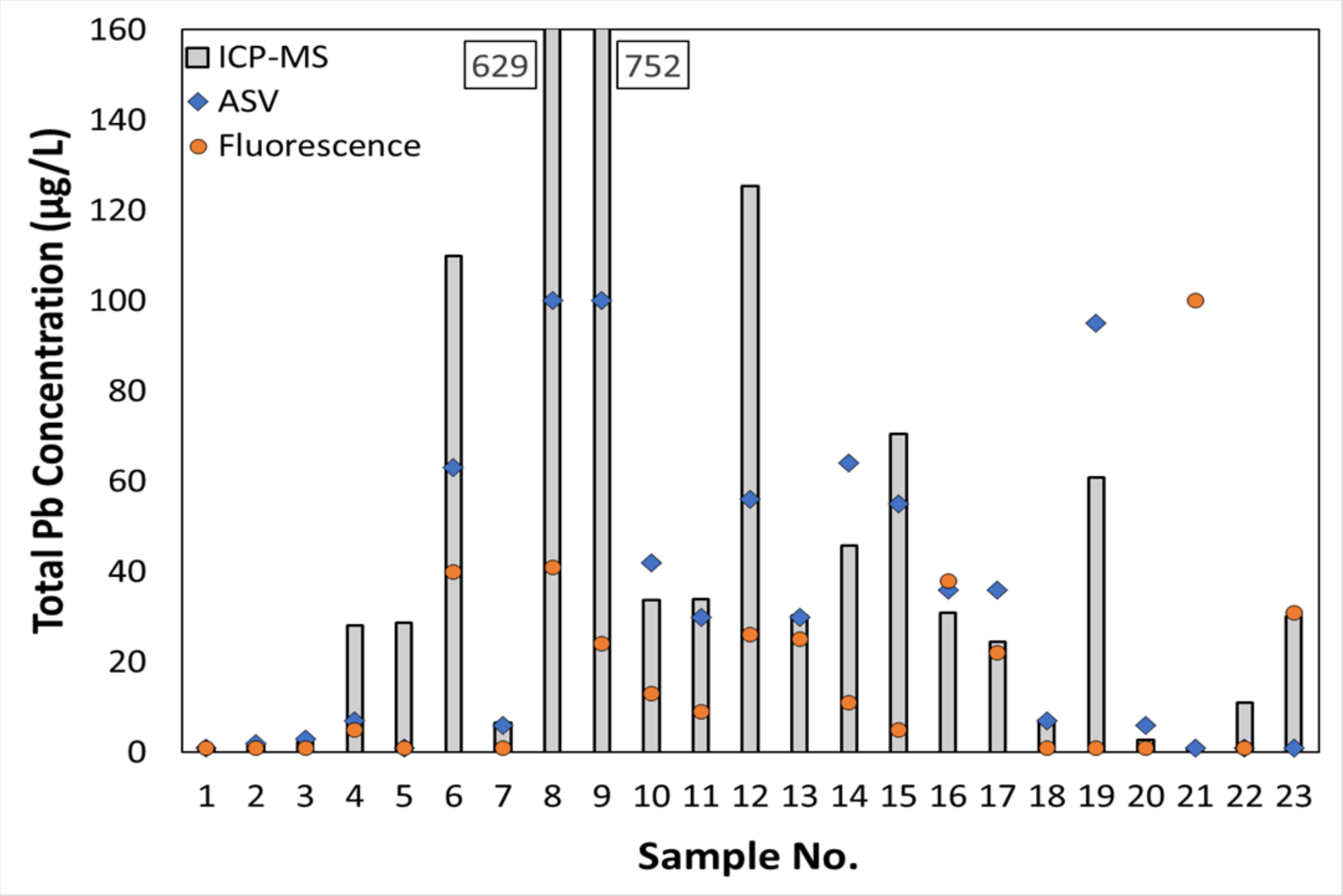
Remaining Sample: Acidified + 16h Hold

15 mL | 15 mL

50mL Sample Aliquot Filtered – Prior to Acidification

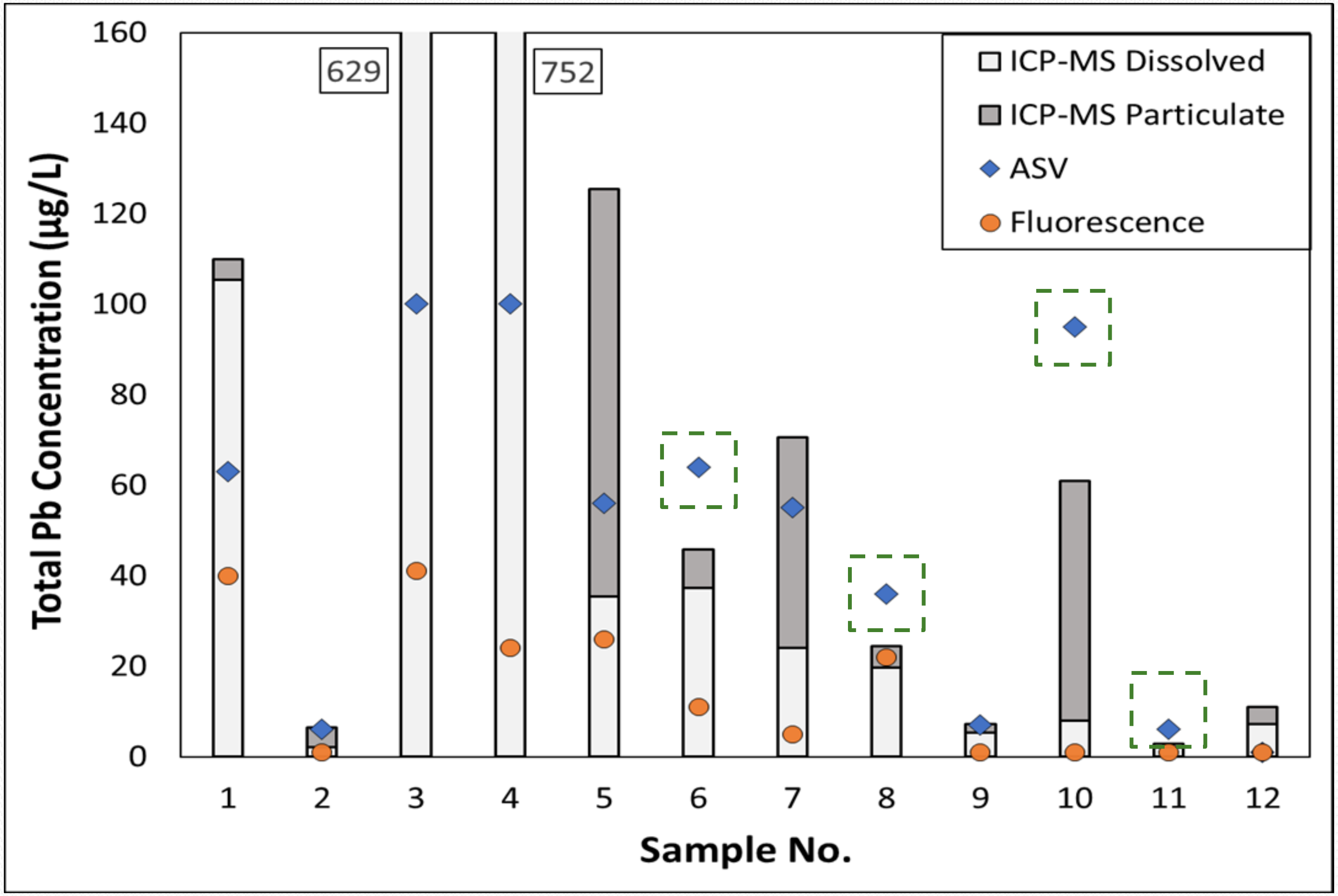
Phase 2 School Testing – Results

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

Percentage of School Samples Mischaracterized as <TL

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

schools: IL

NY, OR

ME, WA

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*	

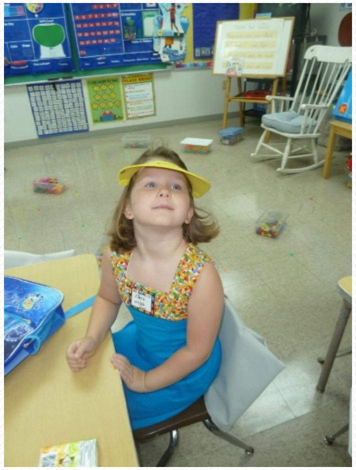
[a]US EPA, 2019, Basic Information about Lead in Drinking Water

[b]Prices do not include shipping or other fees

[c]Based on GCWW hazardous waste disposal cost

Phase 2 School Samples – Summary

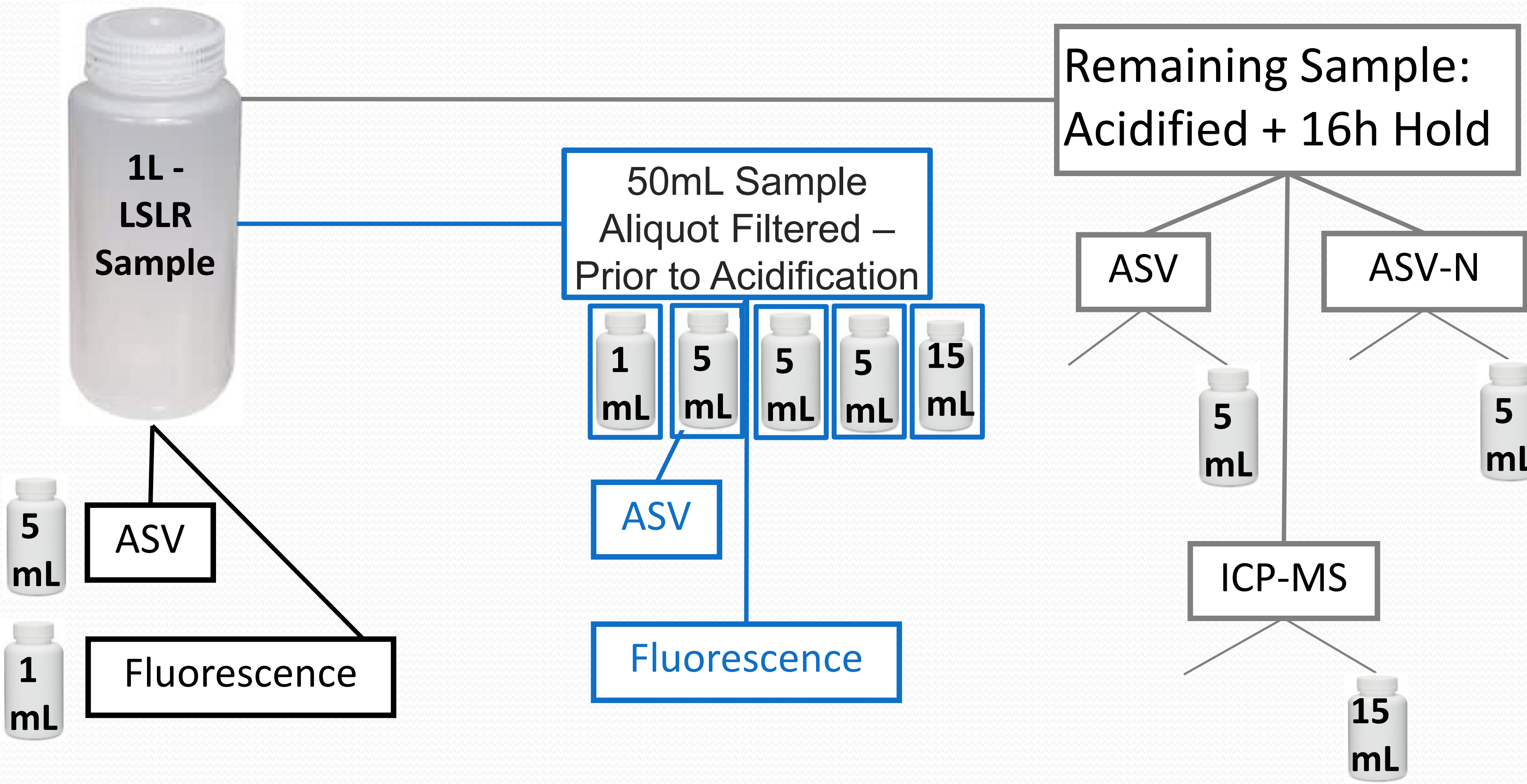
- Minimal specific skill level or training required for ASV, but Fluorescence may be challenging for a non-trained analyst (such as a school administrator or building superintendent)
- Portable analyzers tended to underestimate Pb levels in school samples compared to ICP-MS in the presence of particulate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

- Environmental Defense Fund
- U.S. Environmental Protection Agency
- Evelyne Doré, Oak Ridge Institute for Science and Education (ORISE)

Notice: The findings and conclusions in this presentation have been formally disseminated by the U.S. Environmental Protection Agency but should not be construed to represent any Agency determination or policy. Any mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Questions?

Contact Information:

Lauren Wasserstrom

Lauren.Wasserstrom@gcww.cincinnati-oh.gov

James Nelson

James.Nelson@gcww.cincinnati-oh.gov

A Service of The City of Cincinnati

GREATER CINCINNATI WATER WORKS

leading the way

removing lead
protecting health
revitalizing communities