

Development of U. S. EPA Method 559 for the Determination of Nonylphenol and 4-tert-Octylphenol in Drinking Water by Solid Phase Extraction and LC/MS/MS

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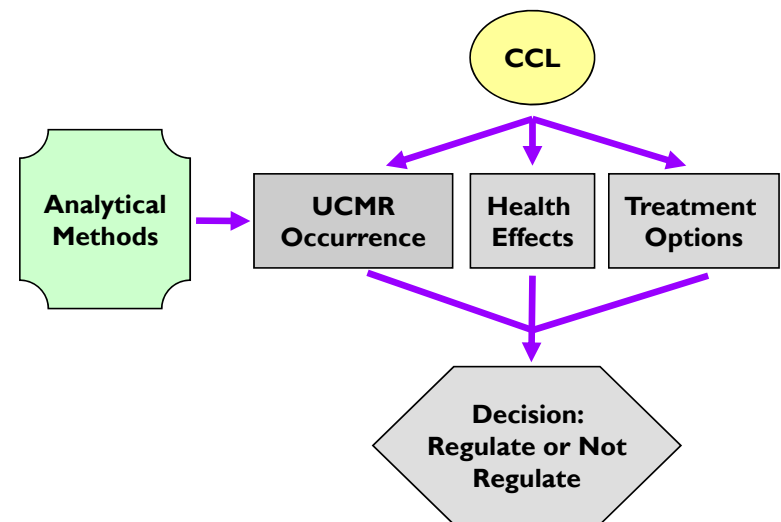
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CCL Background

- ◆ The 1996 amendments to the SDWA required EPA to establish a Drinking Water Contaminant Candidate List (CCL)
 - ✓ **Must decide to regulate or not regulate a minimum of 5 CCL contaminants every 5 years**
- ◆ The first CCL was published in 1998 - updated every 5 years
- ◆ The Final CCL 4 was published in November 2016 and contains 97 chemicals or chemical groups and 12 microbial contaminants

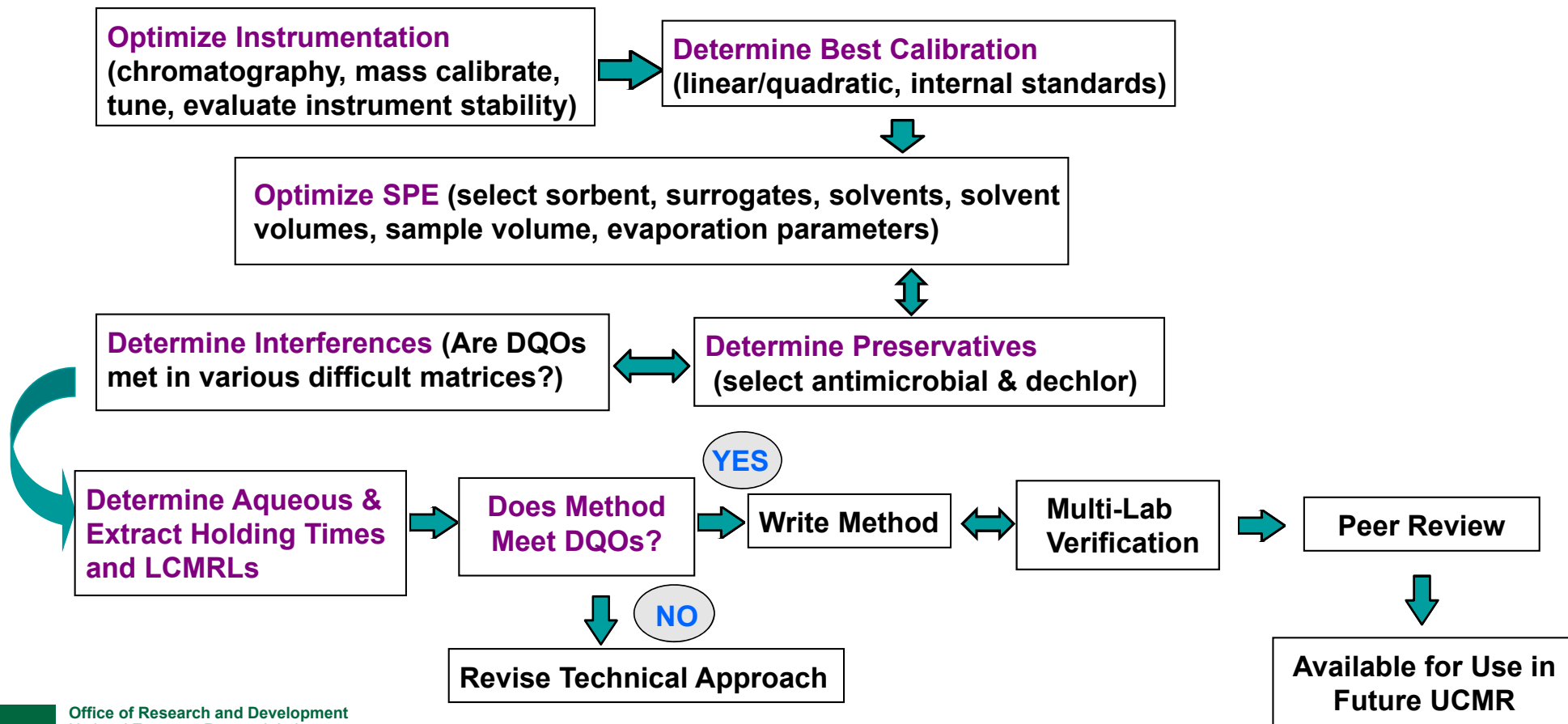




UCMR Background

- ◆ **Nationwide occurrence data needed on CCL chemicals**
- ◆ **EPA's OGWDW collects occurrence data under the Unregulated Contaminant Monitoring Regulation (UCMR)**
- ◆ **EPA methods for drinking water contaminants are needed for UCMR which meet our drinking water method development goals**
- ◆ **Conduct monitoring for up to 30 unregulated contaminants in a 5 year UCMR cycle**
 - ✓ likely to occur in drinking water
 - ✓ could be harmful
 - ✓ testing methods exist
- ◆ **UCMR 4: January 2017 – December 2021**

Method Development Process





Method Development Goals

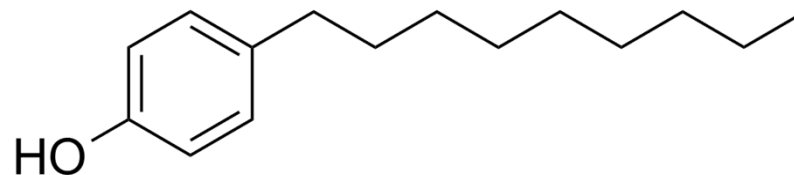
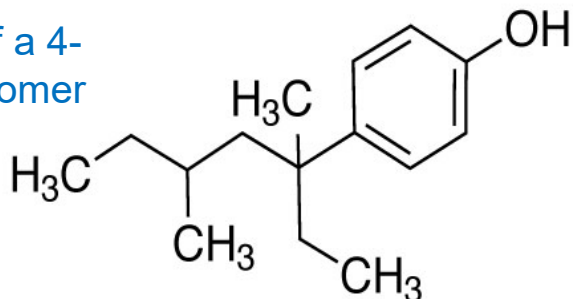
- ◆ **70-130% recovery with <30% RSD**
- ◆ **Laboratory reagent blank (LRB) no more than 1/3 the minimum reporting level (MRL)**
- ◆ **Preservation**
 - ✓ **Dechlorinating agent**
 - ✓ **Antimicrobial**
- ◆ **Establish sample and extract holding times – ideally ≥ 14 days**
- ◆ **Lowest concentration minimum reporting limits (LCMRLs) goal – less than health reference level (HRL)**
- ◆ **HRL for nonylphenol is 105 $\mu\text{g/L}$**

What is Nonylphenol?

- ◆ Nonylphenol is used to make plastics, detergents, paints, pesticides, personal care products
- ◆ Many products have “down the drain” applications and are flushed into the water supply

Technical, Branched Nonylphenol	Linear Nonylphenol
Mostly branched C9-alkyl phenols	Linear C9 chain
CAS# 84852-15-3	CAS# 104-40-5
Best represents commercially produced NP found in environment	Laboratory generated chemical not found in environment

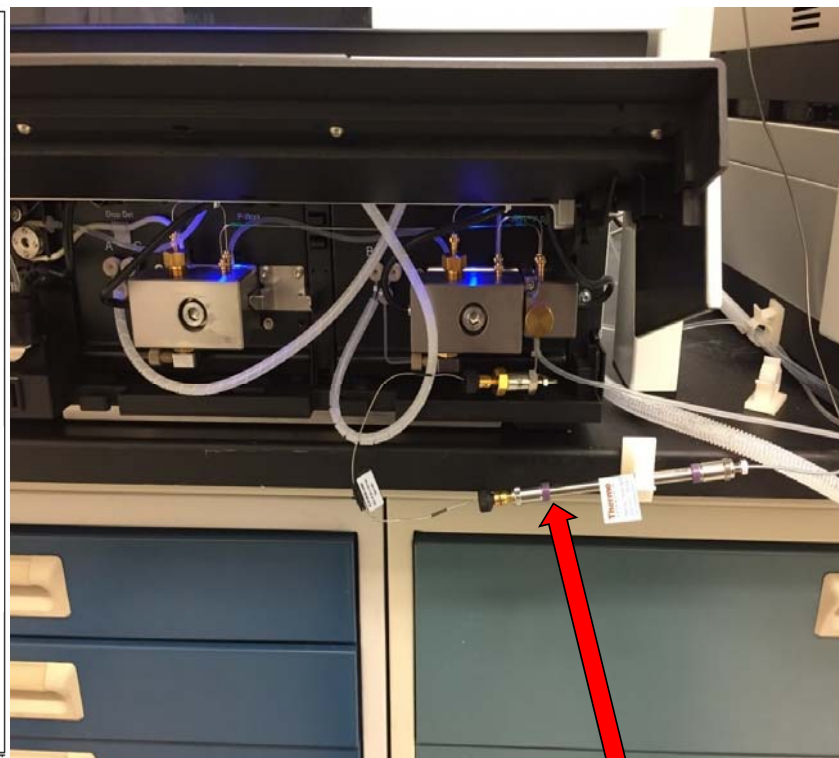
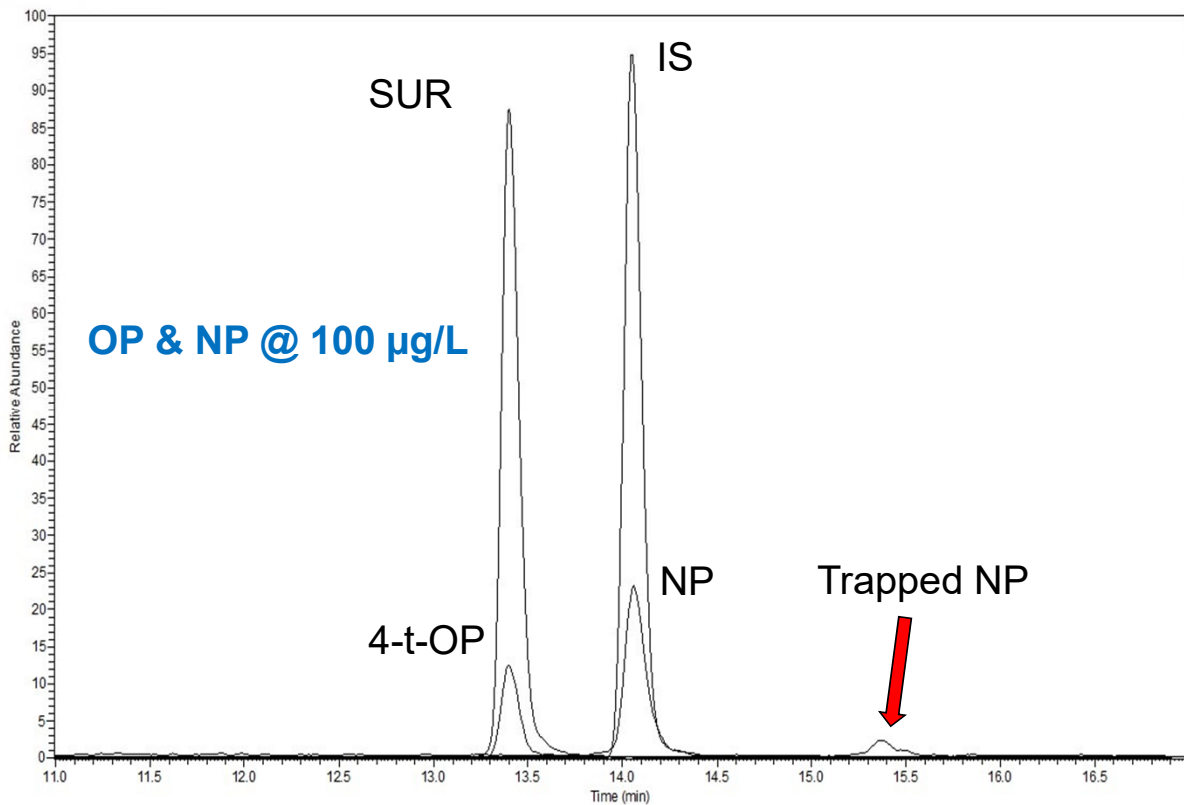
One example of a 4-branched-NP isomer



Method will report technical, branched NP, CAS #84852-15-3

System Background Contribution

NP is a common laboratory contaminant



Trapping Column

Trapping column used to separate LC system contamination away from injected NP peak

Drinking Water Procedure

Preservatives

Sodium bisulfate = antimicrobial
Ascorbic acid = dechlor

Amber Glass Bottle



250 mL sample

Possible Surrogates

4-n-Nonylphenol-¹³C₆ (linear)
4-n-Nonylphenol-2,3,4,5-d₄, OD (linear)
4-n-Octyl-d₁₇-phenol (linear)
4-tert-Octylphenol-¹³C₆ (branched)

Oasis HLB, 150 mg
Strata-X, 100 mg

Rinse cartridge with reagent water
and dry under vacuum

Rinse and elute bottle with
2 X 2 mL acetone

Adjust to 5 mL
final volume with
acetone

Add
IS

10 μ L
injection

LC/MS/MS

Internal Standard

4-(1,3-Dimethyl-1-ethylpentyl) phenol-¹³C₆

Optimized Conditions

Evaporation Study

Nonylphenol % Recovery	Precision % RSD (reps)	Evaporation Temperature	Minimum Extract Volume
86.0%	2.1% (n = 5)	40 °C	0.5 mL
90.3%	1.3% (n = 5)	30 °C	0.5 mL
100%	2.7% (n = 4)	30 °C	2 mL
96.4%	1.6% (n = 4)	No evaporation	No evaporation

- Henry's Law Constant = $11.02 \text{ Pa}\cdot\text{m}^3\cdot\text{mol}^{-1}$, vapor pressure = 4.55 mPa at 25 °C – potentially semivolatile
- Room temperature N₂ evaporation possible option
- Minimal gain in concentration factor, added complexity, and potential loss of recovery = **No Evaporation**

Mobile Phase Conditions

- ◆ Sensitivity increases as mobile phase pH approaches the pKa (10.3)
- ◆ Ammonium hydroxide (0.01%) used to increase pH to 10
 - ◆ Still 1 - 2 pH units below upper pH limit of C₁₈ LC columns
 - ◆ Column damage after two weeks!!

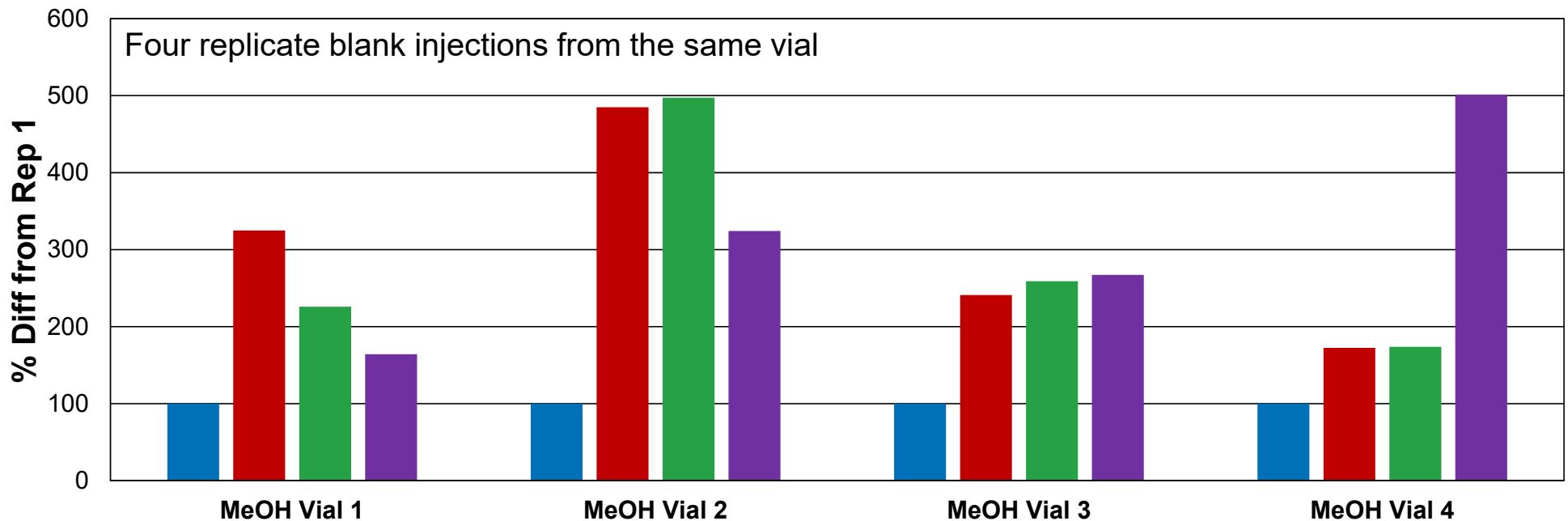
Standard Concentration	NP Area	Summary of Conditions
150 µg/L	2573	0.01% acetic acid in A/B
150 µg/L	3621	5 mM ammonium acetate in A/B pH = estimate 6.5
150 µg/L	18437	no modifiers/neutral pH
150 µg/L	323825	0.01% ammonium hydroxide in A/B pH = 10.1
150 µg/L	308900	0.2 mM ammonium fluoride in A pH = 6.0

Mobile Phase	A	B
Time (min)	DI water No modifiers	Methanol No modifiers
Initial	90	10
15	5	95
19	5	95
19.1	90	10
23	90	10
Thermo Hypersil Gold C ₁₈ , 2.1 x 50 mm, 3 µm, 0.3 mL/min flowrate, 10 µL injection		
Electrospray Conditions		
Polarity		Negative Ion
Capillary needle voltage		-3.5 kV
Sheath Gas		40 L/h
Aux Gas		4 L/h
Sweep Gas		2 L/h
Ion Transfer Tube Temp		325 °C
Vaporizer Temp		375 °C

NH₄F provides good sensitivity at near neutral pH

NP Contamination – Punctured Vial Septa

■ REP 1 ■ REP 2 ■ REP 3 ■ REP 4



❖ Repeat injections from same vial show increase NP area

- Vial Septa?
- Laboratory Air?

One injection per vial to eliminate potential NP contamination

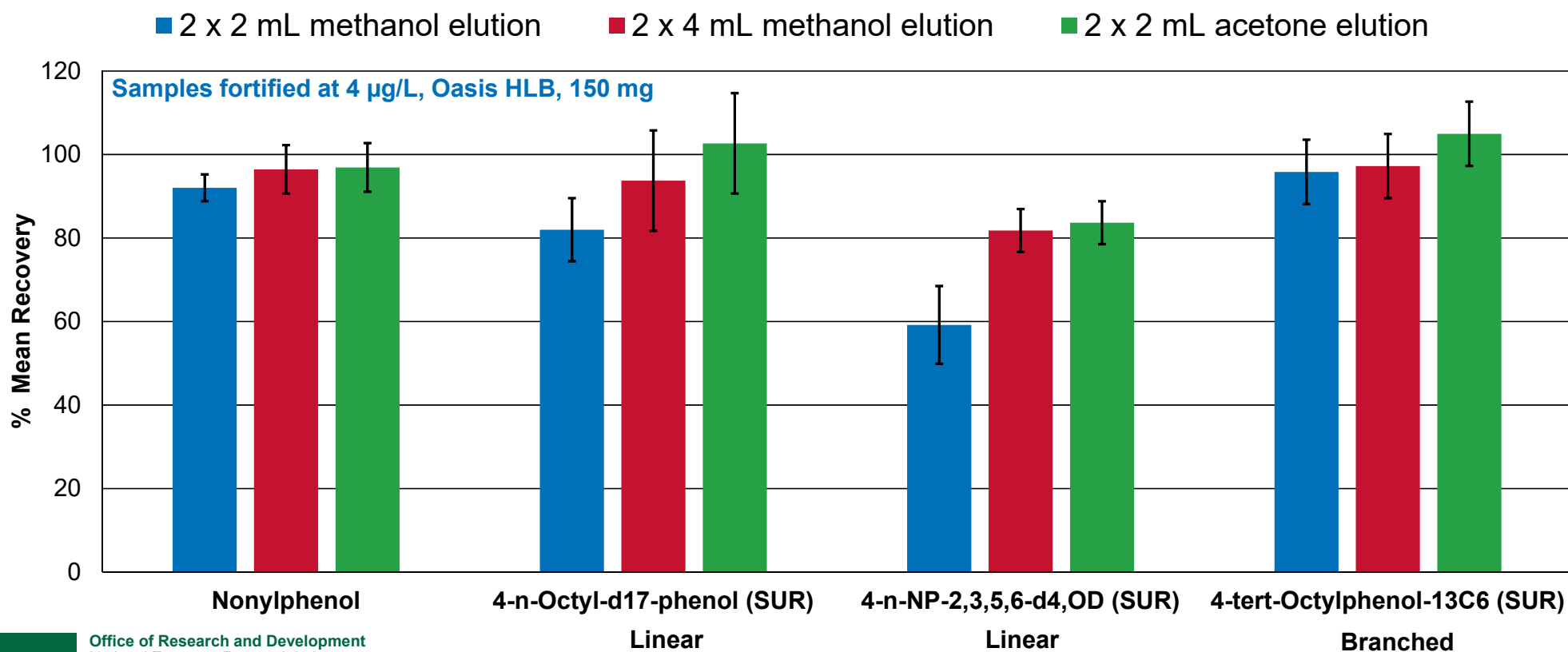


Laboratory Reagent Blank SPE Cartridge Background for Nonylphenol

	Oasis HLB ng/L n = 11	Strata-X ng/L n = 6	Brand C ng/L n=5
Average	7.64	8.06	15.4
Standard deviation	2.50	1.51	1.88
Minimum	4.42	5.70	12.18
Maximum	12.45	9.89	17.48

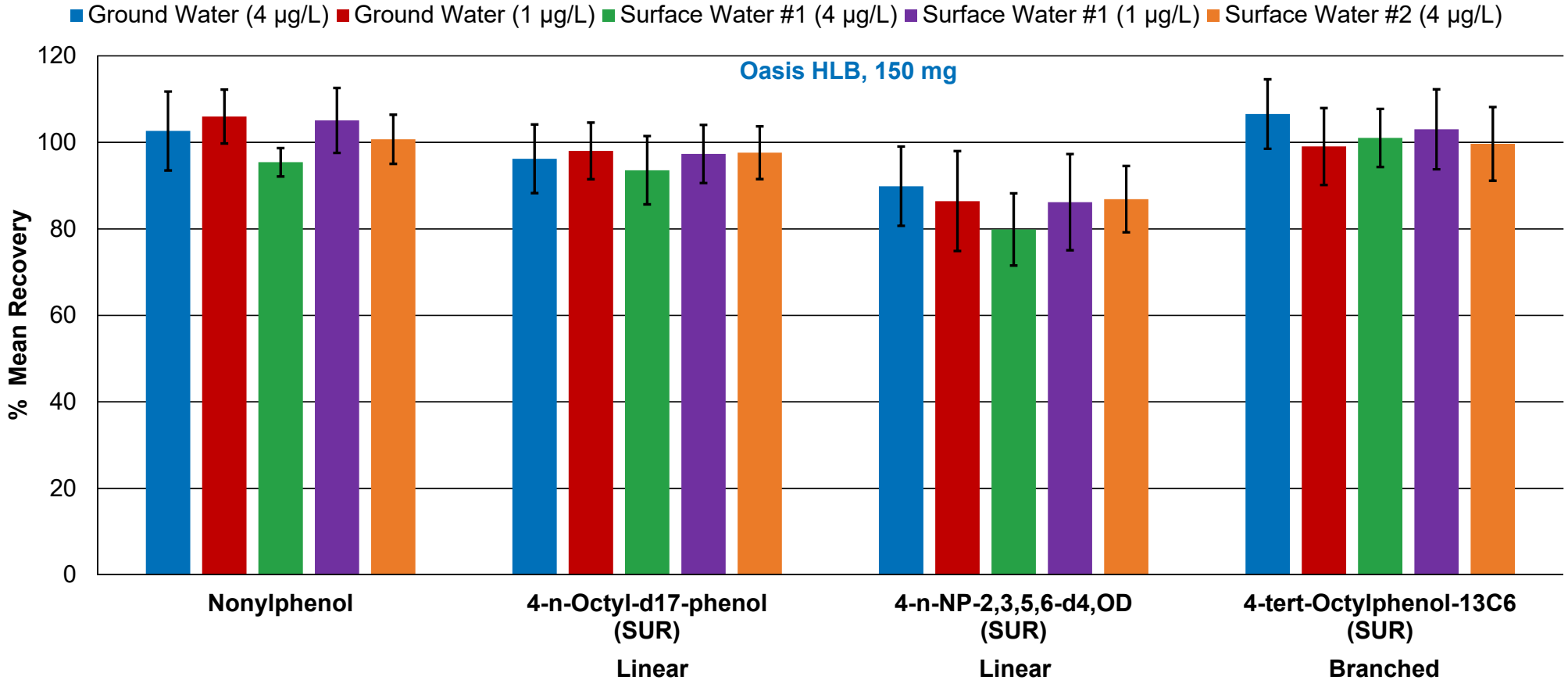
- ◆ Brand C cartridge average about 2X higher than other cartridges
- ◆ Brand C minimum LRB near or above the maximum of other cartridges

Mean Recovery and Precision (n=4) of Laboratory Fortified Blanks Comparing Elution Solvent and Volume



2 X 2 mL acetone chosen for elution

Performance of Linear Versus Branched Alkylphenol Surrogates in Drinking Water Matrices

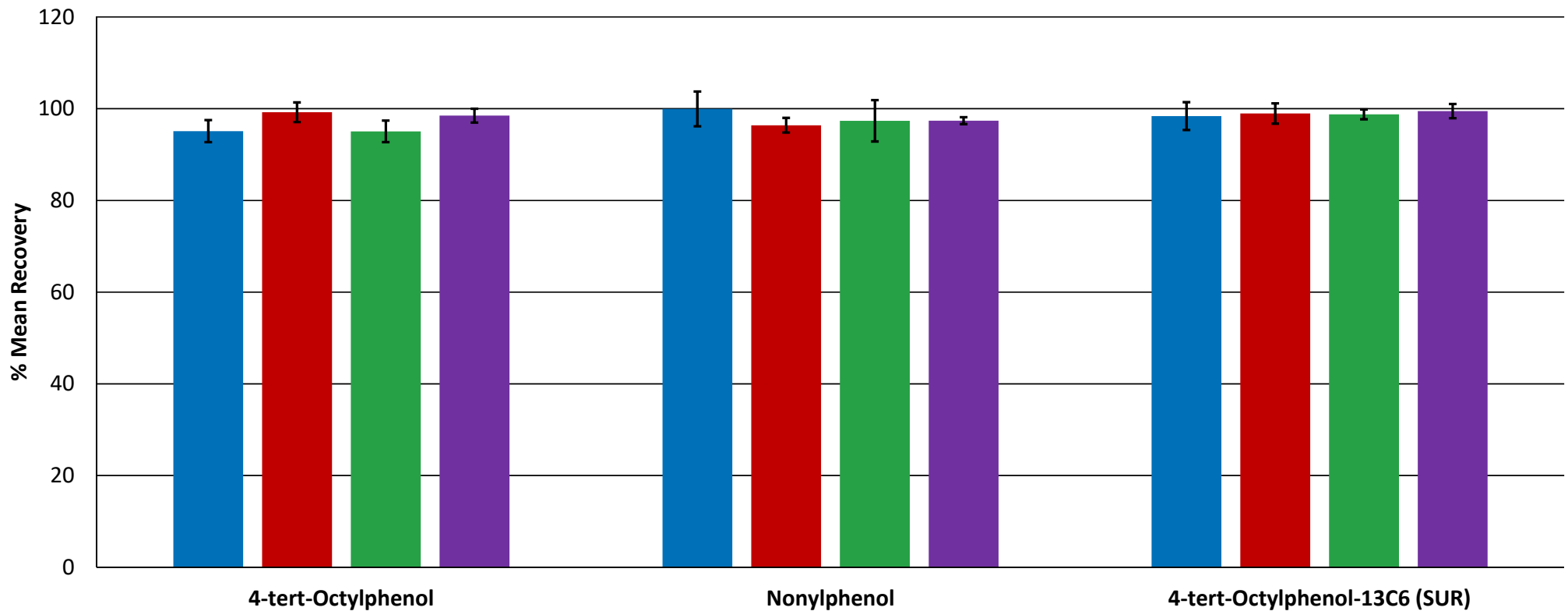


❖ **Branched SUR chosen for method**



Mean Recovery and Precision (n=4) in Laboratory Fortified Blanks

■ Oasis HLB, 100 ng/L ■ Oasis HLB, 600 ng/L ■ Strata-X, 100 ng/L ■ Strata-X, 600 ng/L



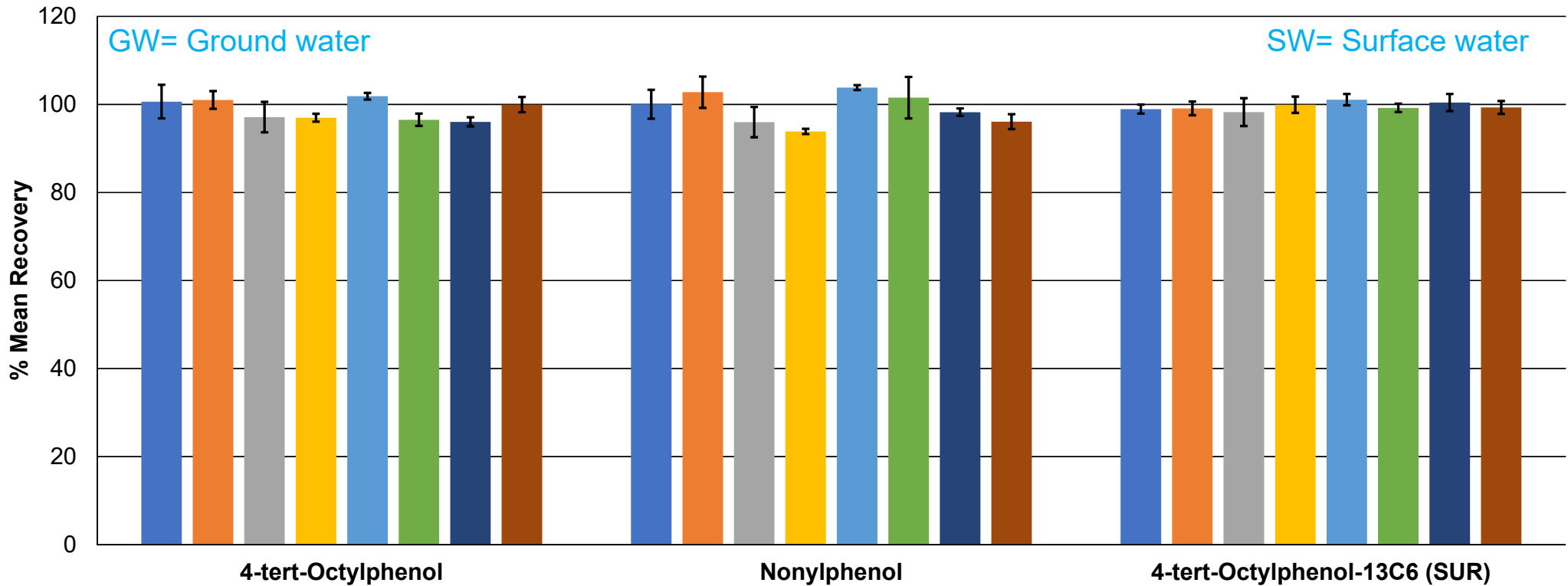
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◆ Results meet DQOs of 70-130%, <30% RSD



Mean Recovery and Precision (n=4) in Laboratory Fortified Drinking Water Samples

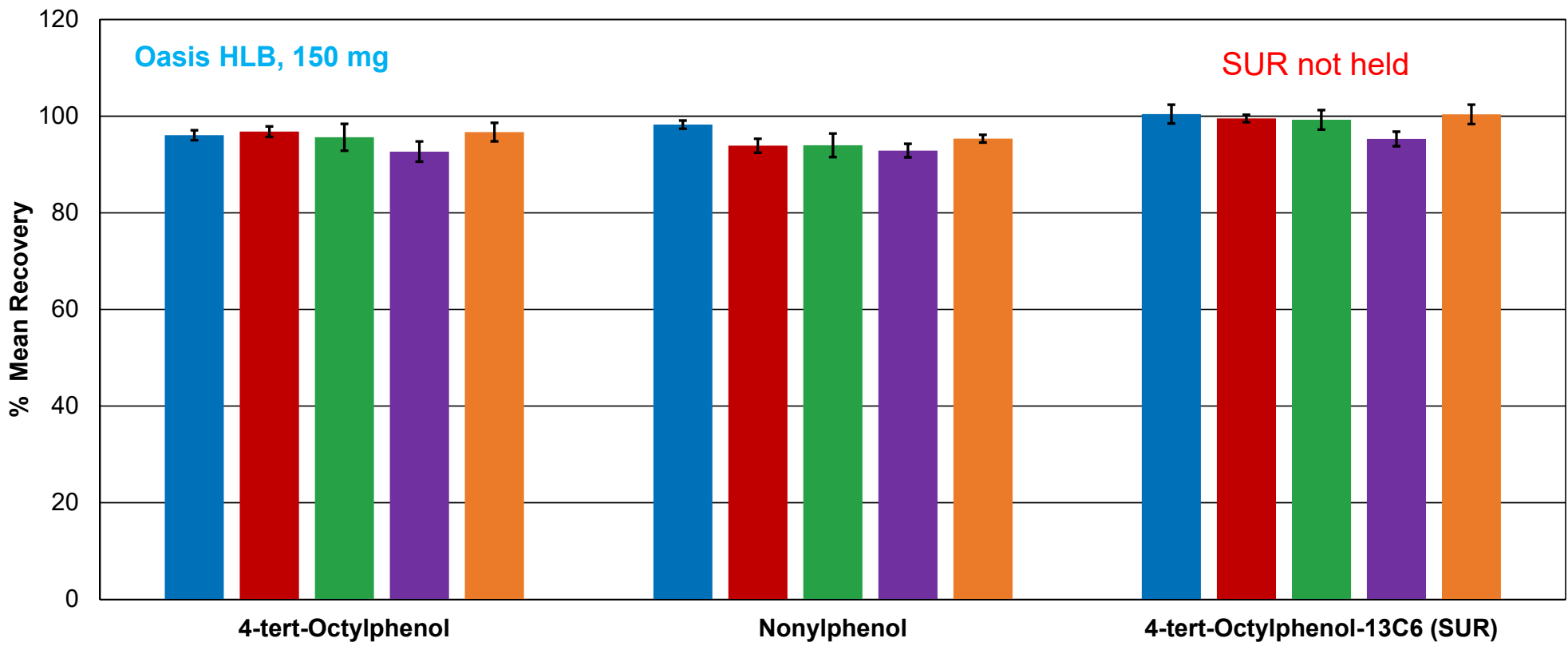
- Oasis HLB, 100 ng/L, GW
- Strata-X, 100 ng/L, GW
- Oasis HLB, 600 ng/L, GW
- Strata-X, 600 ng/L, GW
- Oasis HLB, 100 ng/L, SW
- Strata-X, 100 ng/L, SW
- Oasis HLB, 600 ng/L, SW
- Strata-X, 600 ng/L, SW



Aqueous Holding Time Study

Tap water from a surface water source, fortified at 600 ng/L, n=4

■ Day 0 ■ Day 7 ■ Day 14 ■ Day 21 ■ Day 28



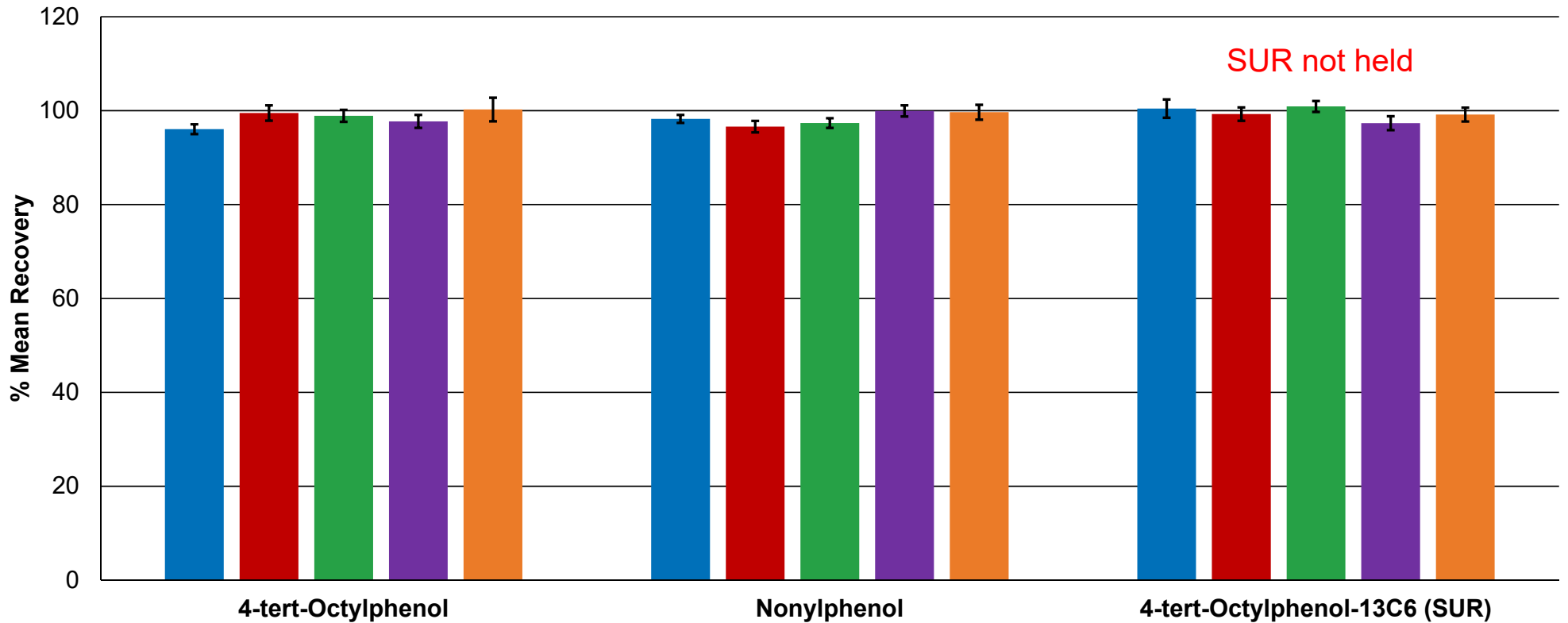
❖ Sodium bisulfate and ascorbic acid preservation



Extract Holding Time Study

Tap water from a surface water source, fortified at 600 ng/L, n=4

■ Day 0 ■ Day 7 ■ Day 14 ■ Day 21 ■ Day 28



SUR not held

◆ Extracts stored in autosampler vials at 4 °C



Drinking Water Method Verification Approach

◆ 4 Laboratories

- ✓ Additional labs for M559 to evaluate LRB background

◆ Labs provided written method

◆ Demonstrate method performance data

- ✓ LRB evaluation
- ✓ accuracy and precision in reagent water
- ✓ accuracy and precision in at least one matrix
- ✓ LCMRL

◆ Provide feedback on written method & any analytical issues encountered

◆ Multi-lab LCMRLs are used to determine MRLs for the UCMR



Preliminary Laboratory Verification Study

LRB Summary

LRB	Nonylphenol, ng/L			
	Lab 1	Lab 2	Lab 3	Lab 4
Average	2.8	1.3	31.7	24.3
Standard deviation	0.8	0.4	10.1	11.1
Minimum	1.9	0.9	24.1	12.1
Maximum	3.8	1.9	56.5	37.3

Highly variable background levels of NP found during verification

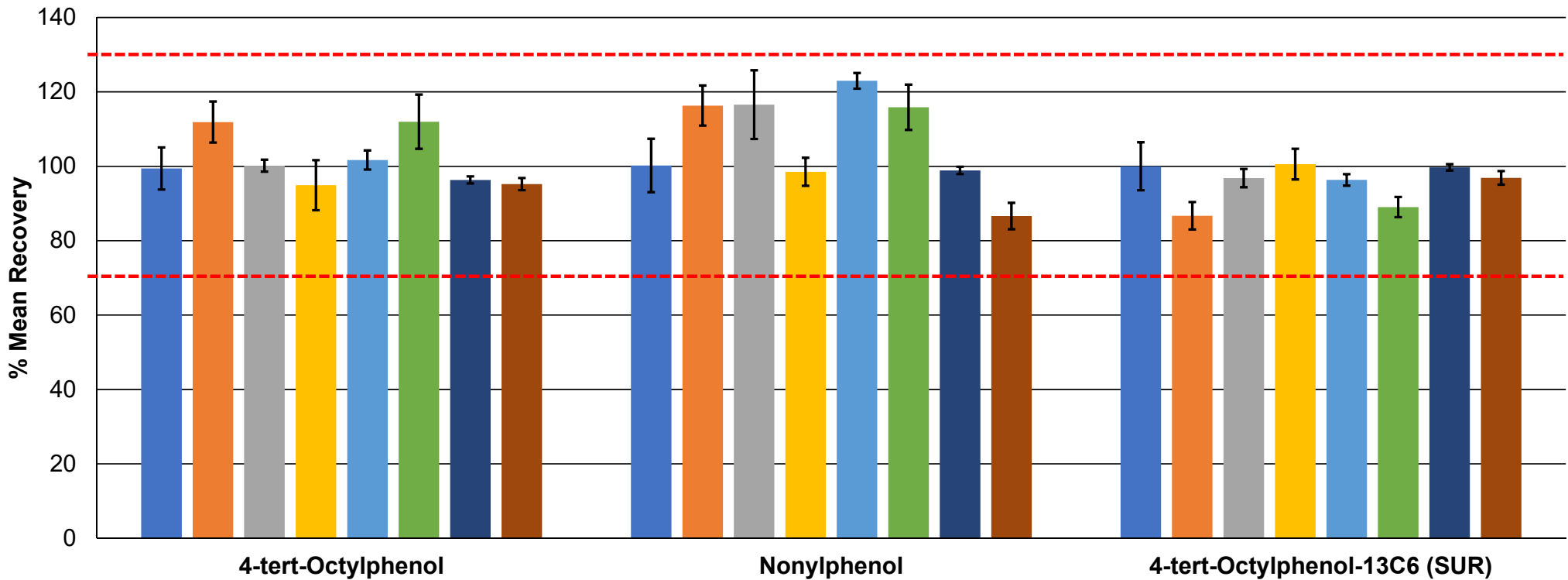
➤ **Reagent water likely source**



Preliminary Laboratory Verification Study

LFBs @ 50-200 ng/L, n=4-7, LFSMs @ 50-500 ng/L, n=4-6

- Lab 1 LFBs
- Lab 2 LFBs
- Lab 3 LFBs
- Lab 4 LFBs
- Lab 1 LFSMs GW
- Lab 2 LFSMs GW/SW
- Lab 3 LFSMs GW
- Lab 4 LFSMs GW



❖ Results meet DQOs of 70-130%, <30% RSD

LCMRL Values

Analyte	ng/L				
	EPA LCMRL	Lab 1 LCMRL	Lab 2 LCMRL	Lab 3 LCMRL	Lab 4 LCMRL
4-tert-Octylphenol	4.9	6.4	15	4.9	12
Nonylphenol	24	29	113	10	38

Reference Guidelines

Guideline	Limit
HRL	105 µg/L
Minnesota Department of Health	20 µg/L

- ❖ LCMRL value for nonylphenol well below current HRL guideline



Summary

- ❖ **Rugged, standardized, sensitive method developed for nonylphenol and 4-tert-octylphenol in drinking water**
- ❖ **Investigated best labeled SUR and IS standards for method, chose branched octylphenol for SUR and branched nonylphenol for IS**
- ❖ **Meets DQOs for two types of SPE cartridges, reagent water, and drinking water from ground water and surface water sources**
- ❖ **Aqueous and extract holding times of 28 days**
- ❖ **Multi-lab verification, easily meet HRL limit for nonylphenol**



Multi-Laboratory Verification Acknowledgements

- ❖ **American Water Central Laboratory – Belleville, IL**
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 - William Lipps, Ali Haghani
- ❖ **Eurofins Eaton Analytical, LLC – South Bend, IN**
 - Yongtao (Bruce) Li, Joshua Whitaker



Questions??