The Use of 2-D IC for the Determination of Haloacetic Acids in Drinking Water – Redux

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Overview

• Haloacetic Acids Analysis (HAA)
  • Background
  • Current Methods

• 2-D IC
  • Matrix removal
  • New columns
  • System configuration

• Analysis of HAA9 with 2-D IC

• Conclusions
## What Are HAAs?

<table>
<thead>
<tr>
<th>Acid</th>
<th>Abbreviation</th>
<th>Chemical Formula</th>
<th>pKa</th>
<th>Boiling Point °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monochloroacetic Acid</td>
<td>MCAA*</td>
<td>ClCH(_2)CO(_2)H</td>
<td>2.86</td>
<td>187.8</td>
</tr>
<tr>
<td>Dichloroacetic Acid</td>
<td>DCAA*</td>
<td>Cl(_2)CHCO(_2)H</td>
<td>1.25</td>
<td>194</td>
</tr>
<tr>
<td>Trichloroacetic Acid</td>
<td>TCAA*</td>
<td>Cl(_3)CO(_2)H</td>
<td>0.63</td>
<td>197.5</td>
</tr>
<tr>
<td>Monobromoacetic Acid</td>
<td>MBAA*</td>
<td>BrCH(_2)CO(_2)H</td>
<td>2.87</td>
<td>208</td>
</tr>
<tr>
<td>Dibromoacetic Acid</td>
<td>DBAA*</td>
<td>Br(_2)CHCO(_2)H</td>
<td>1.47</td>
<td>195</td>
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<tr>
<td>Tribromoacetic Acid</td>
<td>TBAA</td>
<td>Br(_3)CO(_2)H</td>
<td>0.66</td>
<td>245</td>
</tr>
<tr>
<td>Bromochloroacetic Acid</td>
<td>BCAA</td>
<td>BrClCHCO(_2)H</td>
<td>1.39</td>
<td>193.5</td>
</tr>
<tr>
<td>Dibromochloroacetic Acid</td>
<td>DBCAA</td>
<td>Br(_2)ClCO(_2)H</td>
<td>1.09</td>
<td>NA</td>
</tr>
<tr>
<td>Dichlorobromoacetic Acid</td>
<td>DCBAA</td>
<td>Cl(_2)BrCO(_2)H</td>
<td>1.09</td>
<td>NA</td>
</tr>
</tbody>
</table>

* MCAA, DCAA, TCAA, MBAA, DBAA are collectively referred to as HAA5
Formation of HAA’s in Drinking Water

- Disinfection treatment is essential to eliminate waterborne disease-causing microorganisms
- Ozonation – bromate
- Chlorination (chlorine or chloramine)
  - Chlorite, chlorate
  - Trihalomethanes (THM) and haloacetic acids (HAAs)
- Highly regulated due to associated health issues
  - Chlorite: nervous system, affects fetal development, anemia
  - Bromate: carcinogenic
  - Chlorate: produce gastritis, blood diseases, and acute renal failure.
  - THM & HAAs: chronic exposure could increase risk of cancer
- Regulated under Safe Drinking Water Act
- EPA promulgated to the states
Drinking Water Disinfection: Treatment and Byproducts

Haloacetic acids are formed when chlorine or other disinfectants react with naturally occurring organic and inorganic matter in water.
Disinfectant Byproducts (DBPs) Regulation

- Total Trihalomethanes (TTHMs) in 1970s
- 1998 U.S. EPA Stage 1 Disinfectants/Disinfection Byproducts (D/DBP) Rule:
  - Seven new regulations, including HAA5 and bromate
  - Monitoring of HAA5 at all plants that disinfect with chlorine
  - Report total MCAA, MBAA, DCAA, DBAA, and TCAA
  - Maximum Contamination Level (MCL) = 0.060 mg/L annual average
  - MCL Goal (MCLG): DCAA should not be present; TCAA < 0.030 mg/L

- 2006 U.S. EPA Stage 2 D/DBP Rule: Reduced MCLG
  - Total HAA5 MCL < 0.060 mg/L
  - MCAA < 0.07 mg/L; TCAA < 0.02 mg/L
  - DCAA should not be present
# Summary of EPA Methods for HAAs

<table>
<thead>
<tr>
<th>Technique</th>
<th>EPA Method</th>
<th>Dionex IonPac Columns</th>
<th>MDL (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Liquid/Liquid Extraction</td>
<td>552.2</td>
<td>GC-ECD</td>
<td>Mono: 0.13–0.20</td>
</tr>
<tr>
<td></td>
<td>552.3</td>
<td></td>
<td>Di: 0.02–0.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tri: 0.03–0.10</td>
</tr>
<tr>
<td>2) Derivitization</td>
<td></td>
<td>Dionex IonPac AG24 precolumn + Dionex IonPac AS24 separation column (2 mm i.d.)</td>
<td>Mono: 0.06–0.20</td>
</tr>
<tr>
<td>3) GC-ECD</td>
<td></td>
<td></td>
<td>Di: 0.02–0.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tri: 0.04–0.09</td>
</tr>
<tr>
<td>IC-MS, IC-MS/MS</td>
<td>557</td>
<td>First dimension: Dionex IonPac AG24A precolumn + Dionex IonPac AS24A separation column (4 mm i.d.)</td>
<td>Mono: 0.17–0.45</td>
</tr>
<tr>
<td></td>
<td>Pending</td>
<td></td>
<td>Di: 0.06–0.13</td>
</tr>
<tr>
<td>302.0, 314.2</td>
<td>314.2</td>
<td></td>
<td>Tri: 0.08–0.27</td>
</tr>
<tr>
<td>2D-IC Suppressed Cond. (direct)</td>
<td></td>
<td>Second dimension: Dionex IonPac AG26 precolumn + Dionex IonPac AS26 separation column (0.4 mm i.d.)</td>
<td></td>
</tr>
</tbody>
</table>
U.S. EPA Method 552.3

• Sample Handling
  • Add 100 mg/L of granular ammonium chloride to convert residual free chlorine to combined chlorine

• Workflow
  • Acidify 40 mL of sample to pH = 0.5
  • Liquid/Liquid extraction: methyl tert-butyl ether (MTBE) or tert-amyl methyl ether (TAME)
  • Derivitization: Add acidic methanol and heat for 2 h to convert HAAs to methyl esters
  • Separate sample: Add a concentrated sodium sulfate and discard aqueous layer
  • Neutralize: Add saturated sodium bicarbonate solution
  • Analysis: GC/ECD with a run time 25–30 min
  • Total time ~ 3–4 h
U.S. EPA Method 552.3 Reported Detection Limits

**Advantages**
- Good selectivity
- Low MDLs
- Wide applicable concentration range
- 0.5–30 µg/L

**Limitations**
- Requires sample pretreatment
- Time consuming
- Labor intensive
- Subject to multiple procedural errors

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Detection Limits (µg/L)</th>
<th>% Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCAA</td>
<td>0.20</td>
<td>81</td>
</tr>
<tr>
<td>MBAA</td>
<td>0.13</td>
<td>91</td>
</tr>
<tr>
<td>DCAA</td>
<td>0.084</td>
<td>98</td>
</tr>
<tr>
<td>BCAA</td>
<td>0.029</td>
<td>103</td>
</tr>
<tr>
<td>DBAA</td>
<td>0.021</td>
<td>105</td>
</tr>
<tr>
<td>TCAA</td>
<td>0.024</td>
<td>107</td>
</tr>
<tr>
<td>BDCAA</td>
<td>0.031</td>
<td>113</td>
</tr>
<tr>
<td>CDBAA</td>
<td>0.035</td>
<td>112</td>
</tr>
<tr>
<td>TBAA</td>
<td>0.097</td>
<td>109</td>
</tr>
</tbody>
</table>
EPA 557: Determination of Bromate, Dalapon, and HAA9 by Direct Injection Using IC-MS/MS

- **IC-MS/MS**
  - Suppressed ion chromatography with MS or MS-MS detection
  - No need for liquid-liquid extraction or sample pretreatment
  - Direct injection
  - MRL ppb level
  - Matrix diversion setup
  - No need for derivatization
  - Fully automated
  - Recovery >90%
2-D IC for Haloacetic Acids

- Why another method for HAA’s?
  - Avoid sample prep
  - Lower cost alternative

- EPA 2-D IC methods
  - EPA 302.0: DETERMINATION OF BROMATE IN DRINKING WATER USING TWO-DIMENSIONAL ION CHROMATOGRAPHY WITH SUPPRESSED CONDUCTIVITY DETECTION
  - EPA 314.2: DETERMINATION OF PERCHLORATE IN DRINKING WATER USING TWO-DIMENSIONAL ION CHROMATOGRAPHY WITH SUPPRESSED CONDUCTIVITY DETECTION

- Challenge: HAA
  - Matrix
  - Multiple time cuts
  - New columns to improve selectivity
Possible Anions in Drinking Water

- **Common Anions**
  - Fluoride, chloride, nitrite, bromide, nitrate, sulfate, and phosphate
  - High ionic water (HIW, Specified in EPA Methods)
    - Chloride 350 mg/L
    - Bicarbonate 150 mg/L
    - Sulfate 250 mg/L
    - Nitrogen (Nitrate) 20 mg/L

- **Oxyhalide**
  - Chlorite, bromate, chlorate

- **Organic Acids**
  - Acetate, formate, benzoate, etc.
Matrix Elimination with 2-D Ion Chromatography

- Allows Large-Loop Injection in the First Dimension (4 mm column)
  - Possible to inject a larger loop volume than the standard approach because the capacity and selectivity of the analytical column in the first dimension dictates the recovery, and the analyte of interest is analyzed in the second dimension
- Focuses Ions of Interest in a Concentrator Column After Suppression in the First Dimension
  - Hydroxide eluent converted to DI water, providing an ideal environment for focusing or concentrating the ions of interest
- Provides Analysis in the Second Dimension Using a Smaller Column Format with a Smaller Cross-Sectional Area, Yielding Enhanced Sensitivity
  - For example, the cross-sectional area of a 1 mm column is one sixteenth the area of a 4 mm column, providing a sensitivity enhancement factor of ~16
- Provides Analysis in the Second Dimension Using a Different Chemistry
  - Enhanced selectivity
2D-IC Analysis of HAAs in a Fortified Matrix

First Dimension

Concentrator

Second Dimension

Diverted to waste

Thermo Fisher Scientific
2D-IC Analysis of HAAs in Simulated Samples Using the Dionex IonPac AS24A and AS26 Columns

**First Dimension Conditions**
- **Column:** Dionex IonPac AS24A/AG24A (4 × 250 mm)
- **Eluent:** KOH: 7 mM from 0 to 12 min, 7 to 18 mM from 12 to 42 min, step to 65 mM at 42 min
- **Eluent Source:** Dionex EGC III KOH cartridge
- **Flow Rate:** 1.0 mL/min
- **Inj. Volume:** 500 µL
- **Temperature:** 15 °C
- **Detection:** Suppressed Conductivity, Dionex ASRS 300, AutoSuppression, external water mode

**Second Dimension Conditions:**
- **Column:** Dionex IonPac AS26/AG26 Capillary (0.4 × 250 mm)
- **Eluent:** KOH: 6 mM from 0 to 50 min, step to 160 mM at 50 min, 160 mM from 50 to 57 min, step to 130 mM at 57 min
- **Eluent Source:** Dionex EGC III KOH capillary cartridge
- **Flow Rate:** 0.012 mL/min
- **Concentrator:** Dionex IonSwift MAC-200
- **Temperature:** 14 °C
- **Detection:** Suppressed Conductivity, Dionex ACES 300, AutoSuppression, external water mode

**Peaks:**
- 1. MCAA 5 µg/L 6. TCAA 5 µg/L
- 2. MBAA 5 µg/L 7. BDCAA 5 µg/L
- 3. DCAA 5 µg/L 8. CDBAA 5 µg/L
- 4. BCAA 5 µg/L 9. TBAA 5 µg/L
- 5. DBAA 5 µg/L

**Pink Trace:** 100 ppm ammonium chloride
**Blue Trace:** High Ionic Water (250 ppm Chloride, 250 ppm Sulfate, 150 ppm Bicarbonate, 20 ppm nitrate and 100 ppm ammonium chloride)
Sensitivity Improvement increased with Capillary IC

1st Dimension
Large Loop injection
Partially resolve analyte from matrix

.... Load
- Inject

Large Loop
EG
Pump
Valve 1
Suppressor
4-mm Column
Cell 1
CRD

Intermediate Step
Transfer cut volume
Trap and focus ions of interest

2nd Dimension
Separate on smaller ID column
Different Selectivity
Signal Enhancement

CRD
2-mm Column
Concentrator
Suppressor
Cell 2

--- Transfer to 2-D
--- Load Concentrator

--- Pump
--- EG

Load
Inject

Thermo Fisher
Scientific
Second Dimension separation of Haloacetic Acids on 2mm vs. 0.4 mm IonPac® AS 26

10 ppb of each HAA9 injected

2-mm

0.4-mm

Concentration: 6.00 mM
Sensitivity Improvement

- RFIC™ system uses hydroxide eluents which are suppressed to water, resulting in lower backgrounds and higher sensitivity

- Using an RFIC system in 2-D IC method
  - From 4 to 2 mm enhances sensitivity 4x
  - From 4 to 0.4 mm format enhances sensitivity 100x

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Sensitivity</th>
<th>Flow rate (mL/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First (4 mm)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Second (2 mm)</td>
<td>4</td>
<td>0.25</td>
</tr>
<tr>
<td>Second (0.4 mm)</td>
<td>100</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Thermo Scientific Dionex ICS-5000+ HPIC System

The Dionex ICS-5000+ is a universal HPIC system

High-Pressure Ion Chromatography

- Continuous operation up to 5000 psi
- High pressure capable with both standard bore and capillary systems
- Increased productivity with fast run times
- Improved separations and higher resolution with 4 µm particle columns
- Enhanced temperature control for HAAs

HPIC - High Resolution, Fast Analyses
Simplifying on a single IC: First Dimension – System 1

System 1 – Autosampler

System 1 – Standard Pump

System 1 – Detector, Suppressor

System 1 – Standard EGC

System 1 – Column oven
Simplifying on a single IC: First Dimension – System 1

System 1 – Autosampler

System 2 – Low Temperature DC, Dionex IC Cube

System 1 – Detector, Suppressor

System 1 – Column oven

System 2 – Capillary Pump

System 1 – Standard Pump

System 2 – Capillary EGC

System 1 – Standard EGC
First Dimension with Dionex IonPac AS24A Column

Columns: Dionex IonPac AG24A, AS24A, 4 mm
Flow Rate: 1.0 mL/min
Eluent: KOH: 7 mM KOH (0–12 min), 7 to 18 mM (12–32 min), Step to 65 mM at 32.1 min
Eluent Source: Dionex EGC-500 KOH cartridge
Detection: Suppressed conductivity, Dionex ASRS 300 suppressor, 4 mm, 161 mA
Inj. Volume: 500 µL
Temp.: 15 °C
Sample: 20 ppb HAA9 in
   A. HIW* B. 100 ppm NH₄Cl
Peaks:
   1. MCAA  6. TCAA
   2. MBAA  7. BDCAA
   3. DCAA  8. CDBAA
   4. BCAA  9. TBAA
   5. DBAA

* HIW = 250 ppm Cl, 250 ppm, SO₄, 150 ppm HCO₃, 10 ppm NO₃, 100 ppm NH₄Cl
**Second Dimension with Dionex IonPac AS26 Column**

Columns: Dionex IonPac AG26./AS26, 0.4 mm
Flow Rate: 0.012 mL/min
Eluent: KOH: 6 mM (0–50 min)
Step to 160 mM at 50 min
Step to 130 mM at 57 min
Eluent Source: Dionex EGC KOH capillary cartridge
Detection: Suppressed conductivity,
Thermo Scientific™ Dionex™ ACES™
Anion Capillary Electrolytic
Suppressor, 25 mA
Concentrator: Thermo Scientific™ Dionex™
IonSwift™ MAC-200 column
Temp.: 14 °C
Sample: 20 ppb HAA9 in
A. HIW* B. 100 ppm NH₄Cl
Peaks:

1. MCAA
2. MBAA
3. DCAA
4. BCAA
5. DBAA
6. TCAA
7. BDCAA
8. CDBAA
9. TBAA

* HIW = 250 ppm Cl, 250 ppm, SO₄,150 ppm HCO₃, 10 ppm NO₃, 100 ppm NH₄Cl
# 2D-IC LCMRL Results Compared to Method 557

<table>
<thead>
<tr>
<th>HAA</th>
<th>Calculated LCMRL (µg/L)</th>
<th>Method 557 (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCAA* Monochloroacetic acid</td>
<td>0.17</td>
<td>0.58</td>
</tr>
<tr>
<td>DCAA* Dichloroacetic acid</td>
<td>0.15</td>
<td>0.13</td>
</tr>
<tr>
<td>TCAA* Trichloroacetic acid</td>
<td>0.32</td>
<td>0.25</td>
</tr>
<tr>
<td>MBAA* Monobromoacetic acid</td>
<td>0.45</td>
<td>0.19</td>
</tr>
<tr>
<td>DBAA* Dibromoacetic acid</td>
<td>0.32</td>
<td>0.062</td>
</tr>
<tr>
<td>TBAA** Tribromoacetic acid</td>
<td>0.39</td>
<td>0.27</td>
</tr>
<tr>
<td>BCAA** Bromochloroacetic acid</td>
<td>0.21</td>
<td>0.16</td>
</tr>
<tr>
<td>CDBAA** Chlorodibromoacetic acid</td>
<td>0.17</td>
<td>0.080</td>
</tr>
<tr>
<td>BDCAA** Bromodichloroacetic acid</td>
<td>0.47</td>
<td>0.19</td>
</tr>
</tbody>
</table>

+ Lowest concentration method reportable level

*HAA5; **HAA9
Determinations of HAA9 in Ground Water

**First Dimension**
- **Columns:** Dionex IonPac AG24A/AS24A, 4 mm
- **Flow Rate:** 1.0 mL/min
- **Eluent:** 7 mM KOH (0–12 min), 7–18 mM (12–32 min), 65 mM (32.1 min)
- **Eluent Source:** Dionex EGC-500 KOH cartridge
- **Detection:** Suppressed conductivity, Dionex ASRS 300 suppressor, 4 mm, 161 mA
- **Inj. Volume:** 500 µL
- **Temp.:** 15 °C
- **Sample:**
  - A: Ground water
  - B: Sample A + 10 µg/L HAA9

**Second Dimension**
- **Columns:** Dionex IonPac AG26/AS26, 0.4 mm
- **Flow Rate:** 0.012 mL/min
- **Eluent:** 6 mM KOH (0–50 min), 160 mM (50 min), 130 mM (57 min)
- **Eluent Source:** Dionex EGC KOH capillary cartridge
- **Detection:** Suppressed conductivity, Dionex ACES suppressor, 25 mA
- **Concentrator:** Dionex IonSwift MAC-200 column
- **Temp.:** 14 °C
- **Peaks:**
  1. MCAA
  2. MBAA
  3. DCAA
  4. BCAA
  5. DBAA
  6. TCAA
  7. BDCAA
  8. CDBAA
  9. TBAA
Determinations of HAA9 in Surface Water

**First Dimension**
- **Columns:** Dionex IonPac AG24A, AS24A, 4 mm
- **Flow Rate:** 1.0 mL/min
- **Eluent:** 7 mM KOH (0–12 min), 7–18 mM (12–32 min), 65 mM (32.1 min)
- **Eluent Source:** Dionex EGC-500 KOH cartridge
- **Detection:** Suppressed conductivity, Dionex ASRS 300, 4 mm, 161 mA
- **Inj. Volume:** 500 µL
- **Temp.:** 15 °C
- **Sample:**
  - A: Surface water
  - B: Sample A + 10 µg/L HAA9

**Second Dimension**
- **Columns:** Dionex IonPac AG26, AS26, 0.4 mm
- **Flow Rate:** 0.012 mL/min
- **Eluent:** 6 mM KOH (0–50 min), 160 mM (50 min) 130 mM (57 min)
- **Eluent Source:** Dionex EGC KOH capillary cartridge
- **Detection:** Suppressed conductivity, Dionex ACES suppressor, 25 mA
- **Concentrator:** Dionex IonSwift MAC-200
- **Temp.:** 14 °C
- **Peaks:**
  1. MCAA
  2. MBAA
  3. DCAA
  4. BCAA
  5. DBAA
  6. TCAA
  7. BDCAA
  8. CDBAA
  9. TBAA
## Recovery Results

<table>
<thead>
<tr>
<th>HAA5</th>
<th>Spiked Levels (µg/L)</th>
<th>Surface Water</th>
<th>Drinking Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monochloroacetic acid</td>
<td>10</td>
<td>85.4%</td>
<td>107%</td>
</tr>
<tr>
<td>Dichloroacetic acid</td>
<td>10</td>
<td>104%</td>
<td>75.6%</td>
</tr>
<tr>
<td>Trichloroacetic acid</td>
<td>10</td>
<td>101%</td>
<td>82.0%</td>
</tr>
<tr>
<td>Monobromoacetic acid</td>
<td>10</td>
<td>102%</td>
<td>123%</td>
</tr>
<tr>
<td>Dibromoacetic acid</td>
<td>10</td>
<td>115%</td>
<td>120%</td>
</tr>
</tbody>
</table>
### Comparing the 2D-IC Results to EPA Method 552.3

<table>
<thead>
<tr>
<th></th>
<th>Surface Water</th>
<th>Method 552.3</th>
<th>2D-IC HAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCAA*</td>
<td>3.13 µg/L</td>
<td>3.21 µg/L</td>
<td></td>
</tr>
<tr>
<td>DCAA*</td>
<td>32.5</td>
<td>31.2</td>
<td></td>
</tr>
<tr>
<td>TCAA*</td>
<td>26.6</td>
<td>21.4</td>
<td></td>
</tr>
<tr>
<td>MBAA*</td>
<td>Not Reported</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>DBAA*</td>
<td>0.88</td>
<td>1.76</td>
<td></td>
</tr>
<tr>
<td>BCAA**</td>
<td>5.89</td>
<td>5.74</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Ground Water</th>
<th>Method 552.3</th>
<th>2D-IC HAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCAA*</td>
<td>0.33</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>DCAA*</td>
<td>1.20</td>
<td>1.43</td>
<td></td>
</tr>
<tr>
<td>TCAA*</td>
<td>0.30</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>MBAA*</td>
<td>Not Reported</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>DBAA*</td>
<td>1.75</td>
<td>1.05</td>
<td></td>
</tr>
<tr>
<td>BCAA**</td>
<td>1.67</td>
<td>1.28</td>
<td></td>
</tr>
</tbody>
</table>

*HAA5; **HAA9
Method aspects

- Sample Preservation
  - Ammonium Chloride (100 ppb) added to prevent HAA formation.
  - All standards are prepared in Ammonium Chloride.
- Laboratory Synthetic Sample Matrix
  - Contains NH$_4$Cl preservative

<table>
<thead>
<tr>
<th>Compound</th>
<th>Conc. LSSM (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate anion</td>
<td>20</td>
</tr>
<tr>
<td>Bicarbonate anion</td>
<td>150</td>
</tr>
<tr>
<td>Chloride anion</td>
<td>250</td>
</tr>
<tr>
<td>Sulfate anion</td>
<td>250</td>
</tr>
</tbody>
</table>

- Analysis batch cannot exceed 24 hrs.
- Wash cycle for concentrator after each injection
- Concentrator column concentrates approx. 15 mL of sample from the 1$^{st}$ Dimension.
- Determination of the cut window
- Calibration acceptance criteria
Conclusion

The 2D-IC method for HAAs is a viable alternative to EPA methods 552.3 and 557

- HAAs are directly determined without multiple and lengthy derivitization steps as in EPA 552.3
- This method is selective and sensitive and designed to reduce matrix interference effects
- Regulatory acceptance is pending
- Similar to other 2D-IC methods that have regulatory acceptance
- Simplified and less costly using a single system; the Dionex ICS-5000+ HPIC system with its dual system capabilities and enhanced temperature controls
Thank you!