Quantitative Determination of Disinfection Byproduct Haloacetic Acids in Drinking Water using a New Mixed-Mode column and Liquid Chromatography Tandem Mass Spectrometry Haloacetic Acids

Jack, Richard,Wang, Leo,Yang, Charles,Jiang, Guifeng,Liu, Xiaodong
Thermo Scientific, San Jose, CA

Thermo SCIENTIFIC

Overview

Purpose: To demonstrate the quantitative determination of Mono-, di-, and Trihaloacetic (MCAA, MCAA and TCAA, respectively) acids in a drinking water matrix using LC-MS/MS and a new mixed mode column.

Method: The new mixed mode column separates three haloacetic acids from interfering anions that cause signal suppression with MS detectors. It also allows the use of MS compatible eluents without the use of ion pairing agents which can also cause signal suppression. Trace level background contamination was observed in the mobile phase and a trap column was placed between gradient static mixer and autosampler to retain and separate the contaminant(s) in the mobile phase from the target analytes. A triple quadrupole mass spectrometer was operated in selected-reaction-monitoring (SRM) mode and two SRM transitions were selected for each analyte for quantitation and confirmation. Isotope-labeled internal standards were used to eliminate adverse matrix effects and ensure quantitation accuracy.

Results: Recoveries for 1 ppb spikes in a laboratory fortified matrix were within 10% RSD or better for the mono-, di-, and trihaloacetic acids.

Introduction

Haloacetic acids (HAAs) occur in drinking water during the disinfection process and have been regulated by the US EPA as HAA5. European and Asian nations are also considering regulating HAA's. Haloacetic acids have been linked to potential threats to human health thus monitoring of their presence is of critical importance to public health. Various methods have been reported for the analysis of HAAs such as GC, with derivatization; LC/MS with ion paring agents, and IC/MS. This study describes a sensitive LC-MS/MS method for direct analysis of three regulated chlorinated HAAs at trace level in drinking water without sample derivatization, concentration, or ion paring agents. This column was developed specifically for the regulated HAA's in Japan which require the following MCL in drinking water, MCAA, 2 ppb; DCAA, 40 ppb; TCAA 200 ppb.

Methods

Sample Preparation

This is a direct injection method, no sample preparation is required.

Laboratory Fortified Matrix

The following anions were added to a final concentration as shown: Cl^-, 30 mg/L; SO_4^{2-} 50mg/L, NO_3^- 50mg/L, K_2SO_4 50 mg/L; Na_2PO_4 50 mg/L ; Ascorbic acid 10mg/L). Ascorbic acid is added to tap water to remove residual chlorine.

Liquid Chromatography

HPLC : Thermo Scientific™ Dionex™ UltiMate™ 3000 RSLC system with quaternary pump and 150 µL static mixer
Analytical column: Thermo Scientific™ Acclaim™ HAA (2.1 50mm, 3µm)
Trap column: Thermo Scientific™ Trinity™ HAA (2.1 50mm, 3µm) with viper capillary
Temperature: 25ºC
Flow rate: 300 µL/min
Injection vol: 50 µL
Mobile Phase: A: Water
B: Ammonium Acetate (200 mM, pH not adjusted)
C: Acetonitrile

Gradient:

Time	%A	%B	%C
-5.0	85	5	10
0.0	85	5	10
8.0	85	5	10
12.0	15	5	80
19.0	15	5	80
19.1	0	90	10
24.9	0	90	10
25.0	85	5	10

Mass Spectrometric Conditions
System: Thermo Scientific ™ TSQ Quantum Ultra™
Interface: HESI II probe and low flow insert
Spray Voltage: 500V
VaporizerTemp.:400 ºC
Capillary Temp.: 250 ºC
Sheath Gas: 60
Aux. Gas: 10
Ion Sweep Gas: 0
Collision Gas: Argon at 0.8 mTorr
Peak width: 0.7 for Q1 and Q3
Divert Valve: 0.0 - 9.4 waste
9.4-13.5 detection
13.5 - 15.5 waste
15.5 - 19.0 detection
19.0 - 25.0 waste

Peak Width Acquisition Mode: SRM

Table 1 of the MBAA, MCAA, and TCAA with the two transitions for each analyte along with the internal standards used in this method validation

Analyte	Q1MS		Q3MS		CID	Tube Lens
MCAA	$CH_2{}^{35}ClCOO$	92.97	^{35}Cl	34.97	13	80
	$CH_2{}^{37}ClCOO$	94.97	^{37}Cl	36.97	13	80
MCAA-IS	$CH_2{}^{35}Cl{}^{13}COO$	93.98	^{35}Cl	34.97	13	80
DCAA	$CH^{35}Cl_2COO$	126.93	$CH^{35}Cl_2$	82.94	12	85
	$CH^{35}Cl{}^{37}ClCOO$	128.93	$CH^{35}Cl{}^{37}Cl$	84.94	12	85
DCAA-IS	$^{13}CH^{35}Cl_2COO$	127.94	$^{13}CH^{35}Cl_2$	83.95	12	85
TCAA	$C^{35}Cl_3COO$	160.90	$C^{35}Cl_3$	116.91	7	110
	$C^{35}Cl_2{}^{37}ClCOO$	162.89	$C^{35}Cl_2{}^{37}Cl$	118.90	7	110
TCAA-IS	$^{13}C^{35}Cl_3COO$	161.90	$^{13}C^{35}Cl_3$	117.91	7	110

Results

Separation of Matrix ions using the Acclaim HAA column

Separation of haloacetic acids from suppression causing anions is required to achieve the optimal detection limits of the haloacetic acids. Figure 1 shows the separation of anions in the high matrix sample using Corona CAD detection. The separation affords space for the haloacetic acids to be well resolved from the anions themselves. Figure 2 shows the excellent peak shapes for the mono-, di-, and Trihaloacetic acids also confirming that the HAA's do not co-elute. Note the elution times between the HAA's and the various anions in Figure 1.

FIGURE 1. Separation of the sample matrix using Corona Charged Aerosol Detection (CAD). Note the cations Sodium and Potassium elute in the void volume.

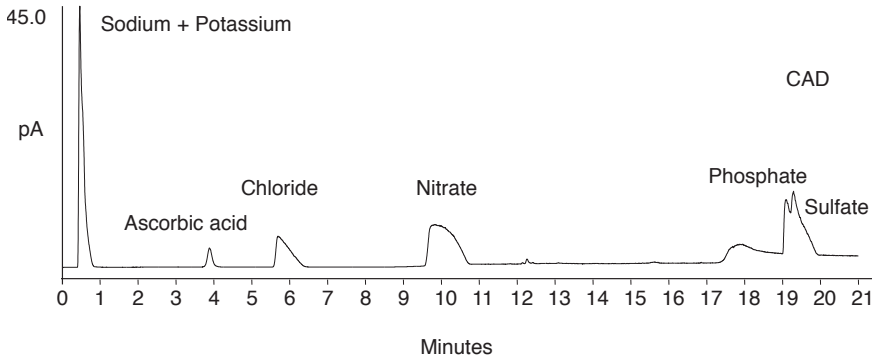
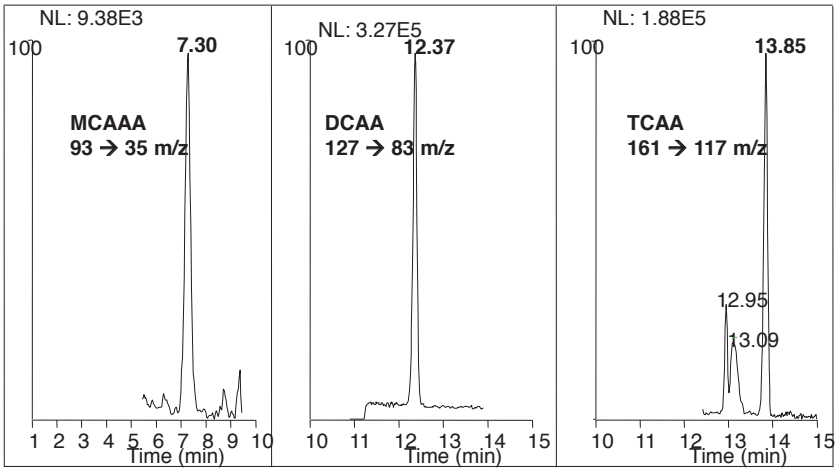


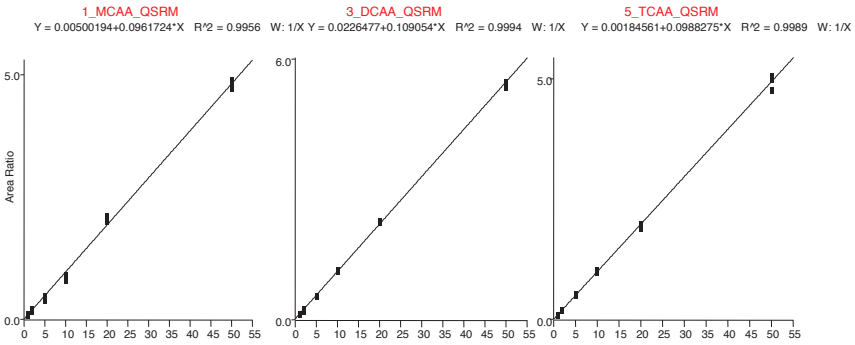
FIGURE 2. Chromatograms of 10ppb haloacetic acids in simulated matrix. Excellent peak shape is observed for each of the haloacetic acids.



Separation and Linearity

Figure 2 above shows the peak shapes for 10 ppb spikes in the simulated matrix. The peak gaussian shaped peaks suggest little, if any, co-elution of matrix ions that would cause broadening or misshapen peaks. Figure 3 below shows the linearity for the HAA's for quantification of samples. Excellent linearity is achieved over the range of quantitation.

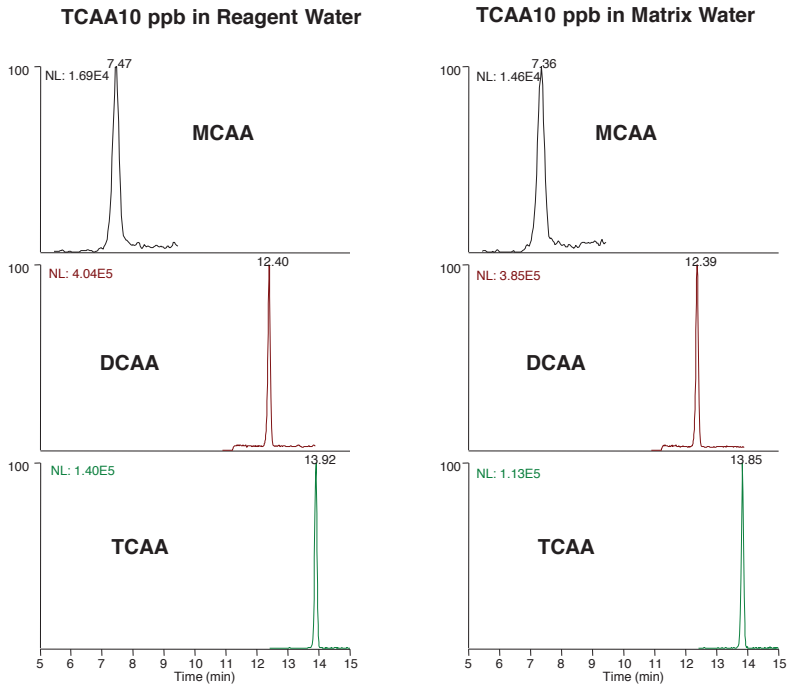
FIGURE 3. Linearity of the HAA's in matrix. This figure shows the linearity of each of the HAA's in matrix over the complete range used for calibration of the method. The concentrations are 1, 2, 5, 10, 20 and 50 ppb



Comparison of Peak shape in Reagent Water versus Matrix Water

Prior to determining our robustness and long term column stability experiments, we assessed the peak shapes and height with our prototype column in reagent water and the laboratory fortified matrix water. Note that the retention times, peak shape and peak height are similar.

FIGURE 4. Comparison of peak retention times, shape and height of Mono-, di-, and trichloroacetic acids in distilled water and laboratory fortified matrix.



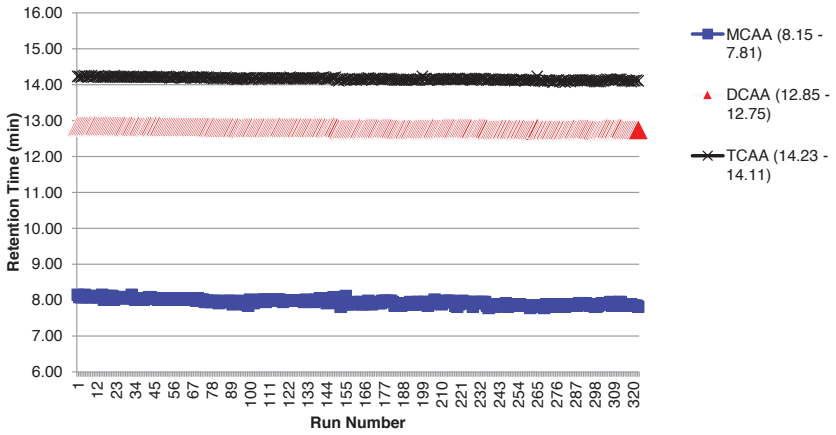
Spike Recoveries

In order to assess the accuracy and precision of this method, we performed a series of spike recovery experiments throughout the calibration range from 1 to 50 ppb. Initially we used n = 3 then performed a more robust n = 10 analysis at 2, 10 and 50 ppb. As shown in Table 2 below the % RSD recoveries for MCAA generally improved for the larger sample size over the entire range tested. The DCAA and TCAA % RSD were slightly less robust with the larger sample set. None the less the experiments overall clearly indicate that all % RSD are below 10% and below 5% in most cases. We compared the calibration using both internal and external standards.

Table 2. Spike recoveries of Mono-, Di-, and Trichloroacetic acids in a Fortified Matrix.

	MCAA			DCAA			TCAA		
Conc.	Mean	%Recovery	%RSD	Mean	%Recovery	%RSD	Mean	%Recovery	%RSD
1ppb (n=3)	1.08	108.3%	9.1%	0.99	99.1%	9.1%	0.98	98.3%	8.1%
2ppb (n=3)	2.06	102.9%	9.9%	1.98	98.9%	6.0%	1.93	96.7%	1.1%
5ppb (n=3)	4.64	92.7%	7.2%	4.91	98.2%	0.4%	5.24	104.8%	0.8%
10ppb (n=3)	8.95	89.5%	6.1%	10.26	102.6%	0.3%	10.21	102.1%	1.9%
20ppb (n=3)	21.32	106.6%	2.5%	20.50	102.5%	0.5%	19.61	98.1%	2.1%
50ppb (n=3)	49.94	99.9%	1.8%	49.36	98.7%	0.9%	50.02	100.0%	3.2%
2ppb (n=10)	1.92	95.9%	5.8%	2.08	104.0%	1.9%	2.05	102.4%	7.2%
10ppb (n=10)	8.82	88.2%	5.6%	10.18	101.8%	2.0%	10.35	103.5%	4.0%
50ppb (n=10)	48.35	96.7%	4.1%	48.70	97.4%	1.2%	49.11	98.2%	5.1%

FIGURE 5. Column stability was investigated with 325 injections in matrix samples. %RSD for MCAA, DCAA and TCAA were 1, 0.3 and 0.3%, respectively.



Conclusion

- This report demonstrates the robust performance for spike recoveries, detection limits and linearity of mono-, di-, and trichloroacetic acid in a simulated drinking water matrix without sample preparation for the Japan Drinking water regulations at 10 x below the MCL.
- The new mixed mode column shows maintains chromatographic resolution of the HAA's from matrix anions using a MS compatible eluent, without the use of an ion pairing agent.
- The chromatographic resolution using MS compatible eluents avoids the use of an ion pairing reagent, resulting in low detection limits in a simulate matrix and reasonable run time.
- Column stability studies demonstrate method robustness.

References

1. U.S. Environmental Protection Agency, Method 557.0 *Determination of Haloacetic Acids, Bromate and Dalapon in Drinking Water by Ion Chromatography Electrospray ionization Tandem Mass Spectrometry. (IC-ESI-MS/MS). Rev 1.0, 2009.*

2. U.S. Environmental Protection Agency, Method 552.2, *Determination of Haloacetic Acids and Dalapon in Drinking Water by Liquid-Liquid Extraction, Derivatization, and Gas Chromatography with Electron Capture Detection, Rev 1.0, 1995.*

3. U.S. Environmental Protection Agency, Method 552.3, *Determination of Haloacetic Acids and Dalapon in Drinking Water Liquid-Liquid Microextraction, Derivatization, and Gas Chromatography with Electron Capture Detection, Rev 1.0, 2003.*

4. Slingsby, R.; Saini, C.; Pohl, C.; Jack, R. *The Measurement of Haloacetic Acids in Drinking Water Using IC-MS/MS–Method Performance,* Presented at the Pittsburgh Conference, New Orleans, LA, March 2008.

www.thermofisher.com

Africa-Other +27 11 570 1840
Australia +61 3 9757 4300
Austria +43 1 333 50 34 0
Belgium +32 53 73 42 41
Canada +1 800 530 8447
China +86 10 8419 3588
Denmark +45 70 23 62 60
Europe-Other +43 1 333 50 34 0
Finland/Norway/Sweden +46 8 556 468 00
France +33 1 60 92 48 00
Germany +49 6103 408 1014
India +91 22 6742 9434
Italy +39 02 950 591
Japan +81 45 453 9100
Latin America +1 561 688 8700
Middle East +43 1 333 50 34 0
Netherlands +31 76 579 55 55
New Zealand +64 9 980 6700
Russia/CIS +43 1 333 50 34 0
South Africa +27 11 570 1840
Spain +34 914 845 965
Switzerland +41 61 716 77 00
UK +44 1442 233555
USA +1 800 532 4752

Thermo SCIENTIFIC

Part of Thermo Fisher Scientific

ASMS13_W034_RJack_E 07/16S