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ABSTRACT

LC-MS/MS quantification methods are commonly used to determine trace levels of organic compounds. Although the development of stationary phases increased significantly during the last decades, even highly polar reversed phases (RPs) lack sufficient retention for very polar compounds, or they fail for charged organics. Hydrophilic interaction liquid chromatography (HILIC) became important for analyzing very polar and/or ionic organic compounds using standard LC-MS/MS devices. The development of HILIC methods are often quite laborious, however, the column equilibration time is significantly increased compared to classical LC. For this reason, the total HILIC-method runtime is much longer than a conventional RP-LC methods. Separation using ion chromatography (IC) and subsequent MS/MS detection is an innovative alternative approach that combines the fast elution and flexibility of the IC system with the excellent resolution and high sensitivity of the MS/MS detector. In this poster, we present a fast and sensitive IC separation method using Metrohm's 940 Professional IC Vario ONE/SeS/PP/HPG instrument coupled to a QTRAP 6500+ system from SCIEX to quantify important halogenated acetic acids (HAAs).

INTRODUCTION

Disinfection processes for drinking water have been identified as a major source of mono- and/or multiple chlorinated and brominated halogenated acetic acids, or various combination of the 2, in water [1]. In this context, HAAs are occurring as undesirable byproducts that are persistent and pose a risk to health [2]. After assessing the health risk of using disinfection products versus the impact of not using those disinfection products, the World Health Organization (WHO) clearly concluded that the health risk posed by using disinfection products is significantly lower than not using these products [3]. The major sources of fluorinated acetic acids are the degradation products of hydrofluorocarbons, formerly widely used as refrigerants [4], as the thermolysis products of fluoropolymers, such as Teflon [5]. To ensure safety and health, the EU Drinking Water Directive was recently updated and finally adopted by the EU Parliament on December 15, 2020. The directive took effective on January 12th, 2021, and now requires the monitoring of 5 HAAs when water intended for human consumption is disinfected using methods that are suitable to generate HAAs. The total sum of HAAs in the representative sample must not exceed 60 µg/L [6].

MATERIALS AND METHODS

Sample preparation:

The sample was injected directly into the IC system. No further sample preparation was required. The Metrohm Inline Ultrafiltration unit can be used to automatically remove particles from the water samples, so filtration is not necessary.

IC conditions:

The Metrohm 940 Professional IC Vario One SeS/PP/HPG instrument, equipped with a Metrosep A Supp 7 - 250/4.0 separation column was used to separate the analytes. The separation was performed using a flow rate of 0.8 mL/min and a gradient, as shown in Table 1. Eluent A consisted of 50 mM NaOH, 7 mM sodium carbonate and 15 Vol. % acetonitrile. Eluent B was ultrapure water. To lower the background noise and signal suppression due to salts/cations, the Metrohm Suppressor Module (MSM) was used. For injection, the 858 Professional Sample Processor equipped with MiPT was used, allowing fast and accurate sample introduction as well as the possibility of automatic internal calibration. All measurements shown in this poster were done using an injection volume of 100 µL.

	Zeit [min]	Eluent A [%]	Eluent B [%]	Kurve	Fluss
1	Start	20	80		0,8
2	2,3	20	80	Linear	0,8
3	4,0	65	35	Linear	0,8
4	6,7	95	5	Linear	0,8
5	23,3	95	5	Linear	0,8
6	23,7	20	80	Linear	0,8
7	24,9	20	80	Linear	0,8

Table 1. Used gradient table to quantify HAAs.

MS/MS conditions:

A QTRAP 6500+ system in negative ionization MRM mode was used. Dependent on the fragmentation capabilities of each HAA (Table 2), 2 traces, a quantifier and a qualifier transition for each HAA at a dwell time of 50 ms were acquired. In addition to the different HAAs, bromate and dalapon can also be determined with this setup (Table 3).

The parameters used on IonDrive Turbo V ion source are listed in Table 4.

Analyte	Acronym
Chloroacetic acid	MCAA
Dichloroacetic acid	DCAA
Trichloroacetic acid	TCAA
Dichloropropionic acid	Dalapon
Bromoacetic acid	MBAA
Dibromoacetic acid	DBAA
Tribromoacetic acid	TBAA
Bromochloroacetic acid	BCAA
Bromodichloroacetic acid	BDCAA
Dibromochloroacetic acid	DBCAA
Trifluoroacetic acid	TFA
Fluoroacetic acid	MFA*
Difluoroacetic acid	DFA*
Iodoacetic acid	MIAA*
Bromate	
Chloride**	* no standard available
Nitrate**	** no standard available; acquired in samples only
Sulfate***	*** possible on principle; suffers somewhat from very high background noise

Name	Q1	Q3	DP	CE
Chloride-1	35	35	-80	-30
Chloride-2	37	37	-80	-30
MCAA-1	93	35	-30	-18
MCAA-2	95	37	-30	-18
TFA	113	69	-55	-18
TCAA-2	117	35	-50	-14
TCAA-3	119	37	-50	-14
DCAA-1	127	83	-30	-14
Bromate-1	127	111	-50	-30
DCAA-2	129	85	-30	-14
Bromate-2	129	113	-50	-30
MBAA-1	137	79	-30	-15
MBAA-2	139	81	-30	-15
Dalapon-1	141	97	-20	-12
Dalapon-2	143	99	-20	-12
TCAA-1	160.9	116.9	-20	-10
BDCAA-2	161	79	-30	-12
BDCAA-1	163	81	-30	-12
BCAA-2	170.9	127	-30	-13
BCAA-1	172.9	129	-30	-13
MIAA	185	127	-30	-15
CDBAA-1	207	79	-30	-12
CDBAA-2	209	81	-30	-12
DBAA-2	214.9	171	-30	-12
DBAA-1	216.9	173	-30	-12
TBAA-1	250.9	78.9	-40	-23
TBAA-2	252.9	80.9	-40	-23

Table 3. MRM transitions for acquired HAAs, sorted by Q1 mass and the declustering potential (DP) and collision energy (CE) used.

Table 2. HAAs acquired using the IC-MS/MS method.

Source parameter	Value
CAD	9 psi
CUR	35 psi
GS1	55 psi
GS2	70 psi
IS	4500 V
TEM	300°C

Table 4. Gas, temperature and ionization voltage used for IC-HAAs analysis.

RESULTS

IC-MS/MS is a robust, sensitive and easy-to-use analytical technique for separating and quantifying ionic compounds. In combination with its reproducibility, dynamic range and, highly important, latest suppressor technologies, IC separation coupled to high-end MS/MS technology provides fast and quantitative results on charged and/or ionic compounds. The overall installation process of coupling of Metrohm 940 Professional IC Vario One SeS/PP/HPG instrument and the QTRAP 6500+ system, including software connection took less than 2 hours, showing that the technique is straightforward and easy to use. The MRM transitions were taken from the SCIEX database. Only the source parameters were optimized. The chromatogram in Figure 1 shows the separation power of a 25-min gradient. Using MiPT as the injection technique enabled fast (out of 1 standard) and accurate automated calibration. Thus, the manual laboratory workload can be reduced to a minimum while increasing the accuracy and reliability of the analysis. The standard concentration started at 0.01 µg/L, following with 0.02, 0.05, 0.1, 0.2, 0.5, etc. up to 200 µg/L. The result tables started with a lower limit of detection (LLOD) for each compound. Table 5 contains a summary of the LLODs for all quantitatively measured HAAs. The calibration curve for TCAA (Figure 2, bottom) is shown as an example. The r^2 value for all HAAs is typically 0.998 and better, which reflects the good linearity for the quantitative analysis of at least 4 orders of magnitude. Measurements injecting a blank, at LLOD and the lower limit of quantification (LLOQ), are displayed in Figure 3. Water samples taken from tap water and from bottled water are analyzed directly. Figure 4 shows both samples additionally spiked at 2 µg/mL and quantitatively analyzed.

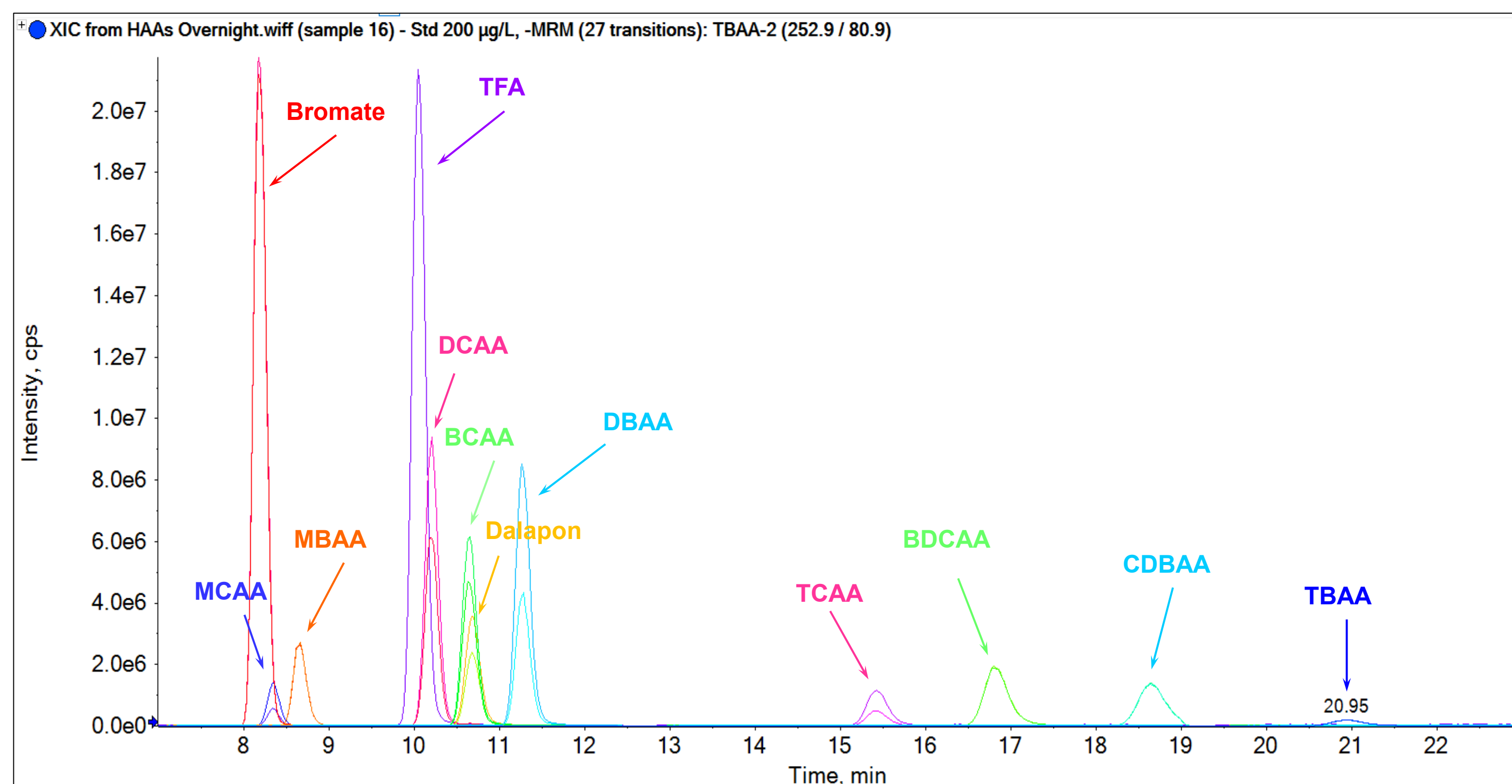


Figure 1. Extracted ion chromatograms (XICs) of quantitatively acquired HAAs.

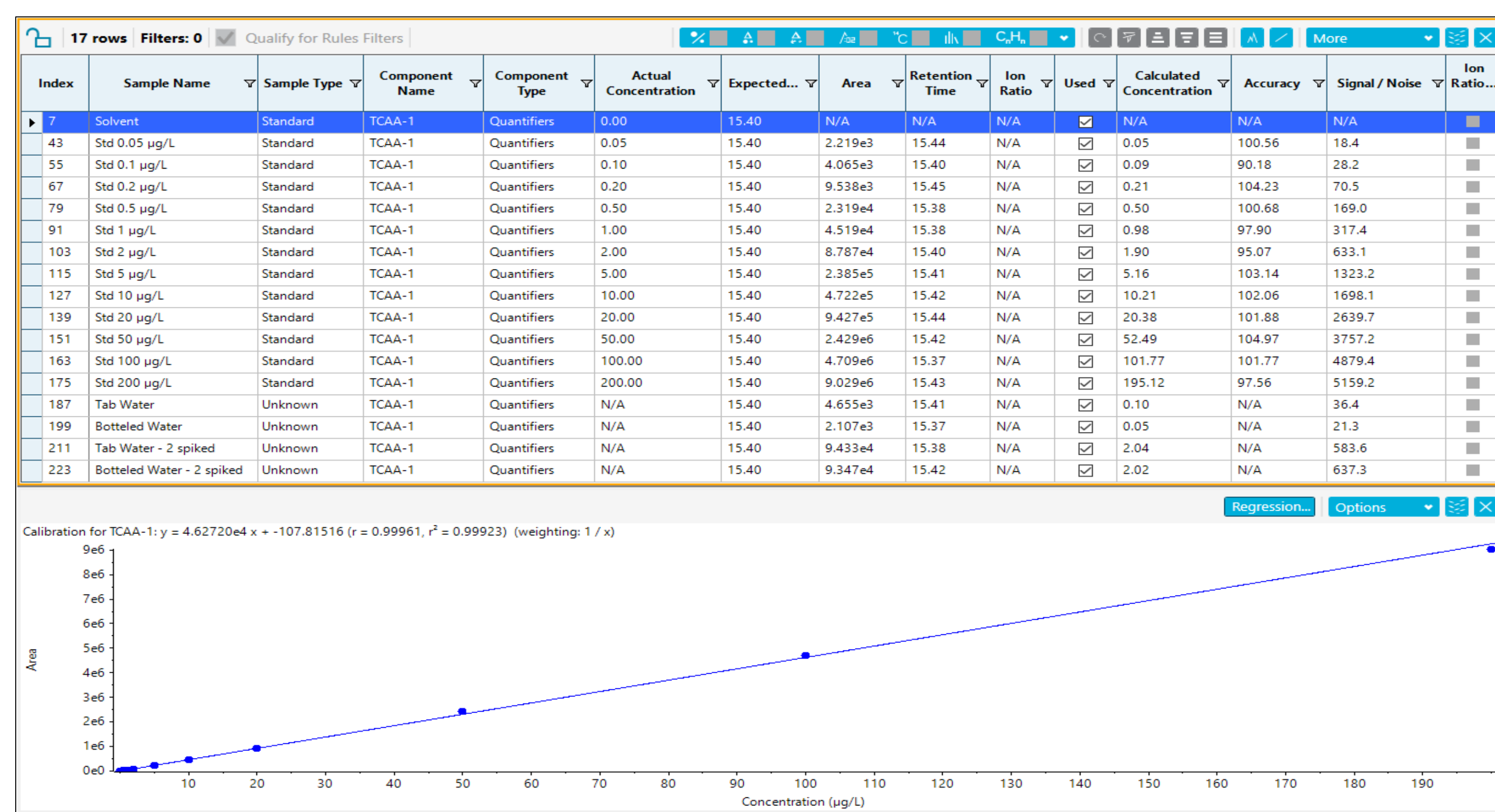


Figure 2. Result table for TCAA with dynamic range of quantification.

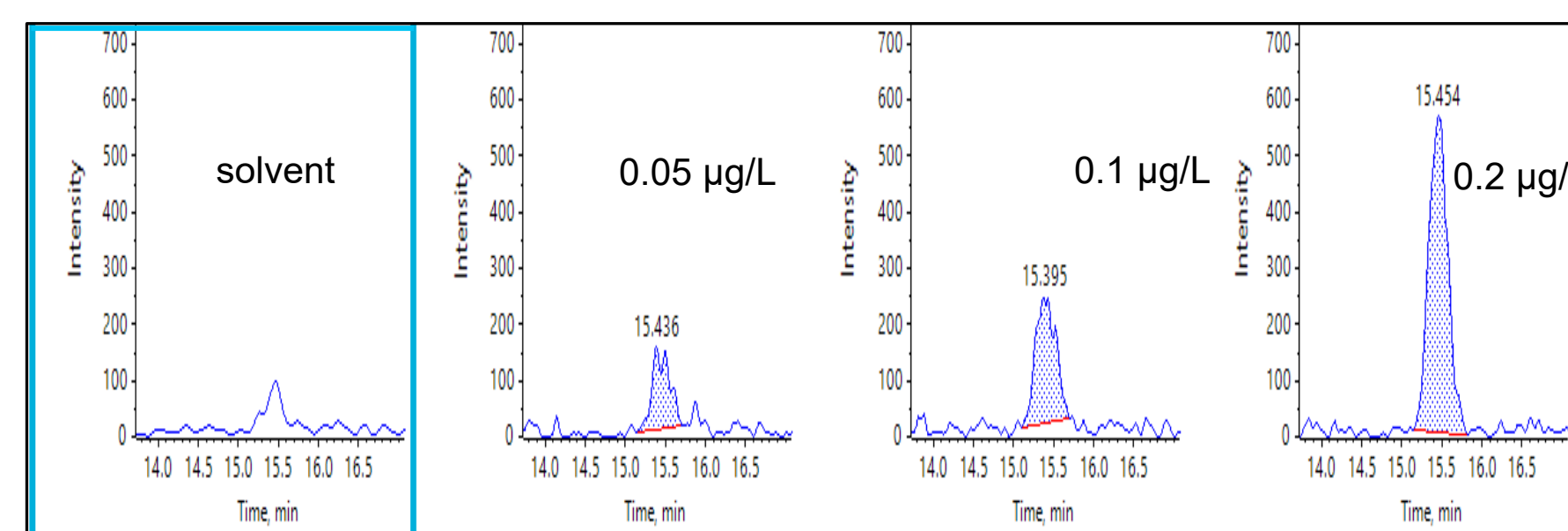


Figure 3. TCAA in blank (left), at LLOD (mid-left), LLOQ (mid-right) and twice LLOQ (right).

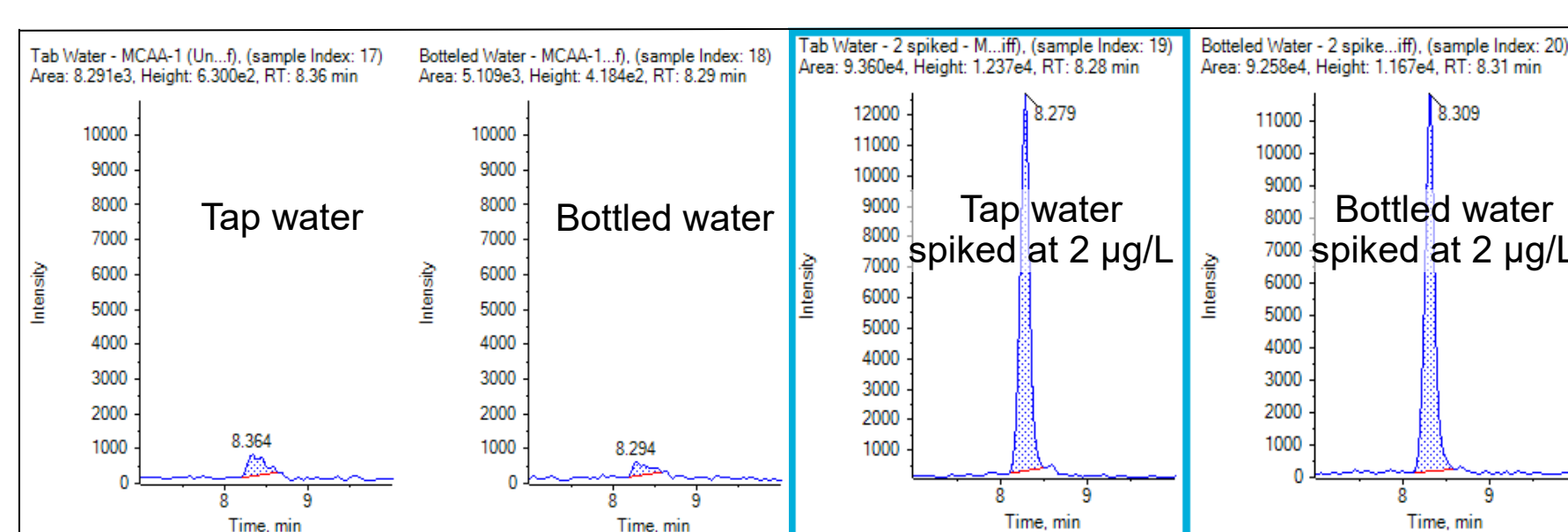


Figure 4. Quantitative detection of MCAA in tap and bottled water (left) and both spiked at 2 µg/mL (right).

HAA	LLOD [µg/L]
MCAA	0.02
DCAA	0.05
TCAA	0.05
Dalapon	0.2
MBAA	0.02
DBAA	0.2
TBAA	0.2
BCAA	0.2
BDCAA	0.05
DBCAA	0.02
TFA	0.2
Bromate	0.02

Table 5. LLODs for acquired HAAs.

CONCLUSIONS

A fast, robust and reliable IC-MS/MS method for the detection of HAAs and other ionic analytes was presented using high-end MS/MS technology from SCIEX (the QTRAP 6500+ system) coupled to IC from Metrohm (the 940 Professional IC Vario One SeS/PP/HPG instrument). This analytical setup is able to identify and quantify the presence of HAAs at trace levels with LLODs between 0.02 µg/mL and 0.2 µg/L on a single HAA. This capability easily fulfills the sensitivity requirements specified in EU Drinking Water Directive, which specifies a maximum residue level (MRL) of 60 mg/mL for the sum of monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid and dibromoacetic acid present in the representative sample.

The inclusion of automated Metrohm Inline Sample Preparation (MISP) allows a variety of sample types to be readily analyzed without the need for extensive manual laboratory work. Automation of sample preparation steps in addition to the analysis results in more reliable and reproducible data.

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TRADEMARKS/LICENSES

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