

Determination of Perchlorate in Drinking Water Using a Reagent-Free Ion Chromatography System

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Key Words

U.S. EPA Method 314.0, Water Analysis, Dionex IonPac AS16 Column, Dionex AERS 500 Suppressor

Goal

Demonstrate an updated method for the determination of perchlorate in environmental samples using U.S. EPA Method 314.0 with an improved suppressor.

Introduction

Perchlorate (ClO_4^-), an environmental contaminant, is found in drinking, ground, and surface waters due to improper use and release of perchlorate salt-containing materials.¹ Perchlorate is mainly released from perchlorate salts like ammonium perchlorate widely used in propellant for rocket, fireworks, and other aerospace materials. Due to its size similarity with iodide, perchlorate can be taken up by the mammalian thyroid gland in place of iodide. Perchlorate is very persistent in the environment because the activation energy associated with its reduction is very high. At high enough concentrations, perchlorate is known to inhibit thyroid gland function and affect normal growth and development.² Hence, in 1998 the U.S. EPA's Office of Groundwater and Drinking Water placed this anion on its Contaminant Candidate List (CCL) for drinking water. Some states have set individual action levels even though the U.S. EPA has currently not established any enforceable health regulations for perchlorate in drinking water or related matrices. For example, the California Department of Public Health (CDPH) has set a maximum contaminant level (MCL) of 6 $\mu\text{g/L}$ perchlorate.³ If concentrations are detected above this level, the CDPH recommends that utilities remove the drinking water source from service for proper treatment.



The previous Dionex (now Thermo Scientific) Application Update 148 (AU148) describes a method for perchlorate determination in drinking water with a Thermo Scientific™ Dionex™ IonPac™ AS16 4 mm column and suppressed conductivity detection with a Thermo Scientific™ Dionex™ ASRS™ ULTRA II suppressor operating in external water mode.⁴ The method described in AU148 is based on U.S. EPA Method 314.0 for perchlorate determination in drinking water. U.S. EPA Method 314.0 allows using an alternate suppressor as long as comparable conductivity detection limits can be achieved and adequate baseline stability is attained as measured by a combined baseline drift/noise of no more than 5 nS per minute over background conductivity (Section 6.1.3). This Application Update updates the method with an improved suppressor, the Thermo Scientific™ Dionex™ AERS™ 500 suppressor, and small modifications to the chromatographic conditions. The Dionex AERS 500 suppressor is a superior suppressor to the Dionex ULTRA II suppressor as it provides high capacity, low noise, high backpressure resilience, and fast startup. Moreover, the Dionex AERS 500 suppressor minimizes peak dispersion and improves peak efficiency particularly when coupled with 4 and 2 mm columns.

This Application Update uses an integrated ion chromatography system with a 4 mm Dionex IonPac AS16 column, a Thermo Scientific Dionex EGC III KOH cartridge, and suppressed conductivity detection with a Dionex AERS 500 suppressor operated in external water mode to determine perchlorate in drinking water. This document evaluates and describes the linear range and initial demonstration of capability (Section 9.2). Initial demonstration of capability includes determination of method accuracy (Section 9.2.3), precision (Section 9.2.4), detection limit (MDL) (Section 9.2.6), and matrix conductivity threshold (MCT) (Section 9.2.8). This document also describes recovery of perchlorate in typical field samples as prescribed in U.S. EPA Method 314.0, Section 9.4.

Equipment

- A Thermo Scientific™ Dionex™ ICS-2100 Reagent-Free™ Ion Chromatography (RFIC™) system* was used in this work. The Dionex ICS-2100 system is an integrated ion chromatograph that includes:
 - Dual piston pump
 - Eluent Generator
 - Column Heater
 - Pump Degas
 - Dionex EG III KOH Cartridge (P/N 074532)
 - Thermo Scientific Dionex CR-ATC Continuously Regenerated Anion Trap Column (P/N 060477)
- Thermo Scientific Dionex AS-AP Autosampler** or Dionex AS-DV Autosampler with 1 mL injection loop
- Thermo Scientific™ Autoselect™ Polyvial™ 10 mL AS-AP Autosampler Vials with caps and septa (P/N 055058)
- Thermo Scientific™ Nalgene™ 2 µm Syringe Filters (P/N 194-2520)
- Thermo Scientific™ Dionex™ Chromeleon™ Chromatography Data System 7.2 Workstation
- Conductivity Meter (Thermo Scientific™ Orion™ (Model 105))
- Thermo Scientific AS-DV Autosampler vials (P/N 038808) and filters (P/N 039528)
- Nalgene Rapid-Flow 0.2 µm filter units, 1000 mL, nylon membrane, 90 mm diameter (Thermo Scientific P/N 164-0020)
- Nalgene Rapid-Flow 0.2 µm filter syringe filter units, polyethersulfonate membrane, 13 mm diameter (Thermo Scientific P/N 180-1320)

This method can also be run on a Thermo Scientific Dionex ICS-5000 system.

**The Dionex AS-AP autosampler was used for the data presented here.

Reagent and Standards

- Deionized (DI) Water, Type I reagent grade, 18 MΩ-cm resistance or better
- Sodium Perchlorate (NaClO₄) (Sigma, Item No 410241)
- Sodium Chloride (NaCl) (J. T. Baker, Item No 4058-05)
- Sodium Sulfate (Na₂SO₄) (Mallinckrodt, Item No 8024)
- Sodium Carbonate, Monohydrate (Na₂CO₃•H₂O) (Fisher Scientific, Item No S262-3)

Conditions

Column:	Dionex IonPac AS16 4 mm Analytical, 4 x 250 mm (P/N 055376) Dionex IonPac AG16 4 mm Guard, 4 x 50 mm (P/N 055377)
Eluent:	50 mM potassium hydroxide (KOH)
Eluent Source:	Dionex EGC III KOH cartridge (P/N 074532)
Flow Rate:	1.2 mL/min
Background Conductance:	<1 µS
Noise:	~1–2 nS/min peak-to-valley
Run Time:	15 min
Injection Volume:	1000 µL in Push-Full mode followed by 2000 µL DI water wash after each injection
Column Temperature:	30 °C
Cell Temperature:	35 °C
Detection Mode:	Suppressed Conductivity with an Dionex AERS 500 suppressor, 4 mm (P/N 082540) in the external water mode setup

Solutions, Reagents, and System Preparation

Perchlorate Standard Stock Solution

Dissolve 0.1231 g of sodium perchlorate in DI water in 125 mL polypropylene bottles. Adjust the volume to 100 mL to make a 1000 mg/L standard solution. This stock standard is stable for at least a month at 4 °C.

Working Standard Solutions

First, dilute the appropriate volume of the 1000 mg/L stock standard with DI water in a 125 mL polypropylene bottle to make a 5 mg/L secondary stock solution. The secondary stock solution is further diluted to make a 200 µg/L working stock solution. In this application, calibration standards were prepared at 1, 2, 5, 10, 25, and 50 µg/L perchlorate by appropriately diluting the working stock solution. Each calibration standard injection was analyzed in triplicate.

Mixed Common Anion Stock Solutions (U.S. EPA Method 314.0, Section 7.4.1)

Prepare 25 mg/mL (25,000 mg/L) each of chloride, sulfate, and carbonate in 125 mL polypropylene bottles as follows. Dissolve 4.1213 g of sodium chloride in DI water and dilute to 100 mL. Dissolve 3.6965 g of sodium sulfate in DI water and dilute to 100 mL. Dissolve 5.1658 g of sodium carbonate monohydrate (4.416 g of sodium carbonate) in DI water and dilute to 100 mL. These solutions were used to prepare 50, 100, 200, 400, 600, 800, and 1000 mg/L (ppm) solutions of mixed anion (MA) standards of chloride, sulfate, and carbonate (MA(50), MA(100), MA(200), MA(400), MA(600), MA(800), and MA(1000), respectively). These standards were used to determine the MCT (Matrix Conductivity Threshold) (U.S. EPA Method 314.0, Section 9.2.8).

System Preparation and Setup

Install a Dionex EGC III KOH cartridge (P/N 074532). Install backpressure tubing in place of the column set to produce a total system pressure between 2000 and 2500 psi at a flow rate of 1 mL/min. Condition the cartridge as directed in the *Dionex EGC III Cartridge Quickstart Guide* (Document No. 031909-04) by setting the KOH concentration to 50 mM at 1 mL/min for 45 min. After completing the cartridge conditioning process, disconnect the backpressure tubing that was temporarily installed in place of the column set. Install a Dionex CR-ATC cartridge between the Dionex EGC III KOH cartridge and Dionex EGC degas. For more information on installing the Dionex CR-ATC cartridge, consult the *Dionex EGC III Cartridge Product Manual* (Document No 065018-05).

Install and configure the Dionex AS-AP or AS-DV autosampler. For the Dionex AS-AP autosampler, precision and accuracy of the autosampler will vary depending on the injection mode. The most accurate and precise injections are made with a calibrated sample loop, flushed with about five times the loop volume. The largest full-loop injection possible with the Dionex AS-AP autosampler is 7500 μ L. Install a 5 mL sample syringe and set the syringe speed to 40 μ L/s to make faster large-loop injections. Enter the correct "Sample Loop Size" and "Sample Syringe Volume" in the Dionex AS-AP Plumbing Configuration Screen. Refer to the *Autoselect AS-AP Autosampler Operator's Manual* (Document No. 065361) for details. The results reported here were obtained in the Push-Full mode (a full-loop injection mode).

Install 4 mm Dionex IonPac AS16 analytical and guard columns in the column oven. Use 0.10 inch diameter (black) tubing for making all the post-inject valve connections, i.e. from inject valve to the columns, then to the suppressor, and finally to the detector cell. Make sure the system pressure is 2300 \pm 200 psi at the target eluent concentration and flow rate to allow the degas assembly to effectively remove electrolysis gases from the eluent. If necessary, install additional backpressure tubing between the degas assembly and the injection valve to adjust the system pressure to 2100–2500 psi. Do not allow the pressure to reach 3000 psi. Therefore, monitor the pressure periodically because pressure can gradually rise over time. To reduce pressure, trim the backpressure tubing.

The Dionex AERS 500 suppressor does not require any *Quick Start* using acid regenerants, and the suppressor can be installed after hydration with DI water. Configure the suppressor for external water mode according to the directions provided in the *Dionex AERS 500 Operator's Manual* (Document No. 031956-09). The storage solution of the Dionex IonPac AS16 column is 35 mM NaOH; equilibrate the column with 50 mM KOH eluent at 1.2 mL/min for approximately 60 min, then analyze a system blank of DI water. An equilibrated system has a background signal of less than 1 μ S and peak-to-peak noise of less than 1 nS. No peaks should elute within the same retention time window as perchlorate. Inject a 25 μ g/L perchlorate standard. The column is equilibrated when two consecutive injections of the standard produce the same retention time for perchlorate.

Methods

Conductivity Meter Calibration

Prior to conducting the MCT study, measure the conductance of the samples with a calibrated conductivity meter that has a minimum measuring range of 1–10,000 μ S/cm. Verify the conductivity meter calibration by measuring the conductance of a commercially available reference solution or a prepared 745 mg/L KCl standard (U.S. EPA Method 314.0, Section 7.5) with a conductance of 1410 μ S/cm at 25 $^{\circ}$ C. The conductivity meter must yield a value between 1380 and 1440 μ S/cm to be considered calibrated.

MCT Study

Section 9.2.8 of U.S. EPA Method 314.0 describes MCT as "an individual laboratory defined value" determined by preparing a series of sequentially increasing concentrations of chloride, sulfate, and carbonate fortified with a constant perchlorate concentration. Deionized water fortified with a recommended perchlorate concentration of 25 μ g/L (LFB) must be initially analyzed and followed by a series of increasing anionic solutions of chloride, sulfate, and carbonate, each containing 25 μ g/L perchlorate. The recommended 25 μ g/L perchlorate assumes that the MRL has been set between 3 μ g/L and 5 μ g/L. However, if an MRL of 1 μ g/L is required, then the MCT should be determined at a perchlorate concentration of 5 μ g/L.

We determined the MCT using 25 µg/L perchlorate. To determine the MCT with 25 µg/L perchlorate, a standard is prepared in DI water and injected in triplicate. Next, standards containing MA(50), MA(100), MA(200), MA(400), MA(600), MA(800), and MA(1000) are prepared by adding 0.2, 0.4, 0.8, 1.6, 2.4, 3.2, and 4 mL of each common anion from the stock solution (see the section *Mixed Common Anion Stock Solutions*) to separate 125 mL polypropylene bottles. Then, 2.5 mL of perchlorate is added from a 1 mg/L secondary stock dilution standard to each MA solution and each standard is diluted to a final volume of 100 mL. A calibrated conductivity meter measures and records the conductance for each of these prepared solutions. Section 9.2.8.5 states that the MA(400) solution “should display a conductance of between 3200 µS/cm and 3700 µS/cm.” After analyzing each solution, the peak area to height ratio (A/H) along with quantified perchlorate concentration are recorded. The A/H values are used to calculate the A/H ratio percent difference ($P/D_{A/H}$) between average A/H ratio of (A/H_{LFB}) and the average A/H ratios for each mixed anion solutions (A/H_{MA}) using the equation provided in Section 9.2.8.8. The MCT is the matrix conductance where the $P/D_{A/H}$ exceeds 20%. As mentioned in Sections 9.2.8.9 and 9.2.8.10, there are two ways to calculate MCT using these data. The MCT can be calculated using linear regression by plotting $P/D_{A/H}$ (as independent variable, x) and conductance (as dependent variable, y). Alternatively, instead of performing regression analysis, MCT can be set at the conductance level of the highest mixed anion solution that yielded a $P/D_{A/H}$ value below 20% threshold.

Field Sample Preparation

Compare the sample conductivity to the MCT previously determined in your laboratory (MCT determination is described above), as explained in U.S. EPA Method 314.0, Section 11. Filter all samples with a 0.2 µm syringe filter. Use a hydrophilic polypropylene or polyethersulfonate (PES) filter; such as Thermo Scientific™ Nalgene™ 0.2 µm PES syringe filters. Do not use a polyvinylidene fluoride (PVDF) filter. Discard the first 300 µL of the filtrate and filter the remainder into a clean, plastic autosampler vial. Qualify filters by analyzing a DI water blank and a 10 µg/L perchlorate standard that has been passed through the filter. The blank should be free of peaks within the retention time window of perchlorate and the recovery of the 10 µg/L standard should fall within 80–120%.

Samples that exceed the MCT can often be analyzed after an appropriate dilution followed by filtration with a 0.2 µm filter. U.S. EPA Method 314.0, Section 11.1.3 explains how to determine a sample’s dilution factor based on the MCT. For diluted samples, the minimum reporting level (MRL) must be raised by a proportion equivalent to the dilution.

If sample dilution does not yield the desired result or to avoid diluting samples, the concentration of the matrix ions can be reduced by treating the sample with Thermo Scientific™ Dionex™ OnGuard™ cartridges. This procedure is explained in further detail in U.S. EPA Method 314.0, Section 11.1.4 and in Dionex (now part of Thermo Scientific) Application Update 145.⁵ In this application, no pretreatment or dilution was required for the samples analyzed.

Results and Discussion

U.S. EPA Method 314.0 specifies the use of a Dionex IonPac AS16 4 mm column with an eluent of 50 mM NaOH at a flow rate 1.5 mL/min, followed by suppressed conductivity detection with a Dionex ASRS ULTRA suppressor operated in the external water mode and a 1000 µL large-loop injection. Section 9.4.3 states that, “In recognition of the rapid advances occurring in chromatography, the analyst is permitted certain options, such as the use of different columns (which meet the criteria in Section 6.1.2.2), injection volumes, and/or eluents, to improve the separations or lower the cost of measurements.” Therefore, a different eluent concentration, column, flow rate, and suppressor may be used for EPA Method 314.0, provided that the quality control parameters are met. Section 6.1.3 of the method further states that “An equivalent suppressor device may be utilized provided that comparable conductivity detection limits are achieved and adequate baseline stability is attained as measured by a combined baseline drift/noise of no more than 5 nS per minute over the background.” We replaced the Dionex ASRS ULTRA II suppressor used in the original AU148 with a Dionex AERS 500 suppressor. The Dionex AERS 500 suppressor provides lower background noise of 2 nS/min or less, and therefore improves the detection limits for perchlorate. In addition, the KOH concentration was reduced from 65 mM to 50 mM, but the flow rate was kept at 1.2 mL/min, as specified in the original Dionex (now part of Thermo Scientific) AU148.

The system was calibrated by injecting one blank and at least five standards to cover 1.5 orders of magnitude concentration range. Section 10.2.2 of the EPA method states that the linear calibration range “should not extend over more than two orders of magnitude in concentration.” The calibration curve is linear over 1.5 orders of magnitude with a coefficient of determination value of 0.999, based on data from triplicate injections of 1, 2, 5, 10, 25, and 50 µg/L perchlorate standards. Figure 1 shows a chromatogram of a 1 µg/L perchlorate standard using the conditions described in this application update.

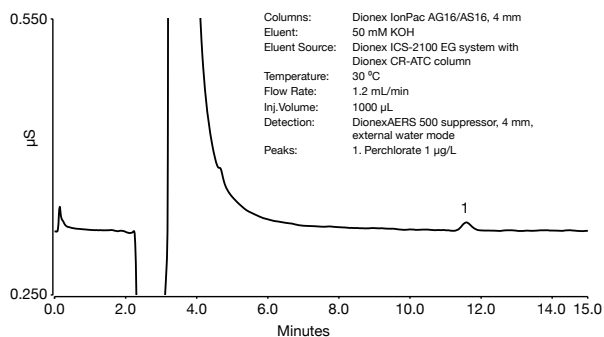


Figure 1. Determination of 1 µg/L perchlorate in DI water.

U.S. EPA Method 314.0 requires an initial demonstration of capability (IDC), as described in Section 9.2. The IDC is used to characterize the instrument and laboratory performance prior to performing any sample analyses by the method. This performance is determined by demonstrating an initial demonstration of accuracy (IDA) and an initial demonstration of precision (IDP) by performing seven replicate injections of a laboratory fortified blank (LFB) fortified with 25 µg/L perchlorate. To meet the requirements of the IDA and IDP, the recovery must be within $\pm 10\%$ and the percent RSD must be less than 10%, respectively. As shown in Table 1, our results for the IDA and IDP met the requirements described in Sections 9.2.3 and 9.2.4. As part of the IDC, a quality control standard (QCS) of 25 µg/L perchlorate was analyzed which resulted in a recovery of 96.1%, as shown in Table 2. This recovery meets the criteria outlined in Section 9.2.5 of the method that states the recovery of the QCS must be within $\pm 10\%$ of the stated value. We determined the MDL, as described in Section 9.2.6, by performing seven replicate injections of DI water fortified with perchlorate at a concentration of three to five times the estimated instrument detection limit. The concentration values determined from the calibration curve were used to calculate the MDL. Figure 2 shows a chromatogram of a 0.5 µg/L perchlorate MDL standard fortified in DI water, and as shown in Table 1, the calculated MDL is 0.2 µg/L for the 4-mm column setup used in this work. This MDL value is only valid for perchlorate in a “clean” matrix, such as DI water. The MDL is expected to change as the ionic strength of the sample increases.

Table 1. Initial demonstration of capability (IDC) for perchlorate.

IDC Requirement (U.S. EPA Method 314.0 Section)	Prescribed Limit	Experimental Value
IDA (9.2.3)	Recovery within $\pm 10\%$ of true value	Recovery = 99.9%
IDP (9.2.4)	%RSD < 10	RSD = 0.72%
QCS (9.2.5)	Recovery within $\pm 10\%$ of true value	96.1%
MDL (9.2.6)	-	0.2 µg/L (perchlorate fortified at 0.5 ug/L)
MRL (9.2.7)	-	4 µg/L

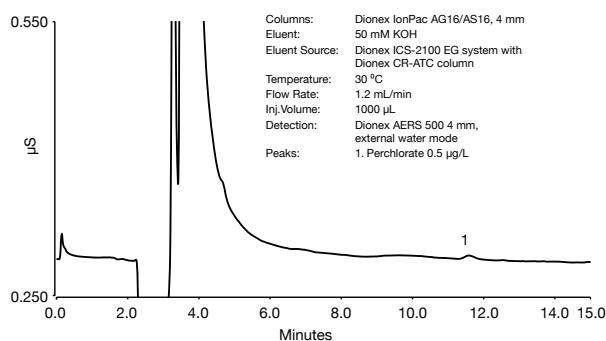


Figure 2. Determination of 0.5 µg/L perchlorate in DI water.

Next, we determined MCT (U.S. EPA Method 314.0, Section 9.2.8) using 25 µg/L perchlorate fortified in DI water as well as in standards containing MA(50), MA(100), MA(200), MA(400), MA(600), MA(800), and MA(1000) as described in the *Methods* section above. In this study, the MCT value was calculated to be 5311 µS/cm using regression analysis. Table 2 shows the data used in this study for MCT calculation using regression analysis shown in Figure 3. Based on multiple determinations, our laboratory concluded that the MCT determined with 25 µg/L perchlorate was a value varying from 5311 to 5794 µS/cm for the setup used here. However, individual results may vary within or between laboratories and analysts.

Table 2. Experimental data used in the MCT determination with perchlorate fortified at 25 µg/L.

Injection Name	Ret. Time (min)	Amount (µg/L)	Recovery (%)	Average Area (µS*min)	Average Height (µS)	A/H Ratio	PD-A/H (%)
LFB	11.74	25.08	100.3	0.0703	0.21	0.3347	0
MA(50)	11.71	24.27	97.1	0.068	0.2	0.3403	1.6
MA(100)	11.69	23.81	95.2	0.0667	0.19	0.3512	4.9
MA(200)	11.70	22.87	91.4	0.0641	0.18	0.3562	6.4
MA(400)	11.66	22.38	89.5	0.0627	0.16	0.3920	17.1
MA(600)	11.67	21.37	85.4	0.0598	0.15	0.3991	19.2
MA(800)	11.64	20.68	82.7	0.0579	0.14	0.4140	23.6
MA(1000)	11.65	20.04	80.1	0.0561	0.13	0.4320	29.0

^aMA indicates a mixed anion a mixed common anion solution of chloride, sulfate, and carbonate included in the sample matrix at the parenthetical mg/L concentration for each anion.

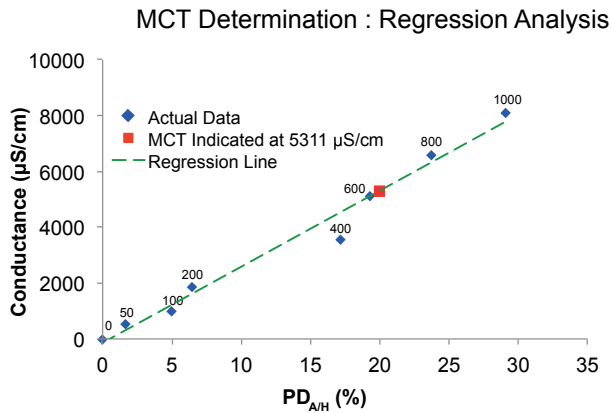


Figure 3. Regression analysis of the MCT determination data.

MCT verification (Section 9.2.8.11) was performed by spiking 4 µg/L perchlorate into a solution representing conductance equivalent to MCT. The mixed anion level required for this conductance level was calculated by plotting the concentration against conductivities measured for each mixed anion solution used in the MCT study. The calculated MCT value, mixed anion concentration required for MCT, and perchlorate recovery for MCT verification are included in Table 3. The calculated perchlorate recovery is within the 70–130% limit required for successful verification. As mentioned in U.S. EPA Method 314.0, (Section 9.2.8.12), if during MCT verification, the MRL recovery fails the criteria, the MCT should be lowered by 10% and MCT verification should be repeated.

Table 3. MCT determination results.

MCT Study Parameter	Value
Calculated MCT	5311 µS/cm
Mixed Anion Concentration at MCT	618 mg/L
Perchlorate Recovery for MCT Verification	74.7%

Figure 4 shows chromatograms of 25 µg/L perchlorate fortified in DI water, MA(200), and MA(1000), respectively. Chromatographic performance of perchlorate can deteriorate at high ionic concentrations, primarily due to the presence of high concentrations of chloride, sulfate, and carbonate. Before samples are analyzed, their conductance must be determined. If the conductance is greater than the determined MCT, the samples should either be appropriately diluted or pretreated to reduce the common anion concentrations (see *Field Sample Preparation* above in *Methods* section).

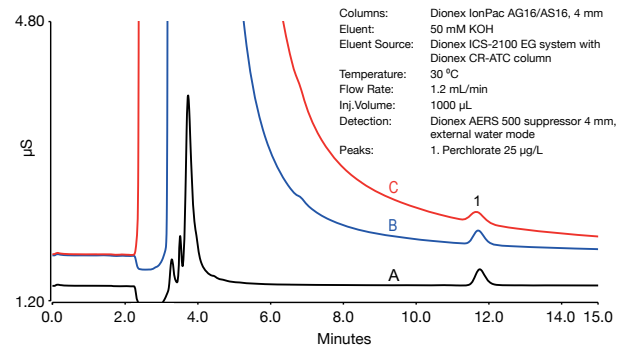


Figure 4. Determination of 25 µg/L perchlorate in (A) deionized water, (B) MA(200), and (C) MA(1000).

Sample matrix effects can bias experimental analytical results. One way to assess matrix effects is to prepare a laboratory fortified matrix (LFM). A LFM is accomplished by spiking a field sample with a known amount of analyte and then determining the percent recovery from the amount added. This application analyzed five matrices: DI water and four drinking water samples from different sources. Figure 5 shows chromatograms of drinking water samples spiked with 4 µg/L perchlorate. Each LFM sample was analyzed and the perchlorate recoveries were calculated with the equation provided Section 9.4.1.3. Figure 6 shows the results of this experiment. The calculated perchlorate recoveries were 82.4–101.3%, which were well within the 80–120% (Section 9.4.1.4) range specified by the method.

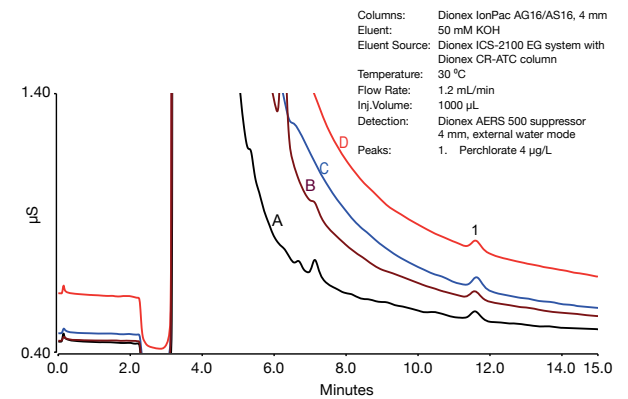


Figure 5. Determination of 4 µg/L perchlorate in four drinking water samples.

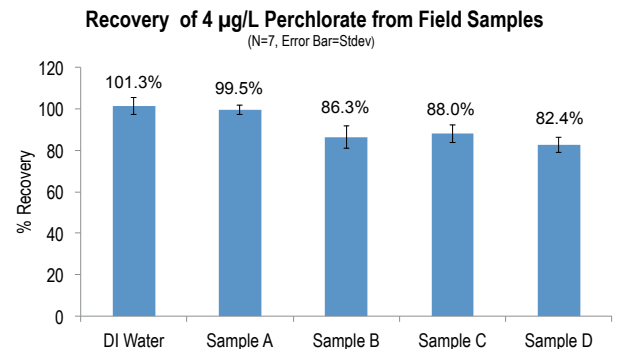


Figure 6. Calculated recoveries of 4 µg/L perchlorate spiked into four drinking water samples shown in Figure 5.

Conclusion

This application update demonstrates an approved approach for the determination of perchlorate in environmental samples using U.S. EPA Method 314.0. Results for precision and accuracy were within limits set by U.S. EPA Method 314.0. The calculated limit of detection was 0.2 µg/L in DI water. The MCT value for this setup, determined in our lab using 25 µg/L perchlorate, was 5311 µS/cm, and the MCT values ranged from 5311 to 5794 µS/cm. Recovery of MRL (4 µg/L perchlorate) spiked into a solution with conductance level similar to MCT is within the recovery limits required for successful MCT verification. Perchlorate recoveries obtained from spiked field samples were within prescribed limits indicating acceptable tolerance to matrix effects. However, results from individual laboratories or analysts may vary; the results presented in this application update meet or exceed the performance requirements specified in U.S. EPA Method 314.0.

Precautions

U.S. EPA Method 314.0 prescribes external water mode to be used with the anionic suppressor device (Section 6.1.3.1). It is possible to use recycle mode instead for perchlorate determination; though in our hands, while using the recycle mode for high ionic strength solutions as well as field samples with higher conductivities, “ghost peaks” are observed intermittently. These ghost peaks appear immediately preceding or following the perchlorate peak and adversely affect perchlorate quantification. An example of this is shown in Figure 7, wherein ghost peaks are observed when a 25 µg/L standard containing mixed anions at 600 mg/L i.e. MA(600) is analyzed using recycle mode. Although results may vary in individual laboratories, the recycle mode operation with the suppressor device is not recommended for perchlorate quantification.

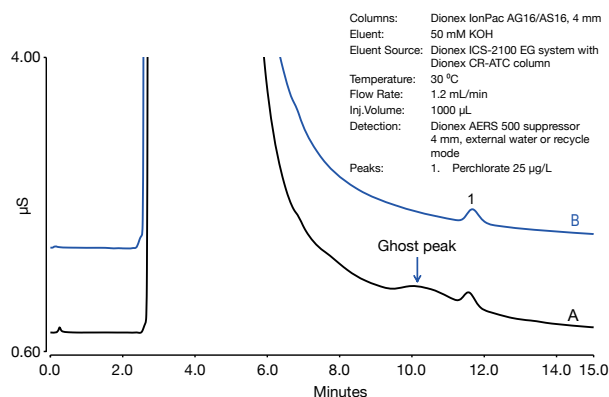


Figure 7. Determination of 25 µg/L perchlorate containing 600 mg/L mixed anions using (A) Recycle mode (B) External water mode suppression.

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