APPLICATION NOTE

ICP-Optical Emission Spectroscopy

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The Analysis of Water and Wastes by U.S. EPA Method 200.7 Using the Optima 8300 ICP-OES and prep*FAST* Auto-Dilution/Calibration System

Introduction

The prevention and control of water pollution is of critical importance to protecting human and environmental health. Monitoring of water and wastes is an efficacious way to prevent the introduction of pollutants and costly remediation of drinking and environmentally important waters. The United States Environmental Protection Agency (U.S. EPA), along with local regulatory bodies, is responsible for regulating water and wastes under the Clean Water Act and the Safe Drinking Water Act. Depending on the number and type of analytes, the number of samples and the productivity requirements, several different analytical techniques can be applied to measure trace elements in water and wastes.

U.S. EPA Method 200.7 Version 4.4 covers the use of inductively coupled plasma optical emission spectroscopy (ICP-OES) in radial and/or axial viewing for the determination of metals and some non-metals in water and wastes for regulatory compliance.[1] Method 200.7 contains a lengthy description of procedures for the collection, preservation and preparation of samples for analysis. The objective of this work was to complete the method using the PerkinElmer® Optima® 8300 ICP-OES coupled with the prep*FAST*™ Automated In-Line Auto-Dilution/Calibration System (Elemental Scientific Inc., Omaha, NE).

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The prep*FAST*™ system provides a number of advantages over conventional ICP-OES introduction systems, the most significant of which is higher sample throughput and reduced memory effects. The prep*FAST*™ system allows accurate, syringe-driven auto dilution of samples and standards, eliminating manual dilution errors and increasing calibration range. Reducing costly high-purity reagent and sample consumption, the prep*FAST*™ Auto-Dilution/Calibration System is one of the best ways to improve laboratory productivity.

Summary of Method 200.7

The direct analysis of samples was performed according to Method 200.7. For samples that require *total recoverable analysis,* refer to section 11.2 of EPA Method 200.7 rev 4.4. Below is a summary of the steps required for compliance with EPA 200.7 revision 4.4.

1) For *direct analysis* (samples with < 1 NTU), dilute, if necessary, to an appropriate volume and preserve samples to a pH < 2 with ultrapure HNO_3.
2) Optimize the instrument using the *plasma solution* (section 10.2.3) after allowing 15-30 minutes for the plasma to stabilize to the environment.
3) Calibrate the instrument using at least one blank and one calibration standard.
4) Run the instrument performance check (IPC sample) immediately following daily calibration and verify its recovery within 5%. The IPC should also be run after every 10th sample and at the end of a sample run and recovered within 10%.
5) Prepare an inter-element correction (IEC) table, if necessary, and analyze the spectral interference check (SIC) solution to verify lack of spectral interferents in the method. This should be repeated on a periodic basis.
6) Perform the initial demonstration of performance (IDP)
   a. Instrument detection limit (IDL) – Calculated as 3x the standard deviation of 10 replicate measurements of the calibration blank.
   b. Method detection limit (MDL) – Calculated as 3.14x the standard deviation of seven replicate aliquots of fortified (2-3x estimated IDL) reagent water.
   c. Quality control sample (QCS) – Prepared from a second source. Verify that the mean concentration of three analyses is recovered within 5%. Also run QCS quarterly or after new calibration standards are made.
   d. Linear dynamic range (LDR) – Analyze successively higher standard concentrations until they return 90% of the stated concentration based on a typical standard curve. Verify annually.
7) Laboratory reagent blank (LRB) – Analyze one every 20 samples. Should be below MDL.
8) Laboratory fortified blank (LFB) – Analyze one with each batch of samples. Verify within 85-115% recovery.
9) Laboratory fortified matrix (LFM) – Spike 10% of the samples prior to sample prep. Verify within 70-130% recovery. Concentration should be ≥ 30% of background concentration.
10) Reference materials – Should be run when available.

Experimental Conditions

Instrumentation

All samples were analyzed with a PerkinElmer Optima 8300® ICP-OES (Figure 1) equipped with an ESI prep*FAST*™ Auto-Dilution System with an ESI SC-2 DX Autosampler (Figure 2). Instrumental parameters are listed in Table 1.

Elements determined and wavelengths used in this study, the peak area, points per peak, and number of background points used for each wavelength are listed in Table 2. All elements were viewed axially. For some elements, alternate wavelengths were investigated in this study. The use of an alternate wavelength may be desirable for a variety of reasons – better sensitivity and greater freedom from spectral interferences are the two primary reasons. The wavelengths cited in Method 200.7 are 'recommended' with the following footnote: "The wavelengths listed are recommended because of their sensitivity and overall acceptability. Other wavelengths may be substituted if they can provide the needed sensitivity and are treated with the same corrective techniques for spectral interference (see Section 4.1)." It is worth investigating these alternate wavelengths for their applicability to the method. The wavelengths recommended by Method 200.7 are denoted in the table, as well as the reason for choosing an alternate wavelength in this study.

Figure 1. The PerkinElmer Optima 8300 ICP-OES with Flat Plate™ plasma technology.

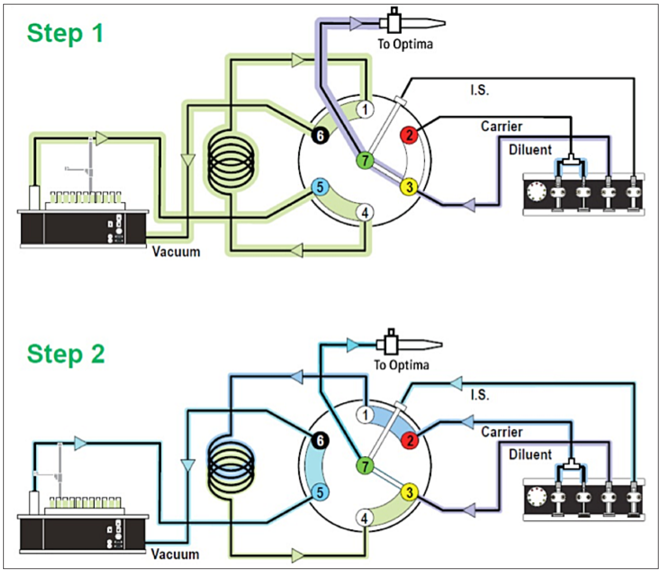

Figure 2. The prep*FAST*™ Auto-Dilution System with an ESI SC-2 DX Autosampler illustrating a two-step process of loading the sample into a loop and in-line dilution.

Sample and Standard Preparation

The solutions that were prepared and used for this study are listed in Table 3. All solutions were diluted in 2% HNO_3. For Sn analysis, solutions were acidified to 1%HCl/2%HNO_3. For calibration, a 1 mg/L (standard 5) and a 5 mg/L (standard 10) standard, depending on the element, were prepared and the prep*FAST*™ system was used to automatically dilute these solutions to prepare standards 1-4 (from standard 5) and standards 6-9 (from standard 10). The concentration of each calibration standard, the prep*FAST*™ dilution factor, and the elements applied to each standard are shown in Table 4. The prep*FAST*™ system was also set up to automatically dilute samples which were over the range of the calibration curve. For this reason, several standard solutions, analyzed as samples, were deliberately prepared so that the results would be high and the prep*FAST*™ system would perform a dilution. Yttrium was used as the internal standard during sample analysis.

Table 1. Instrumental Parameters

Parameter	Value
Nebulizer Type	ESI PFA
Spray Chamber	Non-baffled cyclonic
Injector	Sapphire
Plasma Gas Flow (L/min)	8
Aux Gas Flow (L/min)	0.2
Neb Gas Flow (L/min)	0.55
RF Power (watts)	1500
Resolution	Normal
Read Delay (sec)	50
Peak Processing	Peak area
Calibration Type	Linear, calculated intercept
Torch Cassette Position	-3
ESI Flow Rate (µL/min)	500
ESI Loop Size (µL)	3000

Table 2. Analytical parameters used for EPA Method 200.7 with the Optima 8300 ICP-OES

Analyte	Wavelength (nm)	Points/ Peak	Background Correction Points	Comments
Al	396.153*	1	1	Greater intensity
Al	308.215	3	2	
Sb	206.836	1	2	
As	188.979*	1	1	Greater freedom from spectral interferences
As	193.696	1	2	
Ba	493.408	1	2	
Be	313.042	1	1	
B	249.677	1	2	
Cd	226.502	1	2	
Ca	315.887	1	1	
Ce	413.764	1	1	
Cr	267.716*	1	2	Greater intensity and greater freedom from spectral interferences
Cr	205.560	1	1	
Co	228.616	1	2	
Cu	324.755	3	2	
Fe	259.939	1	2	
Pb	220.353	1	2	
Li	670.794	1	2	
Mg	285.213*	1	2	Greater intensity
Mg	279.077	1	2	
Mn	257.610	1	1	
Mo	203.845	1	2	
Ni	231.604	1	2	
P	213.617*	1	2	Software-suggested wavelength
P	214.914	1	1	
P	178.223*	1	2	Greater freedom from spectral interferences
P	177.435*	1	2	Greater freedom from spectral interferences
K	766.490	3	2	
Se	196.026	1	1	
Si	251.611	1	2	
Ag	328.068	1	1	
Na	589.592*	1	2	Argon interference (shoulder)
Na	588.995	1	1	
Sr	421.552	1	2	
Tl	190.805	5	2	
Sn	189.927	1	2	
Ti	334.942	1	1	
V	292.402	1	2	
Zn	206.200*	1	2	Greater freedom from spectral interferences
Zn	213.857	1	2	

* Alternate wavelengths

Table 3. Solutions used for the calibration and QC procedures in the analysis of water by EPA Method 200.7

Designation	Analytes	Part Number	Preparation
Cal Standard 1-5, IPC Solution LFM	100 mg/L: Al, Sb, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, K, Se, Ag, Na, Sr, Tl, Sn, Ti, V, Zn 1000 mg/L: Ce 1000 mg/L: Li	Instrument Cal. Std. 2: N9301721 N9300110 N9300129	Diluted to 1 mg/L for S5
Cal Standard 6-10 IPC Solution LFM	1000 mg/L: B 1000 mg/L: P 1000 mg/L: Si	N9303760 N9300139 N9300150	Diluted to 5 mg/L for S10
QCS 1	100 mg/L: As, Be, Ca, Cd, Co, Cr, Cu, Fe, Li, Mg, Mn, Mo, Ni, Pb, Sb, Se, Sr, Ti, Tl, V, Zn	QC Standard 21: N9300281	Diluted to 0.4 mg/L
QCS 2	1000 mg/L: K 500 mg/L: Si 100 mg/L: Al, B, Ba, Na 50 mg/L: Ag	QC Standard 7A: N9300280	Diluted 1000x
QCS 3	1000 mg/L P	N9303788	Diluted to 0.4mg/L
QCS 4	1000 mg/L Sn	N9303801	Diluted to 0.4 mg/L
SIC A & SIC B	5000 mg/L: Al, Ca, Mg 2000 mg/L: Fe 1000 mg/L: Fe Stock	Interferents A N9300226 N9300126	Prepared to 200 mg/L: Al, Ca, Mg; 300 mg/L: Fe The SIC B was spiked with the solutions used to prepare the calibration standards
Sample	100 mg/L: Cd, Ni, Zn 60 mg/L: Sb 5 mg/L: Pb 50 mg/L: Ba, Be, Co, Cr, Cu, Mn, V 20 mg/L: Ag 10 mg/L: As	Analytes B Solution: N9300227	Diluted 10x
Sample	See Tables for Elements and Concentrations	Initial Calibration Verification (ICV): N9300224	Diluted 10x
Sample	See Tables for Elements and Concentrations	HPS DWSS Secondary Drinking Water Standard	Diluted 10x
Sample	See Tables for Elements and Concentrations	HPS DWPS Primary Drinking Water Sol. A	Diluted 100x
Sample	See Tables for Elements and Concentrations	HPS CRM TMDW Trace Metals in Drinking Water	No dilution
Lab Sample: Sample (LM), Sample Duplicate (LMdup), Sample Spike (LFM)	First Morning Tap Water		No dilution, acidification to 2% with HNO_3

Results

As an initial qualification of the system, the IDLs and MDLs were determined for each of the wavelengths. The IDLs were determined over two separate days. All results are shown in Table 5. Concentrations of the analytes in the fortified solution used for the MDLs are also listed in Table 5.

To validate the calibration curve, the QCS solution was analyzed after calibration was complete. The QCS solution was prepared from an alternate stock source, as is required by U.S. EPA Method 200.7. Results are shown in Table 6. The solution used for the alternate source QCS did not contain Ce. Rather than risk having contamination occur by spiking in stock, it was decided to leave the solution without this element.

The QCS should be within 5% of the known value. All of the values were within this variance except for Na and K. When calibration was carried to 0.5 mg/L (rather than 1 mg/L), both of these elements were also within 5%.

The ruggedness of the prep*FAST*™ system to dilute solutions was tested in two different ways. First, standard calibration curves created by using the prep*FAST*™ system were run over several days. In all cases, for all the wavelengths used, the correlation coefficient was > 0.999, and in most cases > 0.9999. Next, an instrument performance check (IPC) was

Table 4. Standards and dilutions

Analyte	Standard		prep*FAST*™
	Std. Number	Conc. (µg/L)	Dilution Factor
Al, Sb, As, Ba, Be, Cd, Ce, Ca, Cr, Co, Cu, Fe, Pb, Li, Mg, Mn, Mo, Ni, K, Se, Ag, Na, Sr, Tl, Sn, Ti, V, Zn	1	20	50x
	2	50	20x
	3	100	10x
	4	500	2x
	5	1000	1x
B, P, Si	6	50	100x
	7	100	50x
	8	500	10x
	9	1000	5x
	10	50000	1x

Table 5. Detection limits using the Optima 8300 ICP-OES with the prep*FAST*™ Auto-Dilution/Calibration System and EPA Method 200.7 parameters

Analyte	Wavelength (nm)	IDL (µg/L)	MDL (µg/L)	Spike Concentration for MDL Solution (µg/L)
Al	396.153	0.28	0.70	0.4
Sb	206.836	1.2	1.3	3
As	188.979	0.96	1.8	3
Ba	493.408	0.01	0.018	0.05
Be	313.042	0.06	0.083	0.4
B	249.677	0.66	0.55	3
Cd	226.502	0.05	0.050	0.4
Ca	315.887	0.39	0.58	1
Ce	413.764	0.49	0.49	1
Cr	267.716	0.12	0.15	0.4
Co	228.616	0.21	0.22	0.4
Cu	324.755	0.48	0.69	1
Fe	259.939	0.16	0.12	0.4
Pb	220.353	1.2	1.1	3
Li	670.794	0.02	0.023	0.05
Mg	285.213	0.11	0.30	0.4
Mn	257.610	0.02	0.027	0.05
Mo	203.845	0.37	0.78	1
Ni	231.604	0.21	0.35	1
P	178.223	2.5	3.8	5
K	766.490	0.37	2.4	1
Se	196.026	1.5	1.9	3
Si	251.611	1.7	3.8	5
Ag	328.068	0.17	0.27	0.4
Na	589.592	0.36	1.7	1
Sr	421.552	0.004	0.011	0.05
Tl	190.805	0.04	0.91	1
Sn	189.927	0.44	0.48	1
Ti	334.942	0.05	0.07	0.4
V	292.402	0.15	0.26	0.4
Zn	206.200	0.10	0.88	0.4

Table 6. Quality Control Sample (QCS)

Analyte	Wavelength (nm)	Alternate Source QCS (µg/L)	Determined (µg/L)	Recovery (%)
Al	396.153	100	97.9	97.9
Sb	206.836	400	408	102
As	188.979	400	401	101
Ba	493.408	100	101	101
Be	313.042	400	407	102
B	249.677	100	98.6	98.6
Cd	226.502	400	415	104
Ca	315.887	400	413	103
Ce	413.764	---	---	---
Cr	267.716	400	417	104
Co	228.616	400	408	102
Cu	324.752	400	416	104
Fe	259.939	400	415	104
Pb	220.353	400	414	104
Li	670.784	400	396	99.1
Mg	285.213	400	419	105
Mn	257.610	400	416	104
Mo	203.845	400	401	100
Ni	231.604	400	409	102
P	178.221	400	400	100
K	766.490	1000	1045	105
Se	196.026	400	406	102
Si	251.611	500	526	105
Ag	328.068	50.0	52.1	104
Na	589.592	100	102	102
Sr	421.552	400	419	105
Tl	190.801	400	405	101
Sn	189.927	1000	973	97.3
Ti	334.940	400	410	103
V	292.402	400	419	105
Zn	206.200	400	409	102

analyzed after calibration, throughout the analysis, and at the end of the run. These solutions were prepared from standards 5 and 10 (depending on the analyte), using the prep*FAST*™ system. The results for each wavelength are shown in Table 7. For all analytes except B, P, and Si, the dilution factor was 4x. For B, P, and Si, the dilution factor was 5x. The IPC solution should not vary more than 10% during an analysis. All readings fell into this range with the average recovery reported below. WinLab™ for ICP software can automatically re-analyze any quality control sample that falls out of range, if necessary.

The effect of potential interferences was investigated. An interferent solution (SIC A) was prepared from a commercial solution, and fortified to an Fe concentration of 300 mg/L, as recommended in the Method (see Table 3). A portion of this solution was also spiked with a known concentration of most of the analytes and used as SIC B. Only a few of the wavelengths showed visible spectral peak interference: As, Cd and V. Several of the other wavelengths suffered from an effect that produced slight baseline effects. When the analysis of the SIC A solution produced results of more than ±5.5 µg/L, a baseline effect was decided to have occurred. At that time, an IEC factor was applied to the data. All results are shown in Table 8. In all cases, except for Li, the determined value for the spiked solution, SIC B, was within 10% of the expected value. Contamination occurred during the SIC B solution preparation; therefore, the Li results are not reported.

Several solutions of known concentration were analyzed as samples to determine system reliability. Results are shown in Tables 9-13. The Analytes B solution (Table 9) showed all but one diluted result for Sb within 10% of the expected value.

Table 7. Initial performance check (IPC) run periodically and at end of run; prepared from calibration standards 5 and 10 by the prep*FAST*™ system

Analyte	Wavelength (nm)	Check Concentration (µg/L)	After Calibration (µg/L)	Check #1 (%)	Check #2 (µg/L)	End of Run Recovery (µg/L)	Average (%)
Al	396.153	250	245	243	244	235	96.7
Sb	206.836	250	255	253	258	247	101
As	188.979	250	253	252	255	249	101
Ba	493.408	250	252	250	249	242	99.3
Be	313.042	250	245	244	244	247	98.0
B	249.677	1000	1010	1040	1050	1050	104
Cd	226.502	250	248	246	247	246	98.7
Ca	315.887	250	251	251	251	249	100
Ce	413.764	250	252	250	248	240	99.0
Cr	267.716	250	249	249	249	240	98.7
Co	228.616	250	261	259	262	255	104
Cu	324.752	250	251	250	252	239	99.2
Fe	259.939	250	249	251	249	245	99.4
Pb	220.353	250	257	257	260	242	102
Li	670.784	250	239	235	237	234	94.6
Mg	285.213	250	248	255	251	237	99.1
Mn	257.610	250	248	246	246	237	97.7
Mo	203.845	250	254	254	256	237	100
Ni	231.604	250	243	243	244	251	98.1
P	178.221	1000	1047	1058	1074	1094	107
K	766.490	250	239	238	239	229	94.4
Se	196.026	250	253	251	255	247	101
Si	251.611	1000	1050	1040	1050	1070	105
Ag	328.068	250	253	253	255	239	100
Na	589.592	250	244	240	244	240	96.8
Sr	421.552	250	257	248	254	243	100
Tl	190.801	250	253	252	256	249	101
Sn	189.927	250	254	252	255	246	101
Ti	334.940	250	257	256	256	243	101
V	292.402	250	249	249	250	239	98.7
Zn	206.200	250	247	246	246	264	100

The same is true for the IPC solution (Table 10) – this solution was diluted 10x by the user and then run using the prep*FAST*™ system either directly and/or with a 10x or 100x dilution. All recoveries for a drinking water secondary standard (HPS DWSS) were well within acceptable ranges compared to the known values (Table 11). A trace metals drinking water (HPS TMDW) standard was analyzed without dilution of any kind (Table 12). Determined results are within 15% of the certified values, except for Cu and Ag, where contamination was suspected. A drinking water primary standard (HPS DWPS) was also run (Table 13).

A first-morning tap water was collected to use as a sample (laboratory matrix, LM). This solution was run in duplicate and a portion was fortified with the analytes of interest as a laboratory fortified matrix (LFM). Results are shown in Table 14. Duplicates were all within acceptable limits and, with the exception of Ag, all spike results were within 15%. Based on the determined Zn and Cu concentrations in the sample, the spiked concentration should have been higher. The low Ag recovery was caused by a potential precipitation due to a significant chloride concentration in the sample.

Table 8. Recovery of the SIC solution with and without the use of inter-element correction (IEC) factors

Analyte	Wavelength (nm)	SIC A (µg/L)	Comment	SIC B Added (µg/L)	SIC B No IEC		SIC B with IEC	
					Found (%)	Recovery (µg/L)	Found (µg/L)	Recovery (%)
Sb	206.836	6.4		200	203	102	197	98.5
As	188.979	*		200	202	101	N/A	NA
Ba	493.408	*		200	201	101	N/A	N/A
Be	313.042	*		200	194	97.0	N/A	N/A
B	249.677	-12		2000	2111	106	2122	106
Cd	226.502	39	Fe interference	200	221	111	184	92.0
Ce	413.764	-7.3		200	186	93.0	193	96.5
Cr	267.716	*		200	189	94.5	N/A	N/A
Co	228.616	*		200	187	93.5	N/A	N/A
Cu	324.752	10		200	214	107	204	102
Pb	220.353	*		200	186	93.0	N/A	N/A
Mn	257.610	*		200	186	93.0	N/A	N/A
Mo	203.845	*		200	191	95.5	N/A	N/A
Ni	231.604	-9.3		200	183	91.5	191	95.5
P	178.221	32		2000	2098	105	2067	103
Se	196.026	-82.87	Fe interference	200	120.2	60.1	198	99.2
Si	251.611	16		2000	2128	106	2122	106
Ag	328.068	*		200	209	104	N/A	N/A
Sr	421.552	*		200	200	100	N/A	N/A
Tl	190.801	8.7		200	188	94.0	180	90.0
Sn	189.927	*		200	182	91.0	N/A	N/A
Ti	334.940	*		200	197	98.5	N/A	N/A
V	292.402	15	Fe interference	200	208	104	194	97.0
Zn	206.200	*		200	197	98.5	N/A	N/A

* No baseline effect

Table 9. Sample analysis: recovery of the Analytes B solution+ (referenced to a 10x user prepared dilution) run in duplicate, for most elements, with a further 10x prep*FAST*™ dilution

Analyte	Wavelength (nm)	Known Value (µg/L)	Determined (µg/L)	Recovery (%)	Replicate 1		Replicate 2	
					prep*FAST*™ Diluted 10x (µg/L)	Recovery (%)	prep*FAST*™ Diluted 10x (µg/L)	Recovery (%)
Sb	206.836	6000	5088*	84.5	5296	88	---	---
As	188.979	1000	905.3	90.5	903.9	90.4	---	---
Ba	493.408	5000	4947*	98.9	5064	101	4894	97.9
Be	313.042	5000	4855*	97.1	4965	99.3	4830	96.6
Cd	226.502	10000	9830*	98.3	10320	103	10130	101
Cr	267.716	5000	4880*	97.6	5099	102	4990	99.8
Co	228.616	5000	4941*	98.8	4931	98.6	4854	97.1
Cu	324.752	5000	4788*	95.8	4860	97.2	---	---
Pb	220.353	500	499.7	100	530.5	106	525.2	105
Mn	257.610	5000	4834*	96.7	4743	94.8	4630	92.6
Ni	231.604	10000	9695*	96.9	10090	101	9876	98.8
Ag	328.068	2000	1952*	97.6	2042	102	1999	99.9
V	292.402	5000	4922*	98.4	5128	103	5019	100
Zn	206.200	10000	9763*	97.6	10160	102	10000	100

+ Solution was run as a sample, not for any method requirement purposes.

* Indicates over calibration range for sample run directly.

Table 10. Sample analysis: recovery of the ICV initial calibration verification solution+ (referenced to 10x user-prepared dilution) with further prep*FAST*™ dilutions at 10x or 100x, when necessary

Analyte	Wavelength (nm)	Known Value (µg/L)	Replicate 1 Determined (µg/L)	Replicate 1 Recovery (%)	Replicate 1 prep*FAST*™ Dilution Factor	Replicate 2 Determined (µg/L)	Replicate 2 Recovery (%)	Replicate 2 prep*FAST*™ Dilution Factor
Al	396.153	20000	19900	99.7	100x	---	---	---
Sb	206.836	6000	6260	104	10x	---	---	---
As	188.979	1000	1010	101	0x	999	99.9	10x
Ba	493.408	20000	20200	101	100x	---	---	---
Be	313.042	500	494	98.6	0x	517	103	10x
Cd	226.502	500	480	96.0	0x	491	98.1	10x
Ca	315.887	50000	53000	106	100x	---	---	---
Cr	267.716	1000	982	98.2	0x	994	99.4	10x
Co	228.616	5000	4800	98.8	10x	---	---	---
Cu	324.752	2500	2750	111	10x	---	---	---
Fe	259.939	10000	9660	96.6	10x	10400	104	100x
Pb	220.353	300	291	97.0	0x	---	---	---
Mg	285.213	50000	49300	98.6	100x	---	---	---
Mn	257.610	1500	1500	99.8	10x	---	---	---
Ni	231.604	4000	3880	97.0	10x	---	---	---
K	766.490	50000	49200	98.5	100x	---	---	---
Se	196.026	500	491	98.1	0x	495	99.0	10x
Ag	328.068	1000	1018	102	0x	995	99.5	10x
Na	589.592	50000	47400	94.5	100x	---	---	---
Tl	190.801	1000	952	95.2	0x	992	99.2	10x
V	292.402	5000	5200	104	10x	---	---	---
Zn	206.200	2000	1960	97.9	10x	---	---	---

+ Solution was run as a sample, not for any method requirement purposes.

Table 11. Recovery of a drinking water secondary standard HPS DWSS (referenced to analyst prepared 10x)

Analyte	Wavelength (nm)	Known Diluted Value (µg/L)	Determined (µg/L)	Recovery (%)	Replicate 1 prep*FAST*™ Diluted 10x (µg/L)	Replicate 1 Recovery (%)	Replicate 2 prep*FAST*™ Diluted 10x (µg/L)	Replicate 2 Recovery (%)
Cu	324.752	5,000	4815	96.3	5040	101	---	---
Fe	259.939	10,000	10070	101	10000	103	9910	99.1
Mn	257.610	5,000	4902	98.0	4850	97.0	4790	95.8
Zn	206.200	5,000	5073	101	5170	103	5190	104

Table 12. Recovery of a trace metals drinking water standard HPS TMDW (no dilutions were made)

Analyte	Wavelength (nm)	Known Value (µg/L)	Determined (µg/L)	Recovery (%)
Al	396.153	120	130	110
Sb	206.836	10	11	110
As	188.979	80	79	98.4
Ba	493.408	50	48	96.0
Be	313.042	20	23	115
Cd	226.502	10	11	110
Ca	315.887	35000	36000	102
Cr	267.716	20	20	100
Co	228.616	25	23	92.0
Cu	324.752	20	25	125
Fe	259.939	100	98	98.0
Pb	220.353	40	41	102
Mg	285.213	9000	9000	99.9
Mn	257.610	40	41	102
Mo	203.845	100	99	99.0
Ni	231.604	60	57	95.0
K	766.490	2500	2658	94.1
Se	196.026	10	10.06	100.1
Ag	328.068	2	1.5	76.9
Na	589.592	6000	6800	113
Sr	421.552	250	250	99.6
Tl	190.801	10	9.2	92.0
V	292.402	30	30	100
Zn	206.200	70	74	106

Table 13. Recovery of a drinking water primary standard HPS DWPS (referenced to analyst prepared 100x)

Analyte	Wavelength (nm)	Known Value (µg/L)	Determined (µg/L)	Recovery (%)
As	188.979	1000	1018	102
Ba	493.408	500	483	96.6
Cd	226.502	500	508	101
Cr	205.560	1000	907	90.7
Se	196.026	500	496	99.4
Ag	328.068	100	1011	101

Table 14. Lab sample analysis with sample duplicate and spike

Analyte	Wavelength (nm)	LM (µg/L)	LM Duplicate (µg/L)	Fortification (µg/L)	LFM Found (µg/L)	Recovery (%)
Al	396.153	11.8	11.8	200	216	102
Sb	206.836	13.8	14.4	200	184	85.7
As	188.979	5.6	5.3	200	180	87.9
Ba	493.408	9.52	9.70	200	210	100
Be	313.042	3.44	3.48	200	201	99.0
B	249.677	17.9	18.3	500	539	104
Cd	226.502	1.18	1.16	200	195	97.0
Ce	413.764	0.790	0.904	200	191	95.0
Cr	267.716	1.57	1.56	200	194	96.0
Co	228.616	< MDL	< MDL	200	195	97.5
Cu	324.752	1463	1466	200	1654	101
Fe	259.939	10.8	10.9	200	202	95.5
Pb	220.353	4.1	3.6	200	191	93.8
Mn	257.610	5.96	5.99	200	189	91.5
Mo	203.845	2.19	2.22	200	195	96.5
Na	589.592	18981	18790	200	*	*
Ni	231.604	9.15	9.43	200	213	102
P	178.221	73.3	72.7	1000	1152	107
K	766.490	2159	2134	200	2390	95.2
Se	196.026	7.09	7.79	200	192	92.6
Si	251.611	1790	1820	500	2260	94.0
Ag	328.068	0.112	0.018	200	133.5	65.5**
Sr	421.552	56.8	57.4	200	252	97.5
Tl	190.801	8.30	7.63	200	188	90.4
Sn	189.927	1.17	1.12	200	193	96.0
Ti	334.940	< MDL	< MDL	200	195	97.5
V	292.402	2.12	2.14	200	197	97.5
Zn	206.200	413	418	200	605	98.4

* Spike to sample ratio was < 1

** See note in text

Conclusions

This study has demonstrated the capabilities of the PerkinElmer Optima 8300 ICP-OES to produce results that meet the rigorous requirements outlined in U.S. EPA Method 200.7. The accuracy and precision of the instrument allows less time to be spent on meeting the performance requirements. The ESI prep*FAST*™ system simplifies sample preparation, allowing higher sample throughput, while reducing memory effects and minimizing errors and contamination. The evaluation has clearly demonstrated that the Optima 8300 ICP-OES coupled with the prep*FAST*™ system is well-equipped to handle the real-world demands of U.S. EPA Method 200.7 for the analysis of water samples. It has also shown that the analytical accuracy of reference materials is excellent, together with the spike recoveries in real-world drinking water samples.

References

1. EPA Method 200.7 Revision 4.4, "Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Atomic Emission Spectrometry." http://water.epa.gov/scitech/methods/cwa/bioindicators/upload/2007_07_10_methods_method_200_7.pdf

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