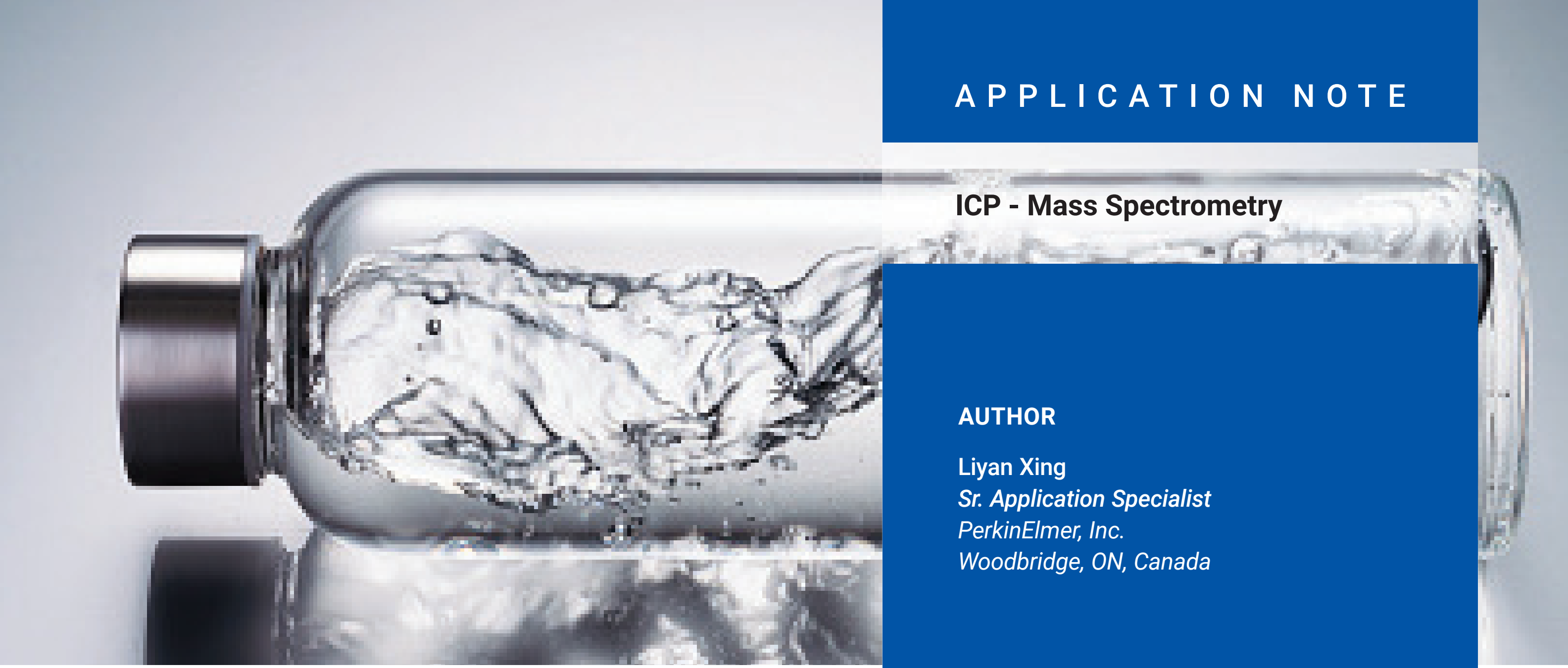

APPLICATION NOTE

ICP - Mass Spectrometry

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Multi-Element Analysis of Drinking Water Using the NexION 1000 ICP-MS Following ISO 17294-2 and (EU) 2020/2184

Introduction

Elemental content is critical to the quality of drinking water. While mineral elements like calcium, magnesium, and iron are essential nutrients for the health of humans and animals, the adverse effects imposed by heavy metals like mercury, cadmium, arsenic, and lead usually at trace levels, cannot be neglected.

The international standard method ISO 17294 outlines the analysis of elements in water samples (for example, drinking water, surface water, groundwater, wastewater, and eluates) using ICP-MS. ISO 17294-1:2004[1] provides the general guidelines for using the ICP-MS technique, and ISO 17294-2:2016[2] describes the determination of selected elements, including uranium isotopes. In drinking water and relatively unpolluted waters, the limit of quantification (LOQ) lies between 0.002 µg/L and 1.0 µg/L for most elements (Table 1).

Also listed in this table are the LOQ specifications set by Directive (EU) 2020/2184. This directive aims to protect human health from the adverse effects of any contamination of water intended for human consumption by ensuring that it is wholesome and clean.

Element	ISO 17294-2	(EU) 2020/2184	Element	ISO 17294-2	(EU) 2020/2184
Li	1	–	In	0.1	–
Be	0.1	–	Sn	1	–
B	1	450	Sb	0.2	3
Na	10	60	Te	2	–
Mg	1	–	Cs	0.1	–
Al	1	60	Ba	3	–
P	5	–	La	0.1	–
S	–	75	Ce	0.1	–
K	5	–	Pr	0.1	–
Ca	50	–	Nd	0.1	–
V	0.1	–	Sm	0.1	–
Cr	0.1	7.5	Gd	0.1	–
Mn	0.1	15	Tb	0.1	–
Fe	5	60	Dy	0.1	–
Co	0.2	–	Ho	0.1	–
Ni	0.1	6	Er	0.1	–
Cu	0.1	600	Tm	0.1	–
Zn	1	–	Yb	0.2	–
Ga	0.3	–	Lu	0.1	–
Ge	0.3	–	W	0.3	–
As	0.1	3	Re	0.1	–
Se	0.1	6	Hf	0.1	–
Rb	0.1	–	Ir	0.1	–
Sr	0.3	–	Pt	0.5	–
Y	0.1	–	Au	0.5	–
Zr	0.2	–	Hg	0.05	0.3
Mo	0.5	–	Tl	0.1	–
Ru	0.2	–	Pb	0.2	1.5
Ag	0.5	–	Bi	0.5	–
Pd	0.5	–	Th	0.1	–
Cd	0.1	1.5	U	0.1	9

Table 1: Limit of quantification (LOQ, µg/L) specifications set by ISO 17294-2 and (EU) 2020/2184.

Compared to other analytical techniques, ICP-MS has the advantages of multi-element detection capability, low detection limits, high-speed of analysis, wide dynamic range, etc. However, it is affected by plasma as well as matrix-based polyatomic interferences and doubly charged species, which need to be accounted for by applying mathematical corrections and/or collision/reaction mechanisms.

PerkinElmer's NexION® 1000 ICP-MS is equipped with a Universal Cell (UCT) that can be operated in both Collision and Reaction modes to tackle the polyatomic interferences. In this work, a pre-mixed gas mixture (7% hydrogen/helium) was used for both Collision and Reaction modes. In addition, the efficiency of interference removal was checked by analyzing certified reference material (CRM) samples as recommended by ISO 17294-2.

Experimental

Samples and Sample Preparation

All sample and solution preparations in this application note were performed volumetrically. Ultrapure water (resistivity >18.2MΩ.cm) and high-purity acids (Tama Chemicals, Kawasaki, Kanagawa, Japan) were used for all samples, including blanks, standards, and wash solutions unless specified otherwise. The diluted acid solution was prepared by dilution of the concentrated acid with ultrapure water. The concentrations were based on concentrated HNO_3 with 70% w/v and concentrated HCl with 37% w/v.

The internal standard (ISTD) solution contains 2 µg/mL of Sc, 0.2 µg/mL of Ga, and 0.1 µg/mL each of In, Ir, Rh, and Tm, and was prepared by 100-fold dilution of an Internal Standard Mix (PerkinElmer Part No. N9307738). The ISTD was introduced into the designated port of the NexION's High Throughput System (HTS) switching valve and mixed inline continuously with the carrier solution/sample flow.

Calibration Standards

The stock calibration standard (SCS) solutions include six subsets of solutions (Table 2), which are either commercial multi-element standards or prepared from single-element standards.

Working Calibration Standards

Working calibration standards were prepared by dilution of the SCS solutions in a diluent made of 2% HNO_3 (v/v) and 0.5% HCl (v/v) spiked with 200 µg/L gold (Au) single-element standard. The addition of HCl helps with the long-term stability of elements like Hg, Ag, Sn, Sb, and Mo; and gold facilitates the washout of mercury (Hg). The diluent is also used as the carrier solution and continuing calibration blank (CCB) sample. The solution set for 6-point calibration (excluding the calibration blank) was prepared at the levels shown in Table 4. Standard 3 in this set was used as the continuing calibration verification (CCV) sample. The CCB and CCV were measured periodically in sequence.

Subset	Elements, Concentration, and Matrix	Part Number
SCS-1	100 µg/mL of Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, Sn, Sr, Tl, V and Zn in 5% HNO_3/trace HF	N9301721
SCS-2	10 µg/mL of B, Th, U in 2% HNO_3	N9307807
SCS-3	10 µg/mL of Bi, Rb, Te, W, in 5% HNO_3/trace HF	See Table 3
SCS-4	10 µg/mL of Hg in 10% HNO_3	N9300253
SCS-5	10 µg/mL of Li, Fe, Ba and Sr, 100 µg/mL of Mg and K, 500 µg/mL of Na and Ca in 5% HNO_3	See Table 3
SCS-6	50 µg/mL of P; 250 µg/mL of S	See Table 3

Table 2: Stock calibration standard (SCS) solutions.

Element	Concentration and Matrix	Part Number
Bi	1000 µg/mL in 10% HNO_3	N9303731
Rb	1000 µg/mL in 2% HNO_3	N9303792
Te	1000 µg/mL in 10% HNO_3	N9304385
W	1000 µg/mL in water	N9303809
Li	1000 µg/mL in 2% HNO_3	N9303781
Fe	1000 µg/mL in 2% HNO_3	N9303738
Ba	1000 µg/mL in 2% HNO_3	N9303729
Sr	1000 µg/mL in 2% HNO_3	N9303802
Mg	1000 µg/mL in 2% HNO_3	N9303743
K	1000 µg/mL in 2% HNO_3	N9303742
Na	1000 µg/mL in 2% HNO_3	N9303746
Ca	1000 µg/mL in 2% HNO_3	N9303733
P	1000 µg/mL in water	N9303788
S	1000 µg/mL in water	N9303796
Au	1000 µg/mL in 10% HCl	N9303759

Table 3: List of single-element standards.

Analytes	Standard 1 (µg/L)	Standard 2 (µg/L)	Standard 3 (µg/L)	Standard 4 (µg/L)	Standard 5 (µg/L)	Standard 6 (µg/L)
Li, Fe, Ba, Sr	1	10	100	200	500	1,000
Mg, K	10	100	1,000	2,000	5,000	10,000
Na, Ca, P	50	500	5,000	5,000	25,000	50,000
S	25	250	2,500	5,000	12,500	25,000
Hg	0.002	0.02	0.2	0.4	1	2
Rest of elements	0.1	1	10	20	50	100

Table 4: List of the concentrations of the analytes in the calibration standards.

Wash Solution

Wash solution consists of 1.5% HCl (v/v) and 0.5% HNO_3 (v/v) spiked with 200 µg/L gold single-element standard.

QC Samples

QC samples include two CRMs, a standard spiked tap water sample, a standard and rare earth elements (REEs) spiked tap water sample, and a continuing calibration verification standard (CCV).

The CRMs used in the analysis were NIST 1643f freshwater (NIST, Gaithersburg, Maryland, USA) and CRM-TMDW-100 synthetic drinking water (HPS, North Charleston, South Carolina, USA).

Calibration Standard 3 (Table 4) was used as the CCV and run periodically in a sequence for drift checking.

Water samples included tap water, bottled water as well as a coffee maker water supply line and were acidified to 2% HNO_3 and 0.5% HCl and spiked with 200 µg/L gold. To evaluate the effect of the matrix on the analysis, a matrix spike recovery test was performed on the tap water. The tap water sample was spiked to the level of Standard 5 (Table 4) for the major elements and the level of Standard 3 (Table 4) for the trace elements using the SCS solutions.

REEs do not have a significant presence in drinking water. But with the increased use of REEs in the industrial process and products, their influence on the environment may not be neglected. Due to their low second ionization potentials, REEs easily form doubly charged ions that interfere with the middle mass elements, e.g., Nd_{150}^{++} and Sm_{150}^{++} on As_{75}, and Gd_{156}^{++} and Dy_{156}^{++} on Se_{78}. To evaluate the effect of the REEs, a split of the matrix spike recovery test solution was further spiked with the single element standards to 10 µg/L of Nd, Sm, Gd, and Dy.

Matrix Check Solution

A matrix check solution is recommended by ISO 17294-2 to determine correction factors for the matrix-based interferences, such as $Ar_{40}Cl_{35}$, $Ca_{40}Cl_{35}$, $Ca_{43}S_{32}$, $Ca_{44}P_{31}$ on As_{75}, and $Cl_{35}O_{16}$, $S_{34}O_{17}$, $S_{33}O_{18}$ on V_{51}. As an alternative to mathematical correction, cell technology can be used to remove the polyatomic interferences. Since Collision/Reaction modes were used in this work, this matrix check solution was used to evaluate the interference-removal efficiency in the stage of system optimization and was monitored in a sample sequence. The matrix solution was prepared by dilution of respective element standards into the diluent. The composition of this matrix solution is as follows, where the concentration of Cl in the diluent is well above the recommended 300 mg/L:

200 mg/L of Ca; 35 mg/L of S; 10 mg/L of P; and 0.5% of Cl

Instrumentation

All measurements were performed with a NexION 1000 ICP-MS (PerkinElmer Inc., Shelton, Connecticut, USA) equipped with an S23 autosampler and a High Throughput System (HTS). HTS features a high flow vacuum pump, a 7-port switching valve, and a sample loop. Using a metal-free fluid path, the vacuum pump can quickly deliver the sample into the sample loop. The sample probe is rinsed with solution drawn by the vacuum pump while the sample is analyzed. The post-run washout is also performed using the vacuum pump. As a result, the overall analysis time per sample is drastically decreased compared to the peristaltic-based sample delivery system. In this method, the sample-to-sample time is 3.5 minutes. The instrument components/parameters are shown in Table 5. Note that the PFA-ST nebulizer has the advantages of low background and high sensitivity.

Instrument Component/Parameter	Type/Value
NexION 1000 ICP-MS	
Nebulizer	PFA-ST MicroFlow
Nebulizer capillary	Green band (0.25 mm i.d.)
Spray chamber (regular quartz)	Quartz cyclonic with AMS (All Matrix Solution) gas port
Torch	One-piece quartz torch for NexION 1000/2000, 2 mm injector
Interface	Standard nickel sampler and skimmer cones. Aluminum hyper-skimmer cone.
Peripump tubing	Carrier: orange/yellow (0.51 mm i.d.). ISTD: orange/red (0.19 mm i.d.). Gray/gray Santoprene (1.30 mm i.d.)
Peripump speed	35 rpm
Sample uptake rate	0.3 mL/min
RF power	1600 W
Plasma gas flow	15 L/min
Auxiliary gas flow	1.2 L/min
Nebulizer gas flow	As optimized
Carrier sample probe	0.5 mm i.d.
Internal standard sample probe	0.5 mm i.d.
Cell gas	Pre-mixed 7% Hydrogen/Helium
Cell gas flow	As optimized
AMS Gas	
AMS gas type	Ar
AMS gas flow	0.2 L/min
S23 Autosampler and HTS	
Sample loop size	2 mL
Autosampler probe	1.0 mm i.d.
Flush delay	16 s
Read delay	10 s
Probe rinse	5
Wash time	25
Peripump speed	80 rpm
Data Acquisition	
Sweeps	15
Dwell time	10 - 300 ms
Replicates	3

Table 5: NexION 1000 ICP-MS instrument parameters and operating conditions.

Instrumentation Optimization

A spray chamber with the All Matrix Solution (AMS) gas port was used to alleviate the matrix effect. A modified tuning procedure was used to compensate for the sensitivity loss due to the dilution gas. AMS provides additional robustness of the method. The tuning procedure for no cell gas (Standard/STD) mode was as follows:

1. Use SmartTune to perform routine instrument optimization with oxide ratio <2.5% and double charge ratio <2%;
2. Apply the AMS gas;
3. Re-tune the instrument, keeping the passing criteria for oxide and double charge the same.

Reaction mode was used to measure Se^{78}, and Collision mode was used for the rest of the elements. The cell gas flow and RPq were optimized for best DLs following the instrument's operation manual. The matrix check solution was used to verify the removal of polyatomic interferences on affected elements, such as V, Cr, Se, As, and Fe. The elements, their isotopes, and modes of analysis used in this method are listed in Table 6. Nd, Sm, Gd, and Dy were monitored for evaluating the doubly charged interferences on As^{75} and Se^{78}. Note that the cell gas flows and RPq used in this application note are listed for reference only, as these parameters are instrument and conditions dependent.

Results and Discussion

Method Detection Limits

Method detection limits (MDLs) and limits of quantification (LOQs) were calculated as three times the standard deviation and ten times the standard deviation of ten replicated measurements of the blank, respectively. The LOQs of this method for all trace elements were well below the specifications from ISO 17294-2 and (EU) 2020/2184, as shown in Figure 1 and Table 7 (pages 7 and 9 respectively). The high LOQ of potassium (K) was due to contamination of the blank and can be reduced by cleaning the sample introduction system and/or contamination control of the blank solution.

ISTD Recovery

Three water samples (one bottled water, one tap water and one filtered water to feed in the coffee maker) were measured repeatedly over six hours to test long-term stability. All the ISTD recoveries (normalized to the calibration blank) were within ± 20% and did not show apparent drifting throughout the sequence (Figure 2 - page 7).

Linearity

Calibration curves using linear regression were plotted after internal standard correction and blank subtraction. The regression coefficients (r^2) higher than 0.9995 were obtained for all elements in the calibrated ranges. Selected calibration curves for B, V, As, Se, Ag, Cd, and Hg are shown in Figure 3 (page 8).

Accuracy and Recovery of CRMs

The accuracy of the method was evaluated by the recoveries of the CRMs and the matrix-spiked standards with and without REEs spiking.

Each sample was measured three times, and the measurements were spread randomly in the sequence. The mean concentration and recovery were calculated for each analyte (Table 8 and Figure 4 - pages 10 and 12 respectively). Recoveries between 90 and 110% were obtained for all certified analytes, except for Te (83%) in NIST 1643f. The certified concentration of Te (at 0.977 ± 0.0084 µg/L) is below the LOQ specified by ISO 17294-2.

Element	Isotope	Cell Mode	Cell Flow (mL/min)	RPq
Li	7	Collison	4.6	0.25
Be	9	Collision	4.6	0.25
B	11	Collision	4.6	0.25
Na	23	Collision	4.6	0.35
Mg	24	Collision	4.6	0.35
Al	27	Collision	4.6	0.35
P	31	Collision	4.6	0.35
K	39	Collision	4.6	0.35
Ca	44	Collision	4.6	0.35
V	51	Collision	5.4	0.35
Cr	52	Collision	5.4	0.35
Mn	55	Collision	4.6	0.35
Fe	56	Collision	5.4	0.35
Co	59	Collision	4.6	0.35
Ni	60	Collision	4.6	0.35
Cu	63	Collision	4.6	0.35
Zn	66	Collision	4.6	0.35
As	75	Collision	4.6	0.35
Se	78	Reaction	4.6	0.4
Rb	85	Collision	4.6	0.35
Sr	88	Collision	4.6	0.35
Mo	95	Collision	4.6	0.35
Ag	109	Collision	4.6	0.35
Cd	111	Collision	4.6	0.35
Sn	118	Collision	4.6	0.35
Sb	121	Collision	4.6	0.35
Te	125	Collision	4.6	0.35
Ba	137	Collision	4.6	0.35
W	182	Collision	4.6	0.35
Hg	202	Collision	4.6	0.35
Tl	205	Collision	4.6	0.35
Pb*	206+207+208	Collision	4.6	0.35
Bi	209	Collision	4.6	0.35
Th	232	Collision	4.6	0.35
U	238	Collision	4.6	0.35

Table 6: Isotopes and mode of analysis for different elements.

* Three Pb isotopes are measured and summed to address the natural abundance variation.

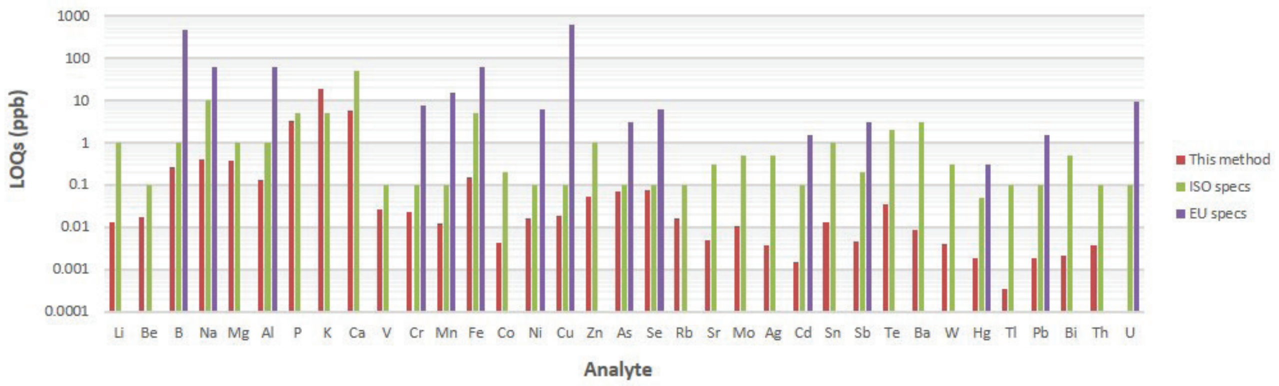

Figure 1: Comparison of LOQs obtained with this method vs. specifications of ISO 17294-2 and (EU) 2020/2184.

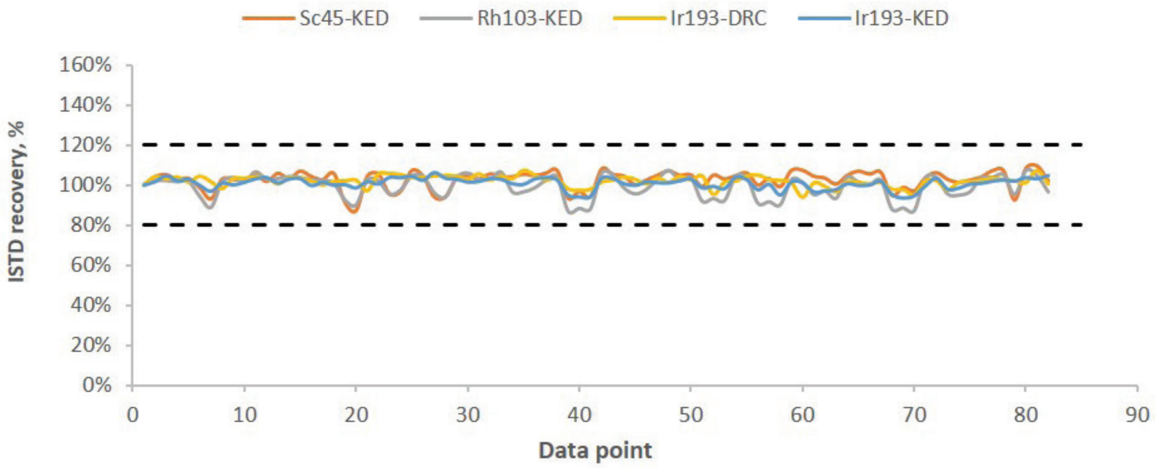

Figure 2: ISTD recoveries (normalized to the calibration blank) during a 6-hour analysis of varied water samples.

Recovery of Matrix Spiked Standards

A matrix spike recovery test was performed on the acidified tap water (TW) sample using the stock calibration standards (SCS). In the water sample, the major elements were added to the level of Calibration Standard 5 (Table 2 - page 3), and the trace elements were added to the level of Calibration Standard 3 (Table 2). A split of this matrix recovery test sample was further spiked with Nd, Sm, Gd, and Dy single-element standards to a concentration of 10 µg/L for each element.

To perform this test, the unspiked water sample was measured six times, and the mean concentration of each analyte was used as the subtrahend to calculate the spiked concentration.

The mean concentrations of the unspiked and spiked samples and the spike recoveries are listed in Table 9 (page 11) and displayed graphically in Figure 5 (page 12). Recoveries between 88 and 111% were obtained for all matrix-spiked standards. With the presence of 10 µg/L REEs, the recoveries for As and Se (highlighted in yellow) are comparable with those non-REE spiked samples. Note that REE interferences may become significant at sufficiently high concentrations when correcting measures must be invoked for the affected samples.

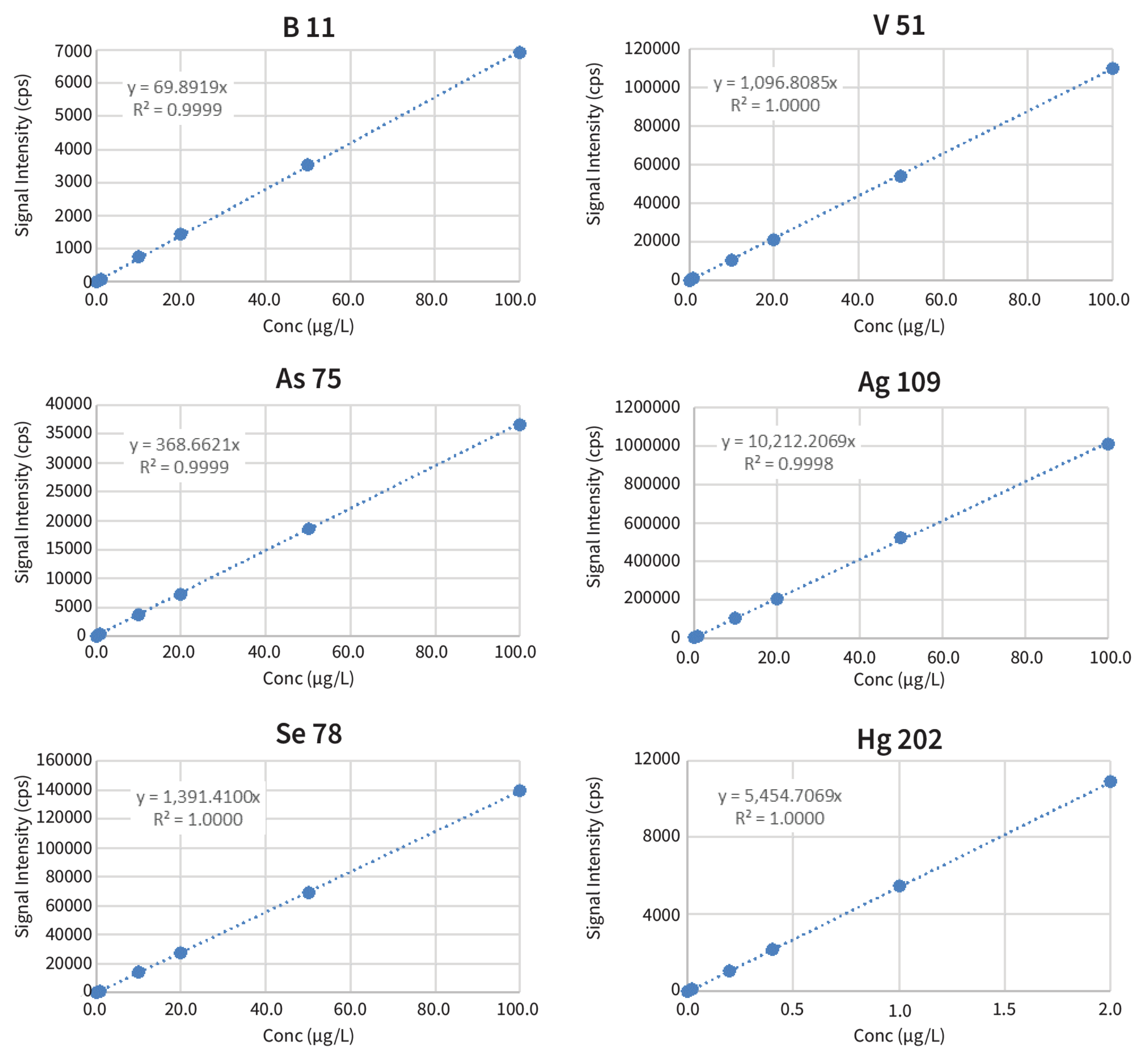

Figure 3: Calibration curves of selected elements.

Element	Isotope	This Method MDL (µg/L)	This Method LOQ (µg/L)	ISO Spec LOQ (µg/L)	EU Spec LOQ (µg/L)
Li	7	0.004	0.013	1	
Be	9	0.005	0.017	0.1	
B	11	0.076	0.255	1	450
Na	23	0.120	0.402	10	60
Mg	24	0.111	0.370	1	
Al	27	0.039	0.132	1	60
P	31	0.962	3.205	5	
K	39	5.679	18.9	5	
Ca	44	1.760	5.867	50	
V	51	0.008	0.027	0.1	
Cr	52	0.007	0.023	0.1	7.5
Mn	55	0.004	0.012	0.1	15
Fe	56	0.046	0.155	5	60
Co	59	0.001	0.004	0.2	
Ni	60	0.005	0.016	0.1	6
Cu	63	0.006	0.019	0.1	600
Zn	66	0.016	0.053	1	
As	75	0.021	0.069	0.1	3
Se	78	0.022	0.072	0.1	6
Rb	85	0.005	0.016	0.1	
Sr	88	0.001	0.005	0.3	
Mo	95	0.003	0.011	0.5	
Ag	109	0.001	0.004	0.5	
Cd	111	0.000	0.001	0.1	1.5
Sn	118	0.004	0.013	1	
Sb	121	0.001	0.004	0.2	3
Te	125	0.010	0.034	2	
Ba	137	0.003	0.009	3	
W	182	0.001	0.004	0.3	
Hg	202	0.001	0.002	0.05	0.3
Tl	205	0.000	0.000	0.1	
Pb	208	0.001	0.002	0.1	1.5
Bi	209	0.001	0.002	0.5	
Th	232	0.001	0.004	0.1	
U	238	0.000	0.000	0.1	9

Table 7: Isotopes and modes of analysis for different elements

Element	NIST 1643f			HPS CRM-TMDW-100		
	Certified Value (µg/L)	Mean Measured VALUE (µg/L)	Recovery (%)	Certified Value (µg/L)	Mean Measured Value (µg/L)	Recovery (%)
Li	16.59 ± 0.35	16.6	100	20.0 ± 0.4	19.8	99
Be	13.67 ± 0.12	13.4	98	20.0 ± 0.4	19.4	97
B	152.3 ± 6.6	150	98	–		
Na	18830 ± 250	18900	100	6000 ± 60	6040	101
Mg	7454 ± 60	7400	99	9000 ± 90	8860	98
Al	133.8 ± 1.2	137	102	120 ± 1	121	100
P	–			–		
S	–			–		
K	1932.6 ± 9.4	2030	105	2500 ± 50	2580	103
Ca	29430 ± 330	27900	95	35000 ± 400	32000	92
V	36.07 ± 0.28	35.6	99	30.0 ± 0.6	29.3	98
Cr	18.5 ± 0.10	17.9	97	20.0 ± 0.2	19.1	96
Mn	37.14 ± 0.60	36.4	98	40 ± 0.8	38.7	97
Fe	93.44 ± 0.78	92.4	99	100 ± 1	97.1	97
Co	25.3 ± 0.17	24.4	96	25.0 ± 0.3	23.7	95
Ni	59.8 ± 1.4	58.1	97	60.0 ± 0.6	58.4	97
Cu	21.66 ± 0.71	21.4	99	20.0 ± 0.2	19.6	98
Zn	74.4 ± 1.7	74.0	99	70.0 ± 1.1	68.6	98
As	57.42 ± 0.38	54.3	95	80.0 ± 2	75.3	94
Se	11.7 ± 0.081	10.6	90	10 ± 0.2	9.10	91
Rb	12.64 ± 0.13	12.6	100	10.0 ± 0.1	9.80	98
Sr	314 ± 19	326	104	250 ± 3	253	101
Mo	115.3 ± 1.7	11	96	100 ± 2	96.2	96
Ag	0.9703 ± 0.0055	0.984	101	2.00 ± 0.02	2.00	98
Cd	5.89 ± 0.13	5.38	91	10.0 ± 0.1	9.20	92
Sn	–			–		
Sb	55.45 ± 0.40	52.9	95	10.0 ± 0.2	9.50	95
Te	0.977 ± 0.0084	0.811	83	3.00 ± 0.06	2.70	91
Ba	518.2 ± 7.3	515	99	50.0 ± 0.5	48.7	97
W	–			–		
Hg	–			–		
Tl	6.892 ± 0.035	7.24	105	10.0 ± 0.1	10.5	105
Pb	18.488 ± 0.0084	19.0	103	40.0 ± 0.8	40.6	102
Bi	12.62 ± 0.11	13.4	106	10.0 ± 0.1	11.0	110
Th	–			–		
U	–			10.0 ± 0.1	10.3	103

Table 8: Recoveries for the certified elements in the CRMs.

Element	TW Mean Concentration (µg/L)	Spike Concentration (µg/L)	TW+Spike Concentration (mg/L)	Recovery (%)	TW+Spike+REE Concentration (µg/L)	Recovery (%)
Li	1.79	600	640	106	653	109
Be	<DL	10	10.44	104	10.58	106
B	20.4	10	29.99	96	30.79	104
Na	17950	30060	47739	99	49298	104
Mg	7205	6060	12778	92	13018	96
Al	19	20	39	101	39	102
P	154	3000	3118	99	3162	100
S	6902	15000	21748	99	21929	100
K	1624	6060	7803	102	8081	107
Ca	27595	30060	58488	103	59085	105
V	0.210	10	11.3	111	11.3	111
Cr	0.083	10	10.8	108	10.9	108
Mn	0.210	10	11.0	108	11.0	108
Fe	4.75	660	647	97	646	97
Co	0.012	10	10.6	106	10.6	106
Ni	0.393	10	10.9	105	10.9	106
Cu	26.2	10	35.5	92	36.2	99
Zn	1.019	10	11.2	102	11.3	102
As	0.497	10	10.7	102	11.2	107
Se	0.137	10	10.8	106	10.7	106
Rb	0.840	10	11.4	106	11.5	106
Sr	149.1	660	795	98	802	99
Mo	0.937	10	11.1	102	11.2	103
Ag	0.016	10	9.9	99	10.1	101
Cd	0.003	10	9.2	92	9.2	92
Sn	0.005	10	10.1	101	10.2	102
Sb	0.106	10	9.7	96	9.8	97
Te	0.001	10	8.8	88	8.8	88
Ba	17.00	660	627	92	630	93
W	0.075	10	10.0	99	10.0	100
Hg	0.001	0.2	0.2	95	0.2	98
Tl	0.002	10	10.7	107	10.7	107
Pb	0.009	10	10.0	100	10.1	101
Bi	0.000	10	10.1	101	10.1	101
Th	0.002	10	10.4	104	10.5	105
U	0.316	10	10.9	105	10.9	106

Table 9: Mean concentrations and recoveries for the matrix spike recovery test.

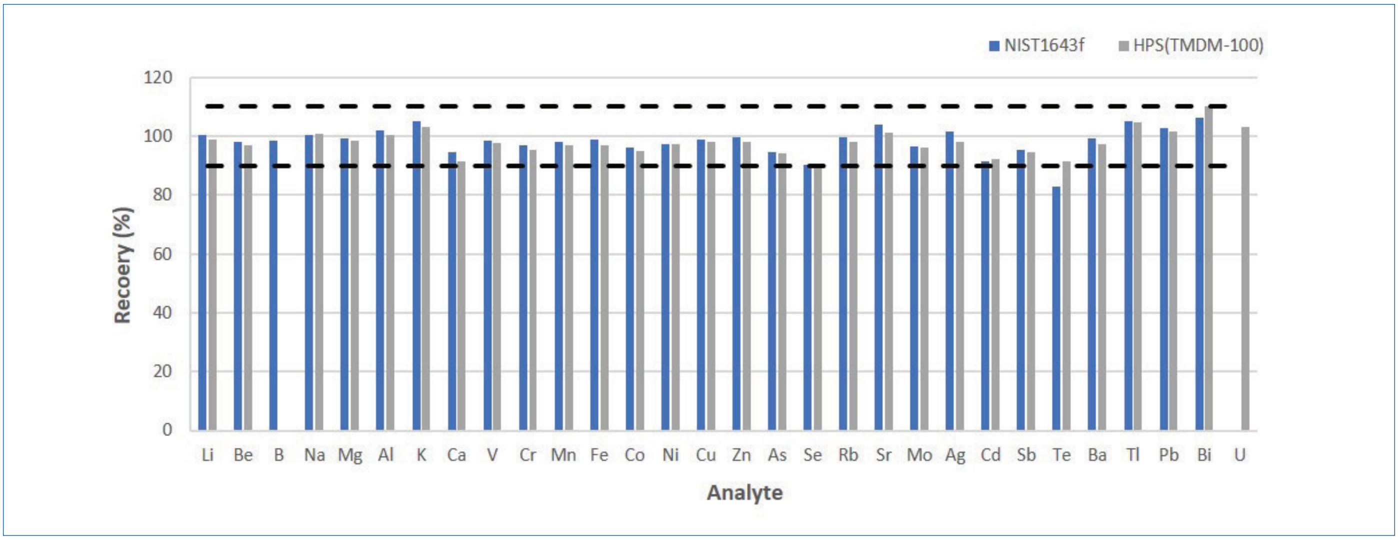

Figure 4: Recoveries for the certified elements in the CRMs.

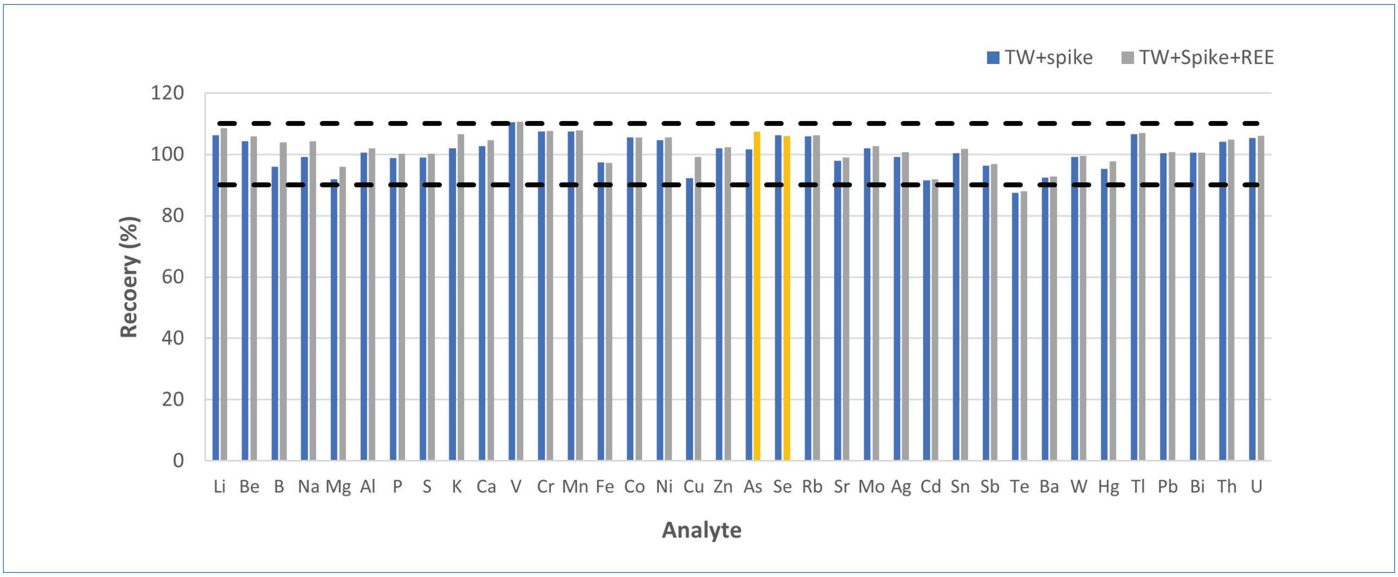

Figure 5: Recoveries for the matrix/REE-spiked samples.

Conclusion

The NexION 1000 ICP-MS has demonstrated the ability to meet and/or exceed the specifications contained within the ISO and EU directives for the analysis of drinking water. In addition, accuracy and robustness have been validated through the analysis of certified reference materials, the matrix spike recovery test, and the stability of ISTD and CCV.

Highlights of the NexION 1000 ICP-MS system include:

- Using the pre-mixed gas mixture, Collision/Reaction modes can be utilized with the one-cell-gas setup to cope with complex analytes like Se;
- The AMS feature is useful and flexible in balancing matrix reduction and retaining sensitivity;
- The HTS offers benefits of fast washout, high sample throughput, and reduced maintenance.

References

1. ISO 17294-1:2004 Water quality-Application of inductively coupled plasma mass spectrometry (ICP-MS)-Part 1: General guidelines.
2. ISO 17294-2:2016 Water quality-Application of inductively coupled plasma mass spectrometry (ICP-MS)-Part 2: Determination of selected elements, including uranium isotopes.

Consumables Used

Component	Part Number
PFA-ST MicroFlow Nebulizer	N8152378
Quartz Cyclonic Spray Chamber with AMS Matrix Port	N8152383
AMS Matrix Gas Line (0.25 mm i.d.) for Cyclonic Spray Chamber	N8152374
Spray Chamber Drain Line Kit for NexION 1000/2000 ICP-MS	N8152456
Cyclonic Spray Chamber/Cassette Light Shield	N8152425
One-Piece SilQ Torch for NexION 1000/2000 ICP-MS, 2 mm injector	N8152428
Torch Light Shield Disk	N8152377
NexION 1000/2000 ICP-MS Torch Mounting Nut	N8152451
Torch and Injector Removal Tool	N8152443
Peripump Tubing for ICP-MS: - Carrier: Orange/Yellow (0.51 mm i.d.) - ISTD: Orange/Red (0.19 mm i.d.) - Waste: Gray/Gray Santoprene (1.30 mm i.d.)	 N8152404 N8152401 N8152415
Sample Probe (1.0 mm i.d.) for S23 and S25 Autosamplers	N0811956
Manual Sampling Probe (0.5 mm i.d) for Carrier and Internal Standard	N8152452

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