# Ultra-fast ICP-OES determination of trace elements in water, conforming to US EPA 200.7 and using next generation sample introduction technology

## Application note

Environmental

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## Introduction

This work describes an implementation of the US EPA 200.7 guidelines for the analysis of trace elements in water using the Agilent SVS 2, a new and innovative sample introduction system for the Agilent 720/730 Series ICP-OES, to improve sample throughput.

A typical sample analysis cycle using an ICP-OES involves sample uptake at high pump rates from the autosampler to the plasma, followed by a stabilization delay to allow the plasma to return to equilibrium. The sample is then measured and rinsed from the system. A high-throughput contract laboratory using a conventional sample introduction system would typically measure a solution in approximately 2 min 30 s.

The SVS 2 improves sample introduction efficiency by greatly reducing sample uptake and washout times. This can more than double sample throughput, and significantly reduce operating costs. In addition, as there is a constant flow of solution to the plasma, plasma stability is improved and stabilization times are reduced.

## Instrumentation

An Agilent 720 Series simultaneous ICP-OES with axially viewed plasma and SPS 3 Sample Preparation System was used for this work.

The Agilent 720 features a custom designed CCD detector, which provides true simultaneous measurement and full wavelength coverage from 167 to 785 nm. The CCD detector contains continuous angled arrays that are matched exactly to the two-dimensional image from the echelle optics. The thermally stabilized optical system contains no moving parts, ensuring excellent long-term stability.

The SVS 2 has two software triggered valve positions. The first position allows the sample to be quickly loaded into a sample loop using a positive displacement pump operating at up to 500 rpm. The sample is loaded and ready to be aspirated into the plasma for measurement. The controlling software triggers the valves to switch and inject the sample into the ICP-OES. In a typical ICP-OES analysis without the SVS 2, sample is fast-pumped into the plasma, and the pump speed is then reduced to normal speed for the duration of the measurement. The change from high to low sample flow destabilizes the plasma and may result in an unstable signal. To allow the plasma to re-equilibrate at the normal pump speed, a stabilization time of 10–15 s is required to enable the signal to stabilize prior to measurement. Using the SVS 2, the flow of solution into the plasma remains constant. High pump speeds are used to fill the sample loop, but the sample loop is disconnected from the plasma during this step. The continuous flow of solution through the nebulizer ensures better plasma stability and allows much shorter stabilization delays to be used. In addition, an uptake delay is not required and a stabilization of <10 s is sufficient to load the sample loop and inject the sample into the plasma to attain a stable signal. Conventional ICP-OES systems operating without the SVS 2 would typically require an additional 25 seconds to perform the same function.

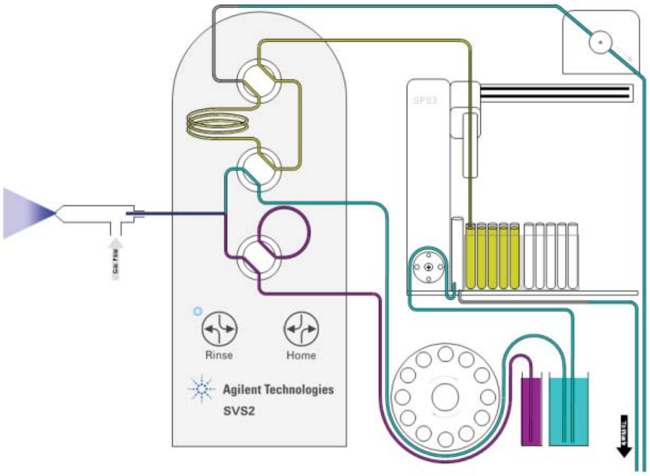

**Figure 1.** Agilent SVS 2 in sample load position

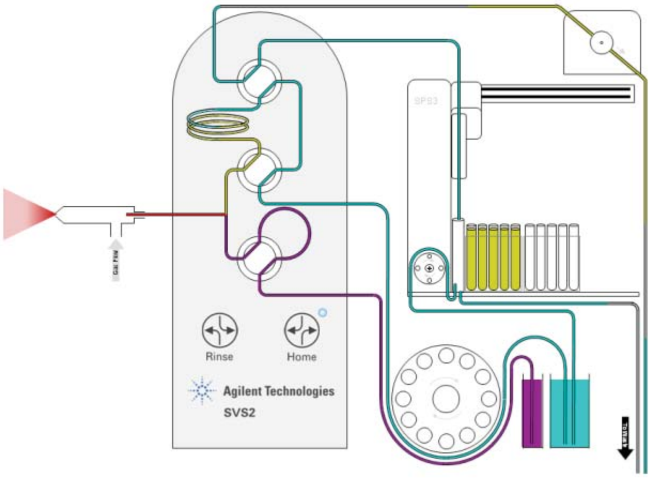

**Figure 2.** Agilent SVS 2 in sample inject position

For a complete description of the SVS 2 throughput advantages, hardware, and modes of operation see Reference 1.

Tables 1 and 2 list the operating conditions used for the ICP OES and the SVS 2 during this analysis.

**Table 1.** ICP OES instrument operating parameters
Note: All Glass sample introduction system (part number 9910117800) used.

| Condition | Setting |
|---|---|
| Power | 1.4 kW |
| Plasma gas flow | 15 L/min |
| Auxiliary gas flow | 1.5 L/min |
| Spray chamber type | Glass cyclonic (single-pass) |
| Torch | Standard one piece quartz axial |
| Nebulizer type | SeaSpray |
| Nebulizer flow | 0.7 L/min |
| Pump tubing | Rinse/Instrument pump: white-white tabs (1.02 mm id)<br>Waste: blue-blue tabs (1.65 mm id)<br>Ionization buffer/Internal standard: black-black tabs (0.76 mm id) |
| Pump speed | 12 rpm |
| Total sample usage | 1 mL |
| Replicate read time | 20 s |
| Number of replicates | 2 |
| Sample uptake delay time | 12 s |
| Stabilization time | 0 s |
| Rinse time | 0 s |
| Fast pump | Off |
| Background correction | Fitted |

**Table 2.** Agilent SVS 2 operating parameters

| Condition | Setting |
|---|---|
| Sample uptake delay time | 12 s |
| Stabilization time | 0 s |
| Rinse time | 0 s |
| Fast pump | Off |
| Background correction | Fitted |
| Nebulizer type | SeaSpray |

## Preparation of calibration solutions

Calibration and quality control solutions were prepared from Inorganic Ventures, Inc multi-element solutions designed for US EPA 200.7 methodology.

Method 200.7 standards — prepared 1:100 from:

- WW-Cal-1 A : Ag, As, B, Ba, Ca, Cd, Mn, Se, Sr
- WW-Cal-1 B : Sb
- WW-Cal- 2 : K, Li, Mo, Na, Ti
- WW-Cal-3 : Ce, Co, P, V
- WW-Cal-4 A : Al, Cr, Hg, Zn
- WW-Cal-4B : SiO2, Sn
- WW-Cal-5 : Be, Fe, Mg, Ni, Pb, Tl

200.7 Quality Control Solutions — prepared 1:100 from:

- QCP-QCS-1 : Ag, Al, As, B, Ba, Be, Ca, Cd, Ce, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Na, Ni, P, Pb, Se, Sr, Tl, V, Zn
- QCP-QCS-2 : Mo, Sb, SiO2, Sn, Ti

200.7 Interference Check Solutions — prepared 1:100 from:

- 2007ICS-1 : B, Mo, Si, Ti
- 2007ICS-2 : Sb
- 2007ICS-3 :Ag, As, Ba, Be, Cd, Co, Cr, Cu, K, Mn, Ni, Pb, Se, Tl, V, Zn
- 2007ICS-4 : Al, Ca, Fe, Mg, Na

Laboratory Fortified Blanks — prepared 1:100 from:

- WW-LFS-1 : Ag, Al, As, B, Ba, Be, Ca, Cd, Ce, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Na, Ni, P, Pb, Se, Sr, Tl, V, Zn
- WW-LFS-2 : Mo, Sb, SiO2, Sn, Ti

Laboratory Fortified Matrix Spikes also prepared from WW-LFS-1 and 2.

The calibration and QC solutions were diluted with >18 MW/cm$^3$ deionized water and stabilized in 5% v/v HNO$_3$ ( Merck Ultrapur). The calibration blank was prepared from >18 MW/cm$^3$ deionized water in 5% v/v HNO$_3$. An ionization buffer/internal standard solution of composition 1% CsNO$_3$/10 ppm Scandium was prepared from Merck Tracepur CsNO$_3$ and 1000 ppm Scandium stock.

**Table 3.** Calibration scheme

| Elt | (nm) | Std 1A | Std 1B | Std 2 | Std 3 | Std 4A | Std 4B | Std 5 |
|---|---|---|---|---|---|---|---|---|
| Ag | 328.068 | 0.5 | | | | | | |
| Al | 308.215 | | | | | 10 | | |
| As | 188.98 | 10 | | | | | | |
| B | 249.772 | 1 | | | | | | |
| Ba | 493.408 | 1 | | | | | | |
| Be | 313.042 | | | | | | | 1 |
| Ca | 315.887 | 10 | | | | | | |
| Cd | 226.502 | 2 | | | | | | |
| Ce | 418.659 | | | | 2 | | | |
| Co | 228.615 | | | | 2 | | | |
| Cr | 205.56 | | | | | 5 | | |
| Cu | 324.754 | 2 | | | | | | |
| Fe | 259.94 | | | | | | | 10 |
| K | 766.491 | | | 20 | | | | |
| Li | 610.365 | | | 5 | | | | |
| Mg | 279.078 | | | | | | | 10 |
| Mn | 261.02 | 2 | | | | | | |
| Mo | 203.846 | | | 10 | | | | |
| Na | 589.592 | | | 10 | | | | |
| Ni | 231.604 | | | | | | | 2 |
| P | 214.914 | | | | 10 | | | |
| Pb | 220.353 | | | | | | | 10 |
| Sb | 206.834 | | 5 | | | | | |
| Se | 196.026 | 5 | | | | | | |
| Si | 251.611 | | | | | | 10 | |
| Sn | 189.925 | | | | | | 4 | |
| Sr | 421.552 | 1 | | | | | | |
| Ti | 334.941 | | | 10 | | | | |
| Tl | 190.794 | | | | | | | 5 |
| V | 292.401 | | | | 2 | | | |
| Zn | 213.857 | | | | | 5 | | |

## US EPA 200.7 guidelines summary

This method is a performance based set of guidelines for the analysis of 32 elements in drinking waters and waste waters. Preferred wavelengths, quality control and calibration procedures are defined. Method performance criteria such as method detection limits, spectral interference check procedures and linear range determination are also outlined. The Minimum QC requirements as described in section 9.0 Quality Assurance/Quality Control of Method 200.7 Rev 5.0 are as follows:

### Demonstration of laboratory capability

Periodic analysis of:

- Laboratory reagent blanks
- Fortified blanks
- Other laboratory solutions as a continuing check of performance
- Maintain performance records of data quality

### Initial demonstration of performance

- Establish Linear Dynamic Range (LDR)
- Measure Quality Control Solution to +-5% Recovery
- Determine Method Detection Limits
- Spectral Interference Check

### Monitor laboratory performance

Periodic analysis of:

- Laboratory Reagent Blank (LRB)
- Laboratory Fortified Blank (LFB)
- Instrument Performance Check Solution (IPC)
- Interference Check Solutions (ICS)

### Assess analyte recovery and data quality

- Laboratory Fortified Matrix Spikes (LFM)
- Standard Reference Materials (if available)

The mnemonics used in the description of the 200.7 quality control scheme are shown in Table 4.

**Table 4.** Mnemonics used in the description of the 200.7 quality control scheme

| Mnemonic | Description | Sample rate | Limit or %R |
|---|---|---|---|
| QCS | Quality Control Solution: Second source calibration check. | After initial calibration | 95–105% |
| ICS | Interference Check Solution: Verifies effectiveness of correction processes. | 3 months | - |
| IPC | Instrument Performance Check: Continuing drift and accuracy verification. | 1 in 10 and end of run | 90–110% |
| Blank | Measure blank as sample. | 1 in 10 | < IDL |

For a full description of the US EPA 200.7 Guidelines including the appropriate standard and sample sequence, see Reference 2.

## Initial demonstration of performance

### Linear range analysis (LRA)

The LRA represents the upper concentration limit for each analyte of the ICP-OES linear range beyond which results cannot be reported without dilution of the sample. The maximum error for each calibration standard within the linear range cannot exceed 10%.

**Table 5.** Linear dynamic range

| Element | LDR (ppm) | Element | LDR (ppm) | Element | LDR (ppm) |
|---|---|---|---|---|---|
| Ag 328.068 | 50 | Cu 324.754 | 100 | Sb 206.834 | 500 |
| Al 308.215 | 1000 | Fe 259.940 | 100 | Se 196.026 | 500 |
| As 188.980 | 200 | K 766.491 | 50 | Si 251.611 | 200 |
| B 249.772 | 100 | Li 670.784 | 100 | Sn 189.925 | 70 |
| Ba 493.409 | 10 | Mg 279.079 | 1000 | Sr 421.552 | 10 |
| Be 313.042 | 2 | Mn 261.020 | 200 | Ti 334.941 | 20 |
| Ca 315.887 | 100 | Mo 203.846 | 100 | Tl 190.794 | 100 |
| Cd 226.502 | 20 | Na 259.592 | 100 | V 292.401 | 30 |
| Ce 413.765 | 100 | Ni 231.604 | 50 | Zn 213.857 | 20 |
| Co 228.616 | 100 | P 214.914 | 1000 | | |
| Cr 205.552 | 40 | Pb 220.353 | 100 | | |

### Method detection limits (MDL)

The MDL of each element was determined following the procedure defined in 40 CFR, part 136 Appendix B, as specified in Section 9.2.1 Method 200.7 revision 5. A standard solution containing analytes at a concentration of 3–5 times the instrument manufacturer's suggested IDL was measured on three non-consecutive days.

**Table 6.** Method detection limits

| Element | MDL (ppb) | Element | MDL (ppb) | Element | MDL (ppb) |
|---|---|---|---|---|---|
| Ag 328.068 | 0.1 | Cu 324.754 | 2 | Sb 206.834 | 2.7 |
| Al 308.215 | 2.6 | Fe 259.940 | 3 | Se 196.026 | 4 |
| As 188.980 | 3.3 | K 766.491 | 15.8 | Si 251.611 | 13 |
| B 249.772 | 1.2 | Li 670.784 | 1.5 | Sn 189.925 | 1.3 |
| Ba 493.409 | 2 | Mg 279.079 | 2.8 | Sr 421.552 | 0.2 |
| Be 313.042 | 0.3 | Mn 261.020 | 0.2 | Ti 334.941 | 0.4 |
| Ca 315.887 | 8.4 | Mo 203.846 | 1.6 | Tl 190.794 | 1.9 |
| Cd 226.502 | 0.2 | Na 259.592 | 5.4 | V 292.401 | 2.1 |
| Ce 413.765 | 1.3 | Ni 231.604 | 1.4 | Zn 213.857 | 0.6 |
| Co 228.616 | 0.4 | P 214.914 | 16.1 | | |
| Cr 205.552 | 1.1 | Pb 220.353 | 1.8 | | |

### Initial QCS performance

As part of the initial demonstration of lab performance, it is necessary to analyze a quality control solution and achieve a recovery of ±5% of the true values for each element.

Table 7.

| Element | %R | Pass/fail | Element | %R | Pass/fail |
|---|---|---|---|---|---|
| Ag 328.068 | 99.2 | Pass | Mn 261.020 | 103.2 | Pass |
| Al 308.215 | 99.2 | Pass | Mo 203.846 | 99.6 | Pass |
| As 188.980 | 101 | Pass | Na 259.592 | 98.1 | Pass |
| B 249.772 | 101 | Pass | Ni 231.604 | 101.2 | Pass |
| Ba 493.409 | 99.4 | Pass | P 214.914 | 98.6 | Pass |
| Be 313.042 | 102 | Pass | Pb 220.353 | 101.5 | Pass |
| Ca 315.887 | 102 | Pass | Sb 206.834 | 92.7 | Pass |
| Cd 226.502 | 101 | Pass | Se 196.026 | 100.3 | Pass |
| Ce 413.765 | 99 | Pass | Si 251.611 | 99 | Pass |
| Co 228.616 | 99.8 | Pass | Sn 189.925 | 100.6 | Pass |
| Cr 205.552 | 104 | Pass | Sr 421.552 | 100.6 | Pass |
| Cu 324.754 | 101.5 | Pass | Ti 334.941 | 99.8 | Pass |
| Fe 259.940 | 99.3 | Pass | Tl 190.794 | 99.6 | Pass |
| K 766.491 | 97.2 | Pass | V 292.401 | 100.7 | Pass |
| Li 670.784 | 97.5 | Pass | Zn 213.857 | 98.5 | Pass |
| Mg 279.079 | 96.9 | Pass | | | |

### Spectral interference check

From METHOD 200.7 Revision 4.4 Section 7.15:

SIC solutions (containing similar concentrations of the major components in the samples, for example, ≥10 mg/L) can serve to verify the absence of effects at the wavelengths selected. These data must be kept on file with the sample analysis data. If the SIC solution confirms an operative interference that is ≥10% of the analyte concentration, the analyte must be determined using a wavelength and background correction location free of the interference or by another approved test procedure. The analysis of solutions 2007ICS-1 through 4 at the utilized wavelengths shows no significant spectral interferences when using the default ICP 720 background correction technique.

## Analytical results

Reference materials were analyzed using the instrument and accessory conditions as defined in Tables 1 and 2. Their results are reported in Tables 8 to 10.

### Instrument stability

The Instrument Performance Check (IPC) solution was analyzed every 10 samples over a period of six hours. The measured concentration of each element in the IPC must be within ±10% of the true value, the IPC results trends are a measure of the stability of the instrument. Figure 3 shows that conditions remain stable over the duration of the six hour period. The precision for all 32 elements was better than 2%.

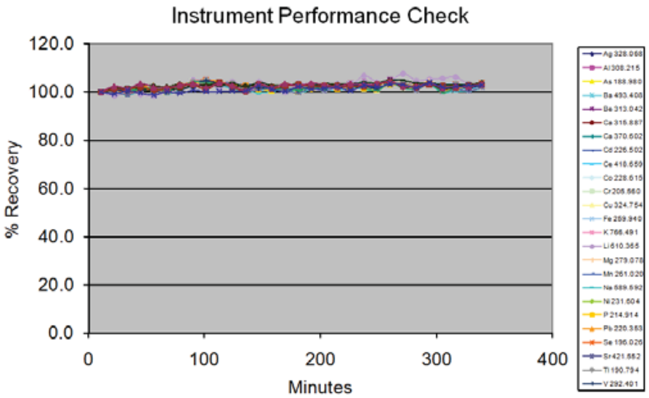

**Figure 3.** Long-term stability of instrument performance check (IPC) was better than 2% over 6 hours

### Speed of analysis

An analysis sequence that conforms to US EPA protocols can be time-consuming since there are a large number of QC solutions required for conformance to the protocol. In this study, the use of the SVS 2 sample introduction system dramatically reduced analysis time, with a resulting tube to tube analysis time of 68 s.

**Table 8.** NIST SRM 1643e results.
Trace elements in water: sample source NIST US Dept of Commerce.

| Element | Spec µg/L | Found | Dup | QC spike | Spike level | % rec LCS | RPD dup % | % spike rec |
|---|---|---|---|---|---|---|---|---|
| Ag 328.068 | 1.062 | 1.123 | 1.042 | 0.061 | 0.075 | 105.7 | 7.5 | 79.8 |
| Al 308.215 | 141.8 | 151.936 | 150.101 | 2.172 | 2 | 107.1 | 1.2 | 101 |
| As 188.980 | 60.45 | 57.051 | 59.461 | 0.862 | 0.8 | 94.4 | 4.1 | 100.6 |
| B 249.772 | 157.9 | 159.72 | 161.242 | 0.473 | 0.3 | 101.2 | 0.9 | 104.4 |
| Ba 493.408 | 544.2 | 534.966 | 537.325 | 0.728 | 0.2 | 98.3 | 0.4 | 96.5 |
| Be 313.042 | 13.98 | 13.843 | 13.867 | 0.212 | 0.2 | 99 | 0.2 | 99.1 |
| Ca 315.887 | 32300 | 30995.4 | 30966.2 | 31.982 | 1 | 96 | 0.1 | 98.7 |
| Cd 226.502 | 6.568 | 6.565 | 6.586 | 0.209 | 0.2 | 100 | 0.3 | 101.2 |
| Co 228.615 | 27.06 | 26.775 | 27.176 | 0.227 | 0.2 | 98.9 | 1.5 | 100.1 |
| Cr 205.560 | 20.4 | 20.271 | 20.423 | 0.423 | 0.4 | 99.4 | 0.7 | 100.7 |
| Cu 324.754 | 22.76 | 23.729 | 23.126 | 0.334 | 0.3 | 104.3 | 2.6 | 103.4 |
| Fe 259.940 | 98.1 | 98.036 | 99.205 | 3.076 | 3 | 99.9 | 1.2 | 99.3 |
| K 766.491 | 2034 | 2017.45 | 2026.59 | 12.149 | 10 | 99.2 | 0.5 | 101.3 |
| Mg 279.078 | 8037 | 7901.66 | 7913.59 | 9.792 | 2 | 98.3 | 0.2 | 94.5 |
| Mn 257.610 | 38.97 | 39.725 | 39.569 | 0.244 | 0.2 | 101.9 | 0.4 | 102.1 |
| Mo 203.846 | 121.4 | 119.736 | 120.517 | | | 98.6 | 0.7 | |
| Na 589.592 | 20740 | 19061.6 | 19007.1 | 21.896 | 3 | 91.9 | 0.3 | 94.5 |
| Ni 231.604 | 62.41 | 61.763 | 60.219 | 0.557 | 0.5 | 99 | 2.5 | 99 |
| P 214.914 | | 41.893 | 56.332 | 6.178 | 6 | | 29.4 | 102.3 |
| Pb 220.353 | 19.63 | 21.138 | 20.422 | 1.028 | 1 | 107.7 | 3.4 | 100.7 |
| Sb 206.834 | 58.3 | 55.64 | 54.15 | | | 95.4 | 2.7 | |
| Se 196.026 | 11.97 | 14.118 | 13.377 | 1.973 | 2 | 117.9 | 5.4 | 97.9 |
| Si 251.611 | | 27.676 | 26.563 | 0.193 | | | 4.1 | |
| Sr 421.552 | 323.1 | 320.029 | 324.499 | 0.517 | 0.2 | 99 | 1.4 | 98.5 |
| Tl 190.794 | 7.445 | 8.162 | 7.773 | 2.008 | 2 | 109.6 | 4.9 | 100 |
| V 292.401 | 37.86 | 36.671 | 36.843 | 0.339 | 0.3 | 96.9 | 0.5 | 100.8 |
| Zn 213.857 | 78.5 | 79.832 | 79.133 | 0.284 | 0.2 | 101.7 | 0.9 | 102.1 |

**Table 9.** NIST SRM 1640a results.
Trace elements in natural water: sample source NIST US Dept of Commerce.

| Element | Spec µg /L | Found | Dup | QC spike | Spike level | % rec LCS | RPD dup % | % spike rec |
|---|---|---|---|---|---|---|---|---|
| Ag 328.068 | 8.081 | 8.07 | 8.192 | 0.071 | 0.1 | 99.9 | 1.5 | 83.9 |
| Al 308.215 | 53 | 53.305 | 52.266 | 2.012 | 2 | 100.6 | 2 | 97.9 |
| As 188.980 | 8.075 | 6.677 | 8.427 | 0.777 | 0.8 | 82.7 | 23.2 | 96.3 |
| B 249.772 | 303.1 | 321.542 | 305.727 | 0.596 | 0.3 | 106.1 | 5 | 91.5 |
| Ba 493.408 | 151.8 | 151.023 | 147.974 | 0.337 | 0.2 | 99.5 | 2 | 93 |
| Be 313.042 | 3.026 | 3.038 | 2.915 | 0.197 | 0.2 | 100.4 | 4.1 | 97 |
| Cd 226.502 | 3.992 | 3.924 | 3.789 | 0.2 | 0.2 | 98.3 | 3.5 | 98 |
| Co 228.615 | 20.24 | 20.064 | 19.738 | 0.216 | 0.2 | 99.1 | 1.6 | 98 |
| Cr 205.560 | 40.54 | 39.52 | 38.749 | 0.429 | 0.4 | 97.5 | 2 | 97.4 |
| Cu 324.754 | 85.75 | 84.949 | 83.357 | 0.378 | 0.3 | 99.1 | 1.9 | 97.7 |
| Fe 259.940 | 36.8 | 37.472 | 35.993 | 2.938 | 3 | 101.8 | 4 | 96.7 |
| K 766.491 | 579.9 | 573.916 | 563.117 | 10.598 | 10 | 99 | 1.9 | 100.2 |
| Mg 279.078 | 1058.6 | 1042.15 | 1022.54 | 2.974 | 2 | 98.4 | 1.9 | 96.6 |
| Mn 257.610 | 40.39 | 40.955 | 40.316 | 0.238 | 0.2 | 101.4 | 1.6 | 98.5 |
| Mo 203.846 | 45.6 | 45.991 | 43.85 | 0.044 |  | 100.9 | 4.8 |  |
| Na 589.592 | 3137 | 2911.38 | 2859.63 | 5.829 | 3 | 92.8 | 1.8 | 97.3 |
| Ni 231.604 | 25.32 | 24.24 | 24.058 | 0.51 | 0.5 | 95.7 | 0.8 | 97.2 |
| P 214.914 |  | 47.423 | 58.729 | 5.933 | 5 |  |  | 117.7 |
| Pb 220.353 | 12.101 | 13.404 | 13.04 | 1.01 | 1 | 110.8 | 2.8 | 99.7 |
| Sb 206.834 | 5.105 | 5.71 | 5.237 | 0.004 |  | 111.9 | 8.6 |  |
| Se 196.026 | 20.13 | 23.159 | 20.121 | 1.912 | 2 | 115 | 14 | 94.4 |
| Sr 421.552 | 126.03 | 127.037 | 124.371 | 0.315 | 0.2 | 100.8 | 2.1 | 94 |
| Tl 190.794 | 1.619 | 1.839 | 1.846 | 1.977 |  | 113.6 | 0.4 |  |
| V 292.401 | 15.05 | 15.101 | 14.542 | 0.309 | 0.3 | 100.3 | 3.8 | 98 |
| Zn 213.857 | 55.64 | 56.157 | 55.004 | 0.256 | 0.2 | 100.9 | 2.1 | 99.9 |

**Table 10.** Trace elements in certified waste water results.
Sample source: High Purity Standards, PO box 41727 Charleston SC. 29423 USA
Cat # CWW-TM-C.

| Element | Spec µg /L | Found | Dup | QC spike | Spike level | % rec LCS | RPD dup % | % spike rec |
|---|---|---|---|---|---|---|---|---|
| Al | 0.5 | 0.535 | 0.545 | 2.553 | 2 | 107.0 | 1.9 | 100.9 |
| Sb | 0.15 | 0.137 | 0.141 | 0.136 | 0 | 91.3 | 2.9 | n/a |
| As | 0.15 | 0.143 | 0.146 | 0.914 | 0.8 | 95.3 | 2.1 | 96.4 |
| Ba | 0.5 | 0.48 | 0.492 | 0.673 | 0.2 | 96.0 | 2.5 | 96.5 |
| Be | 0.15 | 0.14 | 0.144 | 0.331 | 0.2 | 93.3 | 2.8 | 95.5 |
| B | 0.5 | 0.513 | 0.52 | 0.84 | 0.3 | 102.6 | 1.4 | 109.0 |
| Cd | 0.15 | 0.146 | 0.149 | 0.341 | 0.2 | 97.3 | 2.0 | 97.5 |
| Cr | 0.5 | 0.476 | 0.485 | 0.86 | 0.4 | 95.2 | 1.9 | 96.0 |
| Co | 0.5 | 0.478 | 0.487 | 0.668 | 0.2 | 95.6 | 1.9 | 95.0 |
| Cu | 0.5 | 0.494 | 0.502 | 0.789 | 0.3 | 98.8 | 1.6 | 98.3 |
| Fe | 0.5 | 0.486 | 0.495 | 3.374 | 3 | 97.2 | 1.8 | 96.3 |
| Pb | 0.5 | 0.487 | 0.496 | 1.443 | 1 | 97.4 | 1.8 | 95.6 |
| Mn | 0.5 | 0.49 | 0.492 | 0.674 | 0.2 | 98.0 | 0.4 | 92.0 |
| Mo | 0.5 | 0.469 | 0.481 | 0.471 | 0 | 93.8 | 2.5 | n/a |
| Ni | 0.5 | 0.477 | 0.49 | 0.952 | 0.5 | 95.4 | 2.7 | 95.0 |
| Se | 0.15 | 0.151 | 0.149 | 2.051 | 2 | 100.7 | 1.3 | 95.0 |
| Ag | 0.15 | 0.144 | 0.148 | 0.211 | 0.075 | 96.0 | 2.7 | 89.3 |
| Sr | 0.5 | 0.481 | 0.492 | 0.673 | 0.2 | 96.2 | 2.3 | 96.0 |
| Tl | 0.15 | 0.145 | 0.149 | 2.101 | 2 | 96.7 | 2.7 | 97.8 |
| V | 0.5 | 0.48 | 0.49 | 0.77 | 0.3 | 96.0 | 2.1 | 96.7 |
| Zn | 0.5 | 0.498 | 0.509 | 0.696 | 0.2 | 99.6 | 2.2 | 99.0 |

## Conclusion

Using the Agilent SVS 2 with an Agilent 720 Series axially viewed ICP-OES resulted in more than a doubling of sample throughput — from approximately 210 seconds[2] per sample without the SVS 2 to 68 seconds per sample using the SVS 2. Even with the improvement in productivity, analytical performance was maintained. Stability during a six hour period was better than 2% for all elements and detection limits exceeded the requirements of the US EPA.

As the tubing does not make contact with peristaltic pump tubing prior to being aspirated into the plasma, the inert sample path results in reduced sample carry-over.

## References

1. D. Hoobin and E. Vanclay, Ultra-fast ICP OES determinations of soil and plant material using next generation sample introduction technology.

2. S. Bridger and M. Knowles, A complete method for environmental samples by simultaneous axially viewed ICP-OES following US EPA guidelines.

**www.agilent.com/chem**

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