Application Note

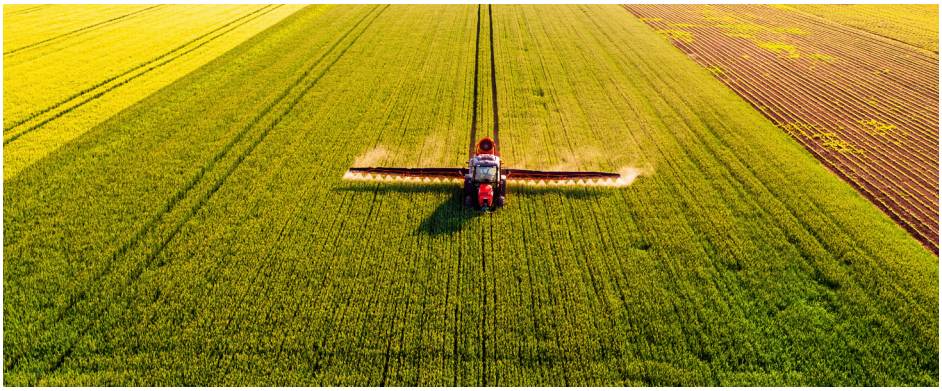
Food and agriculture

Agilent

Trusted Answers

Determination of 21 Elements in Fertilizers using Autodilution with ICP-OES

Automated analysis of multinutrient fertilizers by Agilent 5800 VDV ICP-OES and ADS 2 autodilutor



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Introduction

Crop production relies heavily on fertilizers to achieve high yields, maintain soil fertility, and support sustainable agricultural practices. Fertilizers typically contain high concentrations of essential macronutrients like nitrogen (N), phosphorus (P), and potassium (K), plus lower levels of secondary and micronutrients. In addition to these beneficial elements, fertilizers may also contain contaminants such as heavy metals introduced during manufacturing or from raw materials. To ensure product efficacy, safety, and regulatory compliance, multiple nutrients and potential contaminants must be accurately measured. However, the number of analytes, concentration range, and sample-to-sample variability present significant analytical challenges for laboratories requiring robust, high-throughput, and accurate quantitative methods.

Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) is a powerful technique that is widely used for the simultaneous analysis of multiple elements in complex sample matrices like fertilizers.[1,2] Traditional workflows, however, often require manual preparation of calibration standards and tailored sample dilutions, processes that are time-consuming, error-prone, and can introduce contamination. Modern automation technologies such as the Agilent Advanced Dilution System (ADS 2) simplify the analysis, freeing analysts to focus on more productive tasks.[3,4] Also, by enabling automatic, reactive dilutions based on sample concentration, the ADS 2 avoids manual intervention, reduces consumable usage, and improves data quality. Some key features of the ADS 2 include:

- **Autocalibration:** Automatic generation of calibration curves from one or more stock solutions. This feature significantly reduces time spent on standard preparation, minimizes waste of single-use consumables, and lowers the risk of human error, simplifying the workflow and improving data reliability.
- **Prescriptive dilutions:** Automatic dilution of solutions or samples by a known (prescribed) dilution factor before analysis. This feature is useful in labs where routine dilutions occur, eliminating a time-consuming manual step from daily workflows.
- **Reactive dilutions:** Automatic real-time dilution of overrange samples that exceed calibration limits. This feature eliminates the need for manual dilutions or rework after the analysis, allowing greater flexibility and efficiency within a single method.
- **Summary Row:** A smart software feature that selects and displays the best measurement from multiple iterations, while retaining access to all underlying data. This feature streamlines data review and significantly reduces the time spent on manual processing and reporting.

In this study, the Agilent 5800 Vertical Dual View (VDV) ICP-OES with ADS 2 autodilutor was used to determine 21 elements in multinutrient fertilizers. The elements included aluminum, arsenic, boron, calcium, cadmium, cobalt, chromium, copper, iron, potassium, magnesium, manganese, molybdenum, sodium, nickel, phosphorus, lead, sulfur, selenium, vanadium, and zinc.

Experimental

Instrumentation

The Agilent 5800 VDV ICP-OES was configured with the integrated Agilent Advanced Switching Valve (AVS 7), ADS 2 autodilutor, and Agilent SPS 4 autosampler (Figure 1). The AVS and ADS 2 operate seamlessly together to enhance sample throughput, reduce turnaround time, and lower cost-per-sample. The ADS 2 enabled automated, precise preparation of calibration standards and sample dilutions, minimizing analyst workload and consumables use. Importantly, its integration with the AVS 7 ensures that no additional time is added when dilution is not required, overcoming a common limitation of other dilution systems. The SPS 4 autosampler provided automated sample delivery to the instrument. The 5800 ICP-OES was equipped with a SeaSpray nebulizer, double-pass cyclonic spray chamber, and Agilent semi-demountable VDV torch with a 1.8 mm id injector. All components were controlled by the Agilent ICP Expert Pro software[5] (the ADS 2 is compatible with ICP Expert software version 7.7 or later). Automated Fitted Background Correction (FBC) was selected for background correction of each analyte.[6]

Figure 1. Agilent 5800 VDV ICP-OES with integrated AVS 7, Agilent ADS 2 autodilutor, and Agilent SPS 4 autosampler.

Table 1. Agilent AVS 7 and ADS 2 operating parameters.

Parameter	Setting
Sample Loop Size (mL)*	1.0
Reactive Dilution Rinse Time (s)	10
Pump Rate – Uptake (mL/min)	35
Pump Rate – Inject (mL/min)	5
Valve Uptake Delay (s)	15
Bubble Injection Time (s)	1.5
Pre-emptive Rinse Time (s)	1

*Both the AVS 7 and ADS 2 loops are the same size.

Table 2. Agilent 5800 VDV ICP-OES instrument and method parameters.

Parameter	Setting	
Viewing Mode	Axial	Radial
Viewing Height (mm)	-	8
RF Power (kW)	1.3	
Nebulizer Flow (L/min)	0.7	
Plasma Flow (L/min)	12	
Aux Flow (L/min)	1.0	
Replicates	3	
Rinse Time (s)	0	
Read Time (s)	5	
Stabilization Time (s)	10	3
Sample Pump Tubing	White/white	
Internal Standard Pump Tubing	Orange/white	
Waste Pump Tubing	Blue/blue	
Internal Standard	Y 371.029 nm	
Background Correction	Fitted	

Standard preparation

A multi-element standard containing all 21 elements was prepared at 10 mg/L. To prepare calibration standards for all elements from 0 to 10 mg/L, the 10 mg/L solution was diluted by the ADS 2 system at 100x, 10x, and 1x using 12% reverse aqua regia (RAR). The NIST 695 Trace Elements in Multi-Nutrient Fertilizer standard reference material (SRM, NIST, Gaithersburg MD, USA) contains some elements at higher concentrations. To accommodate these elements in the method, two additional standards were prepared for selected elements at 100 mg/L and 500 or 1000 mg/L. In total, three standard solutions were prepared and the final calibration ranges for each analyte are detailed in Table 4.

It is important to note that analysts do not always need to calibrate up to 500 or 1000 mg/L. A lower autocalibrated range such as 0 to 10 mg/L can be sufficient if the application allows for larger sample dilutions. The ADS 2 system, in combination with the ICP Expert software, can automatically dilute high-concentration samples as needed, ensuring they fall within the calibrated range.

For quality control (QC), a 12% RAR solution was used as the continuing calibration blank (CCB). A separate continuing calibration verification (CCV) solution was prepared using Agilent Quality Control Standard 27, supplemented with an Agilent majors solution and single-element spikes for phosphorus and sulfur. This CCV solution contained 50 mg/L Ca, Fe, K, Mg, Na, P, and S, and 5 mg/L of the remaining analytes.

An internal standard (IS) solution of 5 mg/L yttrium (Y) in 12% RAR was prepared using an Agilent single-element standard. The IS was used to correct any matrix effects and ionization interferences that may arise during the analysis.

Sample preparation

The fertilizer SRM and three commercially available multinutrient fertilizers were selected for analysis. Sample 1 was a fast-release liquid-based fertilizer, sample 2 was a slow-release granular fertilizer, and sample 3 was an inorganic trace element powdered fertilizer. The SRM was dried according to manufacturer instructions before digestion using a MARS 6 Microwave Digestion System (CEM Corporation, Matthews, NC, USA). All samples were prepared using the microwave digestion method outlined in AOAC 2017.02.[7] A 0.5 g portion of each sample was accurately weighed into a digestion vessel, followed by the addition of 9 mL HNO_3 and 3 mL HCl. Digestion was performed using the microwave program specified in Table 3. Spiked samples were prepared by adding a known spike volume before digestion.

After digestion, samples were transferred to volumetric flasks and diluted to 100 mL with de-ionized water. Duplicate digestions were performed for each sample. The final matrix for all samples was 12% RAR. The solutions were then transferred to 50 mL autosampler tubes for analysis.

Table 3. Microwave digestion system parameters.

Parameter	Setting
Maximum Power (W)	1800
Temperature (°C)	200
Ramp Time (min)	25
Hold Time (min)	10

Method development: Optimization tools

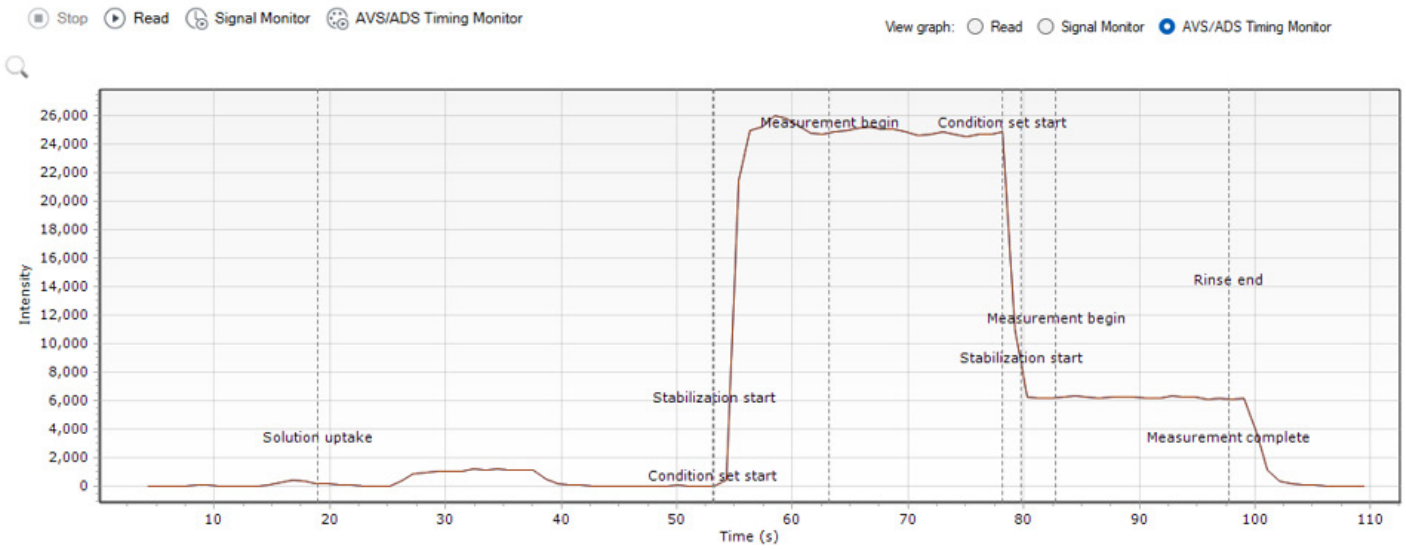

Figure 2. Demonstration of the ADS/AVS timing monitor for Cr 267.716, an optimization and diagnostic feature within the Agilent ICP Expert software.

The ADS/AVS Timing Monitor is an optimization and diagnostic feature within the ICP Expert software that helps analysts optimize measurement timing and AVS/ADS 2 system parameters for best performance. It provides a clear visual breakdown of each step in the measurement process, allowing users to fine-tune settings and verify that the system is operating correctly.[4] Traditionally, analysts would rely on trial and error to determine suitable timing parameters for their setup. The timing monitor removes this guesswork, saving time and enabling users to focus on more critical tasks.

In this study, a wavelength calibration solution containing analytes at 5 mg/L was run, allowing optimization of timings based upon tubing length and loop size. For example, the software indicated that 10 s was required for the solution to reach the nebulizer and stabilize, demonstrating that a stabilization time of 10 s was sufficient compared to the default setting of 15 s. By optimizing each of the timing parameters, a total of 11.5 s was saved for each sample. Instrument settings are shown in Tables 1 and 2.

Automatic calibration standards with ADS 2

To streamline the calibration process, three of the five calibration standards used in this study were automatically prepared from a single stock solution using the autocalibration feature of the ADS 2 and ICP Expert software. The system automatically diluted the 10 mg/L stock solution at predefined factors (100x, 10x, and 1x) to generate a calibration curve (Figure 3). To optimize cost and resource usage, the remaining two calibration standards were prepared manually to accommodate higher concentration ranges. These standards targeted major elements present in fertilizer samples and were formulated separately to avoid the expense of creating a high-concentration stock solution containing all analytes.

Autocalibration	Solution Label	Dilution Factor	Al	As	B	Ca	Cd	Co	Cr	Cu	Fe
	Blank		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
☑	Standard 1	100	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
☑	Standard 2	10	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
☑	Standard 3	1	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
☐	Standard 4		100.0			100.0					100.0
☐	Standard 5					500.0					500.0

Figure 3. Autocalibration setup in the Agilent ICP Expert software for the Agilent ADS 2 autodilutor.

Automatic dilutions and result summaries

Fertilizer samples often exhibit wide variability in elemental composition, with some elements present at trace levels and others at high concentrations. This variability poses a challenge for consistent and accurate analysis, especially when using a fixed calibration range. For example, in this study, sulfur was present at ppm levels in one sample, while exceeding 10% in another. Traditionally, analysts either diluted high-concentration samples manually or created separate calibration curves tailored to each sample type, both time-consuming and resource-intensive procedures.

Using the ADS 2 autodilutor, analysts can set a dilution factor before analysis using the 'prescriptive dilution' feature, perfect for routine labs that have a good understanding of analyte concentration in their samples. But in cases where the required dilution factor is unknown, analysts can also use 'reactive dilution', a feature that automatically adjusts sample concentration based on real-time measurement feedback. If a sample exceeds the calibration range or IS recovery range, the ICP Expert software calculates and applies an appropriate dilution factor to bring the analytes within user-defined thresholds.

An example for sulfur is shown in Figure 4, Solution Label "Dilution – 5". The original measurement of sulfur (579 ppm) exceeded the calibration range, so was automatically diluted 5x by the ADS 2 and remeasured. Reactive dilution occurs without any manual intervention, enabling a single method to handle diverse samples without prescreening or reworking, improving throughput and consistency.

To complement reactive dilution, the Summary Row feature in the ICP Expert software provides a streamlined view of the results. When multiple measurements are taken, such as initial and post-dilution readings, the software automatically selects and displays the most reliable result under the "Summary" header (Figure 4, Solution Label "Summary"). All underlying data are retained, ensuring full traceability while reducing the need for manual data review. This feature improves reporting efficiency and gives analysts confidence in the integrity of the final dataset.

These features make the ADS 2 and ICP Expert software ideal for high-throughput fertilizer analysis, where speed, accuracy, and flexibility are essential.

	Rack:Tube	Solution Label	Timestamp	Pb 220.353 nm ppm	S 180.669 nm ppm
▼	1:10	Sample 2	6/25/2025 11:38:19 AM	0.030	658.545
☑	1:10	Summary	6/25/2025 11:38:19 AM	0.030	658.545
☐	1:10	Original	6/25/2025 11:36:42 AM	0.030	579.326 o
☐	1:10	Dilution - 5	6/25/2025 11:38:19 AM	0.007	131.709

Figure 4. An example of the Agilent ADS 2 performing a reactive dilution of a sample to meet the calibration range requirement for sulfur. The Summary Row selected the best measurement result for each wavelength. The original measurement result was used for Pb 220.353 nm (0.030 ppm), retaining sensitivity, while the 5x diluted measurement result of 658.545 ppm (corrected for the dilution factor) was reported for S 180.669 nm.

Results and discussion

Autocalibration and linearity

As shown in Table 4, 21 elements were calibrated from 0 to 10 mg/L, 0 to 100 mg/L, or 0 to 500 or 1000 mg/L using both auto and manual calibration. The software reported that the calibration error for all wavelengths was below the 10% default threshold, indicating a good linear fit. Correlation coefficients between 0.99988 and 1.00000 for all elements further confirmed the linearity of the calibration curves over the range. A representative spectrum and calibration curve for Mo 202.032 nm is shown in Figure 5.

Method Detection Limits

Method detection limits (MDLs) were determined by analyzing 10 blank solutions (12% RAR) three times over three non-consecutive days using the 5800 VDV ICP-OES with ADS 2 autodilution system. This protocol was then repeated on a second instrument, giving a total of six data sets (n=6) for the MDL calculation. The MDLs were calculated as three times the standard deviation of all blank solution measurements. The six runs were then averaged to produce the MDL of the diluted solution. The dilution factor was applied to give an MDL of elements in-sample, as shown in Table 4.

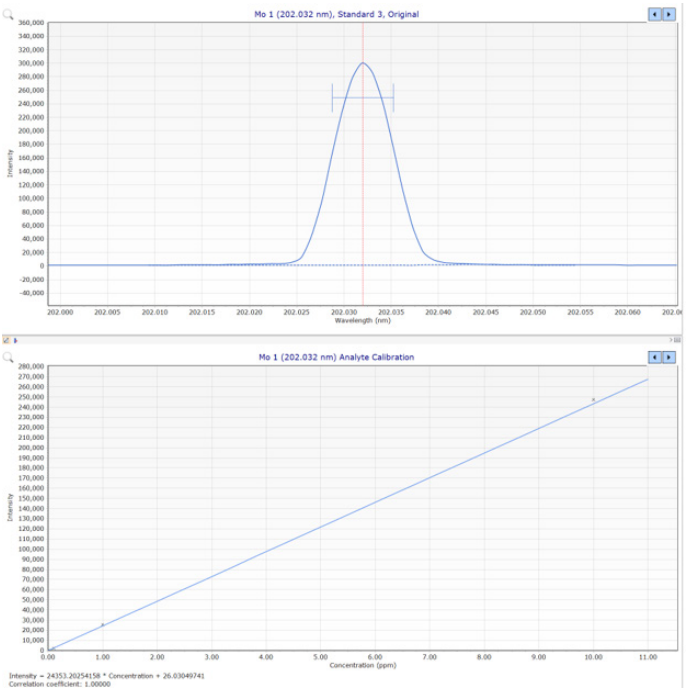

Figure 5. A representative analyte (Mo 202.032 nm) spectrum obtained using automatic Fitted Background Correction (top) and linear calibration curve with a correlation coefficient of 1.00000 (bottom).

Table 4. Analyte calibration information and method detection limits (MDLs) in solution and in-sample.

Element and Wavelength (nm)	Viewing Mode	Calibration Range (mg/L)	Correlation Coefficient	MDL in Solution (mg/L)	MDL in Sample (mg/kg)
Al 396.152	Axial	0 – 100	0.99999	0.00166	0.332
As 188.980	Axial	0 – 10	1.00000	0.00437	0.874
B 249.772	Axial	0 – 10	1.00000	0.00235	0.471
Ca 422.673	Radial	0 – 100	0.99999	0.0122	2.43
Cd 214.439	Axial	0 – 10	0.99999	0.000235	0.0469
Co 230.786	Axial	0 – 10	0.99999	0.000677	0.135
Cr 267.716	Axial	0 – 10	0.99999	0.000439	0.0878
Cu 327.395	Axial	0 – 10	1.00000	0.000448	0.0896
Fe 259.940	Radial	0 – 500	0.99988	0.00196	0.393
K 766.491	Radial	0 – 1000	0.99999	0.199	39.7
Mg 285.213	Radial	0 – 100	0.99998	0.00149	0.298
Mn 260.568	Axial	0 – 100	0.99995	0.000294	0.0588
Mo 202.032	Axial	0 – 10	1.00000	0.000709	0.142
Na 588.995	Radial	0 – 100	0.99998	0.203	40.5
Ni 216.555	Axial	0 – 10	0.99999	0.00122	0.245
P 213.618	Radial	0 – 500	1.00000	0.0140	2.79
Pb 220.353	Axial	0 – 10	0.99999	0.00225	0.450
S 180.669	Axial	0 – 500	0.99990	0.00828	1.66
Se 196.026	Axial	0 – 10	1.00000	0.00952	1.90
V 292.401	Axial	0 – 10	1.00000	0.000751	0.150
Zn 213.857	Radial	0 – 100	0.99995	0.00106	0.212

Table 5. Results of undiluted and 10x diluted measurements (corrected for dilution) of NIST 695 fertilizer SRM, n=3.

Element and Wavelength (nm)	Certified Value (mg/kg)	Undiluted Value (mg/kg)	Undiluted Recovery (%)	10x Diluted Value (mg/kg)	10x Diluted Recovery (%)
Al 396.152	6100	5603	92	5551	91
As 188.980	200	201	100	202	101
B 249.772	1110	1132	102	1142	103
Ca 422.673	22600	21748	96	22842	101
Cd 214.439	16.9	17.4	103	17.8	105
Co 230.786	65.3	60.9	93	63.0	96
Cr 267.716	244	229	94	236	97
Cu 327.395	1225	1279	104	1274	104
Fe 259.940	39900	38519	97	39947	100
K 766.491	116500	109447	94	113150	97
Mg 285.213	17900	16232	91	16939	95
Mn 260.568	3050	2953	97	3030	99
Mo 202.032	20	19.0	95	19.4	97
Na 588.995	4050	3871	96	4011	99
Ni 216.555	135	132	97	135	100
P 213.618	72000	73971	103	74962	104
Pb 220.353	273	264	97	273	100
S 180.669	-	45675	-	46286	-
Se 196.026	2.1	2.24	107	<MDL	-
V 292.401	122	122	100	124	101
Zn 213.857	3250	3141	97	3207	99

SRM analysis

The NIST 695 fertilizer SRM was analyzed three times using the 5800 VDV ICP-OES with ADS 2: two measurements were performed on undiluted samples, and one following a 10x dilution using the autodilutor's prescriptive dilution feature. Table 5 shows the certified values, the mean of the two undiluted results, the 10x diluted result, and recoveries. All measured elements fell within 100 ± 10% of the certified values, demonstrating strong agreement between the undiluted and diluted samples and confirming the method's accuracy across the calibration range.

Spike recovery test and sample analysis

Table 6 shows results from the analysis of spiked fertilizer sample 1 using the 5800 VDV ICP-OES with the ADS 2. The sample was spiked pre-digestion with all elements at 0.5 mg/L, except K and Na, which were spiked at 10 and 5 mg/L, respectively. The unspiked and spiked fertilizer samples were analyzed in triplicate. The tabulated results represent the average of the three measurements before application of the dilution factor and therefore reflect the concentrations in the analytical solution, not the original sample.

All spiked recoveries were within 100 ± 10% of the expected concentrations. These spike recovery results demonstrate the accuracy of the method for detecting analytes at lower levels than those found in the fertilizer SRM or in fertilizer samples 2 and 3 (Table 7).

This high level of accuracy across both low and elevated concentrations highlights the robustness and versatility of the 5800 VDV ICP-OES. The ADS 2 effectively extends the system's linear dynamic range (LDR) with precise autodilution and calibration. This capability ensures reliable quantification across a broad concentration spectrum, making the system ideal for the analysis of complex matrices such as fertilizers.

Table 6. Spiked sample 1 (liquid fertilizer) results, before dilution correction, n=3.

Element and Wavelength (nm)	Sample 1 Concentration (mg/L)	Spike Concentration (mg/L)	Spiked Sample 1 Concentration (mg/L)	Recovery (%)
Al 396.152	0.152	0.500	0.690	108
As 188.980	0.0217	0.500	0.535	103
B 249.772	0.0277	0.500	0.555	106
Ca 422.673	1.32	0.500	1.82	98
Cd 214.439	<MDL	0.500	0.522	104
Co 230.786	<MDL	0.500	0.515	103
Cr 267.716	<MDL	0.500	0.515	103
Cu 327.395	<MDL	0.500	0.518	104
Fe 259.940	0.145	0.500	0.656	102
K 766.491	85.6	10.0	96.1	105
Mg 285.213	1.07	0.500	1.55	96
Mn 257.610	0.00531	0.500	0.529	105
Mo 202.032	<MDL	0.500	0.487	97
Na 588.995	14.3	5.00	19.7	107
Ni 216.555	0.00282	0.500	0.514	102
P 213.618	0.588	0.500	1.09	100
Pb 220.353	<MDL	0.500	0.509	102
S 180.669	2.05	0.500	4.65	94
Se 196.026	<MDL	0.500	0.523	104
V 292.401	<MDL	0.500	0.519	104
Zn 213.857	0.0138	0.500	0.522	102

Quantitative results for all three commercially available fertilizer samples are shown in Table 7. The overrange concentration of certain analytes, such as sulfur in sample 2, triggered the ADS 2 to perform a reactive 5x dilution, avoiding the need for manual dilution and remeasurement. The reported values reflect the sample concentrations after applying the dilution factor, so representing the original sample matrix rather than the undiluted analytical solution.

Table 7. Quantitative results of three different fertilizer samples, after dilution correction, n=3.

Element and Wavelength (nm)	Sample 1 (Liquid Fertilizer) Concentration (mg/kg)	Sample 2 (Granular Fertilizer) Concentration (mg/kg)	Sample 3 (Trace Element Powder) Concentration (mg/kg)
Al 396.152	30.3	361	664
As 188.980	4.34	2.28	3.91
B 249.772	5.55	1298	79.6
Ca 422.673	265	99347	7959
Cd 214.439	<MDL	1.67	0.459
Co 230.786	<MDL	57.7	3.15
Cr 267.716	<MDL	10.4	20.9
Cu 327.395	<MDL	10742	1328
Fe 259.940	28.9	40810	10042
K 766.491	17113	629	62849
Mg 285.213	214	63898	18038
Mn 257.610	1.06	32495	3028
Mo 202.032	<MDL	<MDL	18.8
Na 588.995	2867	7128	1341
Ni 216.555	0.564	96.4	12.4
P 213.618	118	114	12184
Pb 220.353	<MDL	6.61	6.48
S 180.669	836	131709	93591
Se 196.026	<MDL	19.5	0.898
V 292.401	<MDL	2.81	6.57
Zn 213.857	2.76	15968	1395

Long-term stability

To assess the stability of the 5800 VDV ICP-OES and ADS 2, 482 solution measurements were taken over nine hours without recalibration. The solutions consisted of various digested samples in 12% RAR and a QC block, which comprised the CCB and CCV solution at 50 mg/L of Ca, Fe, K, Mg, Na, P, and S, and 5 mg/L of remaining elements. The ADS 2 performed a 10x dilution on each QC, bringing the final concentration to 5 and 0.5 mg/L, respectively, demonstrating the reproducibility of the dilution.

The plot of the CCV recoveries (Figure 6) shows the stability of all elements to be within 100 ± 5% over the entire analytical run, which included an autodilution on each QC before each measurement. The recovery and precision (%RSDs of less than 3.5%) data demonstrate the robustness of the 5800 VDV ICP-OES and ADS 2 for the analysis of fertilizer samples over nine hours.

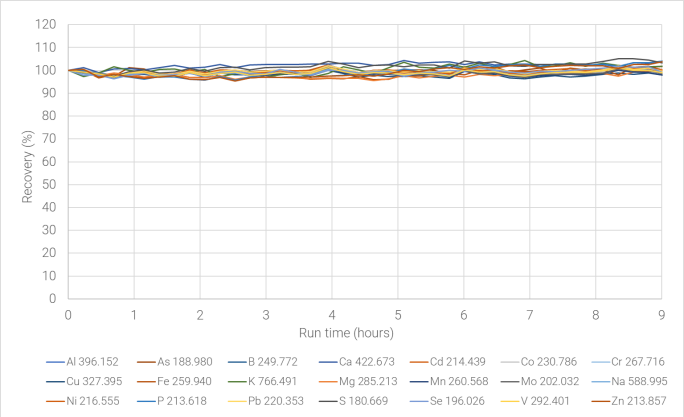

Figure 6. Percent recovery of QC solutions measured over nine hours, with no analyte exceeding 100 ± 5%.

Conclusion

The Agilent 5800 VDV ICP-OES paired with the Agilent ADS 2 autodilutor enabled the fast, high-throughput, multi-elemental analysis of fertilizer samples. The accurate quantification of 21 major and trace elements in microwave-digested fertilizer samples was assisted by the following features of the ADS 2:

- **Autocalibration:** Calibration standards from 0 to 10 mg/L were automatically prepared from a single stock solution, minimizing manual preparation and ensuring consistent, accurate calibration across the range. Additional higher concentration standards were used for selected elements.
- **Prescriptive dilutions:** Automatic dilution of solutions were performed using a known (prescribed) dilution factor before analysis, removing time-consuming and error-prone manual dilutions of the SRM samples.
- **Reactive dilution:** Overrange analyte concentrations in two fertilizer samples triggered dynamic, real-time dilution, eliminating the need for prescreening or manual intervention. This reactive dilution capability streamlined the workflow.
- **Summary Row:** The software feature automatically selected and displayed the most reliable results from multiple measurements of each fertilizer sample, simplifying data review while maintaining full traceability.

The automated-ICP-OES method produced high-quality results, with MDLs below 1 mg/kg for most elements. Accuracy was excellent, with all recoveries for both NIST 695 fertilizer SRM and spiked fertilizer samples falling within 100 ± 10% of expected values. The method also demonstrated excellent stability and robustness over nine hours. Following a 10x automatic prescriptive dilution of each QC using the ADS 2, recoveries ranged from 95 to 105%, with %RSDs below 3.5% for all elements, demonstrating the reproducibility of the autodilutor.

This study confirms the suitability of the 5800 VDV ICP-OES for quantifying major, minor, and trace nutrients, as well as contaminant elements, in three commercial fertilizers—supporting regulatory compliance and product quality assurance. Productivity of the method was further enhanced by the ADS 2, which minimized manual handling and reduced the risk of errors during standard and sample preparation.

References

1. Rapid Multi-Elemental Analysis of Fertilizers using the Agilent 5110 VDV ICP-OES, Agilent publication, 5994-0600EN
2. Elemental Analysis of Animal Feed and Fertilizers Produced From Insects, Agilent publication, 5994-7487EN
3. ICP-OES Automation Systems, https://www.agilent.com/en/product/atomic-spectroscopy/atomic-spectroscopy-automation/automation-systems/icp-oes-automation-systems (accessed September 2025)
4. Capabilities and Operation of the Advanced Dilution System 2, Agilent publication, 5994-7211EN
5. Agilent ICP Expert Software: Powerful software with smart tools for ICP-OES, Agilent publication, 5994-1517EN
6. Fitted Background Correction (FBC): Fast, accurate and fully automated background correction, Agilent publication, 5991-4836EN
7. AOAC Official Method 2017.02 Arsenic, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Magnesium, Manganese, Molybdenum, Nickel, Selenium, and Zinc in Fertilizers, AOAC International, 2017, http://www.aoacofficialmethod.org/index.php?main_page=product_info&products_id=3002 (accessed September 2025)

Products used in this application

Agilent products

Description	Part Number
Easy-fit 1.8 mm semi-demountable torch for 5000 series VDV/SVDV ICP-OES	G8020-68005
Double-pass spray chamber, glass cyclonic design with ball joint socket and UniFit drain outlet, for Agilent 5000 series ICP-OES	G8010-60256
SeaSpray concentric glass nebulizer for 5000 series ICP-OES	G8010-60255
Peristaltic pump tubing, white/white, 12/pk	3710034400
Peristaltic pump tubing, orange/white, 12/pk	3710046900
Peristaltic pump tubing, blue/blue, 12/pk	3710034600
Diluent/carrier bottle kit for ADS 2 and Autosampler (6L HDPE)	5005-0435
Waste container kit, 10L with Stay Safe cap and filter	5005-0437
Agilent Multi-element Quality Control Standard 27	5190-9418
Agilent Calibration Mix Majors for AA and ICP-OES	6610030700
Agilent ICP-OES wavelength calibration solution, 500 mL	6610030100
Agilent 10,000 ppm single element stock solution for Al, 500 mL	5190-8353
Agilent 1000 ppm single element stock solution for As, 500 mL	5190-8247
Agilent 1000 ppm single element stock solution for B, 500 mL	5190-8255
Agilent 10,000 ppm single element stock solution for Ca, 500 mL	5190-8369
Agilent 1000 ppm single element stock solution for Cd, 500 mL	5190-8328
Agilent 1000 ppm single element stock solution for Co, 500 mL	5190-8347
Agilent 1000 ppm single element stock solution for Cr, 500 mL	5190-8345
Agilent 1000 ppm single element stock solution for Cu, 500 mL	5190-8349
Agilent 10,000 ppm single element stock solution for Fe, 500 mL	5190-8403
Agilent 10,000 ppm single element stock solution for K, 500 mL	5190-8433
Agilent 10,000 ppm single element stock solution for Mg, 500 mL	5190-8413
Agilent 10,000 ppm single element stock solution for Mn, 500 mL	5190-8415
Agilent 1000 ppm single element stock solution for Mo, 500 mL	5190-8488
Agilent 10,000 ppm single element stock solution for Na, 500 mL	5190-8206
Agilent 1000 ppm single element stock solution for Ni, 500 mL	5190-8492
Agilent 10,000 ppm single element stock solution for P, 500 mL	5190-8429
Agilent 1000 ppm single element stock solution for Pb, 500 mL	5190-8476
Agilent 10,000 ppm single element stock solution for S, 500 mL	5190-8210
Agilent 1000 ppm single element stock solution for Se, 500 mL	5190-8520
Agilent 1000 ppm single element stock solution for V, 500 mL	5190-8552
Agilent 1000 ppm single element stock solution for Y, 500 mL	5190-8556
Agilent 10,000 ppm single element stock solution for Zn, 500 mL	5190-8235

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