Evaluating the performance of the OneNeb Series 2 Nebulizer with PerkinElmer Optima 7/8x00 Series ICP-OES systems

Competitive Comparison

Figure 1. The Agilent OneNeb Series 2 nebulizer improves performance compared to conventional glass concentric and inert nebulizers used with PerkinElmer Optima ICP-OES instruments.

Introduction

The Agilent OneNeb nebulizer is a novel nebulizer design that offers superior performance compared to other commercially available concentric nebulizers used with ICP-OES instruments. This universal nebulizer provides improved sensitivity, greater tolerance to dissolved salts, and is inert so it is suitable for use with strong acids such as hydrofluoric acid (HF) and most common organic solvents. An evaluation of the OneNeb nebulizer performance has been described previously[1].

This novel nebulizer uses flow blurring technology[2,3] to create the aerosol, rather than the traditional venturi effect. This technology creates a fine aerosol with a narrow droplet size distribution, where most droplets are < 10 µm in diameter. This narrow distribution enhances nebulizer efficiency, as there are fewer transport losses. Flow blurring also ensures efficient operation over a much wider range of flow rates. The fine aerosol is more efficiently desolvated and excited in the plasma, which helps to improve precision. Typical precision achieved using the OneNeb is less than 1 % RSD, even at low sample flow rates.

Agilent has introduced the second-generation OneNeb nebulizer. The OneNeb Series 2 nebulizer retains its predecessor's performance enhancements, and features an improved design, including a removable sample capillary allowing replacement of the sample inlet capillary as required. To improve ease of use, the sample capillary has a thicker wall to reduce kinking when connecting to the peristaltic pump tubing. The OneNeb Series 2 is manufactured from EFTE (ethylene tetrafluoroethylene), which ensures a smoother surface finish for improved wash-out performance and improved robustness.

This Competitive Comparison evaluates the performance of the OneNeb Series 2 nebulizer relative to conventional glass concentric and inert nebulizers recommended by PerkinElmer for use with the Optima Series ICP-OES systems. This study demonstrates the superior performance of the OneNeb Series 2, with up to four times greater sensitivity, improved detection limits, and improved reproducibility, especially with challenging samples such as those with high levels of dissolved solids.

Agilent Technologies

Experimental

Tests

The nebulizers selected for this study included a selection of nebulizers recommended by PerkinElmer for use with the Optima Series ICP-OES instrument. The recommended nebulizer varies, depending on the sample matrix. The nebulizers tested included:

- Agilent OneNeb Series 2: For the PerkinElmer Optima Series ICP-OES systems (p/n 8003-0951)
- Meinhard Type A: Recommended for aqueous solutions and samples with <1 % dissolved solids
- Meinhard Type C: The standard nebulizer used with the Optima 2/4/7x00 Series ICP-OES systems and recommended for samples that have higher levels of dissolved solids
- PerkinElmer high solids GemCone: A low flow nebulizer recommended for samples with up to 20 % dissolved solids
- PerkinElmer GemTip Cross Flow II: Recommended for routine use with strong acids and up to 5 % dissolved solids (with capability to handle high levels of dissolved solids for short periods)

The performance of the Agilent OneNeb Series 2 was evaluated against the nebulizers listed using various sample matrices and test solutions. Nebulizer performance was assessed by comparing instrument response (emission intensity), precision, and measured detection limits. The tests, the pass/fail criteria, and the test solutions used in this study were based on recommendations from PerkinElmer's instrument installation and commissioning documentation for the Optima Series ICP-OES instruments[4,5]. Testing was also completed using solutions prepared in organic solvents, and samples that had high levels of Total Dissolved Solids (TDS). However, there are no defined acceptance criteria or specifications for these matrices in the PerkinElmer documentation.

The performance tests used, and the reason those tests are important is outlined:

- **Sensitivity (emission intensity) test**: Characterizes differences in instrument response between the different nebulizers.
- **Detection limit test**: A different measurement of sensitivity. This test defines the lowest concentration that can be measured with a known degree of certainty (usually 99 %). This test also takes account of the noise level in the measurement and possible random variations from repeated measurements.
- **Precision test**: Characterizes the variation in repeated measurements for the same sample. This variation is influenced by many factors including the fluctuations from nebulization and sample transport into the plasma.
- **Washout or memory test**: Characterizes the washout performance of the sample introduction system, allowing identification of the potential for memory effects, and sets the minimum rinse time required between samples.
- **Long-term stability test**: This test was performed using a sample with higher levels of dissolved solids, and characterizes the nebulizers resistance to blockage and its stability for repeated measurements.

Instrumentation

Two different PerkinElmer Optima ICP-OES instruments were used during this study, an Optima 7300 DV and an Optima 8000 DV. Both instruments provide capability for sequential dual view measurement (axial first, then radial in a separate subsequent measurement).

Instrumental operating conditions were optimized according to the test and nebulizer used. The operating conditions used for each test are outlined in each section.

Reagents and supplies

All performance tests examined in this study were completed using Agilent supplies for the PerkinElmer Optima Series ICP-OES instruments for example, torch, injector, spray chamber, and so forth. The only exception was for the nebulizers, which were either Agilent OneNeb Series 2, Meinhard (Type A/C), or PerkinElmer (GemCone and GemTip). Agilent supplies for PerkinElmer instruments are guaranteed to be fully compatible with the equipment for which they are specified. These supplies are designed and manufactured to meet critical specifications set by Agilent engineers to ensure optimal fit and performance with PerkinElmer instruments.

The Mixed Calibration Standard for PerkinElmer ICP-OES (p/n 5190-9413) was used for the performance tests with an aqueous matrix. The elemental composition of this CRM matches the test solution recommended by PerkinElmer for qualification and commissioning of the PerkinElmer Optima ICP-OES instrument (equivalent to PerkinElmer p/n N0691579). This Agilent CRM contains 50 mg/L of As and K; 10 mg/L of La, Li, Mn, Ni, Sr and Zn; and 1 mg/L of Ba and Mg in a 2 % nitric acid (HNO_3) matrix. This solution was used for all performance tests in radial view. A 1:10 dilution of this solution with 2 % nitric acid in de-ionized water was used for the performance tests performed in axial view.

For the performance tests in a high TDS matrix, the elemental content was identical, but the test solution was prepared in a 5 % NaCl/2 % HNO_3 matrix. These test solutions were prepared from Agilent aqueous single element certified reference materials.

The performance tests performed using an organic matrix were prepared from Agilent metallo-organic certified reference materials, base oils, and solvents.

Determining the optimum nebulizer gas flow

The nebulizer gas flow required to achieve optimum sensitivity varies with each nebulizer, and is dictated by the nebulizer design. To ensure a valid performance comparison, the optimum gas flow for each nebulizer was determined, and the performance tests were completed using the optimum gas flow. The optimum gas flow rate for each nebulizer was determined by measuring the emission intensity for manganese (Mn) while aspirating a 5 mg/L solution prepared in 2 % HNO_3, and varying the nebulizer gas flow. Table 1 lists other instrument conditions used for this test.

The experiment was repeated three times for each nebulizer. Figure 2 shows the variation in emission intensity with the nebulizer gas flow, which is based on the average of the three separate measurements.

The optimum nebulizer gas flow rate was selected by looking for the best combination of emission intensity and precision (% RSD). Table 2 lists the optimum nebulizer flow rates for each of the nebulizers used for this study.

Table 1. Instrument operating conditions used when determining the optimum nebulizer gas flow.

Instrument parameters	
PE Optima 8000 DV	
Power	1,450 W
Plasma gas flow	15 L/min
Auxiliary gas flow	0.5 L/min
Nebulizer gas flow	Variable
Replicates	5
Integration time	1–10 seconds (Auto)
Int type/points	Area/3 points
Spray chamber	Scott (Ryton)
Sample flow	1.5 mL/min
Peristaltic pump tubing	Black-Black PVC for sample and Blue-Blue PVC for waste
Test sample	5 mg/L Mn in 2 % HNO_3

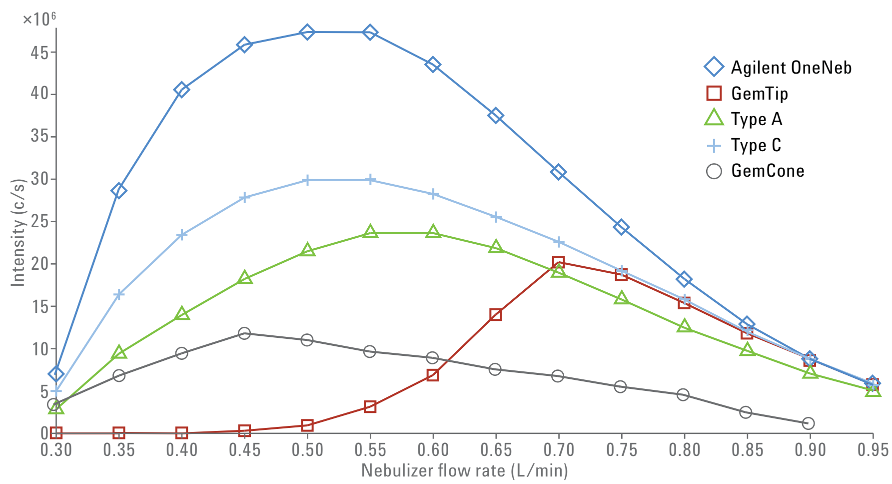


Figure 2. Sensitivity response curves for the nebulizers included in this study, measured on a PerkinElmer Optima 8000 DV ICP-OES instrument.

Table 2. Optimum nebulizer gas flow rate for the nebulizers included in this study.

Nebulizer type	Optimum nebulizer gas flow rate (L/min)
Agilent OneNeb Series 2	0.55
PE GemTip Cross Flow II	0.70
Meinhard Type A	0.60
Meinhard Type C	0.65
PE high solids GemCone	0.55

Results and discussion

Detection limits, sensitivity, and precision in aqueous matrix

The detection limit tests were performed in both axial and radial views according to PerkinElmer's instrument installation and commissioning documentation for the Optima ICP-OES instruments. The detection limit was calculated as a three-sigma value (that is, three times the standard deviation) based on the concentration of 10 replicates with the indicated read time. Table 3 lists the instrument conditions used for this test.

As shown in Tables 4 and 5, the OneNeb Series 2 nebulizer used with the PerkinElmer Optima 8000 DV ICP-OES instrument met PerkinElmer's instrument performance specification. It also produced the lowest detection limits of all the nebulizers tested, in both axial and radial views.

Table 3. Instrument operating conditions used for the sensitivity, detection limit and precision tests.

Instrument conditions		
Instrument	PE Optima 8000 DV	
Power	1,500 W	
Plasma gas flow	15 L/min	
Auxiliary gas flow	0.5 L/min	
Torch injector	Alumina 2.0 mm id	
Nebulizer gas flow	Optimum flow used as defined in Table 2	
Replicates	10	
Read time	DL and sensitivity tests Precision test	20–50 s Axial; 20–20 s Radial 1-5 s Axial
Spray chamber	Baffled glass cyclonic spray chamber	
Sample flow	1.5 mL/min	
Peristaltic pump tubing	Black-Black PVC for sample and Blue-Blue PVC for waste	

Table 4. Measured axial detection limits in a 2 % HNO_3 matrix.

Element and wavelength (nm)	Agilent OneNeb µg/L	Meinhard A µg/L	Meinhard C µg/L	GemCone µg/L	PE Specification µg/L
Tl 190.801	0.25	1.33	1.12	2.21	≤10
As 193.696	0.50	3.06	2.72	6.35	≤10
Se 196.026	0.56	2.47	2.11	2.30	≤5
Pb 220.353	0.18	1.45	1.26	3.35	≤3

Table 5. Measured radial detection limits in a 2 % HNO_3 matrix.

Element and wavelength (nm)	Agilent OneNeb µg/L	Meinhard A µg/L	Meinhard C µg/L	GemCone µg/L	PE Specification µg/L
As 193.696	1.243	5.940	6.540	5.359	≤60
Zn 213.856	0.108	0.287	1.328	0.467	≤2
Mn 257.610	0.014	0.667	0.370	2.511	≤1
La 379.478	0.052	0.284	0.202	0.309	≤3
Ba 455.403	0.003	0.010	0.015	0.232	≤0.3
Ba 493.408	0.020	0.033	0.017	0.123	≤0.6

The sensitivity test characterizes differences in instrument response (emission intensity) between the different nebulizers for the same group of elements used for the detection limits test. The same calibration data generated for the detection limit test was used for the sensitivity test. Figures 3 and 4 show the results of the sensitivity test in both axial and radial views. Due to variations in emission intensity for different elements, the test results are shown in relative intensity units so all elements can be viewed on same graph.

The superior efficiency and sensitivity of the OneNeb Series 2 nebulizer is evident when comparing the instrument response in both radial and axial views. The difference in instrument response using the OneNeb can be up to four times larger than that of its nearest competitor.

The precision test was performed in axial view using the test method outlined in the PerkinElmer documentation. The precision values are calculated as the relative standard deviation (RSD) based on the intensity for 20 replicates (1–5 seconds read time) of the same solution. For this test, the PerkinElmer specification is that the precision for all elements must be less than 1 %, under the conditions listed in Table 3.

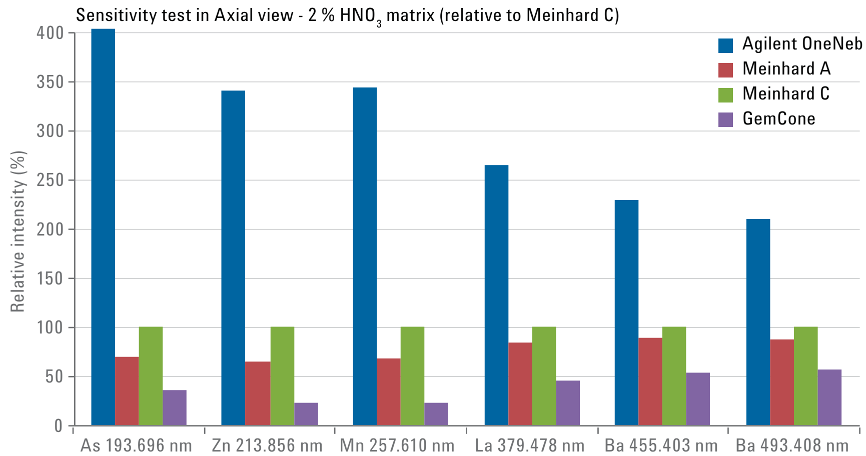


Figure 3. Comparison of instrument sensitivity achieved for the different nebulizers tested using the PerkinElmer Optima 8000 DV ICP-OES in axial view using a 2 % HNO_3 matrix. Results shown relative to the sensitivity achieved for the Meinhard C nebulizer.

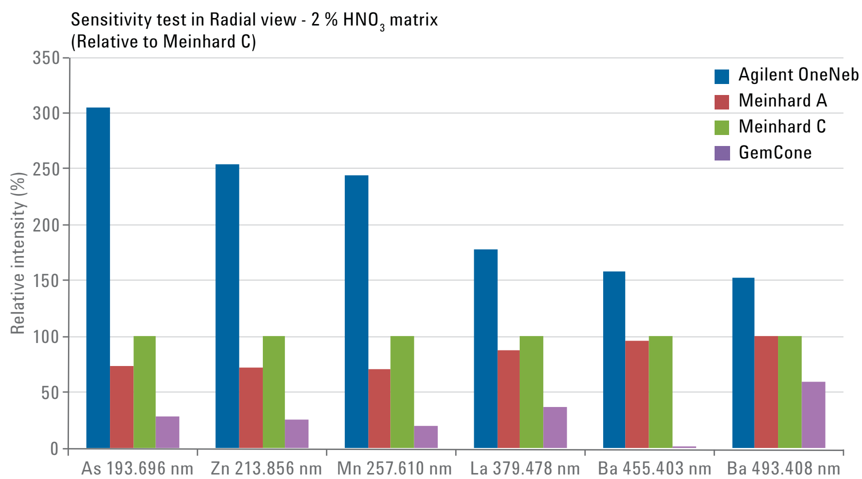
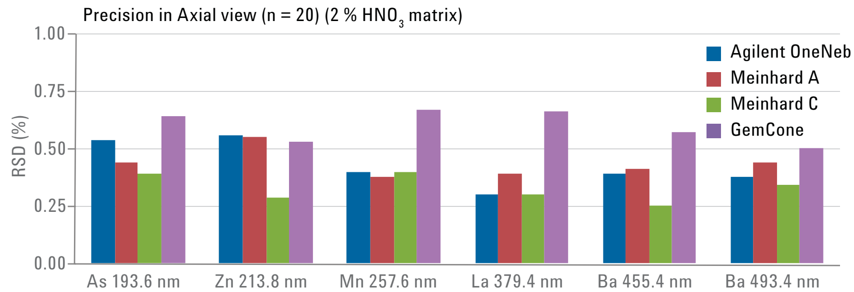


Figure 4. Comparison of instrument sensitivity achieved for the different nebulizers tested using the PerkinElmer Optima 8000 DV ICP-OES in radial view using a 2 % HNO_3 matrix. Results shown relative to the sensitivity achieved for the Meinhard C nebulizer.

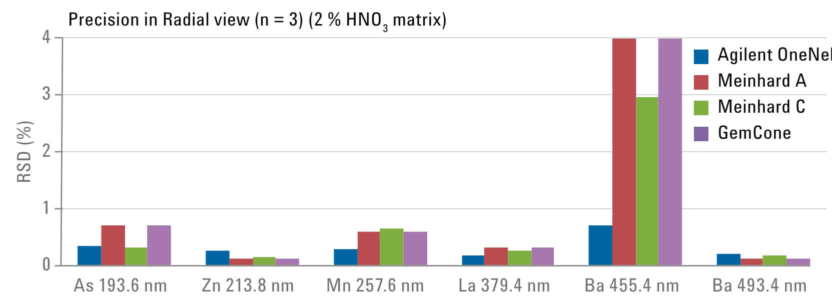
Although PerkinElmer has not published a specification for the precision test in radial view, the test was performed using three replicates with a 10 seconds read time. Figures 5 and 6 show the results.

When used with the PerkinElmer Optima 8000 DV ICP-OES, the OneNeb Series 2 nebulizer achieved PerkinElmer's specification of ≤1 % RSD. These results are comparable with, and sometimes better than, those results obtained with the other nebulizers tested.



OneNeb	0.54	0.56	0.40	0.30	0.39	0.38
Meinhard A	0.44	0.55	0.38	0.39	0.41	0.44
Meinhard C	0.39	0.29	0.40	0.30	0.25	0.34
GemCone	0.64	0.53	0.67	0.66	0.57	0.50

Figure 5. Comparison of precision (% RSD) achieved for the different nebulizers tested using the PerkinElmer Optima 8000 DV ICP-OES in axial view using a 2 % HNO_3 matrix (PerkinElmer specification ≤1 % RSD).



OneNeb	0.35	0.27	0.28	0.17	0.71	0.21
Meinhard A	0.70	0.12	0.59	0.31	4.00	0.13
Meinhard C	0.31	0.16	0.65	0.26	2.96	0.19
GemCone	0.70	0.12	0.59	0.31	4.00	0.13

Figure 6. Comparison of precision (% RSD) achieved for the different nebulizers tested using the PerkinElmer Optima 8000 DV ICP-OES in radial view using a 2 % HNO_3 matrix. There is no PerkinElmer specification for this test.

Detection limits, sensitivity, precision, and long-term stability in a high TDS matrix

As a further test of performance, a more challenging sample with higher TDS levels was selected. The same group of tests were repeated using a 5 % NaCl solution prepared in a 2 % HNO_3 matrix. Table 6 shows the instrument conditions. Tables 7 and 8 show the test results.

Even analyzing challenging samples, with high TDS, the OneNeb Series 2 nebulizer with the PerkinElmer Optima 7300 DV ICP-OES achieved better (lower) detection limits than the PerkinElmer nebulizers in both axial and radial views. Although PerkinElmer has not published a specification for the detection limit test for this matrix, the specification for a 2 % HNO_3 matrix is listed for reference purposes.

Table 6. Instrument operating conditions used for the sensitivity, detection limit and precision tests with the high TDS matrix.

Instrument conditions	
Instrument	PE Optima DV 7300
Power	1,500 W
Plasma gas flow	15 L/min
Auxiliary gas flow	1.0 L/min
Nebulizer gas flow	Optimum flow used as defined in Table 2
Replicates	10
Read time	DL and sensitivity tests 20–50 seconds Axial; 20–20 seconds Radial Precision test 1–5 seconds Axial
Spray chamber	Scott (Ryton)
Sample flow	1.5 mL/min (1 mL/min for long-term stability test)
Peristaltic pump tubing	Black-Black PVC for sample Blue-Blue PVC for waste

Table 7. Measured axial detection limits using a high TDS sample of 5 % NaCl in a 2 % HNO_3 matrix.

Element and wavelength (nm)	Agilent OneNeb µg/L	GemCone µg/L	GemTip µg/L	PE Specification* µg/L
Tl 190.800	4.3	14.4	14.0	≤10
As 193.696	1.4	14.3	13.8	≤10
Se 196.026	5.7	25.4	22.3	≤5
Pb 220.353	2.8	7.7	4.5	≤3

*Only for reference purposes

Table 8. Measured radial detection limits using a high TDS sample of 5 % NaCl in a 2 % HNO_3 matrix.

Element and wavelength (nm)	Agilent OneNeb µg/L	GemCone µg/L	GemTip µg/L	PE Specification* µg/L
As 193.696	32.3	158	42.8	≤60
Zn 213.856	1.6	7.5	6.2	≤2
Mn 257.610	0.56	0.89	0.79	≤1
La 379.478	1.8	5.5	2.7	≤3
Ba 455.403	0.14	0.59	0.20	≤0.3
Ba 493.408	0.29	1.23	0.79	≤0.6

*Only for reference purposes

The sensitivity test was also performed using this high TDS sample matrix. The results of the test are also expressed in relative intensity units. Figures 7 and 8 show the results of the sensitivity test in both axial and radial views.

Even with this challenging, high TDS level sample, the OneNeb Series 2 nebulizer provided superior efficiency and sensitivity when comparing the instrument response in both radial and axial views. The difference in instrument response using the OneNeb can be up to almost three times larger than its nearest competitor.

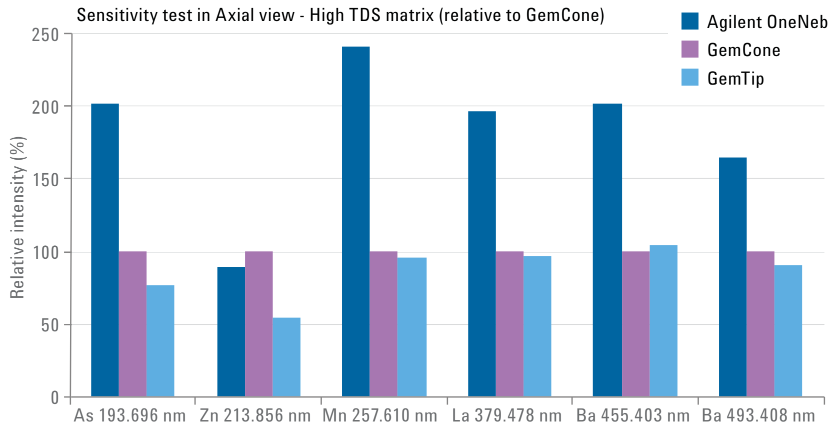


Figure 7. Comparison of instrument sensitivity achieved for the different nebulizers tested using the PerkinElmer Optima 8000 DV ICP-OES, performed in axial view using a high TDS sample of 5 % NaCl in a 2 % HNO_3 matrix. Results shown relative to the sensitivity achieved for the GemCone nebulizer.

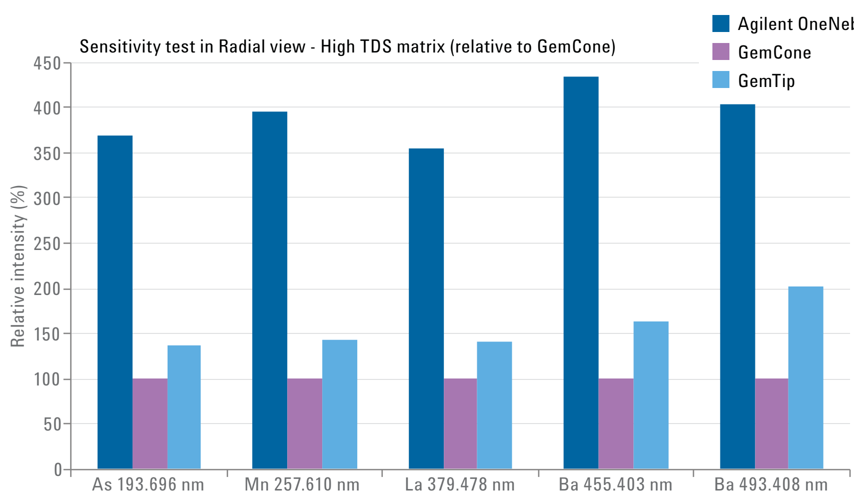


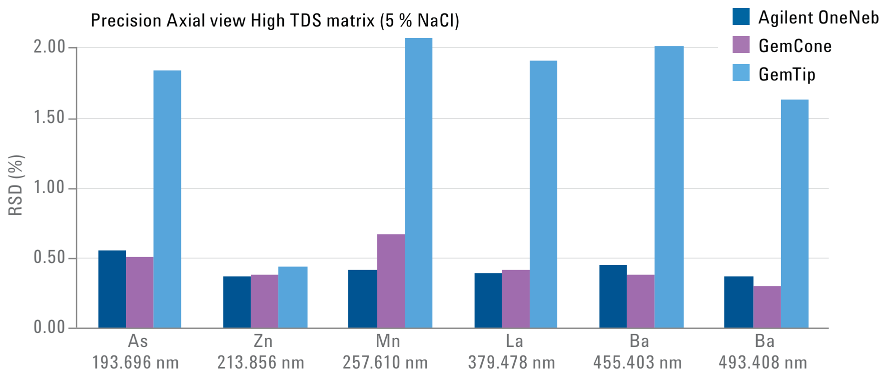
Figure 8. Comparison of instrument sensitivity achieved for the different nebulizers tested using the PerkinElmer Optima 8000 DV ICP-OES, performed in radial view using a high TDS sample of 5 % NaCl in a 2 % HNO_3 matrix. Results shown relative to the sensitivity achieved for the GemCone nebulizer.

The precision test was also performed with the high TDS sample in axial view using the test method outlined in the PerkinElmer documentation. The precision values are calculated as the RSD based on the intensity for 20 replicates (1–5 seconds read time) of the same solution. For this type of matrix, PerkinElmer has not published a specification for the expected precision. Figures 9 and 10 show the results.

When equipped with the OneNeb Series 2 nebulizer, the PerkinElmer Optima 7300 DV ICP-OES was able to meet the precision specification values for a simple aqueous solution, even with this challenging high TDS sample.

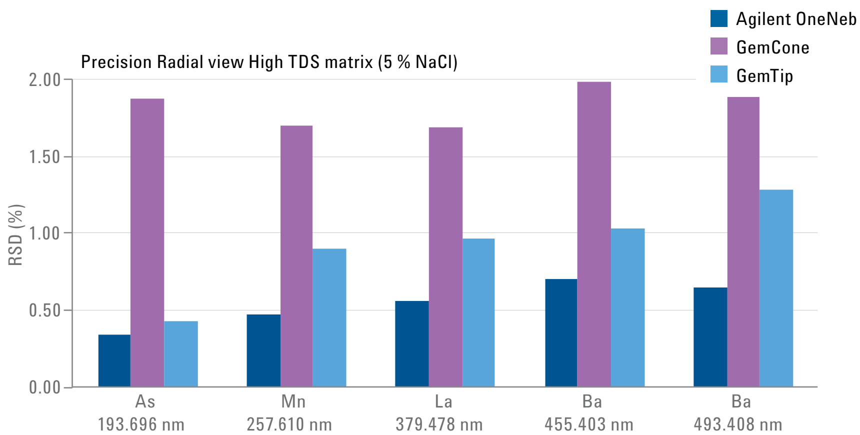
A long-term stability test was also completed to assess the potential for nebulizer blockage, and assess the long-term measurement precision with this high TDS sample. For this test, the high TDS sample of 5 % NaCl in a 2 % HNO_3 matrix was measured repeatedly over an eight-hour period. A solution of 5 mg/L yttrium in a 2 % HNO_3 matrix was used as internal standard. This test simulated a typical working shift.

For this type of sample with high TDS levels, PerkinElmer recommends use of the GemCone nebulizer. Therefore, this long-term stability test with the high TDS sample was only completed for the OneNeb and the GemCone nebulizers. The Agilent argon saturator accessory (p/n G8488A #100) was used throughout this long-term stability test to humidify the nebulizer gas flow. This accessory helps reduce salt deposition in the nebulizer tip, reducing the risk of nebulizer blockage, and enhancing the long-term precision.



OneNeb	0.55	0.37	0.41	0.39	0.45	0.37
GemCone	0.51	0.38	0.67	0.41	0.38	0.30
GemTip	1.84	0.44	2.07	1.91	2.01	1.63

Figure 9. Comparison of precision (%RSD) achieved for the different nebulizers tested using the PerkinElmer Optima 8000 DV ICP-OES, performed in axial view using a high TDS sample of 5 % NaCl in a 2 % HNO_3 matrix. There is no PerkinElmer specification for this test.



OneNeb	0.34	0.47	0.56	0.70	0.65
GemCone	1.88	1.70	1.69	1.99	1.89
GemTip	0.43	0.90	0.97	1.03	1.29

Figure 10. Comparison of precision (%RSD) achieved for the different nebulizers tested using the PerkinElmer Optima 8000 DV ICP-OES, performed in radial view using a high TDS sample of 5 % NaCl in a 2 % HNO_3 matrix. There is no PerkinElmer specification for this test.

The OneNeb Series 2 nebulizer demonstrated superior performance and long-term stability coupled with higher sensitivity and better detection limits than the GemCone nebulizer. Figures 11 and 12 show the long-term measurement of a high TDS sample of 5 % NaCl in 2 % HNO_3.

Table 9. Instrument operating conditions used for the long-term stability study with the high TDS matrix

Instrument conditions	
Instrument	PE Optima 7300 DV
Power	1,500 W
Plasma gas flow	15.0 L/min
Auxiliary gas flow	1.0 L/min
Nebulizer gas flow	OneNeb 0.20 L/min GemCone 0.55 L/min
Replicates	5
Read time	1–5 seconds
Spray chamber	Baffled glass cyclonic spray chamber
Rinse time	120 seconds (at 0.80 L/min)
Sample flow	1.5 m L/min
Peristaltic pump tubing	Black-Black PVC for sample Red-Red PVC for waste
Internal standard	5 mg/L yttrium (Y) in 2 % HNO_3

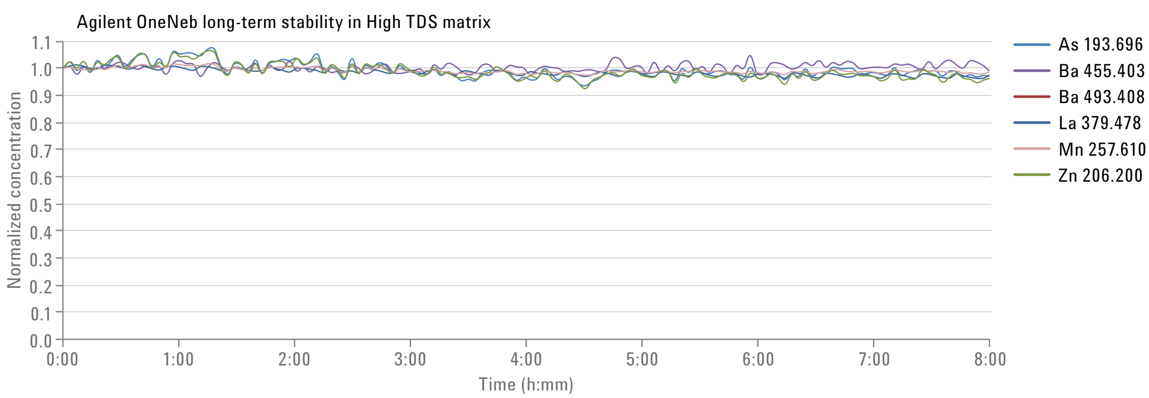


Figure 11. Long-term stability test for the Agilent OneNeb Series 2 nebulizer with the PerkinElmer Optima 7300 DV ICP-OES using a high TDS sample of 5 % NaCl in a 2 % HNO_3 matrix.

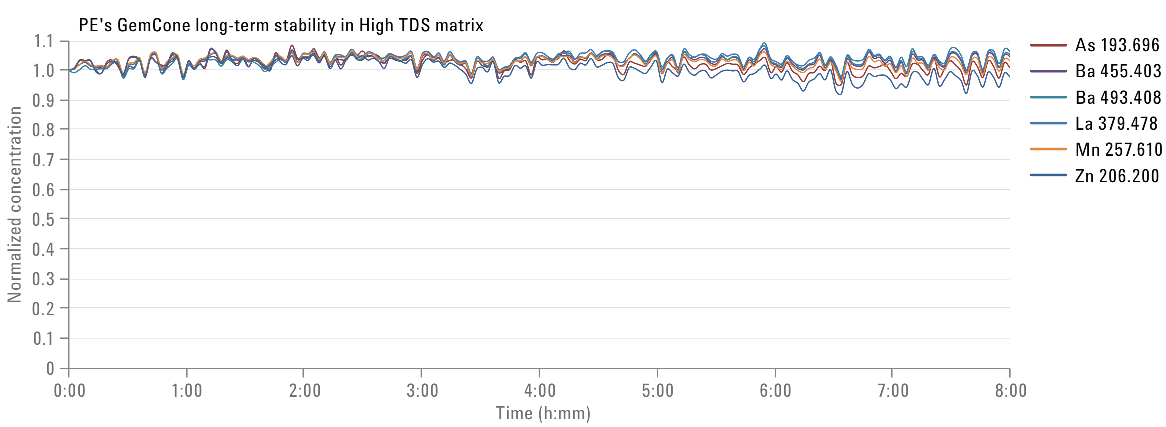


Figure 12. Long-term stability test for the PerkinElmer GemCone nebulizer with the PerkinElmer Optima 7300 DV ICP-OES using a high TDS sample of 5 % NaCl in a 2 % HNO_3 matrix.

Detection limits, sensitivity, and precision in an organic matrix

The chemical resistance, versatility, and excellent performance of the OneNeb nebulizer has been demonstrated in the analysis of challenging organic-based samples with Agilent instruments[6]. Elemental determination of used and unused lubricating oils using ASTM D4951 and D5185 methods is a typical application employing organic matrices. It is considered a challenging application due to the suspended solids usually present in this type of sample. For this reason, PerkinElmer recommends using the GemCone nebulizer[7].

As a further test of performance, the same group of tests were repeated for the GemCone and OneNeb nebulizers using an Agilent multielement metallo-organic standard, prepared in the Agilent A-Solv proprietary solvent (a kerosene-type matrix). Table 10 shows the instrument conditions, and Tables 11 and 12 show the test results. There are no PerkinElmer defined instrument specifications for these tests in an organic matrix.

Even analyzing challenging samples, in organic solvents, the OneNeb Series 2 nebulizer with the PerkinElmer Optima 7300 DV ICP-OES achieved equivalent detection limit performance to the PerkinElmer GemCone nebulizer. These results demonstrate the versatility of the OneNeb which, unlike other nebulizers, can be used in a wide variety of analytical applications and samples in both aqueous and organic matrices.

Table 10. Instrument operating conditions used for the sensitivity, detection limit and precision tests with the metallo-organic standard prepared in the A-solv organic solvent.

Instrument conditions	
Instrument	PE Optima 7300 DV
Power	1,500 W
Plasma gas flow	15 L/min
Auxiliary gas flow	1.0 L/min GemCone 0.5 L/min OneNeb
Nebulizer gas flow	Optimum flow used as defined in Table 3
Replicates	5
Read time	1–5 seconds
View	Axial
Spray chamber	Baffled glass cyclonic spray chamber (4 mm baffle)
Injector	1.2 mm (alumina)
Sample flow	1.0 mL/min GemCone 1.5 mL/min OneNeb
Peristaltic pump tubing	Black-Black PVC Solvaflex for sample Blue-Blue PVC Solvaflex for waste
Sample	Agilent A21 wear metal standard (p/n 5190–8706) diluted 1:10 in Agilent A-Solv solvent (p/n 5190–8717)
Blank	Agilent base mineral oil (p/n 5190–8715) diluted 1:10 in A-Solv solvent
Internal standard	Co 5 mg/L diluted 1:10 in Agilent A-Solv solvent

Table 11. Measured axial detection limits using a wear metal standard prepared in an organic solvent.

Element and wavelength (nm)	Agilent OneNeb (µg/kg)	GemCone (µg/kg)
Ag 328.068	0.006	0.004
Al 396.153	0.09	0.08
B 249.677	0.02	0.01
Ba 233.527	0.006	0.004
Ca 317.933	0.13	0.01
Cd 228.802	0.02	0.01
Cr 267.716	0.008	0.005
Cu 327.393	0.005	0.004
Fe 238.204	0.008	0.004
K 766.490	0.15	0.13
Mg 285.213	0.018	0.002
Mn 257.610	0.003	0.001
Mo 202.031	0.02	0.02
Na 589.592	0.6	1.0
Pb 220.353	0.07	0.04
Si 251.611	0.03	0.01
Sn 189.927	0.12	0.06
Ti 334.940	0.005	0.003
V 290.880	0.005	0.005
Zn 206.200	0.02	0.01
Ni 341.476	0.09	0.09

Table 12. Comparison of precision (% RSD) achieved for the Agilent OneNeb and the GemCone nebulizers tested using the PerkinElmer Optima 7300 DV ICP-OES instrument in axial view using an organic-based sample. There is no PerkinElmer specification for this test.

Element and wavelength (nm)	Agilent OneNeb % RSD	GemCone % RSD
Ag 328.068	0.67	0.85
Al 396.153	0.68	0.74
B 249.677	0.78	0.94
Ba 233.527	0.85	0.84
Ca 317.933	0.94	0.90
Cd 228.802	0.61	0.56
Cr 267.716	0.86	0.87
Cu 327.393	0.72	0.90
Fe 238.204	0.94	0.83
K 766.490	1.06	1.30
Mg 285.213	0.64	0.81
Mn 257.610	0.84	0.84
Mo 202.031	0.57	0.57
Na 589.592	0.85	2.33
Pb 220.353	0.89	0.71
Si 251.611	0.76	0.55
Sn 189.927	0.84	0.51
Ti 334.940	1.13	1.48
V 290.880	0.76	0.95
Zn 206.200	0.81	0.61
Ni 341.476	0.77	0.46

The sensitivity test was also performed with the wear metal standard prepared in an organic solvent in axial view. The results of the test are also expressed in relative intensity units. Figure 13 shows the results of the sensitivity test performed with the OneNeb and the GemCone.

Even with this challenging organic-based sample, the OneNeb Series 2 nebulizer provided superior efficiency and sensitivity when comparing the instrument response in axial view. The difference in instrument response using the OneNeb can be up to 10 times larger than the PerkinElmer recommended nebulizer for this application.

The PerkinElmer Optima 7300 DV ICP-OES with the OneNeb Series 2 nebulizer met the precision specification values for a simple aqueous solution (<1 %), even with challenging organic-based samples. It is also noted that the precision achieved with the OneNeb is better than the precision achieved with the GemCone.

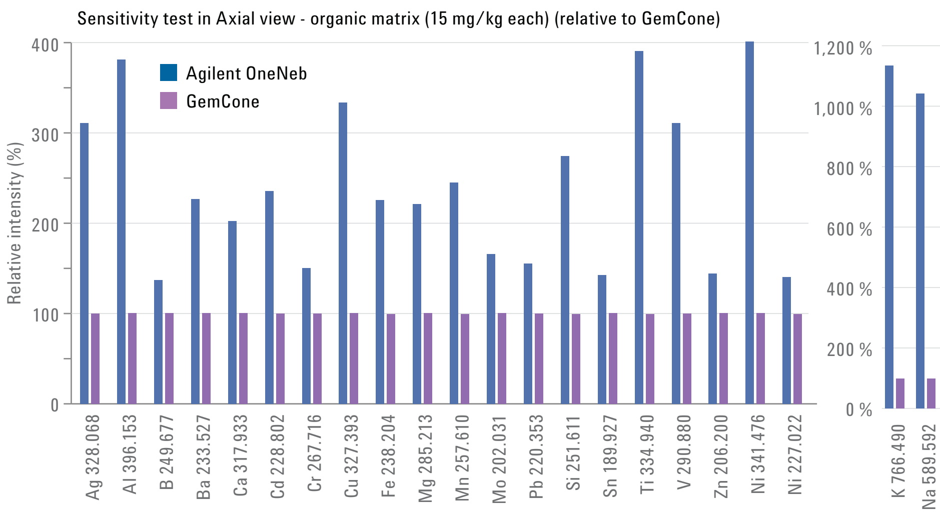


Figure 13. Instrument sensitivity achieved for the wear metal standard prepared in an organic solvent. Comparing the performance of the Agilent OneNeb Series 2 with the GemCone nebulizer using the PerkinElmer Optima 7300 DV ICP-OES instrument in axial view. Results shown relative to the sensitivity achieved for the GemCone nebulizer.

Washout test

The washout profiles were obtained by continuously monitoring the signal for manganese (Mn) at the 257 nm wavelength. A 100 mg/L manganese solution in 2 % nitric acid (washout test solution) was introduced and aspirated for 20 seconds, followed immediately by the blank solution. An Agilent SVS 1 Switching Valve was used to enable reproducible and timed switching between the washout test solution and the blank solution. For increased sensitivity, the test was performed in axial view. This test was performed using all nebulizers.

Equipped with the OneNeb Series 2 nebulizer, the PerkinElmer Optima 8000 DV ICP-OES instrument demonstrated exceptional performance, washing out four orders of magnitude to < 0.1 % baseline concentration faster than any of the other nebulizers. For some of the nebulizers tested, it can take up to 30 seconds longer before a stable baseline signal is achieved, indicating washout has been achieved. This time difference can represent a considerable loss of revenue in a busy laboratory. Most washout issues are due to dead volume within the nebulizer itself, typically where the sample line connects to the nebulizer. The design of the new sample capillary for the OneNeb Series 2 minimizes this dead volume. This ensures superior washout performance, especially when compared with the washout for the PerkinElmer GemTip and the Meinhard type C and K nebulizers.

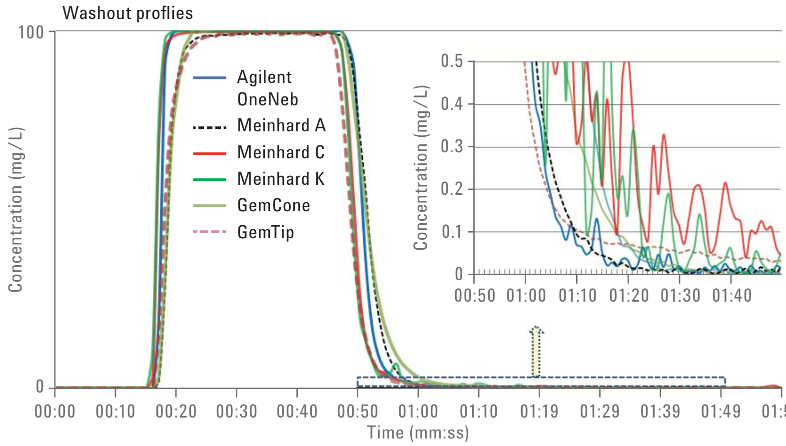


Figure 14. Washout profiles for the nebulizers included in this study, measured on a PerkinElmer Optima 8000 DV ICP-OES instrument.

Conclusions

The results of this study demonstrate the superior performance and versatility of the Agilent OneNeb Series 2 nebulizer when used with PerkinElmer Optima Series ICP-OES instruments. This nebulizer can replace different types of nebulizers typically required to analyze the broad range of samples examined with the ICP-OES technique. The flow blurring technology ensures high nebulization efficiency over a wide range of nebulizer gas flow rates and sample uptake rates. This nebulization efficiency enhances sensitivity with aqueous and high TDS samples, and organic solvents. The PerkinElmer Optima ICP-OES systems easily met PE's published precision and detection limit performance specifications when used with the OneNeb Series 2 nebulizer.

The detection limits achieved with organic solvents using the OneNeb Series 2 nebulizer proved superior to conventional concentric glass nebulizers recommended for use with the Optima ICP-OES. The OneNeb Series 2 nebulizer provided enhanced sensitivity, independent of the sample matrix. It also provided faster washout, which translates into higher sample throughput in the laboratory, and increased revenue.

The OneNeb Series 2 nebulizer with flow blurring technology has demonstrated enhanced tolerance to high TDS samples. As illustrated with repeated measurement of a sample with high TDS levels over 8 hours, the OneNeb Series 2 nebulizer delivered the best long-term stability and precision. Its performance was superior to the PE GemCone high solids nebulizer, a dedicated nebulizer recommended for high TDS samples.

The OneNeb Series 2 nebulizer is also flexible. Its inert construction provides excellent resistance to strong acids such as HF and organic solvents. It is also incredibly robust, so you are less likely to accidentally damage this nebulizer.

With all this capability in a single nebulizer, the OneNeb Series 2 nebulizer can simplify method development for novice users and enhance day-to-day operation. The OneNeb Series 2 nebulizer solves your nebulizer puzzle, it is the only nebulizer you need for your PE Optima ICP-OES instrument. The competitive price with flexible sample handling provides best performance with most sample types, and eliminates the need for different nebulizers for each sample type.

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