

Accurate Elemental Analysis of Drinking Water per Bureau of Indian Standards by ICP-MS

Fast, simple, compliant method using an Agilent 7850 ICP-MS and SPS 4 Autosampler



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Introduction

The provision of clean and safe drinking water from a dependable, uncontaminated supply is essential for public health. However, many freshwater sources are compromised by pollutants from domestic and industrial wastewater, as well as activities related to agriculture, mining, forestry, and construction. These contaminants can pose significant risks to human health. In recent years, heavy metals and other toxic elements have received significant attention in environmental investigations. In response to growing concerns about food and water safety, regulatory authorities in India, such as the Bureau of Indian Standards (BIS) and the Food Safety and Standards Authority of India (FSSAI), have established stringent regulations for drinking water analysis to ensure consumer safety.

In India, BIS plays a critical role in setting regulatory limits for drinking water quality.¹ The relevant BIS standards include:

- BIS 10500: Drinking water
- BIS 14543: Packaged drinking water (other than packaged natural mineral water)
- BIS 13428: Packaged natural mineral water

Recent amendments to the three BIS regulations now mandate the measurement of uranium with a maximum permissible limit of 0.03 mg/L, creating more stringent norms for drinking water quality.

Laboratories in India use various analytical techniques, including Flame Atomic Absorption Spectroscopy (FAAS), Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES), and Inductively Coupled Plasma Mass Spectrometry (ICP-MS), to analyze drinking water. The choice of technique often depends on the number of elements and the concentration range required for the analysis. With the inclusion of uranium in the list of elements specified by BIS regulations, and to ensure preparedness for future updates, ICP-MS is increasingly favored for water analyses. Advantages of ICP-MS include its high sensitivity, low detection limits, wide elemental coverage, and fast, multielement capabilities.

The Agilent 7850 ICP-MS provides drinking water testing laboratories with a comprehensive solution for analyzing multiple elements—including uranium—in drinking water, thereby fulfilling BIS mandatory requirements. A preset method assists the accurate and precise determination of 26 elements, including all 21 elements specified in the standards, in a quick, single run, enabling high sample throughput.

The 7850 ICP-MS uses Octopole Reaction System (ORS⁴) technology and optimized helium (He) collision mode to remove polyatomic ion interferences in routine applications.² He mode effectively separates polyatomic ions from analyte ions based on their kinetic energies. As polyatomic ions pass through the ORS⁴ containing helium gas, they collide more frequently with helium atoms due to their larger collision cross-sections than smaller analyte ions, losing more energy. Upon exiting the cell, the lower-energy polyatomic ions are rejected using kinetic energy discrimination (KED). Meanwhile, analyte ions retain sufficient energy to pass through the KED barrier to the quadrupole and detector. This process removes polyatomic ions from the ion beam, enabling more accurate results for all analytes using a single gas mode.

Operating the ORS⁴ in He KED mode ensures:

- Effective control of the most common spectral interferences
- Multi-element analysis of a wide range of samples³
- Simplified analysis of unknown samples
- Minimal analyte signal loss by reaction
- Fast screening and semiquantitative analysis using IntelliQuant

The 7850 also includes Agilent's Ultra High Matrix Introduction (UHMI) aerosol dilution technology as standard. UHMI further improves the already exceptional plasma robustness of the 7850, enabling the instrument to handle samples with percentage levels of total dissolved solids (TDS). UHMI was not required for the analysis of low-matrix drinking waters; however, it is a valuable tool for labs that analyze other environmental samples, such as surface and wastewater, soils, and sediments.

In this study, the 7850 ICP-MS was used to analyze 26 elements in various types of drinking water in accordance with the requirements of three different BIS standards. The samples included bottled drinking water, bottled natural mineral water, and tap water.

Experimental

Instrumentation

An Agilent 7850 ICP-MS with Agilent SPS 4 autosampler was used for all measurements. The ICP-MS was fitted with the standard sample introduction system, consisting of a MicroMist nebulizer, Scott-type spray chamber, and one-piece quartz torch with 2.5 mm id injector. The interface consisted of a nickel sampling cone and a nickel skimmer cone. All elements were measured using one set of He KED collision cell mode conditions. He KED ensures effective control of most background and matrix-based polyatomic interferences, such as ArO and ArCl.

The instrument was controlled using Agilent ICP-MS MassHunter software. The parameters listed in Table 1 were predefined in the low matrix preset method, while lens voltages were automatically optimized using the autotune feature.

Table 1. The Agilent 7850 ICP-MS operating parameters.

ICP-MS Parameters	Value
Plasma Mode	Low matrix
RF Power (W)	1550
Spray Chamber Temp (°C)	2.0
Sampling Depth (mm)	8.0
Nebulizer Gas Flow (L/min)	1.07
Lens Tune	Autotune
Helium Flow Rate (mL/min)	4.3
KED (V)	2

The shaded parameters are set automatically by the preset method.

Standard and sample preparation

All drinking water samples, calibration blank, and calibration standards were prepared in an acid matrix of 1% HNO₃ and 0.5% HCl on the day of the analysis. The addition of HCl ensures the long-term stability of elements such as Hg, Ag, Sn, Sb, and Mo.⁴

Calibration standards were prepared from Agilent standard solutions, including multi-element calibration standard (p/n 5183-4682), and single-element standards for mercury (p/n 5190-8485) and boron (p/n 5190-8566). B, Na, Mg, Fe, K, Ca were calibrated from 10.0 to 4000.0 µg/L; Hg was calibrated from 0.01 to 4.0 µg/L; Sr was calibrated from 0.1 to 400.0 µg/L; Cu, Zn, and Al were calibrated from 0.1 to 40.0 µg/L; and V, Cr, Mn, Co, Ni, As, Se, Mo, Ag, Cd, Sb, Ba, Pb, Th, and U were calibrated from 0.01 to 40.0 µg/L.

Rhodium (Rh), scandium (Sc), germanium (Ge), lutetium (Lu), and bismuth (Bi) were used as internal standards (ISTDs). Gold (Au) was also added to the internal standard mix to help stabilize mercury (Hg) in the solutions. The ISTD solution (1000 µg/L) was prepared using Agilent standards and mixed with the sample online using a tee connector.

The accuracy and precision of the method were assessed by analyzing NIST Traceable Standard Reference Material (SRM) of Trace Elements in Water 1643f (Gaithersburg, MD, USA).

Bottled drinking water (referred to as Type 1 water) and bottled natural mineral water (Type 2 water) were bought in a local supermarket and tap water (Type 3 water) was obtained from the municipal water supply. The samples (8 mL of water) were diluted 1.25x (acidified) with the 1% HNO₃ and 0.5% HCl diluent to a final volume of 10.0 mL. Ten different preparations of each sample were prepared.

To monitor drift throughout the analysis of the samples, two QC check solutions were prepared. Their concentration levels are listed in Table 5.

Results and discussion

Detection limits

During method development, data was collected for all 26 elements. The Instrument Detection Limits (IDLs) were calculated from the calibration graphs (3 x standard deviation (SD) of the concentration of calibration blanks), while the dilution-adjusted DLs take account of the dilution factor of 1.25x. The DLs reported in Table 2 are well below the maximum permissible limits (MPLs) specified in the three BIS standards, confirming the suitability of the 7850 ICP-MS for the determination of trace elements in drinking water.

Table 2. Calibration coefficient (R), IDLs, and dilution-adjusted IDLs for 26 elements using the Agilent 7850 ICP-MS. MPLs in drinking waters specified in BIS standards.

				BIS: 10500- 2012, updated 2023	BIS: 13428- 2024	BIS: 14543- 2024
Element	R	IDL, µg/L	IDL x 1.25, µg/L	Maximum Permissible Limits, µg/L		
11 B	0.9999	0.3890	0.4863	500	5000	5000
23 Na	0.9999	1.2101	1.5126	–	150000	200000
24 Mg	0.9998	0.1461	0.1826	30000	50000	30000
27 Al	0.9975	0.2254	0.2818	30	–	30
39 K	0.9999	4.5560	5.6950	–	–	–
43 Ca	1.0000	12.2700	15.3375	75000	100000	75000
51 V	0.9995	0.0008	0.0010	–	–	–
52 Cr	0.9999	0.0039	0.0049	50	50	50
55 Mn	1.0000	0.0078	0.0097	100	2000	100
56 Fe	1.0000	0.1499	0.1874	300	–	100
59 Co	0.9999	0.0014	0.0017	–	–	–
60 Ni	0.9999	0.0048	0.0060	20	20	20
63 Cu	0.9995	0.0053	0.0066	50	1000	50
66 Zn	0.9995	0.0440	0.0550	5000	–	5000
75 As	0.9999	0.0062	0.0078	10	10	10
78 Se	0.9999	0.1995	0.2494	10	50	10
88 Sr	1.0000	0.0085	0.0106	–	–	–
95 Mo	1.0000	0.0032	0.0040	70	–	–
107 Ag	0.9999	0.0017	0.0021	100	10	10
111 Cd	0.9999	0.0005	0.0006	3	3	3
123 Sb	1.0000	0.0017	0.0022	–	5	5
137 Ba	0.9999	0.0096	0.0120	700	1000	700
201 Hg	0.9999	0.0064	0.0080	1	1	1
208 Pb*	0.9996	0.0046	0.0057	10	10	10
232 Th	0.9999	0.0017	0.0021	–	–	–
238 U	0.9998	0.0002	0.0003	30	30	30

*Pb was measured as the sum of the three most abundant isotopes, 206, 207, and 208.
– not a specified element.

Quantitative results for water samples

The three types of acidified (1.25x) water samples were analyzed using the 7850 ICP-MS. As shown in Table 3, the %RSD of all the quantitative results was less than 5% of all the elements, except Ba (6.83%) in Type 2 water.

Table 3. Mean measured values (n=8) for three different types of drinking water. Concentration units: µg/L.

Element	Type 1 Water			Type 2 Water			Type 3 Water		
	Average (n=8)	SD	%RSD	Average (n=8)	SD	%RSD	Average (n=8)	SD	%RSD
11 B	11.61	0.54	4.66	25.36	1.01	3.96	49.46	1.43	2.89
23 Na	576	17.77	3.08	1095	5.44	0.50	2152	39.38	1.83
24 Mg	290	10.69	3.68	625	2.89	0.46	1222	16.96	1.39
27 Al	8.20	0.24	2.93	3.40	0.14	4.09	2.81	0.06	2.21
39 K	621	22.09	3.56	1238	15.80	1.28	2433	54.18	2.23
43 Ca	856	16.90	1.97	1655	9.95	0.60	3245	48.92	1.51
51 V	0.06	0.00	2.12	<DL*	–	–	<DL*	–	–
52 Cr	0.06	0.00	3.57	0.05	0.00	2.48	0.09	0.00	1.67
55 Mn	0.43	0.01	3.09	0.12	0.01	4.84	0.30	0.01	3.40
56 Fe	6.90	0.32	4.68	1.86	0.06	3.28	8.94	0.06	0.67
59 Co	<DL	–	–	<DL	–	–	<DL	–	–
60 Ni	0.69	0.02	3.04	0.60	0.03	4.47	3.30	0.08	2.34
63 Cu	0.30	0.01	4.63	2.08	0.01	0.59	1.08	0.02	1.56
66 Zn	1.49	0.06	3.95	2.13	0.04	2.03	5.08	0.08	1.64
75 As	<DL	–	–	<DL	–	–	<DL	–	–
78 Se	<DL	–	–	<DL	–	–	<DL	–	–
88 Sr	1.19	0.00	0.33	2.02	0.05	2.24	3.99	0.14	3.56
95 Mo	<DL	–	–	<DL	–	–	<DL	–	–
107 Ag	<DL	–	–	<DL	–	–	<DL	–	–
111 Cd	<DL	–	–	<DL	–	–	<DL	–	–
123 Sb	<DL	–	–	<DL	–	–	<DL	–	–
137 Ba	0.25	0.01	3.63	0.08	0.01	6.83	0.14	0.01	4.70
201 Hg	<DL	–	–	<DL	–	–	<DL	–	–
208 Pb**	0.33	0.00	0.55	0.08	0.00	3.50	0.03	0.00	4.83
232 Th	<DL	–	–	<DL	–	–	<DL	–	–
238 U	<DL	–	–	<DL	–	–	<DL	–	–

* <DL refers to the dilution adjusted instrument detection limit.

** Pb was measured as the sum of the three most abundant isotopes, 206, 207, and 208.

SRM recoveries

To assess the accuracy of the method, the NIST 1643f Trace Elements in Water SRM was analyzed five times during each batch run to verify the accuracy and precision of the method. The results from the five separate batch runs are shown in Table 4. The mean concentrations were in good agreement with the certified concentrations (80–120% recoveries) for all elements.

Table 4. Recovery and reproducibility data for certified elements in the NIST 1643f water SRM, n=5.

Element	SRM Recoveries		
	Certified Value (µg/L)	Measured Value (µg/L)	Recovery (%)
11 B	152.3	154.7	101.6
23 Na	18830	18480	98.1
24 Mg	7454	7236	97.1
27 Al	133.8	138.6	103.6
39 K	1932.6	1917.3	99.2
43 Ca	29430	29831	101.4
51 V	36.1	34.8	96.4
52 Cr	18.5	18.0	97.3
55 Mn	37.1	35.9	96.8
56 Fe	93.4	89.2	95.5
59 Co	25.3	24.2	95.7
60 Ni	59.8	58.3	97.5
63 Cu	21.7	21.5	99.1
66 Zn	74.4	73.2	98.4
75 As	57.4	55.7	97.0
78 Se	11.7	11.9	101.7
88 Sr	314	318.4	101.4
95 Mo	115.3	117.3	101.7
107 Ag	0.97	1.0	99.9
111 Cd	5.9	5.6	94.9
123 Sb	55.5	54.4	98.0
137 Ba	518.2	511.9	98.8
208 Pb*	18.5	18.5	99.9

*Pb was measured as the sum of the three most abundant isotopes, 206, 207, and 208.

Quality control check

The two QC check solutions were measured twice, before and after the batch analysis of all the samples. The drift (% difference) between the measurements was less than 5.0% for all the elements, demonstrating the stability and robustness of the 7850 ICP-MS after six hours of runtime (Table 5).

ISTD stability

The study evaluated the long-term stability of the analytical method using Rh, Sc, Ge, Lu, Au, and Bi as ISTDs at a concentration of 1000 µg/L in the stock solution. The ISTD solution was mixed with all samples and solutions online, using a tee connector. The analytical sequence included samples, method blanks, quality control (QC) checks, and SRM solutions, totaling 130+ runs.

Throughout the sequence, ISTD recoveries were within ±20%, demonstrating the robustness and stability of the method (Figure 1). The 7850 ICP-MS method maintained reliable data without the need for retuning or recalibration during a typical six to eight hour shift. The post-run performance check function in ICP-MS MassHunter software confirmed instrument status, suggesting minimal maintenance was required before the next day's analysis. Additionally, no significant matrix deposition occurred on the interface during the sequence, as expected for drinking water samples.

Table 5. QC check solution measured before and after the six-hour run using the Agilent 7850 ICP-MS. Concentration units: µg/L (ppb).

Element	Level 1			Level 2		
	Level 1	Before	After	Level 2	Before	After
11 B	100.0	97.00	96.00	400.0	392.4	394.1
23 Na	100.0	91.09	92.05	400.0	391.3	394.1
24 Mg	100.0	92.30	92.49	400.0	384.8	386.2
27 Al	1.0	0.92	0.91	4.0	4.14	4.17
39 K	100.0	90.96	90.50	400.0	388.8	382.5
43 Ca	100.0	90.25	92.42	400.0	389.1	384.2
51 V	1.0	0.98	0.94	4.0	3.94	3.91
52 Cr	1.0	0.99	0.98	4.0	3.88	3.86
55 Mn	1.0	0.95	0.99	4.0	3.97	3.97
56 Fe	100.0	96.45	97.40	400.0	392.2	394.8
59 Co	1.0	0.99	0.98	4.0	3.89	3.93
60 Ni	1.0	1.01	0.96	4.0	3.83	3.92
63 Cu	1.0	0.97	0.96	4.0	3.89	3.85
66 Zn	1.0	1.067	1.060	4.0	4.04	4.04
75 As	1.0	0.93	0.94	4.0	3.96	3.89
78 Se	1.0	0.98	0.99	4.0	3.97	3.88
88 Sr	10.0	9.76	9.81	40.0	38.45	38.22
95 Mo	1.0	0.96	0.95	4.0	3.90	3.84
107 Ag	1.0	0.94	0.93	4.0	3.87	3.89
111 Cd	1.0	0.93	0.98	4.0	3.79	3.78
123 Sb	1.0	0.93	0.93	4.0	3.94	3.90
137 Ba	1.0	0.97	0.93	4.0	4.31	4.23
201 Hg	0.1	0.10	0.09	1.0	0.98	0.97
208 Pb*	1.0	0.93	0.96	4.0	3.91	3.80
232 Th	1.0	0.99	0.95	4.0	3.90	3.89
238 U	1.0	0.97	0.97	4.0	3.85	3.92

*Pb was measured as the sum of the three most abundant isotopes, 206, 207, and 208.

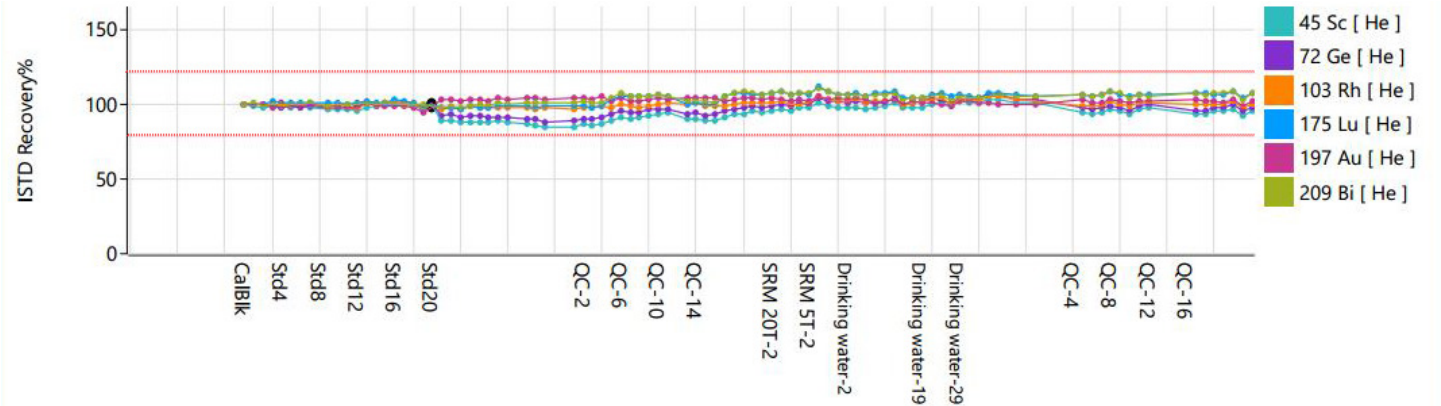


Figure 1. ISTD stability of 130 samples. ISTD recoveries were normalized to the calibration blank for all samples. The red dotted lines show the ±20% control limits.

Conclusion

The Agilent 7850 ICP-MS successfully measured 26 elements in bottled and tap water samples using a single He KED method for all elements. This method adhered to the detection limits and QC requirements defined by the Bureau of Indian Standards (BIS 10500, BIS 14543, and BIS 13428), including the updated requirements for the measurement of uranium.

Using the low matrix preset method and autotuning routine within the Agilent ICP-MS MassHunter software streamlined the analytical workflow, minimizing setup time while ensuring accurate and interference-free results. Excellent recoveries of the certified elements in NIST 1643f Trace Elements in Water SRM confirmed the accuracy of the method for those elements.

The 7850 ICP-MS demonstrated good stability throughout the analysis of 130 solutions, making it a robust tool for quality and safety analysis of drinking water in accordance with Indian government standards.

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Products used in this application

Agilent products


[7850 ICP-MS](#) 

[SPS 4 Autosampler](#) 

[ICP-MS sampler cone, nickel-tip with copper base](#) 

[ICP-MS skimmer cone, platinum-tip with nickel base](#) 

[Multi-element calibration standard](#) 

[Mercury \(Hg\) standard](#) 

[Boron \(B\) standard](#) 

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