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Inside this Issue

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Automated Analysis of Environmental Samples using prep*FAST*-ICP-MS

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Introduction

Elemental Scientific's (ESI) prep*FAST* M5 autodilution system can now be fully integrated with Agilent ICP-MS systems.

What is prep*FAST*?

ESI's prep*FAST* M5 system provides automated preparation of calibration standards, autodilution of samples, and fully integrated autodilution of over-range QCs and samples [1]. As shown schematically in Figure 1, samples from each autosampler location are loaded into the first sample loop at a fast rate of 0.5 mL/sec using a syringe pump. The prep*FAST* M5 syringe pump improves sample loading accuracy as well as reducing the sample consumption compared to a vacuum pump. Once loaded into the first loop, the sample is injected by the switching valve into a carrier stream containing the diluent and internal standards. The mixed solution is then transported to the second valve and loaded in the final injection loop. From there, the mixed solution is injected into the carrier flow and transported to the ICP-MS nebulizer.

prep*FAST* M5 ensures rapid, reliable dilutions using a S500V2 syringe pump capable of precise (<± 0.05% RSD) and accurate (<± 0.2% bias) delivery of solution over a wide range of flow rates from 1 µL/min to 40 mL/min.

Full Control from ICP-MS MassHunter

A software plug-in developed by ESI in collaboration with Agilent allows all prep*FAST* functions to be operated from within the ICP-MS MassHunter Batch software.

By fully integrating prep*FAST* control in ICP-MS MassHunter, autocalibration (Figure 2) and autodilution functionality become part of the ICP-MS method.

Applications of prep*FAST*-ICP-MS

prep*FAST*-ICP-MS is ideally suited to the rapid analysis of environmental samples while maintaining data quality in accordance with standard and regulatory methods.

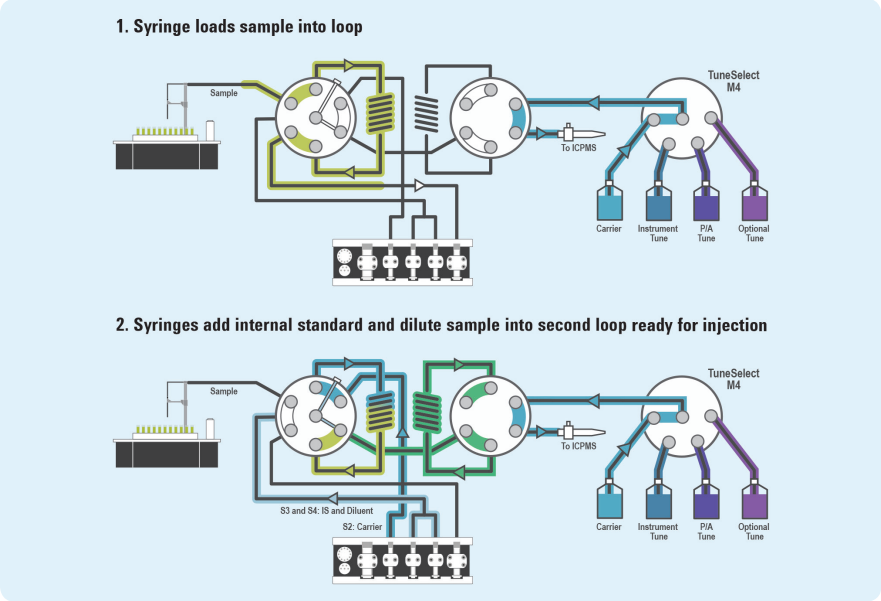

Figure 1. The ESI prep*FAST* M5 system schematic illustrating sample loading during spray chamber rinse, followed by sample dilution, internal standardization, and injection.

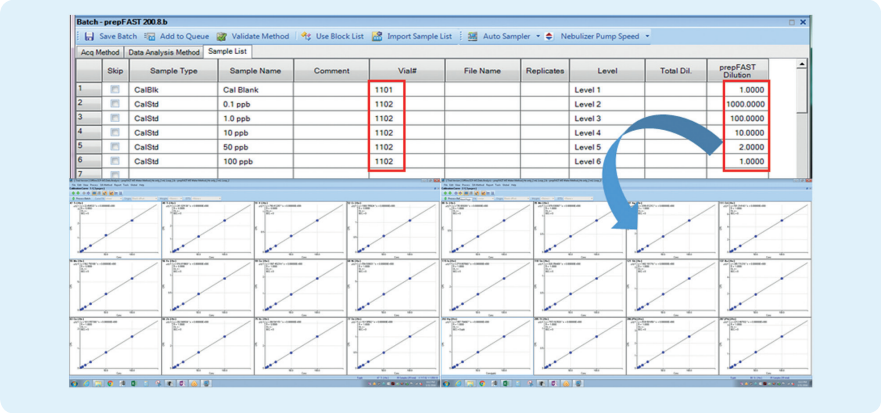

Figure 2. Automatic dilution of calibration standards. Simply specify vial position of calibration stock solution and prep*FAST* dilution factor required for each calibration level.

Meeting EPA 200.8 Requirements

An Agilent 7900 ICP-MS coupled to an ESI prep*FAST* autodilution system was used for the analysis of drinking and bottled water samples in accordance with the QC requirements of US Environmental Protection Agency (EPA) Method 200.8. The long-established method provides guidance on the analysis of groundwaters, surface waters, drinking waters, and wastewaters by ICP-MS [2]. Laboratories that use method 200.8 are required to carry out several performance and quality control (QC) tests to verify the quality of the data. Typical QC criteria include:

- A check on over-range sample concentration results, with an upper limit set at 120% of the top calibration point, above which the sample must be diluted and rerun.
- Internal Standard (ISTD) recovery limits of 60 to 125%, with any out-of-range recoveries triggering sample dilution.
- Automated analysis of Continuing Calibration Verification (CCV) and Continuing Calibration Blank (CCB) solutions after every 10 samples.

Intelligent Autodilution of Out-of-Range Analytes and ISTDs

The analyst specifies the required QC limits in the ICP-MS MassHunter prep*FAST* Batch window. If the out-of-range limits are exceeded, ICP-MS MassHunter calculates the appropriate dilution factor needed to bring the out-of-range analytes within the calibration range, and sends the factor to prep*FAST*. In a real-time update to the sample list, prep*FAST* then

Table 1. Expected concentrations and recoveries for Y ISTD in various dilutions of a water sample spiked with an extra 21 ppb Y

prep*FAST* dilution factor	Total conc of Y (ppb)	Expected conc of Y from ISTD (ppb)	Ratio of Total Y/ISTD Y
1	41.0	20.0	205
5	24.2	20.0	121
10	22.1	20.0	111

Table 2. ISTD recoveries (He mode) at various dilutions for bottled water sample spiked with an extra 21 ppb Y

		ISTD recovery %		
Sample name	Dilution	^{89}Y	^{103}Rh	^{175}Lu
Bottled water + 21 ppb Y	1	203.5	103.7	103.3
	5	124.2	107.0	104.8
	10	110.3	103.7	105.4

reruns the sample at the calculated dilution as a QC Action on Failure (AOF). This function is like a standard QC AOF in ICP-MS MassHunter, and requires no intervention from the analyst. Similarly, if an ISTD signal exceeds the user-set recovery range, the sample is autodiluted 5x (and then 10x, if needed) to bring the ISTD recovery within the defined range.

In this study, the ISTD recovery range was set to much tighter limits of 80–120% instead of the 60–125% range specified in 200.8. The tighter limits reflect the QC requirements specified in some labs' operating procedures. One of the bottled water samples was spiked with Y at 21 ppb. The spike was in addition to the 20 ppb Y ISTD automatically added to each sample. The theoretical concentrations and ratios given in Table 1 show that a 10x dilution of the spiked sample would be required to bring the total Y concentration within 20% of the ISTD reference level (of 20 ppb). This theory was confirmed from the analytical results for the bottled water sample spiked with an extra 21 ppb Y, as shown in Table 2. At 5x dilution, the added Y still causes the Y ISTD recovery to exceed the 120% limit, so a 10x dilution was required to ensure that the sample passed the QC check. The recoveries of the other internal standards remained within the QC limits for all dilutions of the sample.

Meeting EPA 6020 Requirements

EPA 6020A method is a performance-based ICP-MS method that can be applied to the determination of over 60 elements in various matrices. Typical sample types include groundwater, surface water, industrial wastes, soils, sludges, sediments, and other solid wastes for which total (acid-leachable) elemental concentrations are required [3]. Laboratories that implement EPA 6020 methods typically analyze long sequences of samples with high Total Dissolved Solids (TDS) content, so require robust methodology to handle the workload.

An Agilent 7900 ICP-MS coupled to an ESI prep*FAST* autodilution system was used for the analysis of soils and sediments in accordance with US EPA Method 6020A.

The Agilent 7900 ICP-MS excels in the analysis of samples that contain high levels of TDS. It uses Ultra High Matrix Introduction (UHMI) to deliver stable analysis of complex high matrix environmental samples. The 7900 also includes the ORS^4 collision/reaction cell, which is optimized for helium collision mode to ensure reliable control of common polyatomic interferences [4].

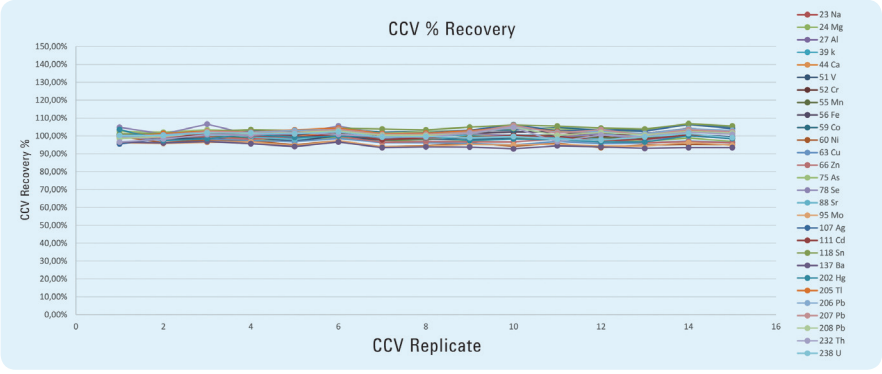

Figure 3. CCV recoveries for an 8-hour analysis sequence of soils and sediment digests run according to EPA Method 6020A

Method 6020A specifies that ISTD recoveries for all samples must exceed 30% of the ISTD response in the calibration blank. If an ISTD falls below the 30% limit, the sample must be diluted and reanalyzed.

In addition, CCV QC samples must be analyzed after every 10 real samples. The CCVs must be prepared near the midpoint concentration of the calibration and must be recovered within ±10% of the true value. If the CCV recovery criteria are not met, the instrument must be recalibrated and the block of samples run after the last successful QC must be reanalyzed. Recoveries for all 15 CCVs run over the course of the 8-hour sequence (total of 230 soil and sediment digest samples) are shown in Figure 3. All elements were within ±10% throughout the run.

References

1. A. Schultz and P. Field, prep*FAST* ICP-MS: Environmental, ESI publication, **www.icpms.com/products/prepfast.php**
2. U.S. EPA Method 200.8 Determination of Trace Elements in Waters and Wastes by ICP-MS, Revision 5.4, 1994: **www.epa.gov/sites/production/files/2015-06/documents/epa-200.8.pdf.**
3. U.S. EPA Method 6020A (SW 846) Inductively Coupled Plasma Mass Spectrometry, Revision 1, 1998: **www.epa.gov/sites/production/files/2015-07/documents/epa-6020a.pdf**
4. K. Yamanaka and S. Wilbur, Maximizing productivity for high matrix sample analysis using the Agilent 7900 ICP-MS with ISIS 3 discrete sampling system, Agilent publication, 2014, **5991-5208EN**

Application Notes

- Automated Routine Analysis of Environmental Water Samples using the Agilent 7900 ICP-MS with the ESI prep*FAST* Autodilution System, **5991-8148EN**
- Automating EPA 6020 Compliant Analysis with the Agilent 7900 ICP-MS and ESI prep*FAST* Autodilution System, **5991-8222EN**

ICP-MS for Elemental Impurities Analysis in Pharmaceuticals According to USP <232>/<233> and ICH Q3D

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New Elemental Impurity Analysis Requirements and Timeline

In February 2017, new procedures for the analysis of elemental (inorganic) impurities in pharmaceutical products and ingredients were finalized. Existing wet chemical and colorimetric tests, such as European Pharmacopoeia Heavy Metals chapter 2.4.8 and United States Pharmacopeial Convention (USP) General Chapter <231>, have been replaced with instrumental methods.

The USP, in parallel with the International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use (ICH), has published new standards. USP General Chapters USP<232> (Elemental Impurities – Limits) [1] and <233> (Elemental Impurities – Procedures) [2] are due to be implemented in January 2018. The equivalent ICH method is defined in the Guideline for Elemental Impurities (Q3D) [3], which has now reached Step 5 (implementation). ICH-Q3D has been in effect since June 2016 for new marketing authorization applications and has a deadline of December 2017 for previously authorized medicinal products.

What Improvements Will USP<232>/ICH Q3D Deliver?

The permitted daily exposure (PDE) limits for elemental impurities in drugs intended for oral, parenteral, and inhalational routes of administration, as per the ICH and USP chapters, are shown in Table 1. The elements that should be included in the Risk Assessment are different depending on the intended route of administration:

- Class 1 and Class 2A elements must be assessed in all products.
- Class 3 elements should be considered for parenteral and/or inhalational routes of administration.
- All listed elements should be included if they may have been added intentionally or unintentionally.

Table 1. The permitted daily exposure (PDE) limits for elemental impurities in drug products, according to their route of administration.

ICH/USP Class	Element	Oral PDE (µg/day)	Parenteral PDE (µg/day)	Inhalational PDE (µg/day)
Class 1	Cd - Cadmium	5	2	2
	Pb - Lead	5	5	5
	As - Arsenic (inorganic)	15	15	2
	Hg - Mercury (inorganic)	30	3	1
Class 2A	Co - Cobalt	50	5	3
	V - Vanadium	100	10	1
	Ni - Nickel	200	20	5
Class 2B	Tl - Thallium	8	8	8
	Au - Gold	100	100	1
	Pd - Palladium	100	10	1
	Ir - Iridium	100	10	1
	Os - Osmium	100	10	1
	Rh - Rhodium	100	10	1
	Ru - Ruthenium	100	10	1
	Se - Selenium	150	80	130
	Ag - Silver	150	10	7
	Pt - Platinum	100	10	1
Class 3	Li - Lithium	550	250	25
	Sb - Antimony	1200	90	20
	Ba - Barium	1400	700	300
	Mo - Molybdenum	3000	1500	10
	Cu - Copper	3000	300	30
	Sn - Tin	6000	600	60
	Cr - Chromium	11000	1100	3

Elements shaded blue should be considered in Risk Assessment. Note: All elements should be included in Risk Assessment if intentionally or unintentionally added.

Agilent's Complete Workflow Solution using ICP-MS

Sample preparation

The USP<233> chapter references several methods that can be used for the preparation of samples for analysis by the compendial procedures ICP-MS and ICP-OES. These include:

- Direct analysis.
- Dilution/solubilization in a suitable aqueous solvent, such as water or dilute acid.
- Dilution/solubilization in a suitable organic solvent, such as 2butoxyethanol: water (25:75), DMSO, or DGME.
- Indirect solution, preferably using closed-vessel microwave digestion with strong acids.

Solution-ready ICP-MS

Implementing the USP/ICH procedures could present a challenge for pharmaceutical laboratories that are new to metals analysis and ICP techniques. The Agilent 7800 ICP-MS provides a simple, complete, workflow-based solution for labs that need to implement the latest procedures, with:

- Hardware features that minimize sample preparation and simplify calibration, including:
  - Unique High Matrix Introduction (HMI) system to allow high and variable matrix level samples to be run routinely.

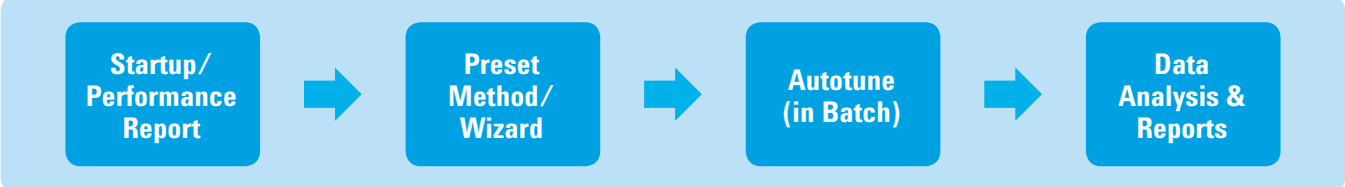

Figure 1. The Agilent 7800 ICP-MS instrument provides a streamlined solution for low-level analysis of elemental impurities in pharmaceutical products and raw materials.

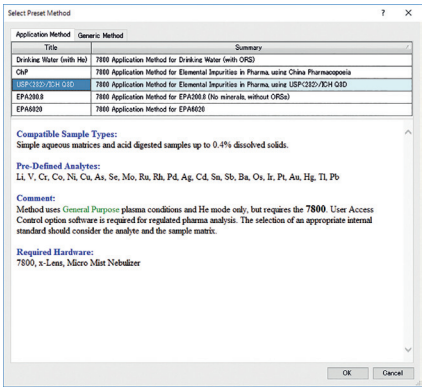

Figure 2. Agilent ICP-MS MassHunter software includes preset methods for elemental impurities analysis using ICH/USP and China Pharmacopeia (ChP) methods.

  - Helium gas cell mode with kinetic energy discrimination (KED) for simple and reliable removal of all common polyatomic interferences, ensuring accuracy and allowing access to qualifier isotopes for unequivocal analyte identification.
  - 10 orders dynamic range detector to measure major and trace elements, and high- and low-concentration level samples in the same sample run.
- Software tools that ensure consistent system performance by automating system optimization and tuning.
- Preset methods that predefine the settings required for the USP/ICH methods, including operating conditions, analyte masses, integration times, and internal standards.
- Built-in templates for system suitability test reports.
- A detailed standard operating procedure (SOP) template you can use as the basis for your laboratory's SOP. It includes stepwise instructions for ICH Q3D and USP<232> method setup and operation.

ICP-MS Method Setup

The 7800 ICP-MS includes preset methods (Figure 2) and predefined report templates to help you to set up your new elemental impurities method.

The Agilent ICP-MS MassHunter software uses a streamlined work-flow supported by a gadget-based toolbar to guide new users through the process of setting up methods, defining sample analysis batches, and processing, approving, and reporting results. Many critical parameters are predefined, while system setup uses robust auto-optimization tools and extensive status monitoring to ensure consistent high performance, regardless of operator experience.

ICH-Q3D/USP <232>/<233> and ChP elemental impurity methods can simply be loaded and run, with settings – from plasma conditions to analyte isotopes, integration times, and internal standards – predefined in a preset method supplied with the software.

If your laboratory has different requirements – for example you always measure a specific subset of the regulated analytes – the preset method can be modified and saved as a new, custom method template.

The ICP-MS MassHunter software also includes QC checks to evaluate whether each analyte complies with the J-value concentration limits derived from the PDE. See Reference 4 for more information on J-values. Flags are displayed in the data table to highlight any analytes that are above the permitted level – different limits apply to drug products intended for different routes of administration.

ICP-MS MassHunter also includes pre-defined report templates for the accuracy (spike recovery), and precision (repeatability and ruggedness) checks defined in USP<233>.

Agilent System Qualification (IQ/OQ) Services

Installation Qualification (IQ) checks that the ICP-MS system is installed correctly before initial utilization:

- Purchase order is complete and correct.
- Confirm operating environment.
- Physical connections and safety.
- Functional parameters.

Operational Qualification (OQ) performs standard operational tests and compares the results to vendor specifications. A compliance data transfer check is included, if appropriate.

Following the IQ and OQ checks, an audit-ready equipment qualification report (EQR) is issued.

Agilent CRM Calibration Standards for ICH/USP

Agilent's ICH/USP certified reference materials (CRMs) are premixed blends of elements at the appropriate relative concentrations for the oral PDE limits defined in the ICH/USP methods. (CRMs appropriate to the PDEs for other routes of exposure are under development). The CRMs eliminate the need for you to prepare your own standards from single element solutions [5]. Options include:

- Four separate calibration CRMs; elements grouped by chemical compatibility and method needs (e.g. all Class 1 elements in a single stock).
- A kit containing all four standards and the ISTD solution, with a single part number.
- ISTD solution is also available separately.

Compliance Solutions for Agilent ICP-MS Systems

The US FDA has regulations in place to ensure the security, integrity, and traceability of electronic records. These regulations are described in Part 11 of Title 21 of the Code of Federal Regulations (21 CFR Part 11). The European Commission has similar regulations in place, as described in Annex 11: Computerised Systems in their Good Manufacturing Practice (GMP) rules. Equivalent regulations that apply in other jurisdictions are described in the Pharmaceutical Inspection Convention/Pharmaceutical Inspection Co-operation Scheme (PIC/S) GMPs, China's GMP, and the chapter on computer systems of the Brazilian GMP.

Agilent has a range of software solutions to help laboratories comply with Part 11, Annex 11, and equivalent regulations. Our ICP-MS instruments can be connected to an Agilent compliance software product to suit any size of laboratory, from a lab with a single ICP-MS instrument, to a global enterprise with multiple sites and dozens or hundreds of instruments.

References

1. USP Chapter <232> Elemental Impurities - Limits, Pharmacopeial Forum, 42(2), Mar-April 2016.
2. USP Chapter <233> Elemental Impurities - Procedures, USP 38–NF 33, Second Supplement
3. ICH Guideline Q3D on Elemental Impurities, EMA/CHMP/ICH/353369/ 2013, July 2016.
4. USP <232>/<233> and ICH Q3D Elemental Impurities Analysis: Agilent's ICP-MS solution, Agilent publication, 2017, **5991-8149EN**
5. Simplify Testing of Elemental Impurities in Pharmaceuticals with Agilent's CRMs Kit, Agilent publication, 2017, **5991-8177EN**

New! ICP-MS MassHunter 4.4 Software

Steve Wilbur
Software Product Manager, Agilent Technologies, USA

ICP-MS MassHunter 4.4 (G7201C C.01.04) was introduced in July 2017. Coming a year after MassHunter 4.3, this new release demonstrates Agilent's commitment to continuous development of the ICP-MS software.

The look and feel of ICP-MS MassHunter 4.4 will be familiar to users of earlier MassHunter 4.x revisions. It is also compatible with methods and data from earlier MassHunter 4.x revisions.

A key priority in the development of MassHunter 4.4 was the elimination of the requirement for Microsoft Excel. By removing the need for Excel, any compatibility issues between the laboratory IT supported version and the MassHunter supported version of Excel are eliminated. Functions previously delegated to Excel (mainly specialized reporting functions) are now handled by MassHunter's Report Designer. The new Report Designer permits much more powerful and simple customization of all report templates. ICP-MS MassHunter 4.4 no longer includes a copy of Excel. Users who have developed Excel custom report templates for MassHunter can still use them if they provide their own copy of Excel.

In addition to eliminating the need for Excel, the Agilent design team, with input from the field advisory team, has continued to review and simplify the user interface and workflow. New functions and enhancements include:

- Intelligent Sequencing support for ESI prep*FAST* autodilution.
- The Nanoparticle Application Module now offers optional support of fast TRA mode for the 7800, and permits multi-element nanoparticle screening in a single run.
- Improvements to Autotune and support for the Teledyne CETAC XLR-860 Extended Rack Autosampler.

Operating System Compatibility

ICP-MS MassHunter 4.4 is compatible with 64 bit versions of Windows 7 or Windows 10.

Availability

Revision 4.4 is available free of charge to ICP-MS MassHunter users who have a current software maintenance agreement (SMA) subscription.

Fully Control the MVX-7100 µL Workstation with ICP-MS MassHunter

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In collaboration with Agilent, Teledyne CETAC Technologies has developed a software plug-in that integrates control of the MVX-7100 µL Workstation from within ICP-MS MassHunter. All MVX-7100 functions can now be operated from within the ICP-MS MassHunter Batch software. This compatibility allows users of Agilent ICP-MS and Agilent ICP-QQQ systems to benefit from the micro-sampling capabilities of this advanced automation system.

What is the MVX-7100 µL Workstation?

The MVX-7100 µL Workstation is a syringe driven, low and 'sub-mL' volume sample introduction system for ICP-MS instrumentation that can deliver samples at any required flow rate from total consumption (single µL/min flow rates) to mL/min level flows. This innovative technology can be used to support low sample volume requirements or to intentionally reduce the sample volume being introduced to the ICP-MS (by at least an order of magnitude compared to standard methods) while maintaining precision and accuracy. With an appropriate nebulizer, low volume analysis can be performed without compromising the number of analytes or sample measurement replicates. A non-metallic sample flow path ensures low detection limits when using the system. The MVX-7100 µL Workstation offers the analyst the following capabilities:

- Syringe driven uptake, sample introduction, and flow path rinsing: a specified sample volume is pulled onto a loop and the entire aliquot injected, enabling analysis of sample volumes as low as 5 µL.
- Sample introduction flow rate control.
- Septum piercing for sealed sample vials or sealed well microplates.
- Optional temperature control (4–40°C).
- Precise sampling from 96 well and 384 well microplates for low volume, biological applications, or cell-based experimentation.
- Internal and external sample probe rinsing in opposing directions with separate solutions.
- No peristaltic pump tubing involved in the sample introduction process.

Applications

The MVX-7100 system provides a solution to the challenge of limited sample volumes in ICP-MS applications across various scientific disciplines. For example, analysis of biological sample types (such as bloods, urines and biological cells), geological materials (such as low mass digests from micro drilling of rocks, speleothems, or shells), and samples of high value (such as may be the case in pharmaceutical or other industrial applications). The MVX-7100 also supports ICP-MS analysis in petrochemical applications and solvent-based samples where sealed vial septum piercing and optional temperature control can be employed to minimize sample evaporation and prolong analytical batch integrity. The system has also been shown to be beneficial for applications requiring accurate control of sample introduction flow rate (such as nanoparticle work). Working with the MVX-7100's low sample volumes also has the potential to reduce the analyst's exposure to hazardous sample types such as radioactive or pyrophoric materials.

Software Availability and Compatibility

The MVX-7100 µL Workstation plug-in for ICP-MS MassHunter is available from Teledyne CETAC Technologies, and is compatible with ICP-MS MassHunter 4.3 with patch 3 and ICP-MS MassHunter 4.4 onwards.

More Information

www.teledynecetac.com/products/automation/mvx-7100

Real-time Inline Monitoring of Metal Contaminants in Semiconductor Process Chemicals

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[2] ICP-MS Marketing Manager, Agilent Technologies, Japan

Figure 1. ESI scoutDX automated process monitoring system

Real time monitoring of semiconductor process chemicals and ultrapure water (UPW) is vital to provide the information needed to improve manufacturing processes and maximize product yield. Metal impurities are monitored in process chemicals at delivery (by tanker or drums), at the central chemical supply, at distribution points, and at the point of use. Chemical monitoring is required 24/7 to verify low or even sub-ppt levels of metal contamination.

To provide a solution for inline process chemical analysis, Agilent has partnered with Elemental Scientific (ESI) to supply an integrated scoutDX/ICP-MS system, as a complete, tested, and supported package.

Agilent is delighted to extend the existing partnership with ESI. ESI is one of the key peripheral suppliers that provides a range of systems to meet the varied needs of Agilent ICP-MS users.

What is the ESI scoutDX?

The scoutDX controls up to 20 remote sampling modules. Each module collects a small amount of a chemical or stream and transfers it to the central scoutDX system for ICP-MS analysis. Rapid transfer rates allow the system to provide real-time ICP-MS detection of ultratrace metal impurities in each chemical. This capability allows monitoring at many locations throughout the semiconductor fabrication plant without compromising detection limits. The fully automated scoutDX central module is capable of:

- Autocalibration
- QC functions (over range, recalibration)
- Monitoring multiple chemicals or streams.

Each scoutDX remote module collects and transfers a sample (TX model) or collects, dilutes, and transfers a viscous sample (DTX model) providing:

- Remote inline sampling for all process chemicals and UPW (from distances of up to 300 m).
- Small volume sampling (<10 mL), minimizing consumption of precious high purity chemicals.
- Dedicated transfer line for each chemical.
- Fast and complete rinse-out.

Full Software Control

Intuitive software controls the scoutDX central module and ICP-MS, as well as all remote modules. Communication of data and tool status uses industry standard machine control and communication protocols. Element-specific limits for contaminants can be user-defined for each sampling point. Any values that exceed the user-defined limits trigger an alarm. An alert is also sent to the central system.

Benefits of Real-time Monitoring

As organizations look to improve productivity and use real-time data to better understand and improve processes, the scoutDX/ICP-MS system offers several benefits:

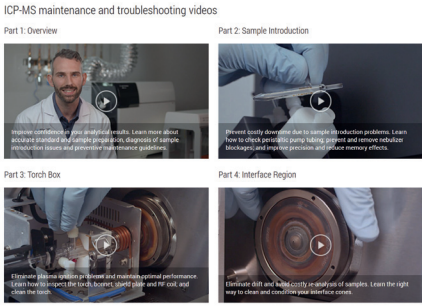
- Immediate detection and notification of metal contamination to:
  - minimize product loss due to accidental contamination.
  - allow investigation and elimination of sources of contamination.
  - optimize chemical lifetime and reduce cost of disposal and replacement.
- Improved product yield
- Reduced human contact with hazardous chemical samples, improving safety and reducing manual handling errors.
- Customizable software to enable flexible, user-defined parameters for contamination control at every sampling station.

More Information

www.icpms.com/products/scoutdx.php

Education Spotlight: Access ICP-MS Resources from a Single Webpage

Kate Lee
Spectroscopy Supplies Global Marketing Program Manager, Agilent Technologies, Singapore



Even experienced analysts can fail to recognize problems, or lack the knowledge to solve some problems that result in instrument downtime and lost productivity. That's where the Agilent ICP-MS Online Resource Library can help. The library is an easy-to-navigate web resource that helps you optimize instrument performance and maintain peak productivity. It puts the latest ICP-MS information, literature, and innovations at your fingertips – including:

- How-to videos that guide you through method setup, calibration, troubleshooting, and more.
- Maintenance tips to help you minimize downtime.
- Featured products designed to maintain the high performance that today's applications require.
- Training resources to help you improve your skills and positively influence your lab's success.

www.agilent.com/chem/icp-ms-resource

Third Edition of Agilent ICP-QQQ Applications Handbook

Title: Handbook of ICP-QQQ Applications using the Agilent 8800 and 8900
Pub Number: 5991-2802EN

A lot has happened since Agilent launched the world's first triple quadrupole ICP-MS, the Agilent 8800, in 2012. The technique has been widely adopted across industry and academia, and has been refined to address emerging applications such as single nanoparticle analysis and to handle signals from laser ablation systems equipped with ultrafast cells.

To capture these developments and more, the third edition of the ICP-QQQ applications primer contains:

- A new foreword by Prof. Frank Vanhaecke, Ghent University.
- A fully updated introduction to include the 8900 ICP-QQQ.
- 16 new papers that demonstrate the extended capability of the 8900: the higher sensitivity; the lower contribution from instrumental background; fast time resolved analysis capability for accurate single nanoparticle analysis; plus much more.
- An extended glossary of terms.

Download your copy from
www.agilent.com/chem/trust2-qqq

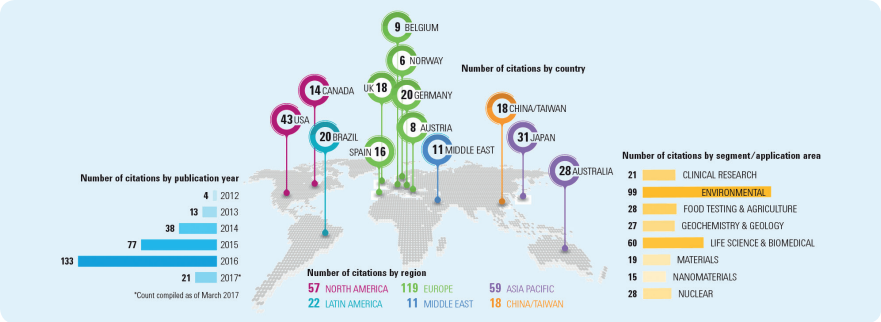
This information is subject to change without notice.

Printed in the U.S.A. July 03, 2017
5991-8213EN

Take a Closer Look: Comprehensive ICP-QQQ Applications Bibliography

Since 2012, customers around the world have relied on Agilent as the trusted expert in triple quadrupole ICP-MS (ICP-QQQ) technology and its applications. As of March 2017, Agilent ICP-QQQ users had published almost 300 peer-reviewed journal articles, illustrating the scope and power of ICP-QQQ to deliver new, advanced analytical capabilities.

You can now access each of the papers via a comprehensive ICP-QQQ Applications Bibliography, available online. The papers are organized by application and include a full reference, title, author information, institution, and country – plus a link to the abstract or full paper.



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