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Review

Future ICPMS - Advanced Dilution System Impact on Analytical Errors

Ravisankar.M^{1*}, S. Alexandar², R. Senthil Kumar³, P. Nataraj⁴, G. Ashley Joanna⁵

¹Department of Pharmaceutical Analysis, Srinivasan College of Pharmaceutical Sciences, Trichy

²Department of Pharmaceutical Analysis, Vinayaka Mission's College of Pharmacy, Salem, Tamil Nadu, India



³Professor & Head, Department of Pharmaceutical Chemistry, Swamy Vivekanandha College of Pharmacy, Tiruchengode, Tamil Nadu, India

⁴Novitium Pharma LLC, New jersey, USA

⁵Srinivasan College of Pharmaceutical Sciences, Trichy

*Author for Correspondence: Dr.M.Ravisankar

Email: pharमारavi18@gmail.com

	Abstract
Published on: 05 Sep 2025	<p>Analytical techniques such as Inductively Coupled Plasma Mass Spectrometry (ICP-MS) can examine biological fluid components at trace levels. Although some labs still use out-dated techniques such as atomic absorption and emission, there has been a steady shift in favour of ICP-MS, particularly in the last ten years. One of the primary causes of the extremely high sensitivity of ICP-MS is the fact that most naturally occurring elements are at least 75% ionised at ordinary plasma conditions. Dilution errors are a frequent issue that arises in a variety of contexts, such as ordinary life, chemical analysis, and laboratory testing. It describes the erroneous assessment or measurement of a substance's concentration brought on by sample dilution. There are several reasons why this error can happen, including poor technique, limited equipment, or human error. Agilent Technologies created the auto dilution system (ADS-2) in the ICPMS to prevent manual dilution falls.</p>
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INTRODUCTION

ICPMS - Global scenario

The global ICP-MS System market is expected to be worth US\$ 495.6 million by 2028, with a compound annual growth rate (CAGR) of 4.0% over the projection period of 2022–2028. This is due to the COVID-19 pandemic. In 2022, the market size was anticipated to be US\$ 392.3 million. Taking into consideration full impact of the health crisis on the economy, single quadrupole ICP-MS, which held a percentage of the worldwide ICP-MS System market in 2021, is expected to rise at a revised % CAGR from 2022 to 2028, with a projected value of US\$ million¹. During this forecast period, the Environmental Analysis segment will now be represented as a percentage CAGR. Leading global manufacturers of ICP-MS systems include Agilent, Thermo Fisher Scientific, and PerkinElmer, with the top three companies collectively accounting for over 60% of the market share. The Asia-Pacific region is the largest producer, contributing approximately 50% of total output, followed by North America and Europe. Among product types, single quadrupole ICP-MS systems dominate the market with around a 60% share. In terms of application, environmental analysis represents the largest segment, followed by pharmaceutical and life sciences sectors.²

Advanced Dilution System – Agilent

With the intelligent auto-dilution feature of the Advanced Dilution System (ADS 2), the Agilent ICP-MS instrument is enhanced. The ADS 2 replaces the need for manual dilutions with its range of intelligent tools integrated into the ICP-MS Mass Hunter, including auto-calibration, predictive dilution, reactive dilution, and other features. Errors in standard preparation are eliminated as a fully integrated, single-supplier automated solution that is made to interface easily with Agilent auto samplers, ICP-OES, and ICP-MS instruments and software. and resources such as time can be conserved with auto-calibration from a standard stock library³. The operator need not even calculate dilution factors attributable to the calibration utility. Reactive and prescriptive dilutions can be mixed together as needed in a single run to enhance the universality of every sample batch. In order to give the analyst a quick overview of the best-combined data, advanced data analysis combines several dilutions into a summary report. The Advanced Dilution System, or ADS 2, is a revolutionary automation workflow solution that will boost output, reduce ownership costs, and enhance overall laboratory efficiency. Agilent Technologies Inc. announced its debut.



Fig 1: Agilent ADS 2 auto dilutor with 7850 ICP-MS

An intelligent auto dilutor, the Agilent ADS 2, is intended to improve procedures in laboratories. It provides a fully integrated, single supplier automated solution and is made to interface easily with Agilent auto samplers, ICP-OES, and ICP-MS instruments and software. The ADS 2 can be set to automatically perform a dilution if the measured result for a sample is above the calibration range or if there is a problem with internal standard recovery⁴. The software reruns the sample measurement after calculating an appropriate reactive dilution factor using an algorithm based on the unsuccessful result. The sophisticated, software-controlled functionality of the ADS 2 further improves its cost-effective operation by reducing analysis time and ICP running expenses (argon and power usage, etc.)⁵

ADS Impact in Environmental analysis

Environmental analysis is the biggest application area, followed by pharmaceuticals and life sciences. In analytical labs, sample preparation must be streamlined. Pre-analysis dilutions of common materials (such as chemicals, dirt, and seawater) take up a lot of analysis time. This procedure is automated via prescriptive auto-dilution, freeing up time for other important work^{6,7}. By precisely delivering the sample to the ICP at a user-defined dilution factor, the ADS 2 improves the quality of the results and uses less labware. Analyte

concentrations in less predictable samples, such as wastewater and groundwater, frequently exceed the linear range or calibration of the procedure.^{8,9} Simultaneously, overly high matrix samples could cause internal standard failure, which calls for time-consuming post-analysis dilution and repeat analysis. The necessary dilution factor is intelligently calculated by Agilent's ADS 2 to guarantee that samples fall inside the acceptable calibration range.¹⁰

Improved Accuracy & Reproducibility

One of the most significant contributions of the Advanced Dilution System (ADS 2) to modern analytical workflows is its ability to improve accuracy and reproducibility in sample preparation. In conventional laboratory practice, manual dilution often introduces variability due to pipetting errors, inconsistent operator skills, and limitations in equipment calibration. Such issues lead to deviations in concentration levels that, in turn, affect the quality of analytical data. By fully automating the dilution process, ADS 2 eliminates operator-dependent inconsistencies and ensures that every sample undergoes a standardized procedure [21]. The integration of auto-calibration and reactive dilution strategies within ICP-MS platforms further enhances the reliability of results. For instance, when a sample exceeds the calibration range or when internal standards fail, ADS 2 recalculates the necessary dilution factor in real time and repeats the analysis with minimal human involvement. This results in greater confidence in data reliability, particularly in applications such as pharmaceutical analysis, environmental monitoring, and trace metal detection where accuracy at low concentrations is critical^{11,12}.

Regulatory Compliance

In today's pharmaceutical, environmental, and food testing laboratories, regulatory compliance is a non-negotiable requirement. Agencies such as the U.S. Food and Drug Administration (FDA), European Medicines Agency (EMA), and International Council for Harmonisation (ICH) demand strict adherence to guidelines on data integrity, traceability, and reproducibility. Manual sample dilution, with its inherent susceptibility to human error and inadequate documentation, can pose significant risks to compliance. The ADS 2 auto dilutor provides an effective solution by integrating automated record-keeping into the dilution workflow. Every step of the dilution process from calibration to reactive adjustment is electronically logged, ensuring a transparent, auditable trail of analytical data¹³. This level of traceability is particularly valuable during regulatory audits, where detailed documentation can demonstrate adherence to Good Laboratory Practice (GLP) and Good Manufacturing Practice (GMP). Additionally, ADS 2 minimizes risks associated with data falsification or unintentional errors by eliminating the manual calculation of dilution factors^{12,13}.

Sustainability

The concept of the "smart laboratory" is rapidly transforming the way analytical science is conducted, with automation, artificial intelligence, and digital connectivity serving as its pillars. The Advanced Dilution System (ADS 2) is a critical enabler of this transformation, offering features that align with Industry 4.0 standards¹⁴. By incorporating auto-calibration, reactive dilution, and algorithm-based decision-making, ADS 2 reduces the need for manual intervention, thereby increasing the autonomy of laboratory operations. Beyond automation, ADS 2 also has the potential for integration with cloud-based data platforms, enabling remote monitoring and predictive maintenance. For example, by analyzing usage patterns and system performance, laboratories can anticipate when maintenance is required, reducing unplanned downtime and improving efficiency¹⁵. Furthermore, ADS 2 supports seamless compatibility with laboratory information management systems (LIMS), ensuring smooth data flow across different platforms. This interconnectivity not only facilitates real-time decision-making but also enhances collaboration across laboratories situated in different geographic locations.

Smart Lab Integration

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CONCLUSION

The ADS 2 dilution system offers a precise and reproducible approach to sample preparation, minimizing manual errors. The ADS 2 auto dilutor can prepare up to 400-fold dilutions. Its automated operation saves time and reduces reagent wastage while ensuring consistent results. The ADS 2 boosts output, saves energy, and minimises waste of reagents and plastic consumables like gloves, pipette tips, and sample vials. By lowering analysis costs and minimising analysis's negative environmental effects, all of these elements work together to make labs more environmentally friendly. The system is user friendly, versatile, and minimizes the risk of contamination during dilution steps. It supports regulatory compliance by improving data reliability and documentation. Overall, ADS 2 enhances laboratory efficiency and quality, making it a valuable tool for analytical applications.

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Conflict of Interest

The authors declare that there is no conflict of interest

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