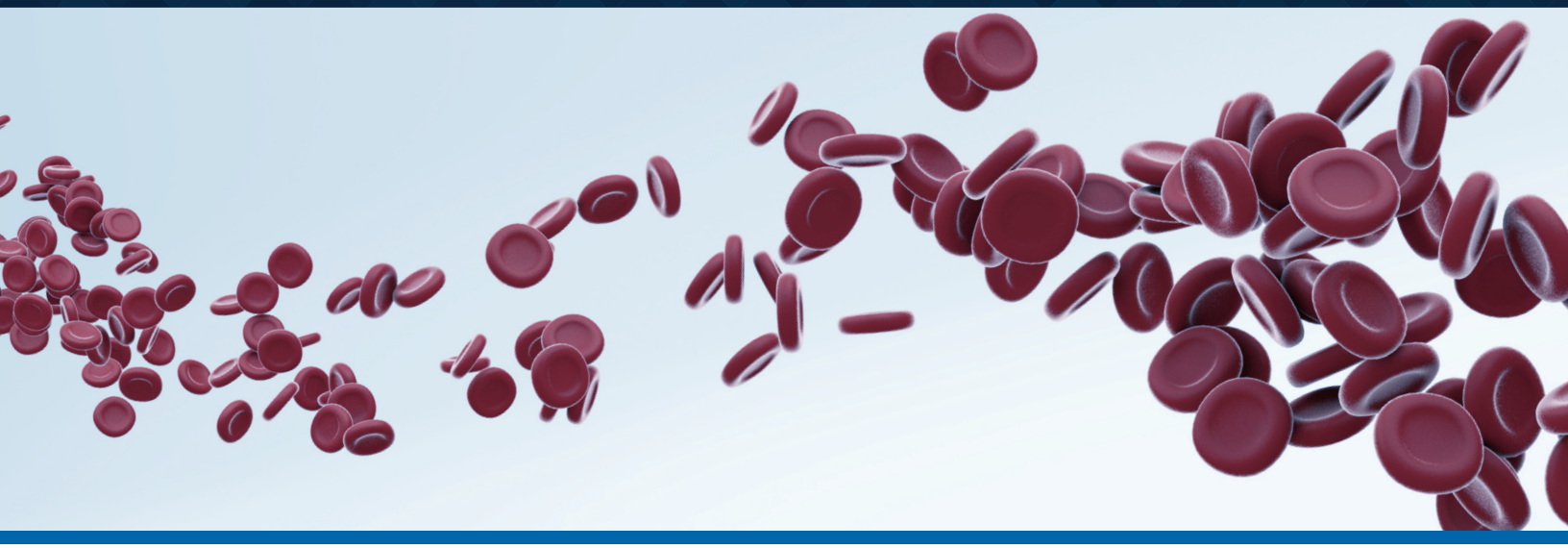

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SampleSense *FAST* UHT-C – Ultra-high Throughput Sample Introduction System for Micro-volume Clinical Samples – 20 Seconds per Sample

Introduction

Preparation of clinical samples in microplates improves laboratory efficiency and reduce reagent consumption compared with traditional test-tube sample preparation. Switching to 96-well microplates for ICPMS metals analysis requires high-throughput sample introduction compatible with sample volumes in the range of <1 mL to 2 mL with high positional accuracy. SampleSense *FAST* UHT-C* has demonstrated reliable analysis of small-volume samples from microplates. Autosampler capacity is increased by 60% (4DX autosampler) to 113% (2DX autosampler) when switching from 90-position sample racks to 96-well microplates. The SampleSense *FAST* UHT-C system is uniquely optimized for high-throughput micro-sampling, positive confirmation of sample introduction, and stable performance for the analysis of difficult clinical sample matrices. Sample analysis rates of >180 blood lead samples per hour are demonstrated with long-term reproducibility of 1% RSD.

SampleSense *FAST*

SampleSense *FAST* combines an autosampler with an inert injection valve with integrated optical sensors that automatically detect the presence of a non-segmented liquid sample as it is quickly vacuum loaded. The sensed sample is automatically injected from the valve loop and the ICPMS analysis is triggered in a tightly timed analytical sequence free of pre-determined delay timings. Due to viscosity effects on sample loading time and variabilities in multi-instrument laboratories, common practice is to add additional seconds to the sample vacuum-load time to ensure the valve loop is completely filled before injection. This is a reliable way to eliminate the effects of varying sample viscosity, creating a common method across the laboratory, but doing so compromises valuable sample volume and time. SampleSense *FAST* was developed to eliminate this method customization and the resulting time wasted while maintaining long-term multi-instrument performance.

Figure 1. SampleSense valve with dual optical sensors.

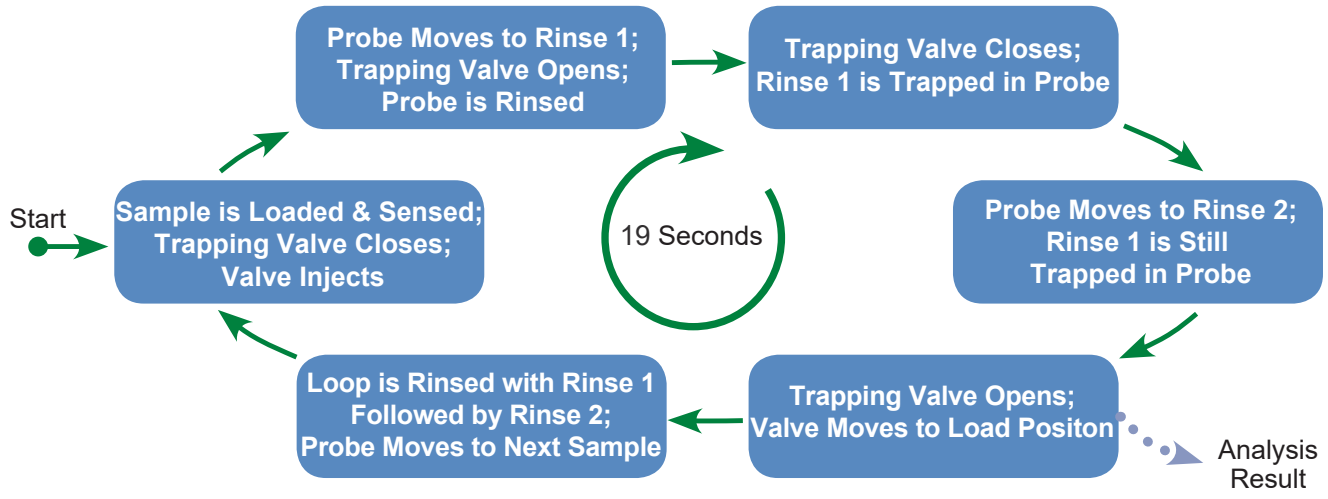
* *Formerly SampleSense Clinical*

SampleSense *FAST* UHT-C System

SampleSense *FAST* UHT-C incorporates a unique vacuum control valve (trapping valve) to further reduce sample consumption by utilizing the detection capabilities of the SampleSense valve to both inject the sample after successful detection on the sample loop and simultaneously switch the position of the trapping valve. Control of this trapping valve during the automation process minimizes sample consumption and allows introduction of customized rinse solutions for clinical matrices within the sample uptake path during ICPMS sample analysis. The integrated optical sensors on the SampleSense valve also detect and report sample loading failures. These unsensed samples – for example, empty tubes or capped tubes – are identified and logged, saving the operator the time and hassle of deciphering ICPMS data from non-sample events.

SampleSense *FAST* UHT-C eliminates wasted time from the ICPMS method during sample uptake, signal stabilization and wash, accelerating clinical trace metal analyses and significantly increasing the proportion of ICPMS operating time spent measuring samples. This, in turn, minimizes ICPMS maintenance by reducing the amount of time samples are nebulized into the instrument.

SampleSense *FAST* UHT-C Analytical Cycle



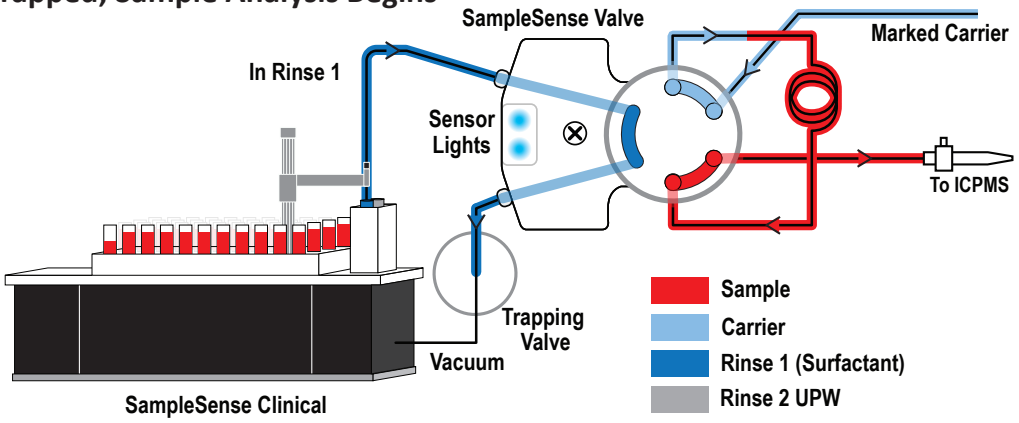
Rinse Trapping with Dual Rinse Solutions

The SampleSense *FAST* UHT-C revolutionary trapping valve optimizes the rinse-out of clinical sample components from the ICPMS sample introduction pathway. Clinical samples (urine, serum, blood) contain components that coat the ICPMS sample introduction uptake lines and result in required downtime for manual cleaning. Customized rinse solutions – described later in this document – containing complexing agents and surfactants are combined with a UPW rinse to effectively remove these sample deposits from the lines. The rinse-trapping capability of the SampleSense *FAST* UHT-C system optimizes the dual rinse of the autosampler by trapping rinse solution from the first rinse station in the sample probe line during the ICPMS data acquisition time. Once analysis is complete, the sample probe moves directly into the second rinse station while the trapping valve opens and the trapped dual rinse solutions – in series – wash the sample uptake components in preparation for the next sample. Fast and efficient washout is achieved using this rinse-trapping capability, facilitating a high throughput rate of 19 seconds per sample

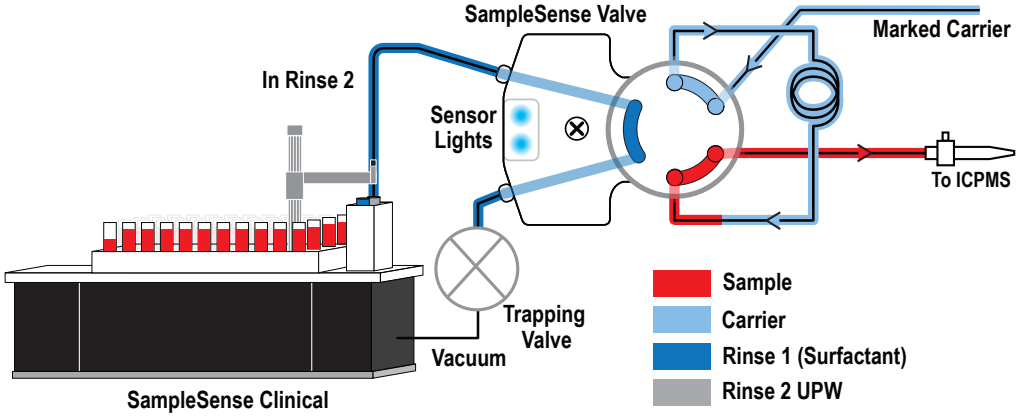
Enhanced Washout

SampleSense *FAST* UHT-C Dual Rinse Trapping Operation for Clinical Samples

1. Rinse 1 Is Trapped; Sample Analysis Begins



2. Probe Moves into Rinse 2 with Trapped Rinse 1; Sample Analysis Continues



3. Valve Opens, Rinse 1 & 2 Clean Loop and Go to Waste; Analysis Complete, Marked Carrier Follows

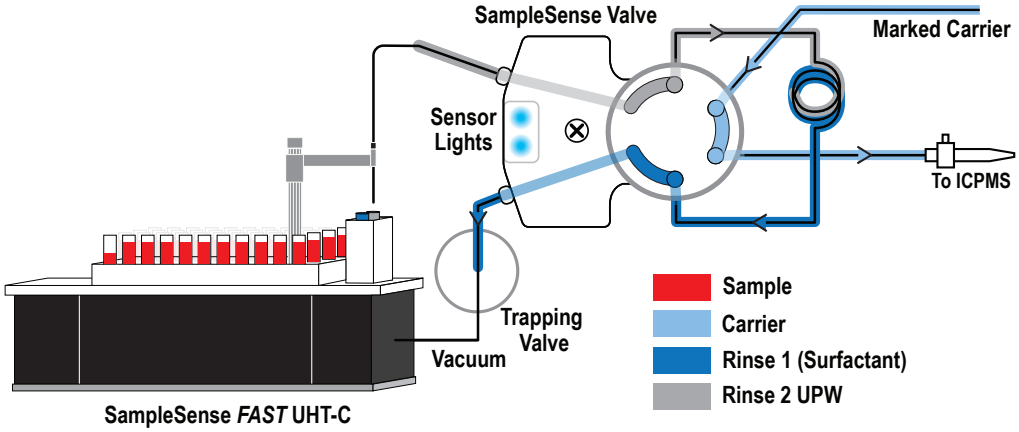


Figure 2. SampleSense *FAST* UHT-C Rinse Diagram: (1) After sample loading and injection, the probe moves to Rinse 1 to begin the rinse sequence. Once the first rinse solution has filled the probe and both sensors are activated, the trapping valve closes, capturing Rinse 1 in the probe. (2) With Rinse 1 trapped, the probe moves into the second rinse station and waits for analysis to complete. (3) Once analysis is complete, the trapping valve opens and both rinses immediately and sequentially clean the loop. The probe moves up and to the next sample for analysis.

Instrumentation and Preparation of Samples and Standards

All samples were analyzed using SampleSense *FAST* UHT-C in combination with a Thermo iCAP RQ ICPMS in standard mode.

Features

- >3 samples per minute
- Automatic sensing, injection and triggering of the analysis
- Detection and reporting of missing or empty sample positions as "unsensed" samples
- Dual rinse with trapping of rinse solution within uptake pathway during sample analysis

Bovine whole blood samples used in analysis were diluted 50x using an aqueous solution of 0.4% v/v TMAH, 1% ethyl alcohol, 0.01% APDC, and 0.05% Triton X-100. This clinical diluent solution was also used as the diluent for the calibration standards and as Rinse 1.

Table 1. Parameters of experiment

Parameter	Standard Mode
ICP RF Power (W)	1550
Nebulizer Gas Flow (L/min)	0.95
Ar Dilution Gas Flow (L/min)	0.2
Auxiliary Gas Flow (L/min)	0.8
Plasma Gas Flow (L/min)	14
Sample Flow Rate (mL/min)	0.65 (Black/Black)
Nebulizer	PFA Integrated Capillary Nebulizer (ICN30-73)
Ar Gas Humidifier	*pergo* 2 (PRG-02)
Spray Chamber	Quartz Cyclonic
Torch	Demountable Quartz
Injector	2.5 mm Quartz
Sampler/Skimmer Cones	Nickel/Ni insert 3.5 mm
Peltier Cooler Set Point	2.7 °C

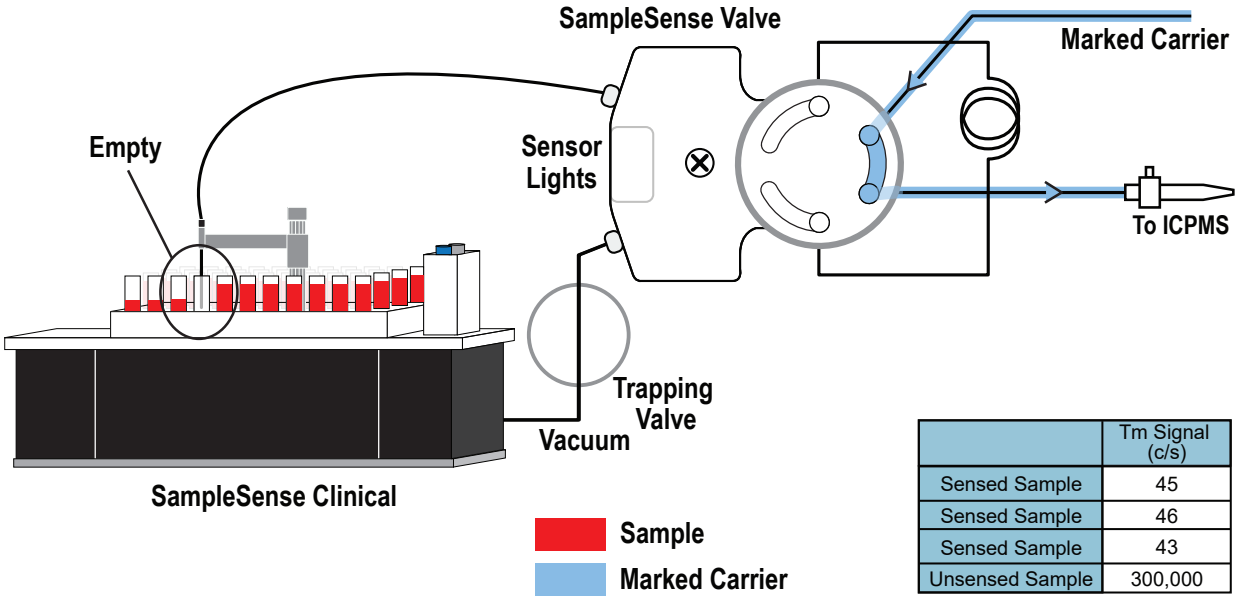
Experimental Conditions

- 4DX SampleSense *FAST* UHT-C Autosampler
- Dual rinse configuration with Rinse 1 trapping
  - Rinse 1: Clinical diluent (TritonX-100, TMAH, EtOH, APDC)
  - Rinse 2: Rinse 2: >18 MΩ cm deionized water
- Total run time for 623 samples <3 h 20 min
  - 19 s/sample
- Analytes
  - Pb 206 + 207 + 208
  - Bi (IS)
  - Tm (Carrier Marker) – Unsensed samples not injected
- Argon Dilutions
  - Ar Dilution gas added above spray chamber to reduce sample loading on the instrument
  - *pergo* 2 accessory utilized to humidify both nebulizer and Ar Dilution gas flows

Figure 3. SampleSense *FAST* UHT-C 4DX and *pergo* 2 on the Thermo iCAP RQ ICPMS with six microplates. Closeup image shows diluted blood being sampled from microplate well.

Confirmation of Sample Loading with SampleSense

In addition to offering the advantages of automatic sample loading, valve injection, and ICPMS triggering, the optical sensors in the SampleSense valve provide positive confirmation to the laboratory that each sample was properly dispensed into its microplate well and subsequently successfully loaded into the loop for analysis. If a sample container is either underfilled or empty, the SampleSense software logs the unsensed sample event and does not inject the contents of the sample loop. As additional confirmation of a missed sample in the raw ICPMS data, a marker component is added to the carrier solution (Tm in this work). SampleSense automatically responds to any unsuccessful sample-loading event by triggering the ICPMS analysis without injecting the sample loop contents, resulting in the analysis of the marked carrier solution. The presence of this marker, Tm, at a high count rate in the ICPMS data provides additional confirmation to the analyst that a sample was not introduced successfully. An example is shown in Figure 3.



	Tm Signal (c/s)
Sensed Sample	45
Sensed Sample	46
Sensed Sample	43
Unsensed Sample	300,000

Figure 4. A carrier marker is an element present in the carrier solution that provides verification of a non-sample event, such as an empty or underfilled sample. If a sample is not successfully loaded, the SampleSense valve will trigger analysis of the marked carrier solution, providing noticeably higher analyte levels in the raw data.

Experimental

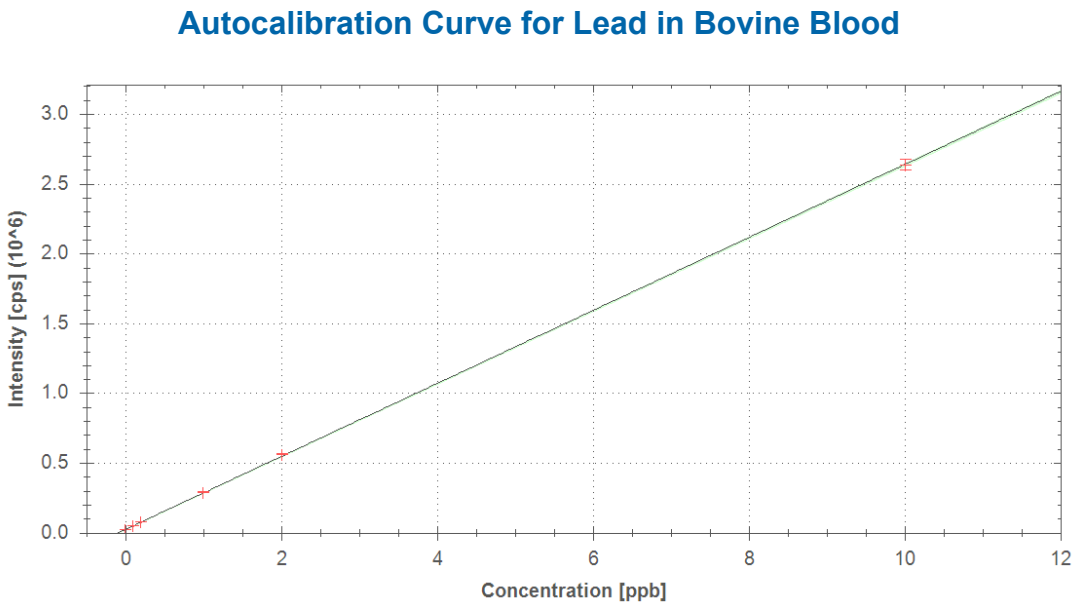


Figure 5. Calibration curve for lead with standards covering the range of 0.1 to 10 µg/L. Standards prepared in clinical diluent solution (Rinse 1). All solutions measured in triplicate at a rate of 19 seconds per sample.

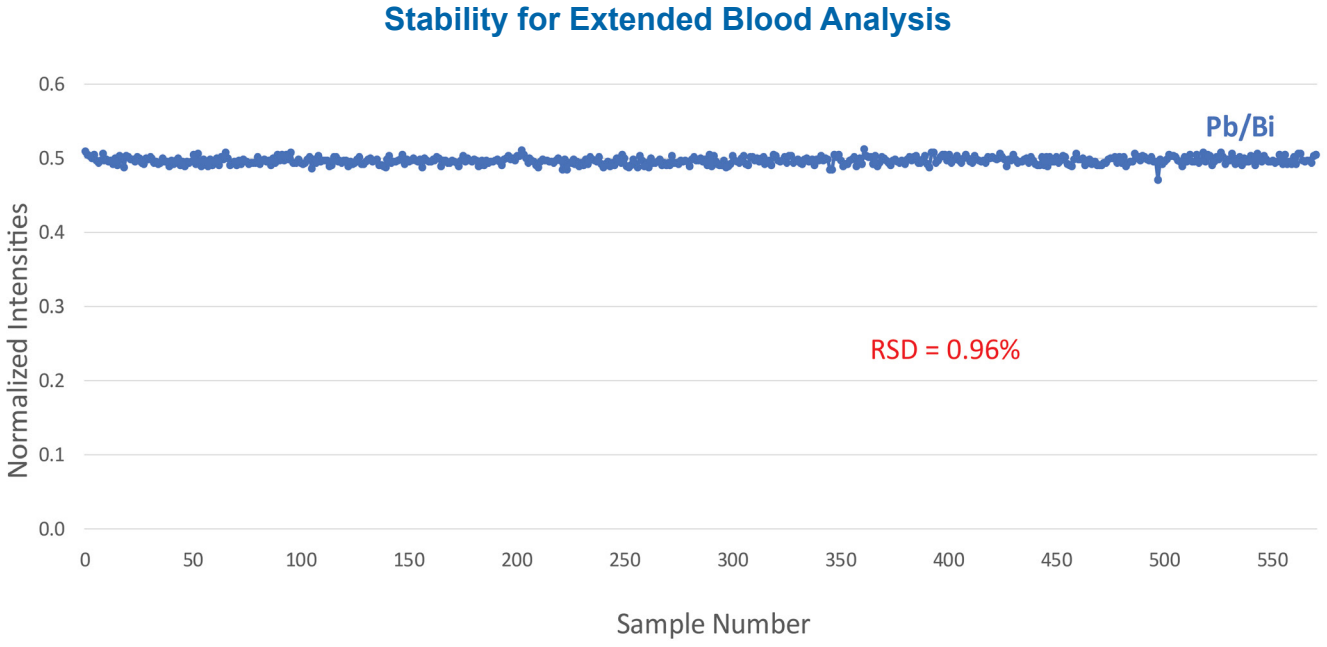


Figure 6. Normalized intensity ratio (Pb [206, 207, 208] / Bi209) during extended analysis of 576 samples from six 96-well microplates. Excellent long-term reproducibility of 1% RSD was observed over the 3 h 20 min analysis of 50x diluted bovine blood samples.

Experimental *(Continued)*

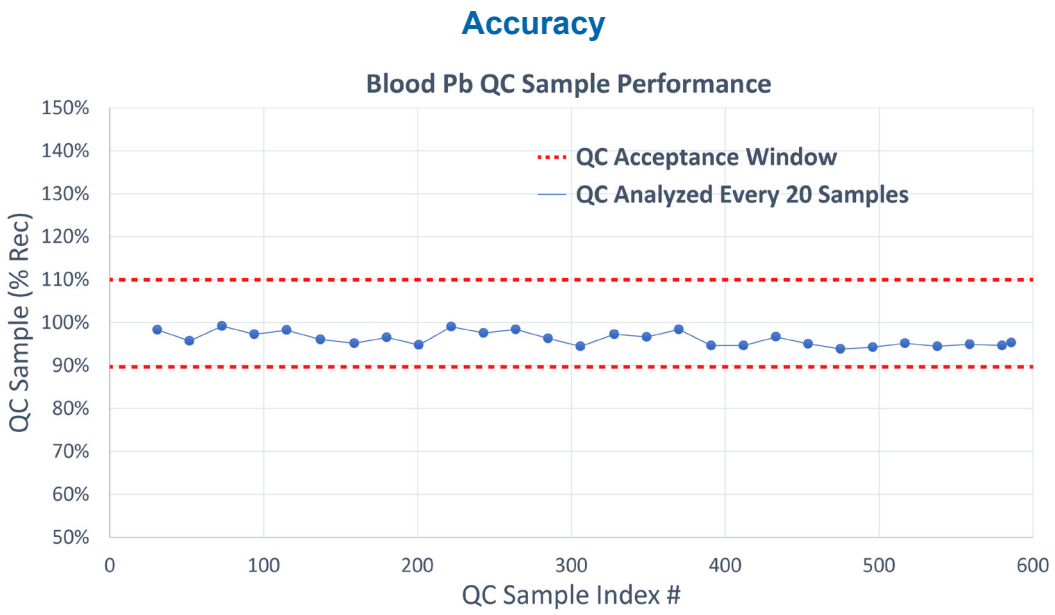


Figure 7. Accuracy obtained for NYS Biomonitoring Proficiency Test sample BE18-04 for trace elements in whole human blood over a 3+ hour analysis run. The QC sample was inserted into the sequence after every 20 bovine blood samples. Average recovery of 96% was obtained for the certified Pb level of 42.7 µg/dL.

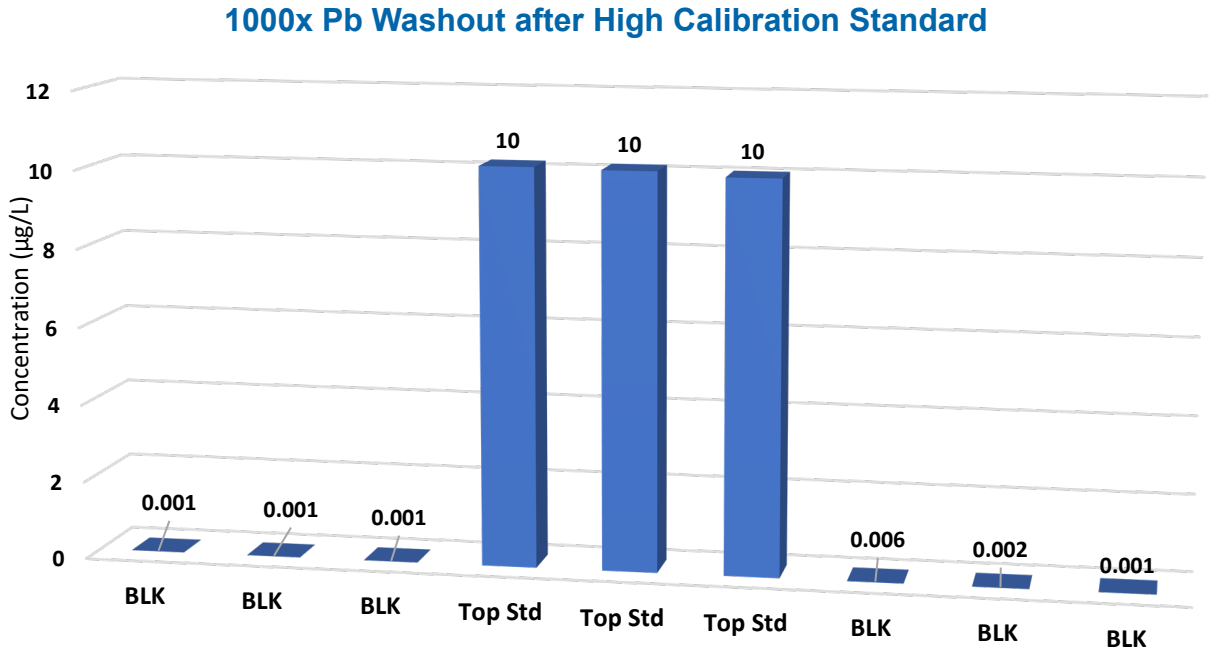


Figure 8. Pb washout performance for SampleSense *FAST* UHT-C system. System rinseout tested by running three blanks, followed by three top standards (10 µg/L), followed immediately by three blanks. Very effective washout was obtained with the dual rinse trapping provided by the ultra-high-throughput system. Blank directly following top standard achieved in excess of 1000x washout in Pb level measured.

Conclusion

SampleSense *FAST* UHT-C automatically optimizes high-throughput clinical analyses using optical sensors for sample loading and a novel trapping valve for rinse enhancement. It eliminates method customization and the need to adjust timing parameters to account for variable sample viscosity and long-term instrument hardware problems, such as a sample line that accidentally becomes kinked. The benefit of SampleSense *FAST* UHT-C is particularly important for micro-volume samples because it allows rapid vacuum-loading and injection of the sample with little waste. Positive detection of the sample improves analytical efficiency in a production laboratory environment by maximizing throughput and minimizing and flagging sampling errors, providing a higher level of data authentication and reliability for patient results.

Description	iCAP Q/RQ/TQ Part Numbers
SampleSense *FAST* UHT-C 2DX	2F-SS6-UHTC-73
SampleSense *FAST* UHT-C 4DX	4F-SS6-UHTC-73
SampleSense *FAST* UHT-C 8DX	8F-SS6-UHTC-73
SampleSense *FAST* UHT-C 14DX	14F-SS6-UHTC-73