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TRAXStation Clinical – Fully Automated Preparation of Serum Samples for the Analysis of Copper and Zinc

Introduction

Trace element analysis plays a critical role in modern clinical diagnostics, providing essential information for evaluating nutritional status, toxic exposures, and metabolic disorders. Traditionally, the workflow for preparing and analyzing clinical samples by inductively coupled plasma mass spectrometry (ICPMS) has relied heavily on manual liquid handling steps. These steps – such as uncapping, rocking, pipetting, and dilution are time-consuming, prone to operator variability, and present ongoing risks of contamination, especially at trace and ultra-trace concentrations. As clinical demand grows, laboratories processing hundreds to thousands of patient samples per day face the mounting pressure to increase throughput while maintaining uncompromising analytical quality.

TRAXStation Clinical directly addresses these challenges by automating routine sample preparation tasks in a controlled, contamination-free environment. Built with chemically inert materials, the platform is designed to handle clinical matrices reliably while eliminating common sources of error. Advanced features such as automated vial uncapping, liquid-level detection, barcode tracking, sample mixing and precise dilution routines ensure consistent preparation across

large sample sets. For high-volume laboratories, this level of automation translates to improved reproducibility, reduced operator workload, and a streamlined path from original patient specimen to analysis-ready sample.



Figure 1. TRAXStation Clinical 422.

Introduction (Continued)

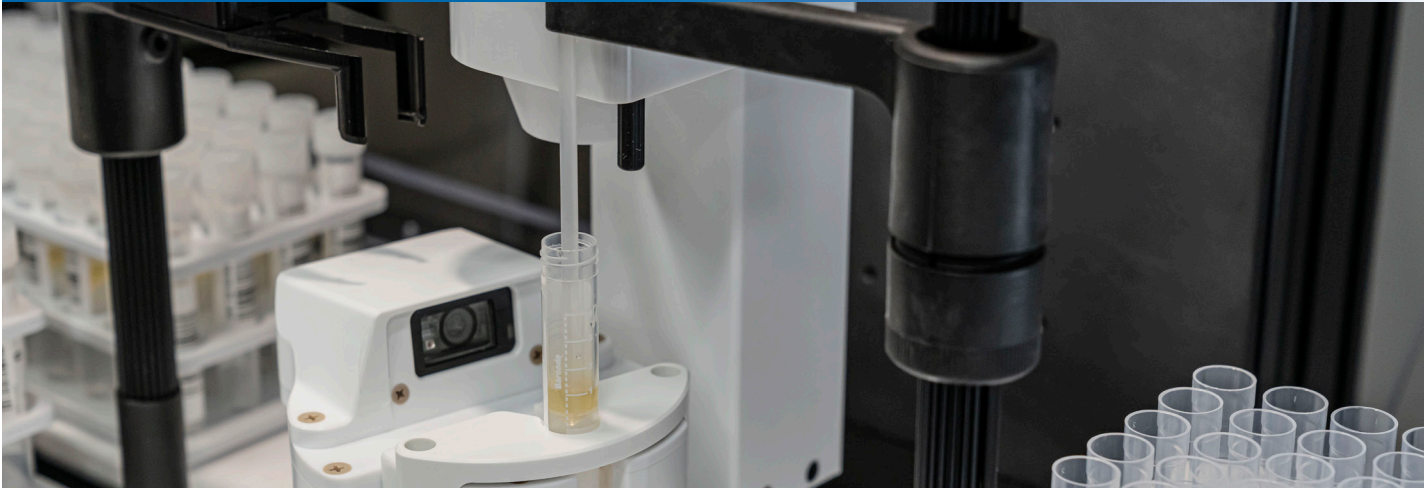


Figure 2. TRAXStation Clinical takes up an aliquot for automated preparation.

TRAXStation Clinical automates the full preparation workflow for serum samples collected in plastic metal free serum tubes. The compact platform integrates all key steps into a single system, improving laboratory efficiency, traceability, and operator safety while ensuring

high-quality, reproducible results. By replacing labor-intensive manual steps, TRAXStation Clinical reduces errors, shortens turnaround times, and increases throughput while maintaining strict regulatory compliance and sample integrity.

TRAXStation Clinical Workflow

Barcode Reading & Sample Tracking

Integrated barcode scanning provides complete traceability and seamless connection to instruments and LIMS.

Automated Uncapping

Hands-free uncapping reduces manual handling, contamination risk, and biohazard exposure.

Ultra-Sonic Sensing

Sound waves are used to detect sample liquid levels. The probe will aspirate from just below the liquid surface.

Precision Sampling & Dilution

High-accuracy pipetting enables aliquoting into tubes or 96-well plates, with programmable dilutions for flexible assay workflows.

Mixing & Plate Preparation

Automated mixing ensures consistent sample readiness.

(Optional) Sample Tube Rocker

Gentle rocking of tubes prior to processing guarantees homogeneous samples for accurate downstream analysis.

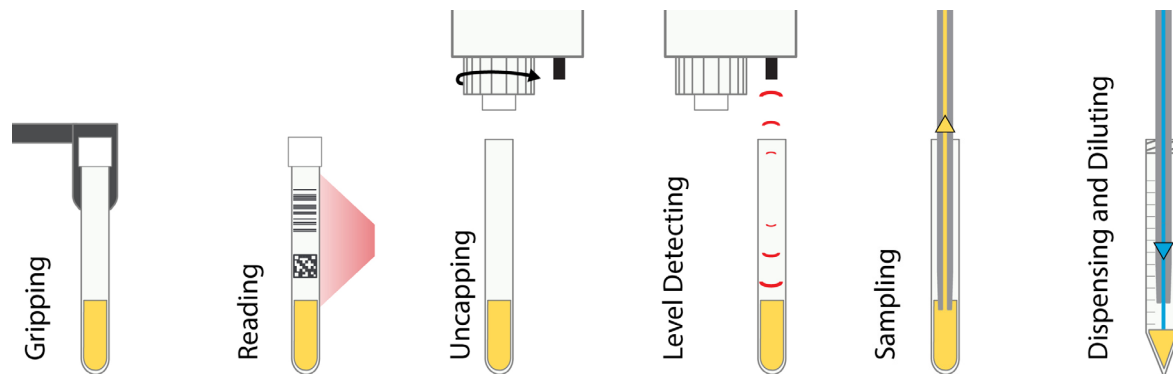


Figure 3. TRAXStation Clinical automated workflow for serum sample preparation.

Background

Laboratories routinely test for Copper and Zinc levels in serum because both are essential trace elements that play critical roles in human health, and imbalances can signal significant clinical conditions. By measuring serum levels of these elements, laboratories provide clinicians

with crucial information for diagnosing deficiencies, monitoring disease progression, and guiding nutritional or therapeutic interventions. Millions of samples are tested by Clinical Laboratories every year. See below for details on each element.

Copper in Serum

Copper is required for enzymes that regulate energy production, connective tissue, brain development, and iron metabolism. Imbalances or disorders related to copper can lead to serious symptoms. Some of the common reasons for testing are:

- Nutritional status – copper deficiency or excess from diet, supplements, or parenteral nutrition
- Wilson's disease – inherited disorder causing toxic copper buildup in liver, brain, eyes
- Menkes disease – rare genetic disorder causing copper deficiency
- Chronic liver disease – since copper is processed and excreted via bile
- Anemia or Neutropenia – copper deficiency can mimic iron deficiency anemia
- Neurologic symptoms – weakness, numbness, movement disorders can be linked to copper imbalance

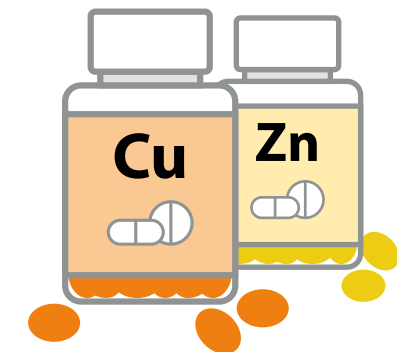
Zinc in Serum

Zinc is essential for immune function, wound healing, growth, and reproduction, serving as a cofactor in hundreds of enzymes affecting metabolism and DNA repair. Some of the common reasons for testing are:

- Nutritional status – zinc deficiency or excess from diet, supplements, or parenteral nutrition
- Malnutrition or malabsorption – e.g. celiac disease, Crohn's, chronic diarrhea
- Chronic illness or inflammation – zinc deficiency can worsen healing and immunity
- Delayed wound healing or frequent infections
- Growth and development issues in children
- Suspected Toxicity – though rare, very high zinc can cause copper deficiency, anemia, and neurologic symptoms

Example for Normal Laboratory Reference Ranges

- Serum Copper: 700 µg/L (men), 800-1550 µg/L (women)
- Serum Zinc: 600-1200 µg/L (both sexes)



Experimental – TRAXStation Automated Sample Prep

Evaluation that the combination of TRAXStation preparation & ICPMS measurement produces acceptable precision (repeatability and reproducibility) and accuracy (bias vs assigned concentrations) for copper and zinc across the clinical range using three pooled sample levels: Low (below normal levels), Normal (clinically relevant mid-range), and High (above normal range that may represent toxicity).

Table 1. Homogenized, bovine serum pools.

Pool Level	Target Concentration (µg/L)	Number of Aliquots into Identical Sample Tubes
Low	~250	25
Normal	~1000	25
High	~2500	25

Table 2. Additional reagents.

Reagent	Preparation
Calibration Standards	Prepare according to method SOP
Blanks	Prepare required blanks
Carryover Check (Negative)	Prepare negative sample
Diluent	1% HNO ₃ (v/v), 20 ppb Ge

Table 3. Run structure.

Component	Description
Samples per Run	25 prepared aliquots of each level: Low, Normal, High
Additional Samples	Blank, Calibrators, Negative (carryover check)
Total Runs	25 total runs
Data Output ICPMS Analysis	Generate accuracy and precision plots Transfer TRAXStation-prepared samples to 4DXCi SampleSense FAST UHT-C autosampler and analyze each batch
Data Processing	Export results to spreadsheet for statistical analysis

Table 4. TRAXStation Clinical preparation.

Component	Setting Preparation
Rinse 1	DI H ₂ O
Rinse 2	DI H ₂ O
Diluent	Connect prepared diluent (1% HNO ₃ , 20 ppb Ge)
Sample Loading	Load capped aliquots, blanks, calibrators
Dilution Method	100x dilution (40 µL sample + 3960 µL diluent)

Data Analysis Criteria

For clinical serum copper and zinc testing, good precision and accuracy are demonstrated through rigorous statistical validation consistent with CLIA, CAP, and CLSI guidelines. Precision is evaluated by repeated analysis of serum pools at low, normal, and high concentrations, with 25 replicates per level over 25 runs/batches and expressed as coefficient of variation (%CV). For trace metals such as copper and zinc, intra-assay and inter-assay %CVs should generally be ≤5% at normal and high levels and ≤10% at low levels. Accuracy is verified by comparison with mean recovery required to fall within ±10% of target values. According to

CLIA proficiency testing criteria, the allowable total error (TEa) is ±15% or 150 µg/L for serum copper and ±15% or 100 µg/L for serum zinc, whichever is greater. Both short-term and long-term reproducibility must be assessed across runs, days, and operators to ensure robustness. Adherence to Good Laboratory Practice (GLP) principles and use of trace-element-free collection and processing materials are essential to minimize contamination. Together, these statistical and procedural controls ensure that serum copper and zinc results are analytically valid, reproducible, and compliant with regulatory standards for clinical testing.

ICPMS Instrument Parameters

All samples were prepared using TRAXStation Clinical, and analyzed using 4DXCi SampleSense FAST UHT-C autosampler in combination with a Single Quad ICPMS.

Table 5. Instrument information.

Parameter	Value
Sample Introduction System	ESI 4DCXi Autosampler SampleSense FAST UHT-C TRAXStation Clinical
Instrument Valve	Single Quad ICPMS Magnetically-Coupled Inert 6-port Valve
Probe Nebulizer	Blue Carbon Fiber Probe High Solids PFA Microflow Nebulizer
Rinse 1	1% Nitric Acid (v/v)
Rinse 2	1% Nitric Acid (v/v)
Carrier	1% Nitric Acid (v/v)
Method Time	24 sec/sample analysis

Table 6. Instrument parameters.

Parameter	Value
Analytes	Cu (m/z 65) Zn (m/z 66)
ISTD	Ge (m/z 72)
ICPMS Mode	Standard Mode
Sweeps per Replicate	10
Replicates per Sample	3
Dwell	100 ms

Figure 4. SampleSense FAST UHT-C AutoBench.



Copper and Zinc Calibration – Analytical Measurement Range (AMR) 50-5000 µg/L

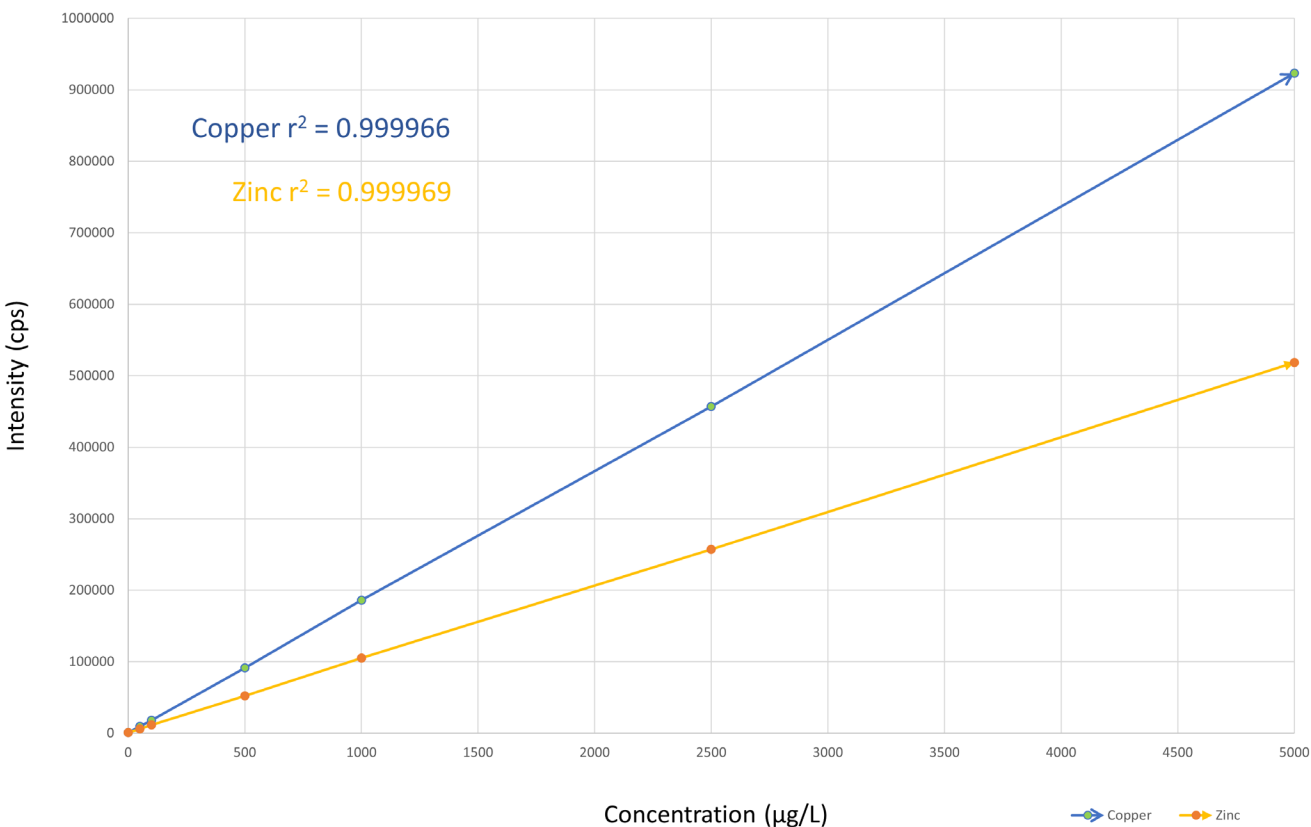


Figure 5. Calibration results demonstrated excellent precision and accuracy for both copper and zinc when aqueous calibrators were pipetted and prepared using the **TRAXStation Clinical** automated platform. Measured concentrations closely matched target values, and all Correlation Coefficients were 0.999 or better, indicating minimal bias and strong agreement with expected results. Together, these findings validate that **TRAXStation Clinical** delivers consistent, contamination-free preparation, ensuring reliable quantitation of copper and zinc in clinical testing workflows.

Summary Results

Serum copper (Cu) and zinc (Zn) were quantified using validated ICPMS methodology following automated preparation on the **TRAXStation Clinical** platform. Results demonstrated exceptional analytical performance, with both elements showing excellent precision and accuracy across the reportable range.

Table 7. Copper serum results.

	Low Concentration	Normal Concentration	High Concentration
Average	268.9 µg/L	1003.9 µg/L	2562.2 µg/L
Standard Deviation	2.86 µg/L	7.70 µg/L	22.49 µg/L
Intra-Assay Precision	1.26% CV	1.34% CV	1.38% CV
Inter-Assay Precision	1.06% CV	0.77% CV	0.88% CV

Table 8. Zinc serum results.

	Low Concentration	Normal Concentration	High Concentration
Average	267.5 µg/L	1002.1 µg/L	2581.0 µg/L
Standard Deviation	3.32 µg/L	9.69 µg/L	38.40 µg/L
Intra-Assay Precision	1.46% CV	1.31% CV	1.39% CV
Inter-Assay Precision	1.24% CV	0.97% CV	1.49% CV

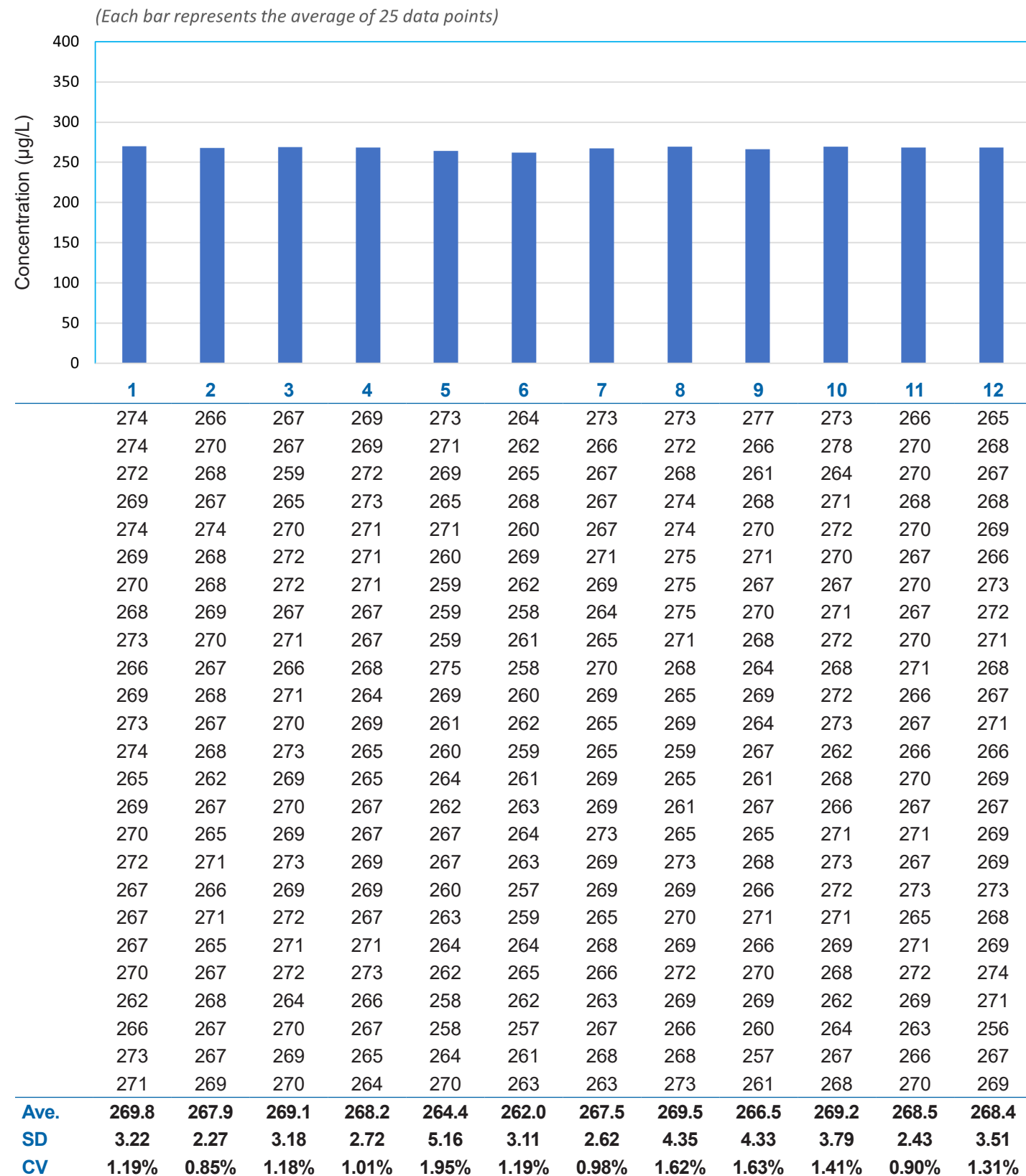
The **TRAXStation Clinical 221** platform was used in this experiment. This compact version delivers the full power of automated sample preparation in a smaller footprint – ideal for laboratories with limited bench space. It automates uncapping, mixing, pipetting, and dilution steps to eliminate manual variability, improve reproducibility, and protect sample integrity through contamination-free, metal-inert processing. With intuitive LabSymphony software, barcode tracking, and flexible rack configurations, the **TRAXStation Clinical 221** integrates seamlessly into existing ICPMS workflows while reducing labor, consumable costs, and operator exposure. Despite its smaller size, it provides high-throughput performance, superior consistency, and enhanced laboratory safety – all in a compact, efficient design.



Figure 6. TRAXStation Clinical 221.

See raw data on the following pages.

Copper Inter and Intra-Assay Data – Low Concentration (625 data points)



Copper Inter and Intra-Assay Data – Low Concentration (625 data points) (Continued)

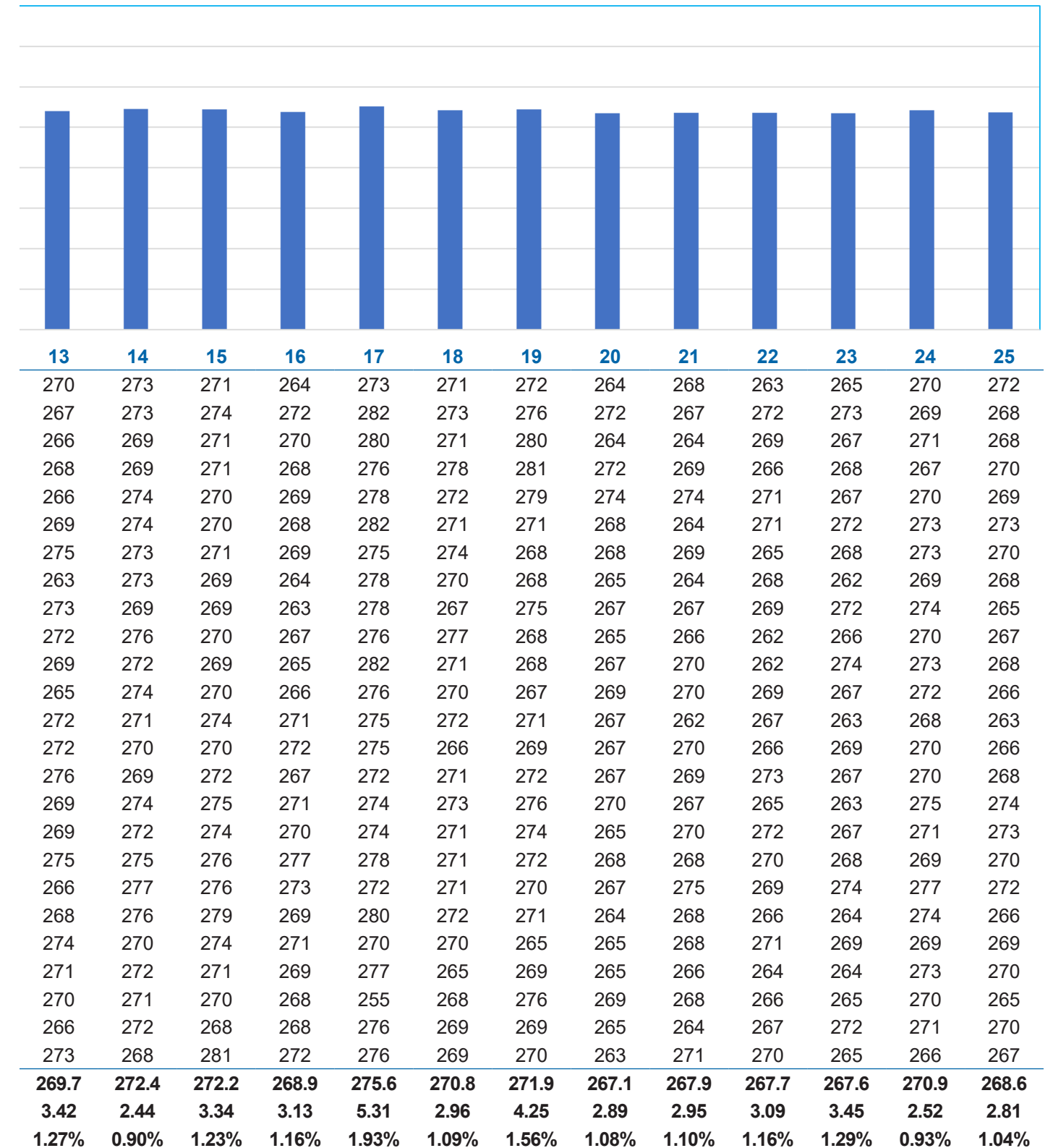


Figure 7. Results of low concentration copper measured by ICPMS (m/z 65). Each number 1-25 corresponds to a batch. The graph above each number shows the average, and the numbers below it show the individual sample data from the batch.

Copper Inter and Intra-Assay Data – Normal Concentration (625 data points)

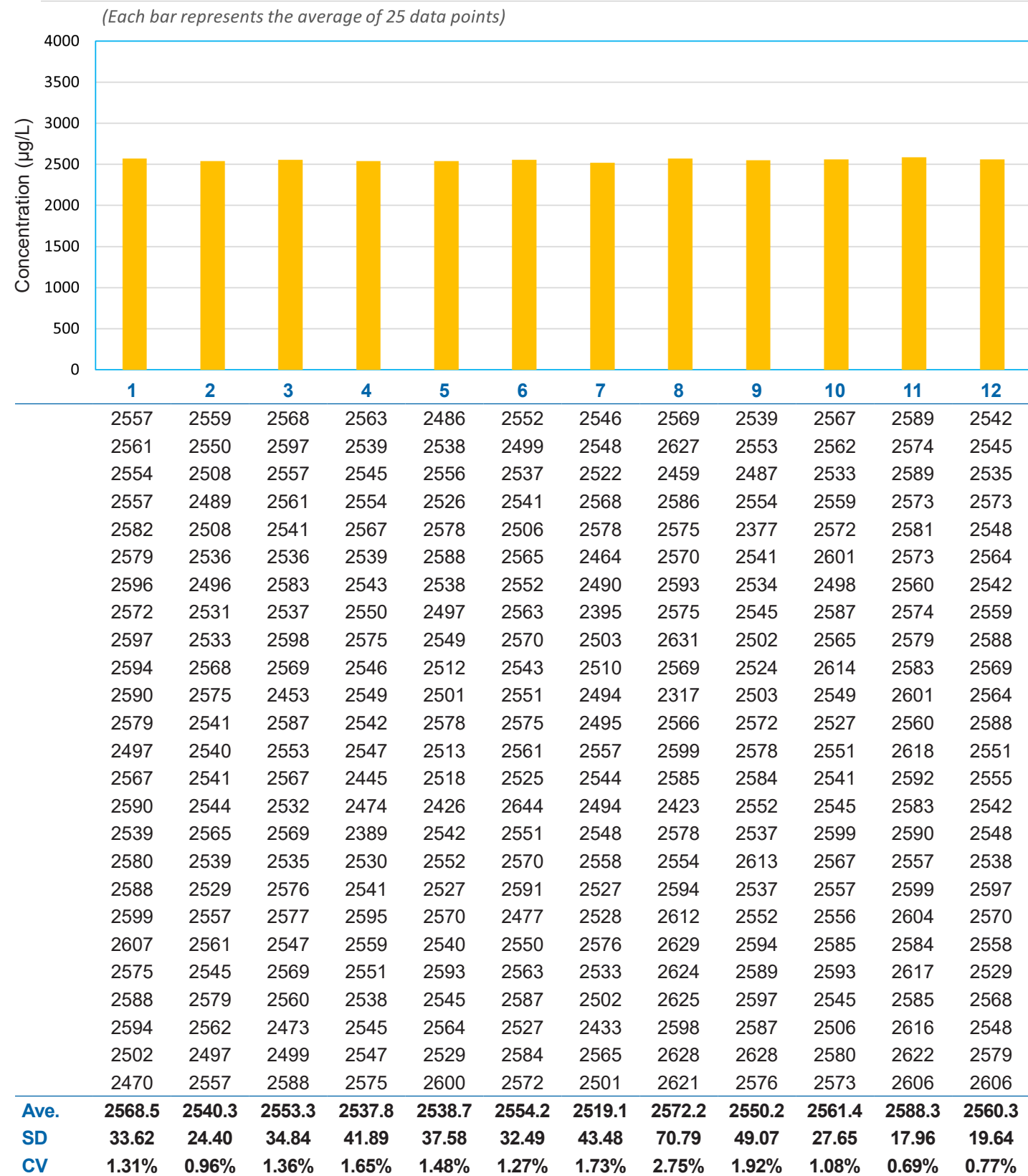


Copper Inter and Intra-Assay Data – Normal Concentration (625 data points) (Continued)



Figure 8. Results of normal concentration copper measured by ICPMS (m/z 65). Each number 1-25 corresponds to a batch. The graph above each number shows the average, and the numbers below it show the individual sample data from the batch.

Copper Inter and Intra-Assay Data – High Concentration (625 data points)



Copper Inter and Intra-Assay Data – High Concentration (625 data points) (Continued)

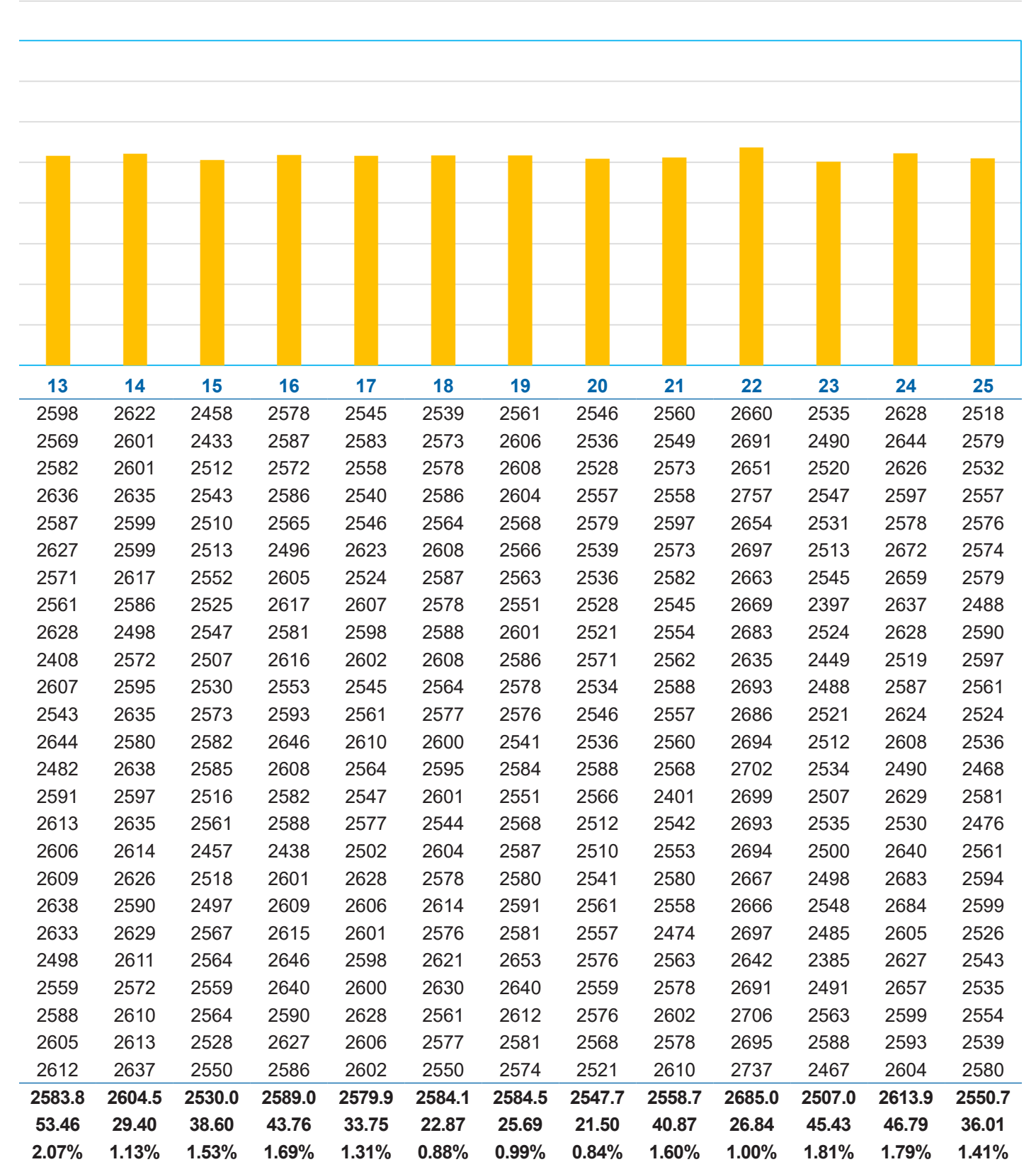
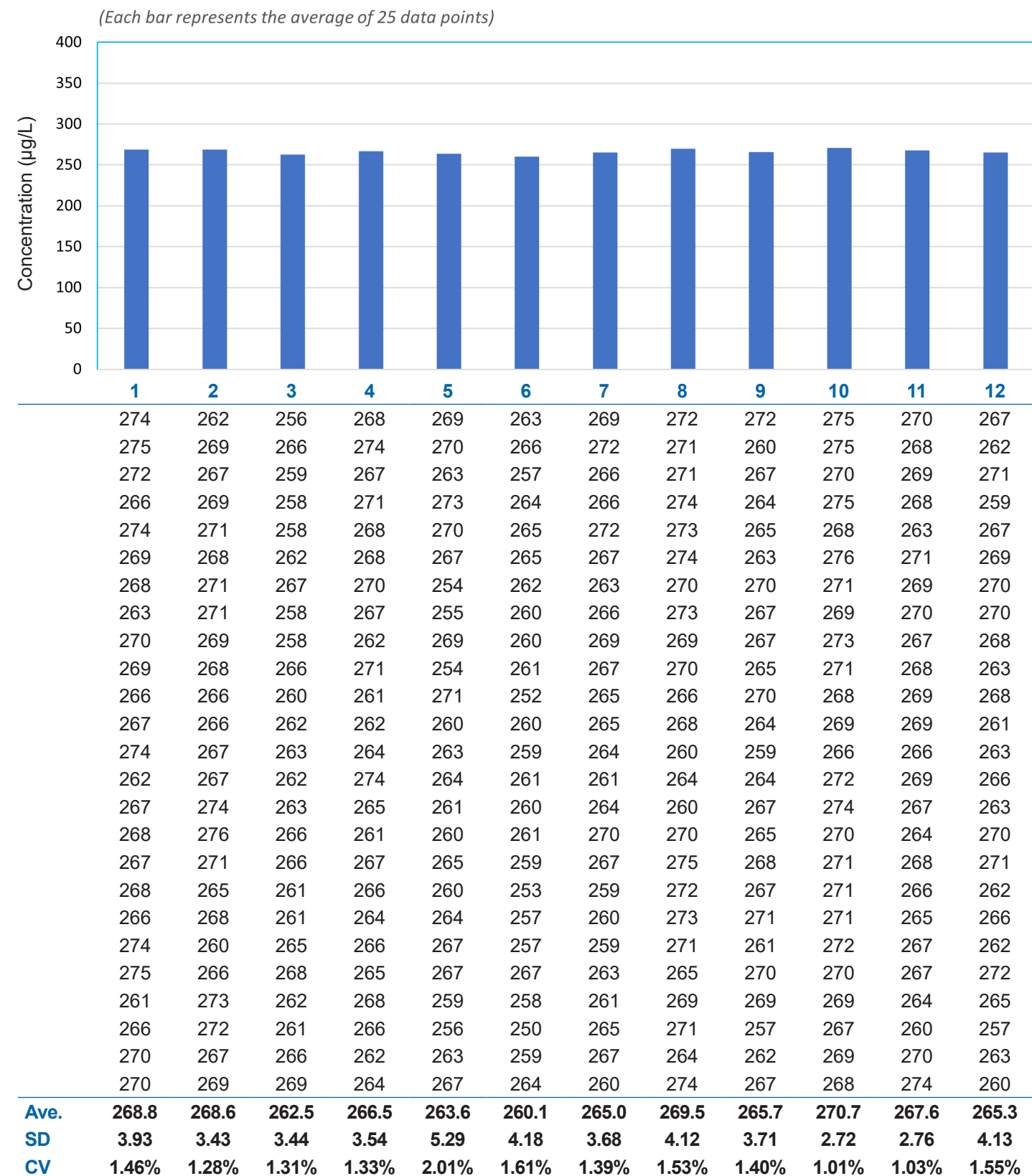


Figure 9. Results of high concentration copper measured by ICPMS (m/z 65). Each number 1-25 corresponds to a batch. The graph above each number shows the average, and the numbers below it show the individual sample data from the batch.

Zinc Inter and Intra-Assay Data – Low Concentration (625 data points)



Zinc Inter and Intra-Assay Data – Low Concentration (625 data points) (Continued)

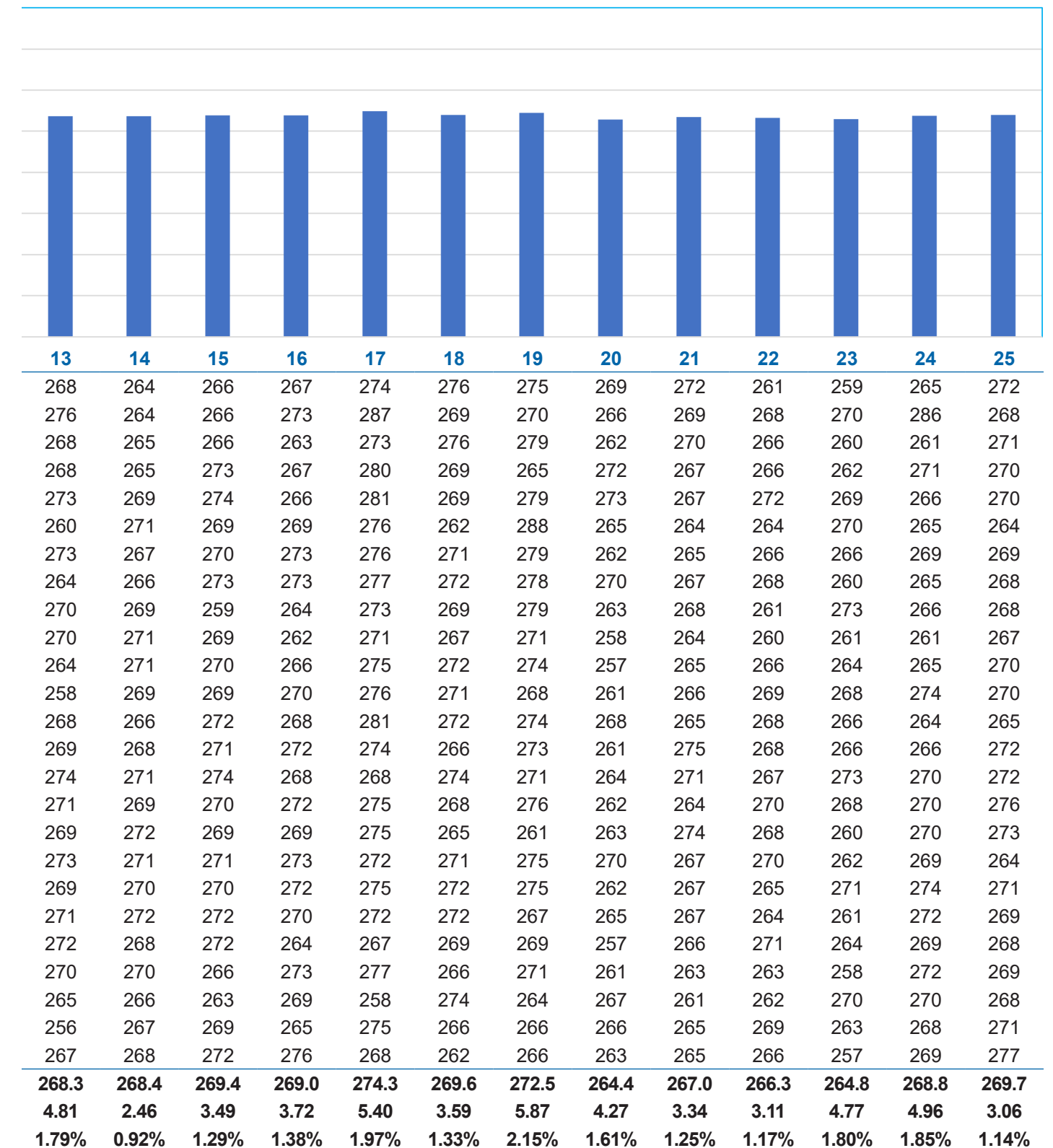
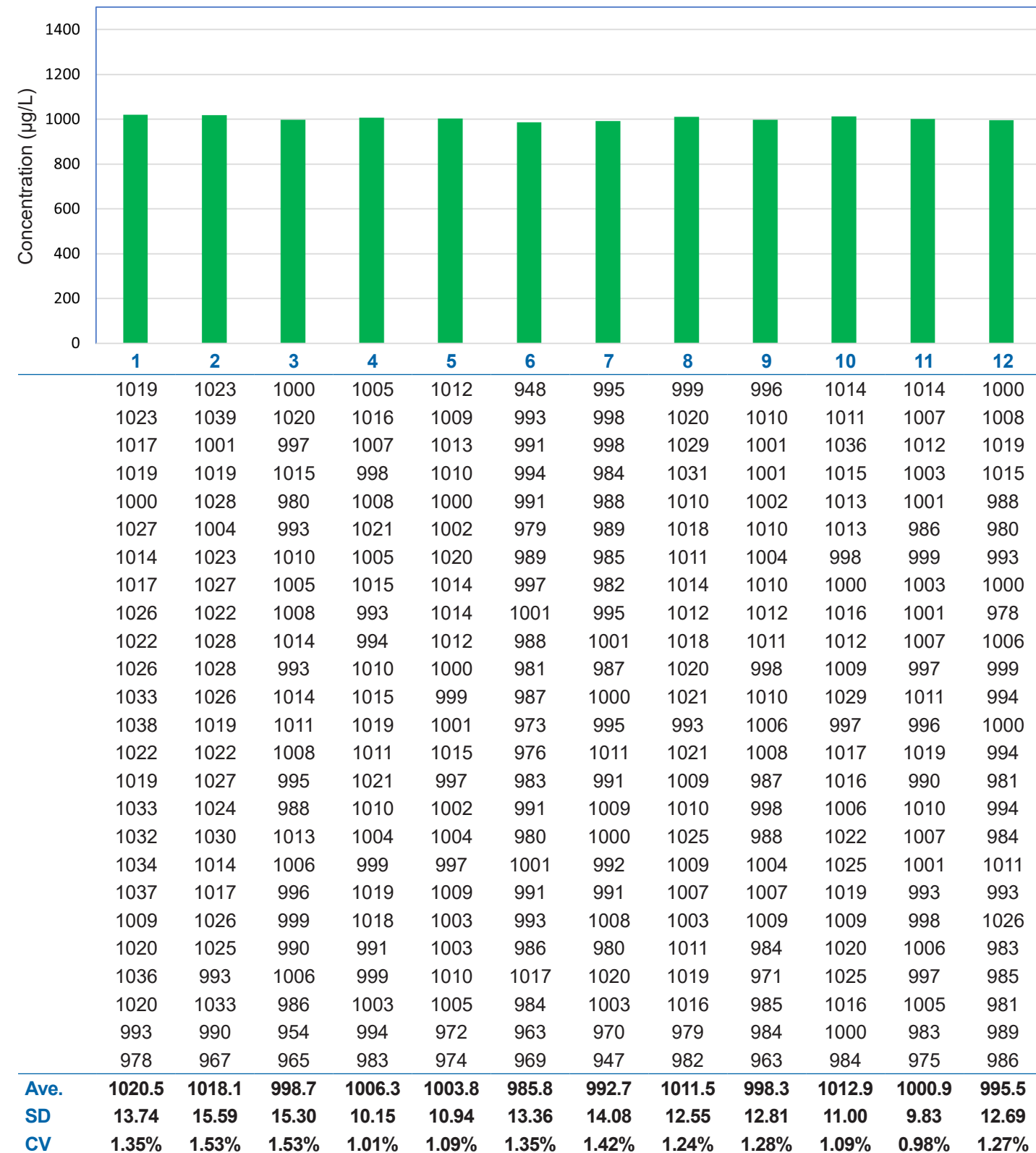


Figure 10. Results of low concentration zinc measured by ICPMS (m/z 66). Each number 1-25 corresponds to a batch. The graph above each number shows the average, and the numbers below it show the individual sample data from the batch.

Zinc Inter and Intra-Assay Data – Normal Concentration (625 data points)

(Each bar represents the average of 25 data points)



Zinc Inter and Intra-Assay Data – Normal Concentration (625 data points) (Continued)

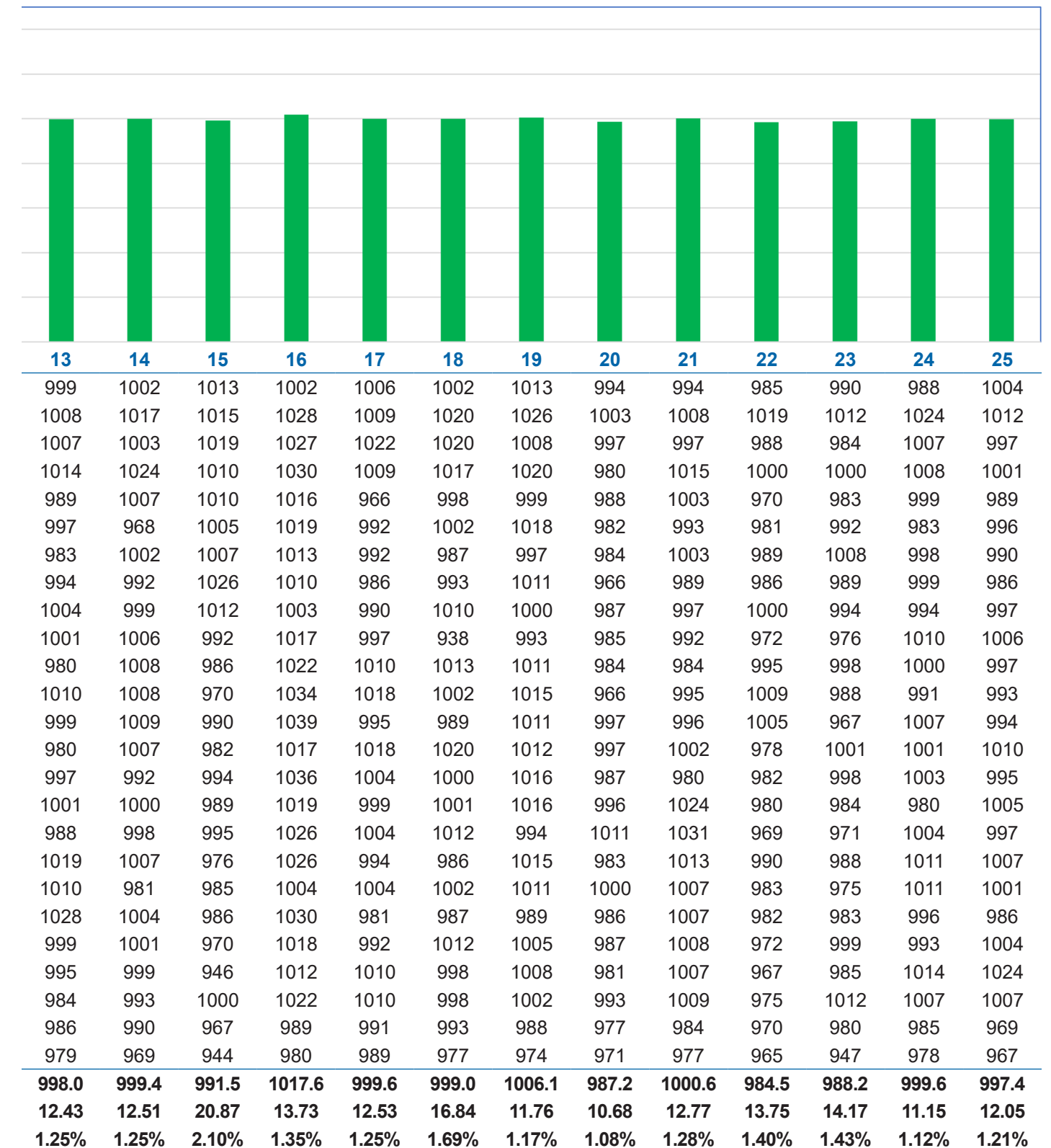
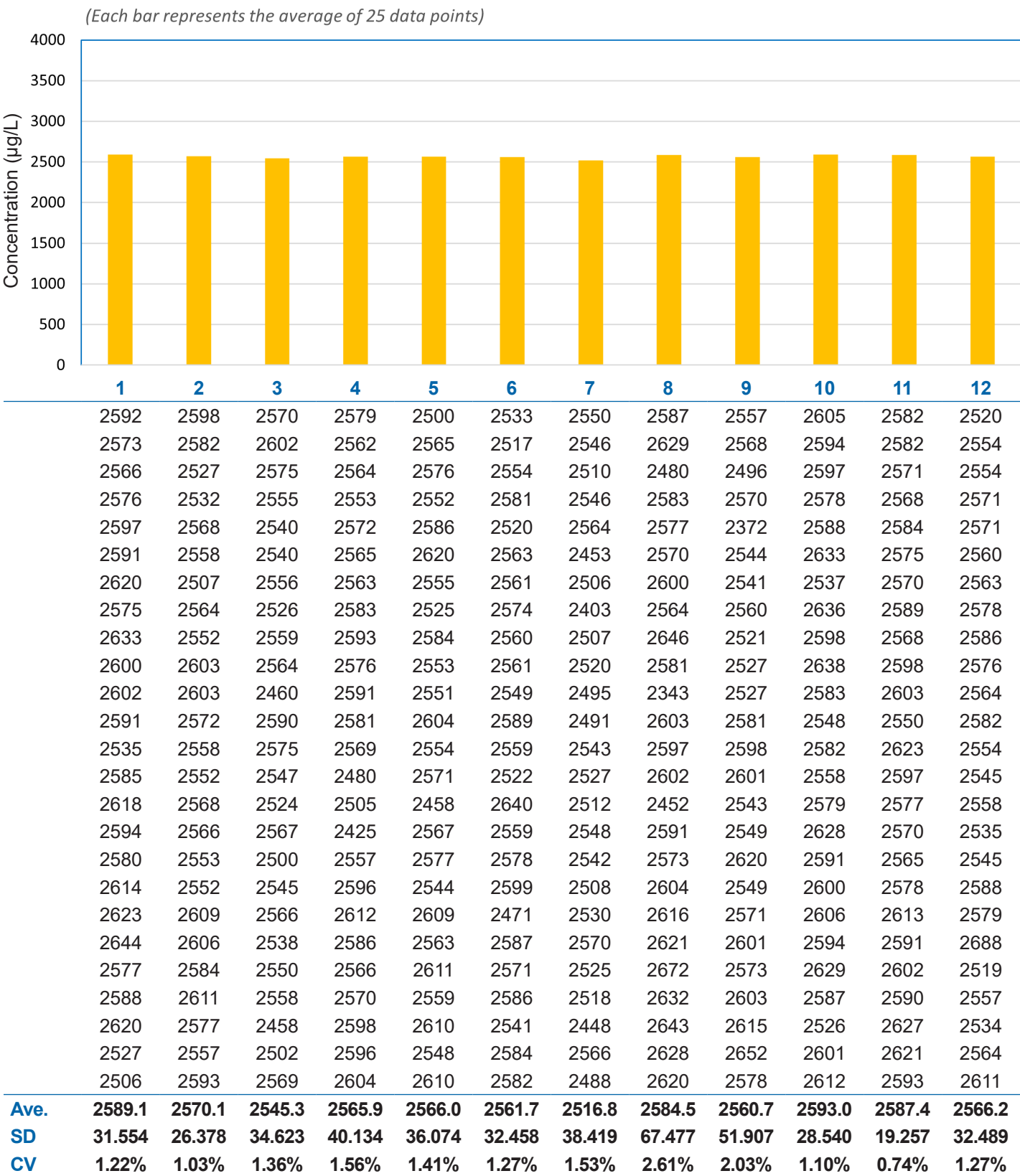


Figure 11. Results of normal concentration zinc measured by ICPMS (m/z 66). Each number 1-25 corresponds to a batch. The graph above each number shows the average, and the numbers below it show the individual sample data from the batch.

Zinc Inter and Intra-Assay Data – High Concentration (625 data points)



Zinc Inter and Intra-Assay Data – High Concentration (625 data points) (Continued)

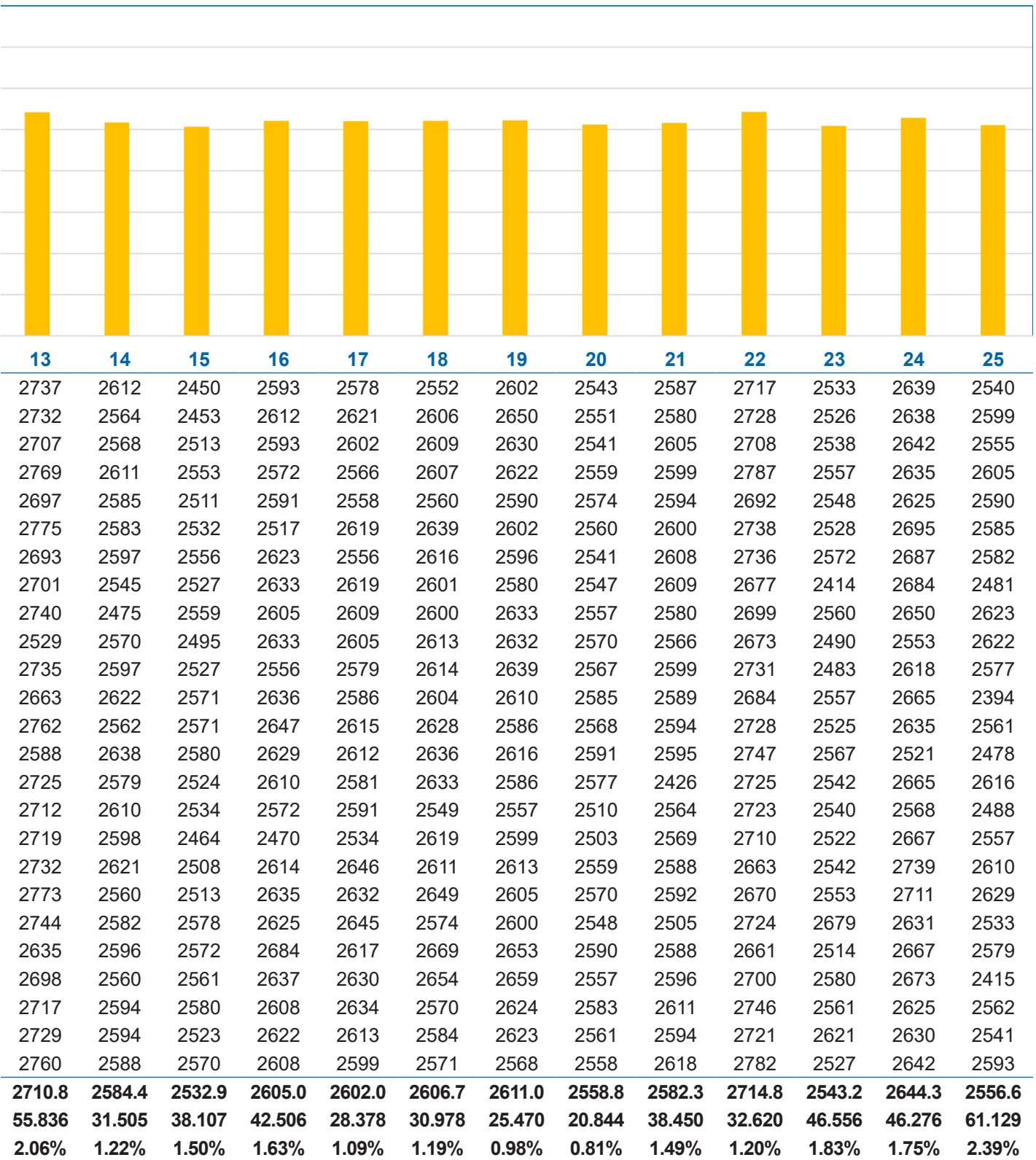


Figure 12. Results of high concentration zinc measured by ICPMS (m/z 66). Each number 1-25 corresponds to a batch. The graph above each number shows the average, and the numbers below it show the individual sample data from the batch.

Conclusion

The **TRAXStation** Clinical Automated Multifunctional Liquid Handling System demonstrated performance that surpassed expected analytical targets for both accuracy and precision. Measured values consistently aligned over extended periods of time indicating minimal systematic error and confirming high method accuracy. Replicate analyses showed

very low variability, with relative standard deviations well below acceptance criteria, reflecting exceptional precision. Collectively, the data provide strong evidence of method robustness and reliability, exceeding established quality benchmarks and reinforcing confidence in both the measurement process and resulting conclusions.

TRAXStation Clinical Features

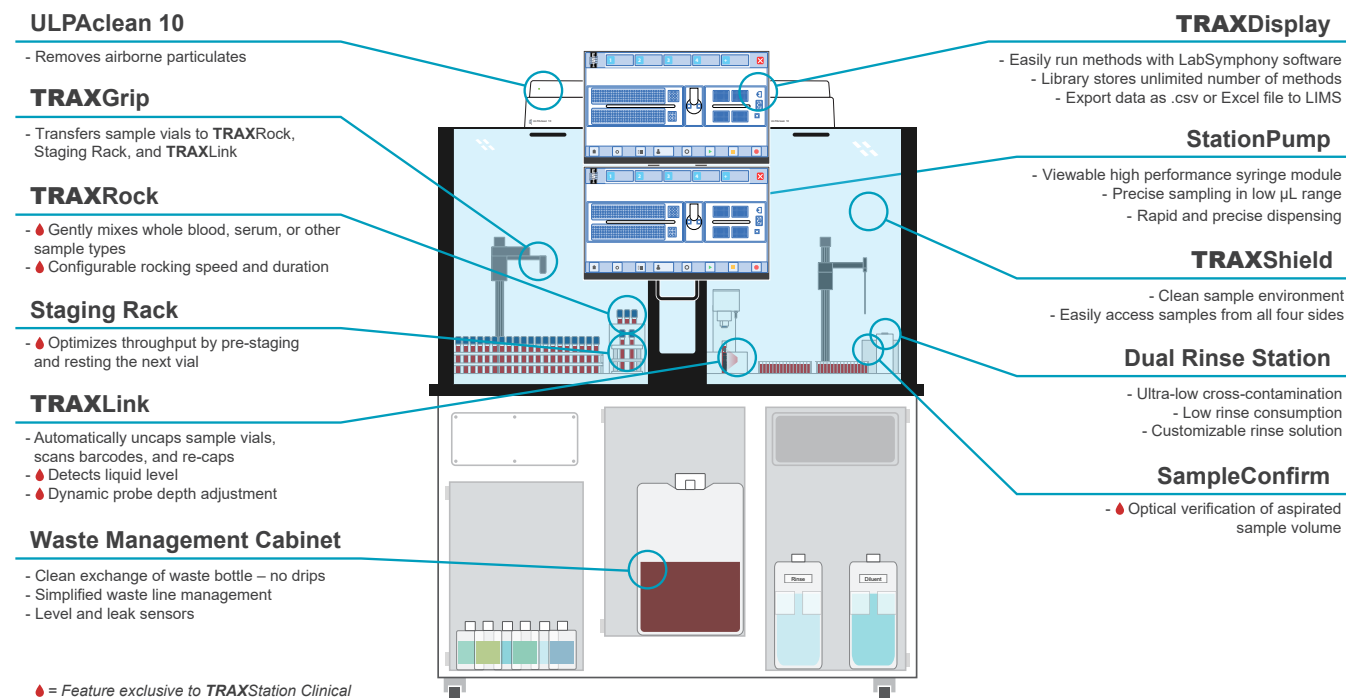


Figure 13. TRAXStation Clinical features diagram. **TRAXStation Clinical** is available in several form-factors to match laboratory throughput requirements. These include **TRAXStation 221**, **422**, and **442**.

