Certification Report of RVMT-BM-1

Processing and certification of a certified reference material made from recycled Li-ion batteries

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Abstract

The certified reference material (CRM) RVMT-BM-1 is made from shredded Li-ion batteries (LIB), so-called black mass, specifically the lithium-nickel-manganese-cobalt oxide type (NMC). This CRM originated from battery production scrap and therefore does not contain added fluoride compounds. This report describes the production and characterisation of the material.

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1. Introduction

RVMT-BM-1 is the abbreviation for **Re**v**o**m**e**t **B**lack**M**ass number **1**. LIBs are key technology powering handheld electronics as well as vehicles. LIBs contain high concentrations of critical raw materials such as Li, Ni, Mn & Co. Therefore, recycling is paramount for sustainable use of finite resources. More and more companies have begun to develop recycling procedures resulting in powdered LIBs, collectively called BlackMass. Knowing the concentrations of critical elements inside the black mass is vital when trading BlackMass as a commodity. The ISO TC 333 is currently working on establishing a sample treatment and analysis protocol for BlackMass using inductively coupled optical emission spectroscopy (ICP-OES). To ensure an accurate analysis, CRMs are required. The certification of RVMT-BM-1 was performed following the provisions of ISO 17034[1] and ISO 33405[2].

2. Starting Material

A total amount of 25 kg was kindly provided by Cronimet Envirotec GmbH, Germany.

To verify the identity of the material in accordance with ISO 17034:2016[1] it was investigated by X-ray diffraction (XRD). The diffractogram confirms the identity (Fig. 1).

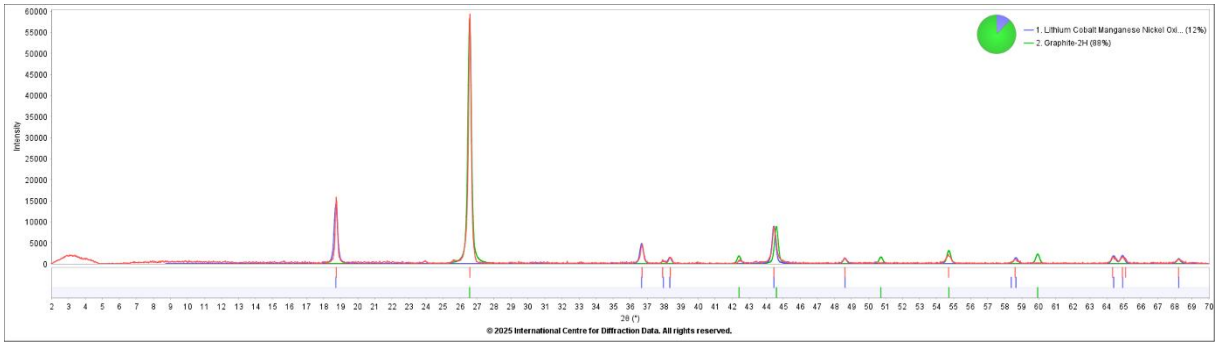

Fig. 1 X-ray diffractogram RVMT-BM-1. The diffractogram shows two phases – Li-Ni-Mn-Co-Oxide and Graphite, consistent with typical compositions of BlackMass

RVMT-BM-1 was made from production scrap and therefore does not contain any added fluoride compounds. A few measurements of fluorine were performed, showing trace levels, consistent with pure NMC cathode material. On the one hand, this hampers the analyst's ability to monitor fluorine concentrations, on the other hand, it makes the material safer to handle and more stable as there are no further reactions between binders and or electrolytes, which could potentially create hydrofluoric acid (HF).

The first preparation step was homogenising the 25 kg of black mass. First, the 25 kg were manually divided into 5 kg sub-units, which were subsequently mixed by repeatedly scooping one 250 ml scoop of each sub-unit to form a new unified 25 kg batch. This new 25 kg batch was then again manually split into 5 kg sub-units.

From these sub-units 1 kg was weighed out and run through a 1:10 rotary sample splitter to produce 10 x 100 g sub-units. This process was repeated until there were 250 x 100 g sub-units.

Finally, 5 x 100 g sub-units, one from each of the 5 kg sub-units, were unified in a polyethylene flask to a 500 g batch. This 500 g batch was then split into 10 x 50 g batches, which were filled into amber glass bottles. A total of 500 amber glass bottles containing 50 g of RVMT-BM-1 were produced. Before sealing the bottles, they were dried in an oven for 24 hours at 105° C.

3. Homogeneity & Stability Testing

Following the provisions of ISO 33405 the minimal number of samples required for homogeneity testing depends on the number of samples produced. In this case 500 samples were made. The minimum number of samples required is supposed to be the larger of 10 or the cubed root of the sample number. The cubed root of 500 is approximately 8, therefore, at least 10 units are required for homogeneity testing.

The homogeneity test was carried out using three techniques. Energy-dispersive x-ray fluorescence (ED-XRF) at Bruker AXS, Karlsruhe Germany, Infrared (IR)-combustion elemental analysis at CAU Kiel, Germany and ICP-OES at MEET, University of Münster, Germany. BlackMass analysis is often carried out in two steps, a quick-check of sample composition using handheld-XRF shortly after battery shredding and a more thorough analysis using WD-XRF and ICP-OES. The elemental content (C, N, O, H, S) is determined using IR-combustion analysis. Any analysis deserves to be validated as best as possible. Therefore, the homogeneity test was performed using ED-XRF, IR-combustion and ICP-OES. The sample size is significantly larger for ED-XRF (5 g) compared to ICP-OES (100-250 mg) and only 10 mg for IR-combustion. By testing homogeneity using all three techniques homogeneity across a wide range of sample masses can be assessed.

The homogeneity-test itself was performed on a total of 30 glass bottles (10 per analytical technique). Following ISO 33405 the minimum number of units to be tested can be calculated based on batch size ($N_{produced}$) as shown in equations (1) and (2):

Minimum # of samples	$N_{min} = \max(10; \sqrt[3]{N_{produced}})$	(1)
This study	$N_{min} = \max(10; \sqrt[3]{500})$	(2)

The cubed root of 500 is 7.94, therefore it follows, that 10 units are the minimum number of samples required for the homogeneity study. The homogeneity test itself was adapted following the example C1. In the Annex of ISO 33405. The results can be found in the annex of this document.

$LiNiMnCoO_2$ is chemically quite stable. Its composition can change due to thermal degradation. This however only begins to occur around 200 °C[3], a temperature highly unlikely to occur during transport or long-term storage. However, interactions with moisture or air have the potential to form compounds such as lithium hydroxide (LiOH) and or lithium carbonate (Li_2CO_3). Each unit contains 50 g, therefore a repeated opening and closing of the CRM will occur during its use in laboratories. To monitor the interactions of the material with moisture and air 2 units were left

open, for 12 hours, after 24 hours of drying at 105° C underneath a laminar flow hood to prevent contamination by dust. These two samples were investigated by elemental analysis to ensure no significant changes in the concentrations of C, N, O and H. Assuming a sample size of 250 mg, the bottle will be opened 200 times before being empty. Further assuming, that the bottle remains open for 2 minutes for accurate weighing this results in the bottle being open under ambient laboratory conditions for 400 minutes or 6.67 hours. Nearly doubling this time was deemed appropriate to ensure stability during repeated use.

The results of the stability test can be found in the appendix. The results show no significant changes. It can be therefore assumed, that the material is stable. The material will be monitored regularly, and all users will be informed in case any changes occur.

Previous stability studies of NMC-battery materials have found that carbon uptake can occur on the pure NMC (BAM-SO14). Here an uptake of 600 mg/kg was extrapolated from data for the materials shelf-life and factored into the uncertainty budget. The mean of means for accepted data sets for carbon is 39.76 g/100g. Leaving out the negligible metal content of Al and Cu this leaves 60.24 g/100g of NMC in this BlackMass. If pure NMC-black mass is assumed to take up to 600 mg/kg of carbon, it can be calculated, that 60.24 g/100g of NMC take up 361 mg/kg of carbon. This is a relative change of 0.06 %. A so-called stability factor of 0.0006 was applied to every mean of means, the result is used as the uncertainty contribution from stability. An example:

Unc. Contribution	$39.76\ \mathrm{g/100g}\ \mathrm{x}\ \text{stability factor}$	(3)
from stability	$39.76\ \mathrm{g/100g}\ \mathrm{x}\ 0.0006 = 0.0234\ \mathrm{g/100g}$	(4)

4. Characterisation & Value Assignment

A total of 16 laboratories participated in the certification interlaboratory comparison. The analysts were asked to take at least 3, but ideally 6 test portions. They were free to choose their suitable analytical method and asked to treat this sample as they would their own. Tab. 1 shows the analytical procedure from each laboratory. The results can be found in the appendix. The graph shows the interlaboratory mean as a solid line. The dotted lines indicate a single standard deviation from the interlaboratory mean. For some elements, e.g. Aluminium, a few laboratory averages fall outside the standard deviation. This can, in most cases, be traced back to the sample decomposition technique and does not reflect poor performance. In case a single laboratory delivered more than one value for the same element, the different analytical and or decomposition

technique were annotated to distinguish them. A few laboratories who sent data did not send the information regarding methodology, which is why there is a slight discrepancy between this table and the interlaboratory comparison in the annex.

Tab. 1: Coded laboratories and their analysed properties, sample preparation and calibration.

Laboratory Code	**Analysed properties**	**Sample Mass**	**Sample preparation**	**Analytical technique & Calibration**
Lab 2	Li, Al, Co, Cr, Cu, Fe, Mn, Ni, P	100 mg	Microwave digestion in a mixture of H_2SO_4 & HNO_3	ICP-MS, calibrated using Spetec standard solutions traceable to NIST
Lab 4	Li, Ni, Mn, Co, Al, P, Cu, Fe, S	100 mg	Microwave digestion in a mixture of HCl and HNO_3	ICP-OES, calibrated using standard solutions traceable to NIST
Lab 5	Al, Co, Cr, Cu, Li, Mn, Ni, P	200 mg	Open dissolution in HCl after drying at 105 °C	ICP-OES, calibration with commercial solutions (AnalytiChem, Supelco)
Lab 5	Al, Co, Cr, Cu, Li, Mn, Ni, P	200 mg	Microwave-assisted digestion in HNO_3 & H_2SO_4 after drying at 105 °C	ICP-OES, calibration with commercial solutions (AnalytiChem, Supelco)
Lab 5	C, S	10 mg	Drying at 105 °C	Elemental analyser, commercial standards (Elementar)
Lab 5	Si	200 mg	Drying at 105 °C, sodium tetraborate, sodium carbonate and potassium carbonate, dissolution in deionised water	ICP-OES, calibration with commercial solutions (AnalytiChem, Supelco)

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Lab 6	Li	100 mg	Sodium peroxide fusion	Ion-chromatography (IC). Calibrated using Supelco standard solution 999 ± 5 mg/l
Lab 6	C, N, O, S	40 mg		Infrared-combustion spectroscopy, calibrated using LECO 502-902 $CaCO_3$
Lab 6	Ni, Co, Mn, Al	200 mg	Oxidising Fusion	XRF analysis, calibrated using OREAS AC 18. 10664
Lab 7	C, S, N, O, H, S	C, S, H, N: 150 mg O: 20 mg		IR-combustion analysis, calibrated using certified reference materials
Lab 8	Al, Co, Cr, Cu, F, Fe, Li, Mn, Ni, Zr,	200-500 mg	Fusion using Na_2O_2 + Na_2CO_3 in Zr crucible at 750 °C	ICP-OES, calibrated with different stock solutions traceable to NIST
Lab 8	Al, Co, Cr, Cu, F, Fe, Li, Mn, Ni, Zr	200-500 mg	Microwave acid decomposition	ICP-OES, calibrated with different stock solutions traceable to NIST
Lab 8	F	200-500 mg	High pressure melting	IC with stock solutions traceable to NIST
Lab 8	C			Gas analysis, calibrated using reference materials
Lab 9	Al, Si, S, Cu, Zr, Mn, Ni, Co		Pressed pellet in Al-cup; 8 g sample mixed with 2 g binder	ED-XRF – quantified using fundamental parameters
Lab 11	Li, Al, Mn, Fe, Co, Ni, Cu, Zn, Pb		Open aqua regia digestion following DIN:EN ISO 54321:2021	ICP-MS & ICP-OES, calibrated using commercial solutions
Lab 11	Li, Al, Cr, Mn, Fe, Co, Ni, Cu		Microwave digestion using HCl, HNO_3 and HF	ICP-MS & ICP-OES, calibrated using commercial solutions

			following DIN:EN ISO 13656	
Lab 11	Li, Al, Cr, Mn, Fe, Co, Ni, Cu		Microwave digestion using HF, HNO_3 following DIN 22022:2014	ICP-MS & ICP-OES, calibrated using commercial solutions
Lab 11	Al, Mn, Fe, Co, Ni, Cu		Li-Borate ($Li_2B_4O_7$ & $LiBO_2$) fusion following DIN:EN ISO 14869-2	ICP-MS & ICP-OES, calibrated using commercial solutions
Lab 11	Li, Al, Mn, Fe, Co, Ni, Cu		4-acid digestion using HF, HCl, $HClO_4$, HNO_3 following DIN:EN ISO 14869-1	ICP-MS & ICP-OES, calibrated using commercial solutions
Lab 12	Al, Co, Cu, Cr, Fe, Li, Mn, Ni, P	50-100 mg	Microwave digestion with reverse aqua regia (HNO_3 / HCl 3:1) after drying at 105 °C for 5 h	ICP-OES, calibrated with commercial solutions (VWR, Merck, Roth)
Lab 13	C	300 mg	[-]	Infrared combustion at 1450 °C in excess oxygen
Lab 14	Ni, Co, Mn, Al, Cu, Si, Zr	5000 mg	Pressed pellet with wax as binder	XRF – measured using fundamental parameters
Lab 14	Li, Ni, Co, Mn, Al, Cu, P, Cr, Fe, Mg, Na, Si, Ti Zr	500 mg	Aqua regia digestion (HNO_3 + HCl)	ICP-OES, calibrated with commercial solutions from Bernd Kraft & Merck.

Lab 14	C	100		Infrared-combustion spectroscopy, calibrated using graphite and various blends
Lab 14	F	50	Soda-Potash dissolution	Ion-chromatography, calibrated using RM from CPA Chem
Lab 16	Al, Co, Cu, Li, Mn, Ni	3.3 g	Dissolution in aqua regia with separate residue after drying at 105 °C to constant weight	ICP-OES, calibration with commercial solutions (VWR, SCP)
Lab 17	Ni	100 mg	Dissolution in HCl + HNO_3,	Dimethyglyoxime (DMG) gravimetry, electronic balance calibrated by standard weight
Lab 17	Li	500 mg	Dissolution in HNO_3	FAAS, calibration solution from Merck
Lab 17	Al, Co	200 mg	Dissolution in HNO_3	ICP-OES, calibration with commercial solutions from Inorganic Ventures
Lab 17	As, Cd, Cr, P	2 g	Dissolution in HCl and HNO_3	ICP-OES, calibration with commercial solutions from Inorganic Ventures
Lab 17	Mn, Pb	2 g	Dissolution in HCl and HNO_3	ICP-OES, calibration with commercial solutions from Sigma-Aldrich
Lab 17	S	100 mg	[-]	Infrared carbon-sulfur analyser, calibrated by third-party in Dec. 2025 (data acquired March 2026)
Lab 19	O			Carrier gas heat extraction
Lab 19	C			Infrared combustion analysis
Lab 19	Al, Co, Mn, Ni, Zr	100 mg	Borate fusion	XRF
Lab 19	Ca, Cu, Fe, Si, Zr			ICP-OES

Lab 19	Li			ICP-OES with internal standardisation

The assigned values and the uncertainty component resulting from the characterisation were calculated using equation (5) and (6):

$$Assigned\ Value = \frac{\sum accepted\ data\ set\ means}{number\ of\ data\ sets} \quad (5)$$

$$Uncertainty_{Characterisation} = \frac{Std.\ Dev.\ of\ data\ set\ means}{\sqrt{number\ of\ data\ sets}} \quad (6)$$

To use equations (5) and (6) the data set means must show an approximately normal distribution. This prerequisite was tested using an online tool from R-Statistics.co (https://r-statistics.co/tools/normality-test-picker.html).

ISO 33405 states, that it is permissible to use the calculations in equations (5) and (6) if the distribution of the data is approximately normal. In most cases two to three outliers caused the data to deviate from a normal distribution. Outlying data sets were excluded only where a documented technical reason justified their removal, such as incomplete sample digestion or inadequate calibration. Otherwise, the data sets were retained for value assignment.

Finally, each certified value needs to be accompanied by a combined expanded uncertainty at the 95 % CL. The uncertainty is calculated (eq. 7) by combining the uncertainty components from characterisation as well as homogeneity- and stability testing.

$$Unc._{Final} = k \times \sqrt{Unc._{Homog.}^2 + Unc._{Char.}^2 + Unc._{Stabil.}^2} \quad (7)$$

The expansion factor k is determined by the effective degrees of freedom and their corresponding value in Student's t-distribution. The coverage factor was applied to reach a confidence level of 95 %, as defined in the Guide to the Expression of Uncertainty in Measurement (GUM)[4]. According to ISO 33405 it is permissible to use an expansion factor of 2 if there are ≥ 10 degrees of freedom. If there are < 10 degrees of freedom the appropriate factor should be taken from a Student's-t table, i.e., the distribution at the desired confidence level.

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Here (eq. 8) and (tab. 2) is an example on how the final uncertainty is calculated:

Tab. 2 Calculation of the final combined and expanded uncertainty, using the analyte Lithium as an example.

	Certified Value	Unit
Lithium (Li)	4.05	g/100g
$Uncertainty_{Characterisation}$	0.059	g/100g
$Uncertainty_{Homogeneity}$	0.002	g/100g
$Uncertainty_{Stability}$	0.048	g/100g
Expansion factor (k)	2	[-]

$$Unc._{Final} = 2 \times \sqrt{0.059^2 + 0.002^2 + 0.048^2} = 0.15 \quad (8)$$

Analyte [g/100g]	Certified Value	Expanded Uncertainty @ 95 % CL
Lithium (Li)	4.05	0.15

5. Minimum Sample Size

Every CRM must have a statement of its minimum sample size. The homogeneity test using ICP-OES for analysis used 100 mg and yielded statistically homogeneous and/or suitable results. Therefore, the minimal sample size is set to 100 mg.

6. Acknowledgements

We would like to thank each and every participant for their efforts in providing high-quality data.

7. References

[1] EN ISO 17034:2016 (D/E), *General requirements for the competence of reference material producers*

[2] ISO 33405:2024 (E), *Reference materials – Approaches for characterization and assessment of homogeneity and stability*

[3] Peng, J., Ablott, T.A., Brand, H.E.A., Abraham, D.P., Cataldo, T., Sharma, N (2026), *Thermal Stability of $LiNi_xMn_yCo_zO_2$ Cathode Materials.* Chemistry of Materials. 38(2): 791-807

[4] ISO/IEC Guide 98-3:2008, *Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

[5] ISO/IEC Guide 99:2007, *International vocabulary of metrology – Basic and general concepts and associated terms (VIM)*

8. Document History

Version	*Date*	*Changes applied*
1.0	19.08.2026	First publication

Annex

Interlaboratory Comparison

Al

								DIN EN ISO 54321:2021		DIN EN 13656		DIN 22022:2014		DIN EN ISO 14869-2		DIN EN ISO 14869-1								
[g/100g]			HCl	$HNO_3 + H_2SO_4$				ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES		ICP-OES	XRF					
Lab Code	**Lab 2**	**Lab 4**	**Lab 5**	**Lab 5**	**Lab 6**	**Lab 8**	**Lab 9**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 12**	**Lab 14**	**Lab 14**	**Lab 15**	**Lab 16**	**Lab 17**	**Lab 18**	**Lab 19**	**n**
	0,264	0,26	0,03	0,26	0,32	0,272	0,611	0,040	0,035	0,039	0,034	0,122	0,115	0,333	0,299	0,175	0,176	0,266	0,036	0,730	0,23	0,24	0,27	0,031	0,31	25
	0,294	0,26	0,04	0,27	0,35	0,280	0,615	0,040	0,036	0,035	0,033	0,115	0,109	0,333	0,289	0,179	0,175	0,272	0,034	0,703	0,24	0,26	0,26	0,0262	0,30	
	0,254	0,24	0,03	0,25	0,30	0,269	0,64	0,038	0,037	0,036	0,042	0,114	0,086	0,313	0,306	0,176	0,176	0,280	0,043	0,716	0,23	0,27	0,26	0,0393	0,31	
	0,270	0,25	0,03	0,25	0,32	0,265	0,611	0,041	0,034	0,035	0,035	0,114	0,113	0,323	0,328	0,171	0,178	0,270	0,056	0,697				0,0222	0,30	
	0,246	0,24	0,04	0,26		0,270	0,608	0,040	0,034	0,044	0,035	0,112	0,116	0,321	0,321	0,176	0,174	0,272	0,035	0,677					0,31	
	0,260	0,24	0,03	0,25		0,273		0,039	0,035	0,036	0,043	0,112	0,087	0,306	0,291	0,175	0,175	0,270	0,037	0,698					0,31	
			0,05	0,25		0,266																			0,32	
			0,03	0,25		0,283																				
						0,288																				
						0,286																				
						0,294																				
						0,275																				
						0,276																				
						0,280																				
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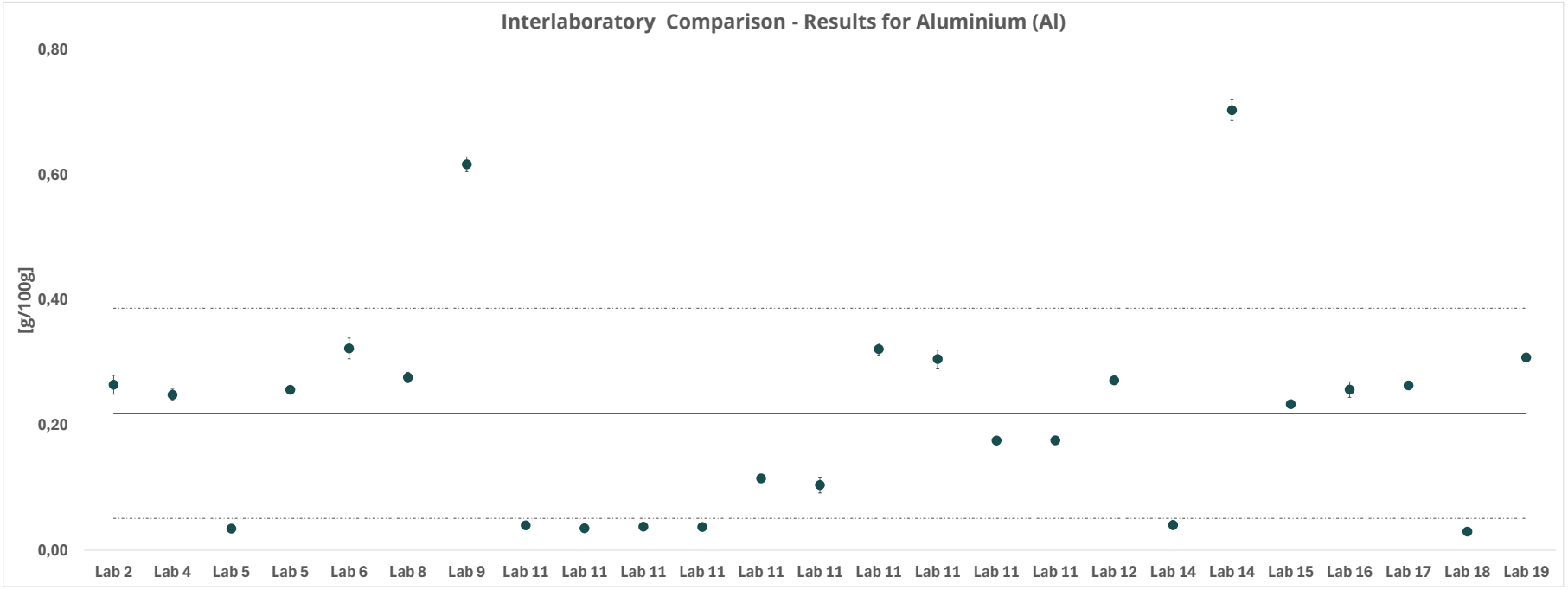
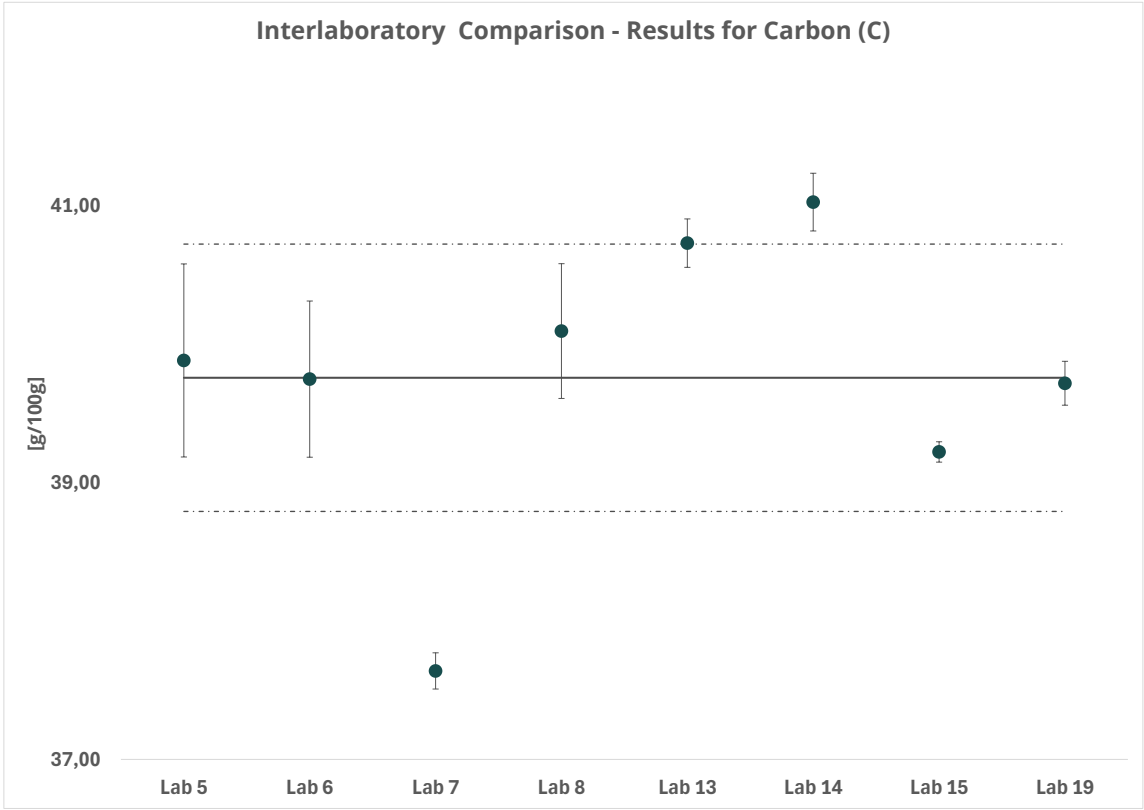
						0,269																				
						0,266																				
						0,265																				
						0,275																				
						0,268																				
						0,267																				
																										Interlaboratory
Average	**0,264**	**0,25**	**0,03**	**0,26**	**0,32**	**0,276**	**0,617**	**0,040**	**0,035**	**0,038**	**0,037**	**0,115**	**0,104**	**0,321**	**0,306**	**0,175**	**0,176**	**0,272**	**0,040**	**0,704**	**0,23**	**0,26**	**0,26**	**0,03**	**0,31**	**0,22**
Standard dev.	*0,015*	*0,01*	*0,01*	*0,005*	*0,02*	*0,008*	*0,012*	*0,001*	*0,001*	*0,003*	*0,004*	*0,003*	*0,013*	*0,010*	*0,014*	*0,002*	*0,001*	*0,004*	*0,008*	*0,017*	*0,005*	*0,01*	*0,005*	*0,01*	*0,01*	*0,17*
RSD-%	5,70%	3,61%	17,63%	1,92%	5,14%	2,96%	1,90%	2,08%	3,04%	8,15%	11,20%	2,88%	12,19%	3,05%	4,73%	1,35%	0,66%	1,53%	18,7%	2,35%	2,02%	4,86%	1,79%	21,47%	1,92%	76,75%



C

[g/100g]

Lab Code	Lab 5	Lab 6	Lab 7	Lab 8	Lab 13	Lab 14	Lab 15	Lab 19	n
	40,24	40,00	37,49	40,74	41,0	41,25	39,28	39,66	8
	40,21	38,80	37,61	39,62	40,6	41,29	39,14	39,55	
	40,23	39,40	37,72	40,2	40,9	41,02	39,25	39,57	
	40,02	39,80	37,82	40,9	40,7	41,01		39,87	
	40,14	40,20	37,56	40,02	40,6	40,80		39,73	
	38,47	40,30		39,62	40,6	40,81		39,94	
				39,85					
				39,83					
									Interlaboratory
Average	**39,89**	**39,75**	**37,64**	**40,10**	**40,7**	**41,03**	**39,22**	**39,72**	**39,76**
Standard dev.	*0,64*	*0,52*	*0,12*	*0,46*	*0,2*	*0,19*	*0,06*	*0,14*	*0,97*
RSD-%	1,60%	1,30%	0,31%	1,14%	0,39%	0,46%	0,15%	0,36%	2,43%



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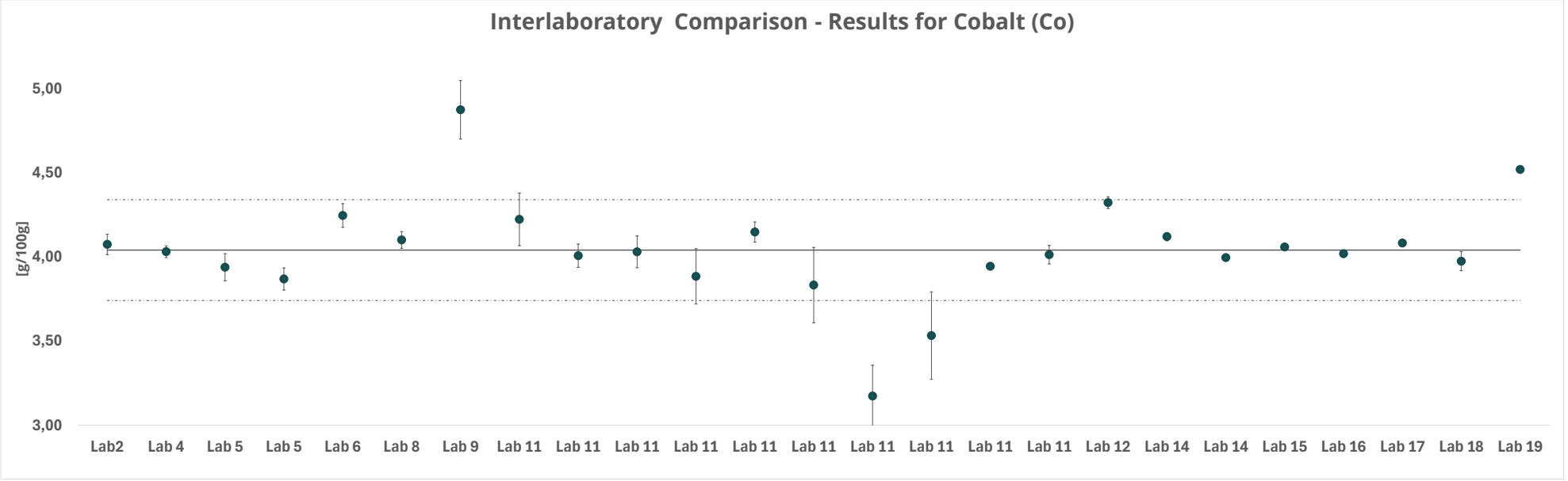
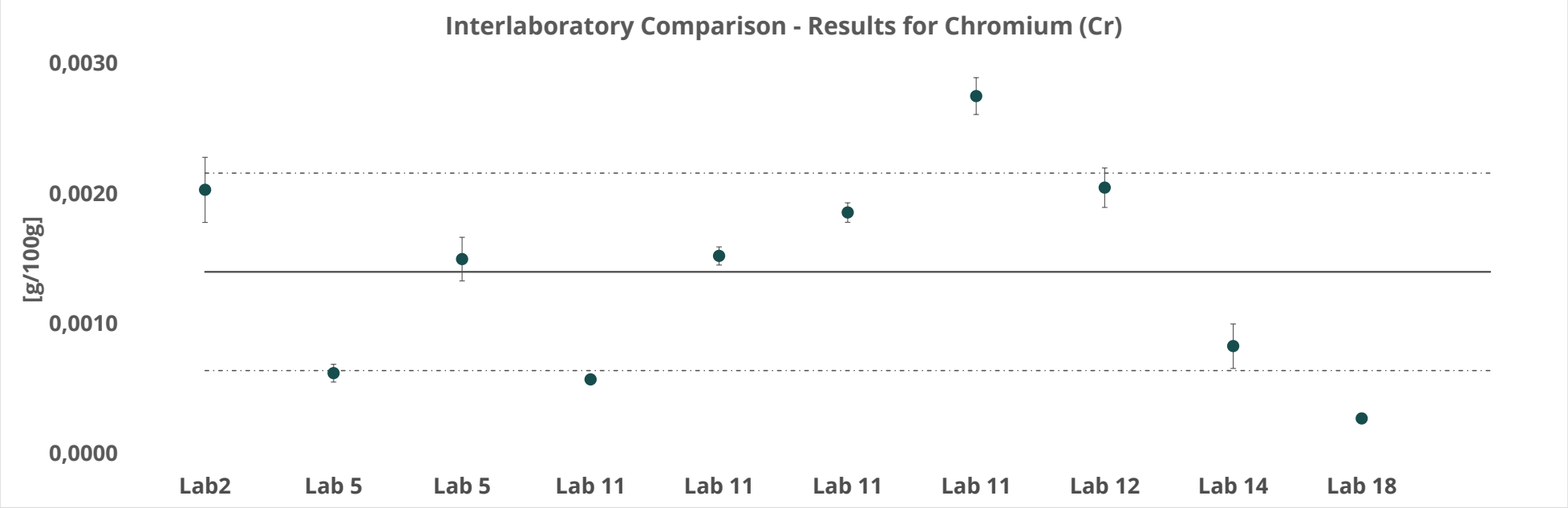
								DIN EN ISO 54321:2021		**DIN EN 13656**		**DIN 22022:2014-04**		**DIN EN ISO 14869-2**		**DIN EN ISO 14869-1**									
[g/100g]			HCl	HNO_3 & H_2SO_4				ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES		ICP-OES	XRF						
Lab Code	**Lab2**	**Lab 4**	**Lab 5**	**Lab 5**	**Lab 6**	**Lab 8**	**Lab 9**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 12**	**Lab 14**	**Lab 14**	**Lab 15**	**Lab 16**	**Lab 17**	**Lab 18**	**Lab 19**	**n**
	4,11	4,08	3,95	3,93	4,22	4,09	4,77	4,20	4,02	3,91	3,70	4,24	3,65	3,24	3,68	3,95	4,04	4,30	4,08	3,98	4,06	4,00	4,09	4,03	4,51	25
	4,17	4,04	3,87	3,93	4,20	4,04	4,79	4,44	4,09	3,95	3,89	4,23	3,53	3,49	3,22	3,96	4,04	4,32	4,11	3,98	4,06	4,01	4,08	4,02	4,52	
	4,00	4,05	3,88	3,90	4,37	4,09	5,22	4,20	4,05	3,95	4,08	4,10	3,65	3,20	3,32	3,94	3,95	4,38	4,10	3,99	4,06	4,05	4,08	3,97	4,54	
	4,00	4,04	3,87	3,90	4,21	4,01	4,78	4,02	4,07	4,10	3,66	4,11	4,04	3,17	3,34	3,95	4,11	4,28	4,15	3,99				3,88	4,51	
	4,05	3,97	3,82	3,95		4,04	4,82	4,08	3,92	4,13	3,90	4,10	4,04	2,88	3,96	3,94	3,98	4,36	4,14	4,01					4,52	
	4,11	4,01	3,95	3,81		4,09		4,41	3,91	4,15	4,08	4,11	4,08	3,05	3,67	3,93	3,97	4,30	4,15	4,03					4,53	
			4,05	3,83		4,03																			4,52	
			4,03	3,83		4,05																				
			4,05	3,74		4,16																				
						4,15																				
						4,18																				
						4,11																				
						4,09																				
						4,10																				
						4,10																				
						4,07																				
						4,09																				
						4,12																				
						4,11																				
						4,15																				
						4,17																				
						4,20																				
																										Interlaboratory
Average	**4,08**	**4,03**	**3,94**	**3,87**	**4,25**	**4,10**	**4,88**	**4,22**	**4,01**	**4,03**	**3,89**	**4,15**	**3,83**	**3,17**	**3,53**	**3,94**	**4,01**	**4,32**	**4,12**	**4,00**	**4,06**	**4,02**	**4,08**	**3,98**	**4,52**	**4,04**
Standard dev.	*0,06*	*0,03*	*0,08*	*0,07*	*0,07*	*0,05*	*0,17*	*0,16*	*0,07*	*0,09*	*0,16*	*0,06*	*0,22*	*0,18*	*0,26*	*0,01*	*0,06*	*0,03*	*0,02*	*0,02*		*0,02*	*0,00*	*0,06*	*0,01*	*0,30*
RSD-%	1,48%	0,85%	2,05%	1,71%	1,67%	1,21%	3,57%	3,70%	1,73%	2,35%	4,24%	1,45%	5,86%	5,80%	7,37%	0,25%	1,37%	0,81%	0,60%	0,45%	0,00%	0,54%	0,12%	1,43%	0,23%	7,42%



Cr

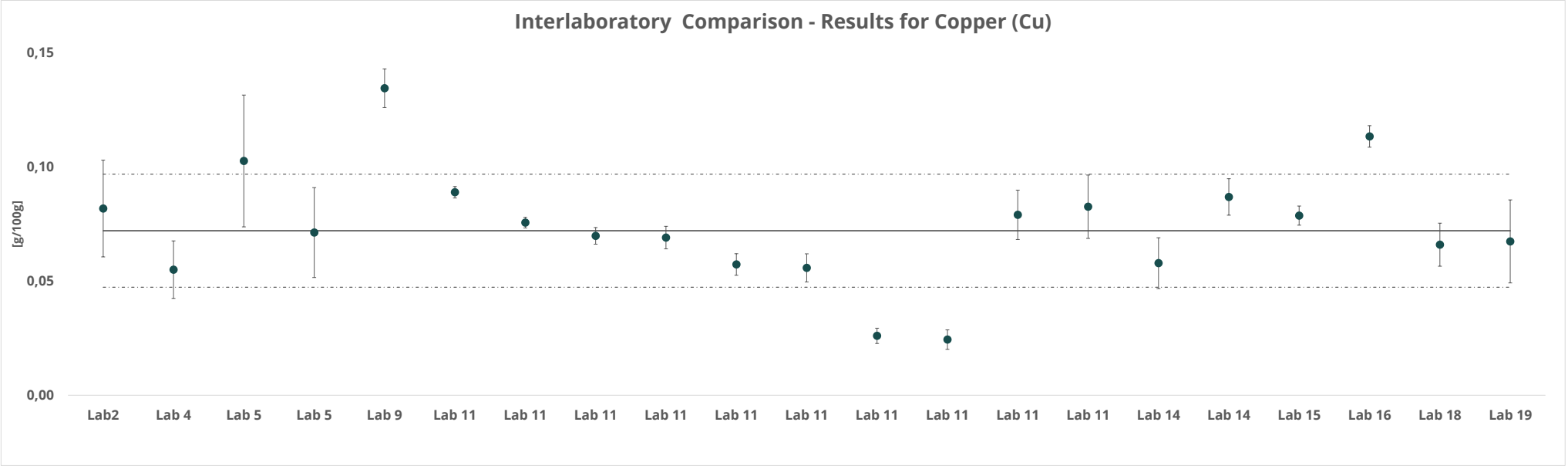
DIN EN ISO 54321:2021 DIN EN 13656 DIN 22022:2014-04 DIN EN ISO 14869-2

[g/100g]		HCl	HNO_3 & H_2SO_4	ICP-MS	ICP-MS	ICP-MS	ICP-MS				
Lab Code	**Lab2**	**Lab 5**	**Lab 5**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 12**	**Lab 14**	**Lab 18**	**n**
	0,0019	0,0007	0,0017	0,0006	0,0015	0,0019	0,0029	0,0019	0,00076	0,00011	10
	0,0022	0,0008	0,0016	0,0006	0,0017	0,0018	0,0029	0,0020	0,00093	0,00046	
	0,0021	0,0006	0,0014	0,0006	0,0015	0,0019	0,0029	0,0023	0,00064	0,00037	
	0,0017	0,0006	0,0016	0,0006	0,0014	0,0018	0,0026	0,0021	0,00075	0,00016	
	0,0024	0,0005	0,0012	0,0005	0,0015	0,0019	0,0026	0,0019	0,00079		
	0,0019	0,0006	0,0017	0,0006	0,0015	0,0019	0,0027	0,0021	0,00112		
		0,0006	0,0013								
		0,0006	0,0015								
											Interlaboratory
Average	**0,0020**	**0,0006**	**0,0015**	**0,0006**	**0,0015**	**0,0019**	**0,0028**	**0,0021**	**0,0008**	**0,0003**	**0,0014**
Standard dev.	*0,0003*	*0,0001*	*0,0002*	*0,0000*	*0,0001*	*0,0001*	*0,0001*	*0,0002*	*0,0002*	*0,0002*	*0,0008*
RSD-%	12,3%	11,0%	11,2%	4,24%	4,58%	4,03%	5,15%	7,40%	20,6%	60,7%	54,13%



Cu

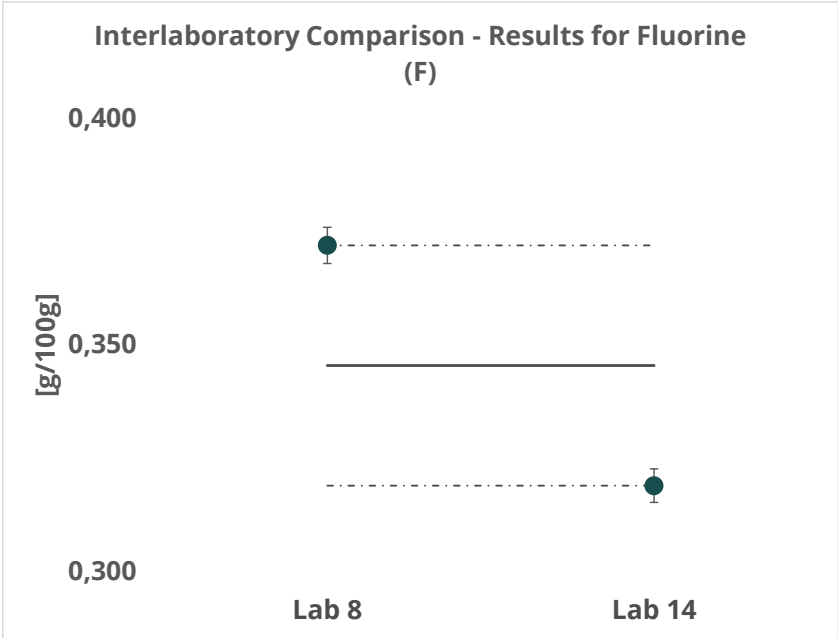
						DIN EN ISO 54321:2021		DIN EN 13656		DIN 22022:2014		DIN EN ISO 14869-2		DIN EN ISO 14869-1								
[g/100g]			HCl	HNO_3 & H_2SO_4		ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-OES	XRF					
Lab Code	**Lab2**	**Lab 4**	**Lab 5**	**Lab 5**	**Lab 9**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 14**	**Lab 14**	**Lab 15**	**Lab 16**	**Lab 18**	**Lab 19**	**n**
	0,079	0,04	0,07	0,07	0,1371	0,088	0,077	0,072	0,063	0,057	0,052	0,022	0,028	0,066	0,087	0,057	0,081	0,073	0,11	0,0692	0,09316	21
	0,087	0,07	0,11	0,08	0,131	0,091	0,074	0,066	0,071	0,056	0,050	0,026	0,023	0,090	0,063	0,050	0,076	0,080	0,11	0,0789	0,07355	
	0,079	0,04	0,11	0,05	0,1441	0,089	0,072	0,076	0,077	0,056	0,064	0,026	0,018	0,089	0,095	0,053	0,080	0,083	0,12	0,0531	0,04224	
	0,097	0,05	0,06	0,07	0,1198	0,084	0,079	0,068	0,073	0,053	0,053	0,029	0,028	0,081	0,064	0,043	0,095			0,0625	0,06634	
	0,109	0,06	0,15	0,04	0,1402	0,091	0,077	0,065	0,064	0,067	0,051	0,022		0,063	0,088	0,076	0,095				0,0908	
	0,041	0,07	0,11	0,07		0,091	0,075	0,072	0,067	0,054	0,065	0,031		0,086	0,098	0,068	0,094				0,0697	
			0,13	0,11																	0,04035	
			0,08																		0,06277	
																						Interlaboratory
Average	**0,082**	**0,055**	**0,103**	**0,071**	**0,134**	**0,089**	**0,076**	**0,070**	**0,069**	**0,057**	**0,056**	**0,026**	**0,024**	**0,079**	**0,083**	**0,058**	**0,087**	**0,079**	**0,113**	**0,066**	**0,067**	**0,072**
Standard dev.	*0,02*	*0,01*	*0,03*	*0,02*	*0,01*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,01*	*0,00*	*0,00*	*0,01*	*0,01*	*0,01*	*0,01*	*0,004*	*0,005*	*0,009*	*0,018*	*0,025*
RSD-%	25,9%	22,9%	28,1%	27,6%	6,31%	2,82%	3,09%	5,23%	7,14%	8,26%	11,03%	12,86%	17,44%	13,69%	16,81%	19,2%	9,20%	5,33%	4,16%	14,30%	27,0%	34,35%



F

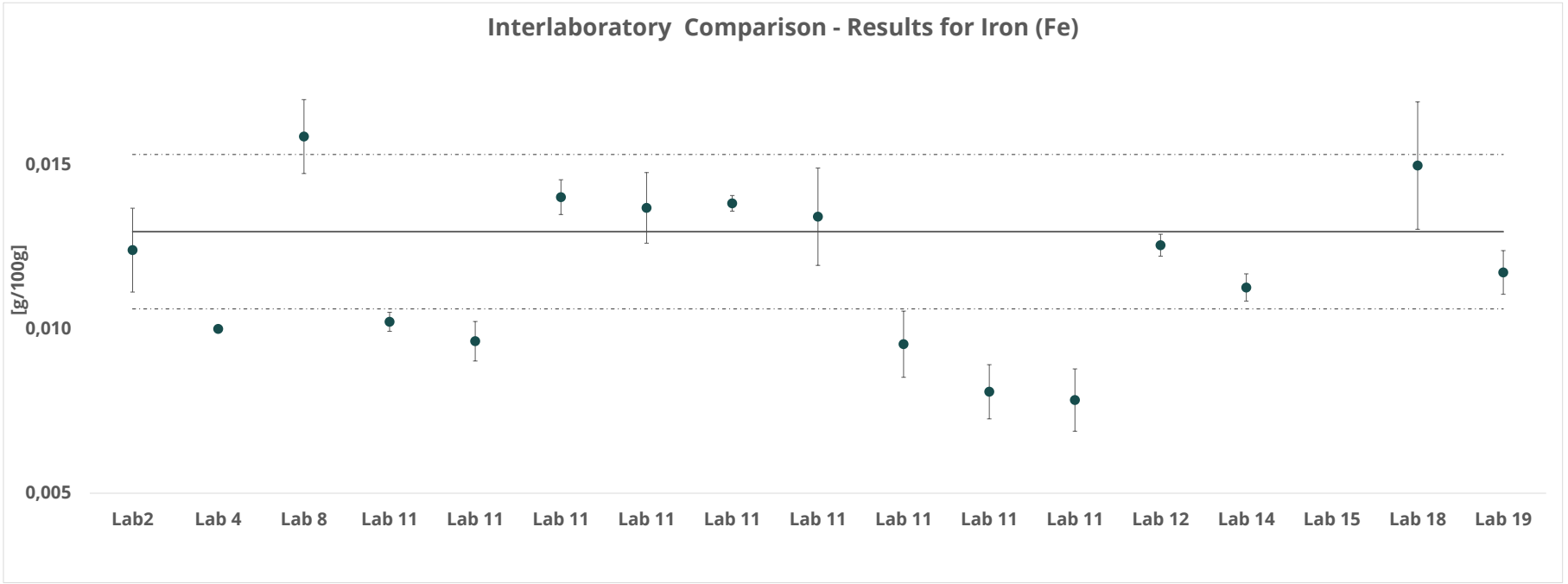
[g/100g]

Lab Code	Lab 8	Lab 14	n
	0,37	0,324	2
	0,37	0,316	
	0,37	0,317	
	0,37		
	0,38		
			Interlaboratory
Average	**0,37**	**0,319**	**0,345**
Standard dev.	*0,004*	*0,004*	*0,027*
RSD-%	1,08%	1,16%	7,68%



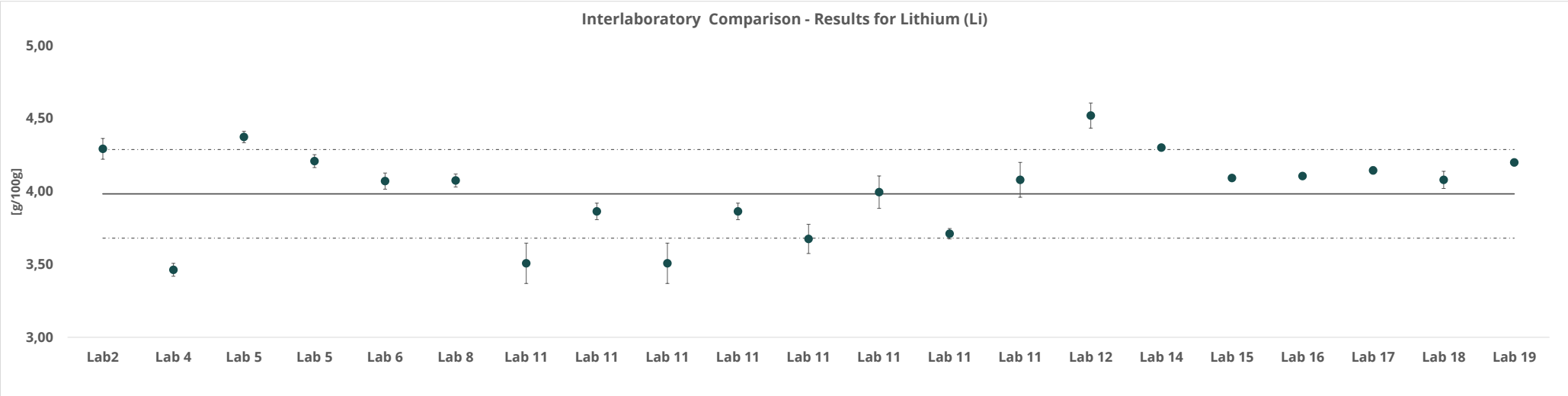
Fe

				DIN EN ISO 54321:2021		DIN EN 13656		DIN 22022:2014		DIN EN ISO 14869-2	DIN EN ISO 14869-1							
[g/100g]				ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-MS	ICP-OES						
Lab Code	**Lab2**	**Lab 4**	**Lab 8**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 12**	**Lab 14**	**Lab 15**	**Lab 18**	**Lab 19**	**n**
	0,011	0,01	0,017	0,0106	0,0106	0,0146	0,0139	0,0137	0,0122	0,0084	0,0066	0,0091	0,0126	0,0108	0,031	0,017	0,0119	17
	0,013	0,01	0,016	0,0104	0,0099	0,0135	0,0132	0,0140	0,0160	0,0094	0,0076	0,0084	0,0125	0,0108	0,032	0,012	0,0128	
	0,010	0,01	0,017	0,0104	0,0096	0,0143	0,0151	0,0142	0,0117	0,0100	0,0087	0,0068	0,0129	0,0116	0,031	0,014	0,01141	
	0,013	0,01	0,014	0,0104	0,0099	0,0147	0,0150	0,0139	0,0141	0,0109	0,0086	0,0078	0,0119	0,0119		0,0169	0,01253	
	0,014	0,01	0,017	0,0099	0,0091	0,0133	0,0126	0,0135	0,0123	0,0082	0,0080	0,0085	0,0129	0,0110			0,01128	
	0,014	0,01	0,016	0,0098	0,0087	0,0138	0,0124	0,0138	0,0142	0,0104	0,0091	0,0064	0,0125	0,0115			0,01198	
			0,017														0,01072	
			0,015														0,01115	
			0,015															
			0,017															
			0,014															
			0,015															
			0,017															
			0,015															
																		Interlaboratory
Average	**0,012**	**0,010**	**0,016**	**0,010**	**0,010**	**0,014**	**0,014**	**0,014**	**0,013**	**0,0095**	**0,0081**	**0,0078**	**0,0126**	**0,0113**	**0,031**	**0,015**	**0,012**	**0,013**
Standard dev.	*0,001*	*0,000*	*0,001*	*0,000*	*0,001*	*0,001*	*0,001*	*0,000*	*0,001*	0,0010073	*0,0008*	*0,0009*	*0,0003*	*0,0004*	*0,0005*	*0,0019*	*0,001*	*0,002*
RSD-%	10,3%		7,1%	2,8%	6,2%	3,8%	7,9%	1,7%	11,0%	10,6%	10,2%	12,1%	2,7%	3,7%	1,5%	13,0%	5,7%	18,13%



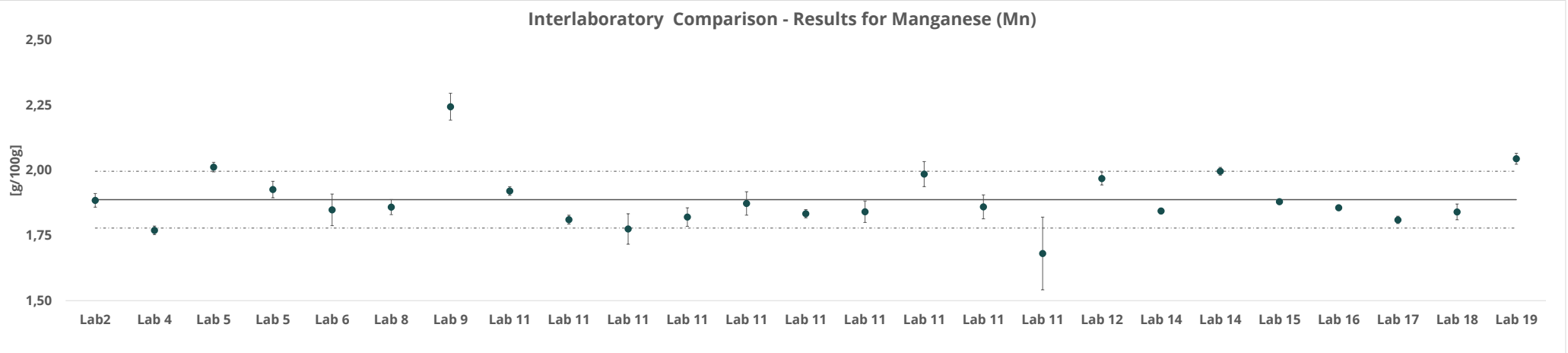
Li

							DIN EN ISO 54321:2021		DIN EN 13656		DIN 22022:2014		DIN EN ISO 14869-1									
[g/100g]			HCl	HNO_3 & H_2SO_4			ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES								
Lab Code	**Lab2**	**Lab 4**	**Lab 5**	**Lab 5**	**Lab 6**	**Lab 8**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 12**	**Lab 14**	**Lab 15**	**Lab 16**	**Lab 17**	**Lab 18**	**Lab 19**	**n**
	4,30	3,49	4,32	4,22	3,99	4,11	3,33	3,90	3,33	3,90	3,64	3,89	3,74	4,12	4,36	4,30	4,09	4,10	4,17	4,12	4,24	21
	4,39	3,48	4,41	4,29	4,03	4,03	3,38	3,89	3,38	3,89	3,73	3,91	3,70	4,14	4,55	4,29	4,10	4,12	4,12	4,14	4,20	
	4,33	3,48	4,38	4,22	4,04	4,10	3,41	3,89	3,41	3,89	3,63	4,12	3,74	4,07	4,49	4,29	4,09	4,10		4,08	4,20	
	4,30	3,52	4,44	4,26	4,10	4,03	3,68	3,93	3,68	3,93	3,86	3,89	3,74	3,84	4,63	4,32				3,98	4,21	
	4,15	3,42	4,41	4,17	4,13	4,11	3,64	3,81	3,64	3,81	3,53	4,00	3,71	4,09	4,50	4,30					4,19	
	4,28	3,39	4,35	4,16	4,14	4,15	3,60	3,77	3,60	3,77	3,67	4,17	3,64	4,23	4,59	4,30					4,21	
			4,32	4,17		4,11															4,16	
			4,37	4,18		4,11																
						4,05																
						4,01																
						4,07																
						4,00																
						4,05																
						4,03																
						4,06																
						4,04																
						4,05																
						4,06																
						4,09																
						4,12																
						4,12																
						4,17																
																						Interlaboratory
Average	**4,29**	**3,46**	**4,37**	**4,21**	**4,07**	**4,08**	**3,51**	**3,86**	**3,51**	**3,86**	**3,68**	**4,00**	**3,71**	**4,08**	**4,52**	**4,30**	**4,09**	**4,11**	**4,15**	**4,08**	**4,20**	**3,98**
Standard dev.	*0,07*	*0,04*	*0,04*	*0,04*	*0,06*	*0,04*	*0,14*	*0,06*	*0,14*	*0,06*	*0,10*	*0,11*	*0,04*	*0,12*	*0,09*	*0,01*	*0,00*	*0,01*	*0,02*	*0,06*	*0,02*	*0,30*
RSD-%	1,7%	1,3%	0,9%	1,1%	1,4%	1,1%	3,9%	1,5%	3,9%	1,5%	2,7%	2,8%	1,0%	2,9%	1,9%	0,3%	0,1%	0,2%	0,6%	1,4%	0,5%	7,63%



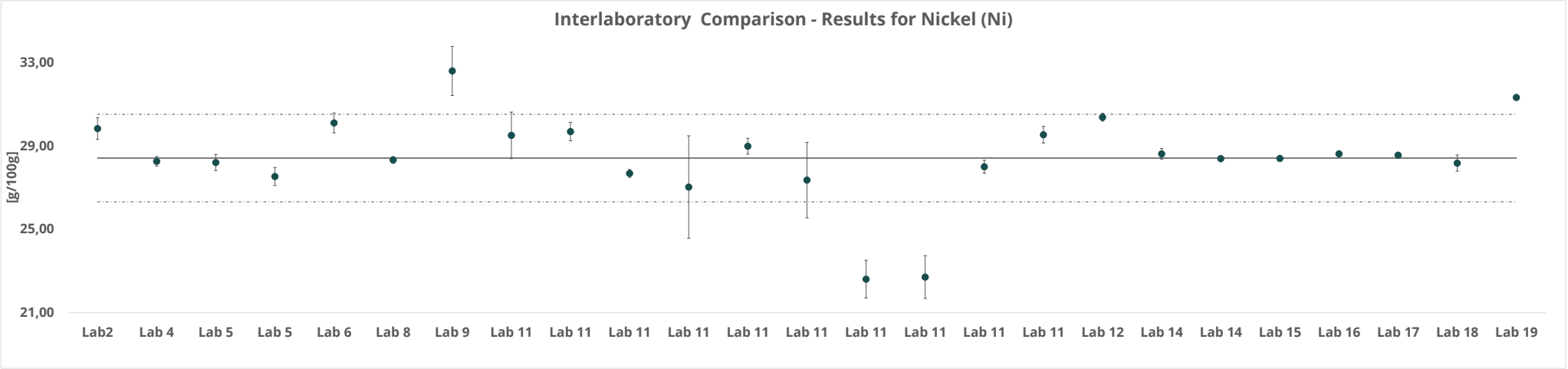
Mn

								DIN EN ISO 54321:2021		DIN EN 13656		DIN 22022:2014		DIN EN ISO 14869-2		DIN EN ISO 14869-1									
[g/100g]			HCl	HNO_3 & H_2SO_4				ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES		ICP-OES	XRF						
Lab Code	**Lab2**	**Lab 4**	**Lab 5**	**Lab 5**	**Lab 6**	**Lab 8**	**Lab 9**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 12**	**Lab 14**	**Lab 14**	**Lab 15**	**Lab 16**	**Lab 17**	**Lab 18**	**Lab 19**	**n**
	1,92	1,79	2,04	1,94	1,75	1,88	2,21	1,90	1,81	1,71	1,83	1,89	1,83	1,86	1,95	1,90	1,56	1,95	1,83	1,99	1,88	1,85	1,79	1,87	2,06	25
	1,91	1,77	2,03	1,97	1,87	1,85	2,22	1,92	1,81	1,68	1,83	1,95	1,80	1,89	2,03	1,92	1,51	1,95	1,84	1,98	1,88	1,86	1,82	1,87	2,06	
	1,89	1,78	2,01	1,95	1,92	1,89	2,35	1,93	1,79	1,83	1,83	1,88	1,83	1,87	1,91	1,89	1,57	1,99	1,84	2,00	1,88	1,86	1,82	1,84	2,05	
	1,88	1,78	1,99	1,96	1,86	1,87	2,21	1,90	1,84	1,82	1,89	1,82	1,85	1,77	1,99	1,81	1,76	1,95	1,86	1,98				1,79	2,02	
	1,84	1,74	2,00	1,90		1,89	2,23	1,93	1,80	1,79	1,78	1,82	1,84	1,82	2,06	1,82	1,81	2,01	1,86	2,01					2,00	
	1,87	1,76	2,01	1,88		1,90		1,95	1,82	1,82	1,78	1,87	1,84	1,83	1,98	1,82	1,88	1,95	1,84	2,02					2,05	
			1,99	1,90		1,91																			2,07	
			2,03	1,92		1,89																				
						1,82																				
						1,83																				
						1,80																				
						1,83																				
						1,83																				
						1,83																				
						1,83																				
						1,87																				
						1,87																				
						1,87																				
						1,86																				
						1,86																				
						1,86																				
																										Interlaboratory
Average	**1,89**	**1,77**	**2,01**	**1,93**	**1,85**	**1,86**	**2,24**	**1,92**	**1,81**	**1,78**	**1,82**	**1,87**	**1,83**	**1,84**	**1,99**	**1,86**	**1,68**	**1,97**	**1,84**	**2,00**	**1,88**	**1,86**	**1,81**	**1,84**	**2,04**	**1,89**
Standard dev.	*0,03*	*0,02*	*0,02*	*0,03*	*0,06*	*0,03*	*0,05*	*0,02*	*0,02*	*0,06*	*0,04*	*0,04*	*0,02*	*0,04*	*0,05*	*0,05*	*0,14*	*0,02*	*0,01*	*0,01*		*0,00*	*0,01*	*0,03*	*0,02*	*0,11*
RSD-%	1,4%	0,9%	0,9%	1,6%	3,3%	1,5%	2,3%	0,9%	0,9%	3,3%	2,0%	2,4%	0,9%	2,2%	2,4%	2,5%	8,3%	1,3%	0,5%	0,7%		0,3%	0,8%	1,6%	1,0%	5,78%



Ni

								DIN EN ISO 54321:202'		DIN EN 13656		DIN 22022:2014		DIN EN ISO 14869-2		DIN EN ISO 14869-1								
[g/100g]			HCl	HNO_3 & H_2SO_4				ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES	ICP-MS	ICP-OES		ICP-OES	XRF						
Lab Code	**Lab2**	**Lab 4**	**Lab 5**	**Lab 5**	**Lab 6**	**Lab 8**	**Lab 9**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 11**	**Lab 12**	**Lab 14**	**Lab 14**	**Lab 15**	**Lab 16**	**Lab 17**	**Lab 18**	**Lab 19**	**n**
	30,14	28,62	28,49	27,80	29,90	28,31	31,8	28,79	30,06	27,37	26,71	29,10	25,75	23,50	23,01	28,62	29,90	30,2	28,4	28,4	28,42	28,73	28,71	28,53	31,12	25
	30,58	28,27	27,88	27,93	29,78	28,04	32,1	29,70	30,24	27,90	24,00	29,63	25,06	23,40	21,46	28,04	29,58	30,5	28,7	28,5	28,41	28,71	28,47	28,53	31,38	
	29,25	28,35	27,99	27,38	30,94	28,44	34,9	31,91	30,08	27,84	23,71	29,22	25,93	23,37	21,42	28,06	29,56	30,4	28,4	28,4	28,40	28,45	28,52	28,10	31,35	
	29,12	28,37	27,77	27,91	29,83	28,04	32,0	28,83	29,40	27,50	29,71	28,43	28,94	21,03	24,38	27,90	30,13	30,3	28,4	28,4				27,58	31,37	
	29,78	27,85	27,56	28,22		28,29	32,2	29,08	29,33	27,78	29,69	28,88	29,06	22,39	23,14	27,86	29,05	30,2	29,1	28,3					31,39	
	30,19	28,16	28,46	27,23		28,32		28,79	29,08	27,75	28,38	28,71	29,46	21,97	22,87	27,59	29,05	30,7	28,8	28,4					31,41	
			28,67	27,40		28,53																			31,33	
			28,50	27,26		28,35																				
			28,60	26,74		28,45																				
						28,45																				
						28,53																				
						28,40																				
						28,11																				
						28,31																				
						28,14																				
						28,23																				
						28,41																				
						28,57																				
						28,65																				
						28,20																				
						28,29																				
						28,31																				
																										Interlaboratory
Average	**29,84**	**28,27**	**28,21**	**27,54**	**30,11**	**28,34**	**32,61**	**29,52**	**29,70**	**27,69**	**27,03**	**28,99**	**27,37**	**22,61**	**22,71**	**28,01**	**29,55**	**30,39**	**28,63**	**28,40**	**28,41**	**28,63**	**28,57**	**28,18**	**31,34**	**28,43**
Standard dev.	*0,52*	*0,23*	*0,39*	*0,43*	*0,48*	*0,16*	*1,18*	*1,12*	*0,44*	*0,19*	*2,46*	*0,38*	*1,81*	*0,91*	*1,03*	*0,31*	*0,40*	*0,19*	*0,25*	*0,06*	*0,01*	*0,13*	*0,10*	*0,39*	*0,09*	*2,10*
RSD-%	1,8%	0,8%	1,4%	1,6%	1,6%	0,6%	3,6%	3,8%	1,5%	0,7%	9,1%	1,3%	6,6%	4,0%	4,5%	1,1%	1,4%	0,6%	0,9%	0,2%	0,0%	0,4%	0,4%	1,4%	0,3%	7,39%

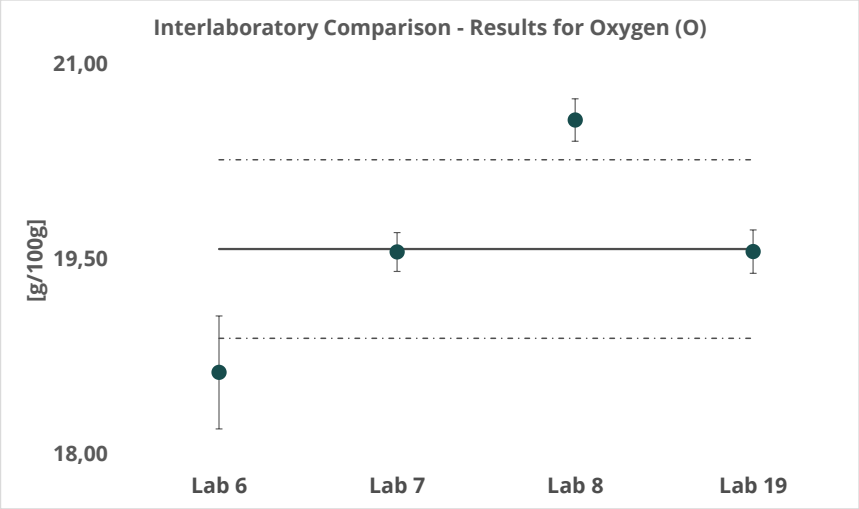


O

[g/100g]

Lab Code	Lab 6	Lab 7	Lab 8	Lab 19	n
	19,40	19,3	20,34	19,69	4
	18,80	19,7	20,57	19,66	
	18,00	19,6	20,35	19,57	
	18,60	19,7	20,60	19,57	
	18,70	19,5	20,81	19,49	
	18,30		20,72	19,66	
			20,64	19,90	
				19,55	
				19,30	
				19,60	
				19,54	
				19,23	

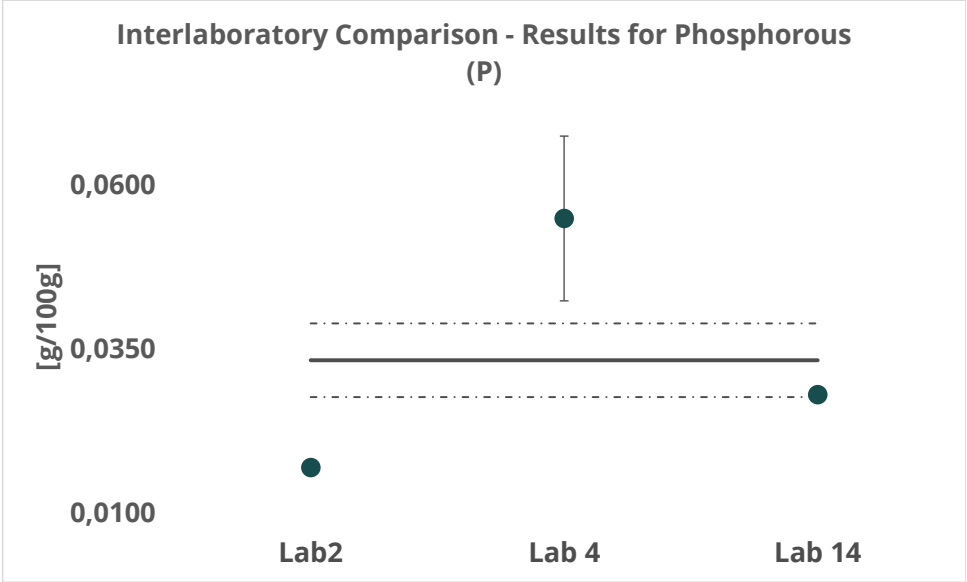
					Interlaboratory
Average	**18,63**	**19,6**	**20,58**	**19,56**	**19,58**
Standard dev.	0,43	0,1	0,16	0,17	*0,69*
RSD-%	2,33%	0,77%	0,79%	0,85%	3,51%



P

[g/100g]

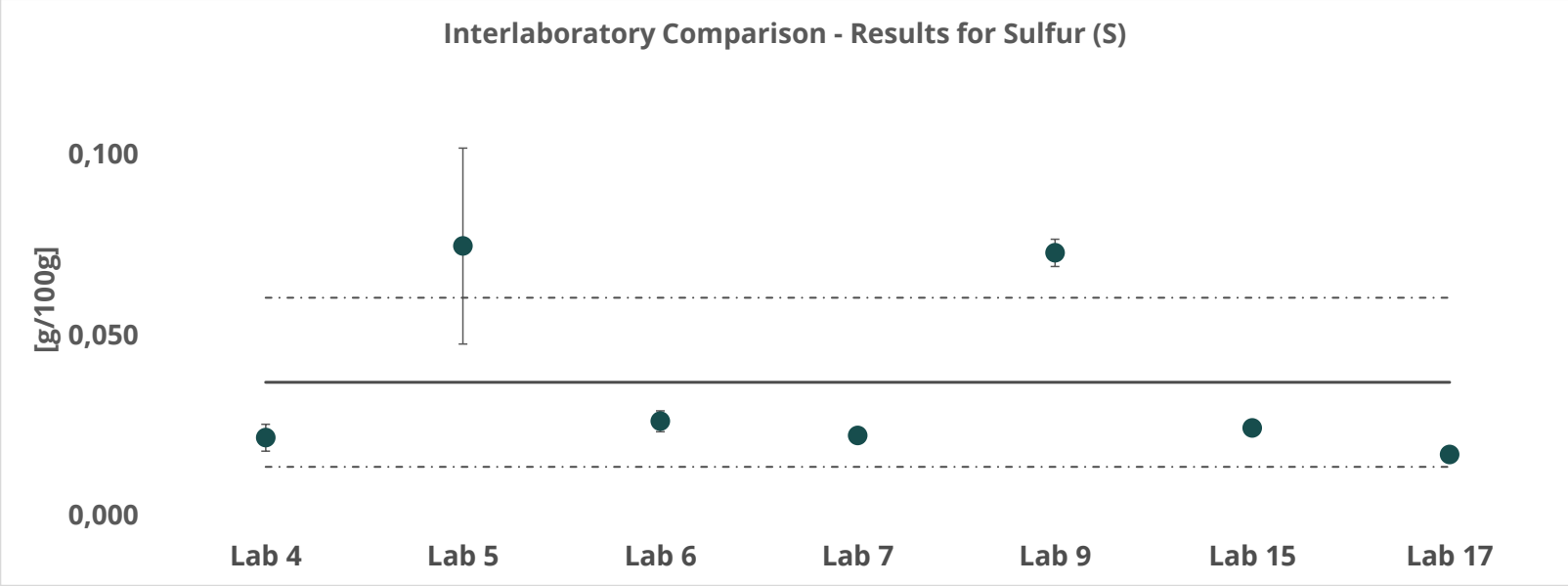
Lab Code	Lab2	Lab 4	Lab 14	n
	0,018	0,04	0,029	3
	0,018	0,07	0,028	
	0,017	0,04	0,028	
	0,016	0,05	0,028	
	0,015	0,06	0,028	
	0,017	0,07	0,027	
				Interlaboratory
Average	**0,017**	**0,055**	**0,0281**	**0,033**
Standard dev.	0,001	0,013	0,0004	*0,006*
RSD-%	5,17%	22,9%	1,51%	16,88%



S

[g/100g]

Lab Code	Lab 4	Lab 5	Lab 6	Lab 7	Lab 9	Lab 15	Lab 17	n
	0,02	0,121	0,03	0,02206	0,0694	0,026	0,017	7
	0,02	0,057	0,02	0,02243	0,0702	0,025	0,017	
	0,02	0,067	0,03	0,02190	0,08	0,022	0,017	
	0,02	0,054	0,03	0,02226	0,073			
	0,02		0,02	0,02284	0,0717			
	0,03		0,03					
								Interlaboratory
Average	**0,02**	**0,075**	**0,03**	**0,02**	**0,0729**	**0,024**	**0,017**	**0,037**
Standard dev.	0,004	0,027	0,003	0,00	0,0038	0,002		*0,02*
RSD-%	17,20%	36,30%	11,03%	1,46%	5,19%	6,98%		63,26%

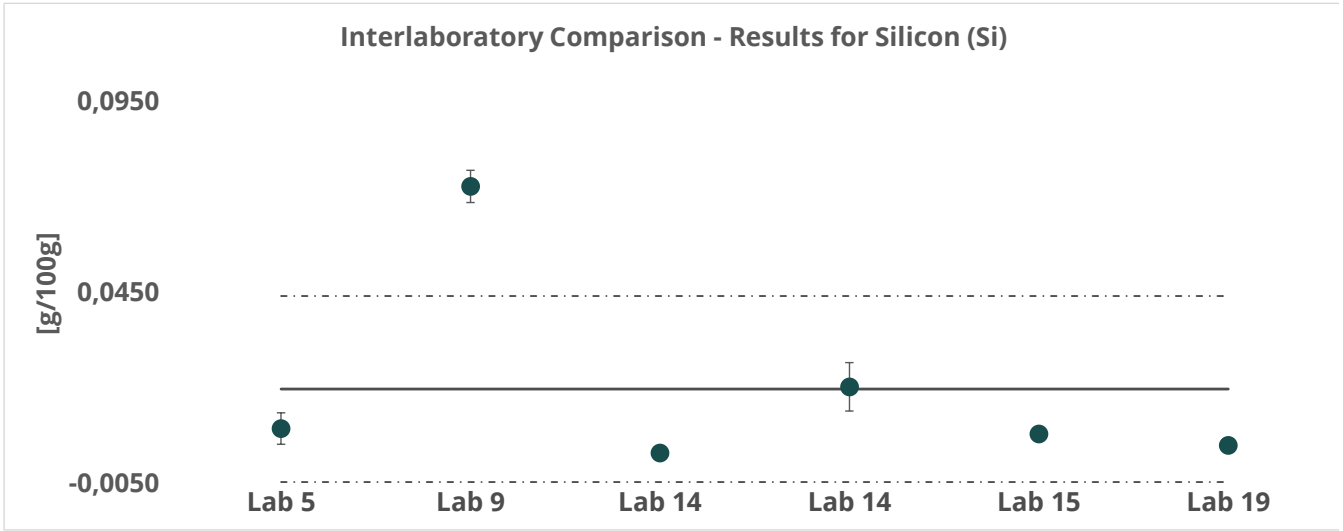


Si

[g/100g]

Lab Code	Lab 5	Lab 9	Lab 14	Lab 14	Lab 15	Lab 19	n
	0,015	0,0694	0,0028	0,028	0,009	0,0056	6
	0,00635	0,0702	0,0031	0,026	0,008	0,0049	
	0,0075	0,08	0,0031	0,024	0,007	0,0045	
	0,00564	0,073	0,0031	0,015		0,0055	
	0,0125	0,0717	0,0029	0,014		0,0049	
	< LOQ		0,0029	0,015		0,0045	
	< LOQ						

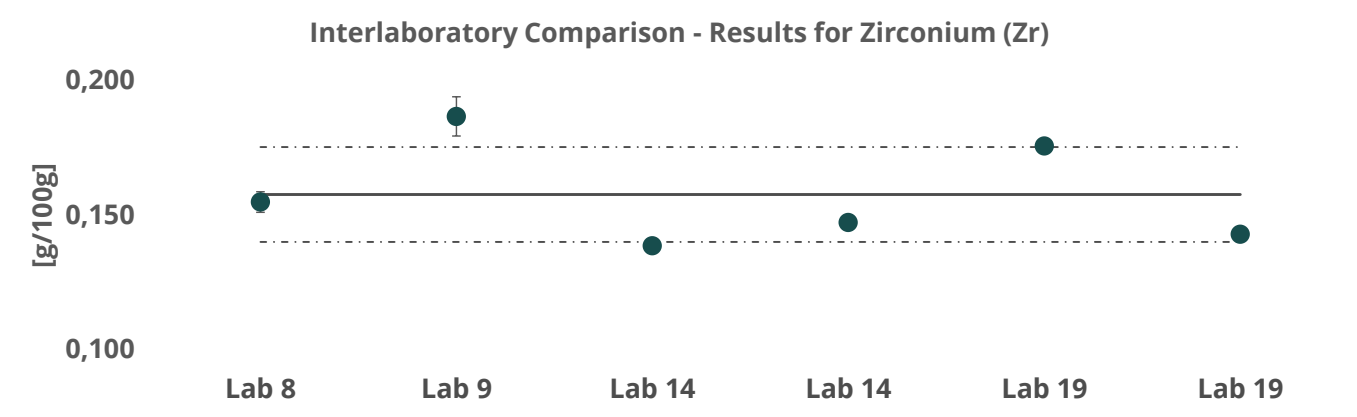
							Interlaboratory
Average	**0,009**	**0,073**	**0,0030**	**0,020**	**0,008**	**0,0050**	**0,020**
Standard dev.	*0,004*	*0,004*	*0,0001*	*0,006*	*0,001*	*0,0005*	*0,024*
RSD-%	43,88%	5,80%	4,06%	31,21%	12,50%	9,62%	123,40%



Zr

[g/100g]

Lab Code	Lab 8	Lab 9	Lab 14	Lab 14	Lab 19	Lab 19	n
	0,158	0,1828	0,13582	0,146	0,18	0,1456	6
	0,159	0,1826	0,14182	0,148	0,18	0,1439	
	0,159	0,2013	0,14138	0,148	0,18	0,1411	
	0,158	0,1830	0,13842	0,148	0,18	0,1428	
	0,149	0,1840	0,13948	0,147	0,18	0,1458	
	0,150		0,13478	0,147	0,17	0,1418	
	0,150				0,18	0,1400	
	0,151					0,1425	
	0,157						
	0,156						
	0,157						
							Interlaboratory
Average	**0,155**	**0,1867**	**0,13862**	**0,147**	**0,18**	**0,1429**	**0,158**
Standard dev.	0,004	0,0073	0,00262	0,001	0,00	0,0019	*0,018*
RSD-%	2,47%	3,91%	1,89%	0,51%	0,40%	1,35%	11,18%



Homogeneity Test

ED-XRF

Results for Aluminium Al

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ED-XRF

[g/100g]	**Result 1**	**Result 2**
Bottle 142	0,585	0,576
Bottle 328	0,578	0,576
Bottle 395	0,578	0,576
Bottle 173	0,568	0,575
Bottle 183	0,574	0,577
Bottle 329	0,565	0,575
Bottle 129	0,578	0,578
Bottle 265	0,575	0,577
Bottle 004	0,573	0,583
Bottle 133	0,571	0,577

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	*Number*	*Sum*	*Average*	*Variance*
Bottle 142	2	1,161	0,581	0,000041
Bottle 328	2	1,154	0,577	0,000002
Bottle 395	2	1,154	0,577	0,000002
Bottle 173	2	1,143	0,572	0,000025
Bottle 183	2	1,151	0,576	0,000005
Bottle 329	2	1,140	0,570	0,000050
Bottle 129	2	1,156	0,578	0,000000
Bottle 265	2	1,152	0,576	0,000002
Bottle 004	2	1,156	0,578	0,000050
Bottle 133	2	1,148	0,574	0,000018

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0001803	9	0,0000200	**1,035**	0,475	3,020
Within Groups	0,00019350	10	0,0000194			
				If F-Value < Critical F-value		
Total	0,000374	19		homogeneity test passed		

$s^2_{between}$	0,00000034	between group variance	if negative use st.dev. of all data points
s_{bb}	0,00432	between group standard deviation	
s_r	0,00440	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise
to determine usability

Results for Cobalt Co

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ED-XRF

[g/100g]	**Result 1**	**Result 2**
Bottle 142	4,73	4,71
Bottle 328	4,69	4,59
Bottle 395	4,67	4,61
Bottle 173	4,66	4,68
Bottle 183	4,68	4,68
Bottle 329	4,70	4,66
Bottle 129	4,66	4,65
Bottle 265	4,66	4,67
Bottle 004	4,68	4,66
Bottle 133	4,60	4,65

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	*Number*	*Sum*	*Average*	*Variance*
Bottle 142	2	9,44	4,72	0,000124
Bottle 328	2	9,28	4,64	0,004453
Bottle 395	2	9,28	4,64	0,001979
Bottle 173	2	9,34	4,67	0,000278
Bottle 183	2	9,36	4,68	0,000000
Bottle 329	2	9,36	4,68	0,000495
Bottle 129	2	9,31	4,66	0,000124
Bottle 265	2	9,33	4,66	0,000124
Bottle 004	2	9,34	4,67	0,000124
Bottle 133	2	9,25	4,62	0,001113

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0126460	9	0,0014051	**1,594**	0,239	3,020
Within Groups	0,00881418	10	0,0008814			
				If F-Value < Critical F-value		
Total	0,021460	19		homogeneity test passed		

$s^2_{between}$	0,0003	between group variance	if negative use st.dev. of all data points
s_{bb}	0,02	between group standard deviation	
s_r	0,03	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise to determine usability

Results for Copper Cu

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ED-XRF

[g/100g]	**Result 1**	**Result 2**
Bottle 142	0,323	0,165
Bottle 328	0,176	0,189
Bottle 395	0,135	0,137
Bottle 173	0,171	0,156
Bottle 183	0,223	0,272
Bottle 329	0,300	0,207
Bottle 129	0,151	0,141
Bottle 265	0,158	0,131
Bottle 004	0,191	0,267
Bottle 133	0,127	0,122

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	***Number***	***Sum***	***Average***	***Variance***
Bottle 142	2	0,488	0,244	0,012435
Bottle 328	2	0,365	0,183	0,000094
Bottle 395	2	0,271	0,136	0,000001
Bottle 173	2	0,326	0,163	0,000108
Bottle 183	2	0,495	0,247	0,001166
Bottle 329	2	0,506	0,253	0,004306
Bottle 129	2	0,292	0,146	0,000046
Bottle 265	2	0,289	0,144	0,000341
Bottle 004	2	0,458	0,229	0,002865
Bottle 133	2	0,250	0,125	0,000014

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0472205	9	0,0052467	**2,454**	0,089	3,020
Within Groups	0,02137616	10	0,0021376			
Total	0,068597	19		If F-Value < Critical F-value homogeneity test passed		

$s^2_{between}$	0,002	between group variance	if negative use st.dev. of all data points
s_{bb}	0,059	between group standard deviation	
s_r	0,046	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise
to determine usability

Results for Manganese Mn

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ED-XRF

[g/100g]	**Result 1**	**Result 2**
Bottle 142	2,14	2,12
Bottle 328	2,11	2,08
Bottle 395	2,11	2,08
Bottle 173	2,10	2,11
Bottle 183	2,11	2,11
Bottle 329	2,11	2,11
Bottle 129	2,10	2,09
Bottle 265	2,10	2,11
Bottle 004	2,11	2,11
Bottle 133	2,07	2,09

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	*Number*	*Sum*	*Average*	*Variance*
Bottle 142	2	4,26	2,13	0,000120
Bottle 328	2	4,18	2,09	0,000480
Bottle 395	2	4,19	2,09	0,000270
Bottle 173	2	4,21	2,10	0,000030
Bottle 183	2	4,23	2,11	0,000000
Bottle 329	2	4,22	2,11	0,000030
Bottle 129	2	4,19	2,09	0,000030
Bottle 265	2	4,21	2,11	0,000120
Bottle 004	2	4,22	2,11	0,000030
Bottle 133	2	4,16	2,08	0,000270

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0035869	9	0,0003985	**2,889**	0,057	3,020
Within Groups	0,00137956	10	0,0001380			
				If F-Value < Critical F-value		
Total	0,004966	19		homogeneity test passed		

$s^2_{between}$	0,00013	between group variance	if negative use st.dev. of all data points
s_{bb}	0,02	between group standard deviation	
s_r	0,01	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise
to determine usability

Results for Nickel Ni

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ED-XRF

[g/100g]	**Result 1**	**Result 2**
Bottle 142	31,64	31,44
Bottle 328	31,27	30,72
Bottle 395	31,15	30,81
Bottle 173	31,13	31,19
Bottle 183	31,31	31,25
Bottle 329	31,33	31,20
Bottle 129	31,10	30,99
Bottle 265	31,06	31,23
Bottle 004	31,20	31,17
Bottle 133	30,72	31,04

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	***Number***	***Sum***	***Average***	***Variance***
Bottle 142	2	63,08	31,54	0,019299
Bottle 328	2	61,99	30,99	0,151304
Bottle 395	2	61,96	30,98	0,057094
Bottle 173	2	62,32	31,16	0,001976
Bottle 183	2	62,55	31,28	0,001976
Bottle 329	2	62,53	31,27	0,008924
Bottle 129	2	62,09	31,05	0,005218
Bottle 265	2	62,29	31,15	0,013617
Bottle 004	2	62,37	31,18	0,000494
Bottle 133	2	61,76	30,88	0,051907

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,6380707	9	0,0708967	**2,274**	0,108	3,020
Within Groups	0,31180982	10	0,0311810			
Total	0,949881	19		If F-Value < Critical F-value homogeneity test passed		

$s^2_{between}$	0,02	between group variance	if negative use st.dev. of all data points
s_{bb}	0,14	between group standard deviation	
s_r	0,18	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise to determine usability

Results for Sulfur S

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ED-XRF

[g/100g]	**Result 1**	**Result 2**
Bottle 142	0,069	0,064
Bottle 328	0,068	0,072
Bottle 395	0,068	0,069
Bottle 173	0,067	0,071
Bottle 183	0,068	0,066
Bottle 329	0,072	0,063
Bottle 129	0,072	0,072
Bottle 265	0,070	0,068
Bottle 004	0,067	0,069
Bottle 133	0,071	0,066

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	*Number*	*Sum*	*Average*	*Variance*
Bottle 142	2	0,133	0,067	0,000010
Bottle 328	2	0,139	0,070	0,000008
Bottle 395	2	0,137	0,068	0,000001
Bottle 173	2	0,138	0,069	0,000011
Bottle 183	2	0,134	0,067	0,000002
Bottle 329	2	0,135	0,067	0,000038
Bottle 129	2	0,144	0,072	0,000000
Bottle 265	2	0,137	0,069	0,000001
Bottle 004	2	0,136	0,068	0,000003
Bottle 133	2	0,136	0,068	0,000012

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0000395	9	0,0000044	**0,521**	0,830	3,020
Within Groups	0,00008432	10	0,0000084			
				If F-Value < Critical F-value		
Total	0,000124	19		homogeneity test passed		

$s^2_{between}$	-0,00000202	between group variance	if negative use st.dev. of all data points
s_{bb}	0,00249	between group standard deviation	
s_r	0,00290	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise
to determine usability

Results for Silicon Si

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ED-XRF

[g/100g]	**Result 1**	**Result 2**
Bottle 142	0,015	0,013
Bottle 328	0,011	0,012
Bottle 395	0,013	0,012
Bottle 173	0,012	0,013
Bottle 183	0,013	0,014
Bottle 329	0,013	0,011
Bottle 129	0,011	0,012
Bottle 265	0,011	0,012
Bottle 004	0,014	0,013
Bottle 133	0,010	0,014

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	***Number***	***Sum***	***Average***	***Variance***
Bottle 142	2	0,027	0,014	0,000003
Bottle 328	2	0,024	0,012	0,000001
Bottle 395	2	0,024	0,012	0,000001
Bottle 173	2	0,025	0,012	0,000001
Bottle 183	2	0,027	0,013	0,000001
Bottle 329	2	0,024	0,012	0,000002
Bottle 129	2	0,023	0,012	0,000001
Bottle 265	2	0,023	0,011	0,000001
Bottle 004	2	0,027	0,013	0,000001
Bottle 133	2	0,025	0,012	0,000008

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0000124	9	0,0000014	**0,766**	0,650	3,020
Within Groups	0,00001798	10	0,0000018			
				If F-Value < Critical F-value		
Total	0,000030	19		homogeneity test passed		

$s^2_{between}$	-0,00000021	between group variance	if negative use st.dev. of all data points
s_{bb}	0,00123	between group standard deviation	
s_r	0,00134	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise
to determine usability

Results for Zirconium Zr

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ED-XRF

[g/100g]	**Result 1**	**Result 2**
Bottle 142	0,181	0,180
Bottle 328	0,180	0,175
Bottle 395	0,177	0,177
Bottle 173	0,179	0,178
Bottle 183	0,180	0,180
Bottle 329	0,181	0,176
Bottle 129	0,179	0,177
Bottle 265	0,178	0,180
Bottle 004	0,179	0,179
Bottle 133	0,178	0,179

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	*Number*	*Sum*	*Average*	*Variance*
Bottle 142	2	0,361	0,180	0,000001
Bottle 328	2	0,355	0,178	0,000011
Bottle 395	2	0,354	0,177	0,000000
Bottle 173	2	0,358	0,179	0,000000
Bottle 183	2	0,360	0,180	0,000000
Bottle 329	2	0,357	0,179	0,000010
Bottle 129	2	0,356	0,178	0,000002
Bottle 265	2	0,359	0,179	0,000002
Bottle 004	2	0,358	0,179	0,000000
Bottle 133	2	0,357	0,178	0,000000

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0000188	9	0,0000021	**0,777**	0,643	3,020
Within Groups	0,00002690	10	0,0000027			
				If F-Value < Critical F-value		
Total	0,000046	19		homogeneity test passed		

$s^2_{between}$	-0,0000003	between group variance	if negative use st.dev. of all data points
s_{bb}	0,0015118	between group standard deviation	
s_r	0,0016401	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise
to determine usability

Homogeneity Test
ICP-OES

Results for Aluminium Al

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ICP-OES

[g/100g]	**Result 1**	**Result 2**
Bottle 107	0,24	0,25
Bottle 135	0,24	0,27
Bottle170	0,25	0,25
Bottle 197	0,25	0,25
Bottle 211	0,25	0,25
Bottle 239	0,25	0,25
Bottle 295	0,25	0,25
Bottle 320	0,26	0,26
Bottle 408	0,24	0,26
Bottle 494	0,24	0,25

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	*Number*	*Sum*	*Average*	*Variance*
Bottle 107	2	0,49	0,25	0,000050
Bottle 135	2	0,51	0,26	0,000450
Bottle170	2	0,50	0,25	0,000000
Bottle 197	2	0,50	0,25	0,000000
Bottle 211	2	0,50	0,25	0,000000
Bottle 239	2	0,50	0,25	0,000000
Bottle 295	2	0,50	0,25	0,000000
Bottle 320	2	0,52	0,26	0,000000
Bottle 408	2	0,50	0,25	0,000200
Bottle 494	2	0,49	0,25	0,000050

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0003450	9	0,0000383	**0,511**	0,836	3,020
Within Groups	0,00075000	10	0,0000750			
				If F-Value < Critical F-value		
Total	0,001095	19		homogeneity test passed		

$s^2_{between}$	-0,000018	between group variance	if negative use st.dev. of all data points
s_{bb}	0,0074	between group standard deviation	
s_r	0,009	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise
to determine usability

Results for Cobalt Co

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ICP-OES

[g/100g]	**Result 1**	**Result 2**
Bottle 107	4,00	4,02
Bottle 135	3,95	3,97
Bottle170	4,00	3,97
Bottle 197	4,00	4,00
Bottle 211	3,98	3,96
Bottle 239	3,88	3,91
Bottle 295	3,92	3,91
Bottle 320	3,89	3,94
Bottle 408	3,90	3,87
Bottle 494	3,84	3,86

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	*Number*	*Sum*	*Average*	*Variance*
Bottle 107	2	8,02	4,01	0,000200
Bottle 135	2	7,92	3,96	0,000200
Bottle170	2	7,97	3,99	0,000450
Bottle 197	2	8,00	4,00	0,000000
Bottle 211	2	7,94	3,97	0,000200
Bottle 239	2	7,79	3,90	0,000450
Bottle 295	2	7,83	3,92	0,000050
Bottle 320	2	7,83	3,92	0,001250
Bottle 408	2	7,77	3,89	0,000450
Bottle 494	2	7,70	3,85	0,000200

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0524050	9	0,0058228	**16,878**	0,000	3,020
Within Groups	0,00345000	10	0,0003450			
				If F-Value < Critical F-value		
Total	0,055855	19		homogeneity test passed		

$s^2_{between}$	0,0027	between group variance	if negative use st.dev. of all data points
s_{bb}	0,05233	between group standard deviation	
s_r	0,02	repeatability standard deviation	

Status **inhomogenous**
If not homogenous use expertise
to determine usability

Usable homogeneity contribution

Results for Copper Cu

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ICP-OES

[g/100g]	**Result 1**	**Result 2**
Bottle 107	0,05	0,06
Bottle 135	0,09	0,06
Bottle170	0,04	0,03
Bottle 197	0,07	0,04
Bottle 211	0,19	0,05
Bottle 239	0,05	0,04
Bottle 295	0,05	0,19
Bottle 320	0,04	0,08
Bottle 408	0,14	0,06
Bottle 494	0,05	0,12

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	*Number*	*Sum*	*Average*	*Variance*
Bottle 107	2	0,110	0,055	0,000050
Bottle 135	2	0,150	0,075	0,000450
Bottle170	2	0,070	0,035	0,000050
Bottle 197	2	0,110	0,055	0,000450
Bottle 211	2	0,240	0,120	0,009800
Bottle 239	2	0,090	0,045	0,000050
Bottle 295	2	0,240	0,120	0,009800
Bottle 320	2	0,120	0,060	0,000800
Bottle 408	2	0,200	0,100	0,003200
Bottle 494	2	0,170	0,085	0,002450

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0166000	9	0,0018444	**0,681**	0,713	3,020
Within Groups	0,02710000	10	0,0027100			
				If F-Value < Critical F-value		
Total	0,043700	19		homogeneity test passed		

$s^2_{between}$	-0,0004	between group variance	if negative use st.dev. of all data points
s_{bb}	0,047	between group standard deviation	
s_r	0,052	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise
to determine usability

Results for Iron Fe

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ICP-OES

[g/100g]	**Result 1**	**Result 2**
Bottle 107	0,010	0,010
Bottle 135	0,020	0,010
Bottle170	0,010	0,010
Bottle 197	0,010	0,010
Bottle 211	0,010	0,010
Bottle 239	0,010	0,010
Bottle 295	0,010	0,010
Bottle 320	0,010	0,010
Bottle 408	0,010	0,010
Bottle 494	0,010	0,010

ANOVA - One Factor Analysis

α= *0,05*

Summary

Groups	*Number*	*Sum*	*Average*	*Variance*
Bottle 107	2	0,020	0,010	0,000000
Bottle 135	2	0,030	0,015	0,000050
Bottle170	2	0,020	0,010	0,000000
Bottle 197	2	0,020	0,010	0,000000
Bottle 211	2	0,020	0,010	0,000000
Bottle 239	2	0,020	0,010	0,000000
Bottle 295	2	0,020	0,010	0,000000
Bottle 320	2	0,020	0,010	0,000000
Bottle 408	2	0,020	0,010	0,000000
Bottle 494	2	0,020	0,010	0,000000

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0000450	9	0,0000050	**1,000**	0,495	3,020
Within Groups	0,00005000	10	0,0000050			
				If F-Value < Critical F-value		
Total	0,000095	19		homogeneity test passed		

$s^2_{between}$	0,0000	between group variance	if negative use st.dev. of all data points
s_{bb}	0,0022	between group standard deviation	
s_r	0,0022	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise
to determine usability

Results for Lithium Li

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ICP-OES

[g/100g]	**Result 1**	**Result 2**
Bottle 107	3,75	3,78
Bottle 135	3,76	3,79
Bottle170	3,74	3,75
Bottle 197	3,72	3,78
Bottle 211	3,79	3,73
Bottle 239	3,75	3,73
Bottle 295	3,74	3,69
Bottle 320	3,72	3,77
Bottle 408	3,62	3,62
Bottle 494	3,64	3,66

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	*Number*	*Sum*	*Average*	*Variance*
Bottle 107	2	7,53	3,77	0,000450
Bottle 135	2	7,55	3,78	0,000450
Bottle170	2	7,49	3,75	0,000050
Bottle 197	2	7,50	3,75	0,001800
Bottle 211	2	7,52	3,76	0,001800
Bottle 239	2	7,48	3,74	0,000200
Bottle 295	2	7,43	3,72	0,001250
Bottle 320	2	7,49	3,75	0,001250
Bottle 408	2	7,24	3,62	0,000000
Bottle 494	2	7,30	3,65	0,000200

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0474050	9	0,0052672	**7,070**	0,003	3,020
Within Groups	0,00745000	10	0,0007450			
Total	0,054855	19		If F-Value < Critical F-value homogeneity test passed		

$s^2_{between}$	0,002	between group variance	if negative use st.dev. of all data points
s_{bb}	0,048	between group standard deviation	
s_r	0,03	repeatability standard deviation	

Status **inhomogenous**
If not homogenous use expertise
to determine usability

Usable homogeneity contribution

Results for Manganese Mn

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ICP-OES

[g/100g]	**Result 1**	**Result 2**
Bottle 107	1,86	1,92
Bottle 135	1,87	1,89
Bottle170	1,85	1,89
Bottle 197	1,84	1,89
Bottle 211	1,90	1,87
Bottle 239	1,85	1,87
Bottle 295	1,87	1,83
Bottle 320	1,86	1,88
Bottle 408	1,86	1,84
Bottle 494	1,83	1,81

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	*Number*	*Sum*	*Average*	*Variance*
Bottle 107	2	3,78	1,89	0,001800
Bottle 135	2	3,76	1,88	0,000200
Bottle170	2	3,74	1,87	0,000800
Bottle 197	2	3,73	1,87	0,001250
Bottle 211	2	3,77	1,89	0,000450
Bottle 239	2	3,72	1,86	0,000200
Bottle 295	2	3,70	1,85	0,000800
Bottle 320	2	3,74	1,87	0,000200
Bottle 408	2	3,70	1,85	0,000200
Bottle 494	2	3,64	1,82	0,000200

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0075800	9	0,0008422	**1,381**	0,310	3,020
Within Groups	0,00610000	10	0,0006100			
				If F-Value < Critical F-value		
Total	0,013680	19		homogeneity test passed		

$s^2_{between}$	0,00012	between group variance	if negative use st.dev. of all data points
s_{bb}	0,010775	between group standard deviation	
s_r	0,02	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise
to determine usability

Results for Nickel Ni

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ICP-OES

[g/100g]	**Result 1**	**Result 2**
Bottle 107	28,78	29,24
Bottle 135	28,94	29,05
Bottle170	29,02	29,23
Bottle 197	29,22	29,41
Bottle 211	29,08	29,19
Bottle 239	28,93	29,11
Bottle 295	29,33	29,27
Bottle 320	29,19	29,31
Bottle 408	29,63	29,37
Bottle 494	29,73	29,28

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	***Number***	***Sum***	***Average***	***Variance***
Bottle 107	2	58,02	29,01	0,105800
Bottle 135	2	57,99	29,00	0,006050
Bottle170	2	58,25	29,13	0,022050
Bottle 197	2	58,63	29,32	0,018050
Bottle 211	2	58,27	29,14	0,006050
Bottle 239	2	58,04	29,02	0,016200
Bottle 295	2	58,60	29,30	0,001800
Bottle 320	2	58,50	29,25	0,007200
Bottle 408	2	59,00	29,50	0,033800
Bottle 494	2	59,01	29,51	0,101250

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,6534450	9	0,0726050	**2,281**	0,107	3,020
Within Groups	0,31825000	10	0,0318250			
				If F-Value < Critical F-value		
Total	0,971695	19		homogeneity test passed		

$s^2_{between}$	0,02	between group variance	if negative use st.dev. of all data points
s_{bb}	0,14	between group standard deviation	
s_r	0,18	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise
to determine usability

Results for Phosphorus P

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ICP-OES

[g/100g]	**Result 1**	**Result 2**
Bottle 107	0,05	0,05
Bottle 135	0,08	0,05
Bottle170	0,04	0,03
Bottle 197	0,06	0,04
Bottle 211	0,18	0,05
Bottle 239	0,04	0,03
Bottle 295	0,04	0,18
Bottle 320	0,04	0,07
Bottle 408	0,11	0,05
Bottle 494	0,03	0,09

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	***Number***	***Sum***	***Average***	***Variance***
Bottle 107	2	0,100	0,050	0,000000
Bottle 135	2	0,130	0,065	0,000450
Bottle170	2	0,070	0,035	0,000050
Bottle 197	2	0,100	0,050	0,000200
Bottle 211	2	0,230	0,115	0,008450
Bottle 239	2	0,070	0,035	0,000050
Bottle 295	2	0,220	0,110	0,009800
Bottle 320	2	0,110	0,055	0,000450
Bottle 408	2	0,160	0,080	0,001800
Bottle 494	2	0,120	0,060	0,001800

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0142450	9	0,0015828	**0,687**	0,708	3,020
Within Groups	0,02305000	10	0,0023050			
				If F-Value < Critical F-value		
Total	0,037295	19		homogeneity test passed		

$s^2_{between}$	-0,0003611	between group variance	if negative use st.dev. of all data points
s_{bb}	0,0431828	between group standard deviation	
s_r	0,0480104	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise to determine usability

Results for Sulfur S

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
ICP-OES

[g/100g]	**Result 1**	**Result 2**
Bottle 107	0,02	0,02
Bottle 135	0,03	0,02
Bottle170	0,03	0,03
Bottle 197	0,02	0,02
Bottle 211	0,02	0,02
Bottle 239	0,03	0,02
Bottle 295	0,03	0,02
Bottle 320	0,03	0,02
Bottle 408	0,02	0,02
Bottle 494	0,02	0,02

ANOVA - One Factor Analysis

α= *0,05*

Summary

Groups	*Number*	*Sum*	*Average*	*Variance*
Bottle 107	2	0,040	0,020	0,000000
Bottle 135	2	0,050	0,025	0,000050
Bottle170	2	0,060	0,030	0,000000
Bottle 197	2	0,040	0,020	0,000000
Bottle 211	2	0,040	0,020	0,000000
Bottle 239	2	0,050	0,025	0,000050
Bottle 295	2	0,050	0,025	0,000050
Bottle 320	2	0,050	0,025	0,000050
Bottle 408	2	0,040	0,020	0,000000
Bottle 494	2	0,040	0,020	0,000000

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0002200	9	0,0000244	**1,222**	0,377	3,020
Within Groups	0,00020000	10	0,0000200			
				If F-Value < Critical F-value		
Total	0,000420	19		homogeneity test passed		

$s^2_{between}$	0,00000222	between group variance	if negative use st.dev. of all data points
s_{bb}	0,001	between group standard deviation	
s_r	0,004	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise
to determine usability

Homogeneity Test IR-Combustion

Results for Carbon C

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
Elemental analyser combustion-IR

[g/100g]	**Result 1**	**Result 2**
Bottle 257	37,66	37,92
Bottle 012	38,52	37,88
Bottle 495	37,53	37,49
Bottle 300	37,61	37,72
Bottle 027	37,82	37,56
Bottle 355	37,91	37,72
Bottle 222	37,71	38,00
Bottle 146	38,06	37,92
Bottle 78	37,99	37,84
Bottle 005	38,02	37,83

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	***Number***	***Sum***	***Average***	***Variance***
Bottle 257	2	75,58	37,79	0,033800
Bottle 012	2	76,40	38,20	0,204800
Bottle 495	2	75,02	37,51	0,000800
Bottle 300	2	75,33	37,67	0,006050
Bottle 027	2	75,38	37,69	0,033800
Bottle 355	2	75,63	37,82	0,018050
Bottle 222	2	75,71	37,86	0,042050
Bottle 146	2	75,98	37,99	0,009800
Bottle 78	2	75,83	37,92	0,011250
Bottle 005	2	75,85	37,93	0,018050

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,6602450	9	0,0733606	**1,938**	0,158	3,020
Within Groups	0,37845000	10	0,0378450			
				If F-Value < Critical F-value		
Total	1,038695	19		homogeneity test passed		

$s^2_{between}$	0,0178	between group variance	if negative use st.dev. of all data points
s_{bb}	0,133	between group standard deviation	
s_r	0,19	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise
to determine usability

Results for Hydrogen H

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
Elemental analyser combustion-IR

[g/100g]	**Result 1**	**Result 2**
Bottle 257	0,107	0,106
Bottle 012	0,106	0,105
Bottle 495	0,108	0,107
Bottle 300	0,107	0,105
Bottle 027	0,105	0,107
Bottle 355	0,105	0,105
Bottle 222	0,106	0,104
Bottle 146	0,107	0,105
Bottle 78	0,105	0,107
Bottle 005	0,106	0,105

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	***Number***	***Sum***	***Average***	***Variance***
Bottle 257	2	0,213	0,107	0,000001
Bottle 012	2	0,211	0,106	0,000001
Bottle 495	2	0,215	0,108	0,000001
Bottle 300	2	0,212	0,106	0,000002
Bottle 027	2	0,212	0,106	0,000002
Bottle 355	2	0,210	0,105	0,000000
Bottle 222	2	0,210	0,105	0,000002
Bottle 146	2	0,212	0,106	0,000002
Bottle 78	2	0,212	0,106	0,000002
Bottle 005	2	0,211	0,106	0,000001

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0000098	9	0,0000011	**0,907**	0,553	3,020
Within Groups	0,00001200	10	0,0000012			
				If F-Value < Critical F-value		
Total	0,000022	19		homogeneity test passed		

$s^2_{between}$	-0,00000006	between group variance	if negative use st.dev. of all data points
s_{bb}	0,001	between group standard deviation	
s_r	0,001	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise
to determine usability

Results for Nitrogen N

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
Elemental analyser combustion-IR

[g/100g]	**Result 1**	**Result 2**
Bottle 257	0,00782	0,00973
Bottle 012	0,01040	0,00982
Bottle 495	0,00850	0,00568
Bottle 300	0,00601	0,00806
Bottle 027	0,00659	0,00605
Bottle 355	0,00927	0,00648
Bottle 222	0,00118	0,00128
Bottle 146	0,00123	0,01180
Bottle 78	0,01250	0,01220
Bottle 005	0,00115	0,00659

ANOVA - One Factor Analysis

α= *0,05*

Summary

Groups	*Number*	*Sum*	*Average*	*Variance*
Bottle 257	2	0,0176	0,0088	0,000002
Bottle 012	2	0,0202	0,0101	0,000000
Bottle 495	2	0,0142	0,0071	0,000004
Bottle 300	2	0,0141	0,0070	0,000002
Bottle 027	2	0,0126	0,0063	0,000000
Bottle 355	2	0,0158	0,0079	0,000004
Bottle 222	2	0,0025	0,0012	0,000000
Bottle 146	2	0,0130	0,0065	0,000056
Bottle 78	2	0,0247	0,0124	0,000000
Bottle 005	2	0,0077	0,0039	0,000015

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0001717	9	0,0000191	**2,304**	0,105	3,020
Within Groups	0,00008282	10	0,0000083			
				If F-Value < Critical F-value		
Total	0,000255	19		homogeneity test passed		

$s^2_{between}$	0,00001	between group variance	if negative use st.dev. of all data points
s_{bb}	0,0023	between group standard deviation	
s_r	0,0029	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise
to determine usability

Results for Oxygen O

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
Elemental analyser combustion-IR

[g/100g]	**Result 1**	**Result 2**
Bottle 257	19,2	19,4
Bottle 012	19,4	19,2
Bottle 495	19,5	19,2
Bottle 300	19,4	18,9
Bottle 027	19,4	18,8
Bottle 355	19,4	19,1
Bottle 222	19,3	19,7
Bottle 146	19,6	19,7
Bottle 78	19,5	19,5
Bottle 005	19,2	19,4

ANOVA - One Factor Analysis

α= ***0,05***

Summary

Groups	***Number***	***Sum***	***Average***	***Variance***
Bottle 257	2	38,6	19,3	0,020000
Bottle 012	2	38,6	19,3	0,020000
Bottle 495	2	38,7	19,4	0,045000
Bottle 300	2	38,3	19,2	0,125000
Bottle 027	2	38,2	19,1	0,180000
Bottle 355	2	38,5	19,2	0,039200
Bottle 222	2	39,0	19,5	0,080000
Bottle 146	2	39,3	19,7	0,005000
Bottle 78	2	39,0	19,5	0,000000
Bottle 005	2	38,6	19,3	0,020000

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,5117800	9	0,0568644	**1,064**	0,458	3,020
Within Groups	0,53420000	10	0,0534200			
				If F-Value < Critical F-value		
Total	1,045980	19		homogeneity test passed		

$s^2_{between}$	0,002	between group variance	if negative use st.dev. of all data points
s_{bb}	0,04	between group standard deviation	
s_r	0,23	repeatability standard deviation	

Status **homogenous**
If not homogenous use expertise
to determine usability

Results for Sulfur S

Homogeneity Study RVMT-BM-1 **ISO 33405:2024 p. 93ff**
Elemental analyser combustion-IR

[g/100g]	**Result 1**	**Result 2**
Bottle 257	0,02524	0,02478
Bottle 012	0,02450	0,02419
Bottle 495	0,02612	0,02444
Bottle 300	0,02536	0,02431
Bottle 027	0,02492	0,02417
Bottle 355	0,02542	0,02438
Bottle 222	0,02205	0,02245
Bottle 146	0,02192	0,02250
Bottle 78	0,02231	0,02275
Bottle 005	0,02264	0,02524

ANOVA - One Factor Analysis

α= ***0,05***

Summary

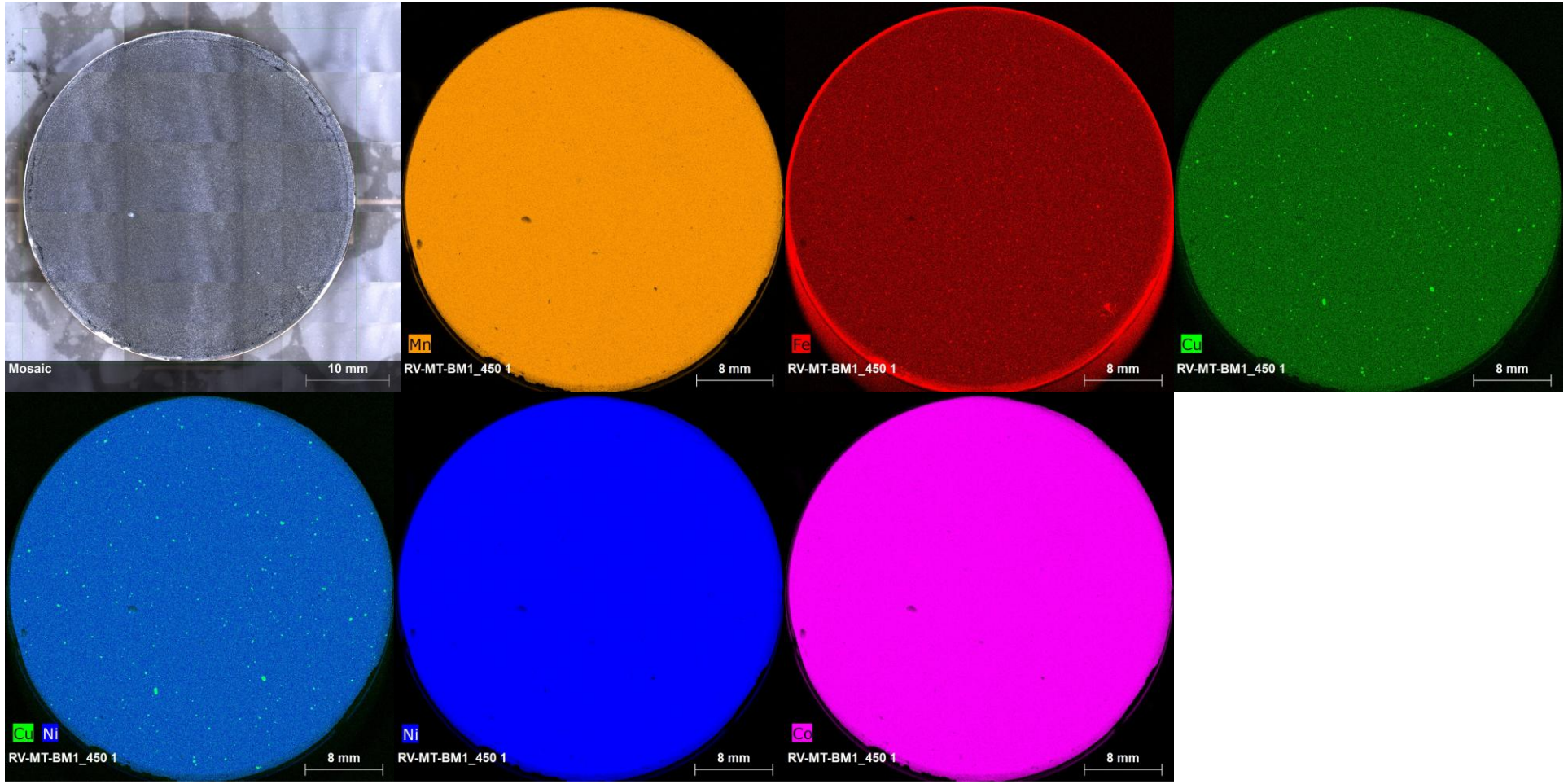
Groups	*Number*	*Sum*	*Average*	*Variance*
Bottle 257	2	0,0500	0,0250	0,000000
Bottle 012	2	0,0487	0,0243	0,000000
Bottle 495	2	0,0506	0,0253	0,000001
Bottle 300	2	0,0497	0,0248	0,000001
Bottle 027	2	0,0491	0,0245	0,000000
Bottle 355	2	0,0498	0,0249	0,000001
Bottle 222	2	0,0445	0,0223	0,000000
Bottle 146	2	0,0444	0,0222	0,000000
Bottle 78	2	0,0451	0,0225	0,000000
Bottle 005	2	0,0479	0,0239	0,000003

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Squares (MS**	**F-Value**	**P-Value**	**Critical F-value**
Between Groups	0,0000260	9	0,0000029	**4,336**	0,016	3,020
Within Groups	0,00000667	10	0,0000007			
				If F-Value < Critical F-value		
Total	0,000033	19		homogeneity test passed		

$s^2_{between}$	0,00000	between group variance	if negative use st.dev. of all data points
s_{bb}	0,0011	between group standard deviation	
s_r	0,0008	repeatability standard deviation	

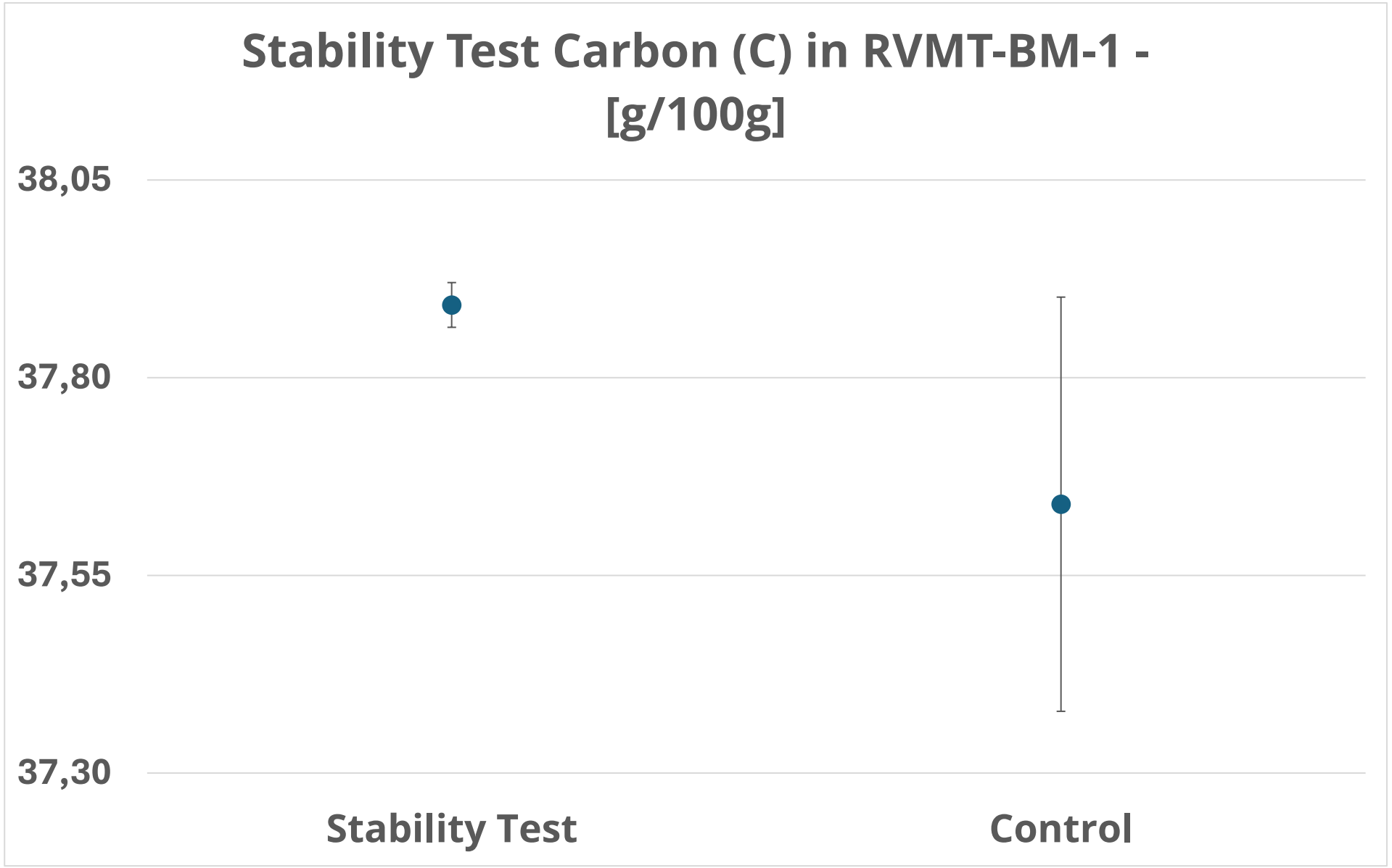
Status **inhomogenous**
If not homogenous use expertise
to determine usability
Uncertainty contribution
is usable

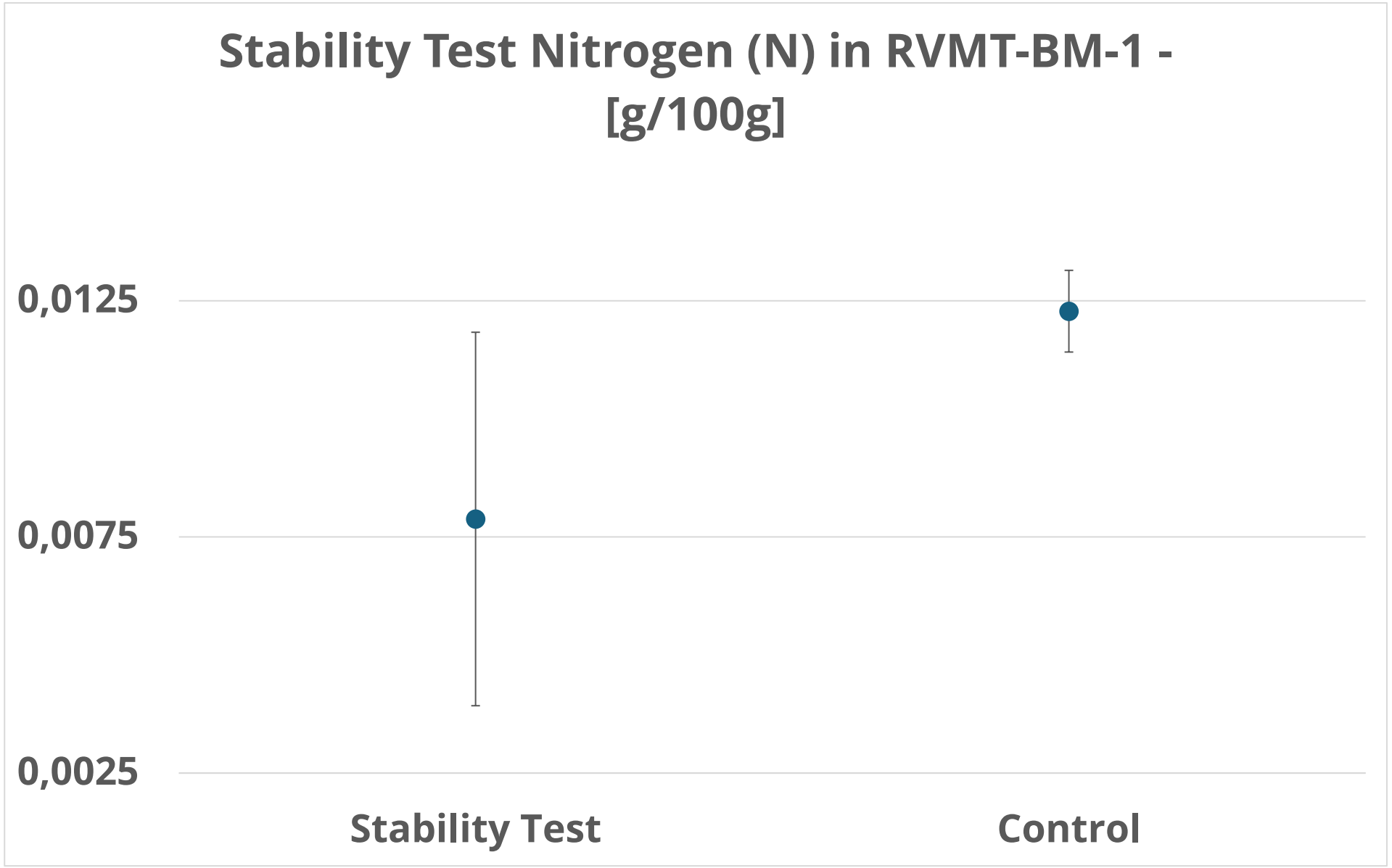
Homogeneity Visualised micro-XRF

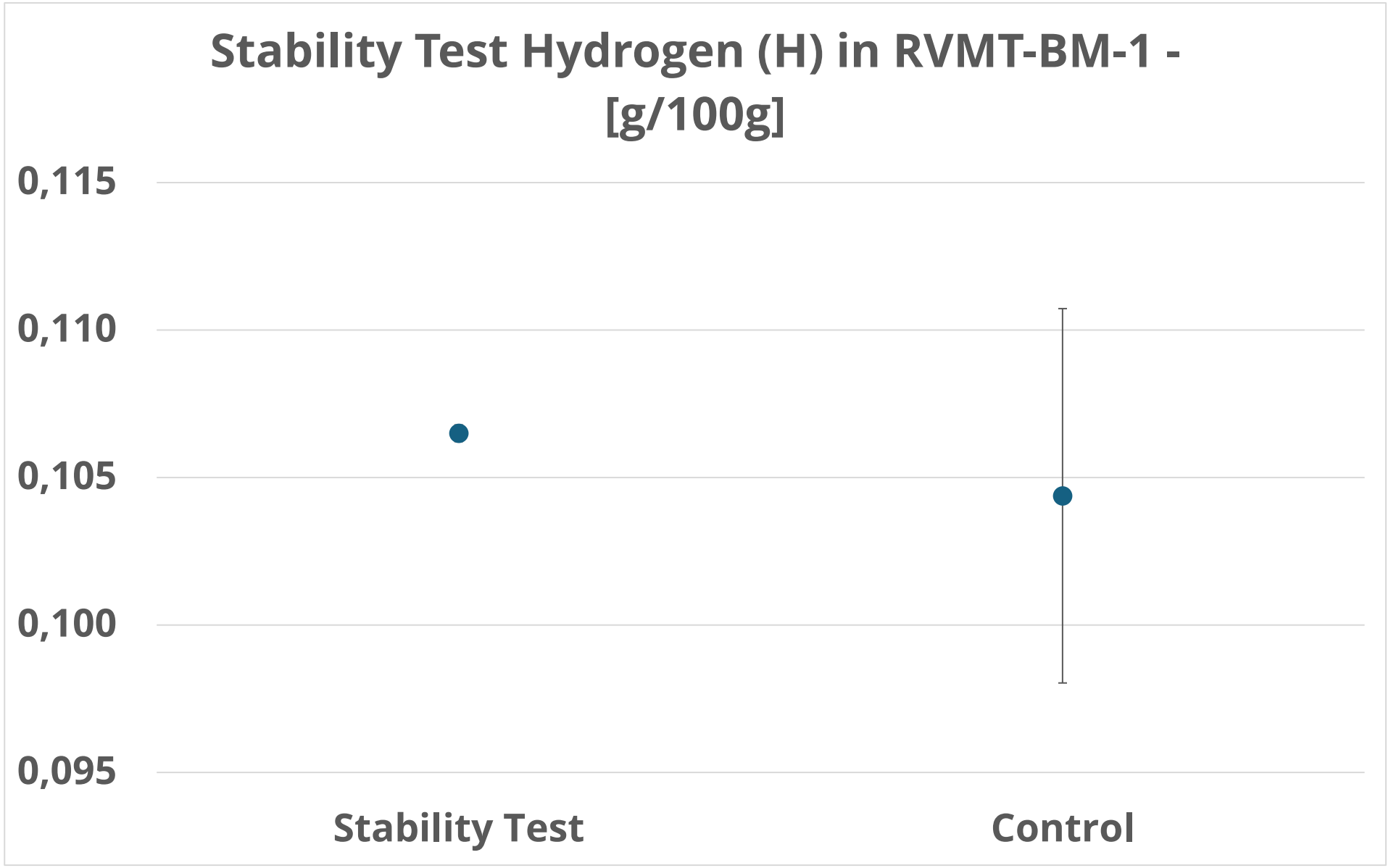


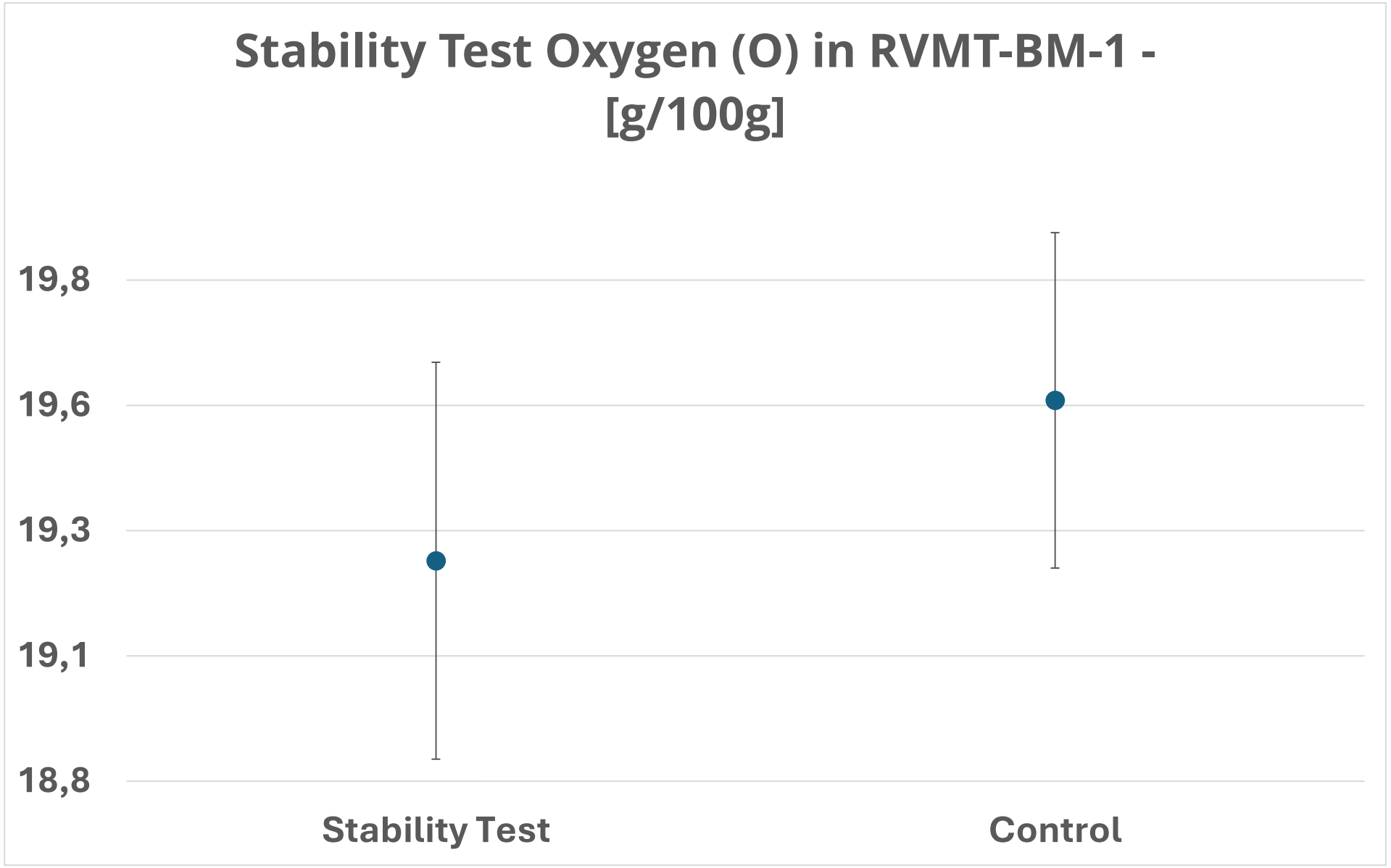
Bruker M4 Tornado micro-XRF elemental distribution maps. The top left shows the stitched mosaic image of the 40 mm diameter pressed pellet in an aluminium cup. Ni, Cu, Mn show excellent micro-homogeneity. Cu shows larger particles, due to inefficient grinding of a malleable metal. Images courtesy of Hannes Lüers, Bruker AXS, Karlsruhe, Germany.

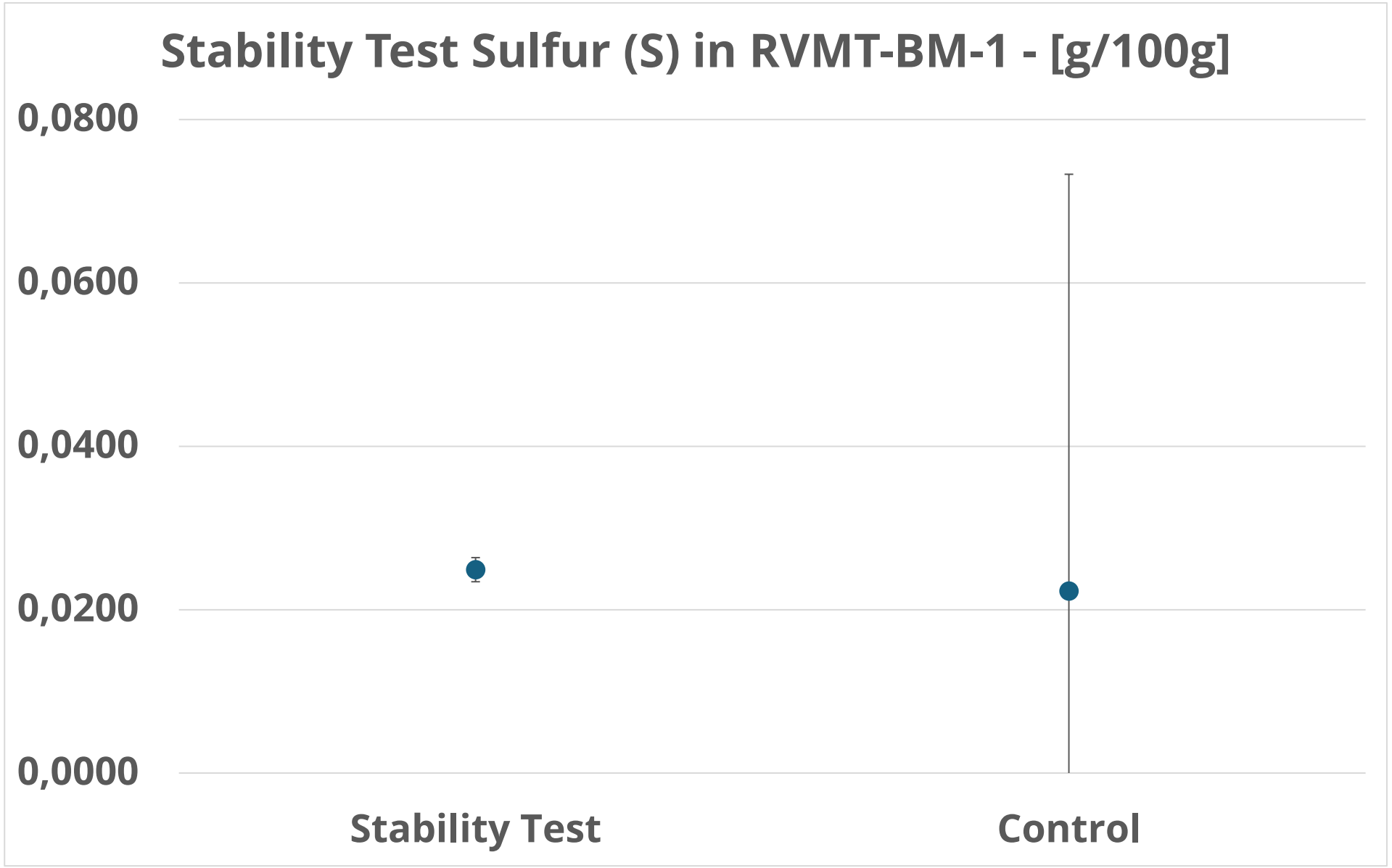
Stability Test


Stability Test Carbon (C) in RVMT-BM-1 - [g/100g]
38,05
37,80
37,55
37,30
Stability Test
Control


Stability Test Nitrogen (N) in RVMT-BM-1 - [g/100g]
0,0125
0,0075
0,0025
Stability Test
Control


Stability Test Hydrogen (H) in RVMT-BM-1 - [g/100g]
0,115
0,110
0,105
0,100
0,095
Stability Test
Control


Stability Test Oxygen (O) in RVMT-BM-1 - [g/100g]
19,8
19,6
19,3
19,1
18,8
Stability Test
Control


Stability Test Sulfur (S) in RVMT-BM-1 - [g/100g]
0,0800
0,0600
0,0400
0,0200
0,0000
Stability Test
Control

Statistical Evaluation

Statistical Evaluation

All data tested using these online tools:

Outlier tests	https://r-statistics.co/tools/outlier-detection-calculator.html	10.08.2026
Normal distribution	https://r-statistics.co/tools/normality-test-picker.html	10.08.2026
α	0,05	

Aluminium - Al

Outliers

Grubbs	no
Generalised ESD	2 flagged
Hampel (MAD)	2 flagged

Normal distribution

Shapiro-Wilk	departs from normal distribution
Anderson-Darling	departs from normal distribution
Lilliefors	departs from normal distribution
Jarque-Bera	departs from normal distribution

Comment

Removal of outliers lead to data being consistent with normal distribution
Removal justified due to technical reason, incomplete sample digestions

Carbon - C

Outliers

Grubbs	no
Generalised ESD	no
Hampel (MAD)	1 flagged

Normal distribution

Shapiro-Wilk	consistent with normal distribution
Anderson-Darling	consistent with normal distribution
Lilliefors	consistent with normal distribution
Jarque-Bera	consistent with normal distribution

Comment

Cobalt - Co

Outliers

Grubbs	no
Generalised ESD	2 flagged
Hampel (MAD)	4 flagged

Normal distribution

Shapiro-Wilk	departs from normal distribution
Anderson-Darling	departs from normal distribution
Lilliefors	consistent with normal distribution
Jarque-Bera	departs from normal distribution

Comment

Removal of outliers lead to data being consistent with normal distribution
Removal justified due to technical reason, incomplete sample digestions

Copper - Cu

Outliers

Grubbs	no
Generalised ESD	no
Hampel (MAD)	2 flagged

Normal distribution

Shapiro-Wilk	consistent with normal distribution
Anderson-Darling	consistent with normal distribution
Lilliefors	consistent with normal distribution
Jarque-Bera	consistent with normal distribution

Comment

Iron - Fe

Outliers

Grubbs	1 flagged
Generalised ESD	1 flagged
Hampel (MAD)	1 flagged

Normal distribution

Shapiro-Wilk	departs from normal distribution
Anderson-Darling	departs from normal distribution
Lilliefors	departs from normal distribution
Jarque-Bera	departs from normal distribution

Comment

Lithium - Li

Outliers

Grubbs	no
Generalised ESD	no
Hampel (MAD)	2 flagged

Normal distribution

Shapiro-Wilk	consistent with normal distribution
Anderson-Darling	consistent with normal distribution
Lilliefors	consistent with normal distribution
Jarque-Bera	consistent with normal distribution

Comment

Manganese - Mn

Outliers

Grubbs	1 flagged
Generalised ESD	1 flagged
Hampel (MAD)	1 flagged

Normal distribution

Shapiro-Wilk	departs from normal distribution
Anderson-Darling	consistent with normal distribution
Lilliefors	consistent with normal distribution
Jarque-Bera	departs from normal distribution

Comment

Nickel - Ni

Outliers

Grubbs	no
Generalised ESD	2 flagged
Hampel (MAD)	3 flagged

Normal distribution

Shapiro-Wilk	departs from normal distribution
Anderson-Darling	departs from normal distribution
Lilliefors	departs from normal distribution
Jarque-Bera	departs from normal distribution

Comment

Removal of outliers lead to data being consistent with normal distribution
Removal justified due to technical reason, incomplete sample digestions and no calibration

Oxygen - O

Outliers

Grubbs	no
Generalised ESD	no
Hampel (MAD)	no

Normal distribution

Shapiro-Wilk	consistent with normal distribution
Anderson-Darling	consistent with normal distribution
Lilliefors	consistent with normal distribution
Jarque-Bera	consistent with normal distribution

Comment

Sulfur - S

Outliers

Grubbs	no
Generalised ESD	2 flagged
Hampel (MAD)	2 flagged

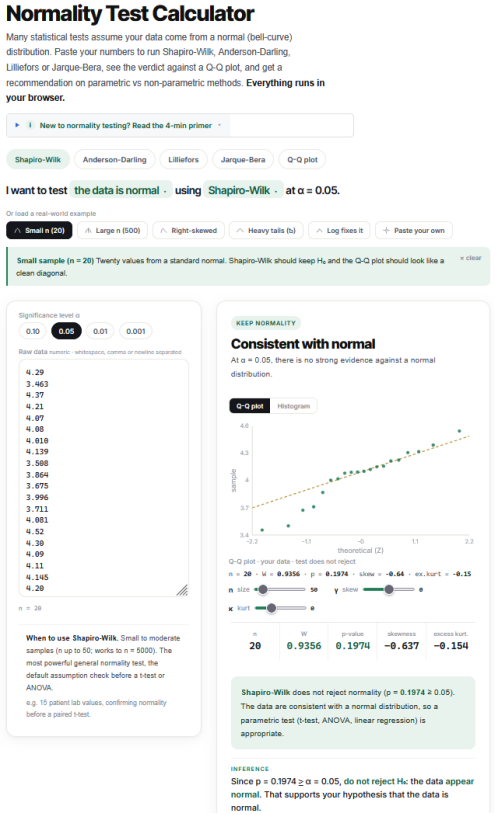
Normal distribution

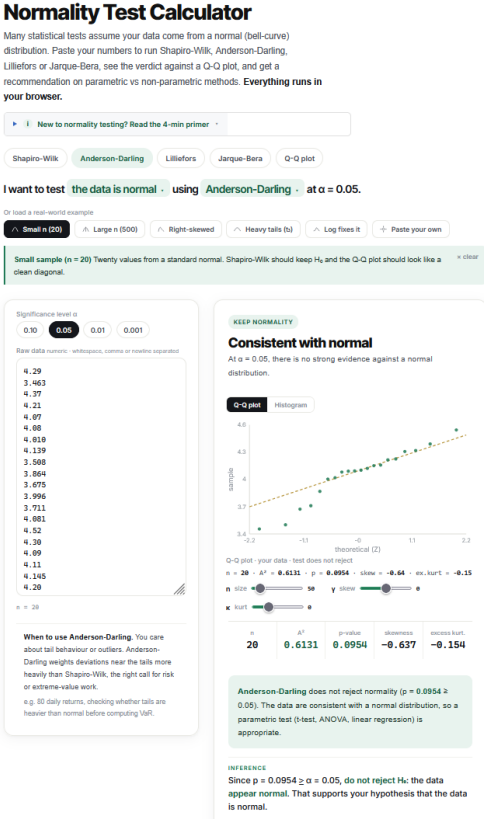
Shapiro-Wilk	departs from normal distribution
Anderson-Darling	departs from normal distribution
Lilliefors	departs from normal distribution
Jarque-Bera	consistent with normal distribution

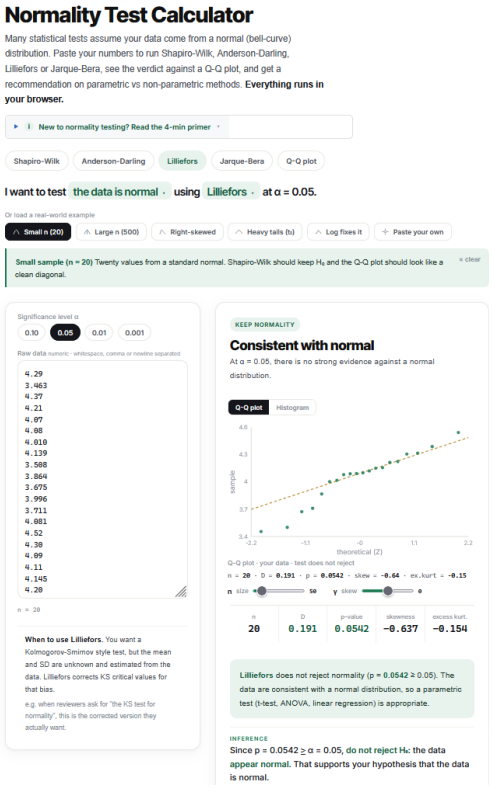
Comment

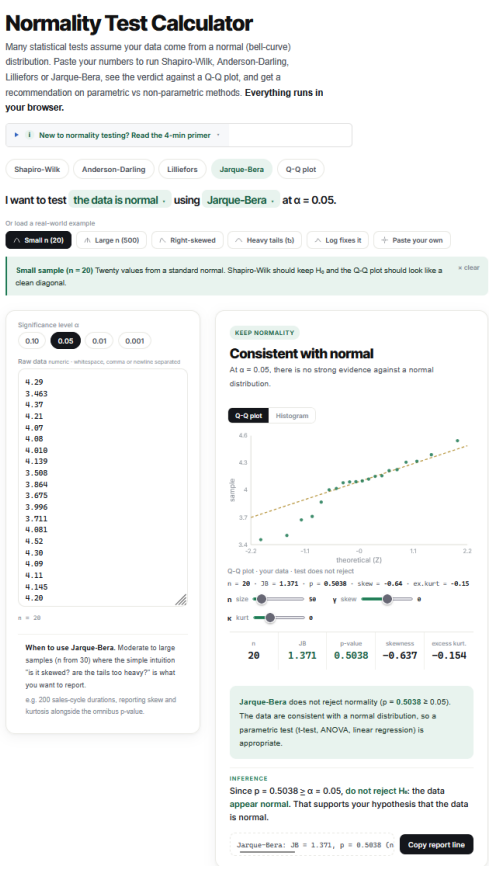
Output from r-statistics.co Normality tester: https://r-statistics.co/tools/normality-test-picker.html

Example: Lithium (Li) Data









Output from r-statistics.co Outlier tester: https://r-statistics.co/tools/outlier-detection-calculator.html

Example: Lithium (Li) Data