

Bundesanstalt für Materialforschung und -prüfung (BAM)

Certification Report

Certified Reference Material

BAM-M323

AlFe1

May 2022

Coordinator: Dr. Sebastian Recknagel
Bundesanstalt für Materialforschung und -prüfung (BAM)
Division 1.6 „Inorganic Reference Materials“
Richard-Willstätter-Str. 11
D-12489 Berlin
Phone: +49 30 8104 1111
Fax: +49 30 8104 71111
E-mail: sebastian.recknagel@bam.de

Summary

This report describes preparation, analysis and certification of the aluminium alloy reference material BAM-M323.

The following mass fractions and uncertainties have been certified:

Element	Mass fraction ¹⁾ in %	Uncertainty ²⁾ in %
Si	0.147	0.005
Fe	1.000	0.012
Cu	0.0182	0.0004
Mn	0.0471	0.0009
Mg	0.0203	0.0013
Cr	0.0106	0.0003
Ga	0.0141	0.0003
Zn	0.0286	0.0006
Ti	0.0189	0.0006
	in mg/kg	in mg/kg
Be	5.3	0.3
Bi	15.0	1.7
Ca	17	4
Cd	20.2	0.9
Co	21.3	1.3
Hg	19.9	1.1
Li ³⁾	6.0 ³⁾	0.7
Na ⁴⁾	8.8 ⁴⁾	1.4
Ni	92.3	2.7
Pb	44.1	1.3
Sb	40	4
Sn	16.3	0.6
V	89.2	2.8
Zr	49.4	1.3

1) Unweighted mean value of the means of accepted sets of data (consisting of at least 5 single results), each set being obtained by a different laboratory and/or a different method of measurement.

2) Estimated expanded uncertainty U with a coverage factor of $k = 2$, corresponding to a level of confidence of approx. 95 %, as defined in the Guide to the Expression of Uncertainty in Measurement, (GUM, ISO/IEC Guide 98-3:2008).

3) Depending on the individual sample number: $M(Li) = (N-48) \times 0.033161 + 6.0$

4) Depending on the individual sample number: $M(Na) = (N-48) \times 0.04788 + 8.8$

Additionally, the mass fraction of B is given for information. The certified reference material (CRM) is available in the form of discs (65 mm diameter and 30 mm height). It is intended for establishing and checking the calibration of optical emission and X-ray

spectrometers (excluding micro-analysis) for the analysis of samples of similar matrix composition. It is also suitable for validation and quality control of wet chemical analysis methods.

This report contains detailed information on the preparation of the CRM as well as on homogeneity investigations and on the analytical methods used for certification analysis. The certified values are based on the results of eight laboratories which participated in the certification inter-laboratory comparison.

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List of abbreviations

(if not explained elsewhere)

AFS	atomic fluorescence spectrometry
CRM	certified reference material
CVAAS	cold vapour atomic absorption spectrometry
FAAS	flame atomic absorption spectrometry
ETAAS	Electrothermal atomic absorption spectrometry
ICP-OES	inductively coupled plasma optical emission spectrometry
ICP-MS	inductively coupled plasma mass spectrometry
SOES	spark optical emission spectrometry
XRF	X-ray fluorescence spectrometry
<i>M</i>	mean value
<i>n</i>	number of accepted data sets
<i>s</i>	standard deviation of an individual data set
<i>s_M</i>	standard deviation of laboratory means
<i>s_{rel}</i>	relative standard deviation
\bar{s}_i	square root of mean of variances of data sets under repeatability conditions
<i>M_i</i>	single result
I	ICP-OES (Tables 2 – 25)
I(R)	ICP-OES, revised value (Tables 2 – 25)
IMS	ICP-MS (Tables 2 – 25)
A	FAAS (Tables 2 – 25)
EA	ETAAS (Tables 2 – 25)
FE	flame emission spectrometry (Tables 2 – 25)
P	spectrophotometry (Tables 2 – 25)
-s	dissolution in acid (Tables 2 – 25)
-a	dissolution in base (Tables 2 – 25)

1. Introduction

In the metal-producing and metal-working industry mainly spark emission spectrometry (SOES) and X-ray fluorescence spectrometry (XRF) are used for reception inspection of raw materials, e.g. scrap, for quality control of end products and production control. These time-saving analytical techniques require suitable reference materials for calibration and recalibration. The certified reference material BAM-M323 is based on the aluminium alloy AlFe1, which has a lot of technical applications.

The CRM was produced in close cooperation with the working group „Aluminium“ of the Committee of Chemists of the Society of Metallurgists und Miners (GDMB). Since all the laboratories participating in this certification project are highly experienced with aluminium analysis and had already participated in earlier inter-laboratory comparisons, there was no preceding round robin for qualification necessary.

Certification was carried out on the basis of ISO 17034 [1] and the relevant ISO-Guides [2, 3].

2. Companies/laboratories involved

Manufacturing of the material:

- Constellium, Centre de Recherches de Voreppe, Voreppe, France

Test for homogeneity:

- Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin, Germany
- Constellium, Centre de Recherches de Voreppe, Voreppe, France

Participants in the certification inter-laboratory comparison:

AMAG Austria Metall AG, Ranshofen, Austria

Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin, Germany

Constellium, Centre de Recherches de Voreppe, Voreppe, France

Speira GmbH, R&D, Bonn, Germany

Hydro Aluminium Rolled Products GmbH, Hamburg, Germany

Łukasiewicz Research Network – Institute of Non-Ferrous Metals, Gliwice, Poland

revierlabor, Essen, Germany

TRIMET Aluminium SE, Essen, Germany

Statistical evaluation of the data:

- Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin, Germany

3. Candidate material

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The candidate material was produced by Constellium, Centre de Recherches de Voreppe, Voreppe, France. About 500 kg of an aluminium melt were doped with the desired elements. The melt was cast into six billets (A – F) with a length of 4450 mm each. 250 mm on both ends of each billet were discarded. The rods were cut into segments of 800 mm length. Between the segments 15-mm discs (A1, A2, A3, A5, A5, B1, B2, ..., F4, F5) were taken for homogeneity testing (see Fig. 1).

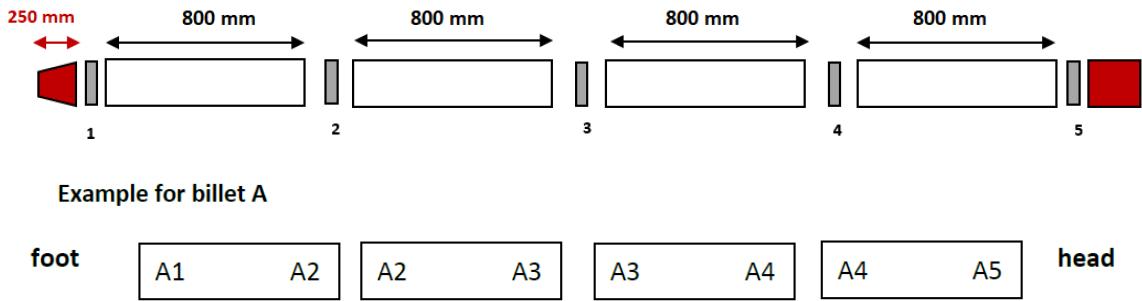


Fig. 1: Preparation of the rods cast (all figures in mm)

In total, 576 discs with a diameter of ca. 65 mm and 30 mm height were obtained.

4. Homogeneity testing

Possible reasons for an inhomogeneous distribution of elements in the raw material may be a change of the composition of the melt during the casting procedure because some elements may volatize or because of possible segregation during the solidification of the material. Since the raw material was produced by casting of a rod, concentration gradients can occur over the length of the rod (axial) as well as over the area of the rod (radial, see Fig. 2):

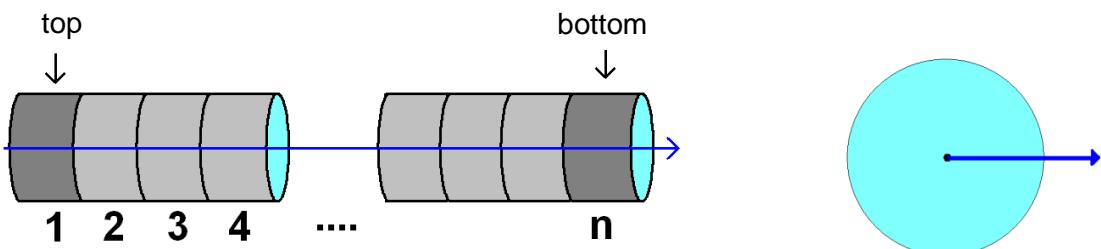


Fig. 2: Axial and radial composition gradient

Therefore, it is necessary to investigate the raw material for both axial and radial inhomogeneities. Radial homogeneity testing of the candidate material using spark emission spectrometry was performed at Constellium, Centre de Recherches de Voreppe on the discs taken from the rods as shown in Fig. 1. In total 30 discs were investigated (five sparks equidistant from the centre), this corresponding to ca. 5.5 % of the whole batch.

The estimate of analyte-specific inhomogeneity contribution u_{bb} to be included into the total uncertainty budget was calculated according to ISO Guide 35 [3] using Eq. (1) and Eq. (2):

$$s_{bb} = \sqrt{\frac{MS_{\text{among}} - MS_{\text{within}}}{n}} \quad (1)$$

$$u_{bb}^* = \sqrt{\frac{MS_{\text{within}}}{n}} \sqrt[4]{\frac{2}{N(n-1)}} \quad (2)$$

where:

MS_{among} mean of squared deviations between discs (from 1-way ANOVA, see Annex 1)

MS_{within} mean of squared deviations within one disc (from 1-way ANOVA)

n number of replicate measurements per disc

N number of discs selected for homogeneity study

s_{bb} signifies the between-discs standard deviation whereas u_{bb}^* denotes the maximum heterogeneity that can potentially be hidden by an insufficient repeatability of the applied measurement method (which has to be considered as the minimum uncertainty contribution). In any case the larger of the two values was used as $u_{bb}(1)$. Eq. (1) does not apply if MS_{within} is larger than MS_{among} .

For the elements Li and Na a decrease of the mass fraction over the length of the rods was observed. This is a result of the low boiling points of the two elements which result in losses from the melt during the melting process. The homogeneity test shows a more or less linear decrease of the two elements over the length of the rods. Therefore, the mass fractions of the two elements in the certificate are given as functions of the sample number which determines the position in the rod.

These functions are calculated based on the spark emission results from homogeneity test and wet chemical results from one laboratory which determined Li and Na on samples taken over the length of the rods (see Tables 18 and 19, Lab. 9/FE resp. Lab. 9/EA):

$$M_x = (N_x - 48) \cdot \frac{\Delta}{n} \cdot M \quad (3)$$

with

M_x : Mass fraction of Disc x

M : Mass fraction obtained from certification interlaboratory comparison

N_x : individual number of disc representing its position in the rod ($1 < N_x < 96$)

n : number of discs per rod ($n = 96$)

Δ : Mean difference of mass fractions over the length of the rods (calculated from the data of SOES and Lab. 9/EA)

$\Delta(\text{Li}) = 3.1835$

$\Delta(\text{Na}) = 4.5965$

In addition to the tests performed over the length of the rods three discs were tested for homogeneity over the area (possible segregation from the outer part to the centre). To perform this test SOES analysis was carried out in circles (outer circle: 8 sparks, mean circle: 8 sparks, inner circle: 8 sparks; centre: 3 sparks).

The analyte-specific within-disc uncertainty component $u_{bb}(2)$ was calculated in the same way as for the total batch. To calculate the necessary data an unbalanced ANOVA was carried out taking into account that the number of single measurements is different for the centre. The middle of the three values obtained as $u_{bb}(2)$ was used for the calculation of the total uncertainty.

Annexes 1 and 2 show the results of the homogeneity calculations.

5. Characterisation study

5.1 Analytical methods

Eight laboratories participated in the certification inter-laboratory comparison. All laboratories were highly experienced in the analysis of aluminium and aluminium alloys and participated successfully in former certification inter-laboratory comparisons. For some elements part of the laboratories used more than one analytical method reporting more than one data set.

The laboratories were asked to analyse six subsamples. They were free to choose any suitable analytical method. Table 1 shows the analytical methods used by the participating laboratories.

For all analytical methods where a calibration was necessary this calibration was performed using liquid standard solutions. All participating laboratories were asked to use only standard solutions prepared from pure metals or stoichiometric compounds or well checked commercial calibration solutions.

Table 1: Analytical procedures used by the participating laboratories

Lab-No.	Element	Sample mass	Sample pretreatment	Analytical method
1*	Si, Fe, Cu, Mn, Mg, Cr, Ga, Zn, Ti, Ni, V	0.5 g	Dissolution with NaOH	ICP-OES, commercial mono-element solution (Merck)
	B, Be, Bi, Ca, Cd, Co, Hg, Li, Na, Pb, Sb, Sn, Zr	0.5 g	Dissolution with HNO ₃ /HCl	ICP-OES, commercial mono-element solution (Merck)
2*	Si, Fe, Cu, Mg, Cr, V	0.5 g	Dissolution with NaOH	ICP-OES, calibration with pure metals or pure chemicals, matrix matching with pure Al (5N5)
	Mn, Zn, Ti, Be, Ca, Co, Ni	0.5 g	Dissolution with HNO ₃ /HF	ICP-OES, calibration with pure metals or chemicals, matrix matching with pure Al (5N5)
	B, Hg, Pb, Sn	0.5 g	Dissolution with HCl/HNO ₃ /HF	ICP-MS, calibration with pure metals or pure chemicals, matrix matching with pure Al (5N5)
	Ga, Bi, Cd, Li, Sb, Zr	0.5 g	Dissolution with HNO ₃ /HF	ICP-MS, commercial mono-element solution (Merck certipur), matrix matching with pure Al (5N5)
	Na	0.5 g	Dissolution with HCl/HNO ₃ /HF	ICP-OES, calibration with Na ₂ CO ₃ , matrix matching with pure Al (5N5)
	Si, Fe, Cu, Mn, Mg, Cr, Zn, Ti, Be, Bi, Cd, Co, Ni, Pb, Sb, Sn, V, Zr	0.1 g	Dissolution with NaOH	ICP-OES, commercial mono-element solution
3*	Si	0.5 g	Dissolution with NaOH	Spectrophotometry, commercial mono-element solution, matrix matching with pure Al (Merck, Ultrascientific)
	Fe	0.2 g	Dissolution with HNO ₃ /HCl	ICP-OES, commercial mono-element solutions, matrix matching with pure Al (Merck, Ultrascientific)
	Cu, Mn, Mg, Cr, Ga, Ti, Zn, Be, Bi, Ca, Cd, Co, Li, Na, Ni, Pb, Sb, Sn, V, Zr	1 g	Dissolution with HNO ₃ /HCl	ICP-OES, commercial mono-element solutions, matrix matching with pure Al (Merck, Ultrascientific)

*accredited acc. to ISO IEC 17025

Table 1 (cont.): Analytical procedures used by the participating laboratories

Lab-No.	Element	Sample mass	Sample pretreatment	Analytical method
5*	Si, Fe, Cu, Mn, Mg, Cr, Ga, Ti, Zn, Bi, Ca, Cd, Co, Li, Pb	0.5 g	Dissolution with NaOH	ICP-OES, commercial mono-element solutions (Merck)
	Ni, Sb, Sn, V	0.5 g	Dissolution with NaOH	ICP-OES, commercial mono-element solutions (Labkings)
	Be	0.5 g	Dissolution with NaOH	ICP-OES, commercial mono-element solutions (Inorganic Ventures)
6	Si, Fe, Cu, Mn, Mg, Cr, Ga, Zn, Ti, B, Be, Bi, Cd, Co, Li, Ni, Pb, Sn, V, Zr	0.5 g	Dissolution with NaOH	ICP-OES, calibration with pure metals or pure chemicals, matrix matching with pure Al
	Ca, Na, Sb	0.5 g	Dissolution with HCl	ICP-OES, calibration with pure metals or pure chemicals, matrix matching with pure Al
7*	Si, Fe, Cu, Mn, Mg, Cr, Ga, Zn, Ti, Be, Bi, Cd, Co, Hg, Li, Na, Ni, Pb, Sb, Sn, V, Zr	0.5 g	Dissolution with HCl/HNO ₃ /HF	ICP-OES, calibration with matrix matched standards, commercial multi-element standard solutions (Merck, Perkin Elmer)
	Cr, Ga, Zn, Ti, Be, Bi, Cd, Co, Li, Na, Ni, Pb, Sb, Sn, V, Zr	0.5 g	Dissolution with HNO ₃ /HF	ICP-MS, with matrix matched standards, commercial mono-element standard solutions (Merck, Perkin Elmer)
	Mg, Cr, Ga, Zn, Ti, Sn, V, Zr, Be, Bi, Cd, Co, Li, Ni, Pb, Sb, Sn, V, Zr	1 g	Dissolution with HCl/HNO ₃ /HF	ICP-MS, with matrix matched standards, commercial mono-element standard solutions (Merck, Perkin Elmer)
9*	Si, Mn, Zr, V	0.25 g	Dissolution with NaOH	Spectrophotometry, calibration with commercial mono-element solutions (Merck)
	Fe, Ti	0.5 g	Dissolution with HCl/H ₂ O ₂	Spectrophotometry, calibration with commercial mono-element solutions (Merck)
	Na	0.25 g	Dissolution with HCl/HNO ₃ /HF	ETAAS, calibration with commercial mono-element solution (Merck)
	Li	0.25 g	Dissolution with HCl/HNO ₃ /HF	Atomic emission spectrometry, calibration with commercial mono-element solution (Merck)
	Fe, Cu, Mn, Mg, Zn	1 g	Dissolution with HCl/H ₂ O ₂	FAAS, calibration with commercial mono-element solution (Merck)
	Cu, Mn, Mg, Cr, Ga, Zn, Ti, B, Be, Bi, Cd, Co, Ga, Li, Na, Ni, Pb, Sn, V, Zr	1 g	Dissolution with HCl/HNO ₃ , Addition of HF and mannite	ICP-OES, calibration with matrix matched standards, commercial mono-element solutions
	Si, Fe, Cu, Mn, Mg, Cr, Ti, Be, Bi, Cd, Co, Li	0.25 g	Dissolution with NaOH	ICP-OES, calibration with matrix matched standards, commercial mono-element solution
	Hg	0.5 g	Dissolution with HCl/HNO ₃ /HF	CVAAS, calibration with commercial mono-element solution (Merck)
	Hg	0.5 g	Dissolution with HCl/HNO ₃ /HF	AFS, calibration with commercial mono-element solution (Merck)

*accredited acc. to ISO IEC 17025

5.2 Analytical results and statistical evaluation

The analytical results of the inter-laboratory certification comparison are listed in Tables 2 to 25. These tables show the single results (M_i) of each laboratory, the respective laboratories' mean values (M), absolute and relative intra-laboratory standard deviation (s and s_{rel} , respectively), the standard deviation of laboratory means (s_M), and in addition the square root of mean of variances of data sets under repeatability conditions (\bar{s}_i) where n is the number of accepted data sets. The continuous line marks the certified value (mean of the laboratories' means), the broken lines mark the standard deviation, calculated from the laboratories' means.

In the related figures for each laboratory its mean value and single standard deviation is given. Outliers which have been excluded after consultation with the resp. laboratory are highlighted in yellow.

Table 2: Results for Si

Lab./Meth.	3/I-a	7/I-s_2	7/I-s_1	1/I-a	9/P	9/I-a	6/I-a	2/I-a	4/P	5/I-a_2	5/I-a_1		
M_i [%]	0.136	0.139	0.139	0.143	0.147	0.147	0.151	0.1501	0.151	0.157	0.159		n
	0.136	0.138	0.137	0.144	0.145	0.147	0.152	0.1498	0.152	0.156	0.157		11
	0.135	0.135	0.139	0.142	0.146	0.155	0.150	0.1499	0.152	0.158	0.159		
	0.135	0.131	0.139	0.144	0.146	0.147	0.151	0.1505	0.152	0.156	0.158		
	0.135	0.141	0.141	0.143	0.146	0.148	0.146	0.1510	0.151	0.157	0.158		
	0.136	0.138	0.137	0.148	0.146	0.152	0.150	0.1510	0.151	0.157	0.157		
M [%]	0.1355	0.1369	0.1388	0.1440	0.1461	0.1493	0.1501	0.1504	0.1515	0.1569	0.1579		0.1470
s [%]	0.0005	0.0033	0.0015	0.0022	0.0006	0.0035	0.0021	0.0005	0.0005	0.0009	0.0007	s_M [%]	0.0076
s_{rel}	0.00404	0.02436	0.01067	0.01501	0.00438	0.02311	0.01386	0.00359	0.00362	0.00603	0.00447	\bar{s}_i [%]	0.0018
													0.05167

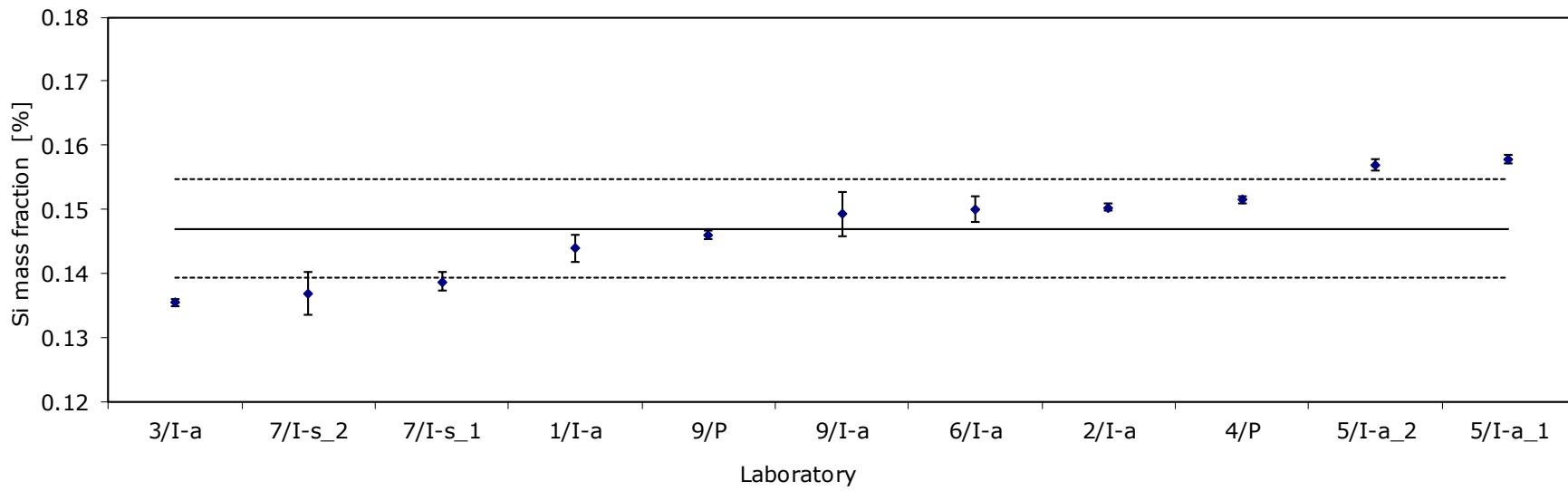


Table 3: Results for Fe

Lab./Meth.	5/I-a_2	1/I-a	9/I-a	2/I-a	4/I-s	7/I-s_1	9/A-s	5/I-a_1	3/I-a	9/P	6/I-s	7/I-s_2		
M_i [%]	0.985	1.005	1.002	0.9982	1.000	0.999	1.005	1.001	1.001	1.000	1.010	1.056		n
	0.992	0.998	1.003	0.9976	0.999	0.999	0.994	1.000	1.003	1.008	1.007	1.035		11
	0.996	0.991	1.005	0.9997	1.000	1.015	1.007	1.003	1.003	1.004	1.004	1.032		
	0.996	0.989	1.003	0.9945	1.000	0.995	0.998	1.005	1.004	1.004	1.007	1.031		
	0.996	0.992	0.976	0.9952	0.993	0.999	1.009	1.004	1.010	1.011	1.008	1.025		
	0.994	0.999	0.985	0.9948	0.996	1.001	0.998	1.003	1.002	1.012	1.008	0.946		
M [%]	0.993	0.995	0.996	0.997	0.998	1.001	1.001	1.003	1.004	1.006	1.007	1.021		1.000
s [%]	0.0043	0.0061	0.0121	0.0021	0.0029	0.0070	0.0057	0.0019	0.0032	0.0046	0.0022	0.0380	s_M [%]	0.0047
s_{rel}	0.00429	0.00612	0.01218	0.00214	0.00290	0.00698	0.00566	0.00192	0.00318	0.00458	0.00216	0.03727	s_i [%]	0.0055
														0.00466

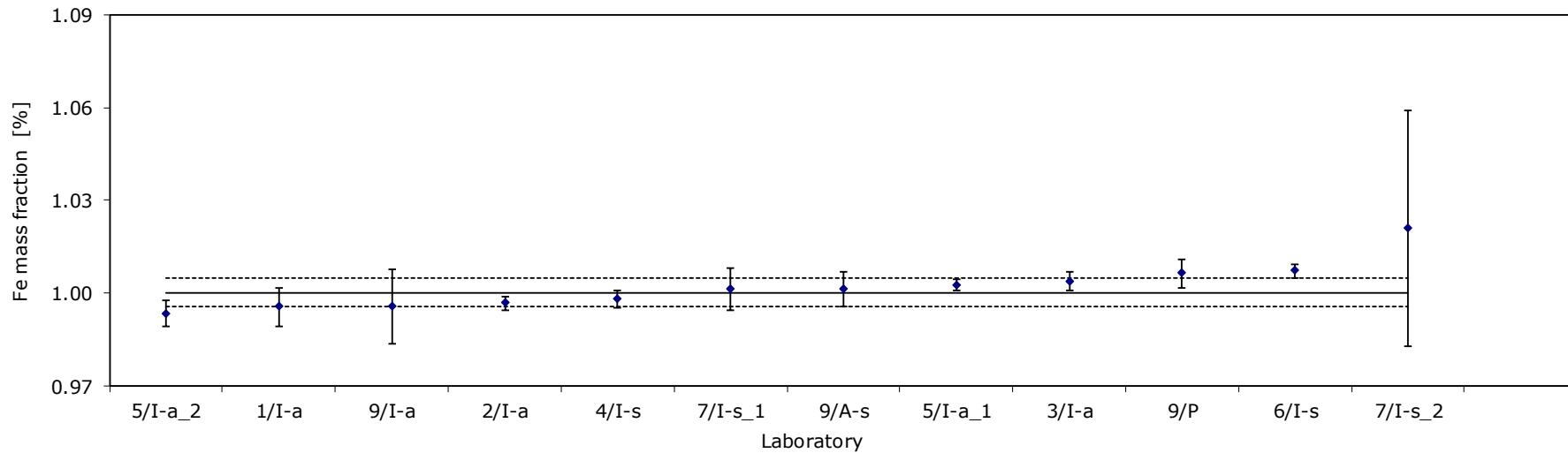


Table 4: Results for Cu

Lab./Meth	7/I-s_1	3/I-a	5/I-a_1	4/I-s	9/A-s	9/I-s	1/I-a	6/I-a	5/I-a_2	2/I-a	9/I-a	7/I-s_2		
M_i [%]	0.0167	0.017	0.0176	0.0182	0.0184	0.0191	0.0183	0.0185	0.0184	0.0186	0.019	0.0189		n
	0.0170	0.017	0.0176	0.0180	0.0179	0.0182	0.0186	0.0185	0.0186	0.0185	0.019	0.0190		12
	0.0175	0.017	0.0176	0.0179	0.0185	0.0175	0.0184	0.0183	0.0185	0.0185	0.018	0.0183		
	0.0168	0.017	0.0177	0.0183	0.0180	0.0188	0.0184	0.0184	0.0185	0.0186	0.018	0.0186		
	0.0169	0.018	0.0176	0.0182	0.0181	0.0177	0.0185	0.0187	0.0185	0.0185	0.019	0.0184		
	0.0172	0.017	0.0176	0.0183	0.0183	0.0185	0.0184	0.0185	0.0186	0.0185	0.0198			
M [%]	0.0170	0.0172	0.0176	0.0182	0.0182	0.0183	0.0184	0.0185	0.0185	0.0185	0.0186	0.0188		0.0182
s [%]	0.0003	0.0004	0.0000	0.0002	0.0002	0.0006	0.0001	0.0001	0.0001	0.0000	0.0005	0.0005	s_M [%]	0.0006
s_{rel}	0.01720	0.02378	0.00138	0.00905	0.01334	0.03329	0.00560	0.00725	0.00477	0.00215	0.02945	0.02902	s_i [%]	0.0003
														0.03193

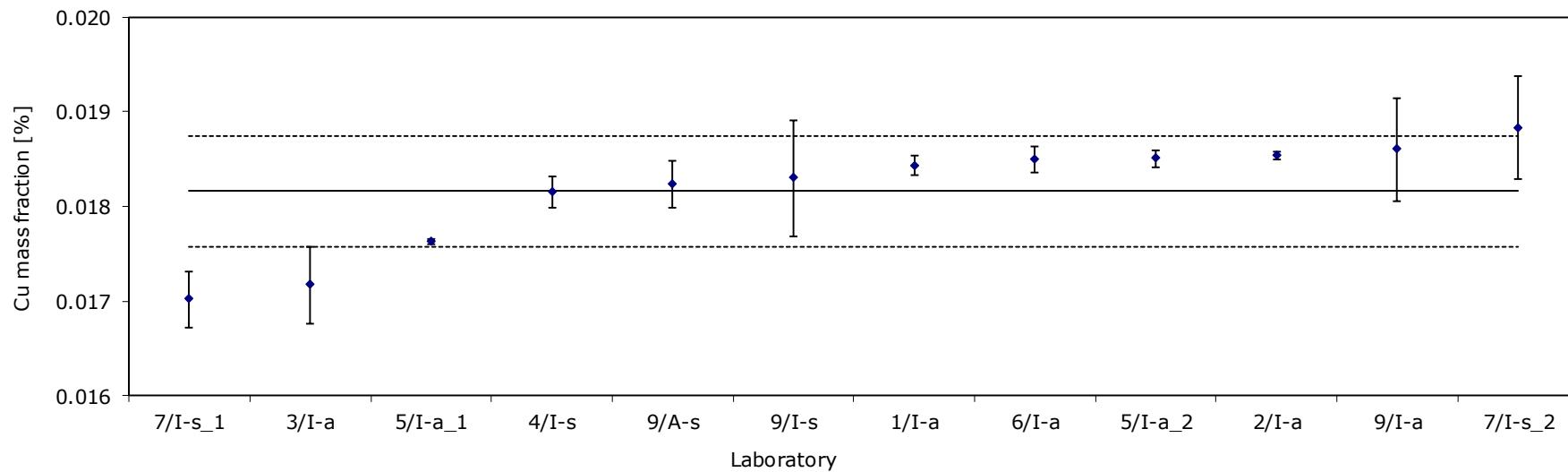


Table 5: Results for Mn

Lab./Meth.	7/I-s_1	9/A-s	9/I-s	9/I-a	6/I-a	9/P	5/I-a_1	7/I-s_2	2/I-s	1/I-a	4/I-s	3/I-a	5/I-a_2		
M_i [%]	0.0442	0.0464	0.0475	0.048	0.0466	0.0465	0.0469	0.0471	0.0475	0.0476	0.0484	0.049	0.0488		n
	0.0447	0.0462	0.0460	0.046	0.0465	0.0466	0.0469	0.0478	0.0476	0.0475	0.0475	0.049	0.0495		13
	0.0437	0.0456	0.0438	0.046	0.0462	0.0467	0.0471	0.0472	0.0476	0.0476	0.0483	0.049	0.0495		
	0.0447	0.0459	0.0466	0.046	0.0469	0.0467	0.0472	0.0471	0.0476	0.0481	0.0482	0.049	0.0494		
	0.0449	0.0456	0.0448	0.046	0.0464	0.0464	0.0471	0.0472	0.0477	0.0479	0.0471	0.049	0.0495		
	0.0451	0.0458	0.0461	0.046	0.0463	0.0468	0.0471	0.0475	0.0476	0.0480	0.0489	0.049	0.0494		
						0.0467	0.0464								
M [%]	0.0446	0.0458	0.0458	0.0463	0.0465	0.0466	0.0470	0.0473	0.0476	0.0478	0.0481	0.0490	0.0493		0.0471
s [%]	0.0005	0.0004	0.0013	0.0008	0.0003	0.0001	0.0001	0.0003	0.0000	0.0002	0.0007	0.0000	0.0003	s_M [%]	0.00134
s_{rel}	0.01151	0.00816	0.02848	0.01762	0.00553	0.00293	0.00239	0.00589	0.00084	0.00520	0.01359	0.00000	0.00529	\bar{s}_i [%]	0.00052
															0.02838

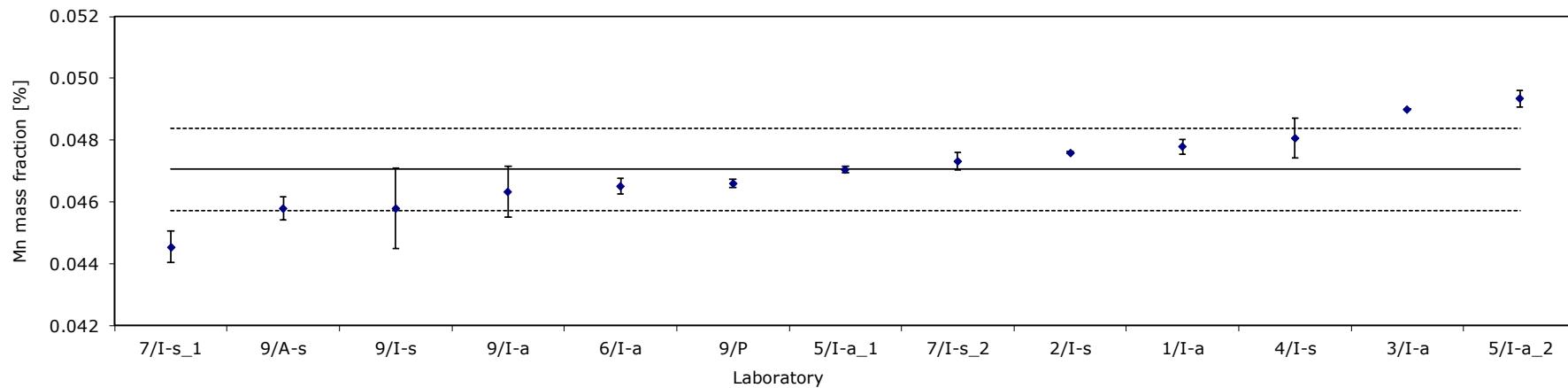


Table 6: Results for Mg

Lab./Meth	3/I-a	7/IMS	7/I-s_1	5/I-a_2	9/I-a	5/I-a_1	4/I-s	9/I-s	7/I-s_2	1/I-a	2/I-a	6/I-a	9/A-s			
M_i [%]	0.017	0.0190	0.0186	0.0186	0.021	0.0202	0.0204	0.0208	0.0207	0.0208	0.0212	0.0226	0.0252		n	
	0.017	0.0168	0.0188	0.0187	0.020	0.0202	0.0201	0.0205	0.0204	0.0208	0.0211	0.0239	0.0257		13	
	0.017	0.0156	0.0190	0.0189	0.020	0.0202	0.0205	0.0196	0.0208	0.0210	0.0212	0.0233	0.0258			
	0.017	0.0190	0.0185	0.0188	0.020	0.0203	0.0202	0.0206	0.0202	0.0210	0.0210	0.0235	0.0256			
	0.017	0.0174	0.0182	0.0189	0.020	0.0202	0.0200	0.0200	0.0206	0.0209	0.0210	0.0224	0.0256			
	0.017	0.0162	0.0184	0.0188	0.020	0.0202	0.0201	0.0207	0.0204	0.0212	0.0210	0.0225	0.0248			
M [%]	0.0170	0.0173	0.0186	0.0188	0.0202	0.0202	0.0202	0.0204	0.0205	0.0210	0.0211	0.0230	0.0253		0.0203	
s [%]	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	s_M [%]	0.0022		
s_{rel}	0.0000	0.0821	0.0154	0.0059	0.0202	0.0013	0.0096	0.0241	0.0109	0.0072	0.0037	0.0272	0.0168	\bar{s}_i [%]	0.0005	
															0.10927	

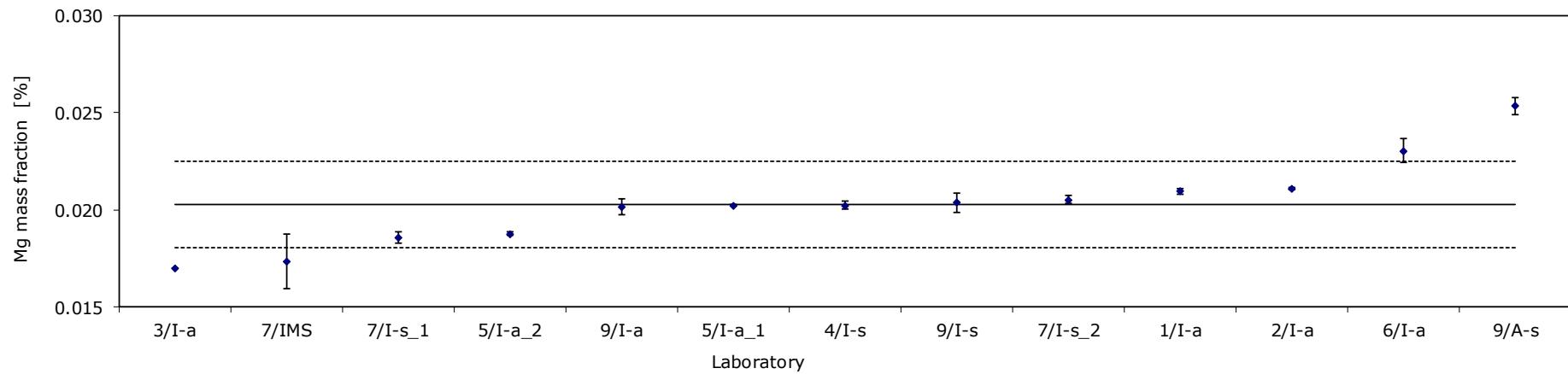


Table 7: Results for Cr

Lab./Meth	7/I-s_1(R)	6/I-a	9/I-s	9/I-a	4/I-s	2/I-s	1/I-a	5/I-a_2	3/I-a	5/I-a_1	7/I-s_2(R)		
M_i [%]	0.0099	0.0103	0.0106	0.012	0.0105	0.0106	0.0106	0.0109	0.011	0.0111	0.0105		n
	0.0098	0.0103	0.0104	0.010	0.0104	0.0106	0.0106	0.0109	0.011	0.0111	0.0105		11
	0.0095	0.0103	0.0100	0.011	0.0105	0.0106	0.0106	0.0110	0.011	0.0111	0.0114		
	0.0097	0.0103	0.0105	0.010	0.0105	0.0106	0.0107	0.0110	0.011	0.0111	0.0114		
	0.0096	0.0103	0.0102	0.010	0.0105	0.0105	0.0106	0.0110	0.011	0.0111	0.0116		
	0.0096	0.0103	0.0111	0.010	0.0106	0.0105	0.0106	0.0109	0.011	0.0111	0.0114		
M [%]	0.0097	0.0103	0.0105	0.0105	0.0105	0.0105	0.0106	0.0109	0.0110	0.0111	0.0111	0.0106	
s [%]	0.0001	0.0000	0.0004	0.0008	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0005	s_M [%]	0.0004
s_{rel}	0.01520	0.00310	0.03736	0.07968	0.00602	0.00485	0.00385	0.00368	0.00000	0.00261	0.04461	s_1 [%]	0.0003
												s_{rel}	0.03980

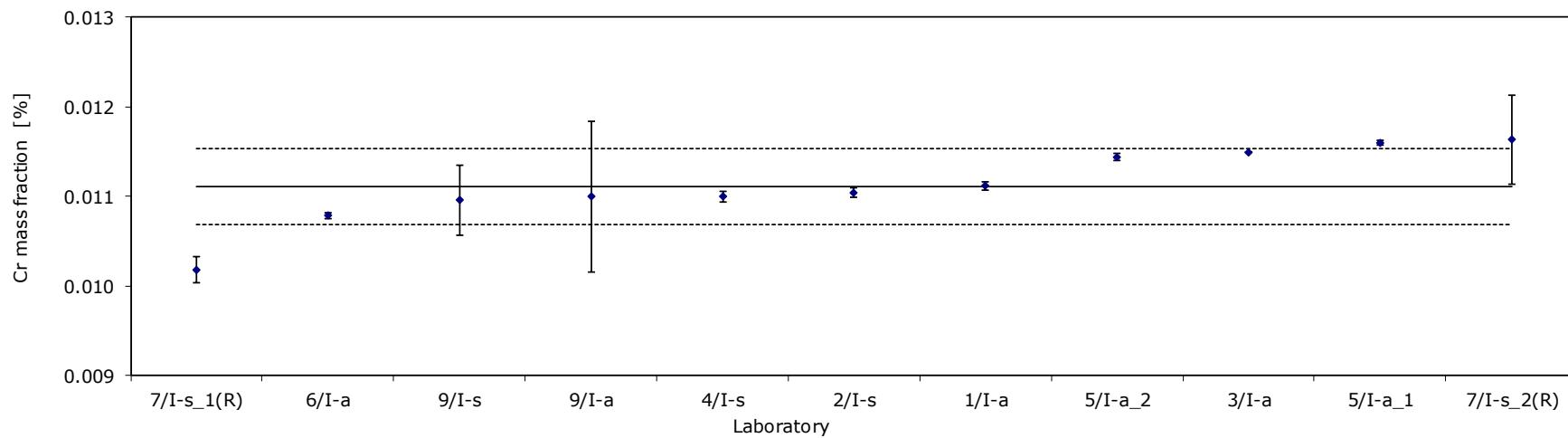


Table 8: Results for Ga

Lab./Meth.	7/I-s_1	7/IMS_1	9/I-s	7/IMS_2	5/I-a_1	7/I-s_2	1/I-a	4/I-s	2/IMS-s	6/I-s	5/I-a_2		
M_i [%]	0.0133	0.0131	0.0141	0.0140	0.0139	0.0147	0.0144	0.0146	0.0144	0.0147	0.0147		n
	0.0135	0.0138	0.0138	0.0138	0.0144		0.0145	0.0142	0.0145	0.0148	0.0148		11
	0.0136	0.0129	0.0132	0.0135	0.0139	0.0142	0.0143	0.0145	0.0145	0.0146	0.0148		
	0.0132	0.0133	0.0139	0.0142	0.0139	0.0142	0.0144	0.0145	0.0144	0.0145	0.0148		
	0.0131	0.0143	0.0135	0.0137	0.0139	0.0138	0.0145	0.0145	0.0146	0.0148	0.0147		
	0.0132	0.0142	0.0137	0.0134	0.0138	0.0148	0.0144	0.0144	0.0144	0.0146	0.0147		
M [%]	0.0133	0.0136	0.0137	0.0138	0.0139	0.0144	0.0144	0.0145	0.0145	0.0147	0.0148		0.0141
s [%]	0.0002	0.0006	0.0003	0.0003	0.0001	0.0004	0.0001	0.0001	0.0001	0.0000	s_M [%]	0.0005	
s_{rel}	0.01457	0.04313	0.02363	0.02187	0.00362	0.02560	0.00522	0.00954	0.00625	0.00790	0.00206	s_i [%]	0.0003
													0.03445

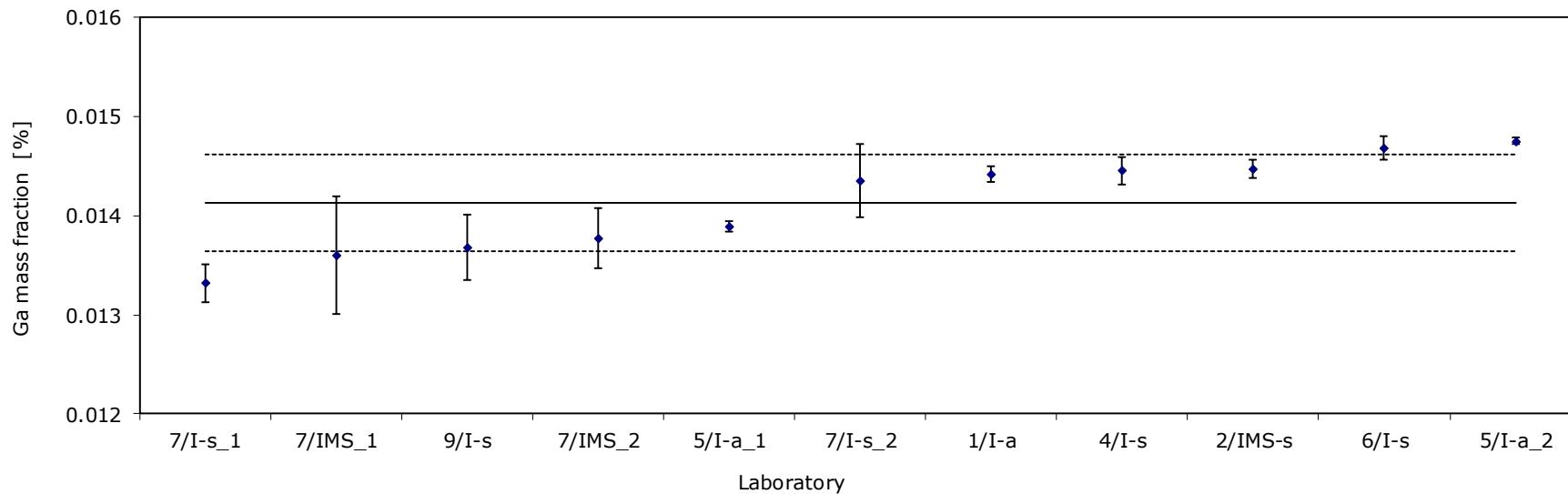


Table 9: Results for Zn

Lab./Meth	3/I-a	5/I-a_1	7/I-s_2	7/I-s_1	7/IMS_1	9/I-a	9/A-s	7/IMS_2	1/I-a	2/I-s	9/I-s	5/I-a_2	4/I-s	6/I-s		
M_i [%]	0.027	0.0275	0.0296	0.0274	0.0277	0.0291	0.0293	0.0284	0.0288	0.0291	0.0302	0.0289	0.0290	0.0306		
	0.027	0.0276	0.0271	0.0280	0.0289	0.0284	0.0283	0.0288	0.0286	0.0290	0.0293	0.0289	0.0297	0.0305		n
	0.027	0.0275	0.0273	0.0283	0.0278	0.0283	0.0284	0.0284	0.0287	0.0289	0.0277	0.0294	0.0294	0.0307		14
	0.027	0.0277	0.0281	0.0283	0.0282	0.0286	0.0286	0.0281	0.0289	0.0291	0.0296	0.0291	0.0294	0.0305		
	0.027	0.0275	0.0270	0.0279	0.0278	0.0281	0.0279	0.0293	0.0286	0.0290	0.0283	0.0292	0.0295	0.0305		
	0.028	0.0274	0.0276	0.0281	0.0282	0.0280	0.0285	0.0288	0.0290	0.0291	0.0293	0.0296	0.0292	0.0303		
M [%]	0.0272	0.0275	0.0278	0.0280	0.0281	0.0284	0.0285	0.0286	0.0288	0.0290	0.0291	0.0292	0.0294	0.0305		0.0286
s [%]	0.0004	0.0001	0.0010	0.0003	0.0004	0.0004	0.0005	0.0004	0.0002	0.0001	0.0009	0.0003	0.0002	0.0001	s_M [%]	0.0009
s_{rel}	0.01503	0.00381	0.03508	0.01195	0.01592	0.01397	0.01598	0.01476	0.00568	0.00232	0.03145	0.00920	0.00825	0.00398	\bar{s}_i [%]	0.0005
																0.02988

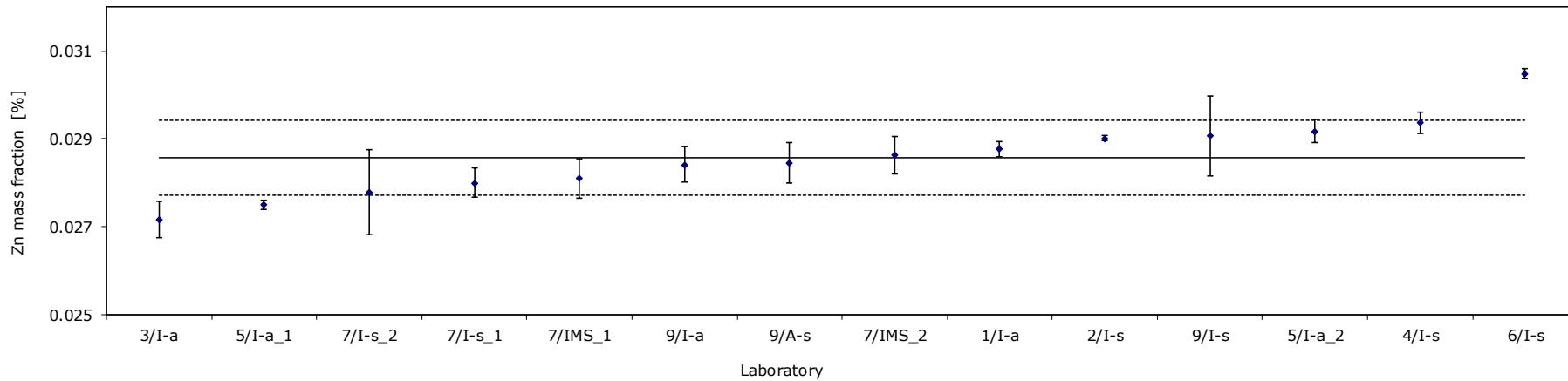


Table 10: Results for Ti

Lab./Meth.	9/I-a	7/IMS_1	2/I-s	1/I-a	4/I-s	6/I-s	9/I-s	5/I-a_1	5/I-a_2	7/I-s_2	3/I-a	7/I-s_1(R)	9/P		
M_i [%]	0.0175	0.0176	0.0186	0.0184	0.0189	0.0188	0.0194	0.0191	0.0192	0.0188	0.021	0.0198	0.0206		n
	0.0175	0.0178	0.0186	0.0185	0.0189	0.0188	0.0189	0.0192	0.0193	0.0194	0.019	0.0205	0.0192		13
	0.0174	0.0166	0.0186	0.0185	0.0188	0.0188	0.0189	0.0191	0.0192	0.0193	0.020	0.0197	0.0201		
	0.0173	0.0171	0.0184	0.0187	0.0189	0.0189	0.0192	0.0192	0.0193	0.0191	0.019	0.0192	0.0195		
	0.0173	0.0176	0.0183	0.0188	0.0188	0.0191	0.0185	0.0192	0.0193	0.0196	0.019	0.0204	0.0205		
	0.0174	0.0177	0.0185	0.0185	0.0189	0.0190	0.0198	0.0192	0.0193	0.0199	0.019	0.0196	0.0200		
M [%]	0.0174	0.0174	0.0185	0.0186	0.0189	0.0189	0.0190	0.0192	0.0193	0.0194	0.0195	0.0199	0.0200		0.0189
s [%]	0.00009	0.00046	0.00010	0.00015	0.00005	0.00010	0.00062	0.00004	0.00007	0.00039	0.00084	0.00050	0.00055	s_M [%]	0.0008
s_{rel}	0.00514	0.02646	0.00539	0.00811	0.00274	0.00547	0.03254	0.00193	0.00338	0.02036	0.04291	0.02500	0.02735	\bar{s}_i [%]	0.0004
															0.04235

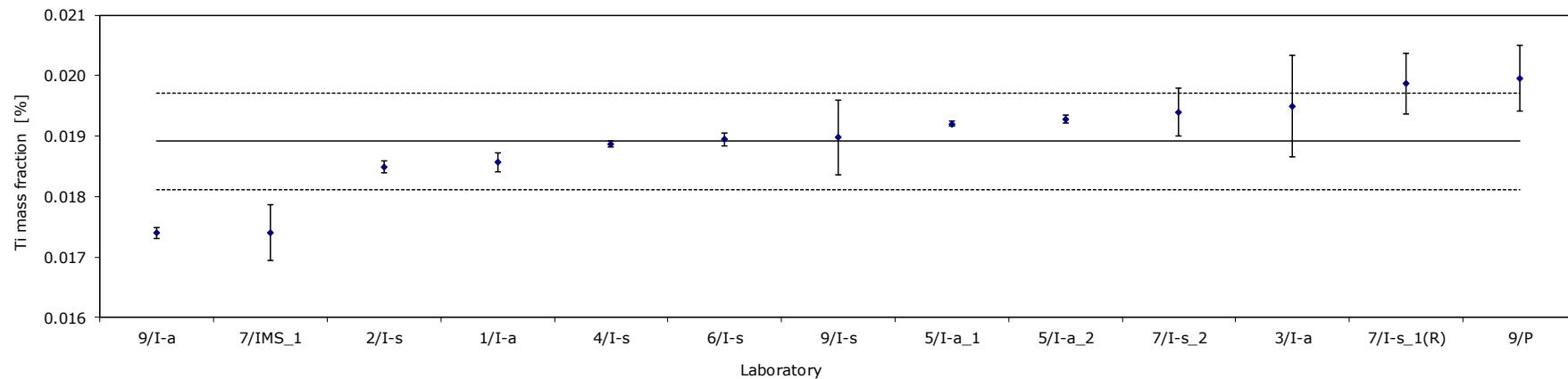


Table 11: Results for B

Lab./Meth.	9/I-s	1/I-s	6/I-s	2/IMS-s		
M_i [mg/kg]	2.2	2.1	2.67	3.27		
	2.1	2.1	2.72	3.22		
	1.9	2.0	2.56	3.33		
	2.2	2.0	2.72	3.17		
	2.1	2.0	2.55	3.19		
	2.2	2.8	2.89	3.19		
					<i>n</i>	4
M [mg/kg]	2.12	2.15	2.69	3.23		2.55
s [mg/kg]	0.117	0.311	0.122	0.059	s_M [mg/kg]	0.52
s_{rel}	0.055	0.144	0.046	0.018	s_i [mg/kg]	0.18
						0.21

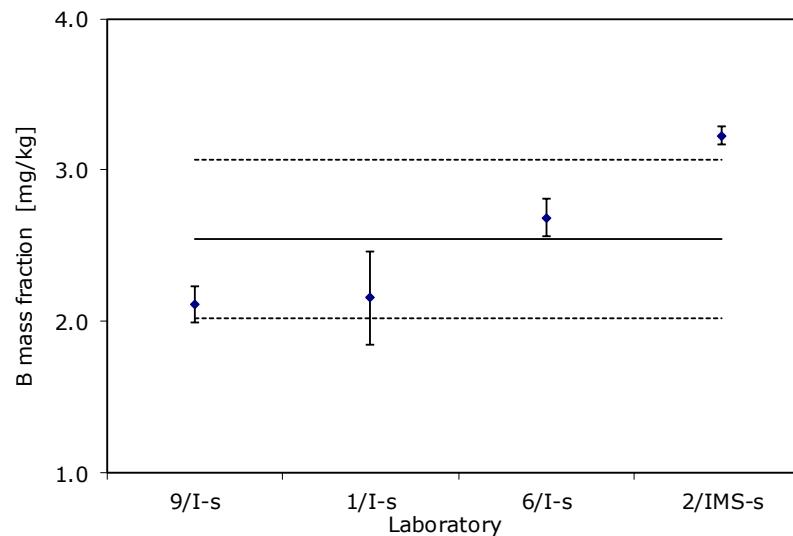


Table 12: Results for Be

Lab./Meth.	1/I-s	5/I-a_1	7/IMS_2	6/I-a	9/I-s	9/I-a	5/I-a_2	2/I-s	4/I-s	7/I-s_2	3/I-a	7/IMS_1		
M_i [mg/kg]	4.6	4.85	4.9	5.03	5.47	5.5	5.42	5.51	5.7	6.0	6.0	5.3		n
	4.6	4.87	4.9	5.07	5.35	5.5	5.45	5.53	5.7	6.0	6.0	6.0		12
	4.5	4.88	4.7	5.02	5.12	5.5	5.49	5.52	5.6	5.0	5.0	5.8		
	4.4	4.89	5.1	5.04	5.38	5.4	5.46	5.52	5.6	5.0	6.0	5.9		
	4.5	4.87	5.0	5.02	5.22	5.4	5.47	5.53	5.5	6.0	5.0	5.6		
	4.5	4.86	4.7	5.02	5.48	5.4	5.46	5.53	5.8	6.0	6.0	5.9		
M [mg/kg]	4.52	4.87	4.88	5.03	5.34	5.46	5.46	5.52	5.65	5.67	5.67	5.75		5.32
s [mg/kg]	0.07	0.01	0.16	0.02	0.14	0.05	0.02	0.01	0.10	0.52	0.52	0.26	s_M [mg/kg]	0.40
s_{rel}	0.016	0.003	0.033	0.004	0.027	0.009	0.004	0.002	0.019	0.091	0.091	0.045	\bar{s}_i [mg/kg]	0.24
														0.074

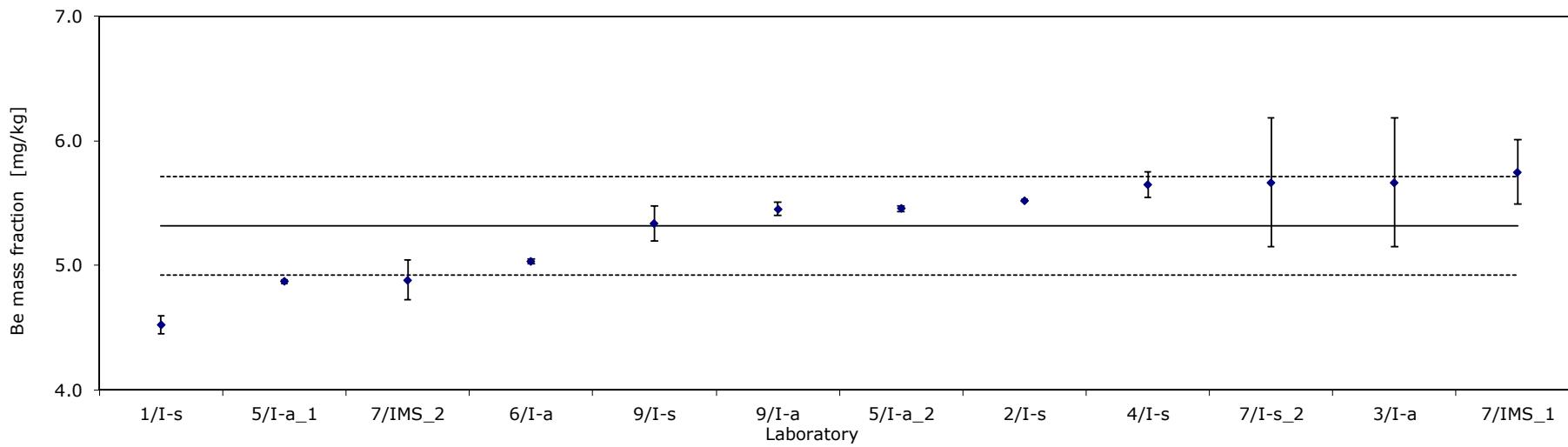


Table 13: Results for Bi

Lab./Meth.	5/I-a_2	7/I-s_2	5/I-a_1	7/I-s_1	2/IMS-s	1/I-s	7/IMS_2	4/I-s	9/I-s	6/I-a	9/I-a	7/IMS_1		
M_i [mg/kg]	11.8	14.0	13.6	14.7	15.1	15.8	15.4	15.4	16.9	16.1	17.0	17.8		n
	12.0	12.0	14.1	14.6	14.9	15.5	15.0	15.1	15.9	16.1	16.6	18.1		12
	12.3	12.0	14.2	14.0	14.9	14.9	14.7	15.6	15.5	17.1	16.4	17.2		
	14.5	13.0	13.5	13.7	14.9	15.4	15.5	15.3	16.4	15.4	18.9	17.5		
	12.8	16.0	13.4	13.4	14.8	14.4	14.,7	15.2	13.6	16.4	16.6	17.8		
	13.6	12.0	12.3	14.9	14.7	13.8	14.7	15.6	15.1	15.5	15.7	18.3		
M [mg/kg]	12.8	13.2	13.5	14.2	14.9	14.9	15.1	15.4	15.6	16.1	16.9	17.8		15.0
s [mg/kg]	1.03	1.60	0.66	0.62	0.12	0.74	0.38	0.21	1.14	0.61	1.10	0.40	s_M [mg/kg]	1.47
s_{rel}	0.080	0.122	0.049	0.043	0.008	0.049	0.025	0.013	0.073	0.038	0.065	0.022	\bar{s}_i [mg/kg]	0.83
													s [mg/kg]	0.098

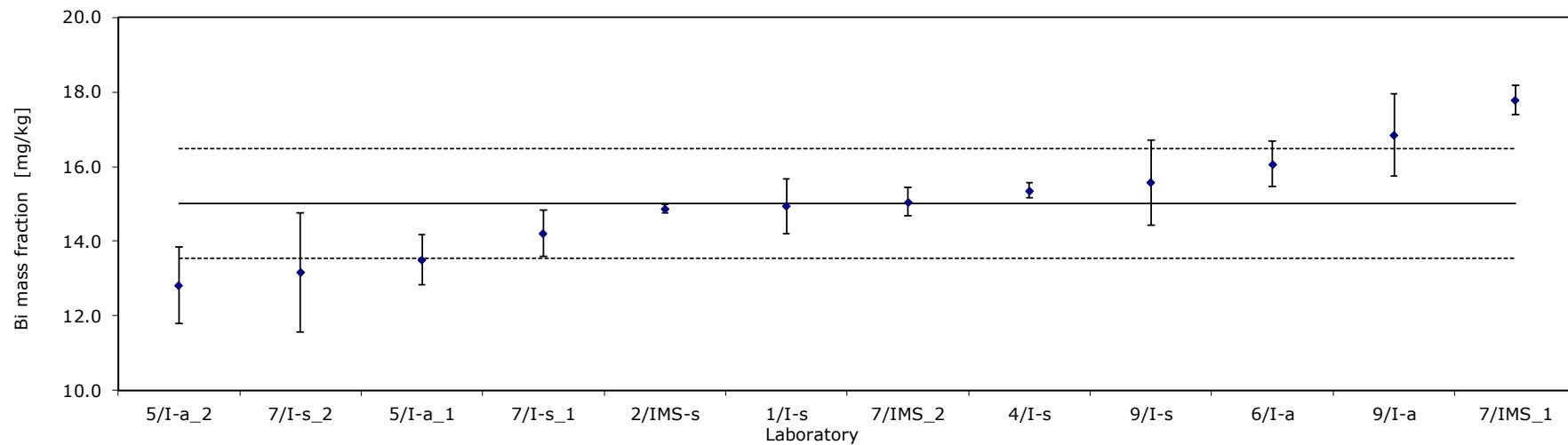


Table 14: Results for Ca

Lab./Meth.	4/I-s	7/I-s_1	2/I-s	6/I-s	1/I-s		
M_i [mg/kg]	14.6 14.6 14.5 13.7 13.1 13.6	15.14 13.91 15.18 14.86 14.26 15.47	17.5 17.5 17.1 17.0 17.1 16.8	17.9 17.7 17.7 18.4 19.2 19.6	18.9 19.5 19.0 18.1 18.9 18.6		n 5
M [mg/kg]	14.0	14.8	17.2	18.4	18.8		16.6
s [mg/kg]	0.64	0.60	0.28	0.82	0.47	s_M [mg/kg] \bar{s}_i [mg/kg]	2.14 0.59 0.129
s_{rel}	0.045	0.040	0.016	0.045	0.025		

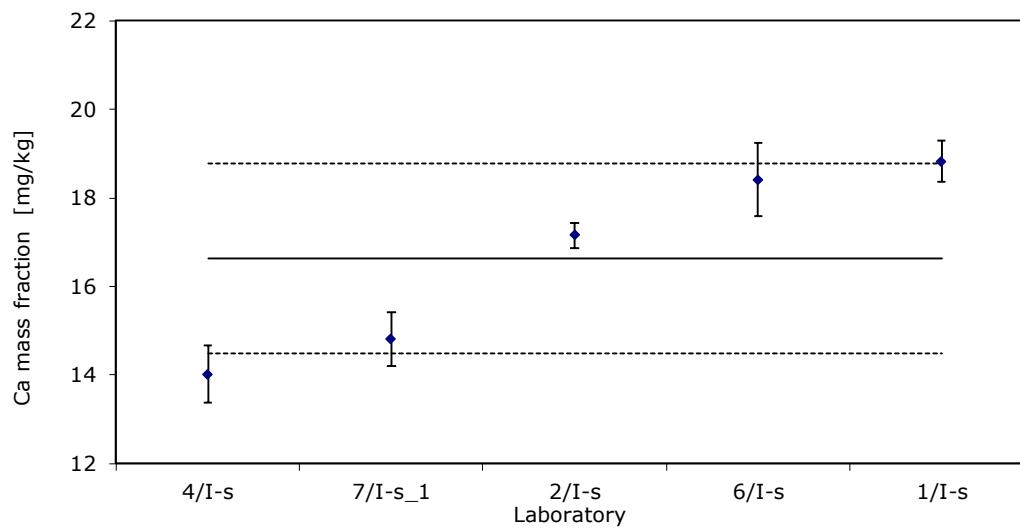


Table 15: Results for Cd

Lab./Meth.	7/I-s_1	9/I-a	4/I-s	7/I-s_2	7/IMS_1	7/IMS_2	9/I-s	2/IMS-s	1/I-s	6/I-s	5/I-a_2	5/I-a_1(R)	3/I-a		
M_i [mg/kg]	18.5	18.8	19.8	20.0	19.5	20.2	21.1	20.6	20.9	21.6	20.9	22.4	25		n
	18.7	18.9	19.9	20.0	20.3	20.5	20.3	20.7	21.2	20.8	21.2	22.3	25		12
	19.4	18.5	19.5	19.0	20.0	20.1	19.5	20.9	20.6	20.9	21.2	22.3	25		
	17.8	18.5	19.1	20.0	19.6	20.0	20.6	20.5	20.2	20.6	21.1	22.5	25		
	18.0	18.6	19.9	20.0	19.6	19.9	19.7	20.3	20.4	21.1	21.1	22.4	25		
	18.6	18.8	19.6	20.0	20.1	20.2	20.3	20.4	20.2	20.9	21.1	22.4	26		
M [mg/kg]	18.5	18.7	19.6	19.8	19.9	20.2	20.3	20.6	20.6	21.0	21.1	22.4	25.2		20.2
s [mg/kg]	0.55	0.17	0.31	0.41	0.33	0.21	0.59	0.20	0.40	0.32	0.11	0.09	0.41	s_M [mg/kg]	1.05
s_{rel}	0.0296	0.0093	0.0157	0.0206	0.0165	0.0103	0.0294	0.0098	0.0192	0.0153	0.0050	0.0042	0.0162	\bar{s}_i [mg/kg]	0.34
														s_{rel}	0.0519

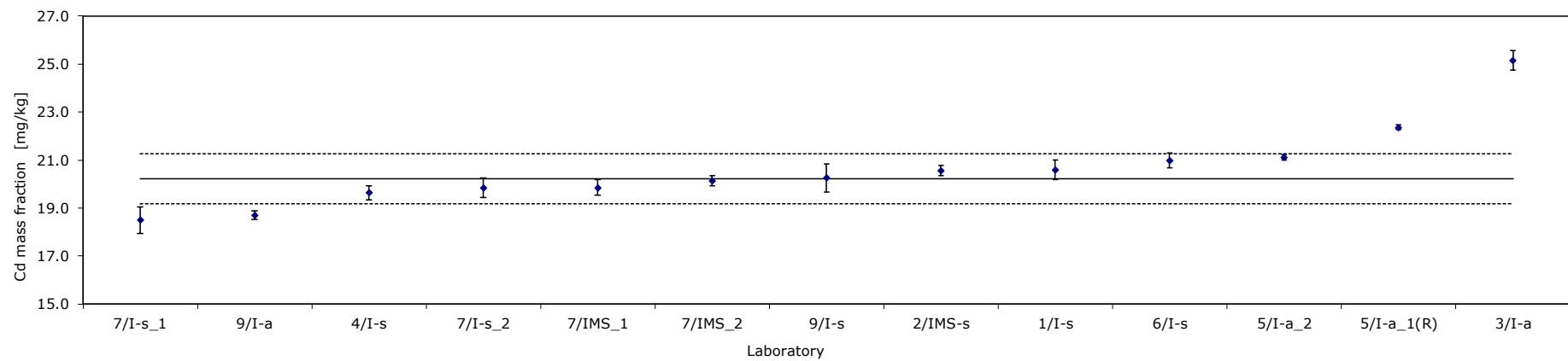


Table 16: Results for Co

Lab./Meth.	9/I-a	5/I-a_2	7/IMS_2	7/IMS_1	5/I-a_1	4/I-s	9/I-s	6/I-s	2/I-s	7/I-s_2	1/I-s	7/I-s_1	3/I-a		
M_i [mg/kg]	17.9	19.4	20.6	19.8	20.1	21.0	22.2	21.7	22.1	22.0	23.1	23.0	25		n
	18.1	19.8	19.5	20.2	20.1	20.9	21.7	21.4	22.3	22.0	23.3	23.6	25		13
	18.0	19.4	18.8	19.0	20.1	21.2	20.7	22.0	22.0	22.0	22.7	25.0	24		
	17.5	19.7	20.9	19.4	20.2	20.8	21.9	21.9	22.1	22.0	22.4	23.7	25		
	18.1	19.8	19.6	20.4	20.2	20.9	21.2	21.7	22.1	22.0	22.5	22.7	24		
	18.0	19.4	18.9	20.9	20.2	20.5	22.0	21.9	22.1	23.0	22.2	23.3	24		
M [mg/kg]	17.9	19.6	19.7	20.0	20.1	20.9	21.6	21.8	22.1	22.2	22.7	23.6	24.5		21.3
s [mg/kg]	0.22	0.20	0.87	0.69	0.06	0.23	0.55	0.19	0.08	0.41	0.45	0.81	0.55	s_M [mg/kg]	1.81
s_{rel}	0.0120	0.0100	0.0439	0.0347	0.0029	0.0111	0.0253	0.0090	0.0035	0.0184	0.0197	0.0345	0.0224	\bar{s}_i [mg/kg]	0.48
															0.0848

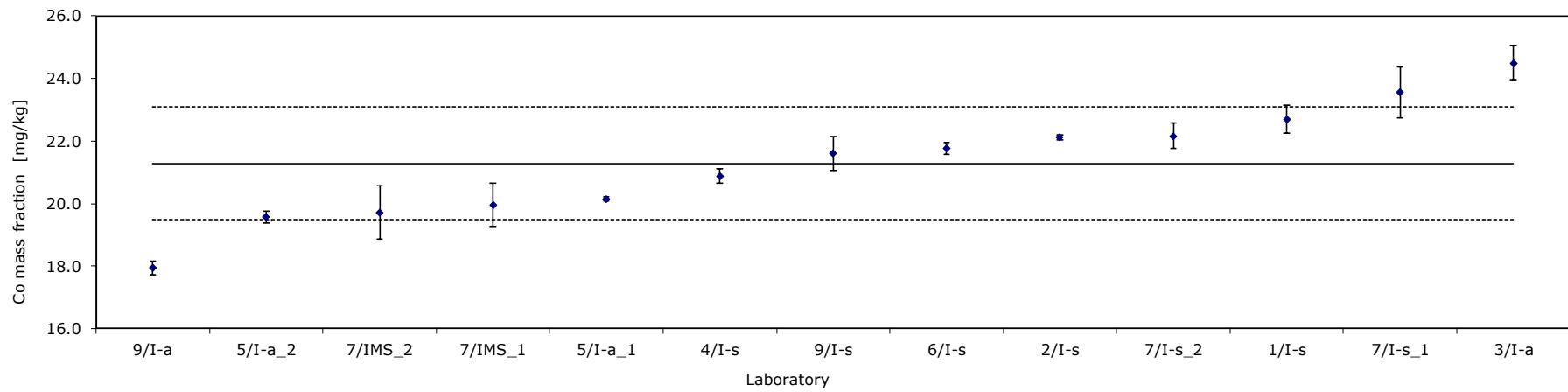


Table 17: Results for Hg

Lab./Meth.	2/IMS-s	6/I-a	1/I-s	9/AFS	7/I-s_1	9/CVAAS		
M_i [mg/kg]	18.4 17.1 18.1 18.0 18.0 18.1	19.81 21.76 19.86 18.09 19.87 19.26	20.2 20.4 20.3 19.3 19.7 19.1	20.39 19.97 20.59 20.56 20.01 20.3	18.6 22.1 21.6 23.9 18.4 20.3	21.1 21.1 21.0 21.3 20.6		n 6
M [mg/kg]	17.9	19.8	19.8	20.3	20.8	21.0		19.9
s [mg/kg]	0.425	1.190	0.539	0.297	2.138	0.258	s_M [mg/kg] s_i [mg/kg]	1.10 1.05 0.055
s_{rel}	0.024	0.060	0.027	0.015	0.103	0.012		

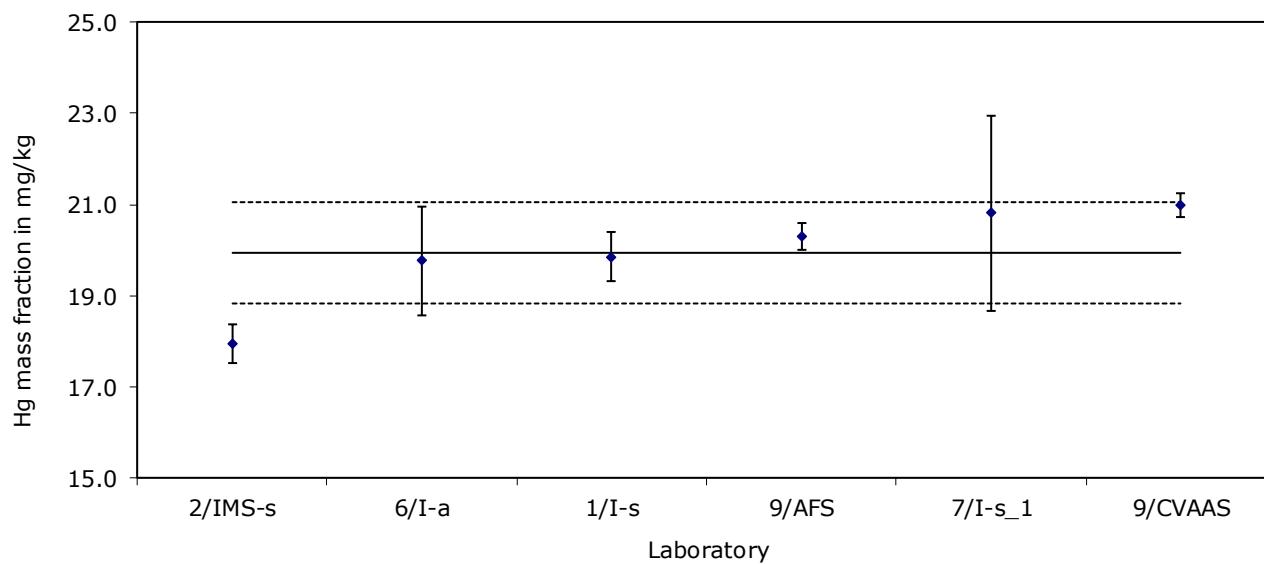


Table 18: Results for Li

Lab./Meth.	9/FE(B1)	9/FE(D2)	9/FE(A3)	9/FE(C4)	9/FE(E5)		4/I-s	7/IMS_2	9/I-a	7/IMS_1	5/I-a_2	9/FE	9/I-s	5/I-a_1	7/I-s_1	6/I-a	2/IMS-s	1/I-s		
M_i [mg/kg]	6.96	6.14	5.77	5.78	3.91		4.2	5.0	4.8	5.1	5.4	7.0	6.2	6.8	6.7	7.3	7.2	8.2		n
M [mg/kg]	7.0	6.1	5.7	5.8	3.9		4.2	4.7	4.7	5.3	5.5	5.7	6.0	6.8	6.7	7.3	7.2	8.1	5.99	
s [mg/kg]	0.03	0.02	0.02	0.02	0.04		0.06	0.39	0.13	0.31	0.07	1.12	0.17	0.07	0.39	0.20	0.08	0.13	s_M [mg/kg]	1.19
s_{rel}	0.004	0.004	0.003	0.003	0.011		0.015	0.085	0.028	0.060	0.013	0.196	0.028	0.010	0.058	0.029	0.012	0.016	\bar{s}_i [mg/kg]	0.39
																			s_M [mg/kg]	0.20

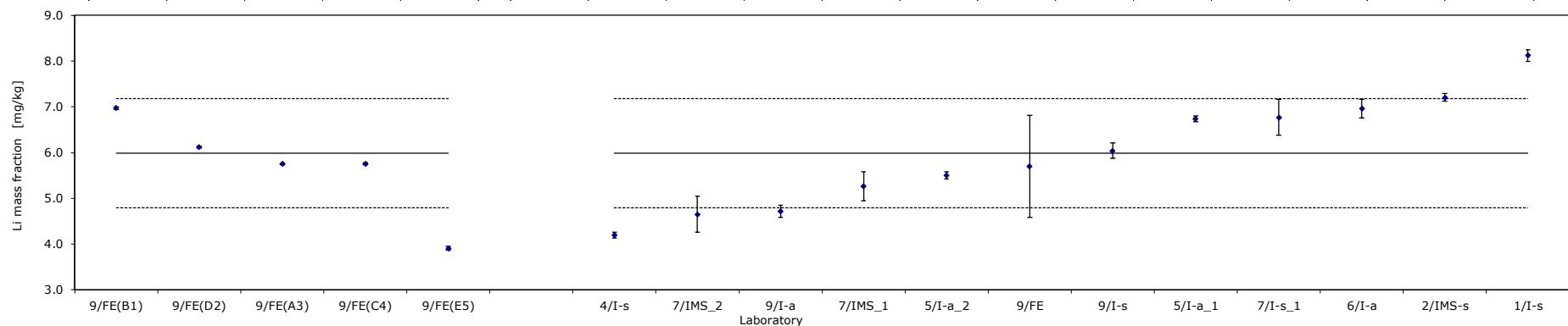


Table 19: Results for Na

Lab./Meth.	9/EA(B1)	9/EA(D2)	9/EA(A3)	9/EA(C4)	9/EA(E5)		4/I-s	9/I-s	9/EA	7/I-s_1	2/I-s	1/I-s		
M_i [mg/kg]	9.88 10.70 10.15 12.24	8.55 8.94 8.88 9.15	8.55 8.52 8.39 8.66	8.07 8.53 8.33 8.37	5.76 5.61 5.79 5.70		6.6 7.0 6.4 6.9 5.7 6.0	7.2 6.4 6.1 6.5 8.0 9.1	10.7 8.9 8.5 8.3 5.7	9.7 10.4 9.8 10.3 10.0 9.5	9.9 9.8 10.3 10.3 10.4 10.3	10.6 10.8 10.4 10.3 10.4 10.5		n 6
M [mg/kg]	10.7	8.9	8.5	8.3	5.7		6.4	7.2	8.4	9.9	10.1	10.5		8.8
s [mg/kg]	1.06	0.25	0.11	0.19	0.08		0.51	1.14	1.80	0.36	0.25	0.18	s_M [mg/kg]	1.69
s_{rel}	0.098	0.028	0.013	0.023	0.014		0.079	0.158	0.213	0.036	0.024	0.017	\bar{s}_i [mg/kg]	0.91
														0.192

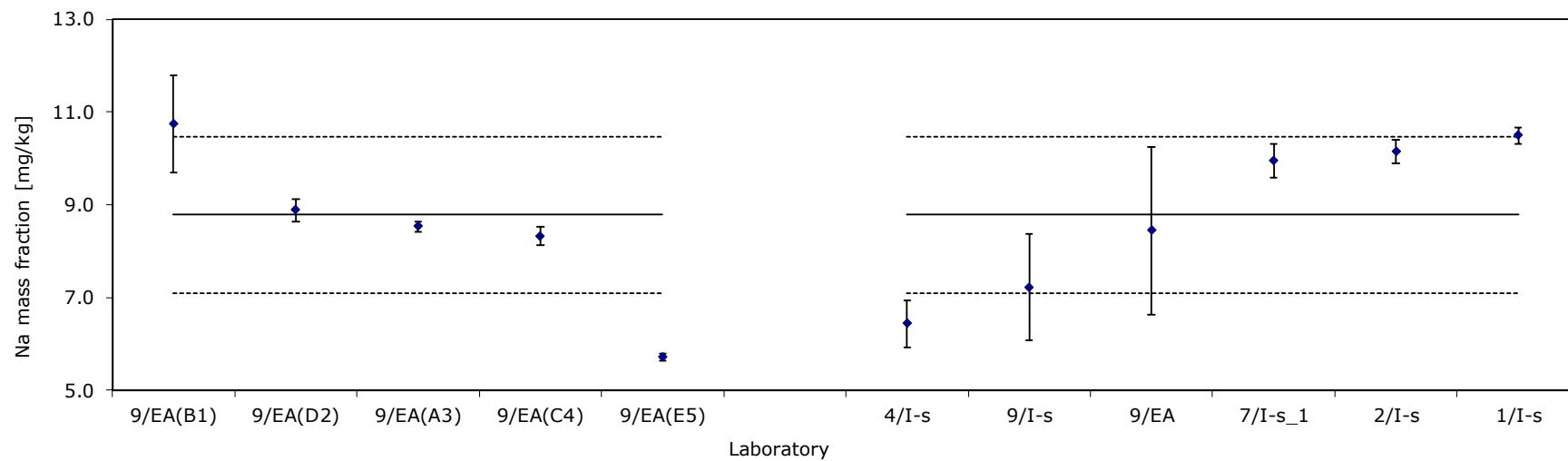


Table 20: Results for Ni

Lab./Meth.	4/I-s	1/I-a	7/I-s_1	3/I-a	9/I-s	7/I-s_2	2/I-s	6/I-a	5/I-a_2	7/IMS_1	7/IMS_2	5/I-a_1		
M_i [mg/kg]	87.6	87.0	89.2	87.0	92.5	90	91.6	91.9	93.7	94.9	98.0	99.2		n
	88.6	88.8	89.4	88.0	90.1	88	91.9	93.0	94.2	99.0	99.4	98.2		12
	88.1	87.6	91.2	89.0	86.2	91	91.7	91.3	93.7	95.0	98.3	98.9		
	87.9	88.3	88.0	87.0	90.9	93	91.3	92.1	94.1	97.5	97.3	99.3		
	86.3	88.3	88.9	88.0	87.4	93	91.4	91.2	94.9	93.2	100.1	99.4		
	87.4	88.0	87.3	99.0	94.1	94	91.3	91.2	94.6	97.4	100.2	99.1		
M [mg/kg]	87.7	88.0	89.0	89.7	90.2	91.5	91.5	91.8	94.2	96.2	98.9	99.0		92.3
s [mg/kg]	0.78	0.65	1.32	4.63	3.00	2.26	0.25	0.72	0.49	2.15	1.19	0.42	s_M [mg/kg]	3.94
s_{rel}	0.009	0.007	0.015	0.052	0.033	0.025	0.003	0.008	0.005	0.022	0.012	0.004	s_i [mg/kg]	1.95
														0.043

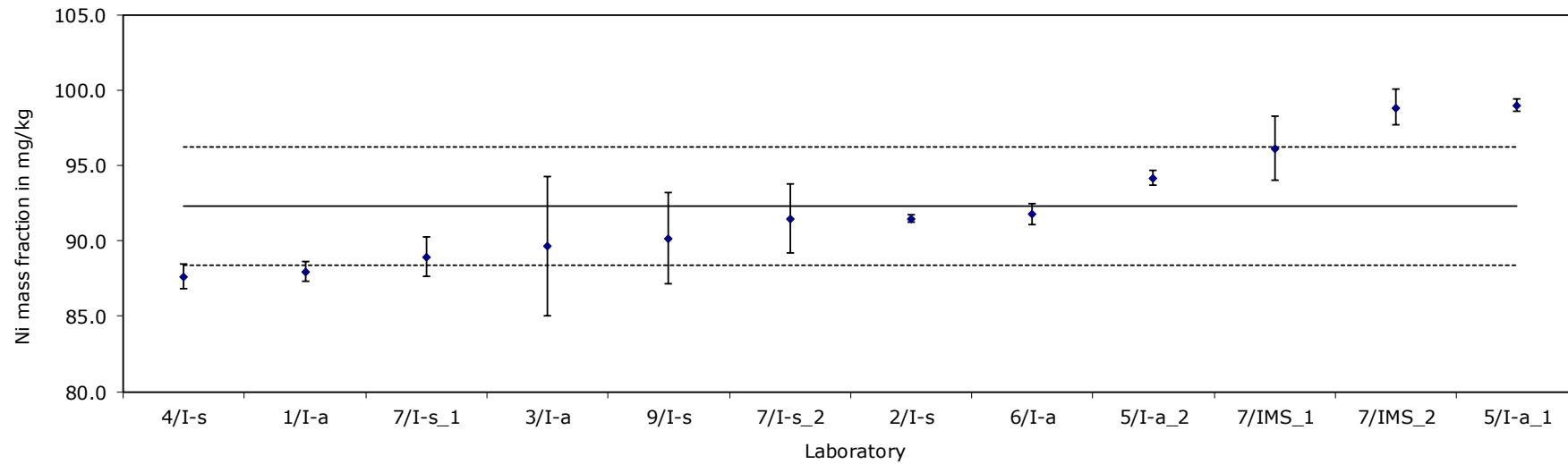


Table 21: Results for Pb

Lab./Meth.	9/I-s	4/I-s	7/IMS_2	7/I-s_1(R)	2/IMS-s	5/I-a_1	7/IMS_1	1/I-s	7/I-s_2(R)	6/I-a		
M_i [mg/kg]	43.3	42.5	43.9	44.0	43.2	46.0	43.8	46.5	46	45.8		
	42.4	43.2	43.0	40.8	43.3	43.3	44.7	46.5	49	47.7		n 10
	41.5	42.6	42.1	43.8	43.2	43.9	43.8	45.3	42	47.3		
	42.2	42.4	43.9	42.5	43.8	43.8	43.3	44.1	45	47.3		
	40.5	41.6	42.8	44.1	43.3	45.3	44.7	45.0	49	47.3		
	42.3	42.4	42.1	43.9	43.5	42.9	45.8	44.4	44	45.9		
M [mg/kg]	42.0	42.5	43.0	43.2	43.4	44.2	44.4	45.3	45.8	46.9	44.1	
s [mg/kg]	0.98	0.51	0.81	1.32	0.23	1.20	0.90	1.02	2.79	0.83	s_M [mg/kg] s_i [mg/kg]	1.56 1.24 0.035
s_{rel}	0.0233	0.0121	0.0188	0.0306	0.0053	0.0272	0.0203	0.0225	0.0608	0.0177		

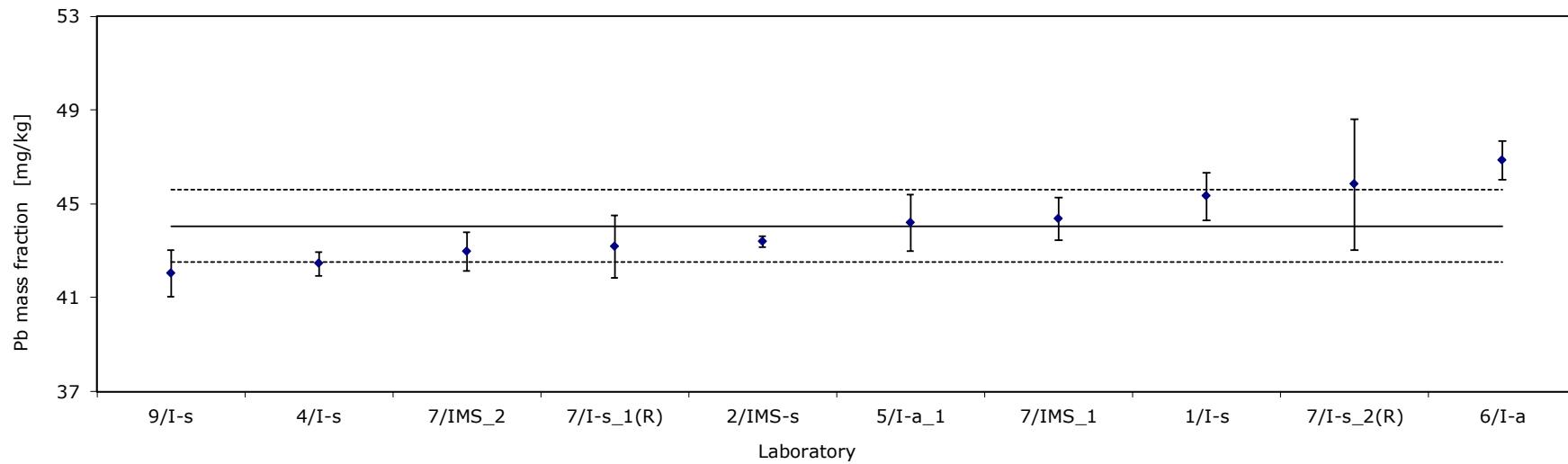


Table 22: Results for Sb

Lab./Meth.	7/I-s_2	7/I-s_1(R)	4/I-s	7/IMS_1	6/I-s	7/IMS_2	2/IMS-s	1/I-s		
M_i [mg/kg]	30.0 38.0 37.0 37.0 34.0 34.0	39.5 40.5 35.4 33.4 39.4 42.2	39.8 38.5 39.2 38.9 38.6 37.8	38.9 38.8 38.9 38.9 39.1 38.9	39.0 39.2 40.3 41.0 40.6 40.0	39.7 40.8 40.9 41.4 40.5 40.5	41.2 41.4 41.1 41.7 41.7 41.2	43.1 44.4 44.3 42.5 42.1 42.3		n 8
M [mg/kg]	35.0	38.4	38.8	38.9	40.0	40.6	41.4	43.1		39.5
s [mg/kg]	2.97	3.31	0.68	0.10	0.76	0.56	0.22	1.02	s_M [mg/kg] s_i [mg/kg]	2.40 1.67
s_{rel}	0.085	0.086	0.017	0.003	0.019	0.014	0.005	0.024		0.061

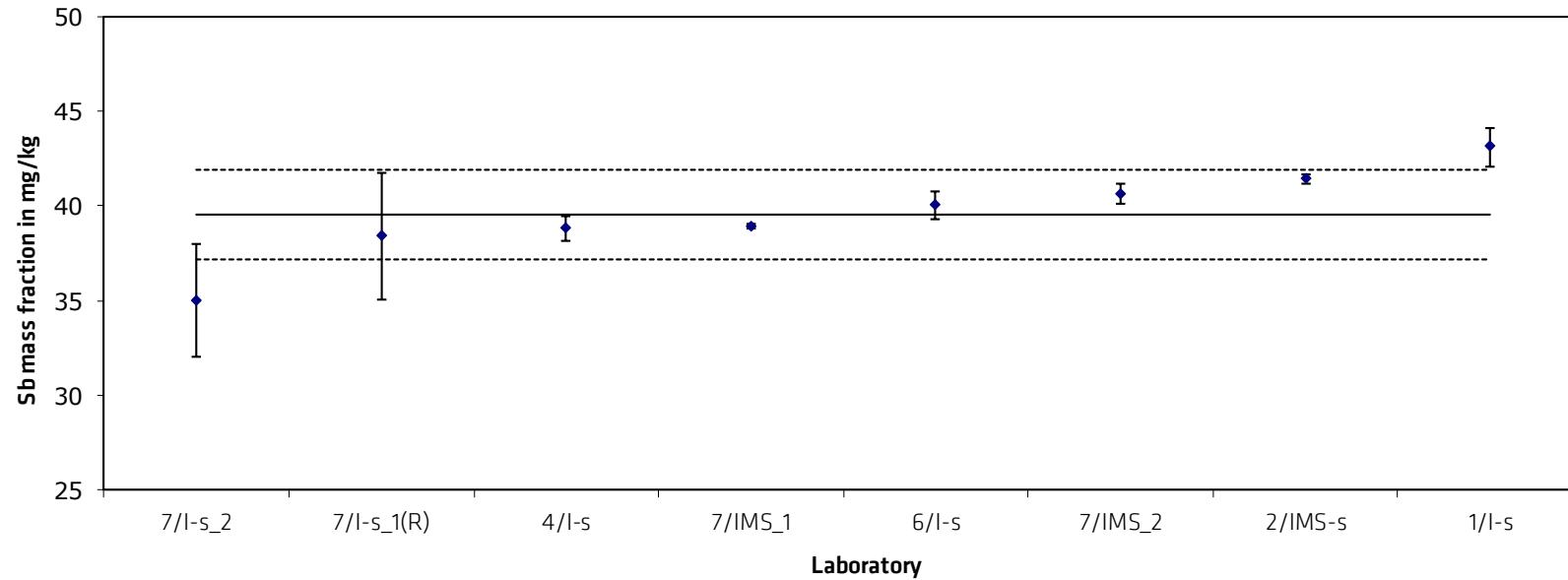


Table 23: Results for Sn

Lab./Meth.	5/I-a_1	6/I-a(R)	7/IMS_1	9/I-s	7/IMS_2	1/I-s	5/I-a_2	7/I-s_1	2/IMS-s	4/I-s	9/I-a		
M_i [mg/kg]	15.8	15.6	16.2	17.3	16.0	16.6	14.2	16.1	16.7	16.7	20.3		$n = 10$
	16.2	15.6	16.1	15.4	16.5	16.8	17.6	16.5	16.7	16.6	21.3		
	15.7	17.4	16.2	16.9	16.4	16.6	16.2	17.1	16.6	16.3	18.5		
	15.3	15.5	15.9	17.0	16.7	16.0	17.6	16.3	16.2	16.4	19.6		
	16.8	16.3	16.1	15.3	16.0	16.1	17.6	16.1	16.3	16.5	19.9		
	15.6	15.7	16.0	15.5	16.2	16.1	15.3	16.3	16.2	16.4	19.9		
M [mg/kg]	15.9	16.0	16.1	16.2	16.3	16.4	16.4	16.4	16.5	16.5	19.9		16.3
s [mg/kg]	0.54	0.74	0.12	0.93	0.28	0.35	1.45	0.37	0.25	0.15	0.91	s_M [mg/kg]	0.21
s_{rel}	0.034	0.046	0.007	0.057	0.017	0.021	0.088	0.023	0.015	0.009	0.046	s_i [mg/kg]	0.65
													0.013

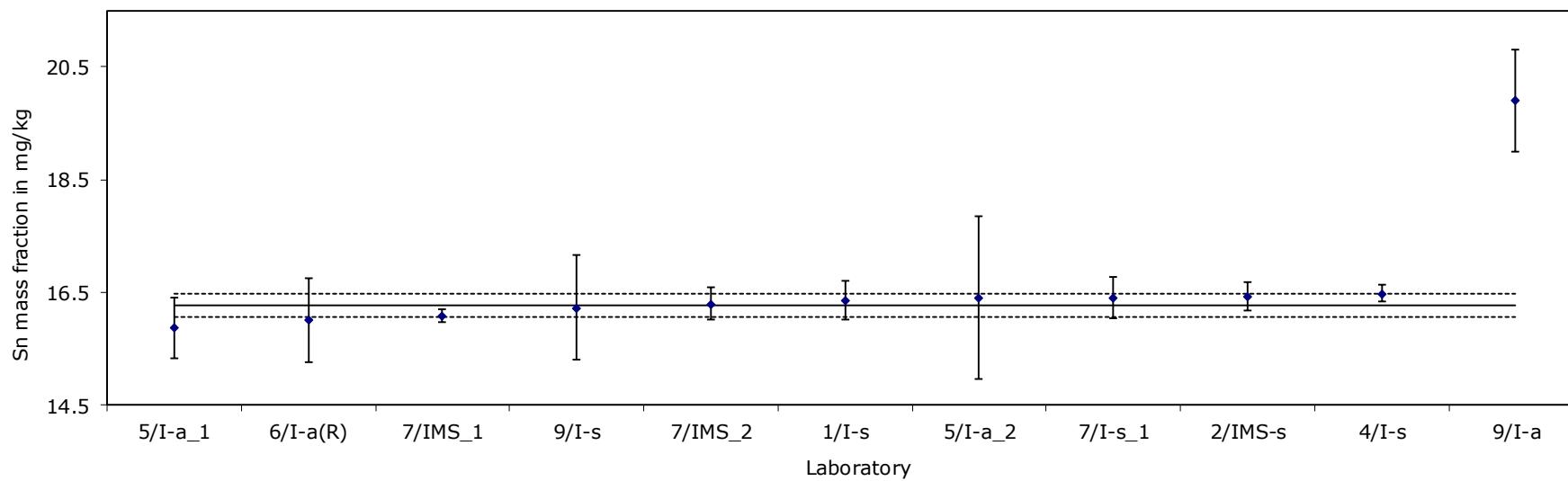


Table 24: Results for V

Lab./Meth.	7/I-s_1	5/I-a_1	9/I-s	4/I-s	6/I-a	1/I-a	2/I-a	9/P	5/I-a_2	7/I-s_2(R)		
M_i [mg/kg]	84.9	86.9	89.6	87.3	88.5	88.5	89.6	90.8	93.5	98		n
	84.3	86.8	87.6	87.2	88.1	88.7	89.1	90.0	93.7	99		10
	78.8	86.9	83.8	88.7	88.3	88.7	89.3	89.2	93.8	96		
	84.3	87.0	88.3	89.4	88.0	89.1	88.7	88.2	92.8	96		
	82.9	86.7	85.9	89.1	89.0	89.5	89.0	88.0	94.0	95		
	83.4	86.6	87.9	87.0	87.8	88.5	89.0	91.6 89.5	93.4	101		
M [mg/kg]	83.1	86.8	87.2	88.1	88.3	88.8	89.1	89.6	93.5	97.5		89.2
s [mg/kg]	2.2	0.1	2.1	1.1	0.4	0.4	0.3	1.3	0.4	2.3	s_M [mg/kg]	3.91
s_{rel}	0.027	0.002	0.024	0.012	0.005	0.005	0.003	0.015	0.004	0.023	\bar{s}_i [mg/kg]	1.33
											s_{rel}	0.044

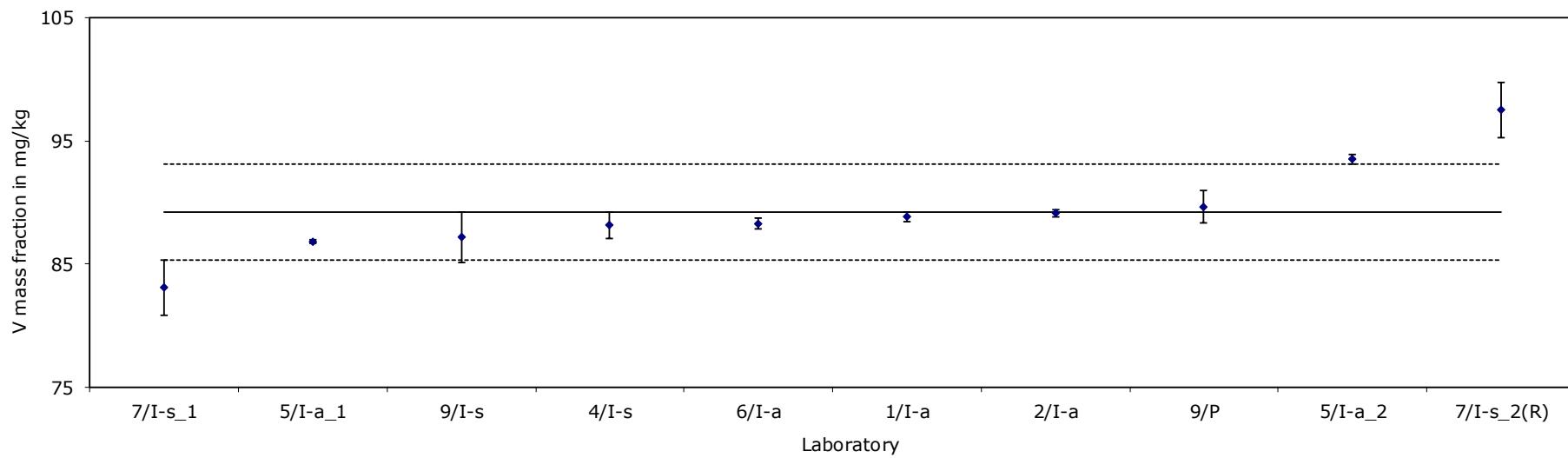
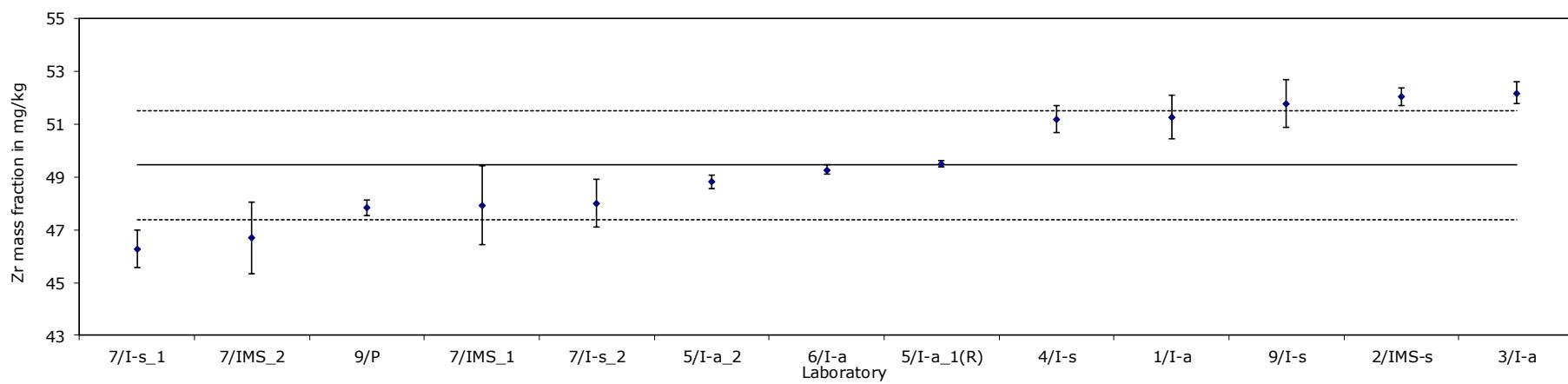


Table 25: Results for Zr

Lab./Meth.	7/I-s_1	7/IMS_2	9/P	7/IMS_1	7/I-s_2	5/I-a_2	6/I-a	5/I-a_1(R)	4/I-s	1/I-a	9/I-s	2/IMS-s	3/I-a		
M_i [mg/kg]	46.2	48.2	48.3	47.8	48	48.4	49.3	49.5	51.8	51.6	53.0	52.1	52		n 13
	46.8	46.8	48.1	47.4	49	48.8	49.1	49.4	51.1	52.7	52.0	52.4	52		
	45.7	45.4	47.7	48.2	49	49.1	49.0	49.6	51.8	51.2	50.3	51.9	53		
	47.5	48.3	47.6	45.4	47	48.7	49.4	49.6	50.6	50.7	52.3	51.7	52		
	45.7	46.4	47.6	49.7	47	48.7	49.4	49.5	50.8	50.9	51.3	52.5	52		
	45.9	45.1	47.6	49.0	48	49.1	49.5	49.4	50.9	50.4	51.7	51.7	52		
M [mg/kg]	46.3	46.7	47.8	47.9	48.0	48.8	49.3	49.5	51.2	51.2	51.8	52.0	52.2		49.4
s [mg/kg]	0.71	1.35	0.31	1.49	0.89	0.25	0.18	0.11	0.52	0.83	0.90	0.33	0.41	s_M [mg/kg] \bar{s}_i [mg/kg]	2.06 0.76 0.042
s_{rel}	0.015	0.029	0.007	0.031	0.019	0.005	0.004	0.002	0.010	0.016	0.017	0.006	0.008		



Using the BAM-software eCerto [4] the data was statistically evaluated to detect outlying values (Grubbs, Nalimov, Dixon, Cochran). The Cochran-test was performed only once. The following results were obtained:

Tab. 26: Outcome of statistical tests on the results obtained for Si and Cu

	Si	Cu
Number of data sets	11	12
Scheffe's test (data compatible?)	yes	yes
Snedecor-F-Test and Bartlett-Test	Pooling not allowed	Pooling not allowed
Dixon ($\alpha = 0.05$)	---	---
Dixon ($\alpha = 0.01$)	---	---
Nalimov ($\alpha = 0.05$)	---	Lab. 7/I-s_1
Nalimov ($\alpha = 0.01$)	---	---
Grubbs ($\alpha = 0.05$)	---	---
Grubbs ($\alpha = 0.01$)	---	---
Grubbs Pair ($\alpha = 0.05$)	---	Labs. 7/I-s_1 and 3
Grubbs Pair ($\alpha = 0.01$)	---	---
Cochran ($\alpha = 0.01$)	---	---
Kolmogorov-Smirnov-Lilliefors Test	Distribution: normal	Distribution: normal

The outliers were not removed.

Tab. 27: Outcome of statistical tests on the results obtained for Fe

	1 st run	2 nd run
Number of data sets	12	11
Scheffe's test (data compatible?)	yes	yes
Snedecor-F-Test and Bartlett-Test	Pooling not allowed	Pooling not allowed
Dixon ($\alpha = 0.05$)	Lab. 7/I-s_2	---
Dixon ($\alpha = 0.01$)	---	---
Nalimov ($\alpha = 0.05$)	Lab. 7/I-s_2	---
Nalimov ($\alpha = 0.01$)	Lab. 7/I-s_2	---
Grubbs ($\alpha = 0.05$)	Lab. 7/I-s_2	---
Grubbs ($\alpha = 0.01$)	Lab. 7/I-s_2	---
Grubbs Pair ($\alpha = 0.05$)	---	---
Grubbs Pair ($\alpha = 0.01$)	---	---
Cochran ($\alpha = 0.01$)	Lab. 7/I-s_2	---
Kolmogorov-Smirnov-Lilliefors Test	Distribution: normal	Distribution: normal

The outlier (Lab. 7/I-s_2) was removed.

Tab. 28: Outcome of statistical tests on the results obtained for Mn and Mg

	Mn	Mg
Number of data sets	13	13
Scheffe's test (data compatible?)	yes	yes
Snedecor-F-Test and Bartlett-Test	Pooling not allowed	Pooling not allowed
Dixon ($\alpha = 0.05$)	---	Lab. 9/A
Dixon ($\alpha = 0.01$)	---	---
Nalimov ($\alpha = 0.05$)	---	Lab. 9/A
Nalimov ($\alpha = 0.01$)	---	Lab. 9/A
Grubbs ($\alpha = 0.05$)	---	---
Grubbs ($\alpha = 0.01$)	---	---
Grubbs Pair ($\alpha = 0.05$)	---	---
Grubbs Pair ($\alpha = 0.01$)	---	---
Cochran ($\alpha = 0.01$)	Lab. 9/I-s	Lab. 7/IMS
Kolmogorov-Smirnov-Lilliefors Test	Distribution: normal	Distribution: normal

The outliers were not removed.

Tab. 29: Outcome of statistical tests on the results obtained for Cr and Ga

	Cr	Ga
Number of data sets	11	11
Scheffe's test (data compatible?)	yes	yes
Snedecor-F-Test and Bartlett-Test	Pooling not allowed	Pooling not allowed
Dixon ($\alpha = 0.05$)	---	---
Dixon ($\alpha = 0.01$)	---	---
Nalimov ($\alpha = 0.05$)	Lab. 7/I-s_1	---
Nalimov ($\alpha = 0.01$)	Lab. 7/I-s_1	---
Grubbs ($\alpha = 0.05$)	---	---
Grubbs ($\alpha = 0.01$)	---	---
Grubbs Pair ($\alpha = 0.05$)	---	---
Grubbs Pair ($\alpha = 0.01$)	---	---
Cochran ($\alpha = 0.01$)	Lab. 9/I-a	Lab. 7/IMS-1
Kolmogorov-Smirnov-Lilliefors Test	Distribution: normal	Distribution: normal

The outliers were not removed.

Tab. 30: Outcome of statistical tests on the results obtained for Zn and Ti

	Zn	Ti
Number of data sets	14	13
Scheffe's test (data compatible?)	yes	yes
Snedecor-F-Test and Bartlett-Test	Pooling not allowed	Pooling not allowed
Dixon ($\alpha = 0.05$)	---	---
Dixon ($\alpha = 0.01$)	---	---
Nalimov ($\alpha = 0.05$)	Lab. 6	Lab. 9/I-a and 7/IMS
Nalimov ($\alpha = 0.01$)	---	---
Grubbs ($\alpha = 0.05$)	---	---
Grubbs ($\alpha = 0.01$)	---	---
Grubbs Pair ($\alpha = 0.05$)	---	Lab. 9/I-a and 7/IMS
Grubbs Pair ($\alpha = 0.01$)	---	---
Cochran ($\alpha = 0.01$)	Lab. 7/I-s_2	Lab. 3
Kolmogorov-Smirnov-Lilliefors Test	Distribution: normal	Distribution: normal

The outliers were not removed.

Tab. 31: Outcome of statistical tests on the results obtained for B and Be

	B	Be
Number of data sets	4	12
Scheffe's test (data compatible?)	yes	yes
Snedecor-F-Test and Bartlett-Test	Pooling not allowed	Pooling not allowed
Dixon ($\alpha = 0.05$)	---	---
Dixon ($\alpha = 0.01$)	---	---
Nalimov ($\alpha = 0.05$)	---	---
Nalimov ($\alpha = 0.01$)	---	---
Grubbs ($\alpha = 0.05$)	---	---
Grubbs ($\alpha = 0.01$)	---	---
Grubbs Pair ($\alpha = 0.05$)	---	---
Grubbs Pair ($\alpha = 0.01$)	---	---
Cochran ($\alpha = 0.01$)	Lab. 1	Labs. 7/I-2_2 and 3
Kolmogorov-Smirnov-Lilliefors Test	Distribution: normal	Distribution: normal

The outliers were not removed.

Tab. 32: Outcome of statistical tests on the results obtained for Bi and Ca

	Bi	Ca
Number of data sets	12	5
Scheffe's test (data compatible?)	yes	yes
Snedecor-F-Test and Bartlett-Test	Pooling not allowed	Pooling not allowed
Dixon ($\alpha = 0.05$)	---	---
Dixon ($\alpha = 0.01$)	---	---
Nalimov ($\alpha = 0.05$)	Lab. 7/IMS_1	---
Nalimov ($\alpha = 0.01$)	---	---
Grubbs ($\alpha = 0.05$)	---	---
Grubbs ($\alpha = 0.01$)	---	---
Grubbs Pair ($\alpha = 0.05$)	---	---
Grubbs Pair ($\alpha = 0.01$)	---	---
Cochran ($\alpha = 0.01$)	---	---
Kolmogorov-Smirnov-Lilliefors Test	Distribution: normal	Distribution: normal

The outlier was not removed.

Tab. 33: Outcome of statistical tests on the results obtained for Cd

	1 st run	2 nd run
Number of data sets	13	12
Scheffe's test (data compatible?)	yes	yes
Snedecor-F-Test and Bartlett-Test	Pooling not allowed	Pooling not allowed
Dixon ($\alpha = 0.05$)	Lab. 3	---
Dixon ($\alpha = 0.01$)	Lab. 3	---
Nalimov ($\alpha = 0.05$)	Lab. 3	Lab. 5/I-a_1
Nalimov ($\alpha = 0.01$)	Lab. 3	---
Grubbs ($\alpha = 0.05$)	Lab. 3	---
Grubbs ($\alpha = 0.01$)	---	---
Grubbs Pair ($\alpha = 0.05$)		---
Grubbs Pair ($\alpha = 0.01$)		---
Cochran ($\alpha = 0.01$)	---	---
Kolmogorov-Smirnov-Lilliefors Test	Distribution: normal	Distribution: normal

The outlier (Lab. 3, 1st run) was removed.

Tab. 34: Outcome of statistical tests on the results obtained for Co and Hg

	Co	Hg
Number of data sets	12	6
Scheffe's test (data compatible?)	yes	yes
Snedecor-F-Test and Bartlett-Test	Pooling not allowed	Pooling not allowed
Dixon ($\alpha = 0.05$)	---	---
Dixon ($\alpha = 0.01$)	---	---
Nalimov ($\alpha = 0.05$)	Lab. 9/I-a	---
Nalimov ($\alpha = 0.01$)	---	---
Grubbs ($\alpha = 0.05$)	---	---
Grubbs ($\alpha = 0.01$)	---	---
Grubbs Pair ($\alpha = 0.05$)	---	---
Grubbs Pair ($\alpha = 0.01$)	---	---
Cochran ($\alpha = 0.01$)	---	Lab. 7/I-s_1
Kolmogorov-Smirnov-Lilliefors Test	Distribution: normal	Distribution: normal

The outliers were not removed.

Tab. 35: Outcome of statistical tests on the results obtained for Li and Na

	Li	Na
Number of data sets	12	6
Scheffe's test (data compatible?)	yes	yes
Snedecor-F-Test and Bartlett-Test	Pooling not allowed	Pooling not allowed
Dixon ($\alpha = 0.05$)	---	---
Dixon ($\alpha = 0.01$)	---	---
Nalimov ($\alpha = 0.05$)	---	---
Nalimov ($\alpha = 0.01$)	---	---
Grubbs ($\alpha = 0.05$)	---	---
Grubbs ($\alpha = 0.01$)	---	---
Grubbs Pair ($\alpha = 0.05$)	---	---
Grubbs Pair ($\alpha = 0.01$)	---	---
Cochran ($\alpha = 0.01$)	---	---
Kolmogorov-Smirnov-Lilliefors Test	Distribution: normal	Distribution: normal

Tab. 36: Outcome of statistical tests on the results obtained for Ni and Pb

	Ni	Pb
Number of data sets	13	11
Scheffe's test (data compatible?)	yes	yes
Snedecor-F-Test and Bartlett-Test	Pooling not allowed	Pooling not allowed
Dixon ($\alpha = 0.05$)	---	---
Dixon ($\alpha = 0.01$)	---	---
Nalimov ($\alpha = 0.05$)	---	---
Nalimov ($\alpha = 0.01$)	---	---
Grubbs ($\alpha = 0.05$)	---	---
Grubbs ($\alpha = 0.01$)	---	---
Grubbs Pair ($\alpha = 0.05$)	---	---
Grubbs Pair ($\alpha = 0.01$)	---	---
Cochran ($\alpha = 0.01$)	Lab. 3	Lab. 7/I-s_2
Kolmogorov-Smirnov-Lilliefors Test	Distribution: normal	Distribution: normal

The outliers were not removed.

Tab. 37: Outcome of statistical tests on the results obtained for Sn

	1 st run	2 nd run
Number of data sets	11	10
Scheffe's test (data compatible?)	yes	yes
Snedecor-F-Test and Bartlett-Test	Pooling not allowed	Pooling not allowed
Dixon ($\alpha = 0.05$)	Lab. 9/I-a	---
Dixon ($\alpha = 0.01$)	Lab. 9/I-a	---
Nalimov ($\alpha = 0.05$)	Lab. 9/I-a	Lab. 5/I-a_1
Nalimov ($\alpha = 0.01$)	Lab. 9/I-a	---
Grubbs ($\alpha = 0.05$)	Lab. 9/I-a	---
Grubbs ($\alpha = 0.01$)	Lab. 9/I-a	---
Grubbs Pair ($\alpha = 0.05$)	---	---
Grubbs Pair ($\alpha = 0.01$)	---	---
Cochran ($\alpha = 0.01$)	Lab. 5/I-a_2	Lab. 5/I-a_2
Kolmogorov-Smirnov-Lilliefors Test	Distribution: normal	Distribution: normal

The outlier (Lab 9/I-a) was removed.

Tab. 38: Outcome of statistical tests on the results obtained for Sb and V

	Sb	V
Number of data sets	10	9
Scheffe's test (data compatible?)	yes	yes
Snedecor-F-Test and Bartlett-Test	Pooling not allowed	Pooling not allowed
Dixon ($\alpha = 0.05$)	---	---
Dixon ($\alpha = 0.01$)	---	---
Nalimov ($\alpha = 0.05$)	Lab. 7/I-s_2	Lab. 7/I-s_2
Nalimov ($\alpha = 0.01$)	---	---
Grubbs ($\alpha = 0.05$)	---	---
Grubbs ($\alpha = 0.01$)	---	---
Grubbs Pair ($\alpha = 0.05$)	---	---
Grubbs Pair ($\alpha = 0.01$)	---	---
Cochran ($\alpha = 0.01$)	Lab. 7/I-s_2	---
Kolmogorov-Smirnov-Lilliefors Test	Distribution: normal	Distribution: normal

The outliers were not removed.

Tab. 39: Outcome of statistical tests on the results obtained for Zr

	Zr
Number of data sets	13
Scheffe's test (data compatible?)	yes
Snedecor-F-Test and Bartlett-Test	Pooling not allowed
Dixon ($\alpha = 0.05$)	---
Dixon ($\alpha = 0.01$)	---
Nalimov ($\alpha = 0.05$)	---
Nalimov ($\alpha = 0.01$)	---
Grubbs ($\alpha = 0.05$)	---
Grubbs ($\alpha = 0.01$)	---
Grubbs Pair ($\alpha = 0.05$)	---
Grubbs Pair ($\alpha = 0.01$)	---
Cochran ($\alpha = 0.01$)	---
Kolmogorov-Smirnov-Lilliefors Test	Distribution: normal

The certified mass fractions of all elements were calculated as mean of the accepted data sets. These values are given in Table 40.

The resp. combined uncertainties were calculated from the spread resulting from the certification inter-laboratory comparison (u_{ilc}) and the uncertainty contributions from possible inhomogeneity over the length ($u_{bb}(1)$) and over area ($u_{bb}(2)$) of the material using Equation 4.

$$u_{\text{combined}} = \sqrt{u_{ilc}^2 + u_{bb}(1)^2 + u_{bb}(2)^2} \quad (4)$$

with

$$u_{ilc} = \sqrt{\frac{s_M^2}{n}} : \text{uncertainty contribution resulting from inter-laboratory comparison}$$

n : number of data sets used for calculating the certified mass fraction of each element

Table 40: Uncertainty calculation ($u_{bb}(\text{rel})$) was calculated with the data from the homogeneity test (see Annex 1 and 2) and used for the calculation of $u_{bb}(1)$ and $u_{bb}(2)$)

	uncertainty contribution from						$u_{bb}(1)^{**}$ Length	$u_{bb}(2)^{**}$ Area	$u(\text{comb})$	U	$u_{bb}(\text{rel})$	
	M	n	s_M	u_{ilc}	$u_{bb}(1)^{**}$ Length	$u_{bb}(2)^{**}$ Area					Length	Area
	%	%	%	%	%	%					%	%
Si	0.1470	11	0.00760	0.0023	0.0004	0.0007	0.0024	0.0049	0.0024	0.0049	0.2845	0.4822
Fe	1.0000	11	0.00466	0.0014	0.0024	0.0052	0.0059	0.0117	0.0059	0.0117	0.2368	0.5188
Cu	0.0182	12	0.00058	0.0002	0.0001	0.0000	0.0002	0.00040	0.0002	0.00040	0.5194	0.2643
Mn	0.0471	13	0.00134	0.0004	0.0001	0.0002	0.0004	0.00085	0.0004	0.00085	0.1872	0.3972
Mg	0.0203	13	0.00222	0.0006	0.0002	0.0001	0.0007	0.00130	0.0007	0.00130	1.0173	0.3266
Cr	0.0106	11	0.00042	0.0001	0.0001	0.0000	0.0001	0.00030	0.0001	0.00030	0.6882	0.2688
Ga	0.0141	11	0.00049	0.0001	0.0000	0.0000	0.0001	0.00030	0.0001	0.00030	0.0783	0.1870
Zn	0.0286	14	0.00085	0.0002	0.0001	0.0001	0.0003	0.00058	0.0003	0.00058	0.3716	0.5072
Ti	0.0189	13	0.00080	0.0002	0.0001	0.0001	0.0003	0.00054	0.0003	0.00054	0.3694	0.7011
	mg/kg		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg				
B	2.55	4	0.523	0.2617	0.2128	0.0452	0.340	0.681		8.3610	1.7739	
Be	5.32	12	0.396	0.1143	0.0868	0.0205	0.145	0.290		1.6324	0.3860	
Bi	15.0	12	1.470	0.4244	0.4698	0.5659	0.849	1.698		3.1275	3.7677	
Ca	16.6	5	2.145	0.9593	1.6792	0.1144	1.937	3.875		10.1156	0.6892	
Cd	20.2	12	1.050	0.3030	0.0483	0.2768	0.413	0.826		0.2391	1.3703	
Co	21.3	13	1.805	0.5007	0.1617	0.3374	0.625	1.250		0.7593	1.5843	
Hg	19.9	6	1.100	0.4489	0.0625	0.2436	0.515	1.029		0.3139	1.2242	
Li	5.99	12	1.192	0.3441		0.0155	0.344	0.689		segregation	0.2595	
Na	8.78	6	1.687	0.6886		0.0499	0.690	1.381		segregation	0.5684	
Ni	92.3	12	3.943	1.1382	0.4340	0.5327	1.330	2.659		0.4702	0.5771	
Pb	44.1	10	1.557	0.4923	0.3261	0.1757	0.616	1.232		0.7396	0.3985	
Sb	39.5	8	2.404	0.8499	1.1046	1.3601	1.947	3.895		2.7963	3.4433	
Sn	16.3	10	0.206	0.0653	0.2309	0.1721	0.295	0.591		1.4164	1.0560	
V	89.2	10	3.906	1.2351	0.4349	0.3850	1.365	2.730		0.4876	0.4316	
Zr	49.4	13	2.055	0.5700	0.2030	0.1911	0.635	1.269		0.4109	0.3869	
**calculated from $u_{bb}(\text{rel})$:						$\frac{M \cdot u_{bb}(\text{rel})}{100}$						

The expanded uncertainties U are calculated by multiplication of u_{combined} with a coverage factor of $k = 2$ using Equation 5.

$$U = k \cdot u_{\text{combined}} \quad (5)$$

The calculated mass fractions and their resp. expanded uncertainties are given on Page 3 of this report. Rounding was done according to DIN 1333 [5].

In addition to the wet chemical characterisation an accompanying inter-laboratory comparison with spark emission was performed to check if there is agreement between SOES and wet chemistry. Tab. 41 shows the mean values of wet chemical and spark emission results as well as their standard deviations. The data obtained with wet chemistry and SOES are consistent for all elements considering their uncertainties. The data from the spark emission inter-laboratory comparison was not used for the calculation of the certified values.

Tab. 41: Comparison wet chemistry vs. SOES

Element	Wet chemical analysis			Spark emission		
	Mass fraction in %	Std.-dev. in %	n	Mass fraction in %	Std.-dev. in %	n
Si	0.147	0.008	11	0.149	0.006	15
Fe	1.000	0.005	11	1.001	0.003	14
Cu	0.0182	0.0006	12	0.0186	0.0011	15
Mn	0.0471	0.0014	13	0.0466	0.0016	14
Mg	0.0203	0.0022	13	0.0207	0.0025	15
Cr	0.0106	0.0004	11	0.0102	0.0008	14
Ga	0.0141	0.0005	11	0.0146	0.0008	11
Zn	0.0286	0.0009	13	0.0290	0.0011	12
Ti	0.0189	0.0008	13	0.0187	0.0008	13
	in mg/kg	in mg/kg		in mg/kg	in mg/kg	
B	2.5	0.6	4	6.0	3.0	11
Be	5.3	0.4	12	5.7	0.5	12
Bi	15.0	1.5	12	17.0	4.2	11
Ca	16.6	2.2	5	15.7	2.4	13
Cd	20.2	1.1	12	20.7	1.4	12
Co	21.3	1.9	13	21.8	2.0	11
Hg	19.9	1.1	6	21.0	2.2	9
Li	6.0	1.2	12	6.4	1.6	12
Na	8.8	1.7	6	8.9	2.1	11
Ni	92.3	4.0	12	89.1	4.1	12
Pb	44.1	1.6	10	42.4	5.4	12
Sb	39.5	2.4	8	32.9	12.3	10
Sn	16.3	0.3	10	16.8	2.9	11
V	89.2	4.0	9	84.0	7.2	14
Zr	49.4	2.1	13	49.8	1.3	12

6. Instructions for users and stability

The certified reference material BAM-M323 is intended for the calibration and quality control of spark emission and X-ray fluorescence spectrometers used for the analysis of

similar materials. It is also suitable for validation and quality control of wet chemical analysis methods.

The surface of the material should be cleaned by turning or milling before analysis. An area 8 mm in diameter in the centre of the discs should be avoided for spark optical emission spectrometry.

If chips prepared from the compact material are used for wet chemical analysis, a minimum sample intake of 0.2 g has to be used.

The material will remain stable provided that it is not subjected to excessive heat (eg, during preparation of the working surface).

7. Metrological Traceability

To ensure traceability of the certified mass fractions to the SI (Système International d'Unités) calibration was performed using standard solutions prepared from pure metals or stoichiometric compounds or traceable commercial calibration solutions.

8. Information on and purchase of the CRM

Certified reference material BAM-M323 is supplied by

Bundesanstalt für Materialforschung und -prüfung (BAM)
Division 1.6 „Inorganic Reference Materials“
Richard-Willstätter-Str. 11, D-12489 Berlin, Germany
Phone +49 (0)30 - 8104 2061
Fax: +49 (0)30 - 8104 72061
E-Mail: sales.crm@bam.de

Each disc of BAM-M323 will be distributed together with a detailed certificate containing the certified values and their uncertainties, the mean values and standard deviations of all accepted data sets and information on the analytical methods used and the names of the participating laboratories.

Information on certified reference materials can be obtained from BAM:

<https://www.bam.de>.

Tel. +49 30 8104 1111.

9. References

- [1] DIN EN ISO 17034, General requirements for the competence of reference material producers, 2016
- [2] ISO Guide 31, Reference materials - Contents of certificates, labels and accompanying documentation, 2015
- [3] ISO Guide 35, Reference materials - Guidance for characterization and assessment of homogeneity and stability, 2017
- [4] J. Lisec, eCerto Software, BAM 2021
- [5] DIN 1333:1992-02 Zahlenangaben

Annex 1: Calculation of uncertainty contribution of potential inhomogeneity (length), SOES

(u_{bb} (rel.) here means u_{bb} (rel) Length in Table 40)

Silicon:

	1	2	3	4	5	
A1	0.1460	0.1455	0.1452	0.1443	0.1472	
A2	0.1460	0.1465	0.1461	0.1468	0.1456	
A3	0.1467	0.1466	0.1460	0.1464	0.1465	
A4	0.1470	0.1463	0.1456	0.1473	0.1464	
A5	0.1483	0.1471	0.1468	0.1466	0.1478	
B1	0.1462	0.1459	0.1459	0.1453	0.1456	
B2	0.1463	0.1478	0.1471	0.1467	0.1472	
B3	0.1465	0.1465	0.1462	0.1467	0.1466	
B4	0.1456	0.1462	0.1457	0.1463	0.1458	
B5	0.1464	0.1462	0.1465	0.1467	0.1467	
C1	0.1458	0.1465	0.1457	0.1460	0.1464	
C2	0.1477	0.1469	0.1473	0.1461	0.1467	
C3	0.1462	0.1459	0.1466	0.1473	0.1459	
C4	0.1466	0.1458	0.1465	0.1472	0.1466	
C5	0.1471	0.1462	0.1467	0.1466	0.1475	
D1	0.1468	0.1463	0.1467	0.1459	0.1458	
D2	0.1463	0.1464	0.1464	0.1464	0.1462	
D3	0.1468	0.1465	0.1470	0.1470	0.1474	
D4	0.1459	0.1470	0.1470	0.1472	0.1467	
D5	0.1474	0.1465	0.1473	0.1464	0.1471	
E1	0.1462	0.1465	0.1469	0.1465	0.1471	
E2	0.1460	0.1469	0.1470	0.1468	0.1475	
E3	0.1463	0.1468	0.1459	0.1457	0.1463	
E4	0.1460	0.1467	0.1462	0.1458	0.1463	
E5	0.1456	0.1466	0.1466	0.1466	0.1469	
F1	0.1463	0.1472	0.1451	0.1464	0.1458	
F2	0.1459	0.1459	0.1464	0.1458	0.1468	
F3	0.1463	0.1467	0.1460	0.1465	0.1461	
F4	0.1477	0.1473	0.1469	0.1464	0.1469	
F5	0.1470	0.1470	0.1478	0.1481	0.1475	
Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	2.734E-05	29	9.42687E-07	3.8078121	1.26671E-07	1.562071
Within groups	2.971E-05	120	2.47567E-07			
Total	5.705E-05	149				
within-sd	0.0004976					
effective n	4.00					
s_{bb}	0.0004169					
u_{bb}^*	8.939E-05					
u_{bb}	0.0004169					
u_{bb} (rel.)	0.284528					

Iron:

	1	2	3	4	5	
A1	0.9823	0.9734	0.9754	0.9721	0.9858	
A2	0.9820	0.9810	0.9801	0.9835	0.9804	
A3	0.9784	0.9736	0.9750	0.9759	0.9824	
A4	0.9748	0.9732	0.9791	0.9812	0.9727	
A5	0.9846	0.9818	0.9772	0.9783	0.9834	
B1	0.9829	0.9781	0.9752	0.9741	0.9726	
B2	0.9767	0.9791	0.9755	0.9718	0.9806	
B3	0.9840	0.9788	0.9786	0.9865	0.9856	
B4	0.9742	0.9834	0.9760	0.9821	0.9740	
B5	0.9746	0.9810	0.9813	0.9842	0.9801	
C1	0.9819	0.9785	0.9740	0.9737	0.9836	
C2	0.9857	0.9822	0.9850	0.9833	0.9827	
C3	0.9833	0.9792	0.9833	0.9844	0.9794	
C4	0.9821	0.9793	0.9772	0.9849	0.9862	
C5	0.9848	0.9768	0.9800	0.9793	0.9844	
D1	0.9787	0.9788	0.9814	0.9779	0.9792	
D2	0.9814	0.9774	0.9796	0.9793	0.9808	
D3	0.9846	0.9838	0.9820	0.9862	0.9866	
D4	0.9830	0.9871	0.9837	0.9819	0.9864	
D5	0.9807	0.9760	0.9833	0.9847	0.9819	
E1	0.9694	0.9752	0.9765	0.9733	0.9801	
E2	0.9781	0.9744	0.9800	0.9806	0.9808	
E3	0.9816	0.9806	0.9795	0.9765	0.9819	
E4	0.9754	0.9786	0.9801	0.9789	0.9792	
E5	0.9844	0.9795	0.9808	0.9815	0.9815	
F1	0.9755	0.9853	0.9741	0.9807	0.9789	
F2	0.9773	0.9791	0.9828	0.9784	0.9830	
F3	0.9779	0.9764	0.9789	0.9749	0.9739	
F4	0.9822	0.9806	0.9761	0.9744	0.9760	
F5	0.9791	0.9778	0.9803	0.9870	0.9841	
	0.9801	0.9790	0.9791	0.9797	0.9809	
Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	0.0009305	29	3.20873E-05	3.0376081	1.16364E-05	1.562071
Within groups	0.0012676	120	1.05633E-05			
Total	0.0021981	149				
within-sd	0.0032501					
effective n	4.00					
S_{bb}	0.0023197					
u^*_{bb}	0.0005839					
u_{bb}	0.0023197					
$u_{bb}(\text{rel.})$	0.2367626					

Copper:

	1	2	3	4	5
A1	0.0168	0.0168	0.0169	0.0168	0.0170
A2	0.0169	0.0169	0.0169	0.0170	0.0168
A3	0.0171	0.0171	0.0171	0.0170	0.0171
A4	0.0171	0.0170	0.0169	0.0171	0.0170
A5	0.0172	0.0171	0.0171	0.0170	0.0172
B1	0.0170	0.0169	0.0168	0.0168	0.0168
B2	0.0170	0.0172	0.0169	0.0170	0.0171
B3	0.0171	0.0170	0.0170	0.0171	0.0170
B4	0.0169	0.0169	0.0168	0.0170	0.0169
B5	0.0170	0.0170	0.0170	0.0171	0.0171
C1	0.0168	0.0169	0.0168	0.0168	0.0168
C2	0.0170	0.0170	0.0170	0.0170	0.0170
C3	0.0168	0.0170	0.0170	0.0170	0.0170
C4	0.0170	0.0169	0.0169	0.0170	0.0170
C5	0.0172	0.0170	0.0171	0.0171	0.0171
D1	0.0170	0.0170	0.0171	0.0170	0.0170
D2	0.0169	0.0169	0.0170	0.0169	0.0169
D3	0.0171	0.0169	0.0170	0.0170	0.0169
D4	0.0170	0.0170	0.0170	0.0170	0.0170
D5	0.0172	0.0170	0.0171	0.0171	0.0171
E1	0.0170	0.0170	0.0170	0.0170	0.0171
E2	0.0170	0.0172	0.0171	0.0171	0.0172
E3	0.0170	0.0170	0.0169	0.0168	0.0170
E4	0.0169	0.0170	0.0169	0.0170	0.0170
E5	0.0170	0.0170	0.0170	0.0170	0.0171
F1	0.0169	0.0171	0.0168	0.0170	0.0169
F2	0.0172	0.0170	0.0170	0.0169	0.0170
F3	0.0171	0.0171	0.0170	0.0171	0.0170
F4	0.0172	0.0172	0.0170	0.0170	0.0171
F5	0.0171	0.0171	0.0172	0.0172	0.0172
	0.0170	0.0170	0.0170	0.0170	0.0170

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	1.057E-06	29	3.64621E-08	6.9231777	9.84526E-15	1.562071
Within groups	6.32E-07	120	5.26667E-09			
Total	1.689E-06	149				
within-sd	7.257E-05					
effective n	4.00					
s_{bb}	8.831E-05					
u_{bb}^*	1.304E-05					
u_{bb}	8.831E-05					
$u_{bb}(\text{rel.})$	0.519416					

Manganese:

	1	2	3	4	5
A1	0.0469	0.0471	0.0470	0.0468	0.0471
A2	0.0470	0.0471	0.0472	0.0471	0.0469
A3	0.0472	0.0475	0.0472	0.0471	0.0472
A4	0.0474	0.0472	0.0470	0.0474	0.0472
A5	0.0474	0.0474	0.0476	0.0473	0.0475
B1	0.0469	0.0468	0.0471	0.0470	0.0471
B2	0.0472	0.0475	0.0474	0.0475	0.0473
B3	0.0472	0.0472	0.0471	0.0473	0.0471
B4	0.0473	0.0469	0.0470	0.0471	0.0472
B5	0.0472	0.0472	0.0472	0.0471	0.0474
C1	0.0469	0.0472	0.0470	0.0471	0.0473
C2	0.0472	0.0470	0.0473	0.0470	0.0470
C3	0.0469	0.0469	0.0471	0.0471	0.0472
C4	0.0471	0.0470	0.0472	0.0473	0.0471
C5	0.0471	0.0471	0.0473	0.0472	0.0472
D1	0.0474	0.0471	0.0472	0.0472	0.0469
D2	0.0471	0.0472	0.0470	0.0470	0.0470
D3	0.0471	0.0471	0.0473	0.0474	0.0471
D4	0.0470	0.0470	0.0472	0.0473	0.0472
D5	0.0474	0.0472	0.0472	0.0470	0.0471
E1	0.0474	0.0473	0.0473	0.0473	0.0472
E2	0.0472	0.0475	0.0472	0.0474	0.0475
E3	0.0470	0.0470	0.0471	0.0471	0.0471
E4	0.0472	0.0471	0.0469	0.0471	0.0472
E5	0.0468	0.0472	0.0472	0.0471	0.0472
F1	0.0470	0.0470	0.0469	0.0468	0.0468
F2	0.0471	0.0470	0.0470	0.0469	0.0472
F3	0.0472	0.0471	0.0472	0.0474	0.0471
F4	0.0475	0.0475	0.0474	0.0473	0.0475
F5	0.0475	0.0475	0.0475	0.0473	0.0474

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	1.057E-06	29	3.64621E-08	6.9231777	9.84526E-15	1.562071
Within groups	6.32E-07	120	5.26667E-09			
Total	1.689E-06	149				
within-sd	7.257E-05					
effective n	4.00					
s_{bb}	8.831E-05					
u^*_{bb}	1.304E-05					
u_{bb}	8.831E-05					
$u_{bb}(\text{rel.})$	0.1872241					

Magnesium:

	1	2	3	4	5	
A1	0.0198	0.0198	0.0198	0.0197	0.0199	
A2	0.0197	0.0197	0.0196	0.0198	0.0197	
A3	0.0197	0.0196	0.0195	0.0196	0.0196	
A4	0.0196	0.0196	0.0195	0.0197	0.0196	
A5	0.0196	0.0196	0.0193	0.0194	0.0195	
B1	0.0199	0.0198	0.0200	0.0198	0.0198	
B2	0.0197	0.0198	0.0198	0.0198	0.0198	
B3	0.0197	0.0197	0.0196	0.0197	0.0196	
B4	0.0196	0.0196	0.0194	0.0196	0.0194	
B5	0.0193	0.0193	0.0193	0.0193	0.0193	
C1	0.0198	0.0198	0.0198	0.0198	0.0199	
C2	0.0197	0.0198	0.0197	0.0198	0.0197	
C3	0.0197	0.0195	0.0195	0.0197	0.0196	
C4	0.0195	0.0195	0.0196	0.0195	0.0195	
C5	0.0195	0.0194	0.0194	0.0195	0.0196	
D1	0.0201	0.0200	0.0200	0.0199	0.0199	
D2	0.0198	0.0197	0.0197	0.0198	0.0198	
D3	0.0196	0.0197	0.0197	0.0197	0.0197	
D4	0.0196	0.0195	0.0196	0.0197	0.0197	
D5	0.0195	0.0194	0.0195	0.0194	0.0195	
E1	0.0199	0.0200	0.0200	0.0199	0.0200	
E2	0.0198	0.0198	0.0198	0.0198	0.0198	
E3	0.0195	0.0196	0.0195	0.0195	0.0195	
E4	0.0196	0.0196	0.0193	0.0195	0.0196	
E5	0.0192	0.0191	0.0194	0.0193	0.0193	
F1	0.0200	0.0199	0.0197	0.0200	0.0199	
F2	0.0197	0.0197	0.0198	0.0198	0.0198	
F3	0.0196	0.0196	0.0196	0.0196	0.0197	
F4	0.0195	0.0197	0.0196	0.0195	0.0196	
F5	0.0194	0.0194	0.0193	0.0194	0.0194	
	0.0197	0.0196	0.0196	0.0197	0.0197	
Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	4.797E-06	29	1.65428E-07	28.853649	2.70147E-41	1.562071
Within groups	6.88E-07	120	5.73333E-09			
Total	5.485E-06	149				
within-sd	7.572E-05					
effective n	4.00					
s_{bb}	0.0001998					
u_{bb}^*	1.36E-05					
u_{bb}	0.0001998					
$u_{bb}(\text{rel.})$	1.0172529					

Chromium:

	1	2	3	4	5
A1	113	113	112	114	113
A2	114	114	113	113	114
A3	112	113	114	114	113
A4	113	114	114	114	114
A5	112	112	114	112	112
B1	112	114	114	114	115
B2	113	113	113	113	113
B3	114	115	114	113	114
B4	113	115	115	115	115
B5	115	115	114	115	114
C1	112	115	114	114	113
C2	115	115	113	117	115
C3	112	113	114	115	112
C4	114	115	115	115	116
C5	113	113	113	114	113
D1	115	113	114	115	114
D2	115	115	114	114	114
D3	115	114	114	113	116
D4	113	114	114	114	114
D5	113	113	112	112	112
E1	116	114	113	113	112
E2	112	114	114	113	112
E3	112	113	113	113	119
E4	115	116	115	117	115
E5	114	115	114	114	114
F1	113	114	115	113	113
F2	115	114	114	117	115
F3	113	115	114	113	117
F4	113	112	113	113	113
F5	112	113	113	112	112

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	101.79333	29	3.510114943	3.3218753	2.16645E-06	1.562071
Within groups	126.8	120	1.056666667			
Total	228.59333	149				
within-sd	1.0279429					
effective n	4.00					
s_{bb}	0.7831744					
u_{bb}^*	0.1846721					
u_{bb}	0.7831744					
$u_{bb}(\text{rel.})$	0.6882427					

Nickel:

	1	2	3	4	5
A1	89	88	89	89	90
A2	88	89	90	90	89
A3	89	88	88	89	88
A4	88	88	89	89	89
A5	89	88	89	88	88
B1	89	89	89	89	88
B2	88	88	88	88	88
B3	88	89	88	89	90
B4	88	89	89	89	89
B5	89	88	88	89	89
C1	89	88	89	89	89
C2	89	89	89	89	89
C3	90	89	89	89	89
C4	90	89	89	89	89
C5	87	87	89	89	88
D1	88	88	88	88	89
D2	89	88	89	89	89
D3	89	89	89	90	90
D4	89	89	89	89	90
D5	89	88	88	88	88
E1	88	88	88	88	88
E2	88	88	88	88	89
E3	88	89	89	89	90
E4	88	89	89	89	89
E5	89	89	89	89	90
F1	89	88	88	88	89
F2	89	88	89	88	89
F3	87	88	87	88	89
F4	88	89	87	88	88
F5	88	88	88	89	89

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	29.233333	29	1.008045977	3.217168	4.01937E-06	1.562071
Within groups	37.6	120	0.313333333			
Total	66.833333	149				
within-sd	0.5597619					
effective n	4.00					
s_{bb}	0.4167471					
u^*_{bb}	0.1005624					
u_{bb}	0.4167471					
$u_{bb}(\text{rel.})$	0.4701923					

Zinc:

	1	2	3	4	5
A1	0.0293	0.0290	0.0292	0.0291	0.0293
A2	0.0290	0.0295	0.0294	0.0294	0.0294
A3	0.0288	0.0291	0.0290	0.0291	0.0291
A4	0.0291	0.0292	0.0293	0.0291	0.0291
A5	0.0293	0.0296	0.0295	0.0296	0.0292
B1	0.0294	0.0293	0.0290	0.0292	0.0293
B2	0.0293	0.0289	0.0289	0.0293	0.0293
B3	0.0295	0.0296	0.0291	0.0299	0.0296
B4	0.0291	0.0295	0.0292	0.0294	0.0292
B5	0.0291	0.0293	0.0292	0.0292	0.0292
C1	0.0293	0.0292	0.0293	0.0293	0.0295
C2	0.0294	0.0292	0.0291	0.0294	0.0294
C3	0.0293	0.0294	0.0291	0.0293	0.0294
C4	0.0293	0.0293	0.0292	0.0294	0.0294
C5	0.0294	0.0294	0.0293	0.0294	0.0294
D1	0.0289	0.0292	0.0296	0.0291	0.0295
D2	0.0291	0.0291	0.0294	0.0291	0.0295
D3	0.0292	0.0291	0.0293	0.0290	0.0293
D4	0.0289	0.0292	0.0294	0.0293	0.0293
D5	0.0290	0.0290	0.0295	0.0292	0.0294
E1	0.0290	0.0291	0.0292	0.0290	0.0290
E2	0.0288	0.0292	0.0291	0.0292	0.0294
E3	0.0291	0.0292	0.0293	0.0292	0.0293
E4	0.0292	0.0292	0.0293	0.0295	0.0292
E5	0.0295	0.0293	0.0293	0.0295	0.0296
F1	0.0290	0.0290	0.0288	0.0291	0.0291
F2	0.0292	0.0291	0.0291	0.0291	0.0291
F3	0.0292	0.0289	0.0292	0.0293	0.0292
F4	0.0293	0.0291	0.0291	0.0293	0.0295
F5	0.0291	0.0291	0.0295	0.0296	0.0294

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	2.144E-06	29	7.39425E-08	2.7693831	5.70959E-05	1.562071
Within groups	3.204E-06	120	2.67E-08			
Total	5.348E-06	149				
within-sd	0.0001634					
effective n	4.00					
s_{bb}	0.0001087					
u_{bb}^*	2.936E-05					
u_{bb}	0.0001087					
$u_{bb}(\text{rel.})$	0.3716291					

Titanium:

	1	2	3	4	5
A1	0.0183	0.0183	0.0183	0.0185	0.0180
A2	0.0183	0.0184	0.0183	0.0184	0.0187
A3	0.0183	0.0195	0.0184	0.0182	0.0184
A4	0.0186	0.0185	0.0182	0.0191	0.0183
A5	0.0184	0.0183	0.0186	0.0182	0.0183
B1	0.0184	0.0182	0.0187	0.0179	0.0183
B2	0.0187	0.0184	0.0182	0.0182	0.0182
B3	0.0183	0.0184	0.0183	0.0183	0.0183
B4	0.0183	0.0182	0.0184	0.0184	0.0184
B5	0.0183	0.0187	0.0184	0.0176	0.0185
C1	0.0183	0.0188	0.0182	0.0178	0.0175
C2	0.0182	0.0179	0.0183	0.0199	0.0183
C3	0.0184	0.0180	0.0183	0.0184	0.0183
C4	0.0183	0.0184	0.0182	0.0183	0.0176
C5	0.0183	0.0183	0.0178	0.0184	0.0185
D1	0.0190	0.0184	0.0182	0.0184	0.0184
D2	0.0183	0.0184	0.0182	0.0183	0.0184
D3	0.0183	0.0185	0.0183	0.0175	0.0188
D4	0.0184	0.0183	0.0184	0.0184	0.0189
D5	0.0183	0.0184	0.0183	0.0182	0.0183
E1	0.0192	0.0183	0.0190	0.0179	0.0184
E2	0.0186	0.0183	0.0183	0.0183	0.0182
E3	0.0184	0.0182	0.0183	0.0182	0.0189
E4	0.0186	0.0184	0.0182	0.0211	0.0183
E5	0.0183	0.0183	0.0183	0.0182	0.0182
F1	0.0183	0.0182	0.0187	0.0183	0.0181
F2	0.0183	0.0183	0.0183	0.0185	0.0183
F3	0.0183	0.0184	0.0186	0.0183	0.0187
F4	0.0183	0.0183	0.0183	0.0183	0.0183
F5	0.0183	0.0183	0.0183	0.0186	0.0184

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	3.236E-06	29	1.11577E-07	0.7817166	0.7755368	1.562071
Within groups	1.713E-05	120	1.42733E-07			
Total	2.036E-05	149				
within-sd	0.0003778					
effective n	4.00					
s_{bb}	0					
u_{bb}^*	6.787E-05					
u_{bb}	6.787E-05					
$u_{bb}(\text{rel.})$	0.3693817					

Boron:

	1	2	3	4	5
A1	6.9	5.8	7.3	5.4	5.4
A2	6.4	5.2	5.6	5.5	5.6
A3	6.0	6.0	8.0	5.1	6.0
A4	7.5	7.4	5.7	8.9	5.4
A5	5.5	5.3	8.3	5.3	5.0
B1	5.6	4.9	18.0	9.1	9.0
B2	21.0	6.3	5.1	6.7	5.6
B3	6.4	5.4	5.3	5.1	5.0
B4	5.3	5.1	6.1	5.6	6.9
B5	5.1	7.4	7.2	9.2	6.3
C1	5.2	6.2	6.8	12.0	9.5
C2	5.0	10.0	5.3	5.4	9.1
C3	6.2	14.0	4.9	5.1	7.7
C4	4.8	5.4	5.0	6.1	9.8
C5	5.3	5.7	9.8	7.4	6.3
D1	16.0	5.9	6.1	5.5	7.3
D2	5.7	5.8	4.7	6.5	5.3
D3	5.5	8.8	5.8	9.0	15.0
D4	6.1	5.2	6.0	5.3	19.0
D5	6.3	6.3	4.9	5.2	5.0
E1	7.0	4.9	21.0	12.0	5.1
E2	10.0	8.0	5.2	5.9	5.7
E3	6.3	5.0	4.7	5.6	11.0
E4	7.3	6.0	4.8	22.0	5.2
E5	5.4	5.3	5.4	5.0	5.1
F1	6.6	4.6	9.8	5.4	5.2
F2	7.6	5.6	6.2	7.1	5.2
F3	5.6	6.5	7.7	5.2	13.0
F4	5.6	5.0	5.5	6.8	6.3
F5	4.8	5.5	4.9	6.7	5.1

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	257.01573	29	8.862611494	0.8450052	0.6926966	1.562071
Within groups	1258.588	120	10.48823333			
Total	1515.6037	149				
within-sd	3.2385542					
effective n	4.00					
s_{bb}	0					
u_{bb}^*	0.5818129					
u_{bb}	0.5818129					
$u_{bb}(\text{rel.})$	8.3609828					

Beryllium:

	1	2	3	4	5
A1	5.5	5.5	5.5	5.4	5.5
A2	5.4	5.4	5.4	5.4	5.4
A3	5.4	5.4	5.4	5.4	5.4
A4	5.4	5.4	5.4	5.4	5.4
A5	5.3	5.3	5.2	5.2	5.3
B1	5.5	5.5	5.5	5.5	5.5
B2	5.5	5.4	5.4	5.4	5.4
B3	5.4	5.4	5.4	5.4	5.4
B4	5.3	5.4	5.3	5.4	5.4
B5	5.2	5.2	5.2	5.2	5.2
C1	5.5	5.5	5.5	5.5	5.5
C2	5.5	5.4	5.4	5.4	5.4
C3	5.4	5.4	5.4	5.4	5.4
C4	5.4	5.4	5.4	5.4	5.4
C5	5.3	5.2	5.3	5.3	5.3
D1	5.5	5.5	5.5	5.5	5.5
D2	5.5	5.4	5.4	5.5	5.4
D3	5.4	5.4	5.4	5.4	5.4
D4	5.4	5.4	5.4	5.4	5.4
D5	5.3	5.3	5.3	5.3	5.3
E1	5.5	5.5	5.5	5.5	5.5
E2	5.4	5.4	5.4	5.5	5.5
E3	5.4	5.4	5.4	5.4	5.4
E4	5.4	5.4	5.3	5.4	5.4
E5	5.3	5.1	5.3	5.2	5.3
F1	5.5	5.5	5.4	5.5	5.5
F2	5.4	5.4	5.5	5.4	5.4
F3	5.4	5.4	5.4	5.4	5.4
F4	5.3	5.4	5.3	5.3	5.3
F5	5.3	5.3	5.2	5.3	5.3

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	0.9349333	29	0.03223908	25.451906	1.48477E-38	1.562071
Within groups	0.152	120	0.001266667			
Total	1.0869333	149				
within-sd	0.0355903					
effective n	4.00					
s_{bb}	0.0879949					
u_{bb}^*	0.0063939					
u_{bb}	0.0879949					
$u_{bb}(\text{rel.})$	1.6323566					

Bismuth:

	1	2	3	4	5
A1	14	17	15	15	16
A2	14	15	16	15	14
A3	16	15	14	15	14
A4	15	15	15	15	15
A5	15	16	15	16	14
B1	13	15	16	16	14
B2	16	15	16	18	15
B3	14	14	15	14	15
B4	15	16	15	16	15
B5	16	17	13	15	17
C1	14	16	14	17	16
C2	15	16	16	16	16
C3	16	14	15	13	16
C4	17	17	15	16	17
C5	14	14	15	14	17
D1	14	13	14	15	15
D2	15	15	16	16	17
D3	14	17	17	15	17
D4	15	15	14	16	15
D5	15	16	15	13	16
E1	13	14	16	15	15
E2	17	16	14	16	16
E3	16	17	15	14	15
E4	15	15	16	17	15
E5	14	16	15	15	16
F1	16	14	14	15	16
F2	17	17	16	16	16
F3	15	15	15	16	16
F4	17	17	17	16	18
F5	16	17	13	15	15

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	56.86	29	1.960689655	1.8852785	0.0093447	1.562071
Within groups	124.8	120	1.04			
Total	181.66	149				
within-sd	1.0198039					
effective n	4.00					
s_{bb}	0.4797629					
u^*_{bb}	0.1832099					
u_{bb}	0.4797629					
$u_{bb}(\text{rel.})$	3.1275285					

Calcium:

	1	2	3	4	5
A1	17	17	17	16	17
A2	15	15	15	15	15
A3	15	14	14	15	15
A4	14	14	14	14	14
A5	13	13	13	13	12
B1	16	17	16	17	17
B2	15	15	15	15	15
B3	14	15	15	14	15
B4	14	14	14	15	14
B5	12	12	13	12	13
C1	17	17	17	17	16
C2	15	15	15	15	15
C3	15	14	15	15	15
C4	14	14	14	15	14
C5	13	13	13	13	13
D1	17	17	17	17	17
D2	15	15	15	15	15
D3	15	15	15	15	15
D4	14	14	15	15	15
D5	13	13	13	13	13
E1	17	17	16	17	18
E2	15	15	15	15	15
E3	14	15	14	15	14
E4	14	14	14	14	14
E5	12	12	13	12	13
F1	17	16	16	17	17
F2	15	15	15	15	15
F3	14	15	14	14	15
F4	14	15	14	14	14
F5	13	13	13	13	13

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	260.24	29	8.973793103	58.524738	1.23972E-57	1.562071
Within groups	18.4	120	0.153333333			
Total	278.64	149				
within-sd	0.391578					
effective n	4.00					
s_{bb}	1.4849629					
u_{bb}^*	0.0703478					
u_{bb}	1.4849629					
$u_{bb}(\text{rel.})$	10.115551					

Cadmium:

	1	2	3	4	5
A1	19.9	20.3	19.6	19.6	20.1
A2	20.2	19.8	20.2	19.7	20.2
A3	19.9	19.9	20.4	20.3	19.7
A4	19.6	19.6	19.6	20.3	20.3
A5	20.1	20.0	20.0	20.4	20.3
B1	19.9	20.0	19.9	19.6	19.8
B2	19.8	19.8	20.4	19.9	19.6
B3	19.6	20.0	20.2	19.7	20.4
B4	19.8	19.7	20.0	19.6	20.2
B5	19.9	20.4	20.4	19.9	19.6
C1	20.0	19.9	19.7	20.1	20.4
C2	19.7	20.4	19.8	19.9	20.2
C3	20.4	20.4	20.2	20.0	20.0
C4	19.7	20.1	20.4	19.6	20.3
C5	20.2	19.8	20.1	19.7	19.7
D1	20.1	19.6	20.1	19.9	20.1
D2	19.8	20.2	20.3	19.7	20.4
D3	20.0	20.4	20.0	19.6	20.0
D4	20.2	20.0	19.9	19.6	20.1
D5	19.7	20.0	19.8	20.0	19.7
E1	20.3	19.9	20.3	19.6	20.0
E2	20.2	19.7	20.0	19.8	19.7
E3	20.0	20.1	20.1	20.1	19.7
E4	20.0	20.2	20.0	19.9	19.7
E5	19.8	20.4	20.2	20.1	20.4
F1	19.9	20.3	20.0	20.1	19.8
F2	20.1	19.9	19.9	20.3	20.1
F3	19.7	19.6	20.3	19.8	20.3
F4	20.3	19.6	20.0	20.3	20.0
F5	20.0	19.9	19.7	19.6	20.4

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	1.2739333	29	0.0439287	0.6207546	0.9310814	1.562071
Within groups	8.492	120	0.0707667			
Total	9.7659333	149				
within-sd	0.26602					
effective n	4.00					
s_{bb}	0					
u_{bb}^*	0.047791					
u_{bb}	0.047791					
$u_{bb}(\text{rel.})$	0.2391067					

Cobalt:

	1	2	3	4	5
A1	21	21	21	21	21
A2	21	22	21	21	21
A3	22	22	21	21	22
A4	22	21	22	21	21
A5	22	22	22	21	22
B1	21	21	21	21	21
B2	22	22	22	22	21
B3	22	22	21	21	21
B4	21	21	21	22	21
B5	21	21	22	21	22
C1	21	21	21	21	21
C2	21	21	21	21	21
C3	22	21	21	22	21
C4	21	22	22	21	21
C5	21	21	22	22	21
D1	22	21	21	21	22
D2	21	22	22	21	21
D3	22	21	22	21	21
D4	22	22	22	21	21
D5	22	22	22	22	22
E1	21	22	21	21	21
E2	22	22	21	22	22
E3	21	21	21	21	22
E4	21	21	22	21	22
E5	22	21	21	21	21
F1	21	21	21	22	21
F2	22	21	21	21	22
F3	21	21	21	21	22
F4	22	21	22	22	21
F5	21	21	22	22	21

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	9.34	29	0.322068966	1.4864721	0.0718624	1.562071
Within groups	26	120	0.216666667			
Total	35.34	149				
within-sd	0.4654747					
effective n	4.00					
s_{bb}	0.1623286					
u^*_{bb}	0.0836235					
u_{bb}	0.1623286					
$u_{bb}(\text{rel.})$	0.7592544					

Gallium:

	1	2	3	4	5	
A1	0.0146	0.0145	0.0147	0.0146	0.0147	
A2	0.0145	0.0147	0.0147	0.0147	0.0147	
A3	0.0146	0.0146	0.0146	0.0147	0.0147	
A4	0.0146	0.0146	0.0147	0.0147	0.0147	
A5	0.0146	0.0146	0.0146	0.0146	0.0146	
B1	0.0146	0.0147	0.0147	0.0146	0.0146	
B2	0.0146	0.0146	0.0146	0.0146	0.0147	
B3	0.0146	0.0147	0.0146	0.0147	0.0146	
B4	0.0146	0.0147	0.0146	0.0147	0.0147	
B5	0.0146	0.0146	0.0146	0.0147	0.0147	
C1	0.0146	0.0145	0.0146	0.0147	0.0147	
C2	0.0146	0.0147	0.0146	0.0147	0.0147	
C3	0.0146	0.0145	0.0147	0.0147	0.0147	
C4	0.0146	0.0146	0.0146	0.0146	0.0147	
C5	0.0145	0.0146	0.0147	0.0147	0.0147	
D1	0.0146	0.0145	0.0147	0.0146	0.0147	
D2	0.0147	0.0146	0.0147	0.0146	0.0146	
D3	0.0146	0.0146	0.0147	0.0147	0.0147	
D4	0.0146	0.0146	0.0146	0.0147	0.0147	
D5	0.0146	0.0147	0.0147	0.0146	0.0148	
E1	0.0146	0.0146	0.0147	0.0146	0.0146	
E2	0.0146	0.0146	0.0147	0.0146	0.0147	
E3	0.0146	0.0146	0.0146	0.0147	0.0146	
E4	0.0146	0.0146	0.0146	0.0147	0.0147	
E5	0.0146	0.0147	0.0146	0.0146	0.0147	
F1	0.0147	0.0145	0.0145	0.0146	0.0147	
F2	0.0147	0.0146	0.0146	0.0146	0.0147	
F3	0.0146	0.0146	0.0146	0.0146	0.0147	
F4	0.0146	0.0147	0.0146	0.0146	0.0147	
F5	0.0146	0.0147	0.0147	0.0148	0.0147	
Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	6.773E-08	29	2.33563E-09	0.5743358	0.9573418	1.562071
Within groups	4.88E-07	120	4.06667E-09			
Total	5.557E-07	149				
within-sd	6.377E-05					
effective n	4.00					
s_{bb}	0					
u_{bb}^*	1.146E-05					
u_{bb}	1.146E-05					
$u_{bb}(\text{rel.})$	0.0782618					

Mercury

	1	2	3	4	5
A1	21	21	21	21	22
A2	21	21	21	21	21
A3	21	22	21	22	21
A4	21	21	21	21	21
A5	21	21	21	21	21
B1	21	21	21	21	21
B2	21	21	22	21	22
B3	21	21	22	21	22
B4	21	22	21	21	21
B5	21	21	21	21	21
C1	21	21	21	21	21
C2	21	21	21	22	22
C3	21	21	21	21	21
C4	21	21	22	21	21
C5	22	22	21	21	21
D1	21	22	21	21	21
D2	21	21	21	21	21
D3	21	21	21	21	21
D4	21	21	21	21	22
D5	22	21	21	22	21
E1	21	21	21	22	21
E2	21	21	22	22	21
E3	21	21	21	21	21
E4	21	21	21	21	21
E5	21	21	22	21	21
F1	21	21	21	21	21
F2	21	21	21	21	21
F3	21	22	21	21	21
F4	21	21	21	22	21
F5	21	21	22	21	21

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	3.76	29	0.129655172	0.9486964	0.5471729	1.562071
Within groups	16.4	120	0.136666667			
Total	20.16	149				
within-sd	0.3696846					
effective n	4.00					
s_{bb}	0					
u^*_{bb}	0.0664146					
u_{bb}	0.0664146					
$u_{bb}(\text{rel.})$	0.3138686					

Lithium (segregation):

	1	2	3	4	5	
A1	8.1	8.2	8.2	8.2	8.1	8.1600
A2	7.2	6.9	7.0	7.2	7.2	7.1000
A3	6.7	6.6	6.4	6.7	6.7	6.6200
A4	6.5	6.4	6.5	6.5	6.6	6.5000
A5	4.7	5.0	4.6	4.8	4.7	4.7600
B1	8.0	8.2	7.9	8.1	8.2	8.0800
B2	7.1	7.1	7.1	7.2	7.2	7.1400
B3	6.6	6.7	6.6	6.6	6.7	6.6400
B4	6.5	6.7	6.5	6.5	6.5	6.5400
B5	4.7	4.6	4.8	4.5	4.6	4.6400
C1	8.2	8.1	8.1	8.2	8.2	8.1600
C2	7.2	7.1	7.1	7.2	7.2	7.1600
C3	6.9	6.6	6.8	7.0	6.8	6.8200
C4	6.6	6.4	6.7	6.8	6.6	6.6200
C5	5.4	4.9	4.9	5.1	5.4	5.1400
D1	8.2	8.0	8.2	8.3	8.2	8.1800
D2	7.1	7.1	7.1	7.1	7.2	7.1200
D3	6.8	6.7	6.8	6.9	6.8	6.8000
D4	6.6	6.6	6.7	6.8	6.9	6.7200
D5	4.9	5.2	5.0	4.9	5.2	5.0400
E1	8.1	8.1	8.1	8.1	8.3	8.1400
E2	7.2	7.1	7.2	7.2	7.3	7.2000
E3	6.5	7.0	6.5	6.5	6.6	6.6200
E4	6.6	6.7	6.2	6.5	6.7	6.5400
E5	4.7	3.9	4.9	4.4	4.6	4.5000
F1	8.1	7.8	8.1	8.1	8.2	8.0600
F2	7.2	7.2	7.3	7.4	7.2	7.2600
F3	6.4	6.5	6.3	6.4	6.5	6.4200
F4	6.2	6.6	6.4	6.4	6.4	6.4000
F5	4.8	4.8	4.7	5.1	5.0	4.8800

Sodium (segregation):

	1	2	3	4	5	
A1	10.0	10.0	10.0	10.0	10.0	10.0000
A2	8.9	8.6	8.5	8.9	9.0	8.7800
A3	8.2	8.1	7.9	8.3	8.2	8.1400
A4	8.0	7.9	8.1	8.0	8.1	8.0200
A5	5.7	6.1	5.6	5.8	5.6	5.7600
B1	9.9	10.0	9.8	9.8	10.0	9.9000
B2	8.8	8.8	8.8	8.8	9.0	8.8400
B3	8.2	8.3	8.2	8.1	8.2	8.2000
B4	7.9	8.2	7.9	7.9	7.9	7.9600
B5	5.6	5.5	5.7	5.3	5.5	5.5200
C1	10.0	10.0	10.0	10.0	10.0	10.0000
C2	8.8	8.7	8.8	8.9	8.7	8.7800
C3	8.4	8.1	8.2	8.6	8.3	8.3200
C4	7.9	7.8	8.1	8.2	8.0	8.0000
C5	6.4	5.8	5.8	6.2	6.5	6.1400
D1	10.0	10.0	10.0	10.0	10.0	10.0000
D2	8.7	8.6	8.6	8.8	8.7	8.6800
D3	8.3	8.4	8.3	8.4	8.4	8.3600
D4	8.1	7.9	8.0	8.3	8.5	8.1600
D5	5.9	6.2	6.0	5.8	6.1	6.0000
E1	10.0	10.0	10.0	10.0	10.0	10.0000
E2	8.9	8.8	9.1	9.0	9.1	8.9800
E3	7.9	8.5	8.0	7.9	8.1	8.0800
E4	8.0	8.1	7.5	7.8	8.1	7.9000
E5	5.7	4.7	5.8	5.3	5.6	5.4200
F1	10.0	9.4	10.0	10.0	10.0	9.8800
F2	8.9	8.8	9.0	9.2	8.8	8.9400
F3	7.9	7.9	7.8	7.8	8.0	7.8800
F4	7.6	8.0	7.7	7.9	7.8	7.8000
F5	5.8	5.8	5.7	6.3	6.1	5.9400

Lead:

	1	2	3	4	5
A1	43	43	43	43	43
A2	43	44	44	46	46
A3	44	44	43	44	44
A4	44	43	45	43	44
A5	43	43	44	44	43
B1	45	44	44	46	44
B2	43	44	43	44	45
B3	43	43	43	45	44
B4	42	45	43	45	44
B5	43	43	44	44	45
C1	44	44	45	44	44
C2	45	44	45	44	44
C3	45	43	44	43	43
C4	43	46	44	43	43
C5	43	43	44	45	45
D1	44	43	44	45	44
D2	44	44	43	45	43
D3	44	44	44	45	44
D4	44	44	45	45	44
D5	43	44	44	45	44
E1	43	43	44	42	45
E2	42	43	44	44	45
E3	43	44	43	43	43
E4	45	45	44	44	45
E5	43	43	44	42	45
F1	44	43	44	46	45
F2	43	43	44	44	44
F3	42	43	43	42	44
F4	43	43	44	43	43
F5	44	44	44	44	44

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	32.293333	29	1.113563218	1.6061008	0.0402354	1.562071
Within groups	83.2	120	0.693333333			
Total	115.49333	149				
within-sd	0.8326664					
effective n	4.00					
s_{bb}	0.3241257					
u_{bb}^*	0.1495902					
u_{bb}	0.3241257					
$u_{bb}(\text{rel.})$	0.7395628					

Antimony

	1	2	3	4	5
A1	31	32	32	31	32
A2	32	33	32	31	33
A3	34	36	34	33	32
A4	34	36	34	34	34
A5	36	36	35	35	35
B1	33	33	33	34	34
B2	36	37	34	37	33
B3	33	32	33	31	35
B4	32	33	31	30	34
B5	36	34	34	32	32
C1	34	34	33	32	31
C2	34	33	33	32	32
C3	32	35	32	32	33
C4	33	32	34	33	32
C5	34	33	34	31	34
D1	32	34	33	31	32
D2	33	32	32	33	33
D3	32	34	31	33	32
D4	34	31	31	34	32
D5	35	33	32	33	32
E1	34	35	36	33	34
E2	35	37	33	34	34
E3	33	33	32	31	33
E4	34	34	32	32	33
E5	33	33	32	32	33
F1	33	33	32	32	33
F2	32	34	34	32	31
F3	34	33	33	34	32
F4	35	34	33	35	36
F5	34	33	34	33	34

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	133.8437	29	4.615300128	3.9509545	5.55222E-08	1.562071
Within groups	140.17778	120	1.168148148			
Total	274.02148	149				

within-sd	1.080809
effective n	4.00
s_{bb}	0.9283254
u_{bb}^*	0.1941696
u_{bb}	0.9283254
$u_{bb}(\text{rel.})$	2.7963479

Tin:

	1	2	3	4	5
A1	16	17	17	17	17
A2	16	17	16	17	17
A3	16	17	16	16	16
A4	17	16	16	16	16
A5	16	16	16	16	16
B1	16	16	16	17	17
B2	16	16	16	16	16
B3	17	17	16	17	16
B4	17	16	16	16	16
B5	16	15	17	16	16
C1	16	17	17	17	17
C2	17	17	17	17	16
C3	16	17	17	16	17
C4	16	17	16	17	16
C5	16	16	16	16	16
D1	16	16	16	16	16
D2	17	17	16	16	16
D3	17	16	16	17	17
D4	16	16	17	16	16
D5	16	16	16	16	16
E1	17	16	16	16	16
E2	17	16	16	16	16
E3	17	16	17	16	17
E4	17	17	16	17	16
E5	16	16	17	16	17
F1	16	16	16	16	16
F2	16	16	16	16	16
F3	16	16	16	16	16
F4	16	16	16	16	16
F5	16	16	16	16	17

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	11.5	29	0.396551724	2.1630094	0.0019805	1.562071
Within groups	22	120	0.183333333			
Total	33.5	149				
within-sd	0.4281744					
effective n	4.00					
s_{bb}	0.2308779					
u_{bb}^*	0.0769224					
u_{bb}	0.2308779					
$u_{bb}(\text{rel.})$	1.4164287					

Vanadium:

	1	2	3	4	5
A1	82	81	83	83	81
A2	81	82	82	82	82
A3	81	81	82	82	81
A4	82	82	82	84	82
A5	80	81	82	80	80
B1	81	81	90	84	84
B2	90	80	80	81	81
B3	81	82	81	81	82
B4	82	81	82	81	83
B5	81	82	82	84	82
C1	81	82	83	87	85
C2	80	84	82	81	85
C3	83	85	81	82	83
C4	82	81	82	82	84
C5	80	81	85	83	81
D1	87	81	81	82	82
D2	83	81	82	82	82
D3	81	83	82	84	89
D4	81	81	81	82	91
D5	81	82	81	81	81
E1	82	81	90	85	80
E2	84	83	81	81	81
E3	82	81	82	82	85
E4	82	82	81	93	82
E5	81	82	81	81	82
F1	81	80	84	80	81
F2	83	81	82	82	81
F3	80	82	82	80	87
F4	80	81	80	81	81
F5	80	81	81	82	81

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	128.8	29	4.44137931	0.8924406	0.6266545	1.562071
Within groups	597.2	120	4.976666667			
Total	726	149				
within-sd	2.2308444					
effective n	4.00					
s_{bb}	0					
u_{bb}^*	0.4007758					
u_{bb}	0.4007758					
$u_{bb}(\text{rel.})$	0.4875618					

Zirconium:

	1	2	3	4	5
A1	50	49	50	50	49
A2	49	50	49	50	49
A3	49	49	49	50	49
A4	49	49	49	50	49
A5	48	49	49	48	48
B1	49	49	51	50	50
B2	51	48	49	49	49
B3	49	50	49	50	50
B4	50	50	49	49	50
B5	50	49	50	51	50
C1	50	49	50	51	50
C2	49	50	50	50	50
C3	50	50	50	49	50
C4	50	49	49	49	50
C5	48	49	50	50	49
D1	49	49	49	50	50
D2	50	49	50	49	50
D3	49	49	49	50	50
D4	49	48	49	49	51
D5	49	49	49	50	49
E1	50	49	51	50	49
E2	50	50	49	49	49
E3	49	49	50	49	50
E4	49	50	49	52	50
E5	49	50	50	50	50
F1	49	48	50	48	49
F2	50	49	49	50	50
F3	49	49	49	49	51
F4	49	49	49	50	49
F5	49	50	50	50	49

Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value
Between groups	18.133333	29	0.625287356	1.3593203	0.1278612	1.562071
Within groups	55.2	120	0.46			
Total	73.333333	149				
within-sd	0.678233					
effective n	4.00					
s_{bb}	0.2032777					
u^*_{bb}	0.121846					
u_{bb}	0.2032777					
$u_{bb}(\text{rel.})$	0.4109388					

Annex 2: Calculation of uncertainty contribution of potential inhomogeneity (area)

(u_{bb} (rel.) here means u_{bb} (rel) Area in Table 40)

The number of degrees of freedom (effective n) is calculated using the following equation

$$n = \frac{\sum_i g_i - (\sum_i g_i^2 / \sum_i g_i)}{i}$$

with

g_i = number of sparks per circle

i = number of circles (= 4: Centre, Inner, Middle, Outer)

Silicon:

Centre	1448.9	1455.2	1459.3						
Inner	1455.4	1453.7	1461.5	1457.9	1450.6	1450.0	1455.4	1451.5	
Middle	1463.3	1457.3	1447.8	1451.5	1448.3	1452.6	1446.9	1452.6	
Outer	1476.9	1476.4	1466.4	1459.7	1466.5	1472.0	1459.0	1461.4	
<i>Source of variation</i>	<i>sums of squares (SS)</i>	<i>degrees of freedom (df)</i>	<i>Mean squares (MS)</i>	<i>F-value</i>	<i>P-value</i>	<i>critical F-value</i>			
Between groups	1061.855463	3	353.951821	11.09243	0.0001059	3.0279984			
Within groups	733.9141667	23	31.90931159						
Total	1795.76963	26							
within-sd	5.648833								
effective n	6.52								
s_{bb}	7.028816								
u^*_{bb}	1.201461								
u_{bb}	7.028816								
$u_{bb}(\text{rel.})$	0.482184								

Iron:

Centre	10003.9	10079.0	10092.5					
Inner	10064.3	10060.1	10098.8	10054.8	9940.2	10059.4	9913.8	10174.7
Middle	9929.6	9963.4	10056.6	9796.2	9890.5	9979.1	10012.3	10098.2
Outer	9824.2	9881.3	9985.2	9969.4	9985.1	9927.6	9901.7	9977.9
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Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	70989.91427	3	23663.30476	3.845735	0.0228752	3.0279984		
Within groups	141521.9748	23	6153.129339					
Total	212511.8891	26						
within-sd	78.441885							
effective n	6.52							
s_{bb}	51.828757							
u^*_{bb}	16.683959							
u_{bb}	51.828757							
$u_{bb}(\text{rel.})$	0.518826							

Copper:

Centre	171.2	172.2	172.1					
Inner	171.8	173.5	174.5	171.8	170.3	174.0	170.3	173.5
Middle	171.6	172.3	174.4	177.6	171.0	171.8	170.4	173.9
Outer	170.0	170.7	176.9	171.9	176.5	172.0	171.2	173.9
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Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	3.136018519	3	1.045339506	0.2270993	0.8765613	3.0279984		
Within groups	105.8691667	23	4.603007246					
Total	109.0051852	26						
within-sd	2.145462							
effective n	6.52							
s_{bb}	0.000000							
u^*_{bb}	0.456323							
u_{bb}	0.456323							
$u_{bb}(\text{rel.})$	0.264319							

Manganese:

Centre	475.6	474.1	474.2					
Inner	475.8	474.2	474.6	474.0	475.0	474.1	474.4	474.5
Middle	480.4	477.0	475.1	476.6	472.9	474.0	475.3	475.4
Outer	485.6	481.2	476.6	478.8	477.2	480.5	475.6	475.3
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Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	86.1498	3	28.7166	5.325890589	0.0061888	3.0279984		
Within groups	124.0134	23	5.391886957					
Total	210.1632	26						
within-sd	2.322044							
effective n	6.52							
s_{bb}	1.891619							
u^*_{bb}	0.493880							
u_{bb}	1.891619							
$u_{bb}(\text{rel.})$	0.397210							

Magnesium:

Centre	168.0	168.7	167.2					
Inner	167.0	167.1	168.4	167.9	165.5	166.6	165.4	169.5
Middle	166.9	166.5	169.0	162.8	165.4	166.3	166.8	168.9
Outer	164.4	165.1	167.1	166.4	166.1	165.5	165.2	167.2
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Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	12.18833333	3	4.062777778	1.9073425	0.1565813	3.0279984		
Within groups	48.99166667	23	2.130072464					
Total	61.18	26						
within-sd	1.459477							
effective n	6.52							
s_{bb}	0.544513							
u^*_{bb}	0.310419							
u_{bb}	0.544513							
$u_{bb}(\text{rel.})$	0.326643							

Chromium:

Centre	83.2	83.7	85.3					
Inner	84.7	83.2	83.8	84.0	82.0	82.7	81.8	83.9
Middle	84.2	81.7	82.7	82.5	83.3	83.0	82.7	83.0
Outer	84.4	83.3	82.4	84.2	85.1	84.5	83.3	84.3
Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	5.220185185	7	0.745740741	0.7377805	0.6433148	2.5435343		
Within groups	19.205	19	1.010789474					
Total	24.42518519	26						
within-sd	1.005380							
effective n	6.52							
s_{bb}	0.000000							
u^*_{bb}	0.224298							
u_{bb}	0.224298							
$u_{bb}(\text{rel.})$	0.268811							

Nickel:

Centre	74.5	71.6	72.1					
Inner	75.7	70.5	72.8	70.4	71.4	71.0	72.8	72.3
Middle	73.3	73.3	72.1	73.3	70.5	74.4	71.3	73.7
Outer	74.1	73.4	73.0	72.2	72.8	71.2	72.5	70.5
Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	19.1162963	7	2.730899471	1.7169785	0.1646976	2.5435343		
Within groups	30.22	19	1.590526316					
Total	49.3362963	26						
within-sd	1.261161							
effective n	6.52							
s_{bb}	0.418263							
u^*_{bb}	0.281362							
u_{bb}	0.418263							
$u_{bb}(\text{rel.})$	0.577150							

Zinc:

Centre	284.2	274.1	282.7					
Inner	286.3	282.2	279.8	279.3	283.1	281.2	275.2	278.2
Middle	293.1	283.2	284.6	280.6	283.2	287.6	284.8	284.0
Outer	283.7	275.9	275.0	279.4	280.7	289.6	289.6	278.8
<i>Source of variation</i>	<i>sums of squares (SS)</i>	<i>degrees of freedom (df)</i>	<i>Mean squares (MS)</i>	<i>F-value</i>	<i>P-value</i>	<i>critical F-value</i>		
Between groups	219.3401852	7	31.33431217	1.7431822	0.158476	2.5435343		
Within groups	341.5316667	19	17.97535088					
Total	560.8718519	26						
within-sd	4.239735							
effective n	6.52							
s_{bb}	1.431568							
u^*_{bb}	0.945874							
u_{bb}	1.431568							
$u_{bb}(\text{rel.})$	0.507242							

Titanium:

Centre	179.7	179.1	174.0					
Inner	181.8	178.5	183.6	179.1	182.1	177.6	185.1	174.3
Middle	187.5	183.9	186.6	180.6	180.9	174.6	171.6	171.6
Outer	190.2	190.2	180.6	186.0	183.0	181.5	187.2	177.0
<i>Source of variation</i>	<i>sums of squares (SS)</i>	<i>degrees of freedom (df)</i>	<i>Mean squares (MS)</i>	<i>F-value</i>	<i>P-value</i>	<i>critical F-value</i>		
Between groups	241.9125	7	34.55892857	1.4365294	0.2485182	2.5435343		
Within groups	457.0875	19	24.05723684					
Total	699	26						
within-sd	4.904818							
effective n	6.52							
s_{bb}	1.269273							
u^*_{bb}	1.094252							
u_{bb}	1.269273							
$u_{bb}(\text{rel.})$	0.701127							

Boron:

Centre	7.41	8.13	8.40					
Inner	7.29	7.40	7.11	7.69	7.57	7.27	7.76	8.01
Middle	7.04	7.38	7.32	7.66	7.05	7.24	5.41	8.71
Outer	7.40	8.47	7.46	7.31	7.44	7.67	7.75	7.44
Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	2.542761574	7	0.363251653	1.0191224	0.449463	2.5435343		
Within groups	6.772279167	19	0.356435746					
Total	9.315040741	26						
within-sd	0.597022							
effective n	6.52							
s_{bb}	0.032336							
u^*_{bb}	0.133194							
u_{bb}	0.133194							
$u_{bb}(\text{rel.})$	1.773908							

Beryllium:

Centre	5.80	5.78	5.83					
Inner	5.90	5.86	5.86	5.85	5.83	5.82	5.79	5.82
Middle	5.97	5.98	5.99	5.94	5.94	5.95	5.94	5.96
Outer	6.04	6.04	6.02	6.00	6.04	6.02	6.01	6.01
Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	0.00132963	7	0.000189947	0.0180917	0.9999922	2.5435343		
Within groups	0.199483333	19	0.010499123					
Total	0.200812963	26						
within-sd	0.102465							
effective n	6.52							
s_{bb}	0.000000							
u^*_{bb}	0.022860							
u_{bb}	0.022860							
$u_{bb}(\text{rel.})$	0.385951							

Bismuth:

Centre	12.78	13.20	8.64					
Inner	9.06	14.08	12.77	12.32	15.25	15.10	13.18	17.58
Middle	14.09	15.50	13.90	12.45	13.25	10.36	10.58	15.28
Outer	13.36	13.56	11.17	8.49	12.04	12.35	11.69	10.83
<i>Source of variation</i>	<i>sums of squares (SS)</i>	<i>degrees of freedom (df)</i>	<i>Mean squares (MS)</i>	<i>F-value</i>	<i>P-value</i>	<i>critical F-value</i>		
Between groups	35.48643241	7	5.069490344	1.1022787	0.4009524	2.5435343		
Within groups	87.38290833	19	4.599100439					
Total	122.8693407	26						
within-sd	2.144551							
effective n	6.52							
s_{bb}	0.268630							
u^*_{bb}	0.478444							
u_{bb}	0.478444							
$u_{bb}(\text{rel.})$	3.767715							

Calcium:

Centre	20.95	22.59	20.34					
Inner	20.78	20.86	20.73	20.52	20.18	20.68	20.02	20.50
Middle	20.64	20.09	20.96	20.48	20.70	21.06	20.03	21.75
Outer	19.85	20.11	20.19	19.64	20.94	20.17	19.82	20.32
<i>Source of variation</i>	<i>sums of squares (SS)</i>	<i>degrees of freedom (df)</i>	<i>Mean squares (MS)</i>	<i>F-value</i>	<i>P-value</i>	<i>critical F-value</i>		
Between groups	2.236199074	7	0.319457011	0.7925722	0.6025603	2.5435343		
Within groups	7.658208333	19	0.403063596					
Total	9.894407407	26						
within-sd	0.634873							
effective n	6.52							
s_{bb}	0.000000							
u^*_{bb}	0.141639							
u_{bb}	0.141639							
$u_{bb}(\text{rel.})$	0.689177							

Cadmium:

Centre	25.60	24.06	25.05					
Inner	24.65	24.73	24.30	25.65	21.94	24.16	25.20	23.57
Middle	24.33	23.11	24.45	24.26	24.46	23.46	24.25	24.83
Outer	22.47	26.70	25.10	26.05	24.71	28.70	23.78	27.35
Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	7.731822917	7	1.104546131	0.4799382	0.8372603	2.5435343		
Within groups	43.72724375	19	2.301433882					
Total	51.45906667	26						
within-sd	1.517048							
effective n	6.52							
s_{bb}	0.000000							
u^*_{bb}	0.338450							
u_{bb}	0.338450							
$u_{bb}(\text{rel.})$	1.370272							

Cobalt:

Centre	25.46	23.52	24.40					
Inner	26.36	25.64	24.36	24.88	25.18	25.58	23.86	22.78
Middle	27.84	25.26	26.86	25.18	26.64	27.44	24.92	25.54
Outer	26.76	25.22	24.90	25.40	26.04	27.38	27.38	24.96
Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	16.30888519	7	2.329840741	1.845952	0.1362849	2.5435343		
Within groups	23.98056667	19	1.262135088					
Total	40.28945185	26						
within-sd	1.123448							
effective n	6.52							
s_{bb}	0.404717							
u^*_{bb}	0.250638							
u_{bb}	0.404717							
$u_{bb}(\text{rel.})$	1.584272							

Gallium:

Centre	121.00	121.70	119.30					
Inner	120.20	120.40	120.10	120.10	121.00	121.20	120.10	121.10
Middle	119.50	120.50	120.10	120.00	120.20	120.60	119.50	121.40
Outer	119.20	118.30	119.70	118.00	118.40	119.20	118.60	119.90
Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)				critical F-value	
Between groups	4.936851852	7	0.70526455	0.6973732	0.6739351	2.5435343		
Within groups	19.215	19	1.011315789					
Total	24.15185185	26						
within-sd	1.005642							
effective n	6.52							
s_{bb}	0.000000							
u^*_{bb}	0.224356							
u_{bb}	0.224356							
$u_{bb}(\text{rel.})$	0.187004							

Mercury:

Centre	23.42	23.33	23.29					
Inner	21.70	23.22	22.52	22.77	25.50	23.12	23.81	24.95
Middle	22.87	25.85	23.69	23.05	22.35	24.54	23.50	22.88
Outer	21.81	23.03	21.37	23.46	21.21	22.79	22.05	21.41
Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	5.036017824	7	0.719431118	0.4481672	0.859217	2.5435343		
Within groups	30.50020625	19	1.605274013					
Total	35.53622407	26						
within-sd	1.266994							
effective n	6.52							
s_{bb}	0.000000							
u^*_{bb}	0.282663							
u_{bb}	0.282663							
$u_{bb}(\text{rel.})$	1.224190							

Lithium:

Centre	6.35	6.44	6.39					
Inner	6.32	6.43	6.37	6.43	6.36	6.38	6.33	6.32
Middle	6.34	6.30	6.40	6.38	6.24	6.38	6.25	6.29
Outer	6.23	6.26	6.22	6.24	6.25	6.28	6.18	6.27
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Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	0.03285463	7	0.004693519	0.8688173	0.5479237	2.5435343		
Within groups	0.102641667	19	0.005402193					
Total	0.135496296	26						
within-sd	0.073500							
effective n	6.52							
s_{bb}	0.000000							
u_{bb}^*	0.016398							
u_{bb}	0.016398							
$u_{bb}(\text{rel.})$	0.259471							

Sodium:

Centre	4.89	4.80	4.86					
Inner	5.07	4.83	4.89	4.74	4.83	4.98	4.89	4.68
Middle	5.10	4.92	4.74	4.98	4.80	4.83	4.92	4.98
Outer	4.77	4.98	4.53	4.68	4.74	4.83	4.86	4.86
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Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	0.112616667	7	0.016088095	1.0531397	0.4290891	2.5435343		
Within groups	0.29025	19	0.015276316					
Total	0.402866667	26						
within-sd	0.123597							
effective n	6.52							
s_{bb}	0.011159							
u_{bb}^*	0.027574							
u_{bb}	0.027574							
$u_{bb}(\text{rel.})$	0.568411							

Lead:

Centre	45.15	44.40	44.95					
Inner	46.15	45.25	44.90	45.20	44.90	44.65	44.60	44.30
Middle	46.65	45.85	46.10	45.35	45.45	46.50	45.75	45.55
Outer	46.75	47.30	46.25	46.05	45.95	46.30	45.70	45.60
Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	2.400462963	7	0.34292328	0.516594	0.8109317	2.5435343		
Within groups	12.6125	19	0.663815789					
Total	15.01296296	26						
within-sd	0.814749							
effective n	6.52							
s_{bb}	0.000000							
u^*_{bb}	0.181768							
u_{bb}	0.181768							
$u_{bb}(\text{rel.})$	0.398502							

Antimony

Centre	59.80	50.70	60.10					
Inner	38.47	53.40	59.00	50.50	39.45	48.77	45.06	51.00
Middle	53.00	55.50	51.70	71.20	51.90	55.00	46.23	46.28
Outer	66.20	62.90	49.35	50.70	46.19	61.60	58.40	63.30
Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	300.2586833	7	42.89409762	0.628084	0.7269694	2.5435343		
Within groups	1297.577783	19	68.29356754					
Total	1597.836467	26						
within-sd	8.263992							
effective n	6.52							
s_{bb}	0.000000							
u^*_{bb}	1.843676							
u_{bb}	1.843676							
$u_{bb}(\text{rel.})$	3.443262							

Tin:

Centre	19.20	17.67	17.67					
Inner	18.50	18.23	19.53	18.87	19.50	18.50	18.20	19.17
Middle	18.97	19.40	18.87	18.63	20.07	17.50	18.77	19.93
Outer	19.50	19.33	19.07	18.53	18.93	18.60	18.23	18.97
Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	4.295823045	7	0.613689006	1.72377945	0.16305956	2.5435343		
Within groups	6.764259259	19	0.356013645					
Total	11.0600823	26						
within-sd	0.596669							
effective n	6.52							
s_{bb}	0.198821							
u^*_{bb}	0.133115							
u_{bb}	0.198821							
$u_{bb}(\text{rel.})$	1.056032							

Vanadium:

Centre	74.3	75.1	76.3					
Inner	76.8	76.1	76.0	73.6	77.2	75.0	76.8	76.1
Middle	75.9	74.4	76.0	75.3	75.5	76.2	74.5	77.6
Outer	75.3	80.3	77.1	77.4	76.5	77.2	75.6	75.6
Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	4.418981481	7	0.631283069	0.2916037	0.9490303	2.5435343		
Within groups	41.13245885	19	2.164866255					
Total	45.55144033	26						
within-sd	1.471348							
effective n	6.52							
s_{bb}	0.000000							
u^*_{bb}	0.328254							
u_{bb}	0.328254							
$u_{bb}(\text{rel.})$	0.431563							

Zirconium:

Centre	68.30	67.20	65.80					
Inner	69.40	65.60	67.60	65.70	66.90	66.40	67.20	67.20
Middle	67.20	67.70	67.30	68.10	65.60	67.30	66.80	68.60
Outer	69.00	69.60	65.70	67.10	67.20	65.70	66.00	65.80
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Source of variation	sums of squares (SS)	degrees of freedom (df)	Mean squares (MS)	F-value	P-value	critical F-value		
Between groups	11.985	7	1.712142857	1.3452635	0.2837799	2.5435343		
Within groups	24.18166667	19	1.272719298					
Total	36.16666667	26						
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within-sd	1.128149							
effective n	6.52							
s_{bb}	0.259637							
u^*_{bb}	0.251687							
u_{bb}	0.259637							
$u_{bb}(\text{rel.})$	0.386877							