

CERTIFICATION ADDITIONS TYPE II FOR CONCRETE

- FLY ASH FOR CONCRETE

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INTERLABORATORY TESTING CAMPAIGN

FLY ASH 2023-2025

Final Report



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1 Introduction

The Round Robin testing campaign on fly ash for concrete, edition 2023-2025, was organized by PROCERTUS and KIWA. This renowned campaign has been organized for more than 10 years and is an important reference in the field of testing fly ash for concrete.

Participants in this Round Robin testing campaign gain many benefits, such as:

- an assessment and monitoring during the entire campaign of the performance of their laboratory, by repeating tests on the same sample.
- a comparison of their results to those of many other specialized laboratories by using the reports that PROCERTUS publishes periodically.
- the detection of possible deviations that might occur in their laboratory or to identify any potential for improvement.

Stakeholders not participating in the Round Robin testing campaign, such as certification bodies, research institutes, and users of fly ash for concrete, also find interesting information in this report, such as improved understanding of the variability of test results and their influencing factors, and reliable information on the confidence interval for several tests.

The 2023-2025 campaign started in November 2023 and ended in October 2025.

2 Description of the sample

A reference cement sample of type CEM I 52,5 R and a fly ash sample originated from pure coal combustion has been the subject of this Round Robin testing.

A 6 kg barrel of fly ash was sent to the laboratories that perform “chemical testing”.

A pallet containing 3 barrels of 6 kg of fly ash and 2 bags of 25 kg of cement was sent to the laboratories that perform “mechanical testing”.

The participants had been given the responsibility to store the containers in such a way that they are protected from any condition that could affect the stability of the products, e.g. temperature fluctuations that could cause condensation.

3 Test program

This Round Robin testing campaign bears on testing of fly ash using test methods and calculations of the European standards of the EN 196 series, EN 197-1, EN 451-1, EN 451-2, EN 933-10, EN 1097-7 and ISO 29581-2 or - in case the relevant standard allows for it - test methods that have been proven to be equivalent.

The participating labs have been asked to introduce the samples into their normal testing routine, without giving them any special preferential treatment, to ensure that the test results are representative of the performance of the laboratory.

3.1 Chemical Testing

The following chemical tests are concerned:

1) A series of 24 evaluations for the following tests:

- Loss on ignition.
- Sieve residue of 45 µm.

2) A series of 12 evaluations for the following tests:

- total CaO.
- free CaO.
- chloride.
- SO₃.
- SiO₂.
- Al₂O₃.
- Fe₂O₃.
- Na₂O.
- K₂O.
- MgO.
- P₂O₅ total.

3.2 Mechanical Testing

At the beginning and at the 13th month of the testing campaign, the following mechanical characteristics had to be determined:

- Activity index: test with reference cement at 28 and 90 days.
- Initial setting time of the reference cement.

Every two months, with a total of twelve tests, the following tests were executed:

- Activity index: test performed with 75% cement and 25 % fly ash at 28 and 90 days respectively.
- Initial setting time.
- Volumetric mass.

Table 2: Overview of Tests

Chemical characteristics	
Characteristic	Test Method
Loss on Ignition (LOI)	EN 196-2:2013
Sulphate (SO ₃) content	EN 196-2:2013
Free calcium oxide (CaO)	EN 451-1:2017
Total calcium oxide CaO	EN 196-2:2013
Silicon dioxide (SiO ₂), aluminium oxide (Al ₂ O ₃) and iron oxide (Fe ₂ O ₃)	EN 196-2:2013
Total content of alkalis	EN 196-2:2013
Magnesium oxide (MgO)	EN 196-2:2013
Total Phosphate (P ₂ O ₅)	ISO 29581-2:2010

Mechanical characteristics	
Characteristic	Test Method
Compressive strength (28d and 90d)	EN 196-1:2016
Fineness (sieve residue 45 µm)	EN 451-2:2017 or EN 933-10:2009
Activity index (28d and 90d)	EN 196-1:2016
Soundness	EN 196-3:2016
Particle density	EN 1097-7:2022
Initial setting time	EN 196-3:2016

4 Statistical processing of the test results

4.1 Reporting graphs

For each characteristic, a set of graphs and tables has been prepared to present the results in a transparent way. The set of default graphs and tables is as follows:

- Table with the processed results of every lab. This table comprises the number of test results, the mean, standard deviation and median for each lab for the specific characteristic, the calculated z-scores (see 5.2), the variance coefficient (see 5.3) and the minimum and maximum values.
- In this table, some min and max values are coloured red, which means that these results are not compliant with the requirements in EN 450-1 for this type of fly ash. To draw the attention, the calculated z-scores are marked in yellow if exceeding 2, and in red if exceeding 3.
- Graph with, for each lab, the minimum and maximum value, as well as the mean value for the lab for the specific characteristic. As an additional information, the overall mean value of all results of all labs is added.
- Graph with, for each lab, the mean value and the standard deviation for the lab for the specific characteristic. As an additional information, the overall mean value of all results of all labs is added, as well as the values of 1.5 and 2 times the standard deviation of all results of all labs, denoted as $\pm 1.5S$ and $\pm 2S$.

For some characteristics, adapted graphs or information were added, when assumed relevant for better understanding.

4.2 Calculation of the z-scores

Two different types of z-scores are calculated.

The first one, z-score (1) is calculated as follows:

$$\frac{Mean_{Lab} - Mean_{General}}{st.dev_{General}}$$

Where

- $Mean_{Lab}$ is the average of all results supplied by lab xxx for the specific test.
- $Mean_{General}$ is the average of all results supplied by all the labs for the specific test.

- St. dev_{General} is the standard deviation of all results supplied by all the labs for the specific test.

The second one, z-score (2) is calculated as follows:

$$\frac{Mean_{Lab} - Mean_{Avg Labs}}{st. dev_{Avg Labs}}$$

Were

- Mean_{Lab} is the average of all results supplied by lab xxx for the specific test.
- Mean_{Avg Labs} is the average calculated out of the averages per lab (regardless the number of individual test results per lab).
- St. dev_{Avg Labs} is the standard deviation calculated out of the averages per lab.

4.3 Calculation of the variance coefficient

The variance coefficient is calculated as follows:

$$\left(\frac{st. dev_{Lab}}{Mean_{Lab}} \right) * 100$$

Were

- St. dev_{Lab} is the standard deviation of all results supplied by lab xxx for the specific test.
- Mean_{Lab} is the average of all results supplied by lab xxx for the specific test.

4.4 Treatment of Outliers

Outliers are calculated using the Grubbs outlier method.

Calculations are made as follows:

$$\frac{Lab_{Max} - Mean_{Lab}}{st. dev_{Lab}} = outlier_{Lab_{Max}}$$

$$\frac{Mean_{Lab} - Lab_{Min}}{st. dev_{Lab}} = outlier_{Lab_{Min}}$$

Were

- Lab_{Max} is the maximum result supplied by lab xxx for the specific test.
- Lab_{Min} is the minimum result supplied by lab xxx for the specific test.
- Mean_{Lab} is the average of all results supplied by lab xxx for the specific test.
- St. dev_{Lab} is the standard deviation of all results supplied by lab xxx for the specific test.
- Outlier_{LabMax} is the calculated Grubbs value.
- Outlier_{LabMin} is the calculated Grubbs value.

Both calculated Grubbs values are checked against the critical Grubbs value (Grubbs table) with a certainty of 99 %. If one of the calculated values is higher than the critical value, the supplied value will be rejected from the result, if the lab supplied us with at least 13 results for that specific test.

If there are less than 13 results, outlier calculations are not considered and results are not dismissed.

Table 3 gives the complete overview of rejected values per lab due to the above-mentioned procedure of outlier rejection.

Table 3: dismissed values due to outlier calculation

Test	Mean all labs $\bar{X}$	standard deviation all labs s	Dismissed lab	Critical value Grubbs method	Measured value	calculated value Grubbs method
Fineness 45 μm	16.74	0.91	103	3.0866	21.4	4.1120
				3.0599	15.9	3.1010
Total CaO	3.211	0.222	101	3.1117	3.28	3.3685
SO ₃	0.543	0.179	103	3.0866	0.78	4.2775
Na ₂ O	1.369	0.065	103	3.0866	2.1	4.5835
Compressive strength 28 days	56.54	1.98	101	3.8763	46.2	5.5930
			117	3.5985	50.0	4.0700
Compressive strength 90 days	71.77	2.44	101	3.8763	63.4	4.8421
Activity index 90 days	93.46	3.55	101	3.1117	87.809	3.2773

5 Results

5.1 Overview of mean values and standard deviation

An overview of the mean value and standard deviation of each characteristic is given in table 4. Also, the number of test results is given, to give an indication on the statistical validity of the results. This information is also given for each individual laboratory per characteristic in the next paragraphs.

Table 4: Overview of overall mean value and standard deviation for each characteristic.

Test	Unit	Mean $\bar{X}$	standard deviation s	number of results n
Compressive strength 28 days	MPa	56.54	1.98	111
Activity index 28 days	%	80.86	3.21	106
Compressive strength 90 days	MPa	71.77	2.44	104
Activity index 90 days	%	93.46	3.55	98

Test	Unit	Mean $\bar{X}$	standard deviation s	number of results n
Initial setting time	min	153.1	19.7	103
Particle density	kg/m ³	2336.4	37.1	98
Fineness: Sieve residue 45 µm	%	16.74	0.91	211
Total CaO	%	3.211	0.222	100
Free CaO	%	0.285	0.111	104
Loss on Ignition	%	2.259	0.166	252
SO ₃	%	0.543	0.179	117
SiO ₂	%	60.089	1.297	101
Al ₂ O ₃	%	19.742	0.855	101
Fe ₂ O ₃	%	7.904	0.297	101
Na ₂ O	%	1.369	0.065	94
K ₂ O	%	2.121	0.063	95
P ₂ O ₅ (total)	%	0.221	0.053	101
MgO	%	2.461	0.089	89

5.2 Comments on specific tests

5.2.1 Strength development & Activity index

The overall mean compressive strength at 28 days and 90 days with their corresponding standard deviations are 56.54 ± 1.98 MPa and 71.77 ± 2.44 MPa, respectively.

The overall activity index at 28 days and 90 days with their corresponding standard deviations are $80.86 \pm 3.21\%$ and $93.46 \pm 3.55\%$, respectively.

5.2.2 Other mechanical characteristics

The overall initial setting time is 153.1 ± 19.7 min. Except for lab 120 (164.2 ± 36.8 min), the value of the mean $\pm$ the standard deviation for all labs lies within the $\pm 1.5S$ -range.

The overall mean particle density is 2336.4 ± 37.1 kg/m³. Except for lab 101 (2291.0 ± 32.78 kg/m³) all participating labs found similar results for this characteristic.

The overall mean fineness (sieve residue 45 μm) is $16.74 \pm 0.90\%$. Lab 110 is the only lab that reported an average value for this characteristic (slightly) outside of the $\pm 1.5S$ -range respectively.

5.2.3 Total and free CaO

The overall total CaO has an average value and standard deviation of $3.211 \pm 0.222\%$, whereas for the free CaO, this value amounts $0.285 \pm 0.111\%$. For the total CaO, the reported standard deviation of lab 105 is significantly (4.010%) larger than the reported standard deviation of the other labs. For the free CaO, only lab 107 reported an average value outside of the $\pm 1.5S$ -range, namely 0.081%.

5.2.4 Loss on Ignition

Based on all received data, the overall mean loss on ignition has a value of $2.259 \pm 0.166\%$. Lab 109 reported a significantly lower value of $1.735 \pm 0.016\%$ for this characteristic, compared to the other participating labs. This reported value lies even outside of the $\pm 2S$ -range.

5.2.5 Chemical Analysis

The overall SO_3 -content is $0.543 \% \pm 0.179\%$. Except for lab 103, whose value falls outside the $\pm 1.5S$ -range, all participating laboratories reported similar values.

The overall SiO_2 -content is $60.089 \pm 1.297\%$. All mean values of the individual laboratories stayed within the $\pm 1.5S$ -range.

The overall Al_2O_3 -content is $19.742 \pm 0.855\%$. All mean values of the individual laboratories stayed within the $\pm 1.5S$ -range for this characteristic.

The overall Fe_2O_3 -content is $7.904 \pm 0.297\%$. Except for lab 103, whose mean value falls outside the $\pm 1.5S$ -range, all participating laboratories reported similar values.

The overall Na_2O -content is $1.369 \pm 0.065\%$. Except for lab 102, all mean values of the individual laboratories stayed within the $\pm 1.5S$ -range.

The overall K_2O -content is $2.121 \pm 0.063\%$. All mean values of the individual laboratories stayed within the $\pm 1.5S$ -range for this characteristic.

The overall P_2O_5 -content is $0.221 \pm 0.053\%$. Disregarding lab 103 whose results fall slightly outside of the $\pm 1.5S$ -range, all results fall within the $\pm 1.5S$ -range.

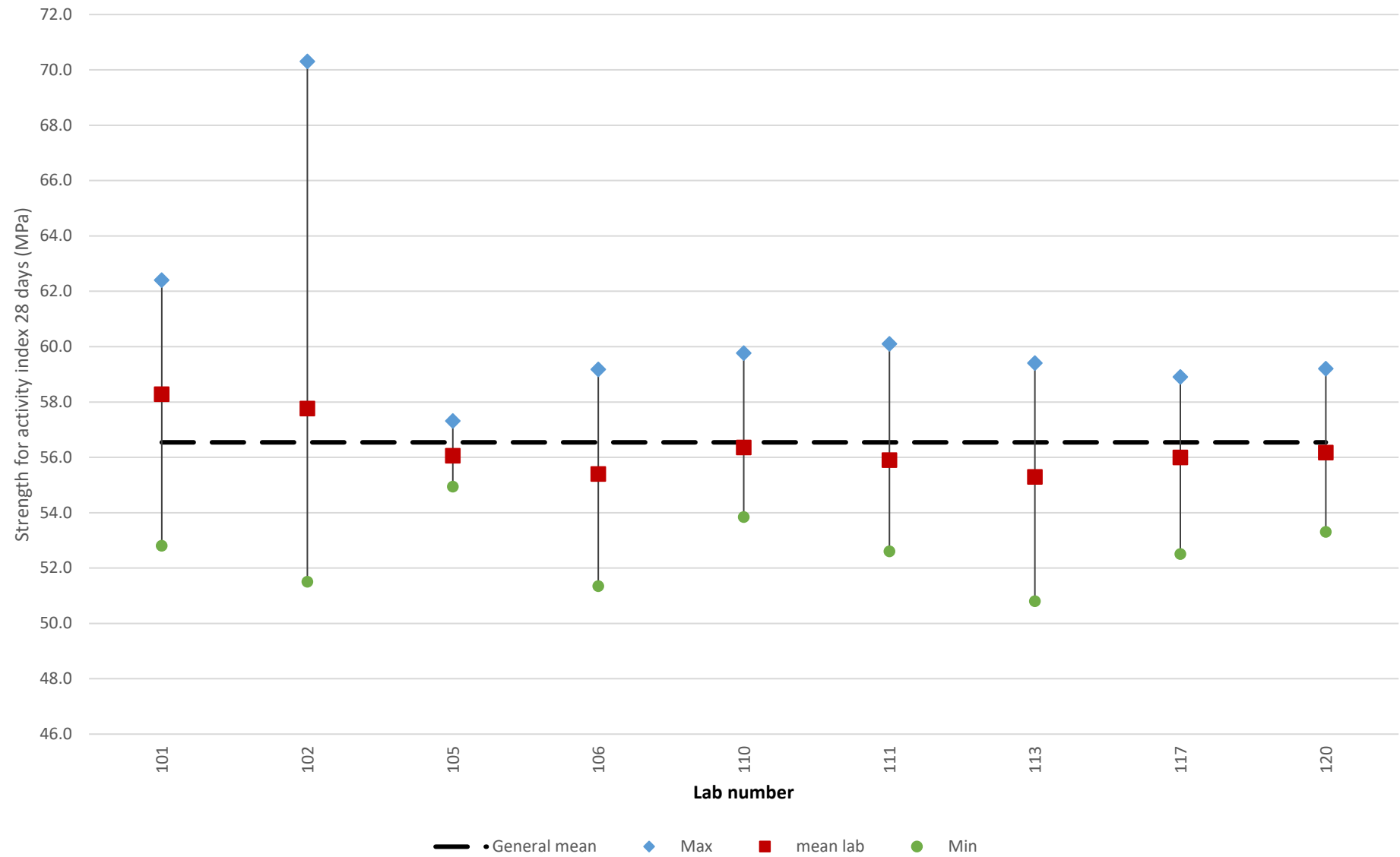
The overall MgO-content is $2.461 \pm 0.089\%$. Except for lab 102 whose reported mean value falls slightly outside of the $\pm 1.5S$ -range, all participating laboratories reported similar values.

5.3 Distribution of test results

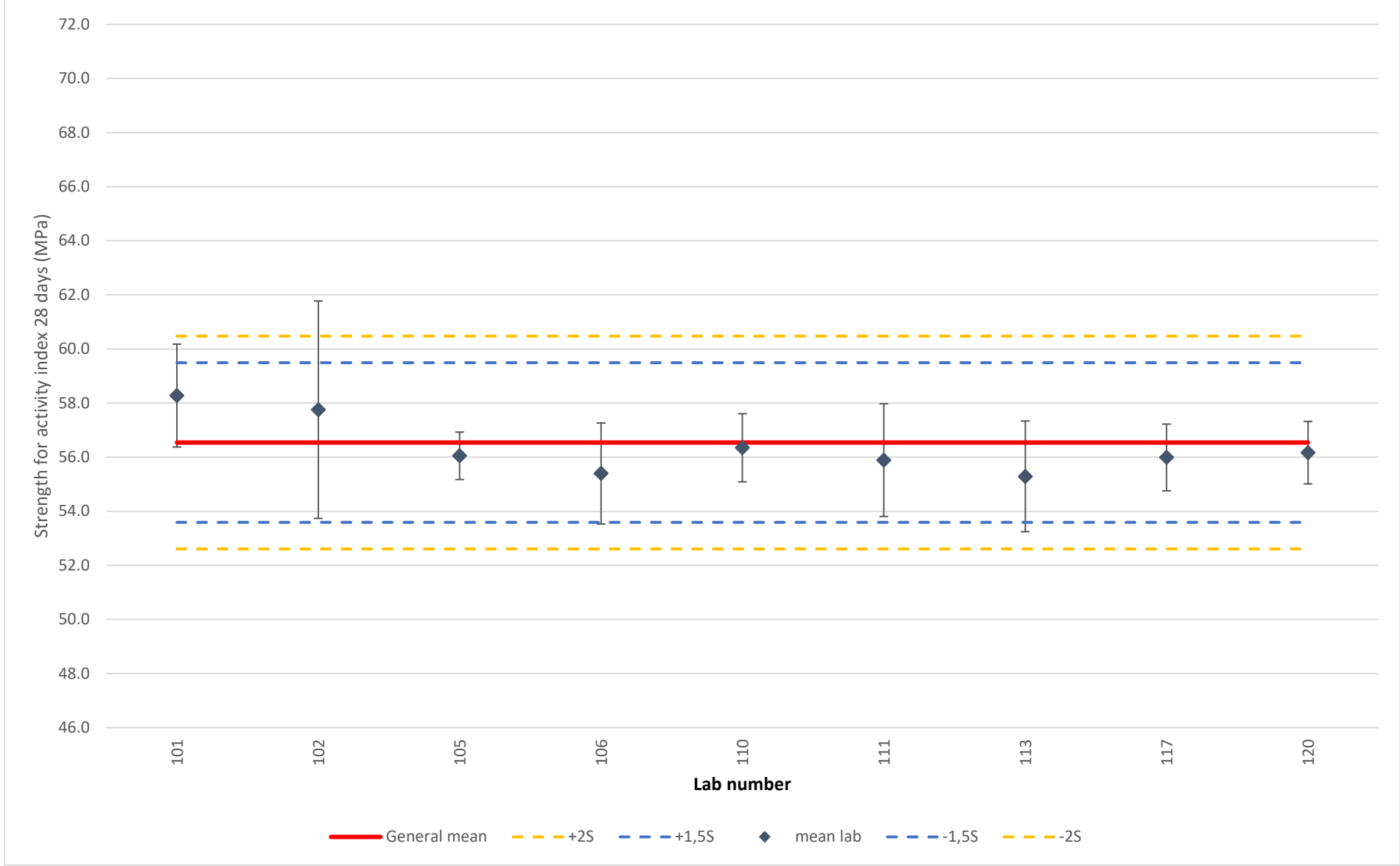
The final pages of the report give the distribution of all the test results for each characteristic.

Compressive strength 28 days (MPa)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	112	56.54	1.97			3.478	70.3	50.8
101	143	58.28	1.90	0.88	2.02	3.264	62.4	52.8
102	54	57.76	4.02	0.62	1.47	6.959	70.3	51.5
105	6	56.05	0.88	-0.25	-0.32	1.565	57.3	54.9
106	72	55.40	1.87	-0.58	-1.00	3.370	59.2	51.3
110	66	56.35	1.26	-0.10	0.00	2.235	59.8	53.8
111	144	55.89	2.08	-0.33	-0.48	3.726	60.1	52.6
113	42	55.29	2.05	-0.64	-1.11	3.701	59.4	50.8
117	71	55.99	1.23	-0.28	-0.38	2.204	58.9	52.5
120	72	56.17	1.15	-0.19	-0.19	2.056	59.2	53.3
Activity index 28 days (%)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	107	80.88	3.20			3.955	94.0	73.0
101	24	82.52	2.36	0.51	0.96	2.863	87.1	77.9
102	4	81.64	7.75	0.24	0.54	9.492	94.0	73.0
105	1	78.16		-0.85	-1.14		78.2	78.2
106	12	83.51	2.84	0.82	1.44	3.396	86.8	78.9
110	11	81.48	1.41	0.19	0.46	1.734	84.6	79.5
111	24	79.16	1.87	-0.54	-0.66	2.364	82.2	75.0
113	7	77.70	3.20	-0.99	-1.36	4.122	83.4	73.3
117	12	82.31	1.19	0.45	0.86	1.444	84.8	80.0
120	12	78.25	1.26	-0.82	-1.10	1.605	81.3	76.2
Compressive strength 90 days (MPa)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	106	71.77	2.42			3.368	78.2	55.8
101	143	73.34	1.87	0.65	1.44	2.551	77.2	66.6
102	54	73.04	2.19	0.53	1.20	3.003	77.5	68.3
106	72	69.68	3.23	-0.87	-1.41	4.633	75.0	62.1
110	42	69.74	4.45	-0.84	-1.36	6.386	74.6	55.8
111	144	71.59	3.34	-0.08	0.07	4.660	78.2	65.6
113	42	70.85	2.58	-0.38	-0.50	3.635	77.3	65.1
117	72	71.43	2.26	-0.14	-0.05	3.157	75.4	63.2
120	66	72.26	2.26	0.21	0.60	3.130	77.6	65.8
Activity index 90 days (%)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	100	93.56	3.62			3.871	103.9	80.2
101	23	92.54	1.03	-0.28	-0.73	1.114	95.0	90.7
102	4	95.31	2.51	0.48	0.72	2.634	99.2	92.8
106	12	95.21	3.88	0.46	0.67	4.072	101.0	86.9
110	7	92.73	5.36	-0.23	-0.62	5.784	97.8	80.2
111	24	92.50	2.93	-0.29	-0.74	3.165	96.8	87.9
113	7	94.35	5.31	0.22	0.22	5.624	103.9	88.8
117	12	97.51	2.52	1.09	1.88	2.583	102.1	94.1
120	11	91.24	2.13	-0.64	-1.40	2.334	94.8	87.1

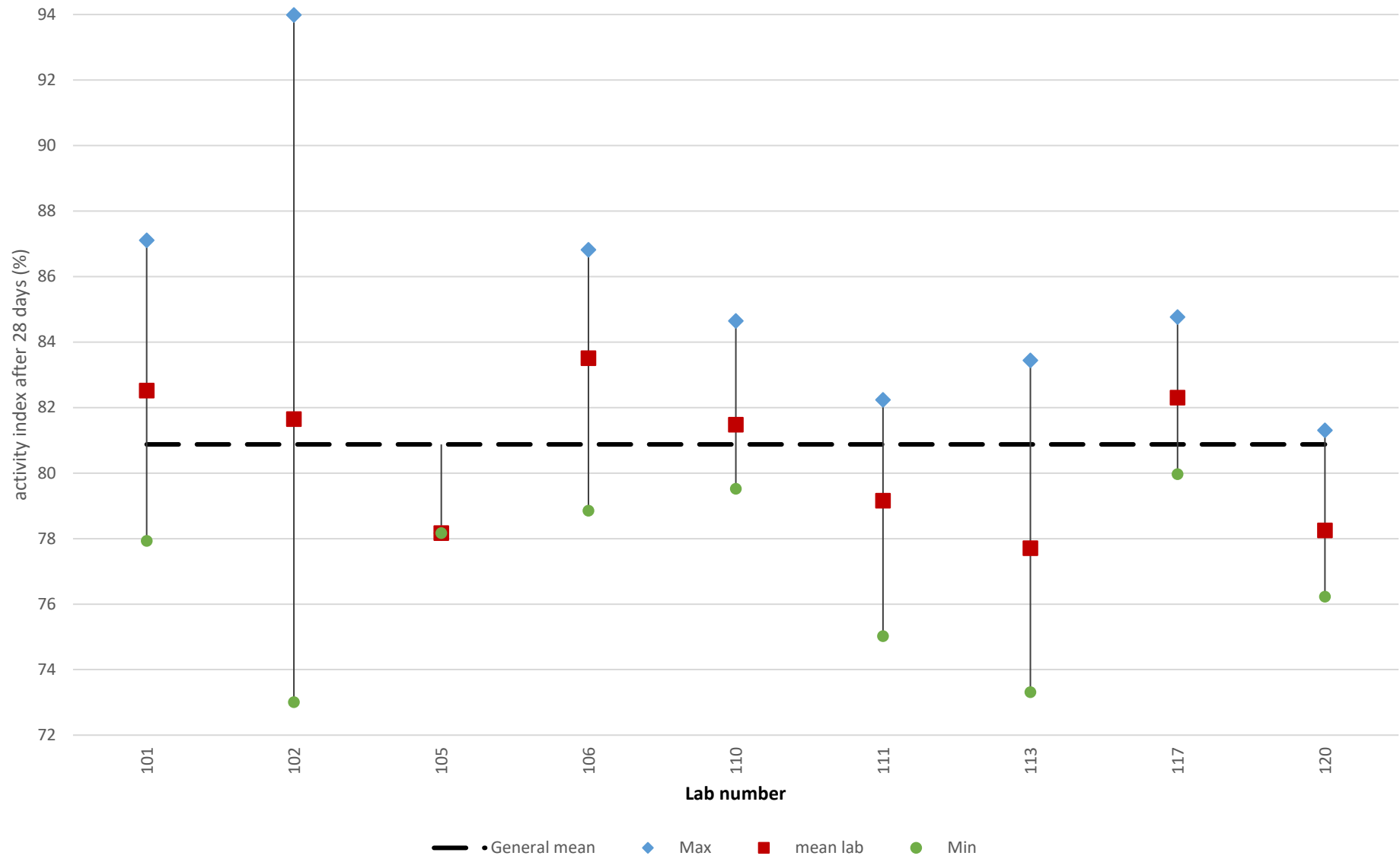
Strength for activity index 28 days (MPa)



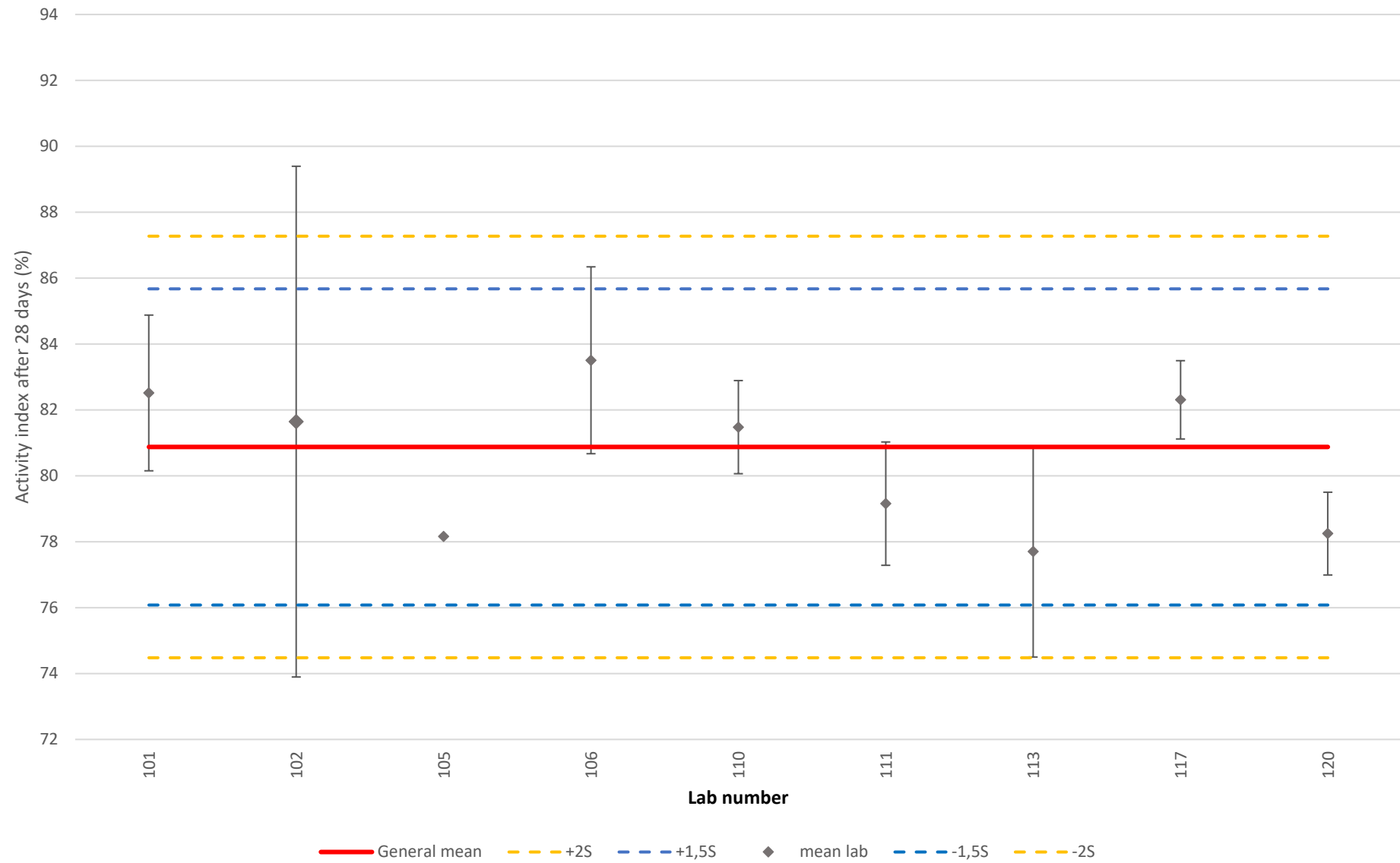
Strength for activity index 28 days (MPa)



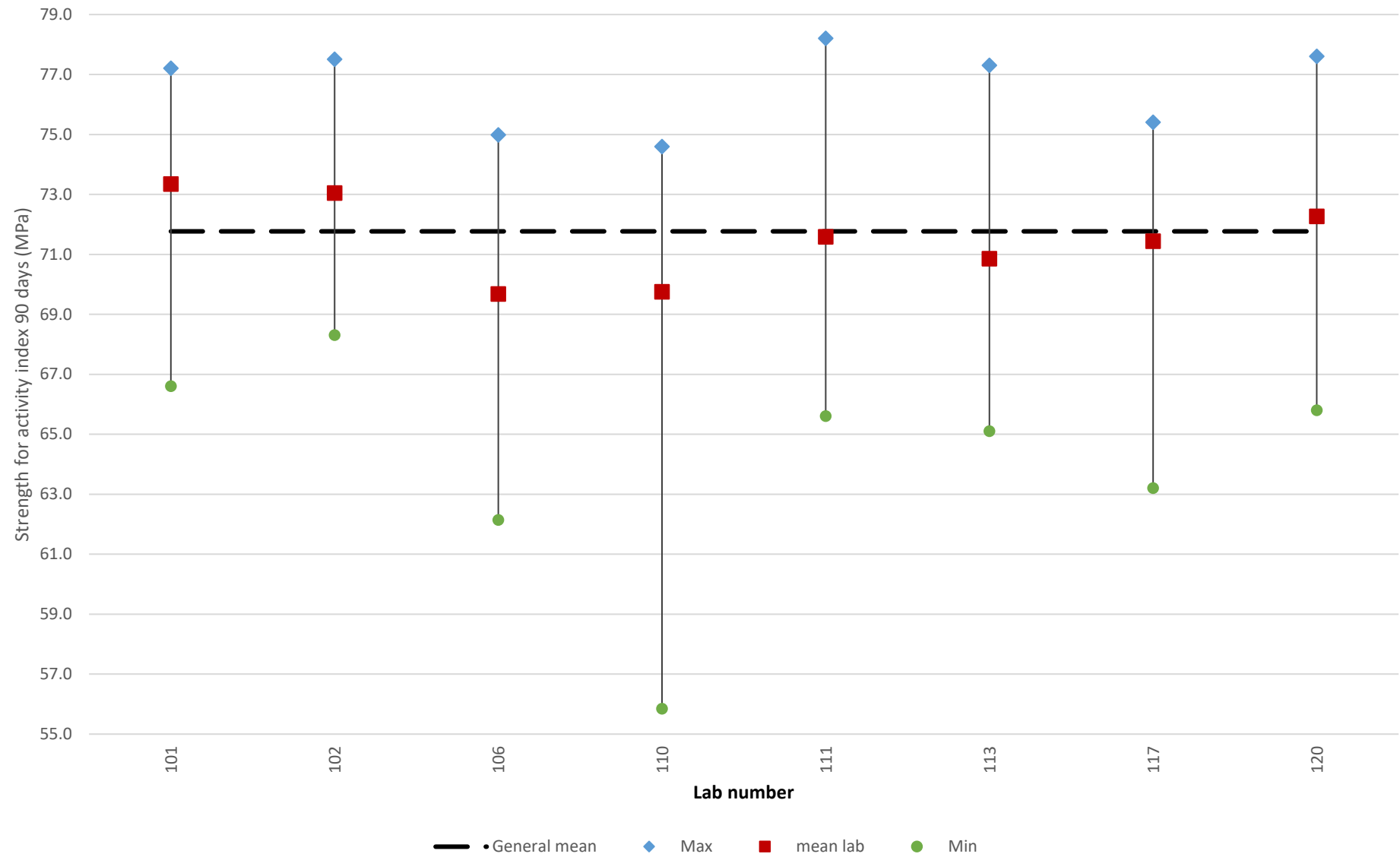
Activity index after 28 days (%)



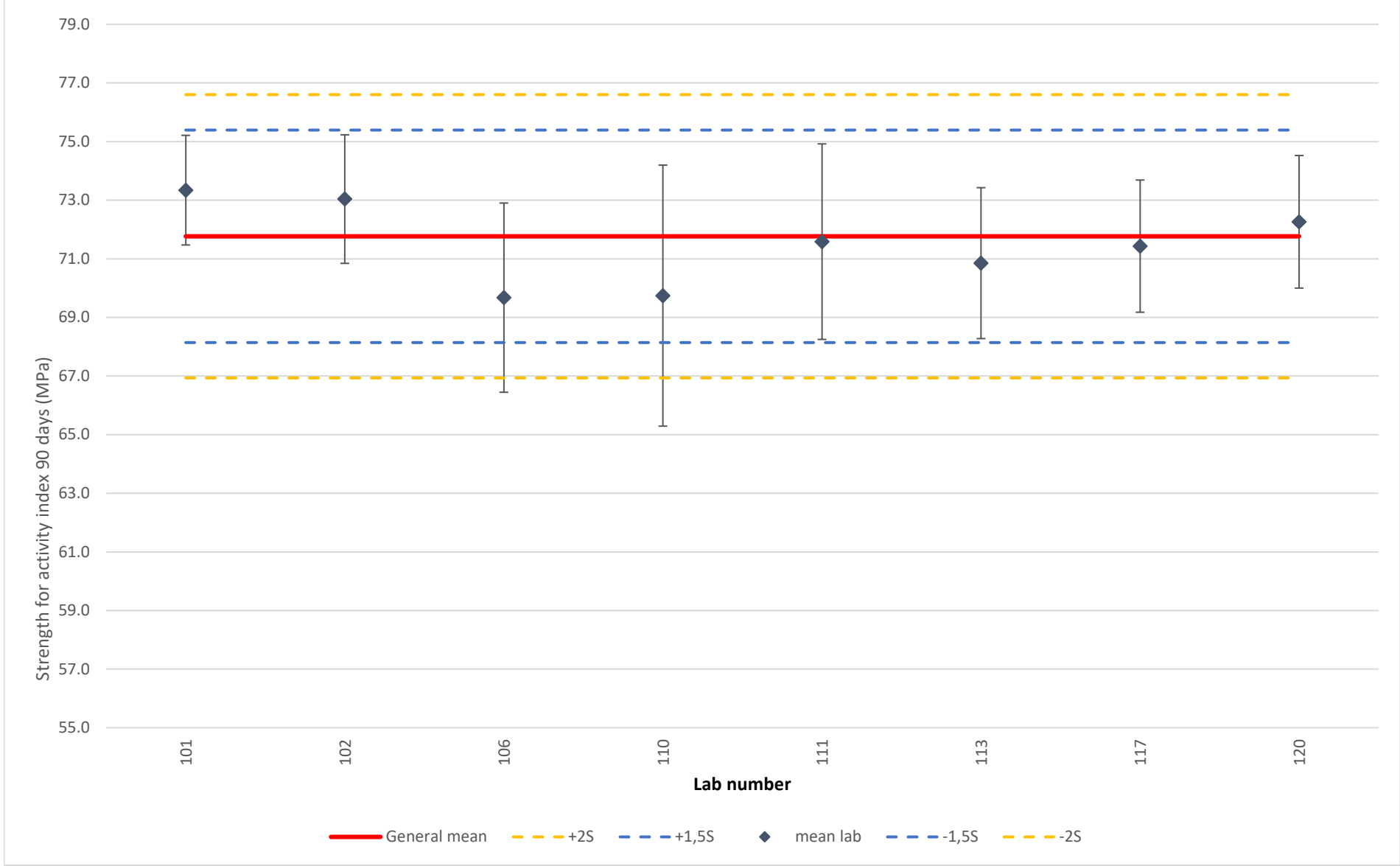
Activity index after 28 days (%)



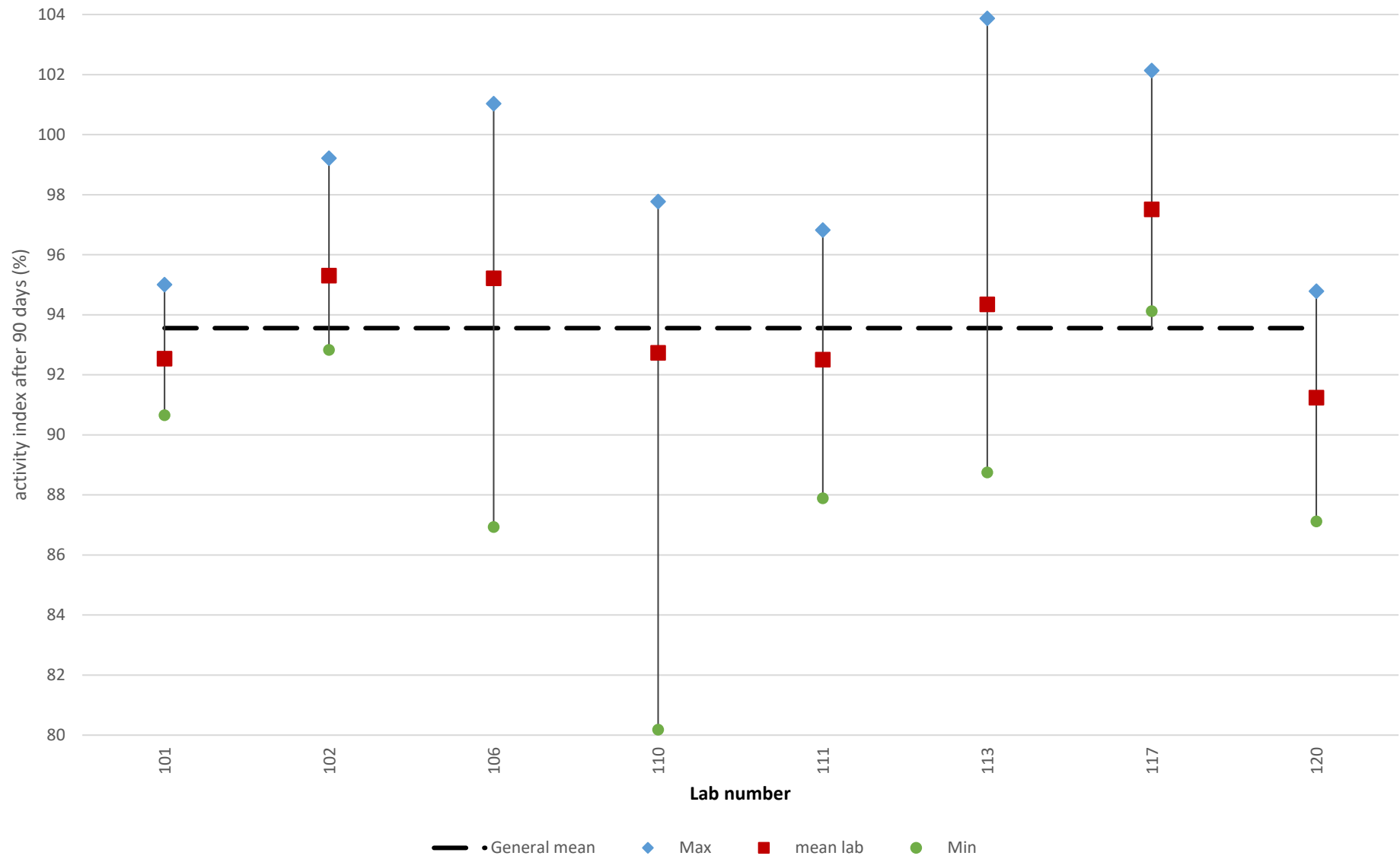
Strength for activity index 90 days (MPa)



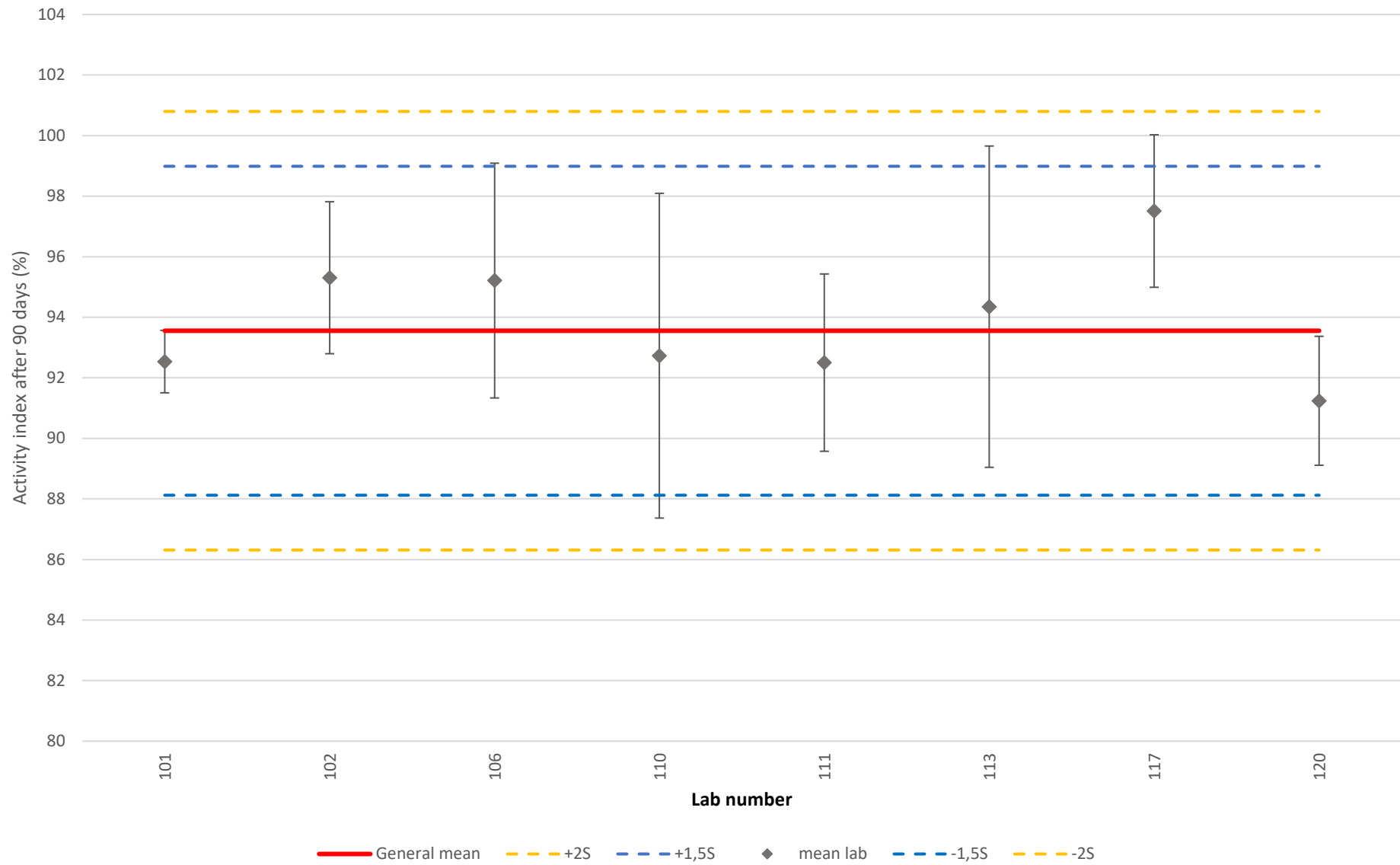
Strength for activity index 90 days (MPa)



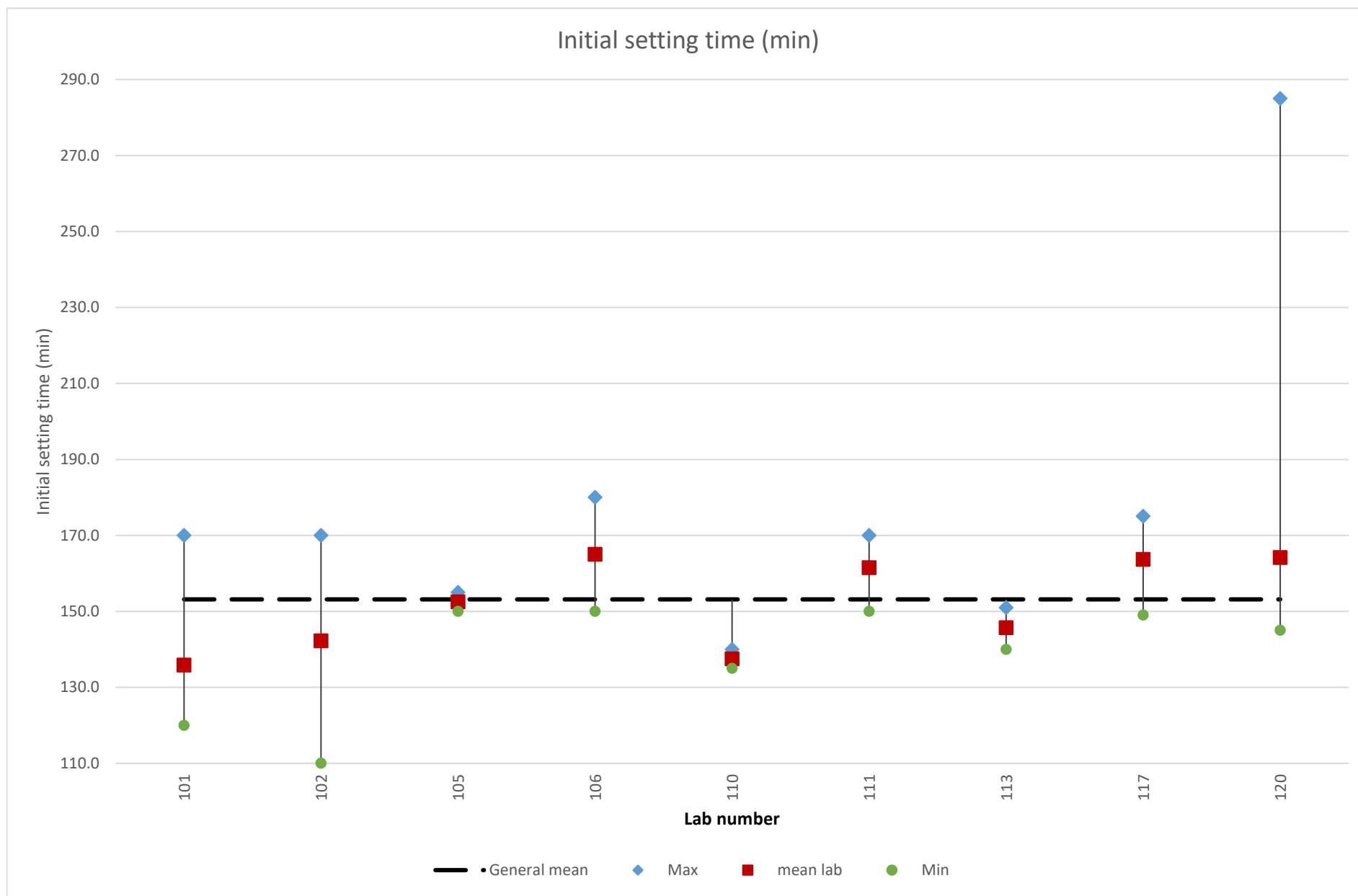
Activity index after 90 days (%)



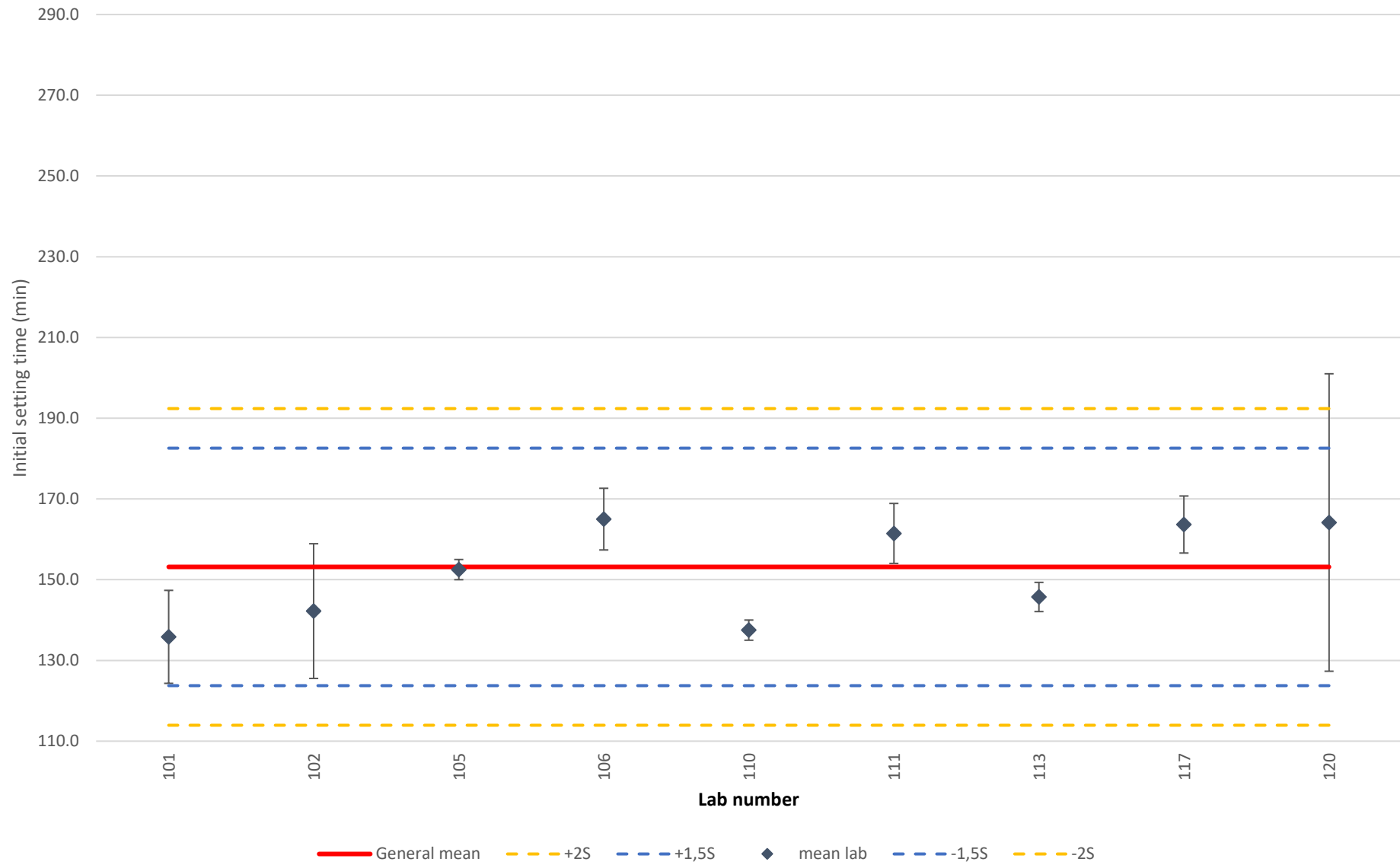
Activity index after 90 days (%)

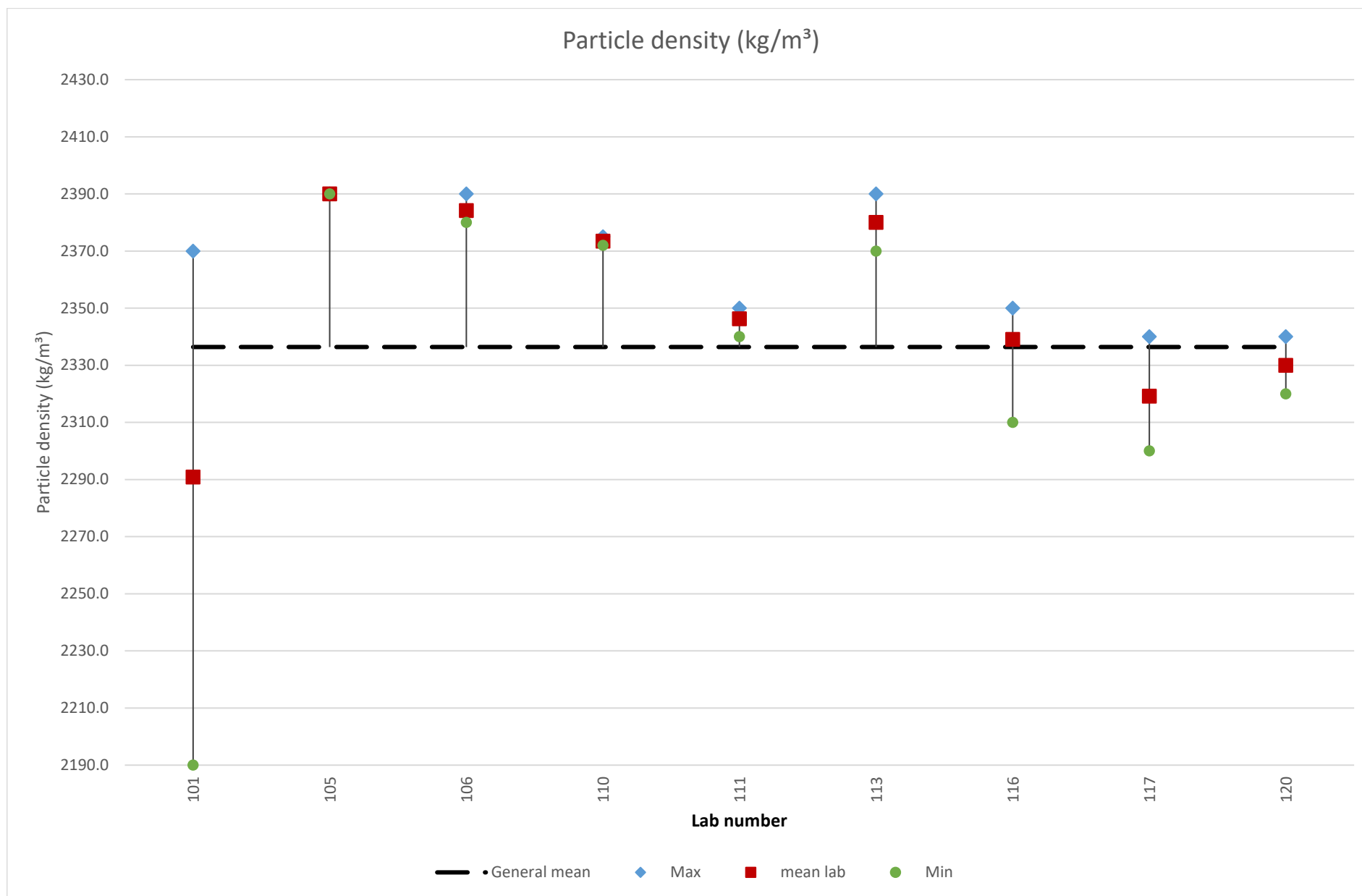


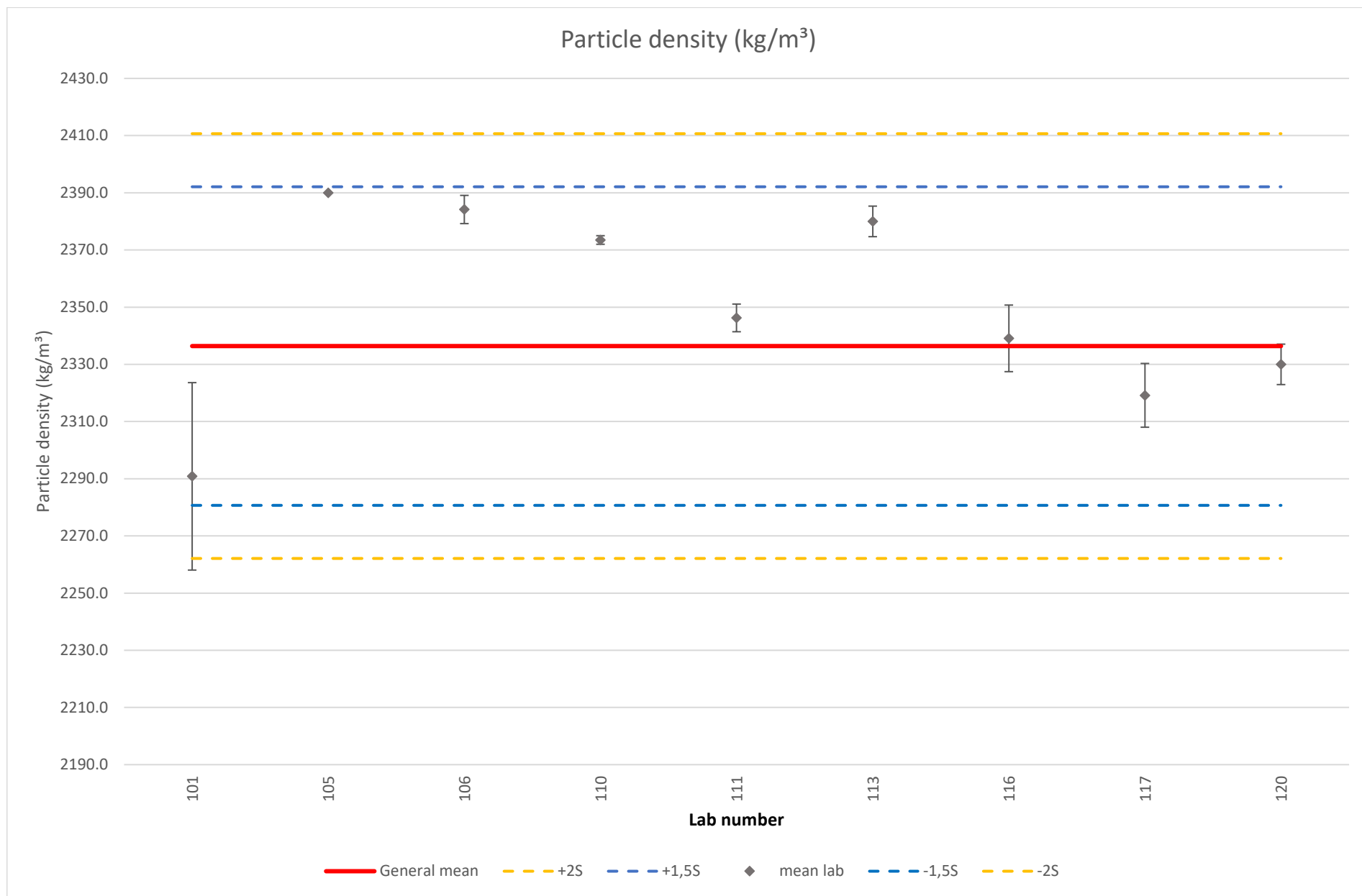
Initial setting time (min)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	104	153.2	19.6			12.803	285	110
101	24	135.8	11.5	-0.88	-1.43	8.479	170	120
102	9	142.2	16.7	-0.56	-0.87	11.732	170	110
105	2	152.5	2.5	-0.03	0.04	1.639	155	150
106	12	165.0	7.6	0.60	1.15	4.629	180	150
110	2	137.5	2.5	-0.80	-1.28	1.818	140	135
111	24	161.5	7.4	0.42	0.84	4.600	170	150
113	7	145.7	3.6	-0.38	-0.56	2.480	151	140
117	12	163.7	7.1	0.54	1.03	4.316	175	149
120	12	164.2	36.8	0.56	1.08	22.444	285	145
Particle density (kg/m³)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	98	2336.4	37.1			1.590	2390	2190
101	24	2290.8	32.8	-1.23	-1.86	1.431	2370	2190
105	2	2390.0		1.44	1.24		2390	2390
106	12	2384.2	4.9	1.29	1.06	0.207	2390	2380
110	2	2373.5	1.5	1.00	0.72	0.063	2375	2372
111	24	2346.3	4.8	0.27	-0.13	0.206	2350	2340
113	7	2380.0	5.3	1.17	0.93	0.225	2390	2370
116	11	2339.1	11.6	0.07	-0.35	0.498	2350	2310
117	12	2319.2	11.1	-0.46	-0.97	0.481	2340	2300
120	4	2330.0	7.1	-0.17	-0.64	0.303	2340	2320
Fineness: Sieve residue 45 µm (%)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	214	16.73	0.90			5.38	18.8	14.4
101	24	16.15	1.28	-0.65	-0.50	7.90	18.8	14.6
102	14	17.49	0.25	0.85	1.20	1.42	17.9	17.1
103	21	17.43	0.35	0.77	1.12	1.99	18.3	17.0
105	3	16.95	0.56	0.24	0.51	3.31	17.4	16.2
106	24	17.40	0.27	0.74	1.08	1.57	17.9	16.7
107	8	15.47	0.59	-1.41	-1.37	3.83	16.5	14.4
108	7	17.03	0.07	0.33	0.61	0.41	17.1	16.9
109	7	15.87	0.48	-0.96	-0.86	3.04	16.6	15.0
110	3	15.22	0.22	-1.68	-1.69	1.48	15.4	14.9
113	15	15.74	0.38	-1.10	-1.02	2.42	16.1	14.9
117	24	16.30	0.24	-0.47	-0.31	1.50	17.0	15.9
118	24	16.92	0.19	0.21	0.47	1.15	17.4	16.4
119	24	17.66	0.27	1.04	1.42	1.52	18.0	17.1
120	16	16.03	0.61	-0.78	-0.65	3.79	17.2	15.2



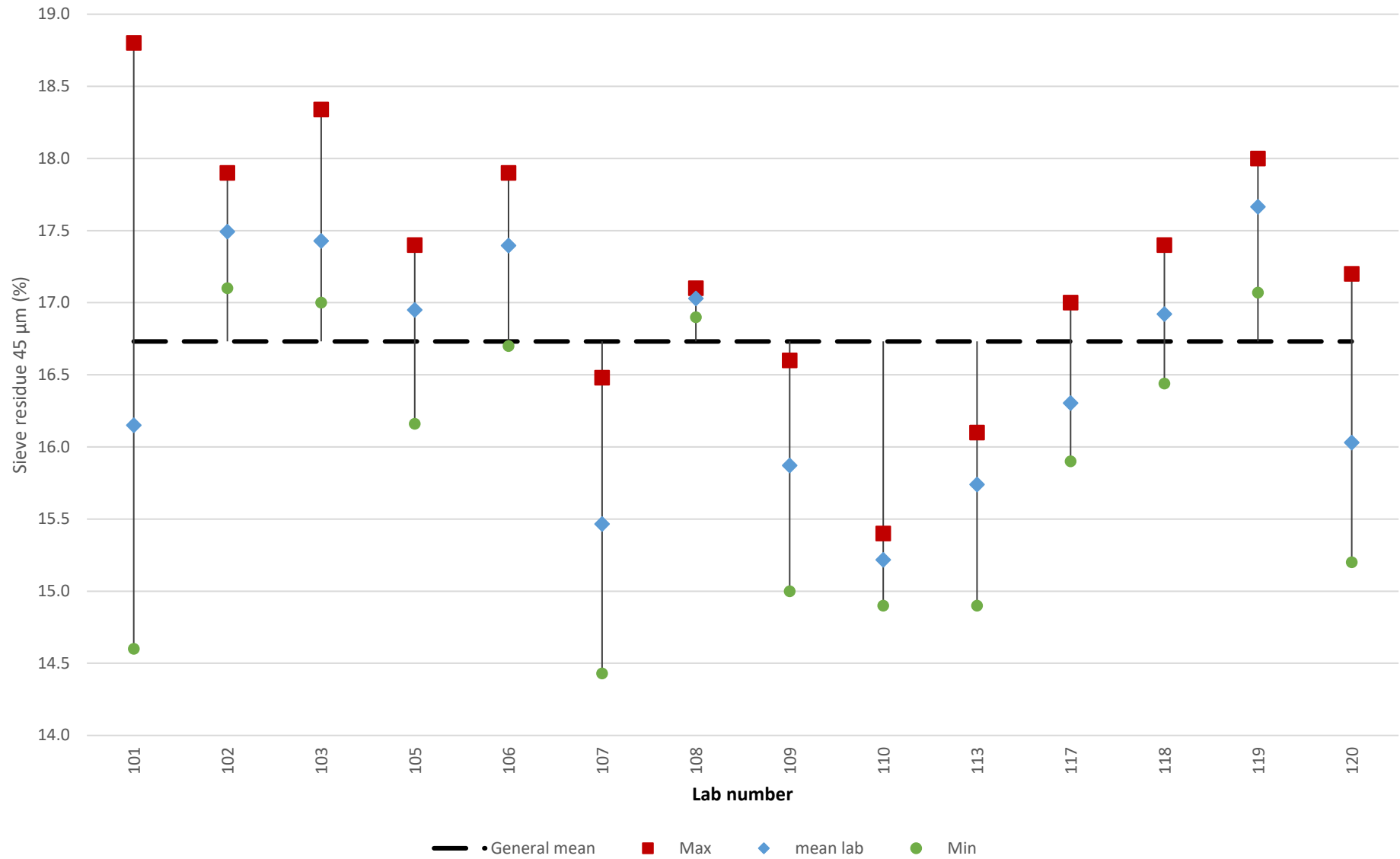
Initial setting time (min)



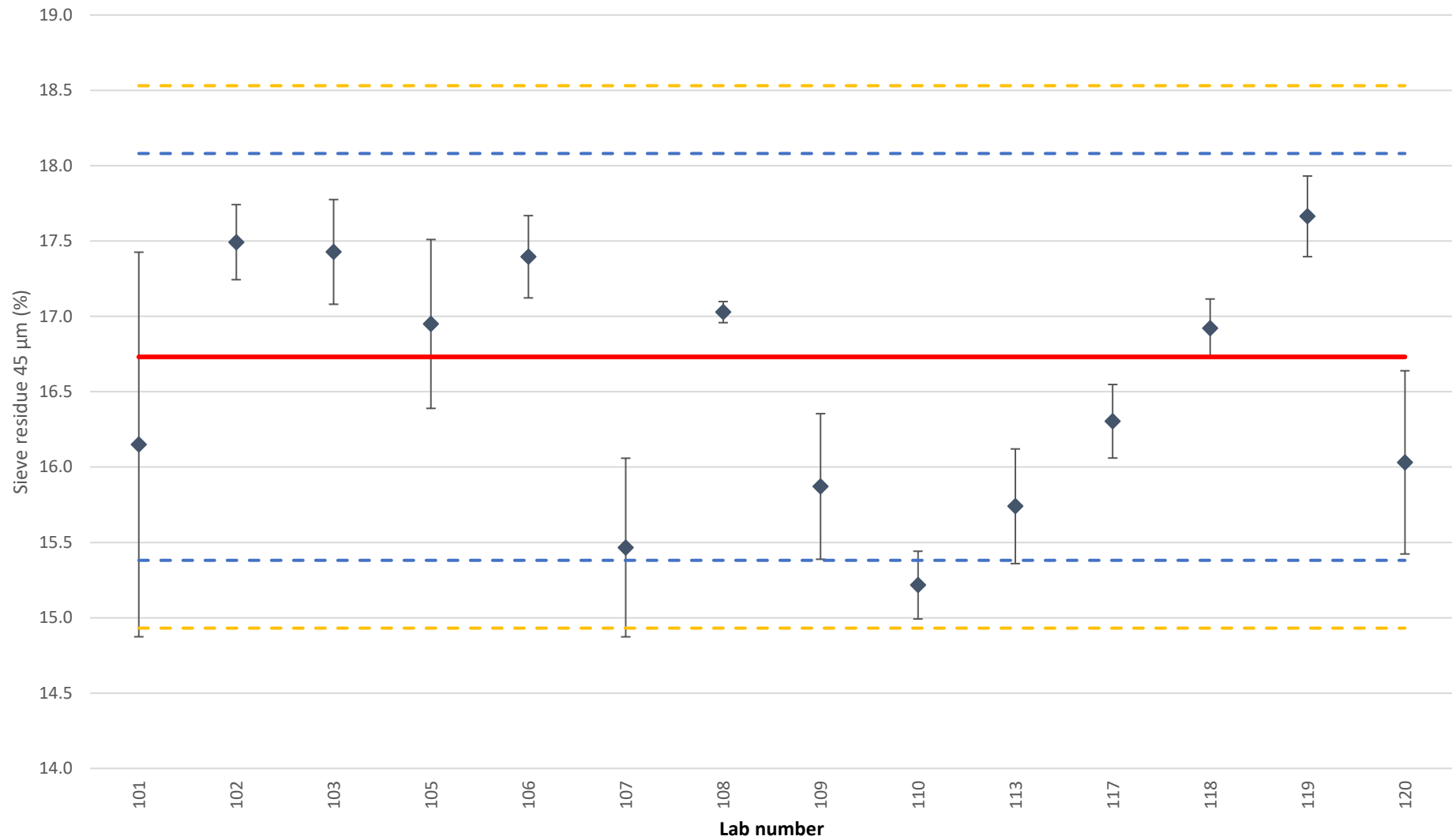




Fineness: Sieve residue 45µm (%)

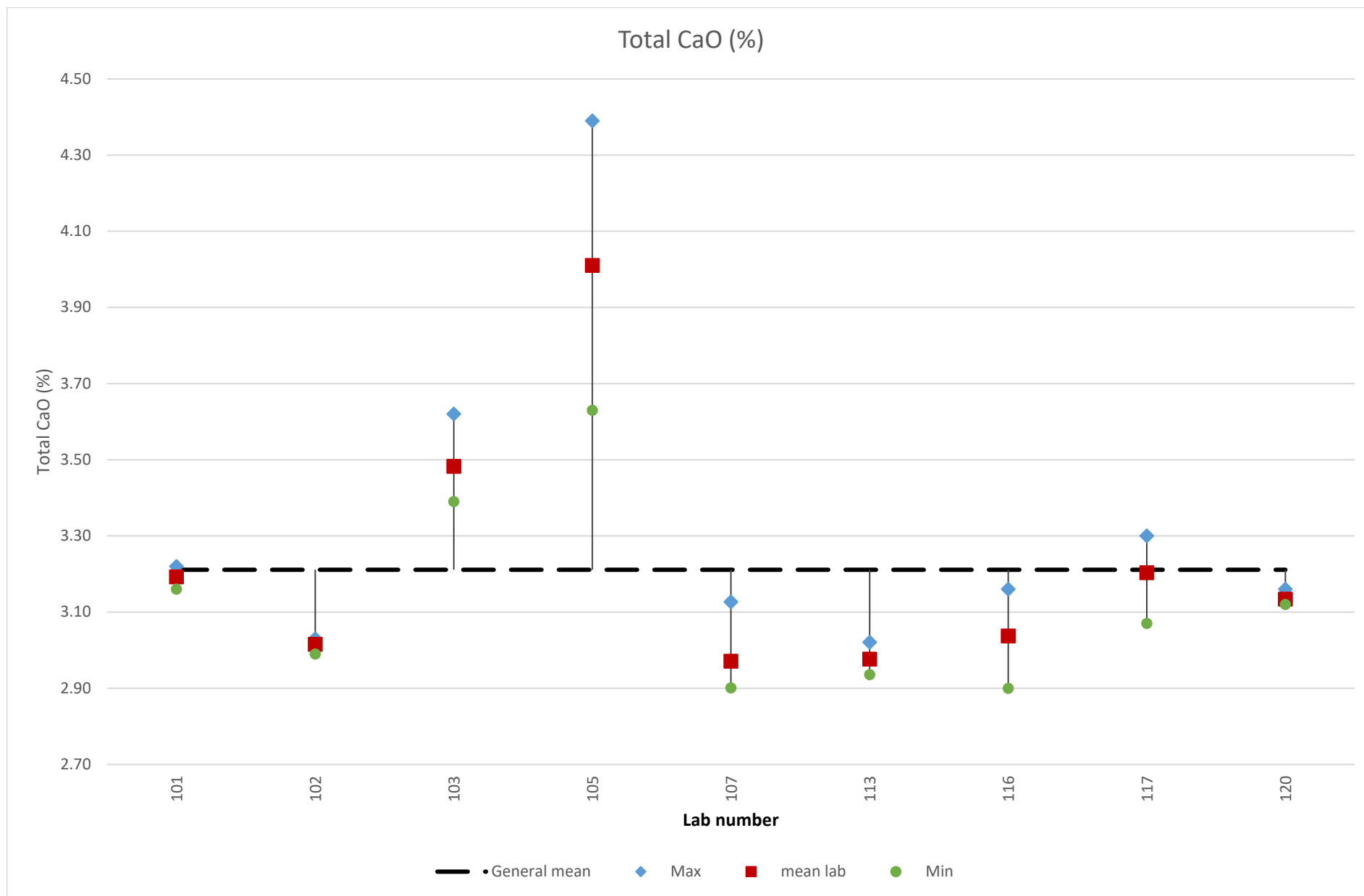


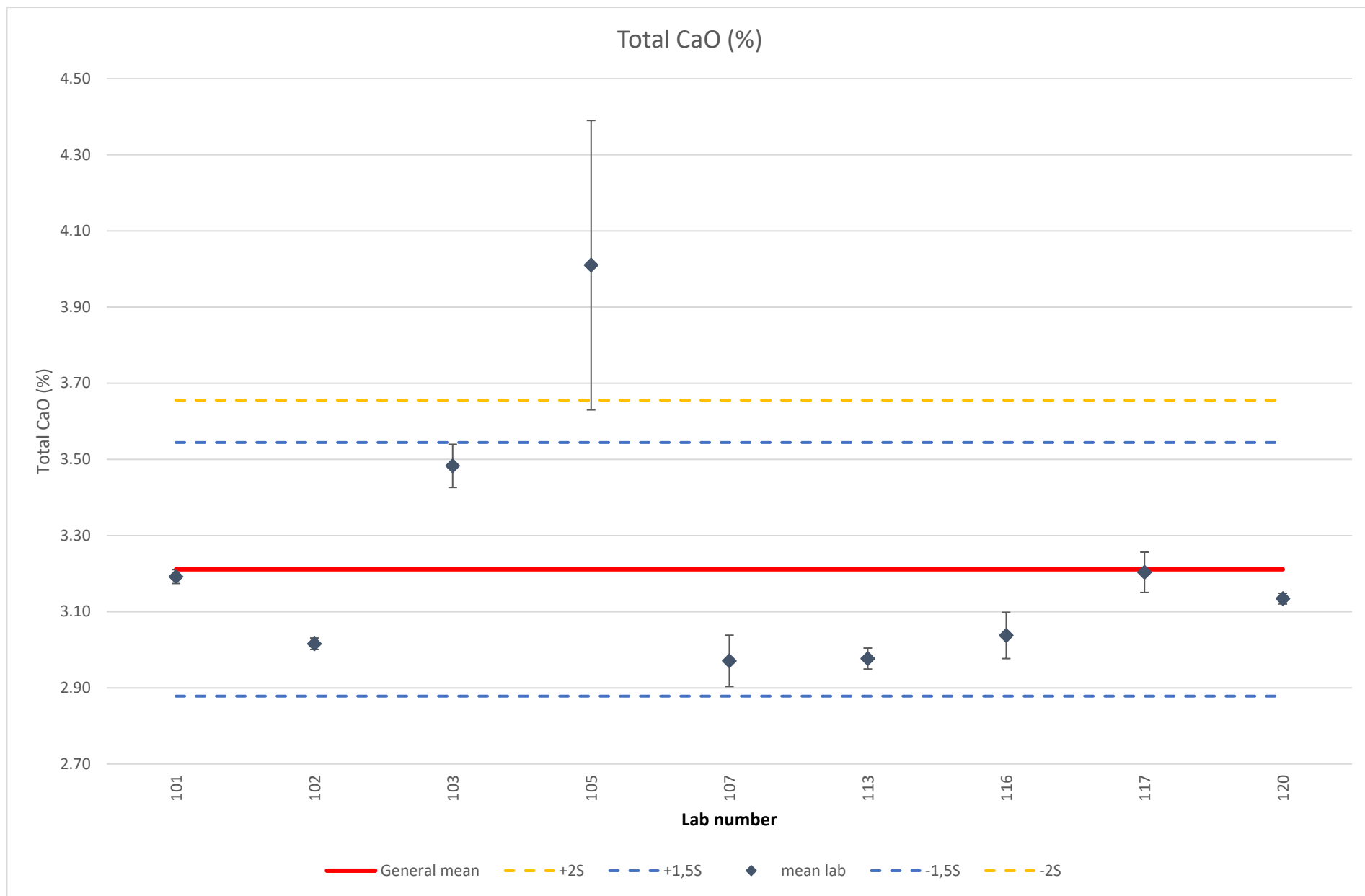
Fineness: Sieve residue 45 µm (%)

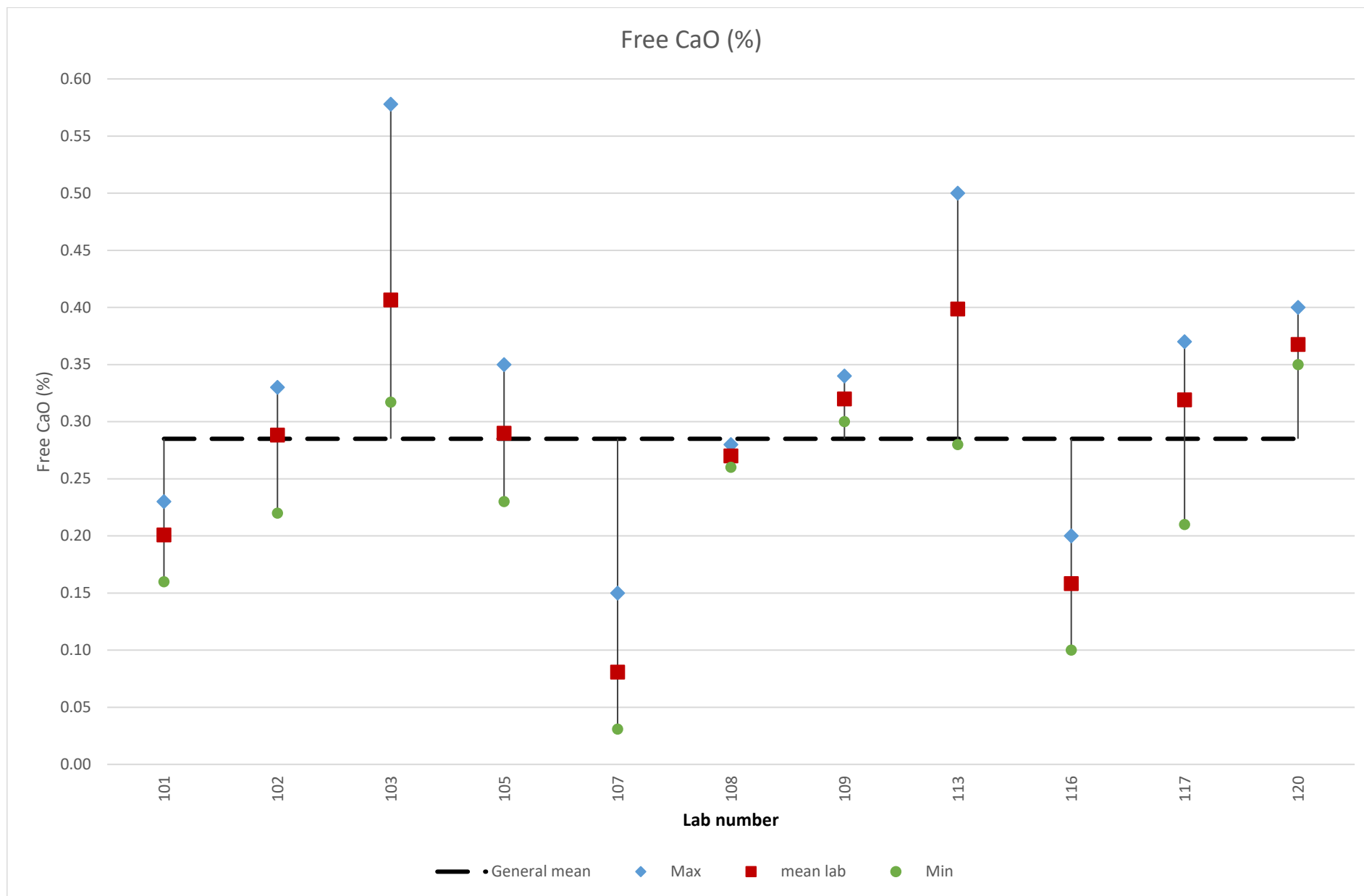


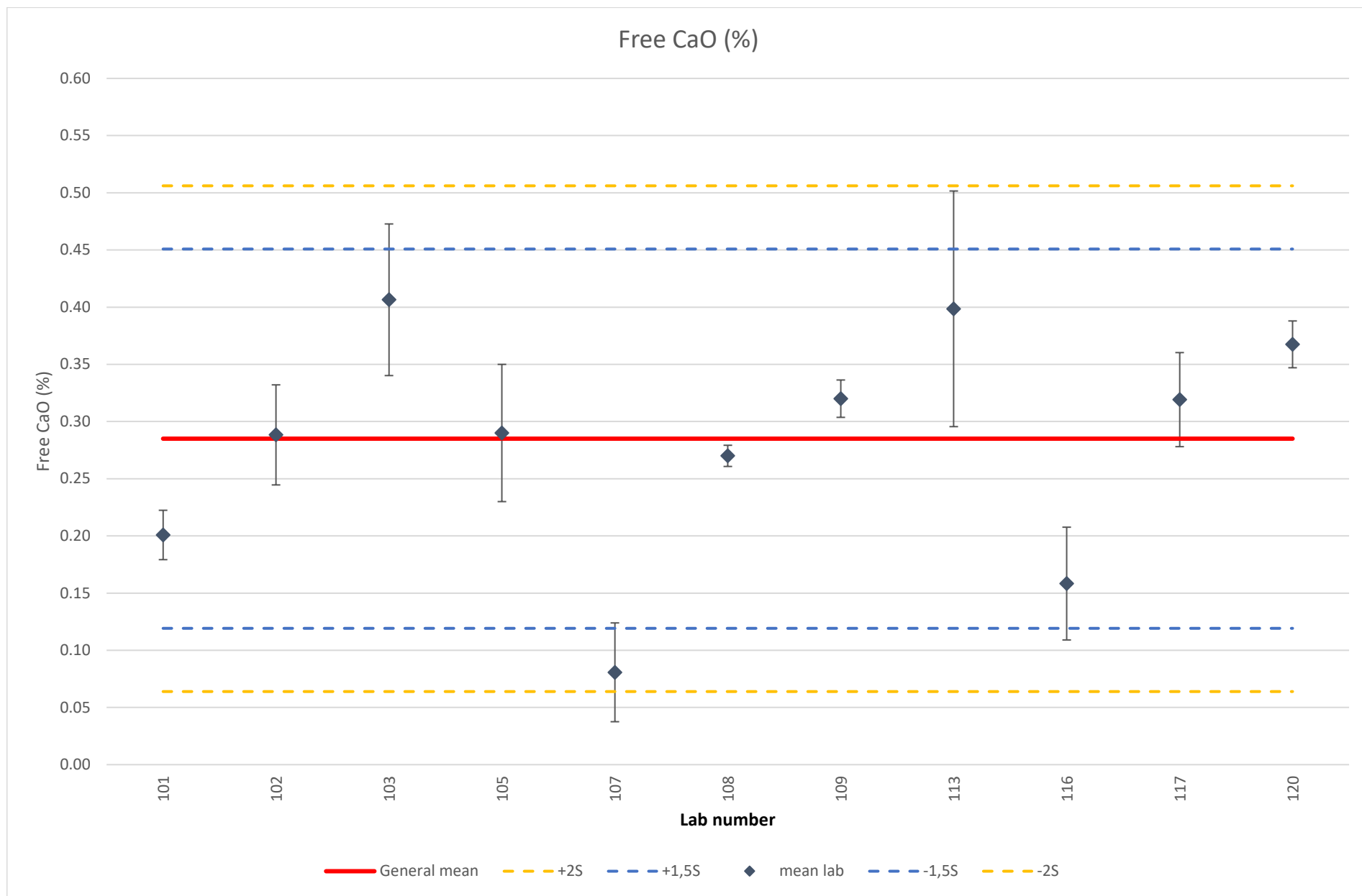
General mean +2S +1,5S mean lab -1,5S -2S

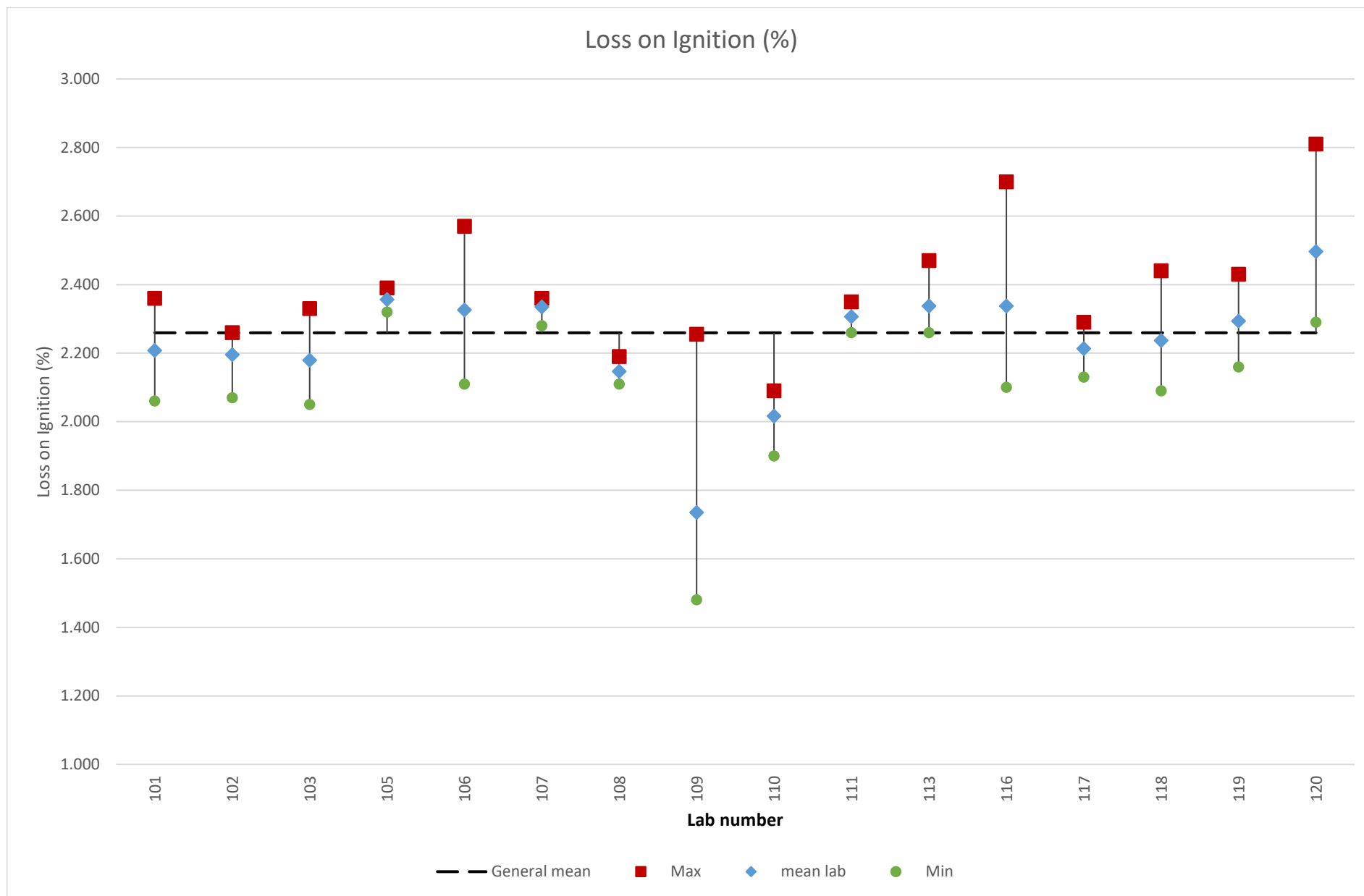
Total CaO (%)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	100	3.211	0.222			6.92	4.39	2.90
101	23	3.192	0.018	-0.09	-0.10	0.57	3.22	3.16
102	7	3.016	0.015	-0.88	-0.66	0.50	3.03	2.99
103	23	3.483	0.057	1.22	0.82	1.62	3.62	3.39
105	2	4.010	0.380	3.60	2.49	9.48	4.39	3.63
107	7	2.971	0.067	-1.08	-0.80	2.27	3.13	2.90
113	7	2.977	0.028	-1.06	-0.79	0.92	3.02	2.94
116	12	3.038	0.061	-0.78	-0.59	2.00	3.16	2.90
117	12	3.203	0.053	-0.04	-0.07	1.65	3.30	3.07
120	7	3.134	0.014	-0.35	-0.29	0.45	3.16	3.12
Free CaO (%)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	104	0.285	0.111			38.79	0.58	0.03
101	24	0.201	0.022	-0.76	-0.84	10.75	0.23	0.16
102	6	0.288	0.044	0.03	0.07	15.17	0.33	0.22
103	23	0.406	0.066	1.10	1.30	16.31	0.58	0.32
105	2	0.290	0.060	0.05	0.09	20.69	0.35	0.23
107	4	0.081	0.043	-1.85	-2.09	53.49	0.15	0.03
108	7	0.270	0.009	-0.14	-0.12	3.43	0.28	0.26
109	3	0.320	0.016	0.32	0.40	5.10	0.34	0.30
113	7	0.399	0.103	1.03	1.21	25.85	0.50	0.28
116	12	0.158	0.049	-1.15	-1.28	31.14	0.20	0.10
117	12	0.319	0.041	0.31	0.39	12.88	0.37	0.21
120	4	0.368	0.020	0.75	0.89	5.57	0.40	0.35
Loss on Ignition (%)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	252	2.259	0.166			7.330	2.81	1.48
101	24	2.208	0.082	-0.31	-0.15	3.727	2.36	2.06
102	14	2.196	0.045	-0.38	-0.22	2.071	2.26	2.07
103	23	2.179	0.084	-0.48	-0.32	3.863	2.33	2.05
105	3	2.357	0.029	0.59	0.75	1.217	2.39	2.32
106	24	2.326	0.108	0.40	0.56	4.623	2.57	2.11
107	8	2.335	0.025	0.46	0.62	1.071	2.36	2.28
108	7	2.147	0.027	-0.68	-0.51	1.238	2.19	2.11
109	7	1.735	0.297	-3.17	-2.99	17.142	2.26	1.48
110	6	2.017	0.058	-1.47	-1.30	2.901	2.09	1.90
111	6	2.307	0.030	0.29	0.45	1.317	2.35	2.26
113	15	2.337	0.074	0.47	0.63	3.161	2.47	2.26
116	24	2.338	0.152	0.47	0.63	6.513	2.70	2.10
117	24	2.213	0.039	-0.28	-0.12	1.768	2.29	2.13
118	24	2.237	0.103	-0.14	0.02	4.615	2.44	2.09
119	24	2.294	0.073	0.21	0.37	3.181	2.43	2.16
120	20	2.497	0.122	1.43	1.59	4.888	2.81	2.29



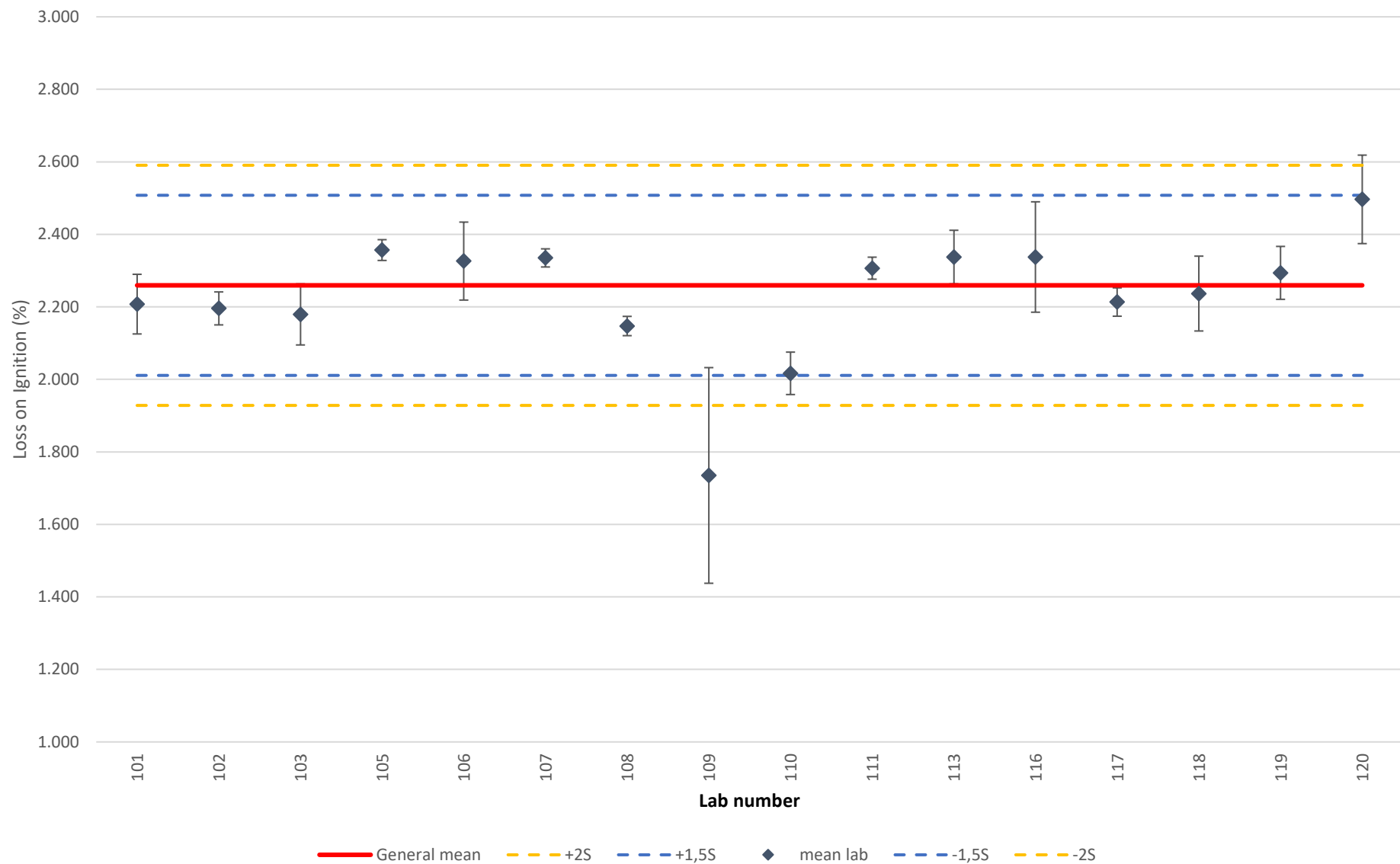




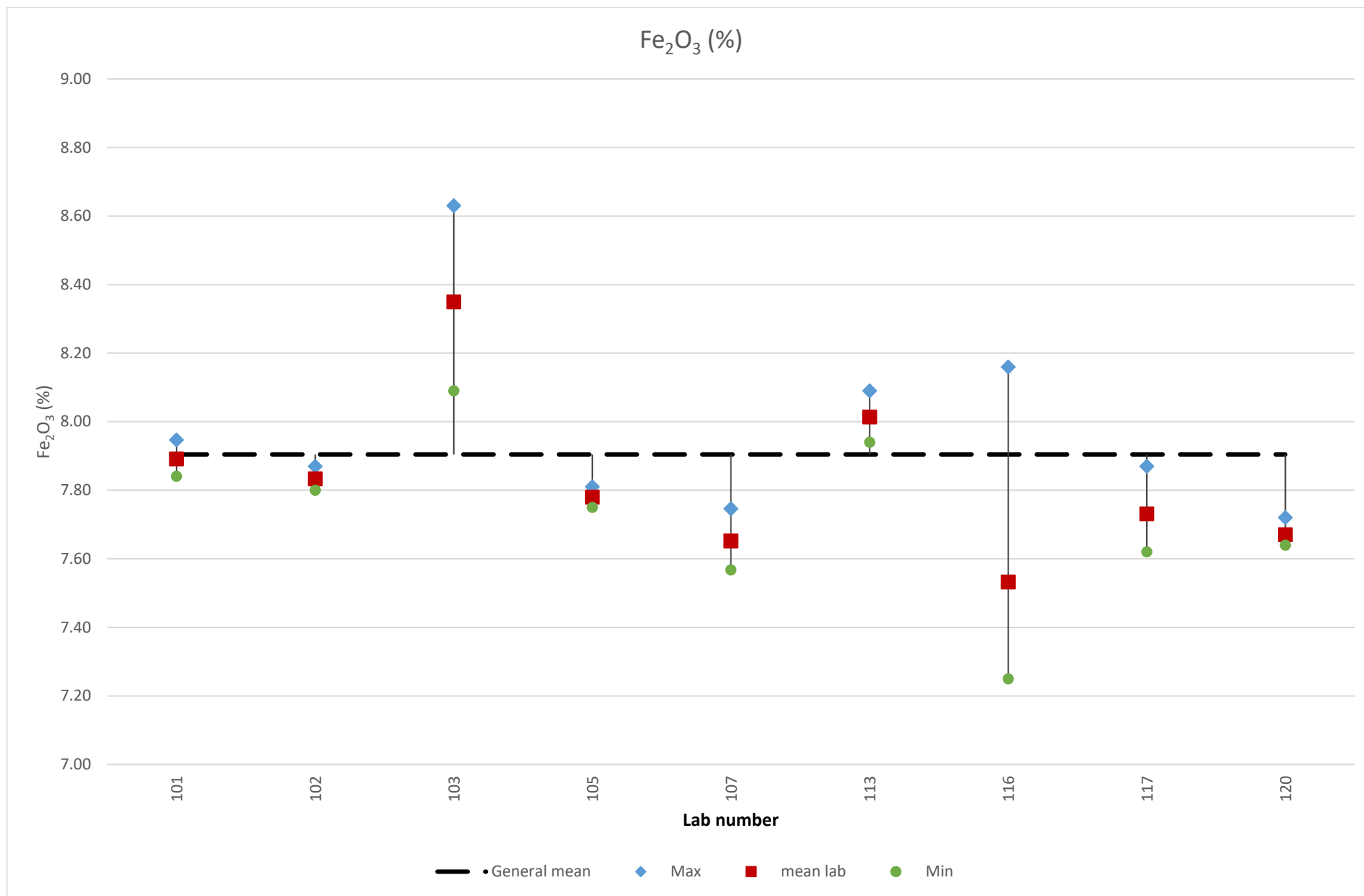


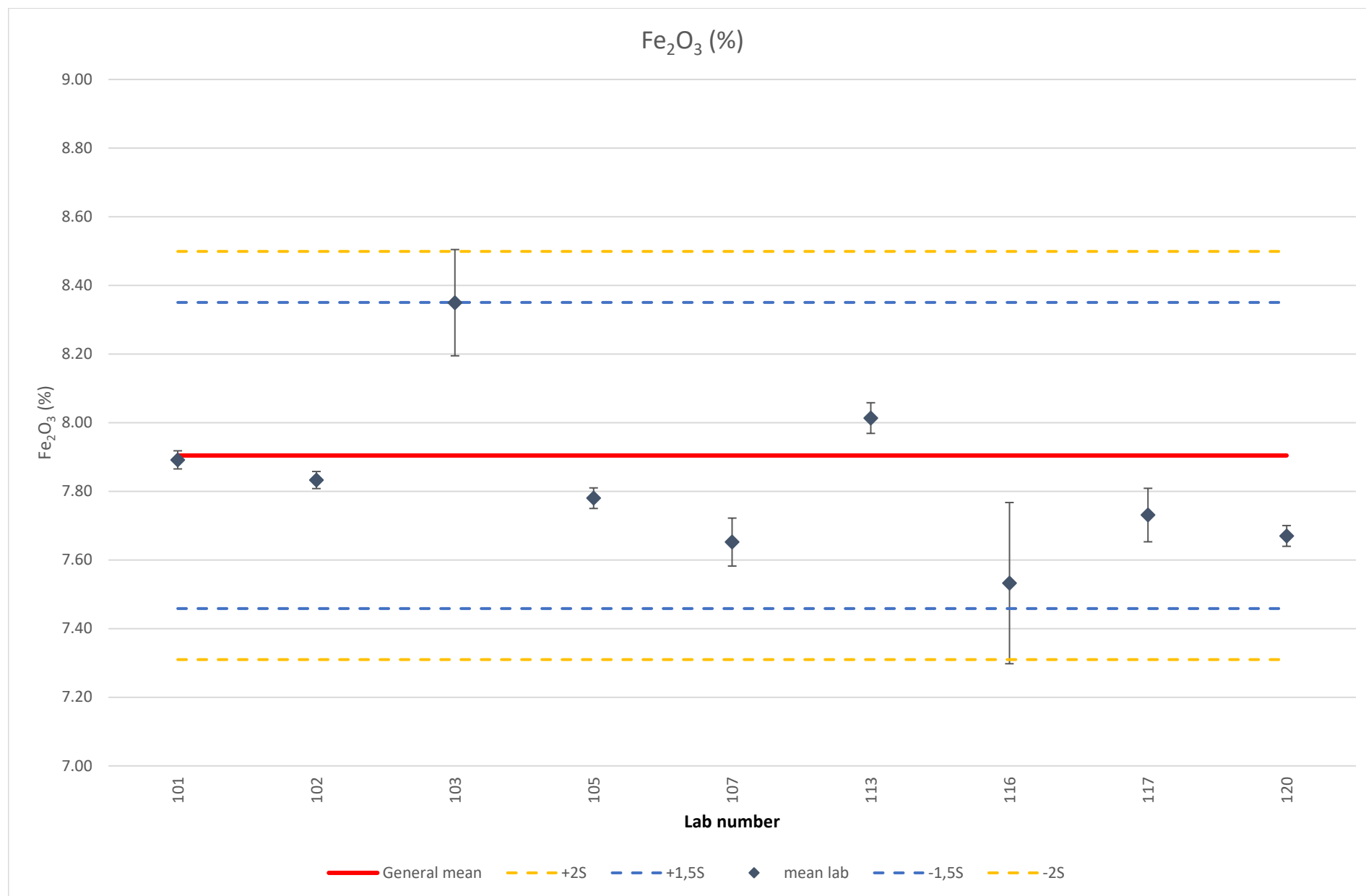


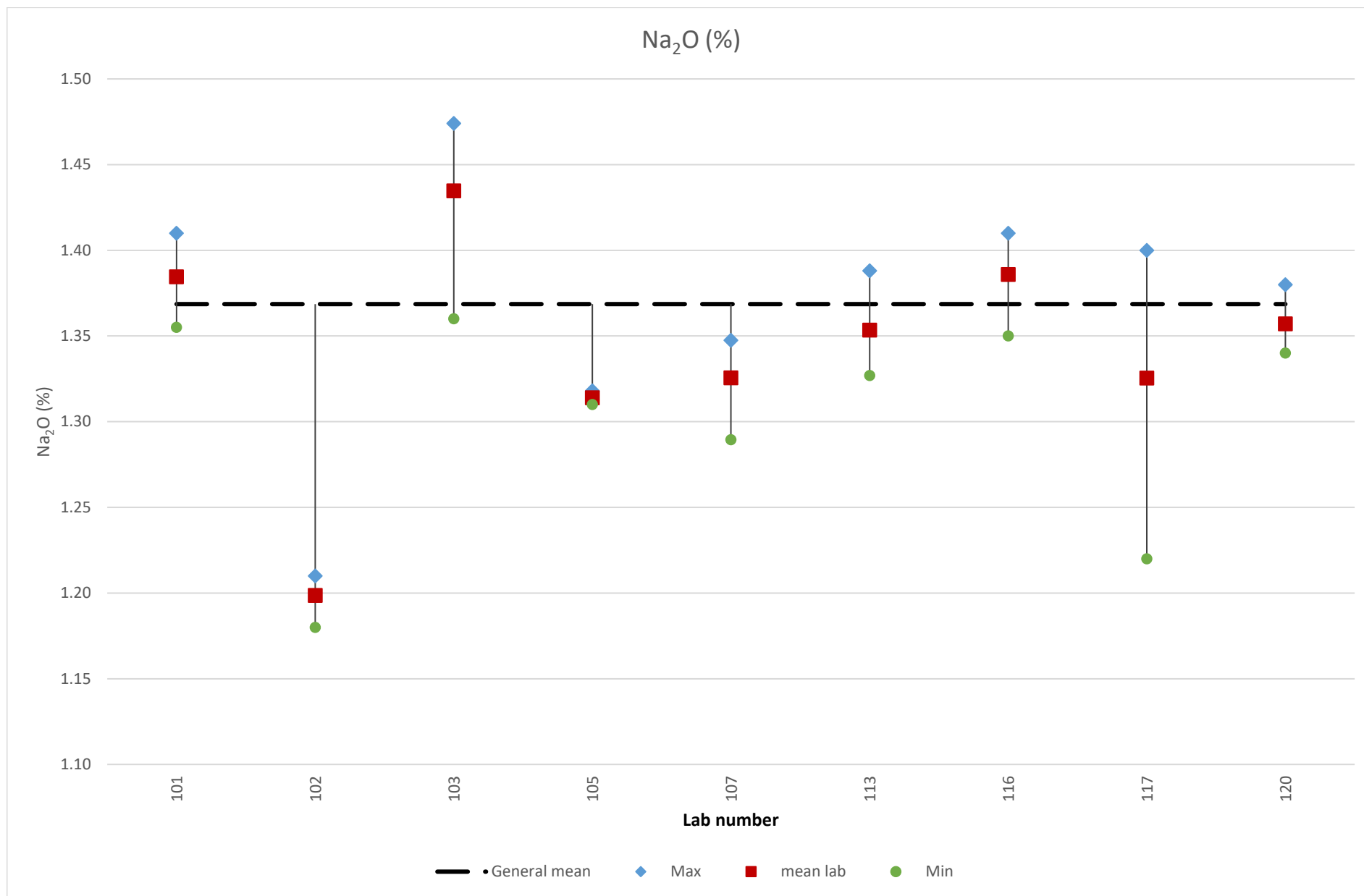
Loss on Ignition (%)

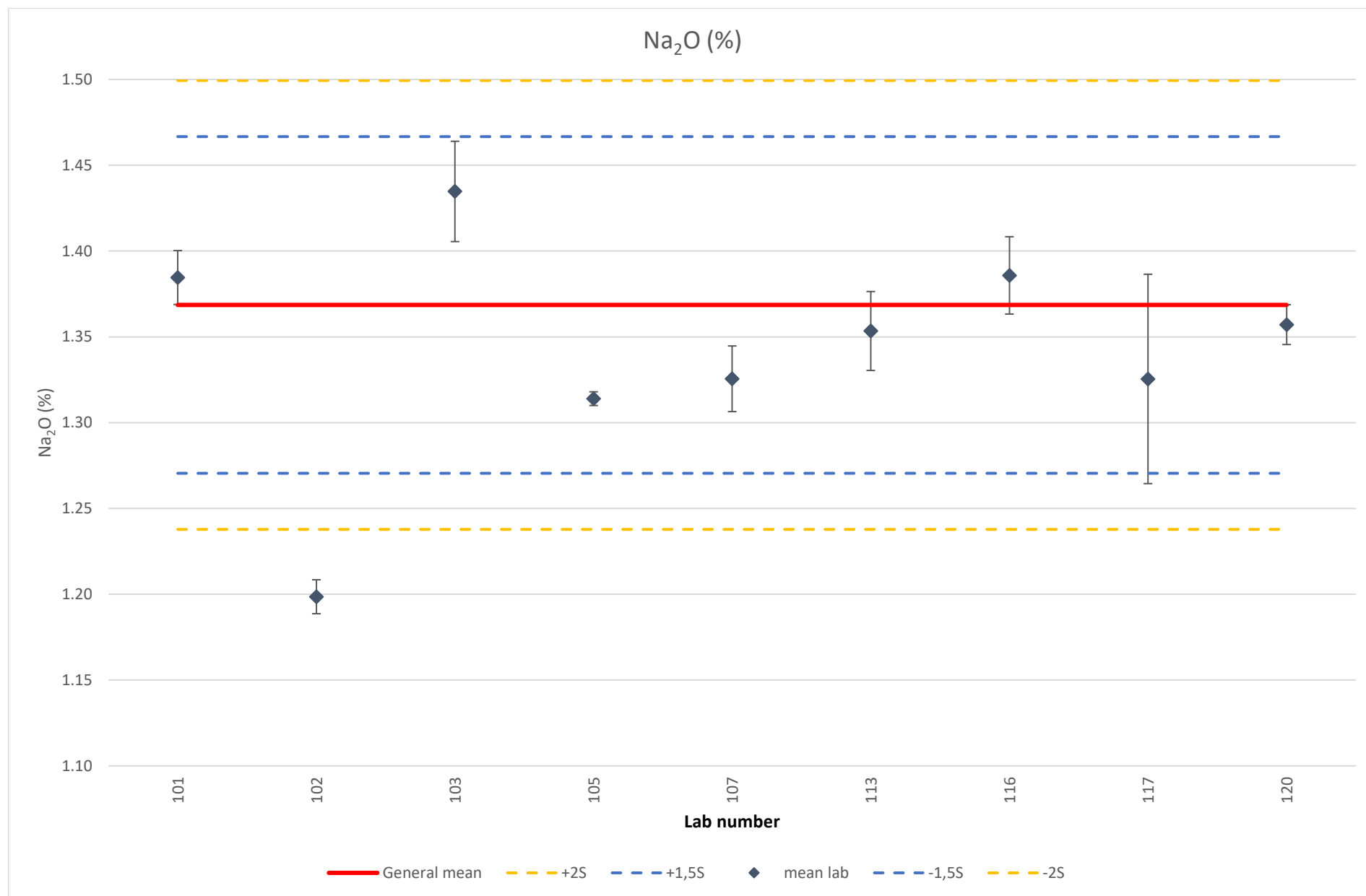


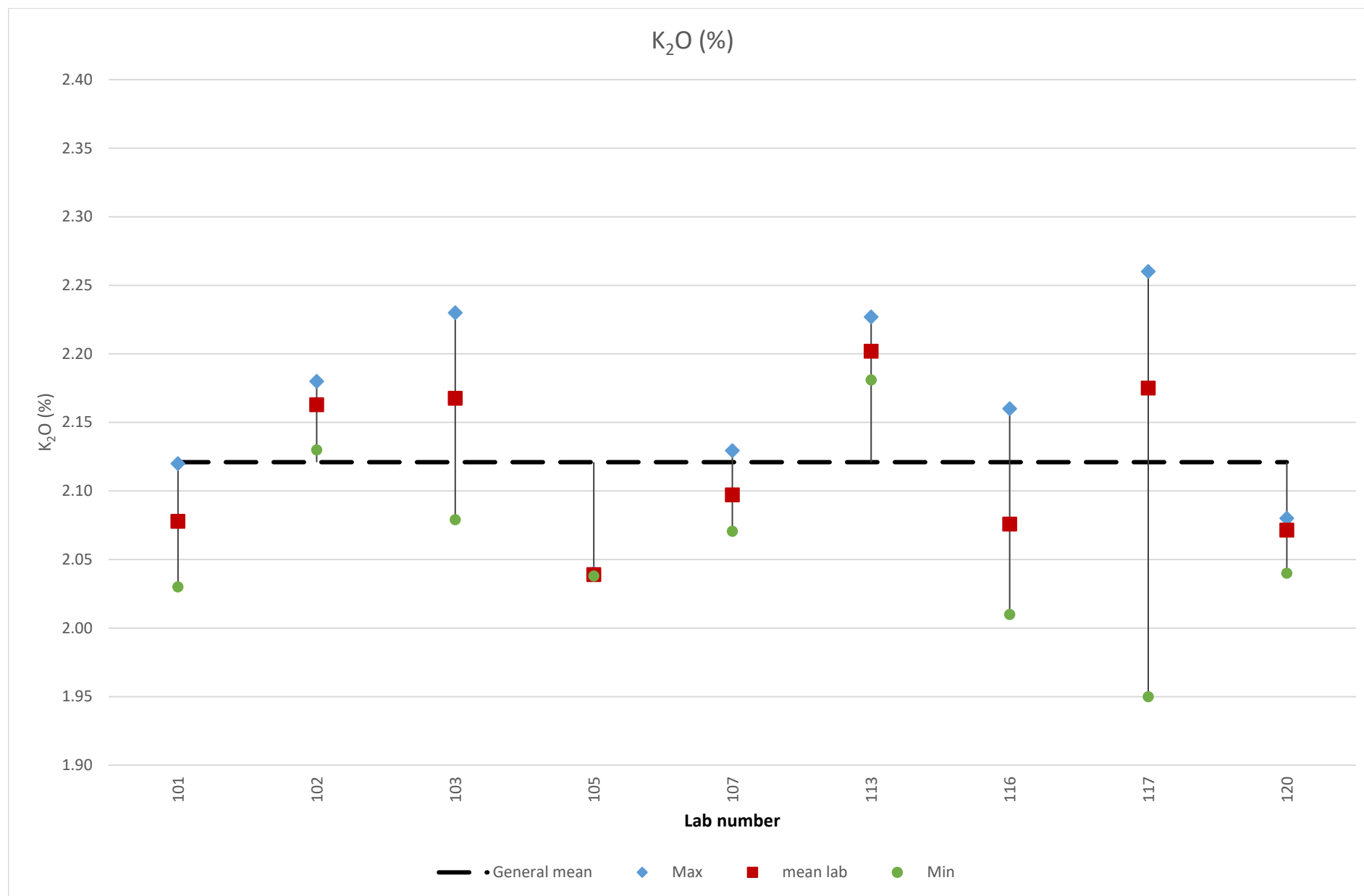
Fe ₂ O ₃ (%)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	101	7.904	0.297			3.76	8.63	7.25
101	24	7.892	0.026	-0.04	0.28	0.33	7.95	7.84
102	7	7.833	0.025	-0.24	0.02	0.32	7.87	7.80
103	23	8.350	0.155	1.50	2.29	1.85	8.63	8.09
105	2	7.780	0.030	-0.42	-0.21	0.39	7.81	7.75
107	7	7.652	0.070	-0.85	-0.77	0.91	7.75	7.57
113	7	8.013	0.045	0.37	0.81	0.56	8.09	7.94
116	12	7.533	0.235	-1.25	-1.30	3.12	8.16	7.25
117	12	7.731	0.078	-0.58	-0.43	1.01	7.87	7.62
120	7	7.670	0.030	-0.79	-0.70	0.39	7.72	7.64
Na ₂ O (%)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	94	1.369	0.065			4.8	1.47	1.18
101	24	1.385	0.016	0.24	0.68	1.1	1.41	1.36
102	7	1.199	0.010	-2.60	-2.32	0.8	1.21	1.18
103	22	1.435	0.029	1.01	1.49	2.0	1.47	1.36
105	2	1.314	0.004	-0.83	-0.45	0.3	1.32	1.31
107	7	1.326	0.019	-0.66	-0.27	1.4	1.35	1.29
113	7	1.353	0.023	-0.23	0.18	1.7	1.39	1.33
116	12	1.386	0.023	0.26	0.70	1.6	1.41	1.35
117	6	1.326	0.061	-0.66	-0.27	4.6	1.40	1.22
120	7	1.357	0.012	-0.18	0.24	0.9	1.38	1.34
K ₂ O (%)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	95	2.121	0.063			3.0	2.26	1.95
101	24	2.078	0.021	-0.69	-0.75	1.0	2.12	2.03
102	7	2.163	0.016	0.67	0.81	0.7	2.18	2.13
103	23	2.168	0.039	0.74	0.89	1.8	2.23	2.08
105	2	2.039	0.001	-1.31	-1.46	0.0	2.04	2.04
107	7	2.097	0.019	-0.38	-0.39	0.9	2.13	2.07
113	7	2.202	0.015	1.29	1.52	0.7	2.23	2.18
116	12	2.076	0.049	-0.72	-0.78	2.4	2.16	2.01
117	6	2.175	0.104	0.86	1.03	4.8	2.26	1.95
120	7	2.071	0.014	-0.79	-0.86	0.7	2.08	2.04
Na ₂ O _{EQ} (%) (Na ₂ O + 0,658 * K ₂ O)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	85	2.768	0.078			2.8	2.92	2.59
101	24	2.752	0.024	-0.21	0.23	0.9	2.79	2.70
102	7	2.622	0.018	-1.87	-1.35	0.7	2.64	2.59
103	22	2.862	0.051	1.20	1.56	1.8	2.92	2.73
105	2	2.656	0.005	-1.44	-0.94	0.2	2.66	2.65
107	7	2.706	0.028	-0.80	-0.33	1.0	2.74	2.66
113	7	2.802	0.028	0.44	0.84	1.0	2.84	2.77

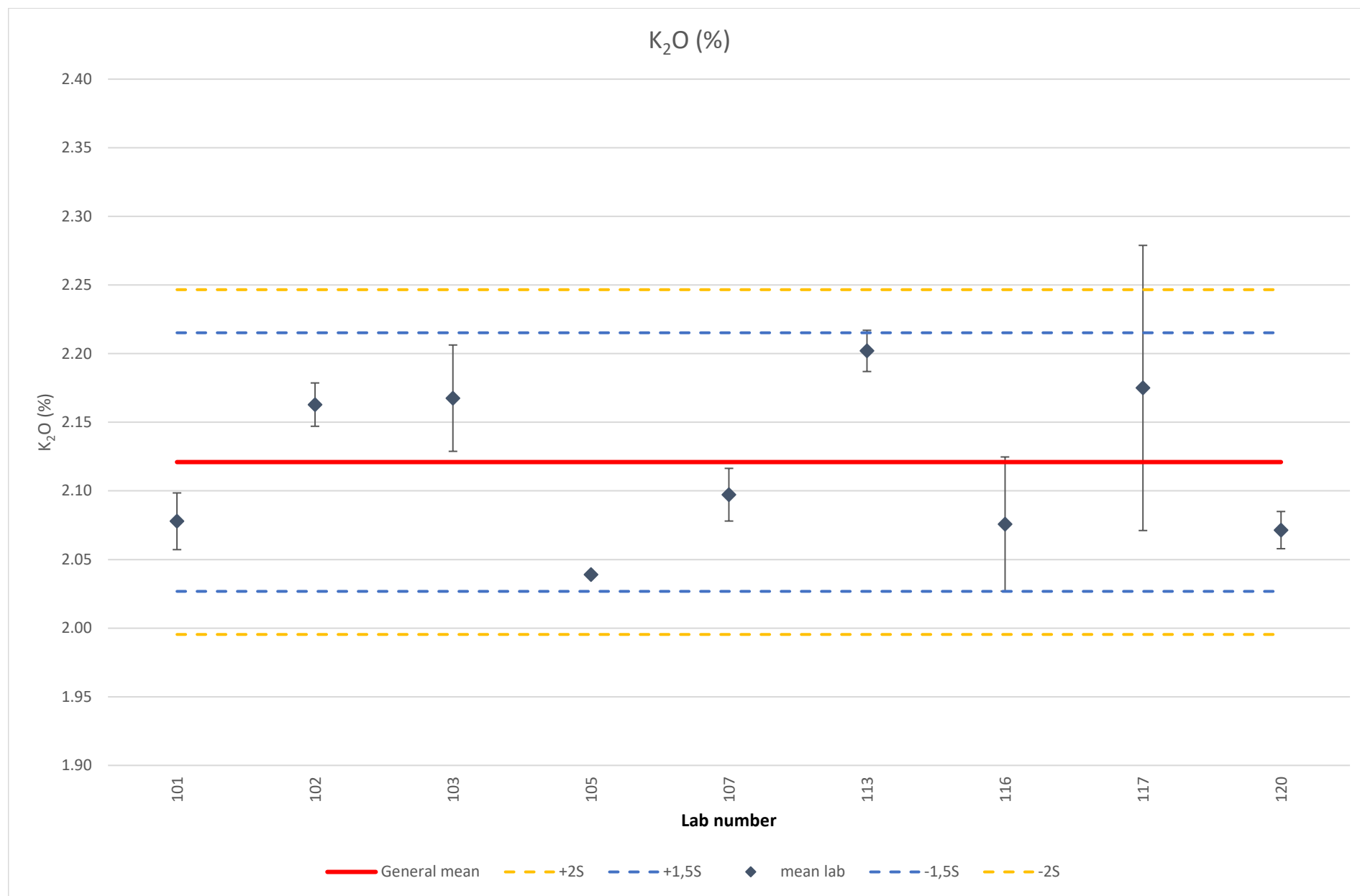


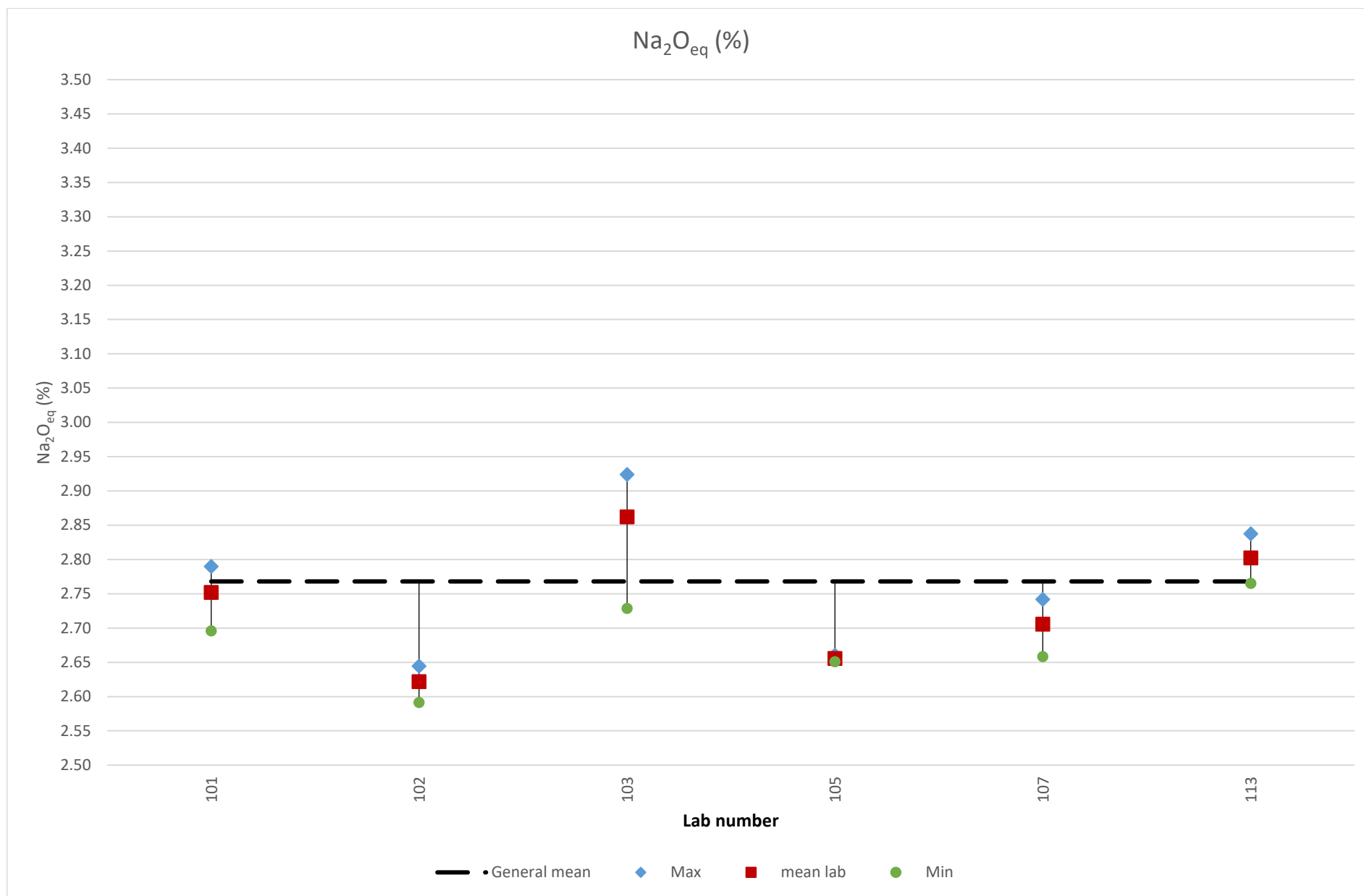


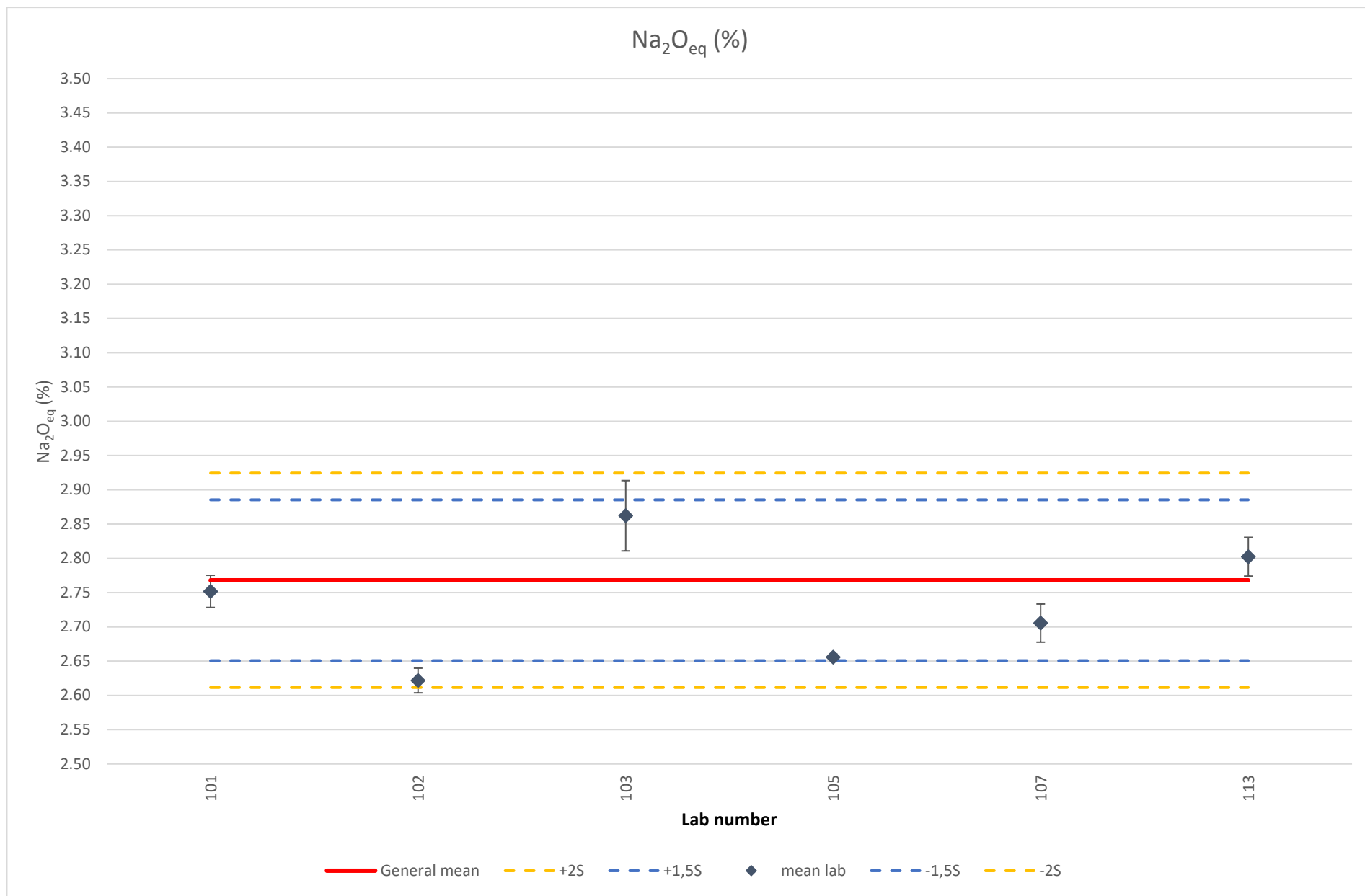




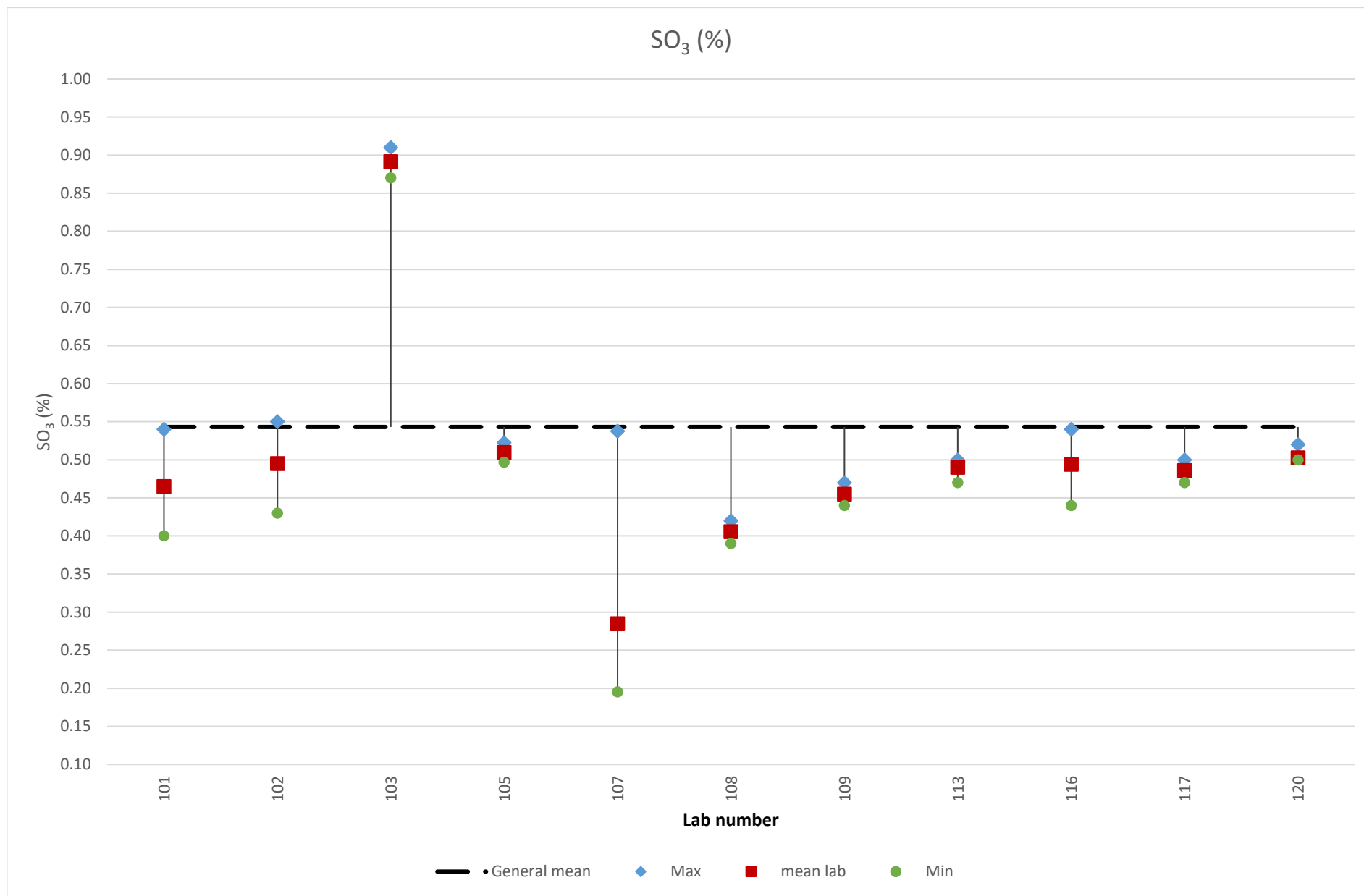


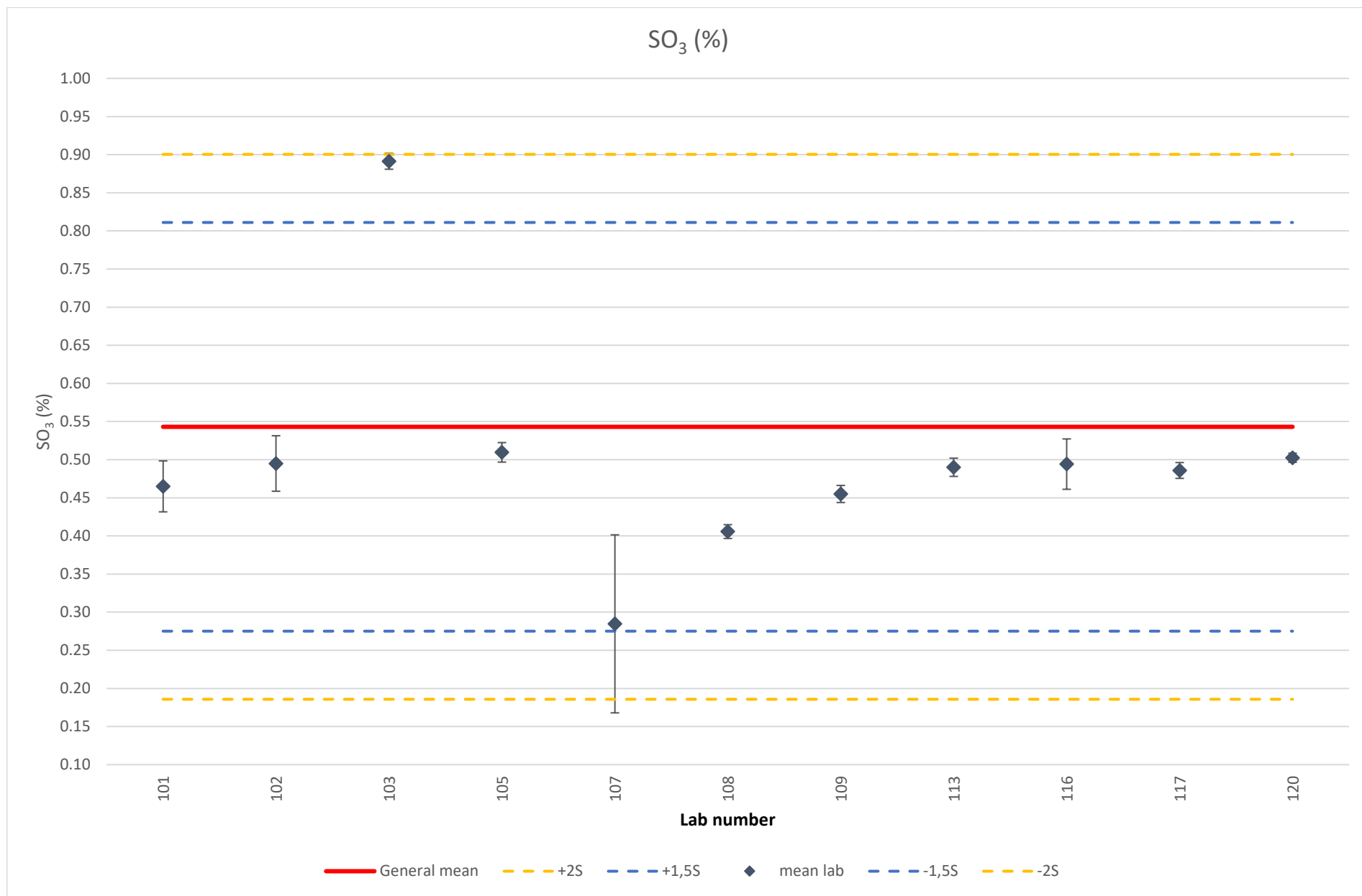


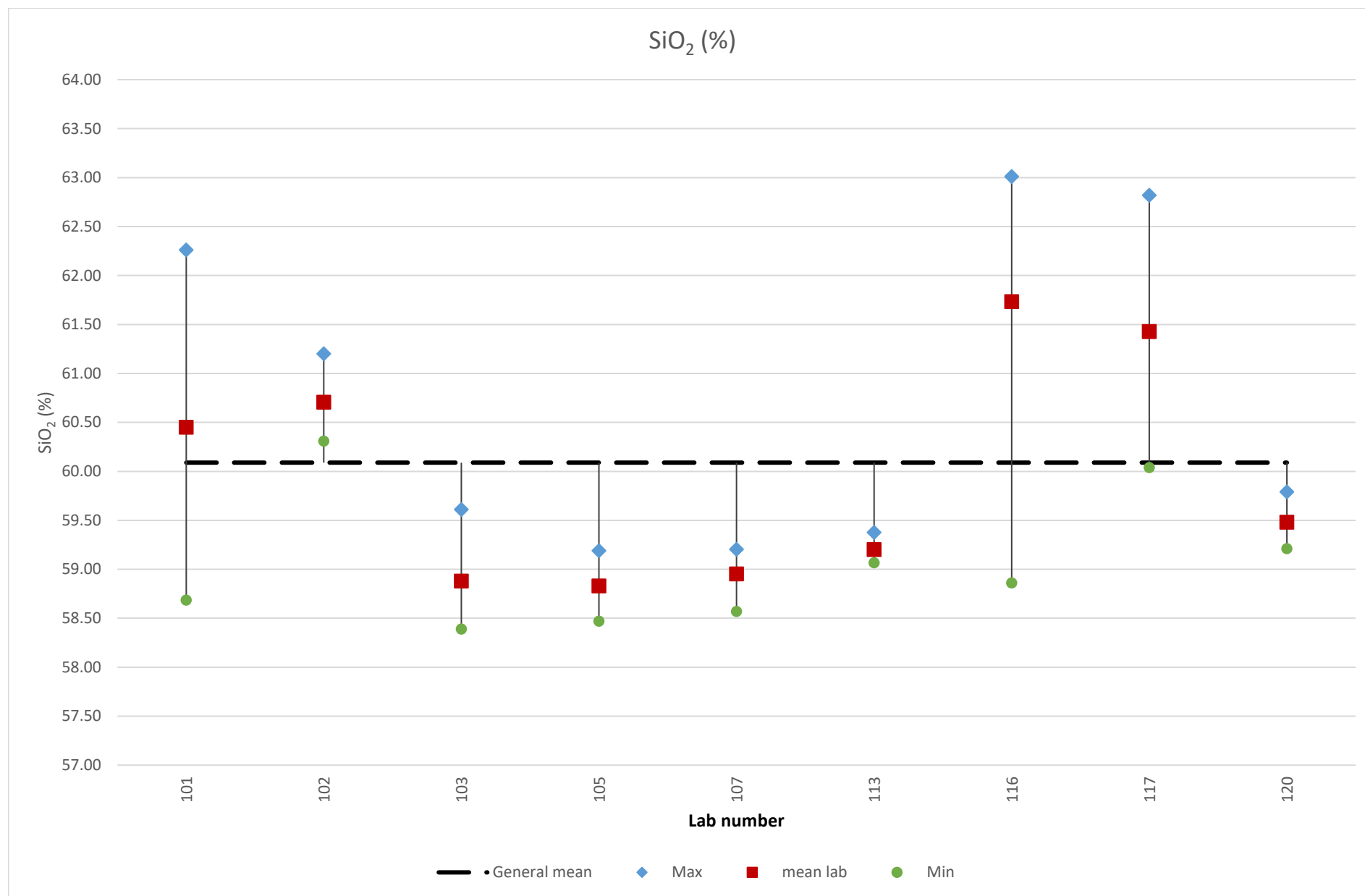


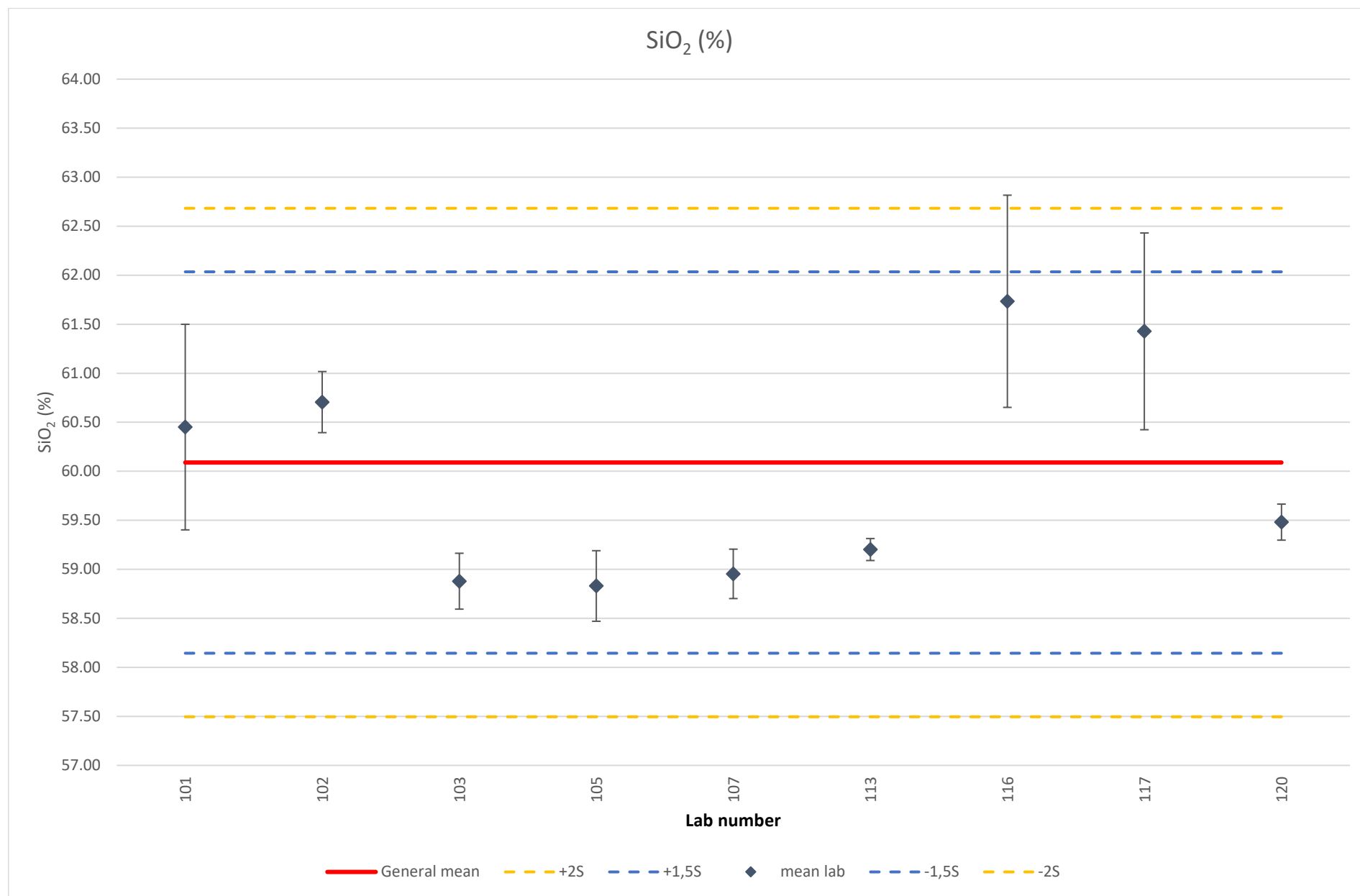


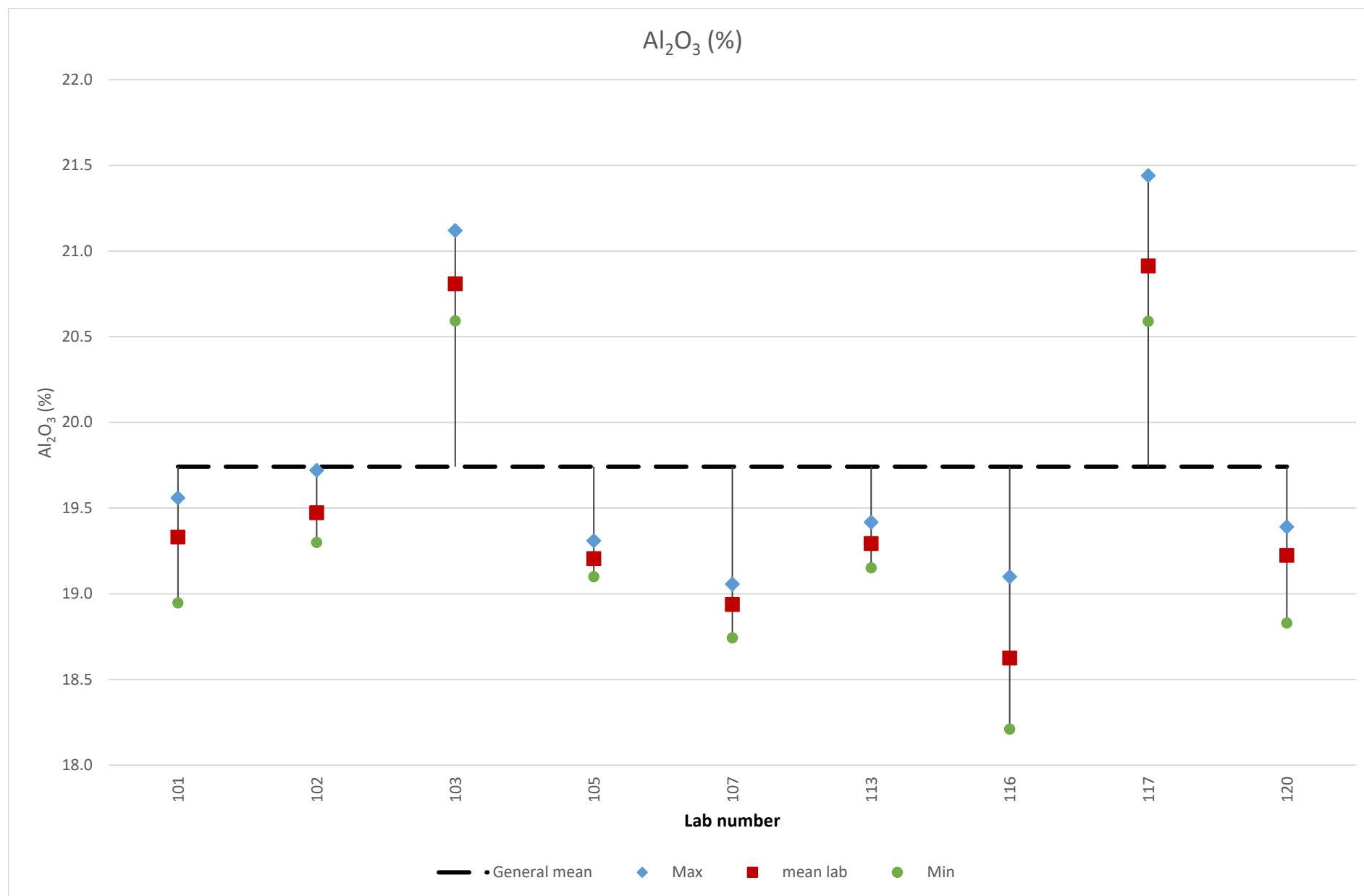
SO ₃ (%)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	117	0.543	0.179			32.90	0.91	0.20
101	24	0.465	0.033	-0.44	-0.24	7.19	0.54	0.40
102	6	0.495	0.036	-0.27	-0.02	7.35	0.55	0.43
103	22	0.891	0.010	1.95	2.83	1.17	0.91	0.87
105	2	0.510	0.013	-0.19	0.08	2.51	0.52	0.50
107	7	0.285	0.117	-1.45	-1.54	41.01	0.54	0.20
108	7	0.406	0.009	-0.77	-0.67	2.23	0.42	0.39
109	6	0.455	0.011	-0.49	-0.31	2.46	0.47	0.44
113	7	0.490	0.012	-0.30	-0.06	2.44	0.50	0.47
116	12	0.494	0.033	-0.27	-0.03	6.68	0.54	0.44
117	12	0.486	0.010	-0.32	-0.09	2.14	0.50	0.47
120	12	0.503	0.006	-0.23	0.03	1.18	0.52	0.50
SiO ₂ (%)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	101	60.089	1.297			2.1582	63.01	58.39
101	24	60.451	1.049	0.28	0.45	1.7	62.26	58.68
102	7	60.706	0.312	0.48	0.69	0.5	61.20	60.31
103	23	58.879	0.285	-0.93	-1.01	0.5	59.61	58.39
105	2	58.830	0.360	-0.97	-1.06	0.6	59.19	58.47
107	7	58.954	0.252	-0.88	-0.94	0.4	59.20	58.57
113	7	59.202	0.112	-0.68	-0.71	0.2	59.38	59.07
116	12	61.734	1.082	1.27	1.65	1.8	63.01	58.86
117	12	61.428	1.004	1.03	1.37	1.6	62.82	60.04
120	7	59.481	0.184	-0.47	-0.45	0.3	59.79	59.21
Al ₂ O ₃ (%)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	101	19.742	0.855			4.3	21.44	18.21
101	24	19.331	0.138	-0.48	-0.27	0.7	19.56	18.95
102	7	19.473	0.133	-0.31	-0.08	0.7	19.72	19.30
103	23	20.809	0.142	1.25	1.71	0.7	21.12	20.59
105	2	19.205	0.105	-0.63	-0.44	0.5	19.31	19.10
107	7	18.938	0.107	-0.94	-0.80	0.6	19.06	18.74
113	7	19.293	0.100	-0.52	-0.32	0.5	19.42	19.15
116	12	18.626	0.283	-1.31	-1.22	1.5	19.10	18.21
117	12	20.913	0.271	1.37	1.85	1.3	21.44	20.59
120	7	19.224	0.171	-0.61	-0.42	0.9	19.39	18.83

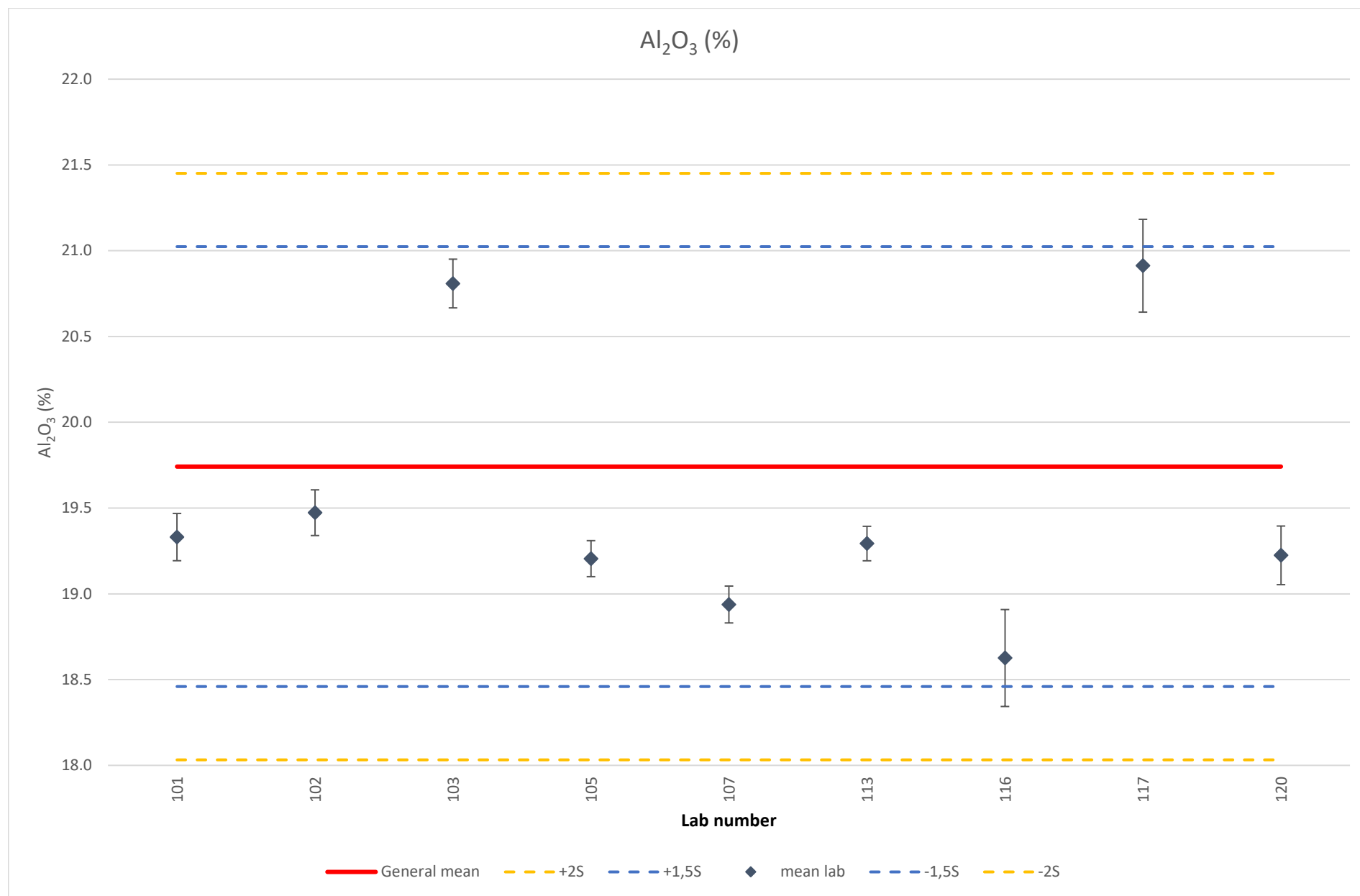




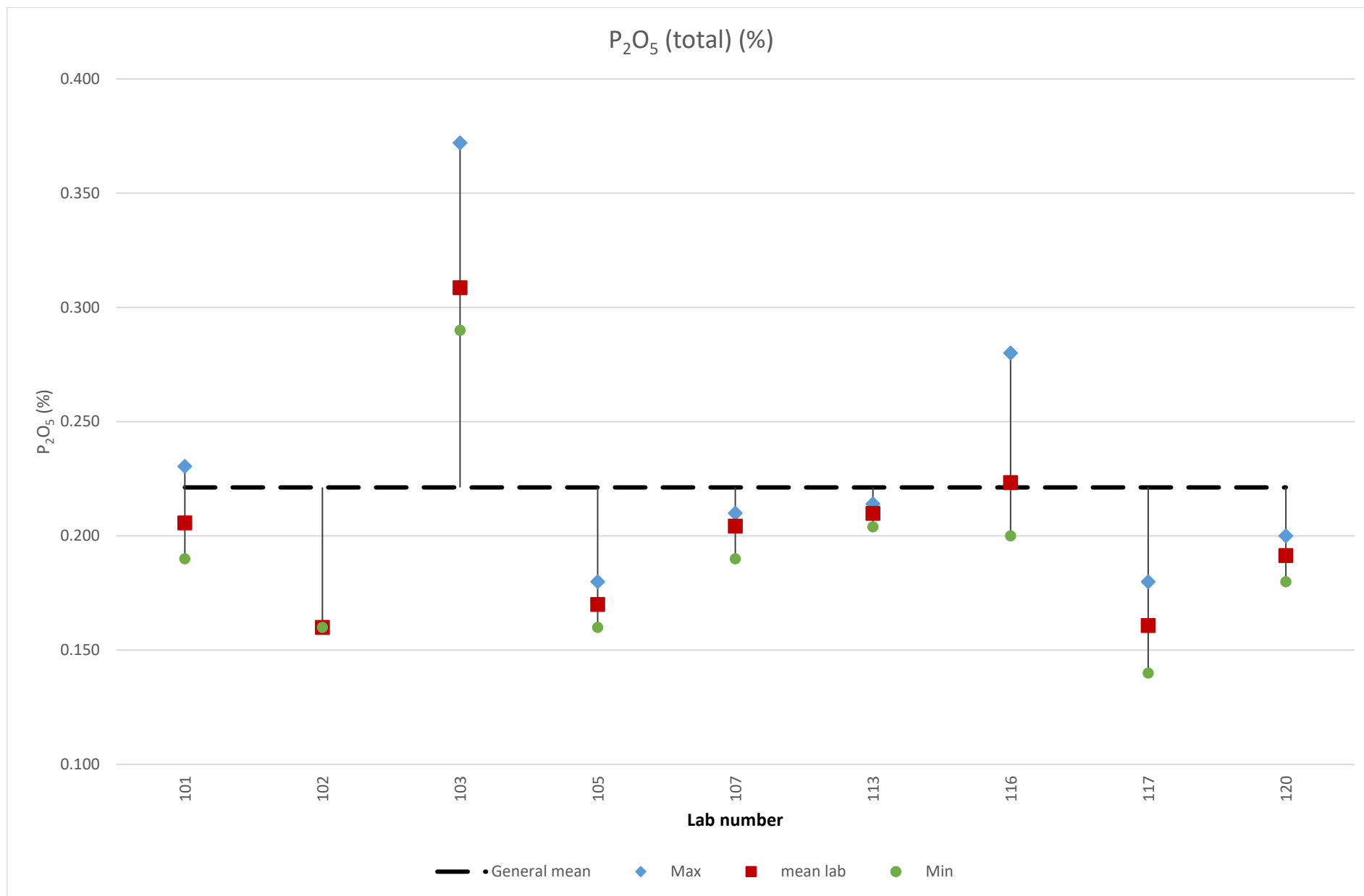


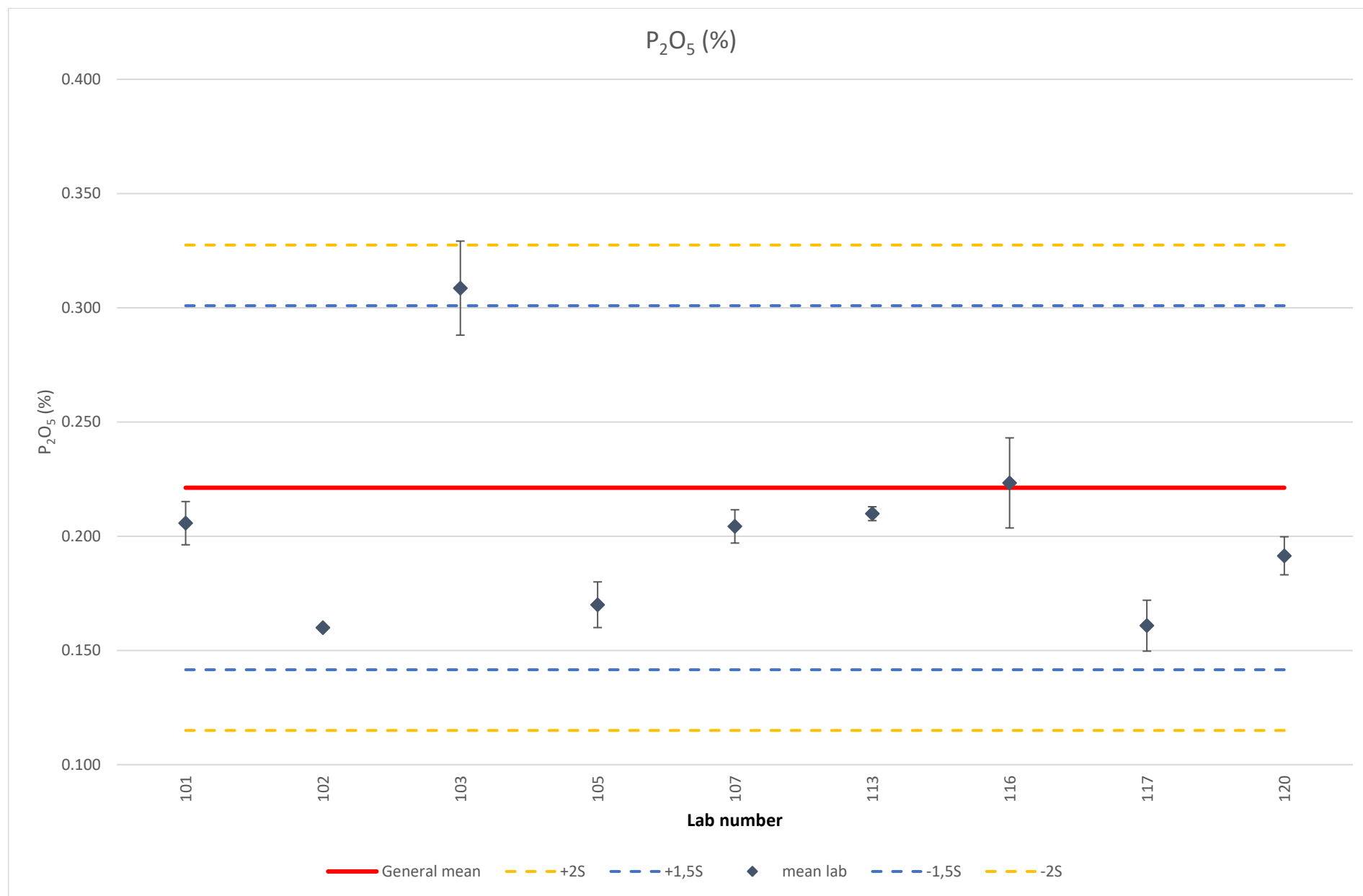


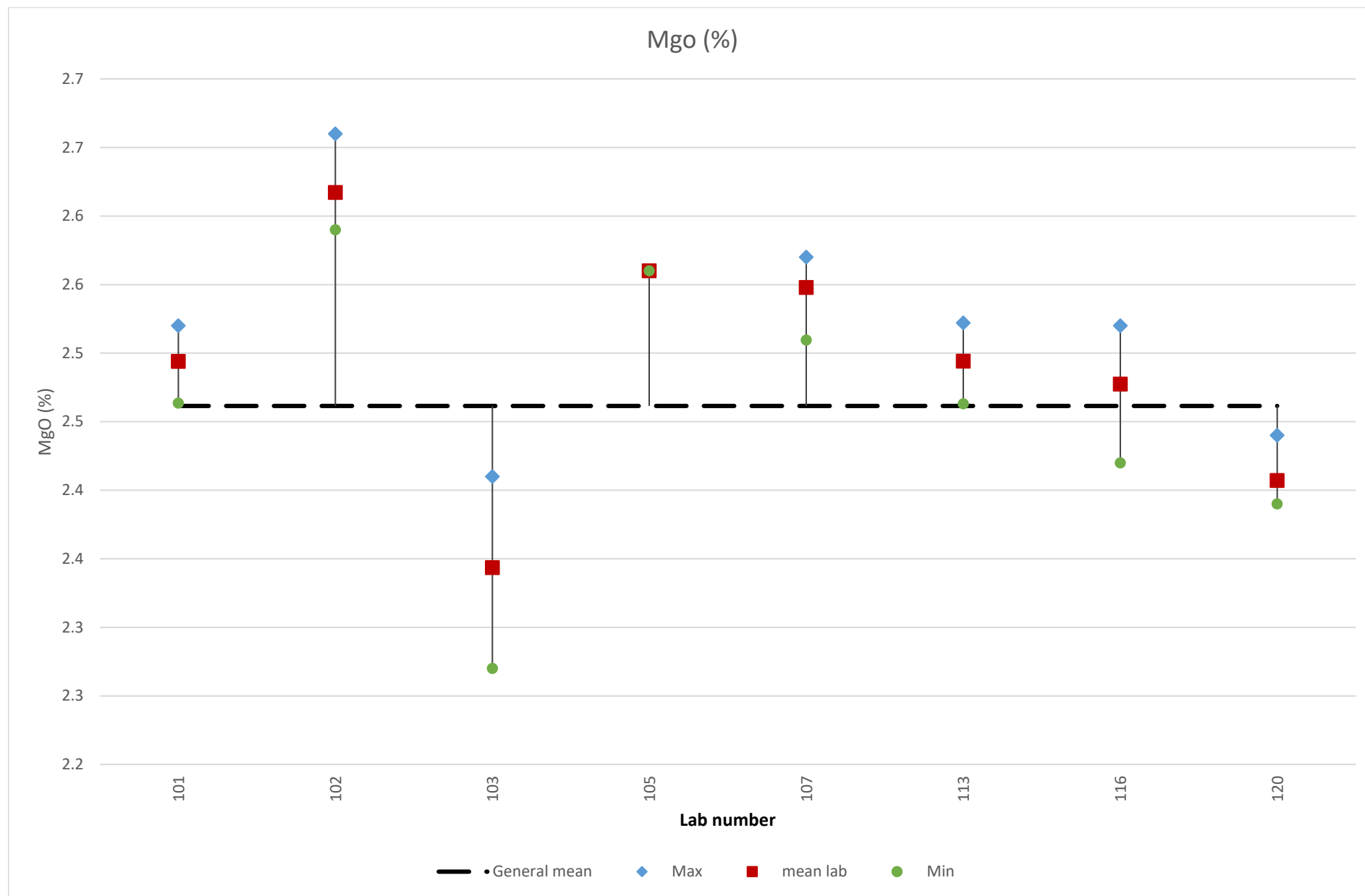


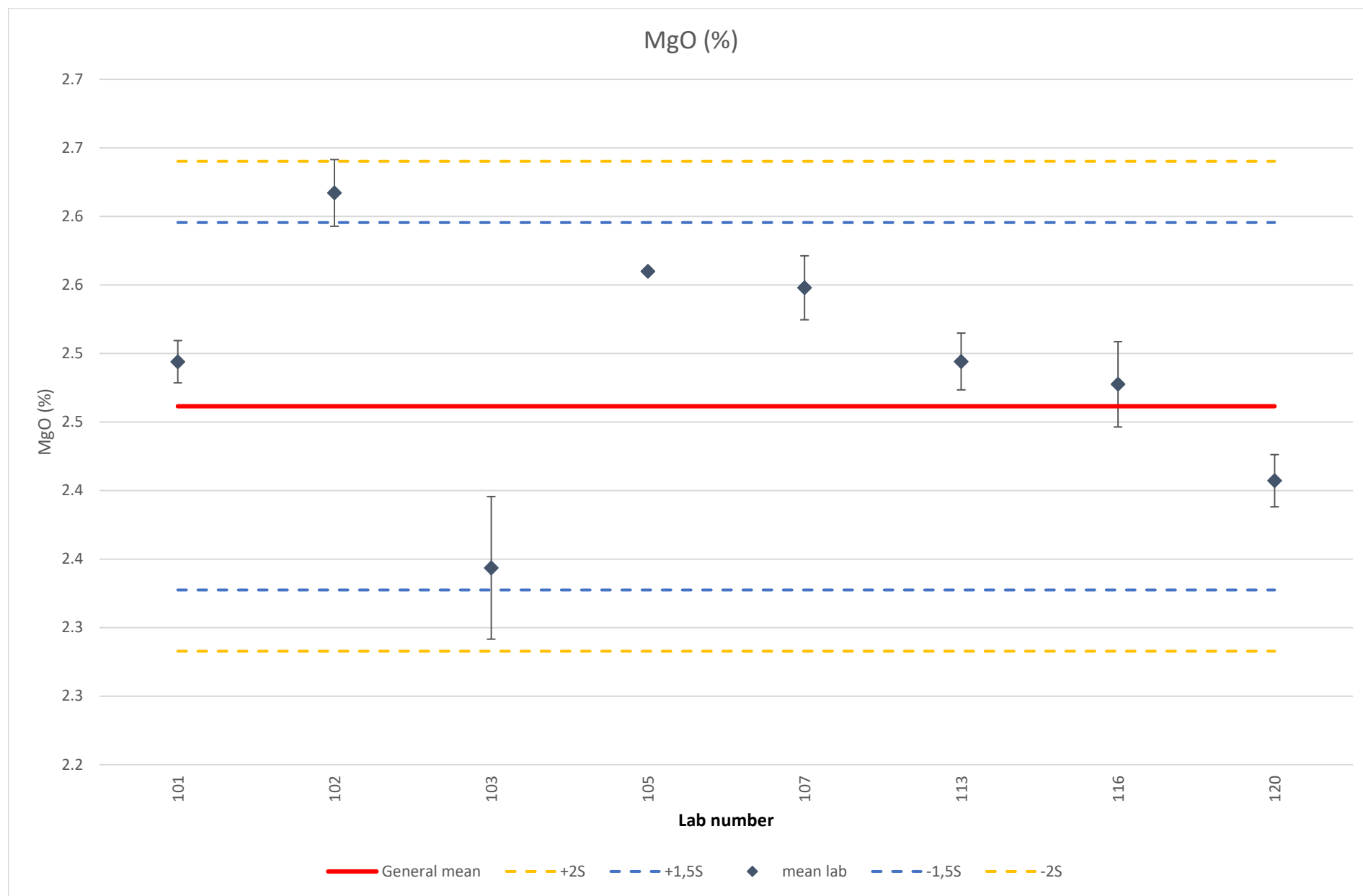


P ₂ O ₅ (total) (%)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	101	0.221	0.053			24.0	0.37	0.14
101	24	0.206	0.009	-0.29	0.04	4.6	0.23	0.19
102	7	0.160		-1.15	-1.02		0.16	0.16
103	23	0.309	0.021	1.64	2.45	6.7	0.37	0.29
105	2	0.170	0.010	-0.96	-0.79	5.9	0.18	0.16
107	7	0.204	0.007	-0.32	0.01	3.6	0.21	0.19
113	7	0.210	0.003	-0.21	0.14	1.5	0.21	0.20
116	12	0.223	0.020	0.04	0.46	8.8	0.28	0.20
117	12	0.161	0.011	-1.14	-1.00	6.9	0.18	0.14
120	7	0.191	0.008	-0.56	-0.29	4.4	0.20	0.18
MgO (%)								
Lab	Tests	Mean	Standard Deviation	z-score (1)	z-score (2)	Variation Coefficient	Max	Min
General	89	2.461	0.089			3.6305	2.66	2.27
101	24	2.494	0.015	0.36	0.02	0.619	2.52	2.46
102	7	2.617	0.024	1.74	1.53	0.930	2.66	2.59
103	23	2.344	0.052	-1.32	-1.83	2.219	2.41	2.27
105	2	2.560		1.10	0.83		2.56	2.56
107	7	2.548	0.023	0.97	0.68	0.916	2.57	2.51
113	7	2.494	0.021	0.37	0.02	0.830	2.52	2.46
116	12	2.478	0.031	0.18	-0.19	1.256	2.52	2.42
120	7	2.407	0.019	-0.61	-1.05	0.792	2.44	2.39

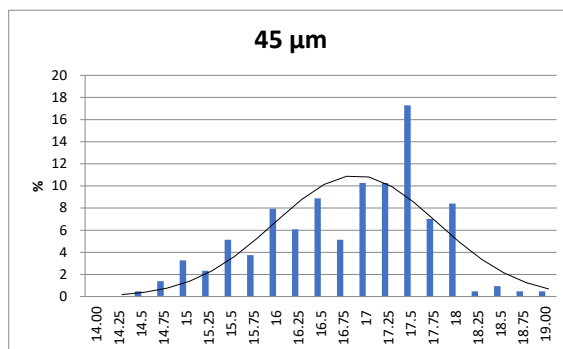
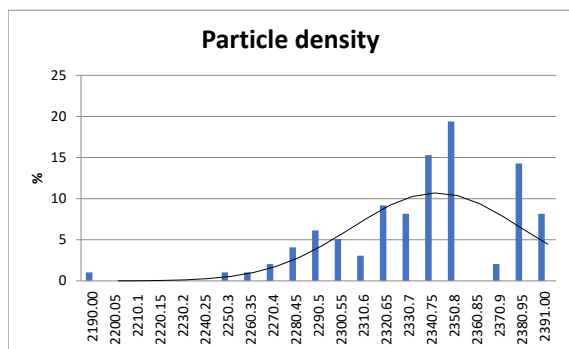
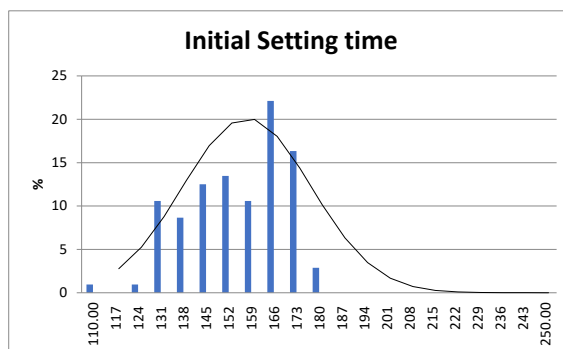
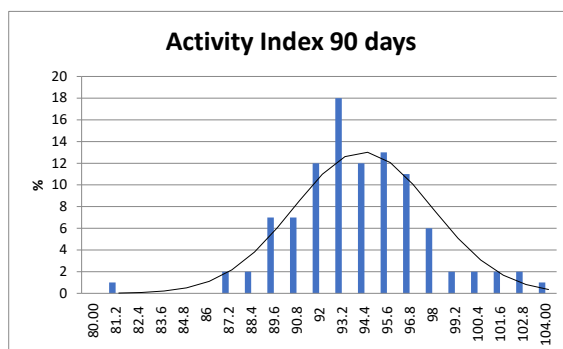
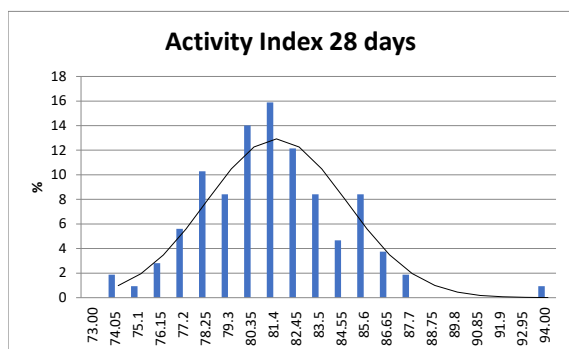
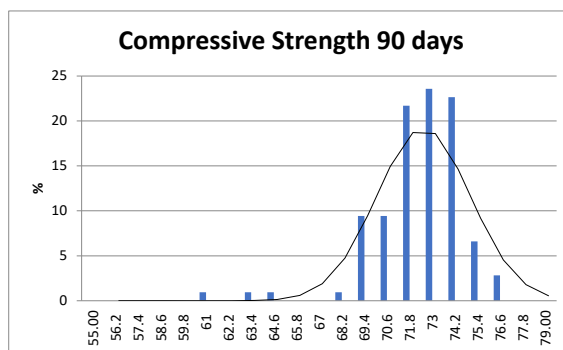
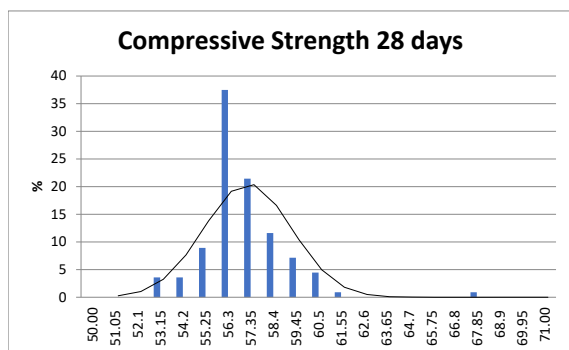




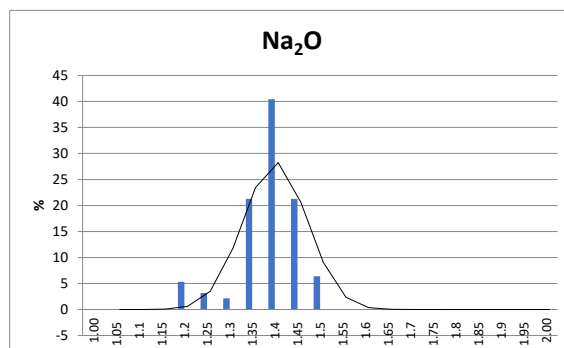
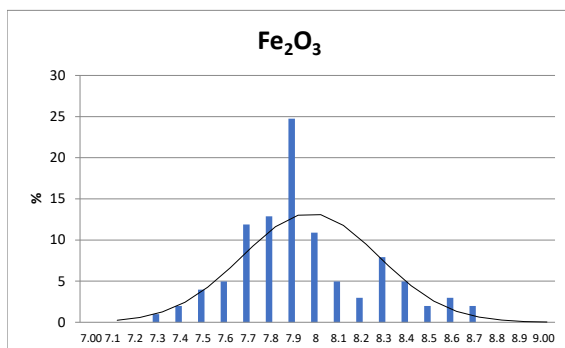
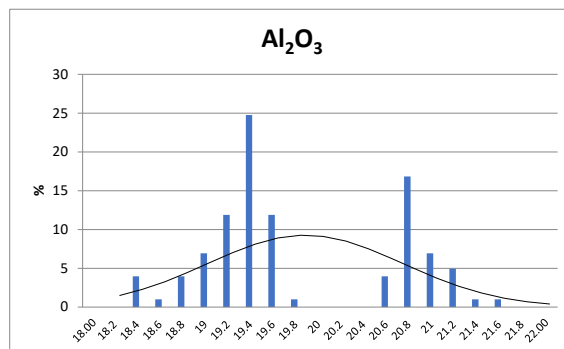
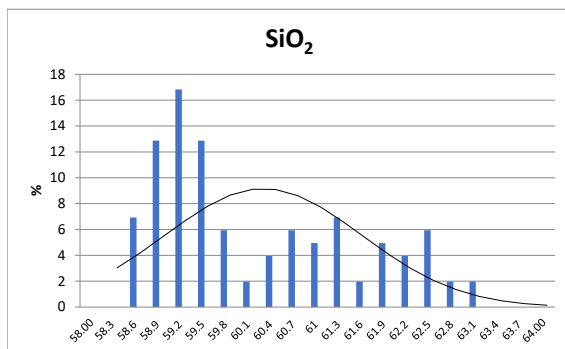
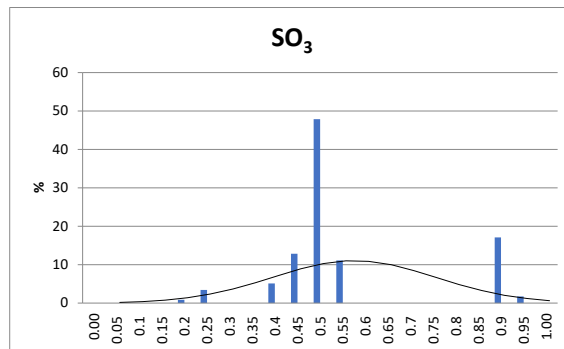
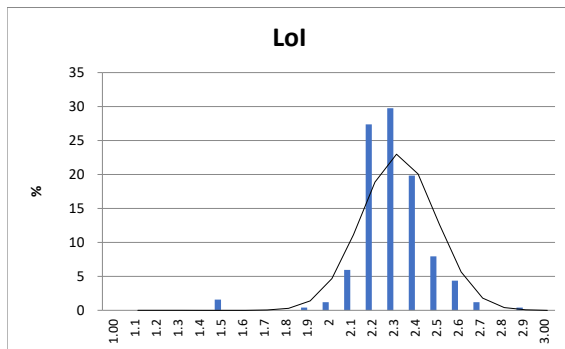
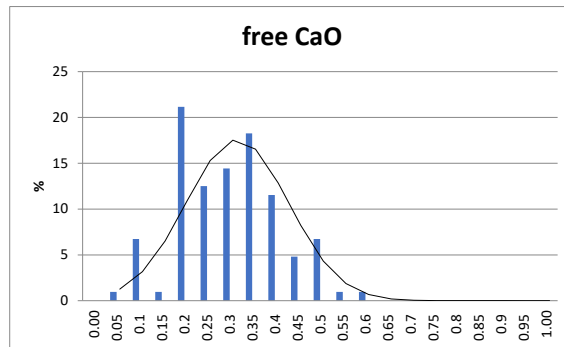
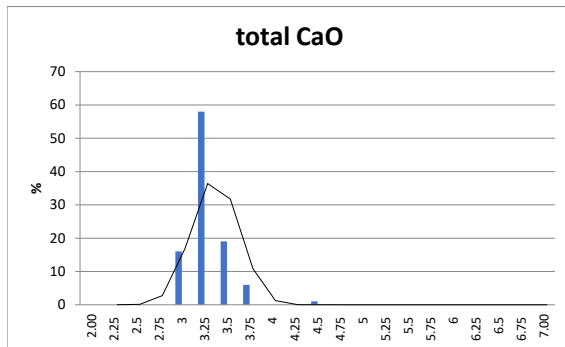




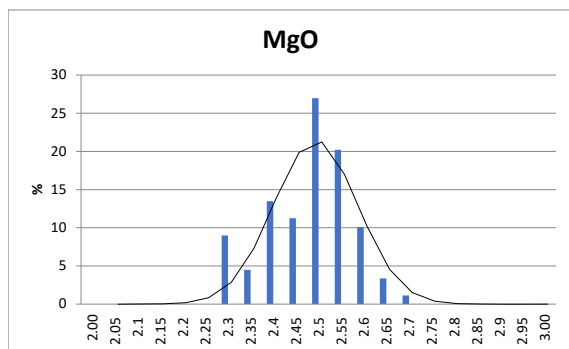
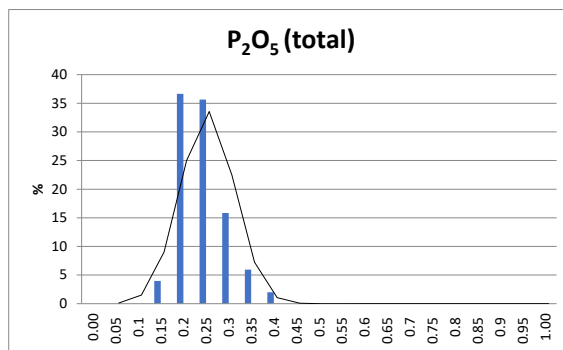
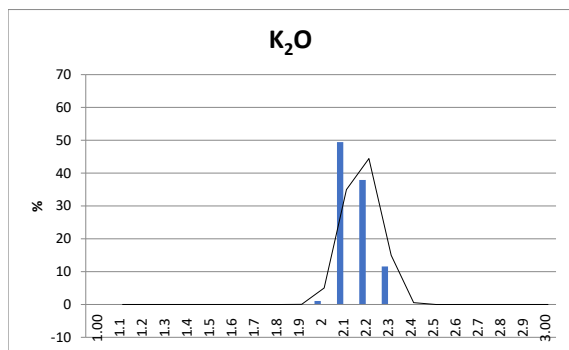
Distribution of the test results



The histograms are indicative. Not all participants report the same number of analyses, which can lead to an erroneous image in the graphs.



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