

# FLUXANA®

XRF Application Solutions

RV-2021-02

## Final Proficiency Test Report for recycling material from used catalysts

FLX-142

Bedburg-Hau, February 10<sup>th</sup>, 2022

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## XRF Application Solutions

### RV-2021-02

FLX-142	Al <sub>2</sub> O <sub>3</sub> <sup>1</sup>	CaO	Cr <sub>2</sub> O <sub>3</sub>	Cu	Fe <sup>1</sup>	K <sub>2</sub> O	MgO	Mn
Unit	%	%	%	%	%	%	%	%
No. of laboratories	14	13	13	13	14	11	14	14
Mean m	27,256	7,445	2,662	0,933	7,469	0,287	0,869	0,979
Reproducibility standard deviation s <sub>R</sub>	1,915	0,483	0,214	0,251	1,211	0,028	0,127	0,120
Repeatability standard deviation s <sub>r</sub>	0,269	0,093	0,039	0,036	0,121	0,009	0,034	0,040
Robust standard deviation s*	1,918	0,377	0,200	0,226	1,269	0,028	0,140	0,106
Uncertainty U (s*)	1,282	0,262	0,138	0,157	0,848	0,021	0,094	0,071
Uncertainty U (s <sub>R</sub> )	1,280	0,335	0,148	0,174	0,809	0,021	0,085	0,080
Mean - 2*s <sub>R</sub>	23,426	6,479	2,233	0,431	5,048	0,232	0,615	0,739
Mean + 2*s <sub>R</sub>	31,085	8,410	3,090	1,434	9,890	0,343	1,123	1,219
	Na <sub>2</sub> O	Ni <sup>1</sup>	P <sub>2</sub> O <sub>5</sub>	SiO <sub>2</sub>	TiO <sub>2</sub> <sup>2</sup>	V <sub>2</sub> O <sub>5</sub> <sup>2</sup>	Zn	
Unit	%	%	%	%	%	%	%	
No. of laboratories	12	13	14	14	9	8	14	
Mean m	0,831	21,006	0,470	7,516	0,068	0,021	0,108	
Reproducibility standard deviation s <sub>R</sub>	0,181	2,428	0,058	1,036	0,010	0,019	0,025	
Repeatability standard deviation s <sub>r</sub>	0,034	0,179	0,018	0,091	0,004	0,003	0,004	
Robust standard deviation s*	0,199	2,210	0,058	1,016	0,004	0,016	0,025	
Uncertainty U (s*)	0,143	1,533	0,039	0,679	0,004	0,014	0,017	
Uncertainty U (s <sub>R</sub> )	0,131	1,684	0,039	0,692	0,008	0,017	0,017	
Mean - 2*s <sub>R</sub>	0,469	16,150	0,353	5,443	0,048	0,017	0,058	
Mean + 2*s <sub>R</sub>	1,194	25,861	0,586	9,589	0,088	0,059	0,159	

All values are in mass % and are based on annealed sample material.

Mean	calculated from laboratory means using traceable methods only
s <sub>R</sub>	Reproducibility standard deviation
s <sub>r</sub>	Repeatability standard deviation
s*	Robust standard deviation
U (s*)	uncertainty calculated for a confidence interval of P= 95% (k=2)
U (s <sub>R</sub> )	uncertainty calculated for a confidence interval of P= 95% (k=2)
Range of tolerance	Mean ± 2 x s <sub>R</sub> ; all labs within this range show satisfactory performance

<sup>1</sup> Heterogeneities in the material cause extended tolerance ranges

<sup>2</sup> <10 laboratories in evaluation



## RV-2021-02

### Introduction

FLUXANA GmbH & Co. KG is a company providing services in the field of X-ray fluorescence analysis (XRF).

In 2011, FLUXANA introduced its own quality management.

In 2020 the accreditation of the FLUXANA Laboratory in Bedburg-Hau, Germany, was updated to DIN EN ISO/IEC 17025:2018 and FLUXANA received accreditation as Producer of Reference materials according to DIN EN ISO 17034:2017, as well.

The performance of proficiency tests is not yet accredited. However, the proficiency tests are conducted following the corresponding norms.

### Outliers

Outliers in the statistical sense are typically not detected when using robust statistical methods because the robust A+S algorithms were found to work better than the classical approach (which is outlier detection plus arithmetic mean and classical s.d. formula). Obvious blunders are taken out before calculation and will be marked as 'information only'.

### Further Information

All laboratory data is listed in the following evaluation report. Additional information about laboratory accreditation and analytical methods used is also provided. Calculation was done only on traceable methods.

Other methods, e.g., XRF using "pressed pellets" as the sample preparation method or XRF with the "standardless analysis" method, which are not traceable can also be used. These values will not be included in the evaluation. They will, however, be shown as 'information only' in the report and laboratory comparison.

The laboratory performance is shown based on z-scores. The diagrams show the laboratory data in comparison with the calculated mean values.



## RV-2021-02

### Participants

Aperam stainless Châtelet	Belgium
Nait Industry Solutions	Canada
Neste Oyj	Finland
Umicore Autocat France SAS	France
Chemilytics GmbH & Co. KG	Germany
FLUXANA GmbH & Co. KG	Germany
Fraunhofer IVV	Germany
Heraeus Deutschland GmbH & Co. KG	Germany
ReMetall Deutschland AG	Germany
Rigaku Europe SE	Germany
SGS Institut Fresenius GmbH	Germany
ThyssenKrupp Steel AG	Germany
BASF Nederland	Netherlands
Shell Global Solutions International B.V.	Netherlands
Institute of Chemical and Engineering Sciences, A*STAR Research Entities	Singapore
Sampyo Cement	South Korea
Universidade da Coruña	Spain
Accurate Converter	United States

### Statistical Evaluation used for this PT

#### Calculation of Mean $\bar{m}$

The mean  $\bar{m}$  for all laboratories is calculated using the Hampel estimator (ISO/TS 20612:2007 9.2.3) based on the laboratory means  $\mu$  using traceable methods only.

#### Calculation of reproducibility standard deviation $s_R$

The reproducibility standard deviation  $s_R$  is calculated using the Q-method (ISO/TS 20612:2007 9.2.3).

#### Calculation of repeatability standard deviation $s_r$

The repeatability standard deviation  $s_r$  is also calculated using the Q-method.

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### Calculation of robust standard deviation $s^*$

The robust standard deviation  $s^*$  is calculated from the laboratory means  $\mu$  using the Q-method.

### Calculation of uncertainty $U_{S_R}$ (according to Nordtest TR 537 ed 3.1.)

The **uncertainty**  $U_{S_R}$  for a confidence interval of P=95% (k=2) can be calculated from the **reproducibility standard deviation**  $S_R$  (factor 1.25 for average median, robust statistics) and the number of participating laboratories  $p$ :

$$U_{S_R} = 2 * 1.25 * \frac{S_R}{\sqrt{p}}$$

### Calculation of uncertainty $U_{s^*}$ (according to ISO 13528:2020)

The **uncertainty**  $U_{s^*}$  for a confidence interval of P=95% (k=2) can be calculated from the **robust standard deviation**  $s^*$  (factor 1.25 for average median, robust statistics)) and the number of participating laboratories  $p$ :

$$U_{s^*} = 2 * 1.25 * \frac{s^*}{\sqrt{p}}$$

The **uncertainty**  $U_{s^*}$  only takes the between laboratories uncertainty into account while the **uncertainty**  $U_{S_R}$  also includes the within laboratories uncertainty. Therefore  $U_{S_R}$  is recommended for use in accredited laboratories.

### Laboratory performance

Laboratory proficiency assessment is based on z-scores.

The **z-score**  $z$  is calculated from all laboratory means  $\mu$ :

$$z = \frac{m - \mu}{S_R}$$

$m$	Mean value for all laboratories (assigned value)
$\mu$	Mean value of individual laboratory
$S_R$	Reproducibility standard deviation

**RV-2021-02****Assessment on z-scores:**

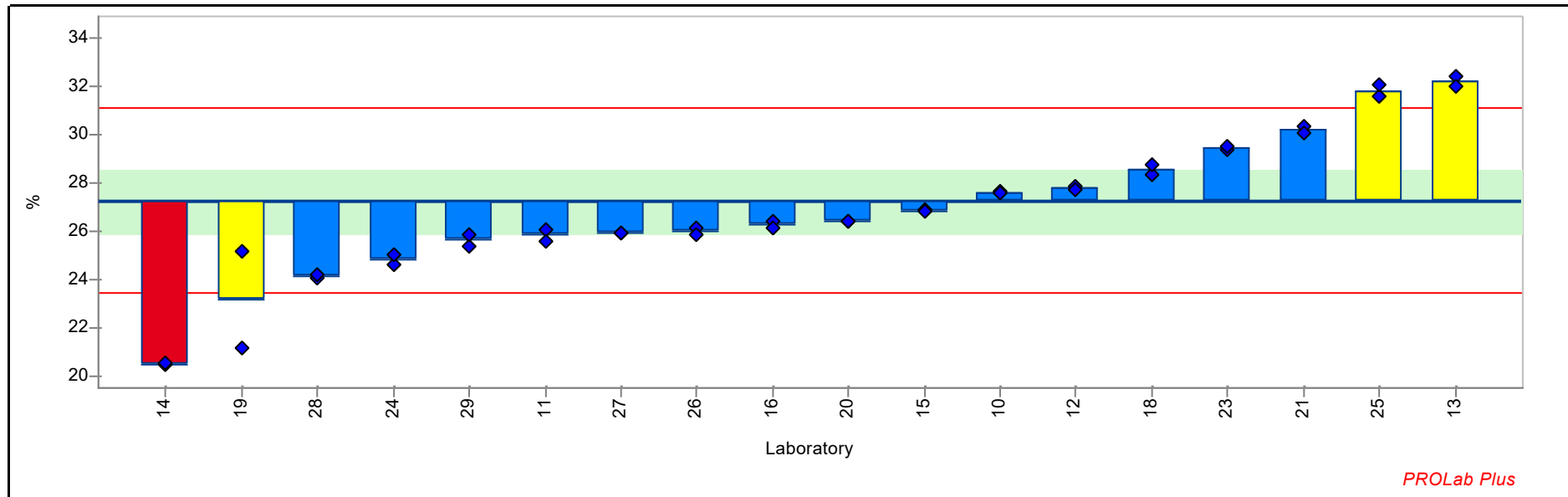
$ z  \leq 2.0$	indicates "satisfactory" performance = generates no signal
$2.0 <  z  < 3.0$	indicates "questionable" performance = generates a warning signal
$ z  \geq 3.0$	indicates "unsatisfactory" performance = generates an action signal

Z-scores with  $3 \geq |z| \geq 2$  are highlighted with a yellow color, z-scores with  $|z| \geq 3$  are highlighted with a red color.

## RV\_2021\_02\_Recycling Material from used Catalysts

## Summary results

**Sample:** FLX-142      **Reproducibility s.d.:** 1,915 %  
**Measurand:** Al<sub>2</sub>O<sub>3</sub>      **Repeatability s.d.:** 0,269 %  
**Mean ± U(Mean):** 27,256 ± 1,282 %      **Range of tolerance:** 23,426 - 31,085 % (|z-score| ≤ 2,000)  
**No. of laboratories:** 14      **Statistical method:** Q/Hampel



Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
10	27,602	0,049	0,181	27,636	27,567	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
11	25,865	0,346	-0,726	26,110	25,620	no accreditation	XRF (fusion)	
12	27,808	0,085	0,288	27,868	27,748	ISO 17025	XRF (fusion)	
13	32,250	0,283	2,608	32,450	32,050	no accreditation	XRF (pressed pellet)	information only
14	20,526	0,067	-3,515	20,478	20,573	no accreditation	XRF (pressed pellet)	information only
15	26,873	0,059	-0,200	26,915	26,831	no accreditation	XRF (fusion)	

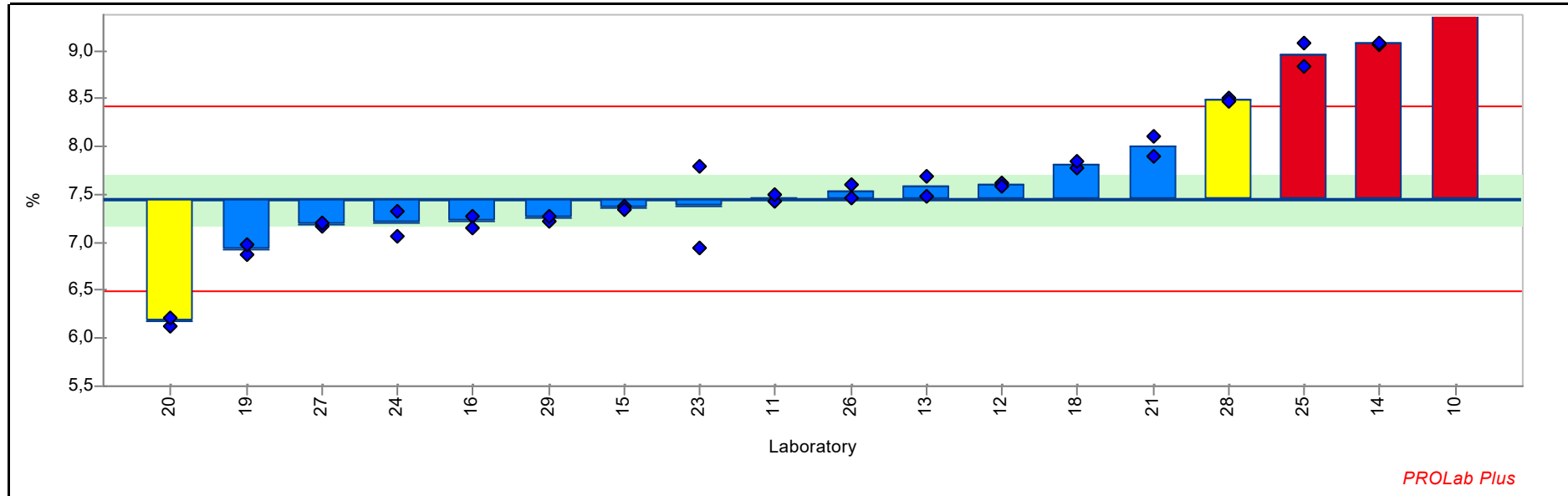
**RV\_2021\_02\_Recycling Material from used Catalysts**

Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
16	26,285	0,163	-0,507	26,400	26,170	no accreditation	XRF (fusion)	
18	28,559	0,313	0,681	28,338	28,780	no accreditation	XRF (fusion)	
19	23,188	2,871	-2,124	21,158	25,218	no accreditation	XRF (pressed pellet)	information only
20	26,450	0,013	-0,421	26,440	26,459	no accreditation	XRF (fusion)	
21	30,253	0,201	1,565	30,395	30,111	no accreditation	XRF (fusion)	
23	29,456	0,071	1,149	29,406	29,506	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
24	24,843	0,286	-1,260	24,641	25,046	no accreditation	XRF (fusion)	
25	31,837	0,308	2,393	31,619	32,055	no accreditation	XRF (fusion)	
26	26,020	0,220	-0,646	26,175	25,864	no accreditation	XRF (fusion)	
27	25,919	0,006	-0,698	25,914	25,923	ISO 17025	Other Method	ICP-OES
28	24,119	0,095	-1,638	24,052	24,186	no accreditation	XRF (pressed pellet)	information only
29	25,645	0,310	-0,841	25,425	25,864	no accreditation	XRF (fusion)	



## RV\_2021\_02\_Recycling Material from used Catalysts

**Sample:** FLX-142 **Reproducibility s.d.:** 0,483 %  
**Measurand:** CaO **Repeatability s.d.:** 0,093 %  
**Mean ± U(Mean):** 7,445 ± 0,262 % **Range of tolerance:** 6,479 - 8,410 % (|z-score| ≤ 2,000)  
**No. of laboratories:** 13 **Statistical method:** Q/Hampel



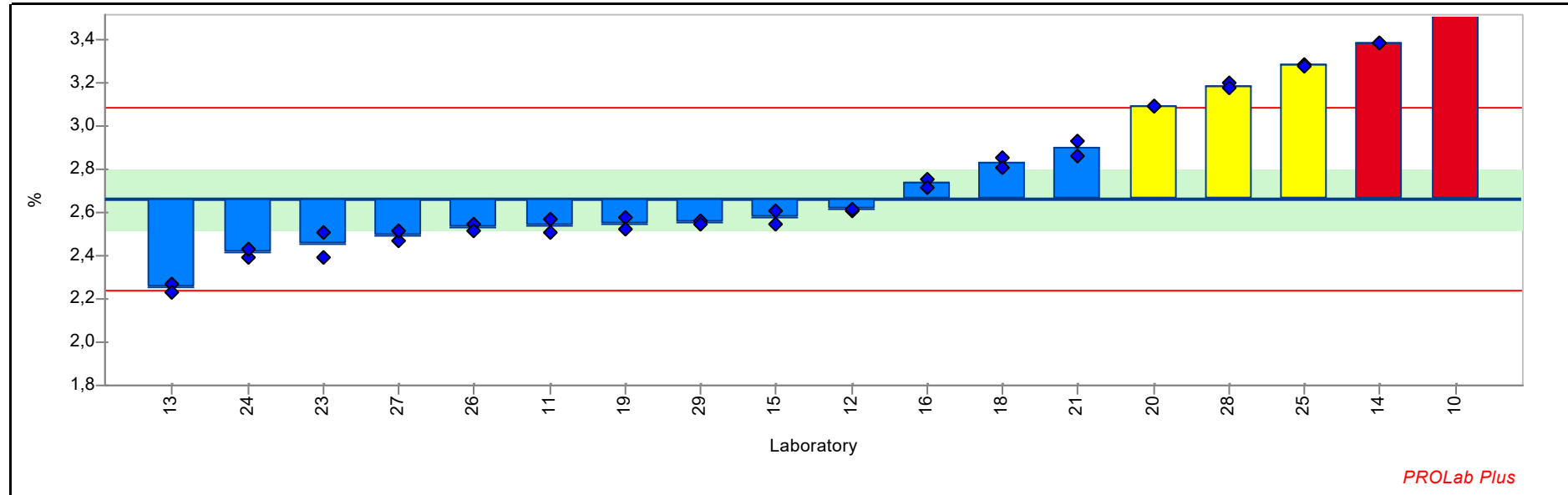
Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
10	10,065	0,028	5,429	10,085	10,045	no accreditation	XRF (fusion)	information only
11	7,455	0,049	0,022	7,420	7,490	no accreditation	XRF (fusion)	
12	7,595	0,022	0,311	7,610	7,579	ISO 17025	XRF (fusion)	
13	7,585	0,148	0,291	7,690	7,480	no accreditation	XRF (pressed pellet)	information only
14	9,074	0,016	3,376	9,063	9,085	no accreditation	XRF (pressed pellet)	information only
15	7,357	0,029	-0,182	7,377	7,336	no accreditation	XRF (fusion)	
16	7,210	0,085	-0,486	7,270	7,150	no accreditation	XRF (fusion)	
18	7,816	0,049	0,769	7,781	7,850	no accreditation	XRF (fusion)	

**RV\_2021\_02\_Recycling Material from used Catalysts**

Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
19	6,925	0,081	-1,076	6,868	6,982	no accreditation	XRF (pressed pellet)	information only
20	6,172	0,063	-2,635	6,128	6,217	no accreditation	XRF (fusion)	
21	7,997	0,151	1,146	8,104	7,891	no accreditation	XRF (fusion)	
23	7,371	0,602	-0,151	6,946	7,797	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
24	7,197	0,185	-0,513	7,066	7,328	no accreditation	XRF (fusion)	
25	8,959	0,163	3,138	8,844	9,074	no accreditation	XRF (fusion)	
26	7,527	0,101	0,170	7,598	7,455	no accreditation	XRF (fusion)	
27	7,187	0,023	-0,534	7,171	7,203	ISO 17025	Other Method	ICP-OES
28	8,489	0,021	2,165	8,504	8,475	no accreditation	XRF (pressed pellet)	information only
29	7,245	0,045	-0,412	7,214	7,277	no accreditation	XRF (fusion)	

## RV\_2021\_02\_Recycling Material from used Catalysts

**Sample:** FLX-142 **Reproducibility s.d.:** 0,214 %  
**Measurand:** Cr2O3 **Repeatability s.d.:** 0,039 %  
**Mean ± U(Mean):** 2,662 ± 0,138 % **Range of tolerance:** 2,233 - 3,090 % (|z-score| ≤ 2,000)  
**No. of laboratories:** 13 **Statistical method:** Q/Hampel



PROLab Plus

Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
10	3,891	0,017	5,741	3,879	3,903	no accreditation	XRF (fusion)	information only
11	2,540	0,042	-0,568	2,510	2,570	no accreditation	XRF (fusion)	
12	2,611	0,002	-0,234	2,610	2,613	ISO 17025	XRF (fusion)	
13	2,250	0,028	-1,922	2,270	2,230	no accreditation	XRF (pressed pellet)	information only
14	3,386	0,001	3,383	3,387	3,385	no accreditation	XRF (pressed pellet)	information only
15	2,576	0,041	-0,400	2,605	2,547	no accreditation	XRF (fusion)	
16	2,737	0,030	0,352	2,758	2,716	no accreditation	XRF (fusion)	
18	2,832	0,028	0,793	2,851	2,812	no accreditation	XRF (fusion)	

**RV\_2021\_02\_Recycling Material from used Catalysts**

Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
19	2,550	0,040	-0,523	2,578	2,521	no accreditation	XRF (pressed pellet)	information only
20	3,095	0,000	2,024	3,095	3,095	no accreditation	XRF (fusion)	
21	2,898	0,049	1,104	2,933	2,863	no accreditation	XRF (fusion)	
23	2,450	0,086	-0,988	2,511	2,389	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
24	2,411	0,023	-1,170	2,395	2,427	no accreditation	XRF (fusion)	
25	3,283	0,010	2,902	3,290	3,276	no accreditation	XRF (fusion)	
26	2,533	0,021	-0,600	2,548	2,518	no accreditation	XRF (fusion)	
27	2,494	0,032	-0,785	2,471	2,516	ISO 17025	Other Method	ICP-OES
28	3,190	0,011	2,468	3,198	3,182	no accreditation	XRF (pressed pellet)	information only
29	2,553	0,006	-0,505	2,558	2,549	no accreditation	XRF (fusion)	



**RV\_2021\_02\_Recycling Material from used Catalysts**

Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
20	0,631	0,042	-1,201	0,661	0,602	no accreditation	XRF (fusion)	
21	0,939	0,012	0,024	0,930	0,947	no accreditation	XRF (fusion)	
23	0,516	0,075	-1,661	0,569	0,463	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
24	0,635	0,013	-1,189	0,644	0,625	no accreditation	XRF (fusion)	
25	1,040	0,100	0,430	1,111	0,970	no accreditation	XRF (fusion)	
26	1,111	0,086	0,713	1,051	1,172	no accreditation	XRF (fusion)	
27	1,059	0,024	0,504	1,076	1,042	ISO 17025	Other Method	ICP-OES
28	1,382	0,006	1,792	1,378	1,386	no accreditation	XRF (pressed pellet)	information only
29	1,107	0,011	0,698	1,115	1,100	no accreditation	XRF (fusion)	



**RV\_2021\_02\_Recycling Material from used Catalysts**

Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
19	4,143	0,031	-2,748	4,121	4,165	no accreditation	XRF (pressed pellet)	information only
20	6,030	0,608	-1,189	6,460	5,600	no accreditation	XRF (fusion)	
21	9,244	0,217	1,466	9,090	9,397	no accreditation	XRF (fusion)	
23	8,969	0,447	1,239	9,285	8,653	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
24	7,264	0,051	-0,169	7,300	7,228	no accreditation	XRF (fusion)	
25	8,303	0,687	0,689	7,817	8,789	no accreditation	XRF (fusion)	
26	7,197	0,157	-0,225	7,086	7,308	no accreditation	XRF (fusion)	
27	6,475	0,066	-0,821	6,522	6,428	ISO 17025	Other Method	ICP-OES
28	5,058	0,001	-1,992	5,057	5,059	no accreditation	XRF (pressed pellet)	information only
29	8,399	0,334	0,768	8,635	8,162	no accreditation	XRF (fusion)	



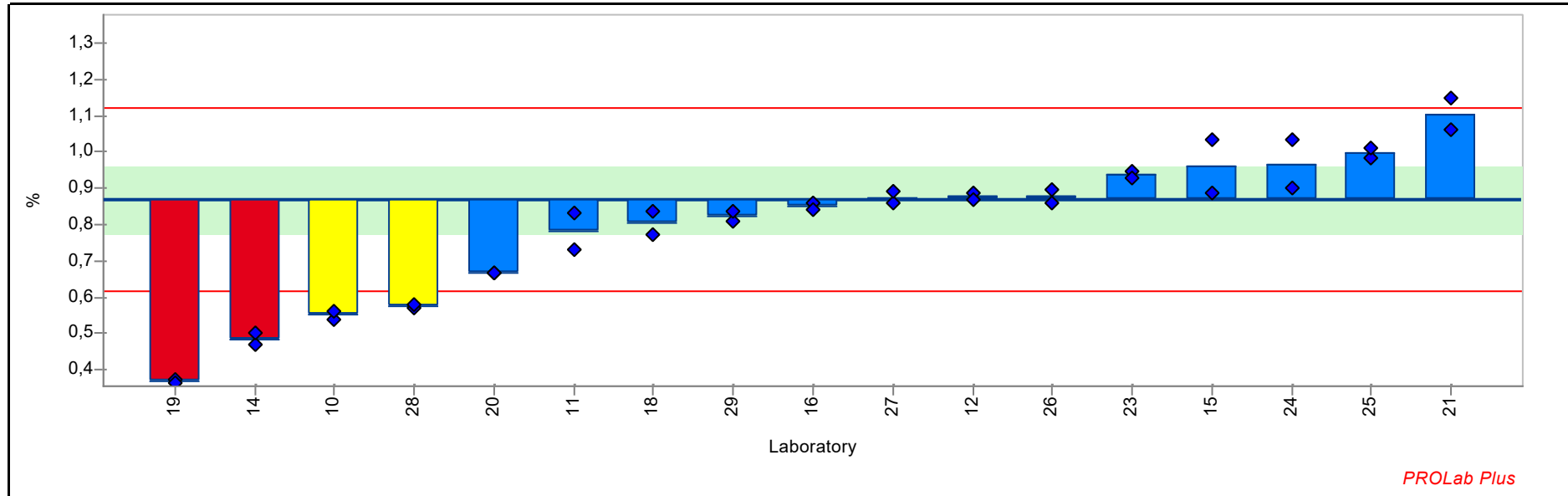


**RV\_2021\_02\_Recycling Material from used Catalysts**

Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
19	0,215	0,015	-2,593	0,205	0,226	no accreditation	XRF (pressed pellet)	information only
20	0,175	0,005	-4,034	0,172	0,179	no accreditation	XRF (fusion)	information only
21	0,316	0,006	1,028	0,312	0,320	no accreditation	XRF (fusion)	
23	0,309	0,078	0,776	0,254	0,364	no accreditation	XRF (fusion)	information only
25	0,307	0,018	0,704	0,320	0,294	no accreditation	XRF (fusion)	
26	0,280	0,009	-0,251	0,287	0,274	no accreditation	XRF (fusion)	
27	0,265	0,006	-0,809	0,269	0,261	ISO 17025	Other Method	ICP-OES
28	0,292	0,006	0,181	0,288	0,297	no accreditation	XRF (pressed pellet)	information only
29	0,259	0,003	-1,025	0,257	0,261	no accreditation	XRF (fusion)	

## RV\_2021\_02\_Recycling Material from used Catalysts

**Sample:** FLX-142 **Reproducibility s.d.:** 0,127 %  
**Measurand:** MgO **Repeatability s.d.:** 0,034 %  
**Mean ± U(Mean):** 0,869 ± 0,094 % **Range of tolerance:** 0,615 - 1,123 % (|z-score| ≤ 2,000)  
**No. of laboratories:** 14 **Statistical method:** Q/Hampel



Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
10	0,552	0,016	-2,487	0,541	0,564	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
11	0,780	0,071	-0,699	0,730	0,830	no accreditation	XRF (fusion)	
12	0,877	0,013	0,067	0,887	0,868	ISO 17025	XRF (fusion)	
13						no accreditation	XRF (pressed pellet)	information only
14	0,486	0,025	-3,014	0,468	0,503	no accreditation	XRF (pressed pellet)	information only
15	0,960	0,104	0,712	0,886	1,033	no accreditation	XRF (fusion)	
16	0,850	0,014	-0,149	0,860	0,840	no accreditation	XRF (fusion)	
18	0,804	0,047	-0,511	0,837	0,771	no accreditation	XRF (fusion)	

**RV\_2021\_02\_Recycling Material from used Catalysts**

Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
19	0,370	0,007	-3,922	0,375	0,365	no accreditation	XRF (pressed pellet)	information only
20	0,667	0,000	-1,587	0,667	0,667	no accreditation	XRF (fusion)	
21	1,105	0,061	1,855	1,148	1,062	no accreditation	XRF (fusion)	
23	0,936	0,012	0,531	0,945	0,928	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
24	0,968	0,091	0,774	1,032	0,903	no accreditation	XRF (fusion)	
25	0,996	0,018	1,002	0,984	1,009	no accreditation	XRF (fusion)	
26	0,879	0,026	0,083	0,861	0,898	no accreditation	XRF (fusion)	
27	0,875	0,025	0,051	0,858	0,893	ISO 17025	Other Method	ICP-OES
28	0,576	0,006	-2,303	0,572	0,580	no accreditation	XRF (pressed pellet)	information only
29	0,823	0,021	-0,361	0,808	0,838	no accreditation	XRF (fusion)	



**RV\_2021\_02\_Recycling Material from used Catalysts**

Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
19	0,720	0,006	-2,164	0,715	0,724	no accreditation	XRF (pressed pellet)	information only
20	0,938	0,005	-0,346	0,941	0,934	no accreditation	XRF (fusion)	
21	1,115	0,037	1,134	1,141	1,089	no accreditation	XRF (fusion)	
23	0,836	0,014	-1,193	0,826	0,846	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
24	0,985	0,047	0,050	1,018	0,952	no accreditation	XRF (fusion)	
25	1,048	0,059	0,575	1,090	1,006	no accreditation	XRF (fusion)	
26	1,040	0,028	0,508	1,020	1,060	no accreditation	XRF (fusion)	
27	1,073	0,007	0,784	1,068	1,078	ISO 17025	Other Method	ICP-OES
28	0,899	0,022	-0,663	0,884	0,915	no accreditation	XRF (pressed pellet)	information only
29	0,982	0,026	0,021	0,963	1,000	no accreditation	XRF (fusion)	



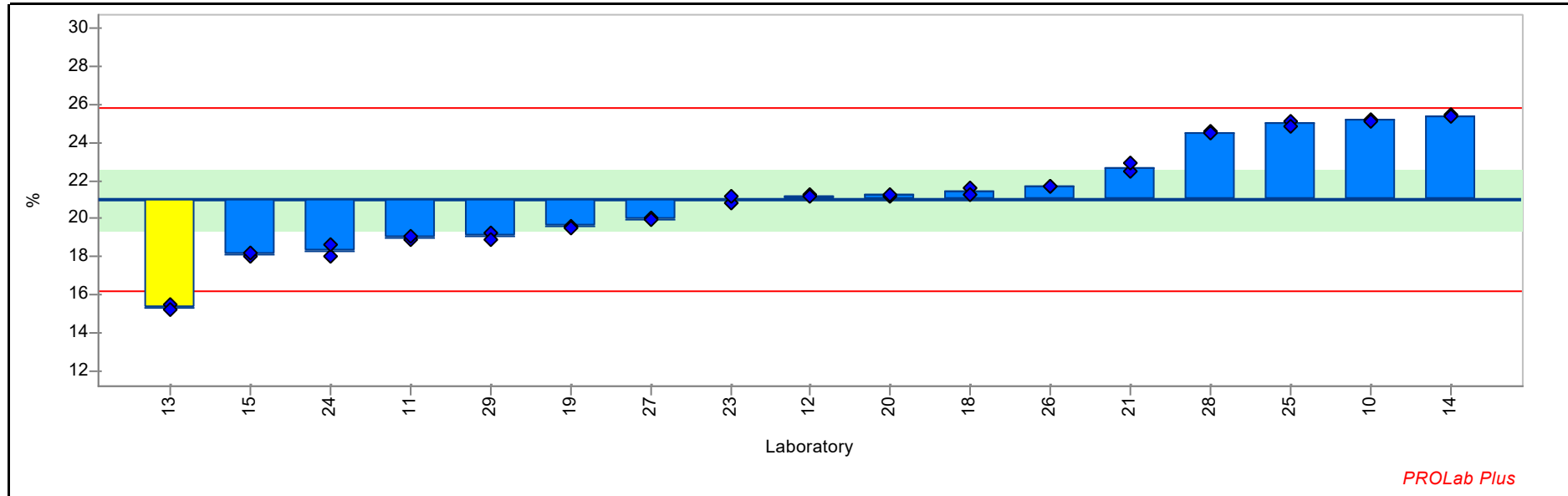
**RV\_2021\_02\_Recycling Material from used Catalysts**

Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
19	0,626	0,033	-1,133	0,603	0,649	no accreditation	XRF (pressed pellet)	information only
20	1,510	0,000	3,745	1,510	1,510	no accreditation	XRF (fusion)	
21	0,929	0,109	0,539	1,006	0,852	no accreditation	XRF (fusion)	
23	1,086	0,062	1,405	1,042	1,130	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
25	1,069	0,073	1,308	1,120	1,017	no accreditation	XRF (fusion)	
26	0,800	0,023	-0,170	0,784	0,817	no accreditation	XRF (fusion)	
27	0,821	0,022	-0,060	0,836	0,805	ISO 17025	Other Method	ICP-OES
28	0,881	0,011	0,277	0,874	0,889	no accreditation	XRF (pressed pellet)	information only
29	0,565	0,002	-1,467	0,564	0,567	no accreditation	XRF (fusion)	



## RV\_2021\_02\_Recycling Material from used Catalysts

**Sample:** FLX-142 **Reproducibility s.d.:** 2,428 %  
**Measurand:** Ni **Repeatability s.d.:** 0,179 %  
**Mean ± U(Mean):** 21,006 ± 1,533 % **Range of tolerance:** 16,150 - 25,861 % (|z-score| ≤ 2,000)  
**No. of laboratories:** 13 **Statistical method:** Q/Hampel



Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
10	25,179	0,046	1,719	25,212	25,147	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
11	19,000	0,085	-0,826	18,940	19,060	no accreditation	XRF (fusion)	
12	21,215	0,067	0,086	21,263	21,168	ISO 17025	XRF (fusion)	
13	15,350	0,212	-2,330	15,500	15,200	no accreditation	XRF (pressed pellet)	information only
14	25,422	0,096	1,819	25,490	25,354	no accreditation	XRF (pressed pellet)	information only
15	18,114	0,096	-1,191	18,046	18,182	no accreditation	XRF (fusion)	
18	21,438	0,285	0,178	21,639	21,236	no accreditation	XRF (fusion)	
19	19,565	0,050	-0,594	19,600	19,529	no accreditation	XRF (pressed pellet)	information only

**RV\_2021\_02\_Recycling Material from used Catalysts**

Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
20	21,227	0,023	0,091	21,211	21,243	no accreditation	XRF (fusion)	
21	22,693	0,325	0,695	22,463	22,923	no accreditation	XRF (fusion)	
23	21,006	0,233	0,000	20,841	21,170	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
24	18,312	0,445	-1,110	17,997	18,627	no accreditation	XRF (fusion)	
25	25,004	0,167	1,647	25,122	24,886	no accreditation	XRF (fusion)	
26	21,700	0,000	0,286	21,700	21,700	no accreditation	XRF (fusion)	
27	19,996	0,014	-0,416	20,006	19,986	ISO 17025	Other Method	ICP-OES
28	24,511	0,053	1,444	24,549	24,474	no accreditation	XRF (pressed pellet)	information only
29	19,080	0,251	-0,793	19,257	18,902	no accreditation	XRF (fusion)	

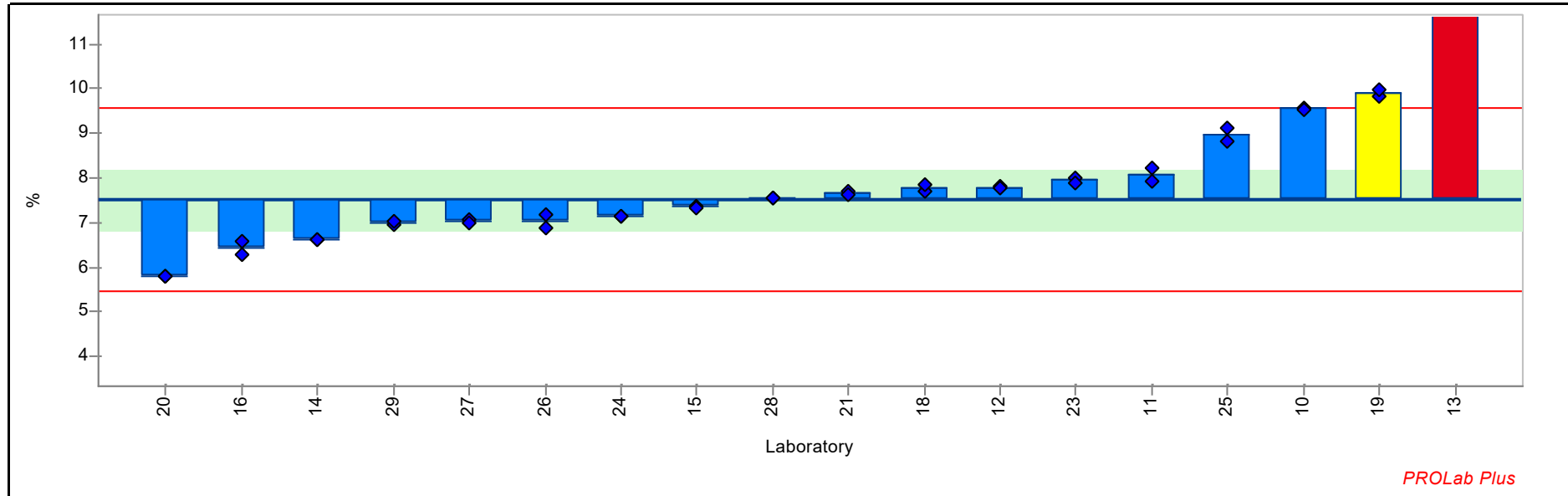


**RV\_2021\_02\_Recycling Material from used Catalysts**

Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
19	0,500	0,023	0,509	0,483	0,516	no accreditation	XRF (pressed pellet)	information only
20	0,495	0,018	0,431	0,482	0,508	no accreditation	XRF (fusion)	
21	0,467	0,011	-0,057	0,474	0,459	no accreditation	XRF (fusion)	
23	0,510	0,020	0,689	0,496	0,524	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
24	0,460	0,048	-0,169	0,426	0,494	no accreditation	XRF (fusion)	
25	0,545	0,021	1,289	0,560	0,530	no accreditation	XRF (fusion)	
26	0,400	0,032	-1,189	0,423	0,378	no accreditation	XRF (fusion)	
27	0,422	0,002	-0,812	0,424	0,421	ISO 17025	Other Method	ICP-OES
28	0,482	0,001	0,217	0,482	0,483	no accreditation	XRF (pressed pellet)	information only
29	0,471	0,003	0,020	0,469	0,473	no accreditation	XRF (fusion)	

## RV\_2021\_02\_Recycling Material from used Catalysts

**Sample:** FLX-142 **Reproducibility s.d.:** 1,036 %  
**Measurand:** SiO<sub>2</sub> **Repeatability s.d.:** 0,091 %  
**Mean ± U(Mean):** 7,516 ± 0,679 % **Range of tolerance:** 5,443 - 9,589 % (|z-score| ≤ 2,000)  
**No. of laboratories:** 14 **Statistical method:** Q/Hampel



Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
10	9,557	0,010	1,970	9,564	9,550	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
11	8,060	0,212	0,525	7,910	8,210	no accreditation	XRF (fusion)	
12	7,787	0,030	0,262	7,809	7,766	ISO 17025	XRF (fusion)	
13	13,950	0,453	6,209	14,270	13,630	no accreditation	XRF (pressed pellet)	information only
14	6,624	0,004	-0,860	6,627	6,622	no accreditation	XRF (pressed pellet)	information only
15	7,354	0,025	-0,157	7,371	7,336	no accreditation	XRF (fusion)	
16	6,435	0,205	-1,043	6,580	6,290	no accreditation	XRF (fusion)	
18	7,777	0,100	0,252	7,706	7,848	no accreditation	XRF (fusion)	

**RV\_2021\_02\_Recycling Material from used Catalysts**

Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
19	9,906	0,081	2,306	9,849	9,963	no accreditation	XRF (pressed pellet)	information only
20	5,783	0,003	-1,672	5,781	5,785	no accreditation	XRF (fusion)	
21	7,676	0,057	0,155	7,716	7,636	no accreditation	XRF (fusion)	
23	7,952	0,071	0,420	8,002	7,901	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
24	7,147	0,019	-0,355	7,134	7,161	no accreditation	XRF (fusion)	
25	8,960	0,207	1,394	9,107	8,814	no accreditation	XRF (fusion)	
26	7,027	0,221	-0,472	6,870	7,183	no accreditation	XRF (fusion)	
27	7,018	0,049	-0,481	7,052	6,983	ISO 17025	Other Method	ICP-OES
28	7,561	0,011	0,044	7,553	7,569	no accreditation	XRF (pressed pellet)	information only
29	6,998	0,071	-0,500	6,947	7,048	no accreditation	XRF (fusion)	



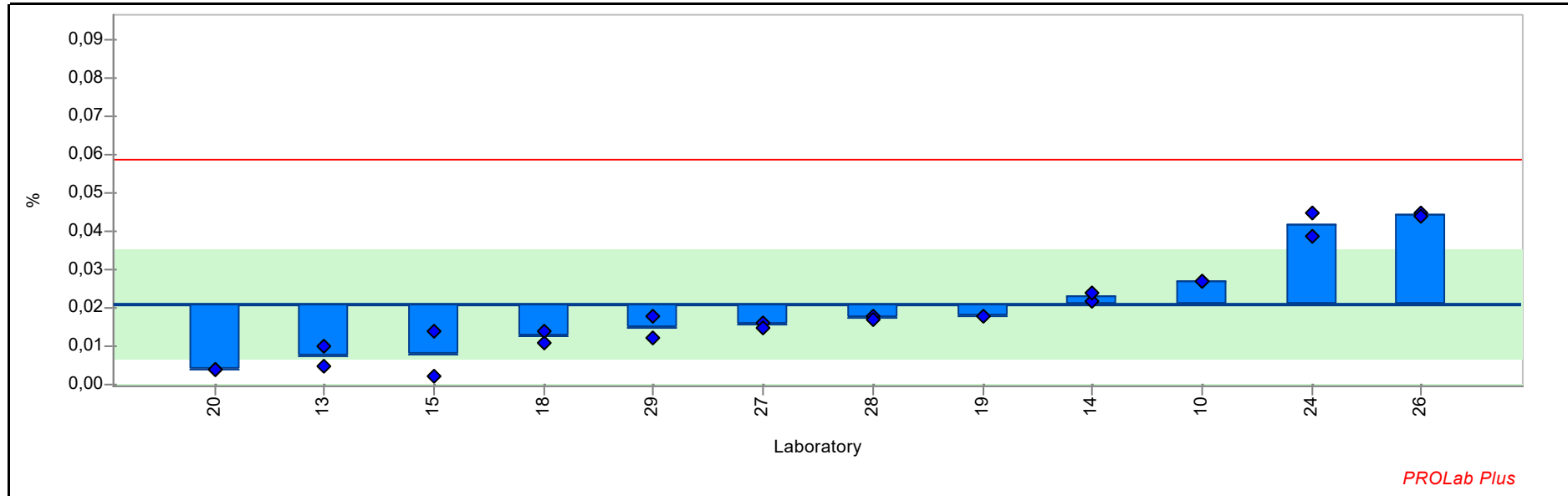
**RV\_2021\_02\_Recycling Material from used Catalysts**

Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
20	0,071	0,001	0,247	0,071	0,070	no accreditation	XRF (fusion)	
23	<0,100			<0,100	<0,100	no accreditation	XRF (fusion)	information only
24	0,069	0,012	0,046	0,060	0,077	no accreditation	XRF (fusion)	
25	0,108	0,037	3,980	0,134	0,081	no accreditation	XRF (fusion)	information only
26	0,071	0,011	0,298	0,063	0,079	no accreditation	XRF (fusion)	
27	0,061	0,001	-0,711	0,062	0,060	ISO 17025	Other Method	ICP-OES
28	0,082	0,006	1,407	0,078	0,086	no accreditation	XRF (pressed pellet)	information only
29	0,060	0,004	-0,812	0,057	0,063	no accreditation	XRF (fusion)	



## RV\_2021\_02\_Recycling Material from used Catalysts

**Sample:** FLX-142 **Reproducibility s.d.:** 0,019 %  
**Measurand:** V2O5 **Repeatability s.d.:** 0,003 %  
**Mean ± U(Mean):** 0,021 ± 0,014 % **Range of tolerance:** -0,017 - 0,059 % (|z-score| ≤ 2,000)  
**No. of laboratories:** 8 **Statistical method:** Q/Hampel



Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
10	0,027	0,000	0,314	0,027	0,027	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
13	0,007	0,004	-0,717	0,010	0,005	no accreditation	XRF (pressed pellet)	information only
14	0,023	0,001	0,102	0,022	0,024	no accreditation	XRF (pressed pellet)	information only
15	0,008	0,008	-0,690	0,002	0,014	no accreditation	XRF (fusion)	
18	0,013	0,002	-0,453	0,011	0,014	no accreditation	XRF (fusion)	
19	0,018		-0,162	0,018		no accreditation	XRF (pressed pellet)	information only
20	0,004	0,000	-0,902	0,004	0,004	no accreditation	XRF (fusion)	
23	<0,100			<0,100	<0,100	no accreditation	XRF (fusion)	information only

**RV\_2021\_02\_Recycling Material from used Catalysts**

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Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
24	0,042	0,004	1,107	0,045	0,039	no accreditation	XRF (fusion)	
25	<0,010			<0,010	<0,010	no accreditation	XRF (fusion)	information only
26	0,044	0,001	1,239	0,045	0,044	no accreditation	XRF (fusion)	
27	0,015	0,001	-0,294	0,016	0,015	ISO 17025	Other Method	ICP-OES
28	0,018	0,001	-0,188	0,018	0,017	no accreditation	XRF (pressed pellet)	information only
29	0,015	0,004	-0,320	0,012	0,018	no accreditation	XRF (fusion)	



**RV\_2021\_02\_Recycling Material from used Catalysts**


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Lab code	Lab mean	s.d.	z-score	Conc. 1	Conc. 2	Accreditation	Analytical method	Comment
19	0,089	0,003	-0,757	0,087	0,091	no accreditation	XRF (pressed pellet)	information only
20	0,115	0,000	0,274	0,115	0,115	no accreditation	XRF (fusion)	
21	0,116	0,002	0,294	0,117	0,114	no accreditation	XRF (fusion)	
23	0,096	0,007	-0,480	0,091	0,101	no accreditation	XRF (fusion)	DIN 51418-2-2015-03
24	0,094	0,017	-0,559	0,106	0,082	no accreditation	XRF (fusion)	
25	0,132	0,004	0,929	0,129	0,134	no accreditation	XRF (fusion)	
26	0,114	0,011	0,254	0,107	0,122	no accreditation	XRF (fusion)	
27	0,102	0,001	-0,222	0,103	0,102	ISO 17025	Other Method	ICP-OES
28	0,119	0,004	0,433	0,116	0,122	no accreditation	XRF (pressed pellet)	information only
29	0,084	0,001	-0,976	0,084	0,083	no accreditation	XRF (fusion)	

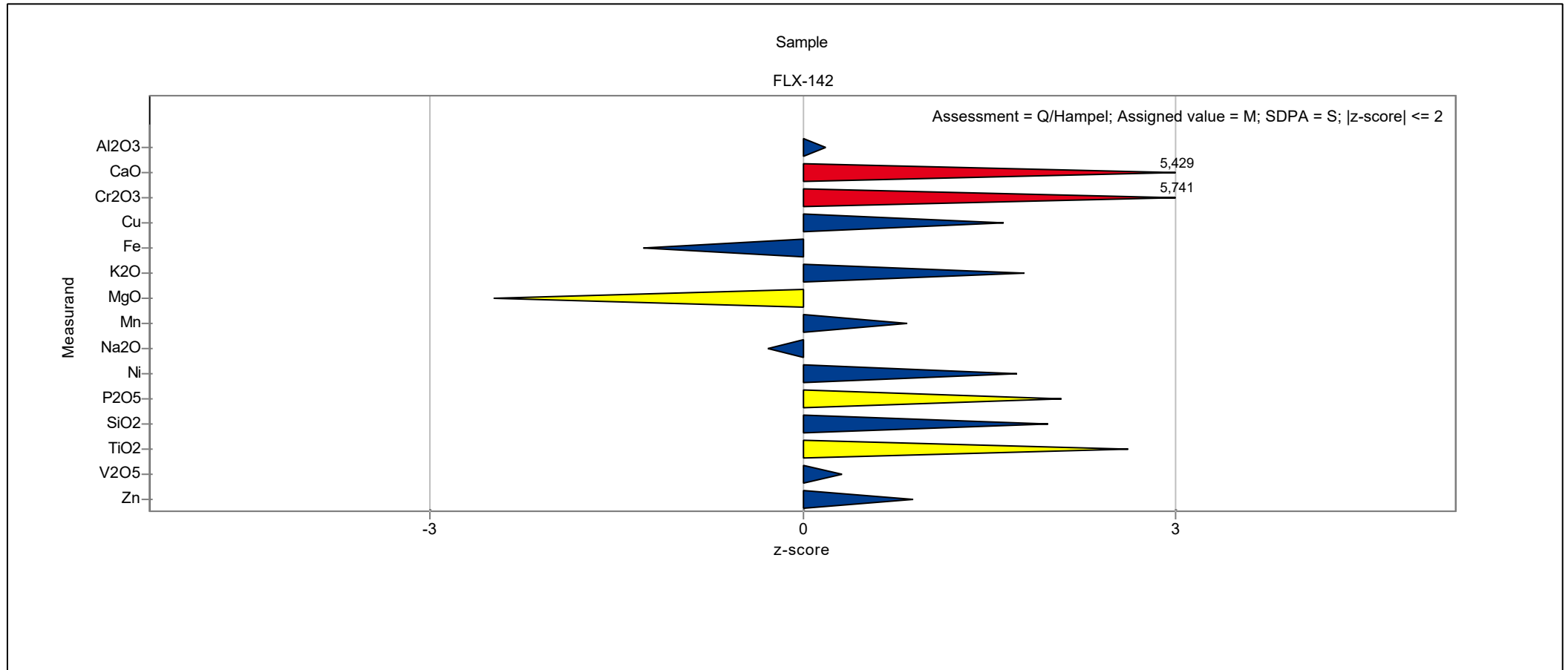
Ring test RV\_2021\_02\_Recycling Material from used Catalysts

## Survey of scores

Lab code	Al2O3	CaO	Cr2O3	Cu	Fe	K2O	MgO	Mn	Na2O	Ni	P2O5	SiO2	TiO2	V2O5	Zn
10	0,181	5,429	5,741	1,617	-1,280	1,785	-2,487	0,842	-0,281	1,719	2,078	1,970	2,618	0,314	0,889
11	-0,726	0,022	-0,568	0,747	0,546	-0,809	-0,699	-0,826	0,434	-0,826	0,346	0,525			-0,321
12	0,288	0,311	-0,234	0,486	-0,463	0,019	0,067	-0,321	-0,786	0,086	-0,512	0,262	-0,055		1,068
13	2,608	0,291	-1,922	-0,630	-3,233	-3,151		-3,027		-2,330	6,785	6,209	-2,829	-0,717	-1,789
14	-3,515	3,376	3,383	1,300	-1,780	-0,557	-3,014	-0,613	-0,380	1,819	-0,658	-0,860	1,357	0,102	0,829
15	-0,200	-0,182	-0,400	-0,369	-0,627	-0,665	0,712	0,071	0,078	-1,191	-0,478	-0,157	-2,173	-0,690	-0,281
16	-0,507	-0,486	0,352		0,214	0,091	-0,149	-0,938	-0,752		-1,043	-1,043	0,147		-1,670
18	0,681	0,769	0,793	-0,844	-0,148	0,217	-0,511	-0,359	-0,248	0,178	-0,014	0,252	-0,660	-0,453	0,631
19	-2,124	-1,076	-0,523	0,020	-2,748	-2,593	-3,922	-2,164	-1,133	-0,594	0,509	2,306	-0,307	-0,162	-0,757
20	-0,421	-2,635	2,024	-1,201	-1,189	-4,034	-1,587	-0,346	3,745	0,091	0,431	-1,672	0,247	-0,902	0,274
21	1,565	1,146	1,104	0,024	1,466	1,028	1,855	1,134	0,539	0,695	-0,057	0,155			0,294
23	1,149	-0,151	-0,988	-1,661	1,239	0,776	0,531	-1,193	1,405	0,000	0,689	0,420			-0,480
24	-1,260	-0,513	-1,170	-1,189	-0,169		0,774	0,050		-1,110	-0,169	-0,355	0,046	1,107	-0,559
25	2,393	3,138	2,902	0,430	0,689	0,704	1,002	0,575	1,308	1,647	1,289	1,394	3,980		0,929
26	-0,646	0,170	-0,600	0,713	-0,225	-0,251	0,083	0,508	-0,170	0,286	-1,189	-0,472	0,298	1,239	0,254
27	-0,698	-0,534	-0,785	0,504	-0,821	-0,809	0,051	0,784	-0,060	-0,416	-0,812	-0,481	-0,711	-0,294	-0,222
28	-1,638	2,165	2,468	1,792	-1,992	0,181	-2,303	-0,663	0,277	1,444	0,217	0,044	1,407	-0,188	0,433
29	-0,841	-0,412	-0,505	0,698	0,768	-1,025	-0,361	0,021	-1,467	-0,793	0,020	-0,500	-0,812	-0,320	-0,976

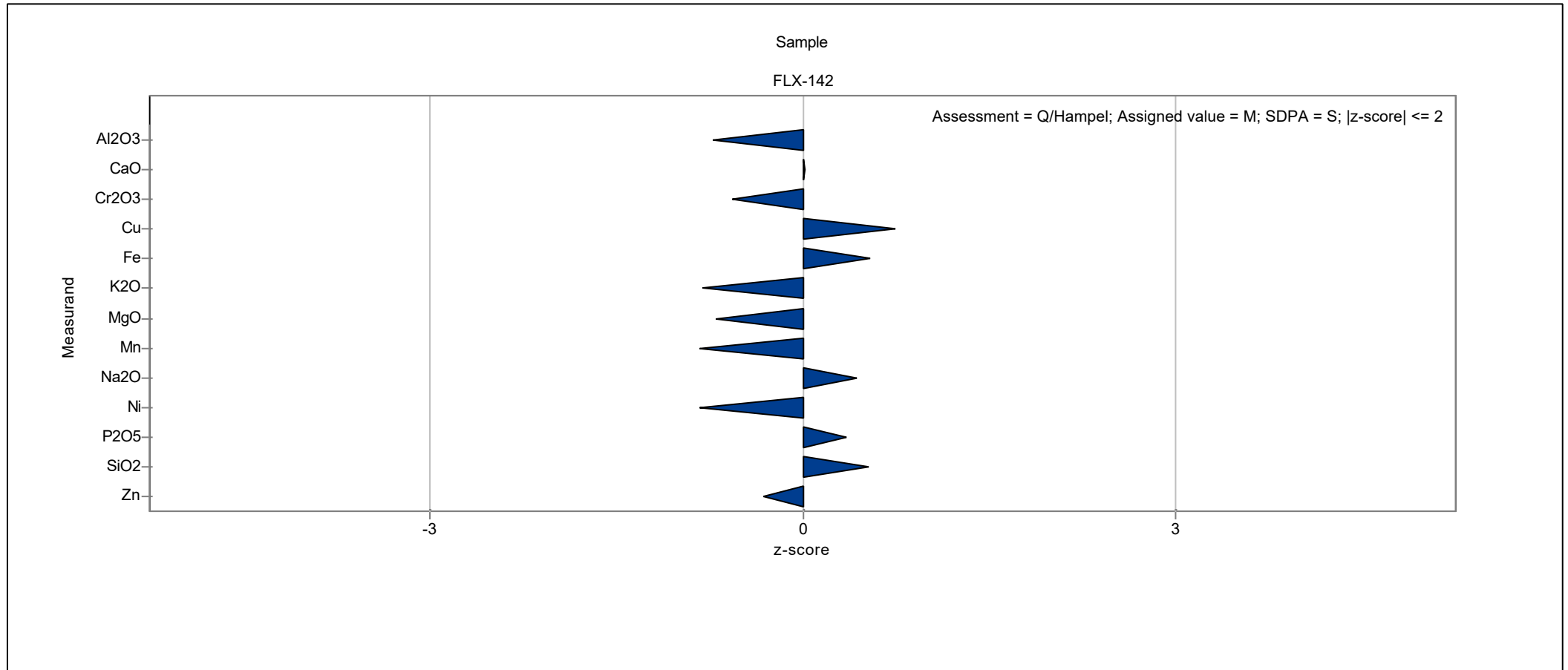
## Laboratory chart of z-scores

Laboratory: 10



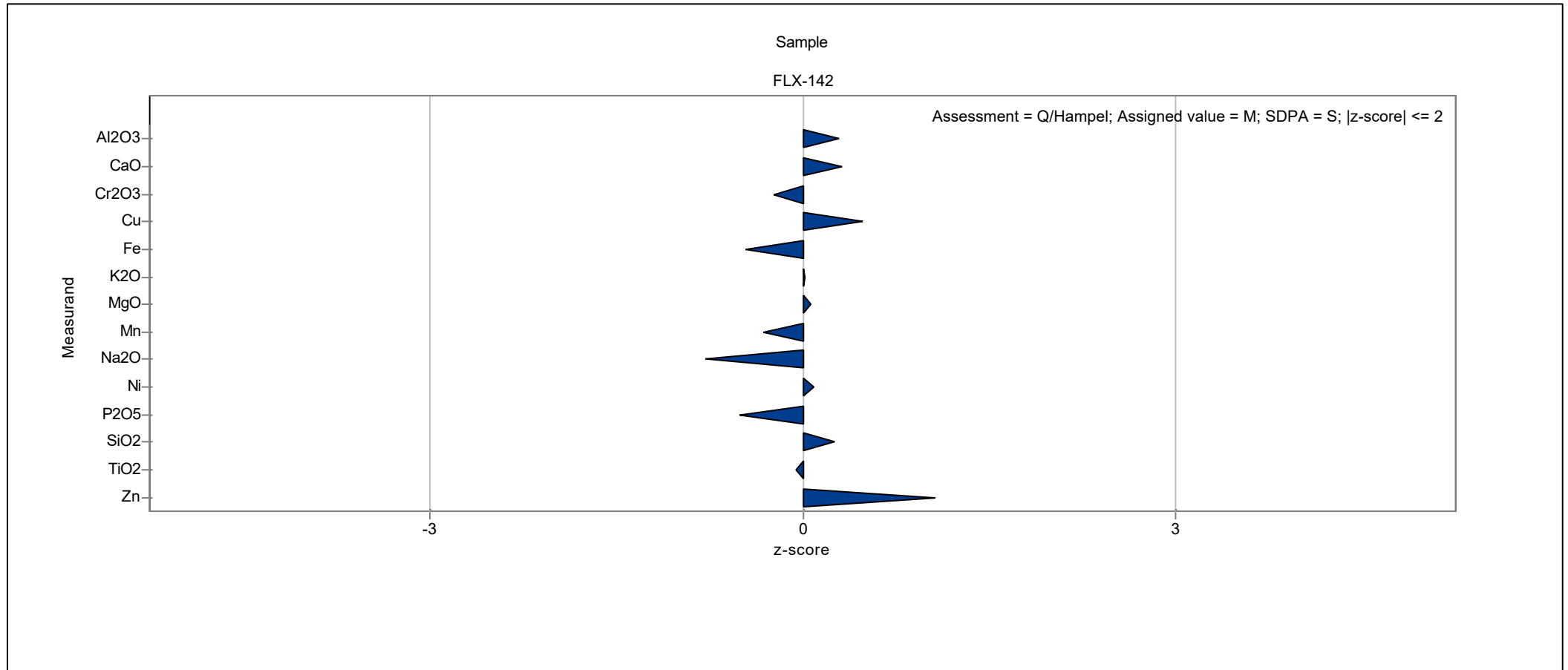
## Laboratory chart of z-scores

Laboratory: 11



## Laboratory chart of z-scores

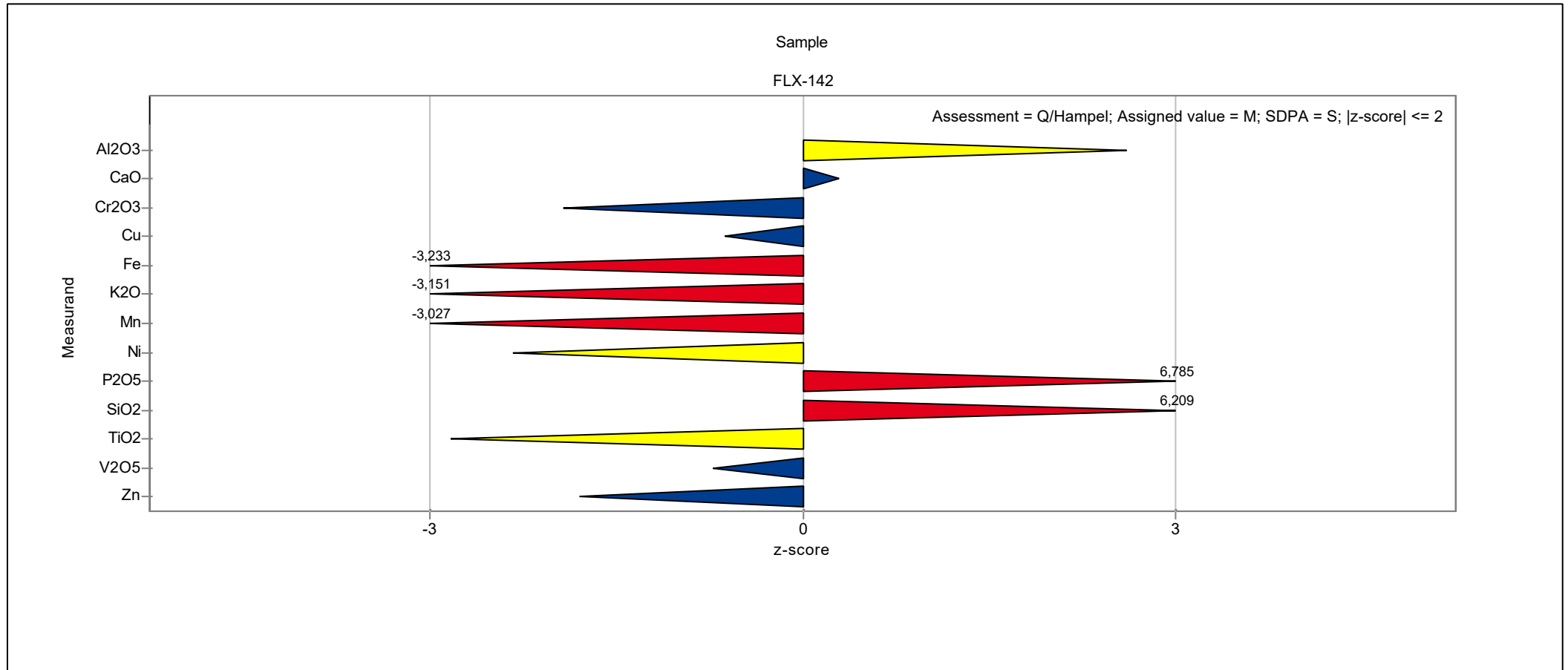
Laboratory: 12





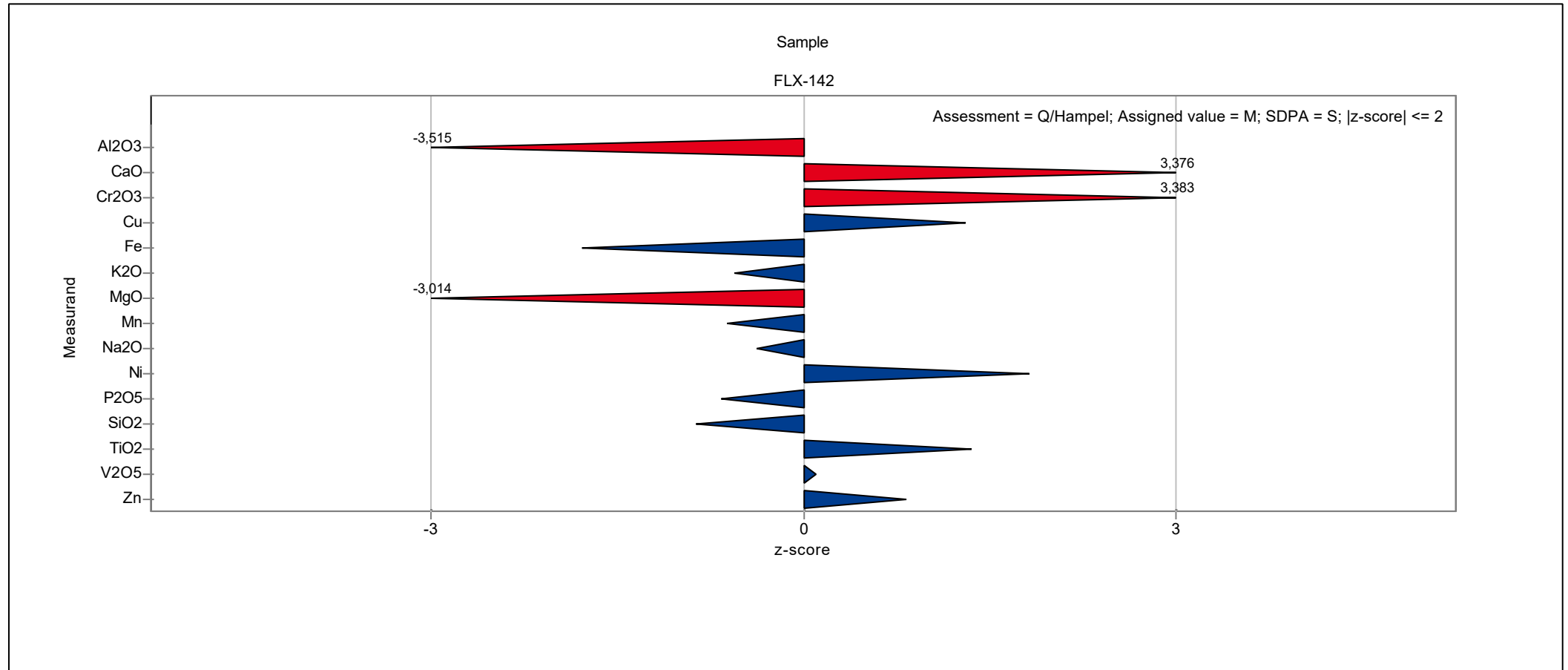
## Laboratory chart of z-scores

Laboratory: 13



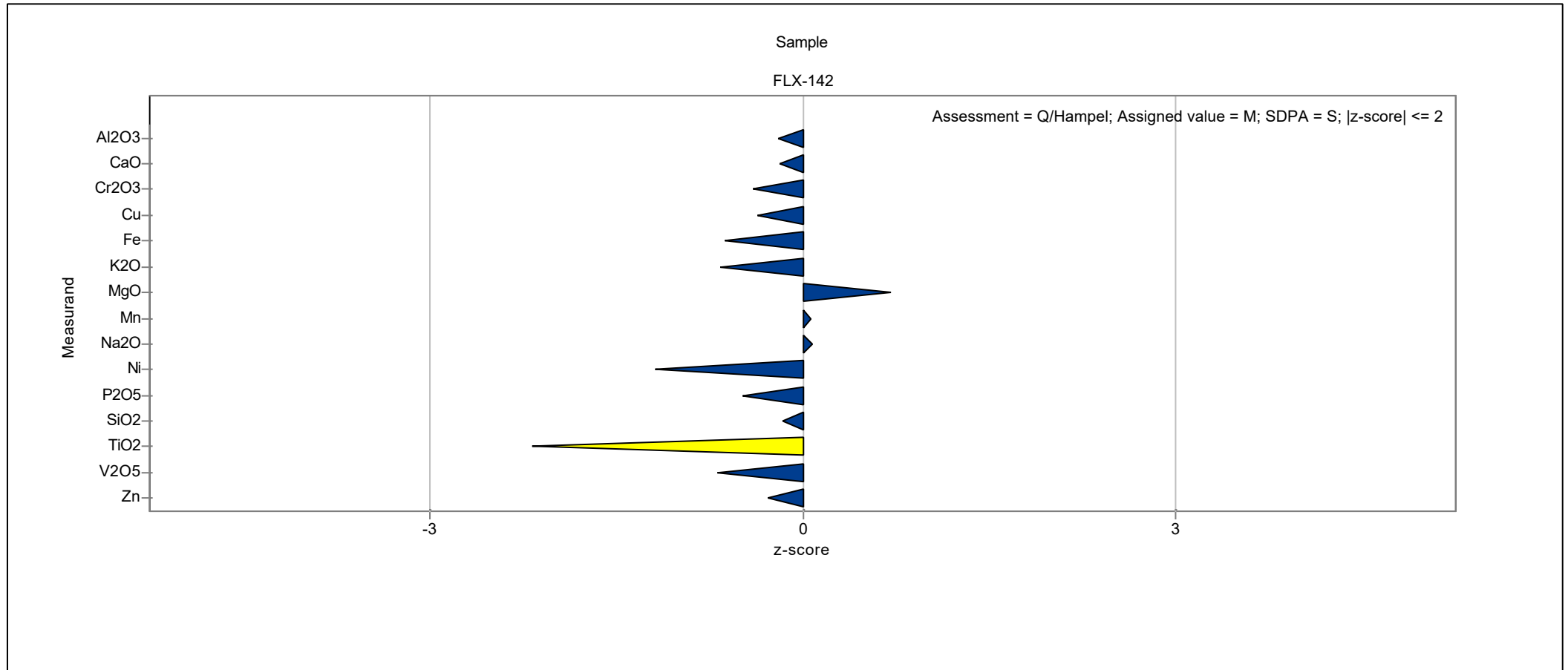
## Laboratory chart of z-scores

Laboratory: 14



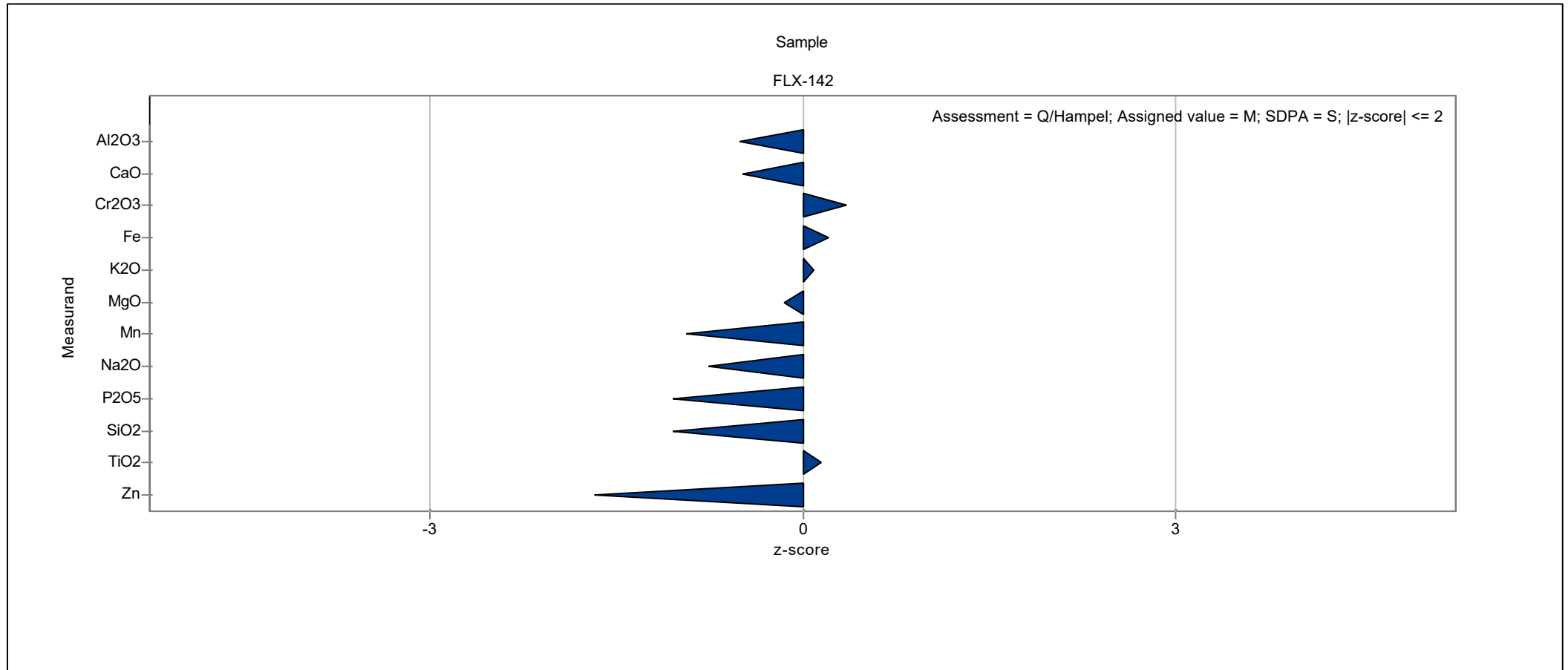
## Laboratory chart of z-scores

Laboratory: 15



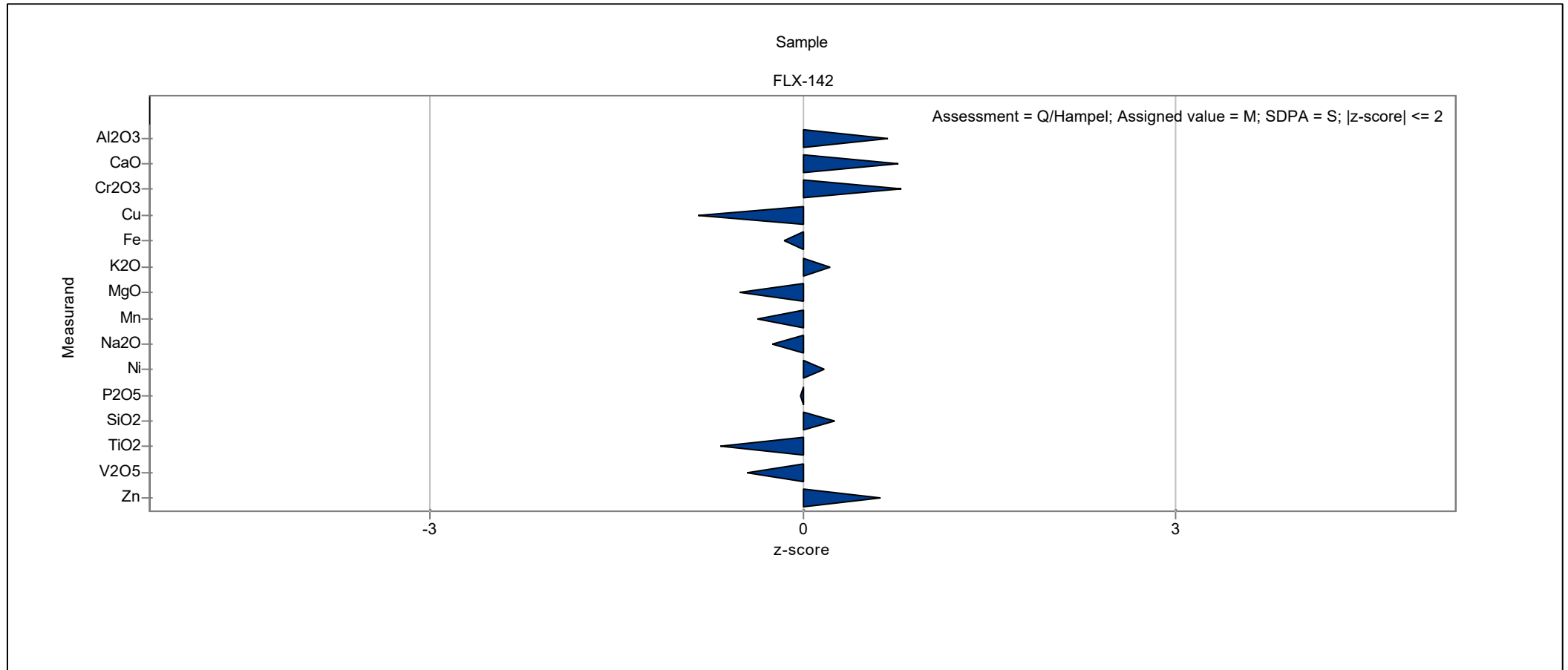
## Laboratory chart of z-scores

Laboratory: 16



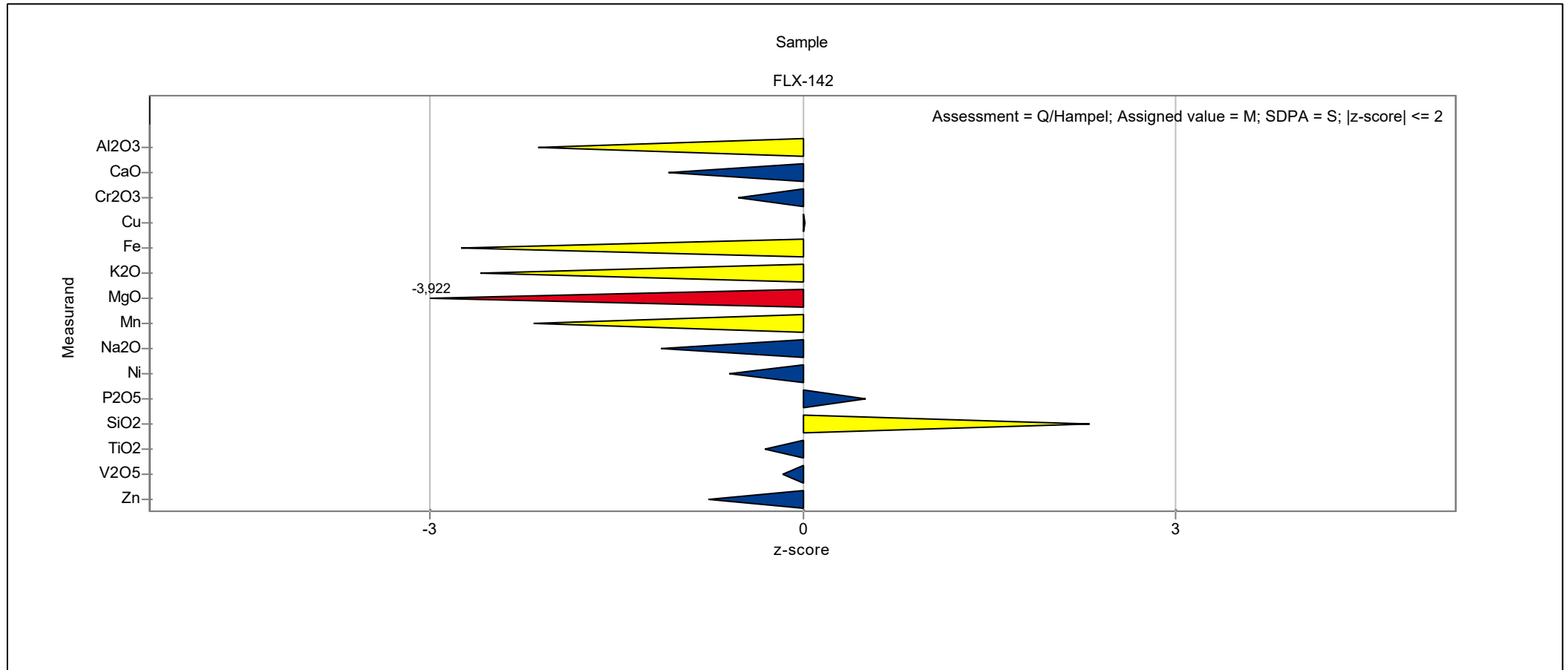
## Laboratory chart of z-scores

Laboratory: 18



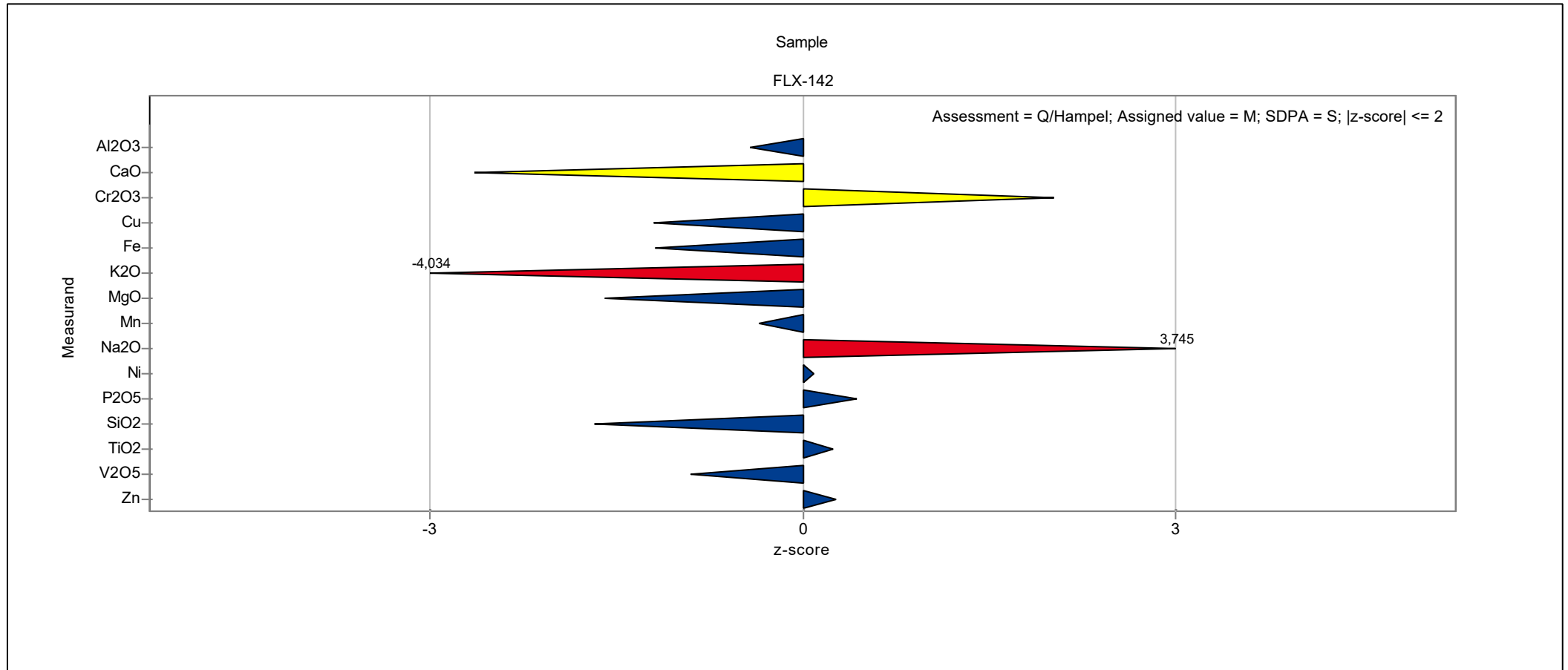
## Laboratory chart of z-scores

Laboratory: 19



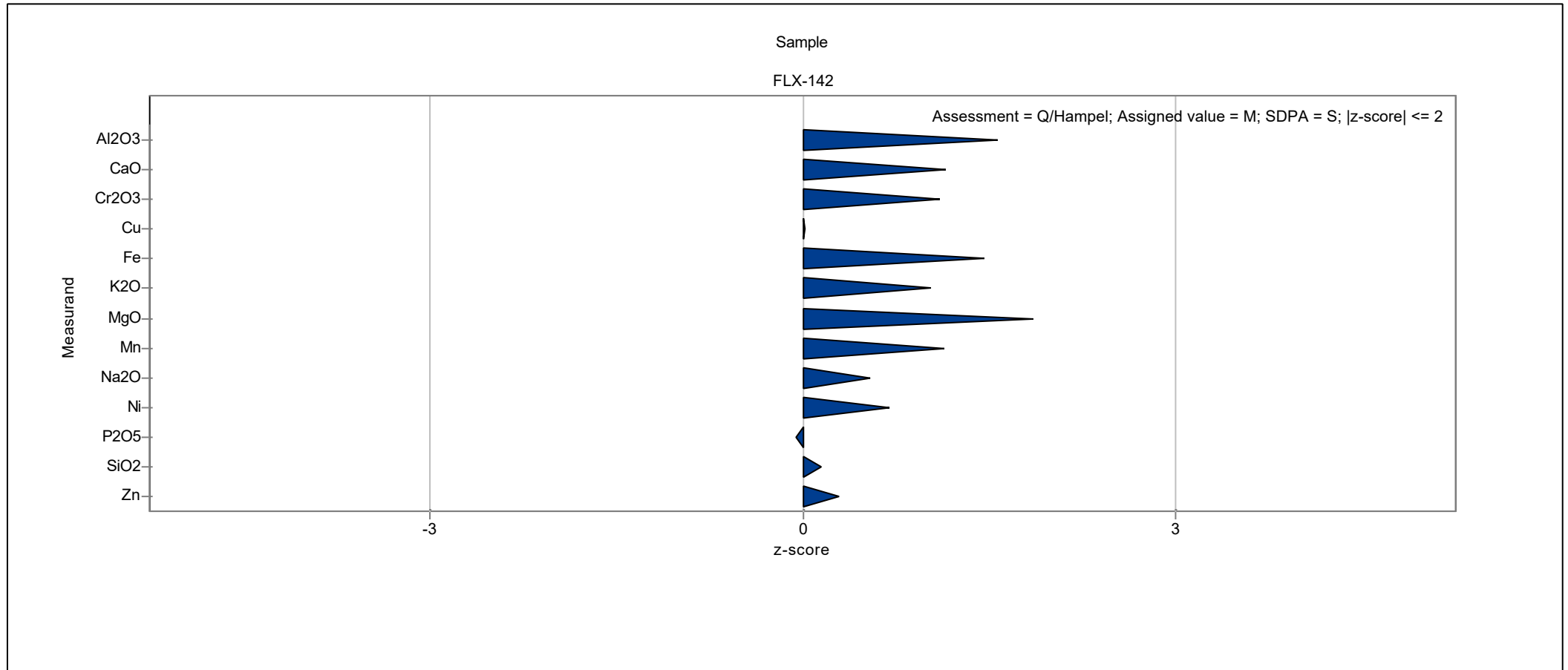
## Laboratory chart of z-scores

Laboratory: 20



## Laboratory chart of z-scores

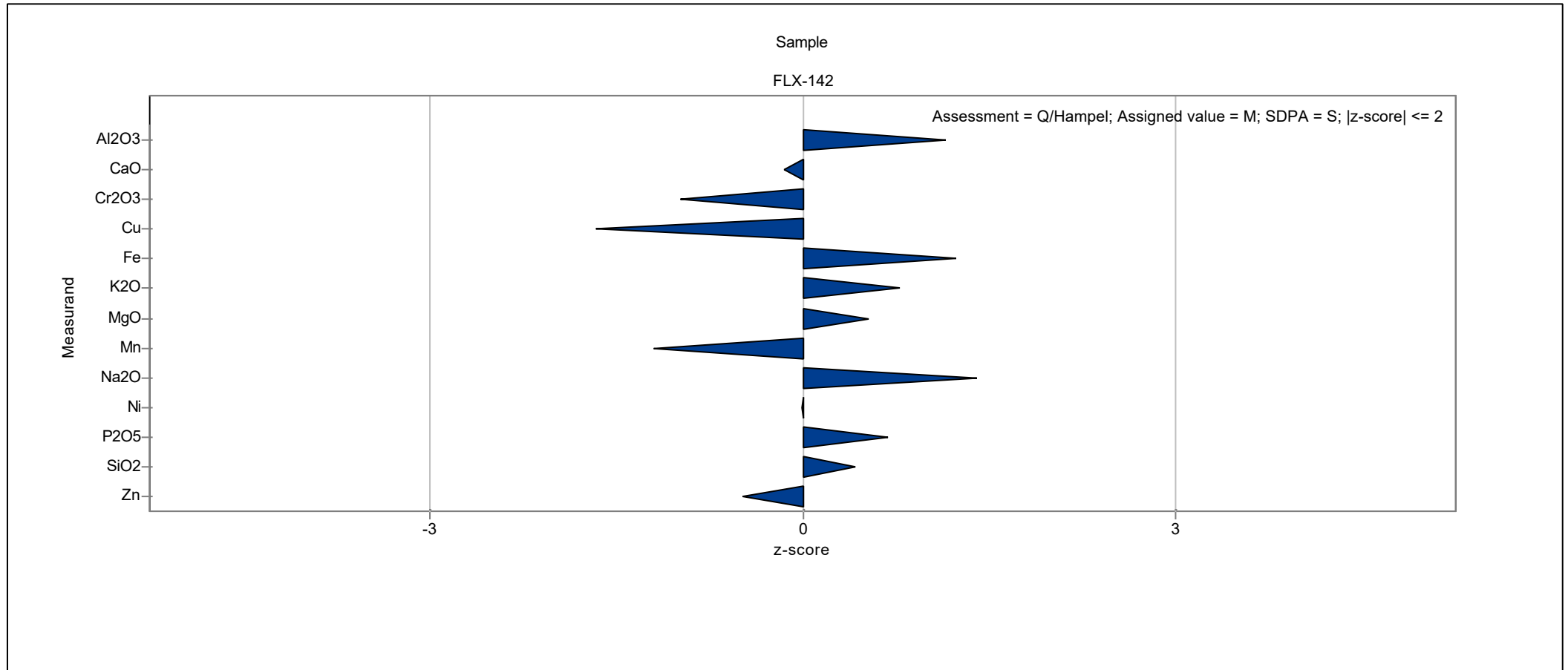
Laboratory: 21





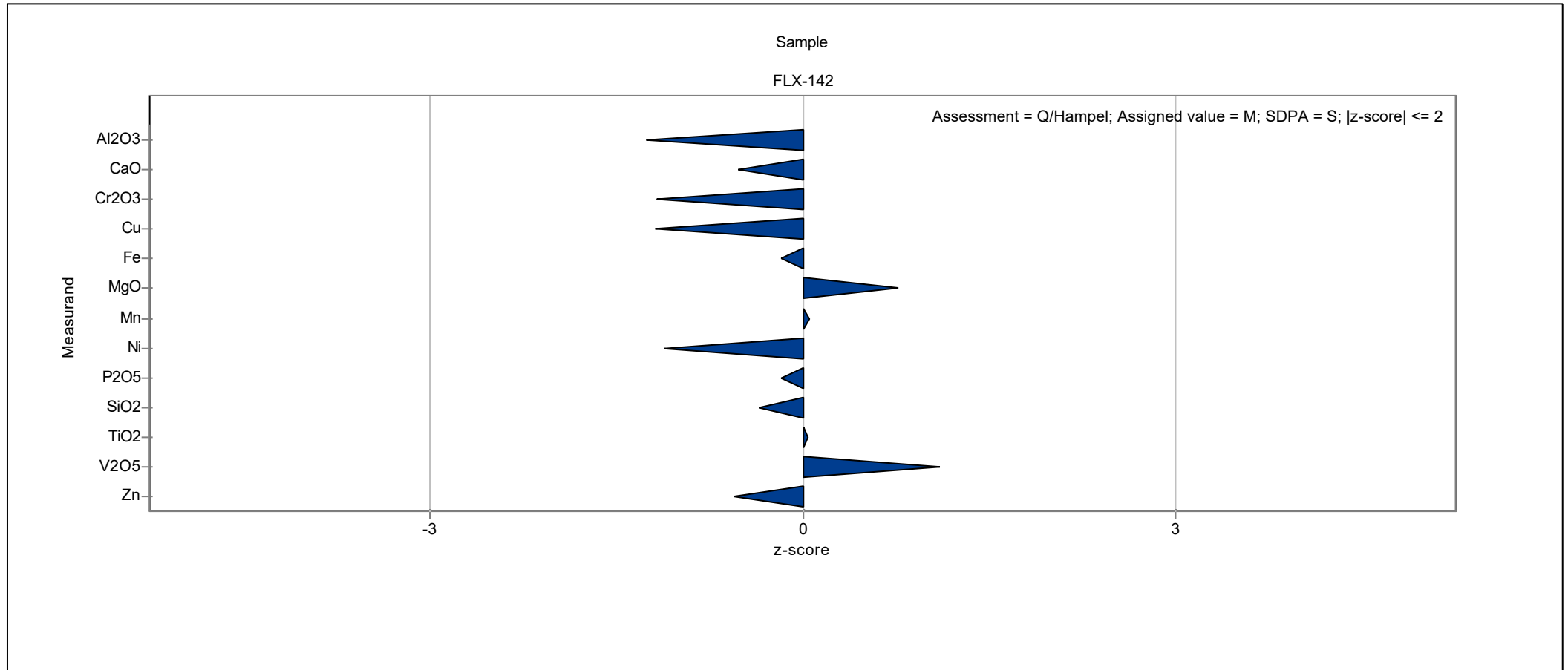
## Laboratory chart of z-scores

Laboratory: 23



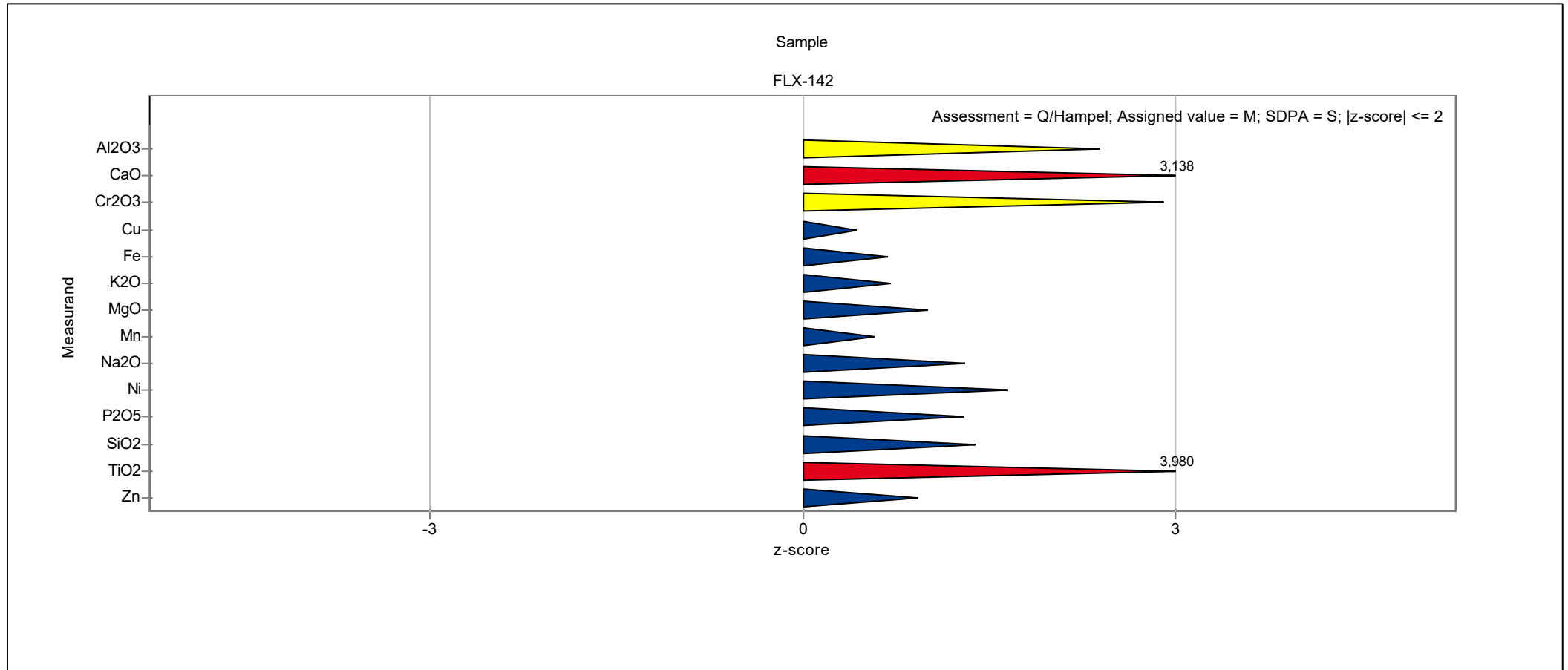
## Laboratory chart of z-scores

Laboratory: 24



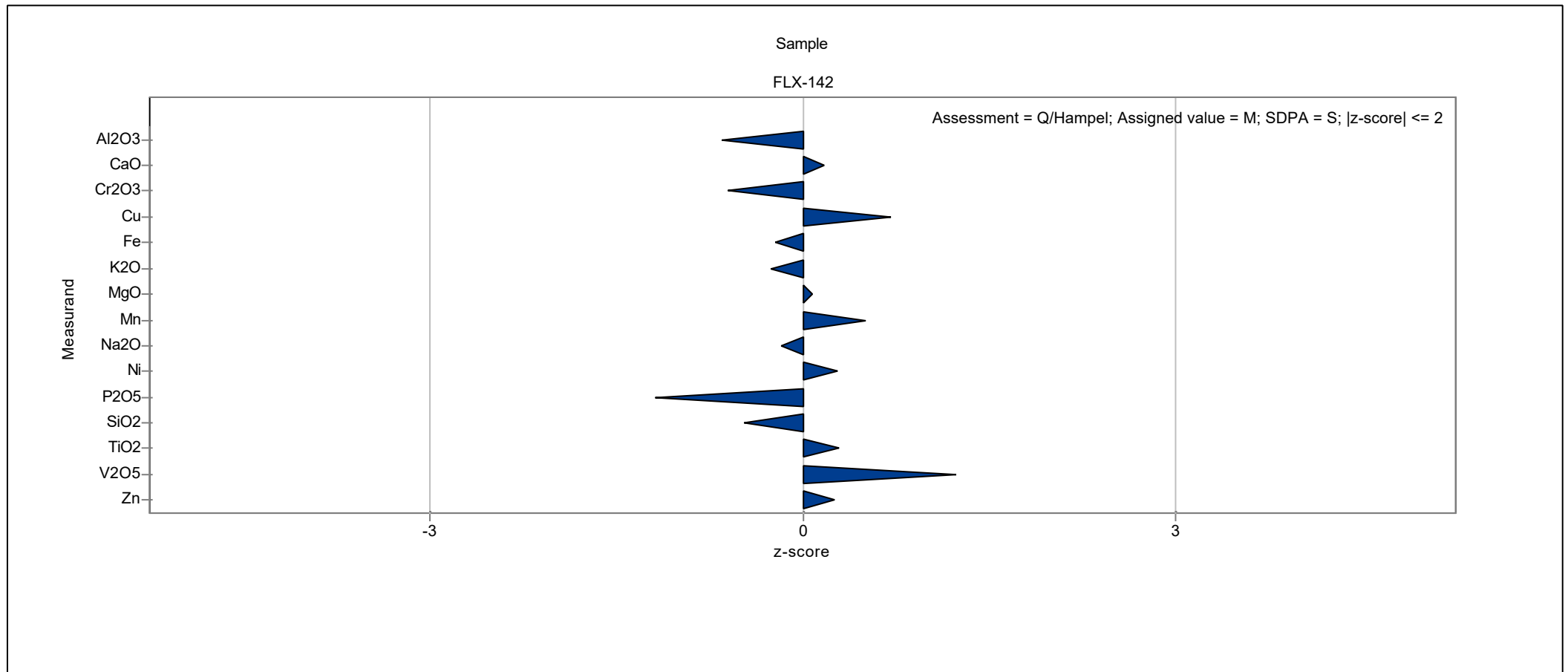
## Laboratory chart of z-scores

Laboratory: 25



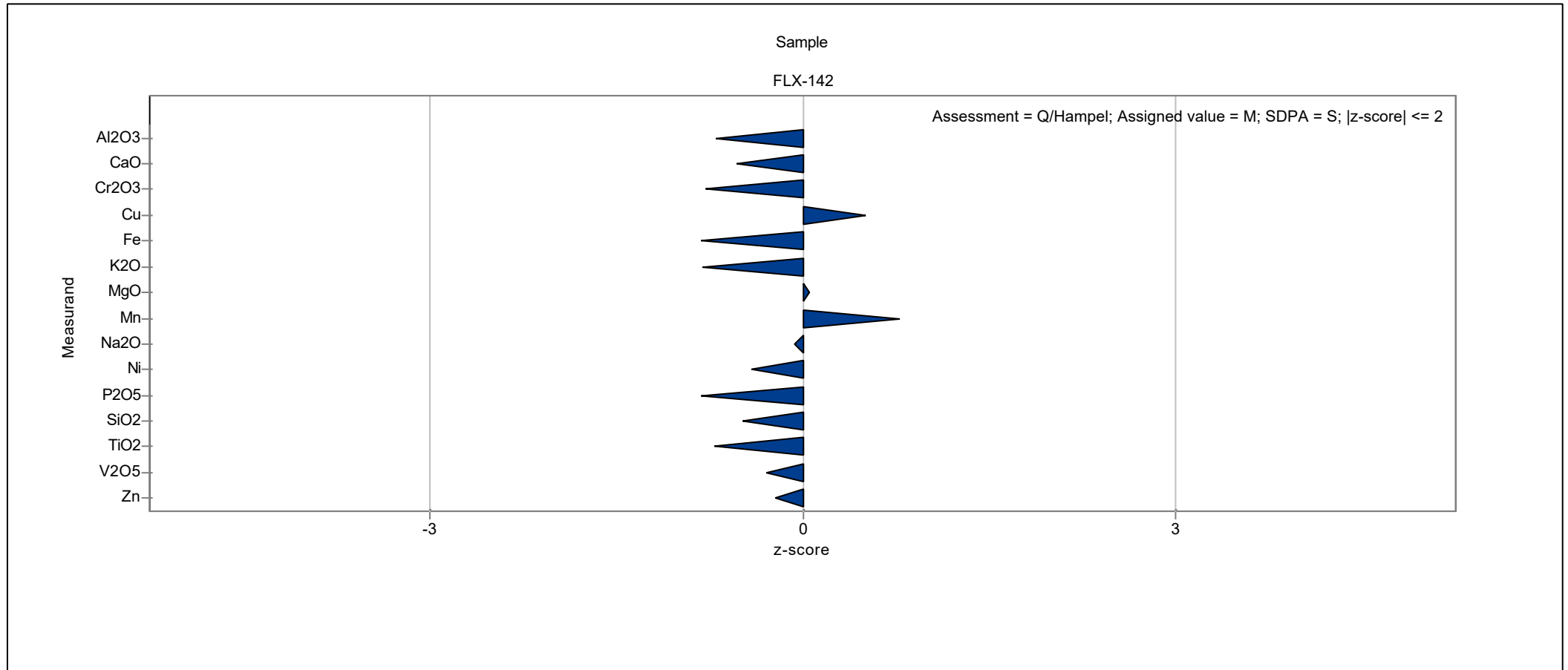
## Laboratory chart of z-scores

Laboratory: 26



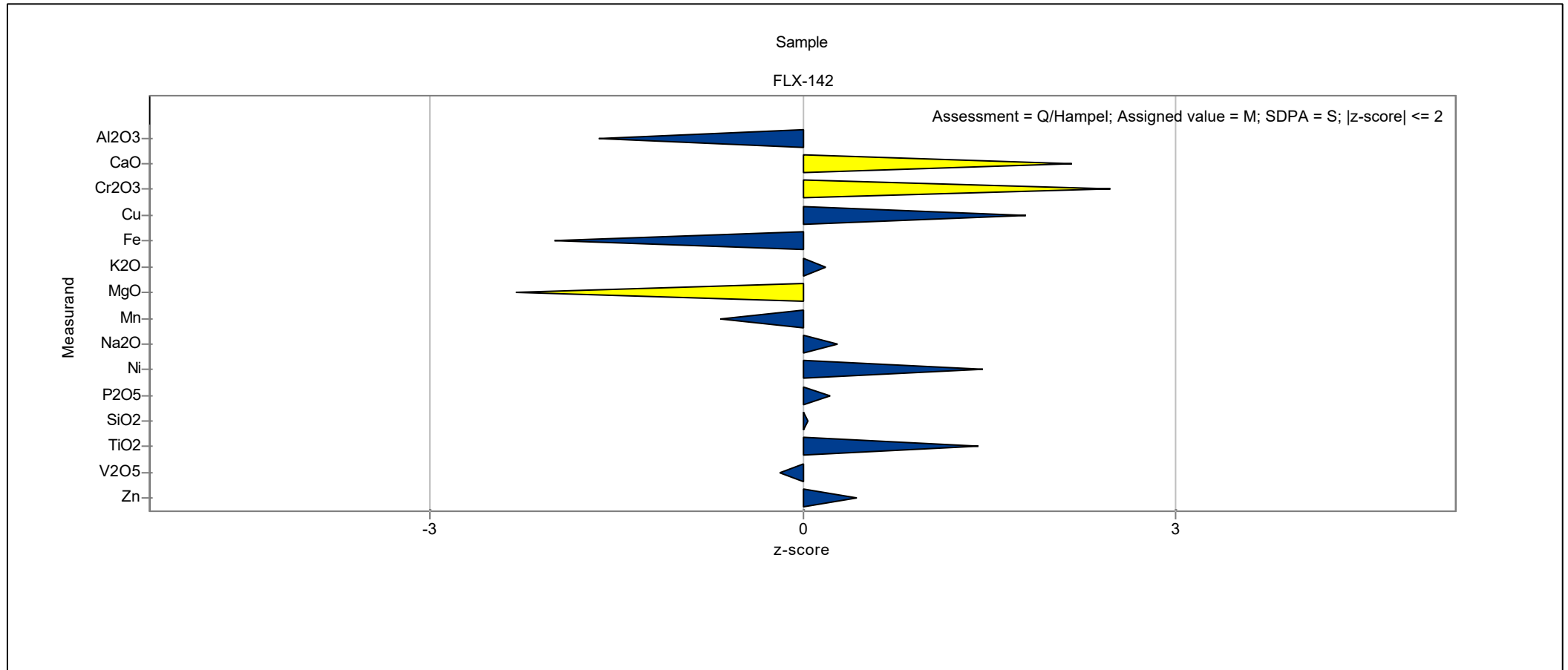
## Laboratory chart of z-scores

Laboratory: 27



## Laboratory chart of z-scores

Laboratory: 28



## Laboratory chart of z-scores

Laboratory: 29

