

**ASSESSMENT OF THE CHEMICAL ANALYSIS OF COLDWATER  
IN SOME LABORATORIES PARTICIPATING IN TECHNICAL COOPERATION  
PROJECTS ON ISOTOPE HYDROLOGY**

by

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# ASSESSMENT OF THE CHEMICAL ANALYSIS OF COLDWATER IN SOME LABORATORIES PARTICIPATING IN TECHNICAL COOPERATION PROJECTS ON ISOTOPE HYDROLOGY

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## 1. INTRODUCTION

An assessment of the results of the chemical analysis of coldwater in laboratories participating in the UNDP/RCA/IAEA project in Asia, RAS/8/084, Access to Clean Drinking Water was conducted by the International Atomic Energy Agency (IAEA) in May 1999. This exercise was extended to other regions which have active Technical Co-operation (TC) projects with the IAEA. As all the three previous exercises of the same nature proved to be of significant value to the improvement and assurance of high quality analytical results in participating laboratories, this assessment was organised:

- to assess the chemical results of laboratories which are providing analytical services to various TC projects for chemical species commonly used in water resources investigations; and
- to determine areas where improvements in chemical analyses are required.

The assessment of chemical results was by statistical analysis and did not examine the detailed analytical procedures employed by the participating laboratories. It is, thus, beyond the scope of this report to provide an extensive examination of the potential reasons attributed to differing procedures and equipment in the different laboratories if the reported chemical results are variable.

Natural samples were sent to 47 hydrochemical laboratories in 31 Member States in Asia, Latin America, the Middle East and Africa (Annex 1), with the IAEA Isotope Hydrology Laboratory serving as the reference laboratory. A total of 39 results (81% turn-out) were received and are evaluated in this report.

## 2. PROCEDURE FOR SAMPLE PREPARATION AND DISTRIBUTION

The Isotope Hydrology Laboratory prepared two sets of samples from a drinking water source. Due to low concentrations of  $\text{NO}_3^-$  and  $\text{Na}^+$ , the samples were artificially spiked with  $\text{NaNO}_3$ . The samples consisted of: 1) half a litre of water acidified with 2.5 ml of concentrated  $\text{HNO}_3$ ; and 2) half a litre of unacidified water. These were distributed to all participants in May 1999. All participating laboratories were requested to measure the pH, EC as well as the concentrations of the following chemical species:  $\text{HCO}_3^-$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{SiO}_2$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Li}^+$ , B,  $\text{NH}_4^+$  and  $\text{NO}_3^-$  (which was optional), and to report results, including the ionic balance as well as the analytical methods, according to the format attached as Annex 2.

**RESULTS OF THE 1999 IAEA INTERLABORATORY COMPARISON FOR CHEMISTRY OF COLD WATER**

Lab no. no.	pH	EC	HCO3-1	Cl	SO4	SiO2	B	Na	K	Ca	Mg	Li	NH4	NO3	Accepted Results [%]
2			250.0	12.0 *	35.0 *#			20.0 *#	12.0 *#	85.0	21.0				43
4	7.8	640.7	210.0	4.5	140.7	3.6 *#	0.1	4.8 *#	43.0	79.2	19.3	0.1	0.1	0.9	82
5	7.8	556.0	252.0	3.8	117.0			9.7	5.4	94.6	19.9	0.1		8.2	100
8	8.0	525.7	248.4	14.1	98.2			9.8	5.6	97.1	19.9		0.2	6.8	80
9	7.9	604.0	276.8	3.4	117.0	8.7	0.1	17.0 *#	5.2	89.6	21.3	0.5	0.0	6.1	91
10					103.7			9.7	4.4	111.7 #	19.8	0.1			80
11	8.0	564.0	276.0	7.6 *	120.0			0.1 *#	1.2 *#	58.0 *#	44.0 *#			1.3	50
13	8.1	580.0	179.0	4.5	137.4			8.1	3.5	82.0	20.6			5.5	90
14	7.7	532.4	244.0	5.0	97.0	8		10.0	4.0	98.0	23.0 #			2.0	82
15	7.9	573.0	273.0	12.2 *	80.0 #					83.6	19.2			10.0	75
16	7.7	519.0	44.0 *	7.0	146.0			7.7	4.7	172.0 *#	140.0 *#		0.2	7.8	40
17	7.7	650.0	304.0	4.2	180.0 *#	1.1 *#	0.0	10.9	1.3 *#	608.5 *#	18.8	0.1			60
18	7.9	606.0	246.7	6.0	110.9	9.1	1.0	9.6	5.1	108.7	22.2	0.1	0.5		100
20	7.4	584.0	186.0	4.0	138.0	4 *#		7.7	4.8	66.4 #	33.8 *#	0.0			40
21	7.0 *#		218.0	8.9 *	110.0					96.7	84.6 *#			1.3	57
22	7.7	599.0	278.0		142.0				3.6	83.5					100
23	7.7	591.7	289.8	6.4	107.4	10.2 #	8.5	10.9	5.2	99.8	17.6	0.1	0.0	4.5	81
24	7.8	610.0	258.0	3.6	121.0	8.6	0.2	12.0 #	4.7	91.0	20.0	0.1		1.5	100
25	7.4	514.0	213.0	5.6	114.4	8.2	0.1	9.3	4.4	82.4	20.0	0.1	0.0	6.2	91
26	7.7		208.3	11.2 *	117.7			9.7	4.9	95.2	30.2 *#			7.7	78
28	7.8	540.0	244.3	3.8	116.0	8.9	0.0	9.4	4.8	91.6	20.0	0.1		6.3	100
29			245.4	4.6	119.2	8.6	0.0	10.2	4.9	95.2	20.3	0.1		6.9	100
30	7.8	575.0	206.0	3.6	120.8	3.2 *#		9.8	4.4	87.9	19.2	0.2		6.2	91
31	8.0	600.0	241.0	2.9	108.9			10.4	4.8	99.8	14.9 *#	0.9		6.1	89
32	8.0	600.0	240.2	2.9	107.6			10.4	4.8	99.6	14.1 *#	0.9		6.1	90
33	7.4	560.0		4.9 *	116.3			10.1	4.5	192.3 *#				7.4	88
34	7.8	631.0	251.9	9.6 *	118.1	8	0.0	9.4	3.5	87.8	35.6 *#		0.4	5.9	82
35	8.1	536.0	95.0 *	6.5	70.0 *#			10.0	5.4	93.0	20.0	0.5		5.9	70
38	7.5	680.0	204.1	38.0 *	133.3					85.6	19.0			10.7	75
39	7.5	542.0	48.8 *	40.0 *	118.0			62.2 *#	3.4 #	16.0 *#	9.7 *#		0.5	13.6	70
40	1.5 *#	1000.0 *		931.0 *	0.2 *#			11.6	5.7	200.0 *#	24.3 *#		0.0	69.0 *	22
41	7.9	466.0		17.7 *	133.3				8.2 *#	77.3	2.5 *#		0.1	1.2	50
42	8.3 #	568.3	268.5	3.0	121.0			12.0 #	5.1	90.4	7.2 *#		0.1	0.3	70
43	7.6	609.0	255.2		77.1 #	6.3 *#		9.7	5.2	89.7	18.4	0.1			78
44	7.8	606.0	211.0	4.7	137.0			9.0	4.6	84.0	23.0 #			6.9	90
45	7.8		231.0	4.0	123.5			8.6	5.8	106.0	19.5	0.1		5.7	100
46	7.7	610.0	238.0	4.0	118.0			9.8	4.9	93.8	20.7		0.0	6.6	100
47	7.6	770.0 *	205.0	38.0 *	1159.0 *#					100.0	50.0 *#		0.0		43
100 (IAEA)	7.8	626.0	265.0	3.9	110.0	8.4	-	10.2	4.9	91.6	20.0	0.1	-	7.1	100
±SD (IAEA)	±0.01	±1.2	±1.4	±0.1	±0.9	±0.1	-	±0.2	±0.1	±0.8	±0.6		-	±0.1	-

TABLE 1: Values reported by 39 participating laboratories. The IAEA results (Lab 100) are the reference values  $\pm 2 SD$ . The outliers which are marked with \*(star) were rejected by the statistical test. Those marked with # (number sign) were, likewise, rejected because they were outside of the range of 2 standard deviation (SD) from the mean of accepted results or of the reference value.



**METHODS OF ANALYSIS OF THE PARTICIPATING LABORATORIES**

Lab ID NO.	pH	EC	HCO3-1	Cl	SO4	SiO2	B	Na	K	Ca	Mg	Li	NH4	NO3
2														
4	PH	CM	TM	IC	IC	PE	PE	PE	PE	PE	PE	PE	IS	
5	PH	CM	TM	IC	IC			AA	AA	AA	AA			IC
8	PH	CM	TM	VD	TU			AA	AA	AA	AA		CO	CO
9	PH	CM	TM	IC	IC	CO	CO	FE	FE	VD	VD	FE	CO	IC
10					CO			AA	AA	AA	AA	AA		
11	PH	CM	TM	VD	TU			AA	AA	VD	VD			CO
13	PH	CM	TM	VD	TU			AA	AA	CP	CP			CO
14														
15	PH	CM	TM	VD	CO					CP	CP			
16	PH	CM	TM	TM	CO			AA	AA	TM	TM		CO	CM
17	PH	CM	TM	CO	CO	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS		CO
18	PH	CM	TM	VD	TU	PE	PE	AA	AA	PE	PE	AA	CO	
20	PH	CM	TM	IC	TU	PE	PE	AA	AA	AA	AA	PE		
21	PH		TM	AG	TU					CP	CP			CO
22	PH	CM	TM		TU				TXRF	TXRF				
23	PH	CM	TM	VD	CO	CO	IS	AA	AA	CP	CP	AA	CO	CO
24	PH	CM	TM	IC	IC	PE	PE	FE	FE	PE	PE	PE		IC
25	PH	CM	TM	VD	CO	CO	CO	AA	AA	VD	AA	AA	CO	CO
26	PH	CM	TM		TU			FE	AA	AA	AA			CO
28	PH	CM	TM	IC	IC	PE	PE	PE	PE	PE	PE	PE		IC
29			TM	IC	PE	PE	PM	PE	AA	PE	PE	PM		
30	PH	CM	TM	IC	IC	CO		IC	IC	IC	IC	IC		IC
31	PH	CM	TM	IC	IC			IC	IC	IC	IC	IC		IC
32	PH	CM	TM	IC	IC			IC	IC	IC	IC	IC		IC
33	PH	CM		VD				FE	FE	CP				
34	PH	CM	TM	IC	IC	CO	CO	FE	FE	TM	TM		CO	IC
35	PH	CM		IC	IC			AA	AA	AA	AA	IC		IC
38	PH	CM	TM	TM	CO					TM	TM			CO
39									TXRF	TXRF				
40	PH	CM	TM	VD	GM			FE	FE	CP	CP		CO	CO
41														
42	PH	CM	TM	CO	CO	FE	FE	CP	CP	CO	CO			
43	PH	CM	TM		CO	AA	AA	AA	AA	AA	AA	AA		
44														
45	PH		TM	IC	IC			AA	AA	AA	AA	AA		IC
46	PH	CM	TM	CE	CE			AA	AA	CP	CP		CO	
47	PH	CM	TM	VD	GM					CP	CP		CO	
100	PH	CM	TM	IC	IC	PE	PE	PE	PE	PE	PE	PE		IC

Table 2:

AA	Atomic Absorption methods	IS	Ion selective electrode
AG	Argentometric titration	PE	Plasma emission methods
CE	Capillary electrophoresis	PH	pH meter
CM	Conductivity meter	PM	Plasma mass spectrometry
CO	Colorimetric methods (UV-vis spectrophotometry)	PO	Potentiometric determination
CP	Complexometric Ca and Mg	TM	Titrimetric Alkalinity determination
FE	Flame emission method	TU	Turbidity method
GM	Gravimetric determination	TXRF	Total reflection x-ray fluorescence
IC	Ion chromatographic method	VD	Volumetric determination

#### 4. METHOD OF EVALUATION OF RESULTS

The analytical results were evaluated by identifying outliers using the Dixon, Grubbs, Skewness and Kurtoses tests in the programme, HISTO-Statistical Analysis for Inter-comparison Data [1], a Windows-based interactive application for statistical analysis. The mean and the standard deviation (SD) were calculated from all statistically accepted results, i.e., excluding the outliers identified by the tests. The 95% confidence limit from the mean of all statistically accepted results was subsequently determined according to the formula:

$$(F / \sqrt{n}) \times 1.96$$

where:

$F$  is the standard deviation (SD) of the mean of the accepted population

$n$  is the number of accepted results

The range of the 95% confidence limit of the mean is reflected as a shaded area in all the graphs (Figures 1 to 11).

The results of the IAEA, which is considered as a reference laboratory, are indicated as the recommended “reference values”, with 2SD obtained from 8 repeated measurements over an extended period of time. These measurements were all carefully calibrated with certified calibration solutions and are in agreement with the values indicated by the supplier of the drinking water from which the samples were obtained.

The reference value (solid line in Figures 1 to 11) is taken as similar to the mean of all statistically accepted results (dashed lines in Figures 1 to 11) if the reference value falls within the intervals defined by the limits of the 95% uncertainty range of the mean. When this is the case, the evaluation of statistically accepted results proceeds further by rejecting those values which are outside the  $2F$  range from the mean. The reference value and the mean value essentially converge though when the accepted results are of uniformly high quality. The rejected values (i.e., outliers) are marked # in Table 1 and crossed (X) symbols in Figures 1 to 11.

When the reference value is, however, outside of the 95% confidence limit of the mean of statistically accepted results, as in the case of pH, EC,  $\text{Cl}^-$  and  $\text{NO}_3^-$ , the outliers are only identified by the four statistical tests. The discrepancies in the values results from certain factors which are elaborated in the succeeding paragraphs.

While the participating laboratories were requested to report 14 parameters, only a few submitted results for B,  $\text{Li}^+$  and  $\text{NH}_4^+$ . A statistical analysis for a small number of population for these parameters is, therefore, not considered significant. The evaluation of results was, thus, limited to the 11 parameters, excluding these species. The laboratories may simply compare their results on these ions with the rest of the reported values.

As an overall evaluation of the acceptability of results in each laboratory, the number of accepted values in each laboratory was, thus, divided by 11 parameters. The results are reflected in % on the last column of Table 1. A similar evaluation was made for the performance of all laboratories for each ion by taking the number of laboratories whose results were accepted, divided by the total number of participating laboratories. The results are reflected in % in Table 3.

## 5. RESULTS OF THE EVALUATION

Table 1 reflects the analytical results as submitted by the participating laboratories which are identified by codes known only to them. The marks \* and # indicate the outliers from the evaluation procedures. The methods of analysis by the respective labs for each ion are reflected in Table 2 while Table 3 reflects the overall results of the evaluation.



Analysed components	Reference Value $\pm 2$ SD (IAEA) [mg/l]	Mean of all accepted results $\pm 2$ SD [mg/l]	Percent of accepted Results for evaluated ions
pH	7.8 $\pm 0.01$	7.8 $\pm 0.4$	91
EC	626.0 $\pm 1.2$	581.0 $\pm 90.0$	(94) ^
HCO <sub>3</sub>	265.0 $\pm 1.4$	241.0 $\pm 60.0$	(91)^
Cl	3.9 $\pm 0.1$	4.5 $\pm 2.2$	(67)^
SO <sub>4</sub>	110.0 $\pm 0.9$	117.8 $\pm 31.4$	82
SiO <sub>2</sub>	8.4 $\pm 0.1$	8.5 $\pm 0.8$	60
B	- -	not evaluated	-
Na	10.2 $\pm 0.2$	9.8 $\pm 2.2$	79
K	4.9 $\pm 0.1$	4.7 $\pm 1.3$	68
Ca	91.6 $\pm 0.8$	91.4 $\pm 18.6$	80
Mg	20.0 $\pm 0.6$	20.0 $\pm 2.6$	60
Li	0.1	not evaluated	-
NH <sub>4</sub>	- -	not evaluated	-
NO <sub>3</sub>	7.1 $\pm 0.1$	5.8 $\pm 6.2$	-

TABLE. 3. This table reflects the reference values  $\pm 2$  standard deviations (SD), the mean values of the accepted results  $\pm 2$  SD and the percentage of the accepted results. The symbol ^ indicates that the reference value and mean value do not converge within the 95% confidence limit, therefore, the criterion using 2SD of the mean to identify outliers has not been applied on the data set and the numbers reflect only on the statistical rejection.

The results of the evaluation are graphically presented in the s-plots for each ion (Figures 1 to 11). There is good agreement, within the 95% confidence limit, between the mean of statistically accepted results and the reference value for most parameters. In all except four cases involving EC, HCO<sub>3</sub><sup>-</sup>, Cl<sup>-</sup> and NO<sub>3</sub><sup>-</sup> the reference value (solid line in Figures 1 to 11) and the mean value of the statistically accepted results (dashed line in Figures 1 to 11 and Table 3) fall within the interval defined by the limits of the 95% uncertainty range of the mean (shaded area). There is a big difference though between the mean and the reference values for EC and HCO<sub>3</sub><sup>-</sup> (Figs. 2 and 3) while this is very slight for Cl<sup>-</sup> and NO<sub>3</sub><sup>-</sup> (Fig. 4 and 11, respectively). In these four parameters, therefore, the outliers were identified purely from the statistical tests.

There can be no other explanation for the discrepancies in EC except a lack of calibration of instruments since the method used by all the labs was the same. For HCO<sub>3</sub><sup>-</sup>, however, 3 sets of populations are reflected in Figure 3. One set has a value around 210 mg/l, the second with high values around 270 mg/l and the third around the mean of the accepted values at 240 mg/l. The IAEA Laboratory (code number 100) obtained a HCO<sub>3</sub><sup>-</sup> concentration of 265 mg/l by titrating the sample at pH of 4.3. A few laboratories reportedly titrated at the same pH and obtained lower values while a number of the laboratories which titrated their samples at pH of 4.5 or with a methyl orange indicator reported values in all ranges. While there is a tendency for measurements towards lower values, no correlation between the values and methods could be established.

A slight difference, but which is within the range of uncertainty, between the reference value and the mean value is observed for Cl<sup>-</sup> and NO<sub>3</sub><sup>-</sup> (Fig. 4 and 11, respectively). There is a general tendency for Cl<sup>-</sup> values to be on the higher side. Contrary to HCO<sub>3</sub><sup>-</sup> though, a direct



correlation apparently exists between  $\text{Cl}^-$  values and methods. Higher values are associated with the volumetric determination method (Table 2) which is not really precise because the detection limit is high and in general, not recommended for analysis of low  $\text{Cl}^-$  water, as in the case of the drinking water sample.

Likewise, the mean of accepted  $\text{NO}_3^-$  values is on the low side due to a small group of population with low  $\text{NO}_3^-$  results. It would also be noted that values determined by the colorimetric method either result to high or low results which dominate the tail ends of the s-curve. On one hand, the accepted values were determined by the ion chromatographic method. The colorimetric method has less sensitivity in comparison to the ion chromatographic method which produced acceptable results. The latter has low detection limits, good separation capabilities and is free from interference from other substances.

The last column in Table 1 reflects that acceptability of results in individual laboratories for the 11 parameters that were evaluated range from as low as 22% up to 100%. It also indicates that more than half of the laboratories submitted results which are below 80% acceptability. Table 3 indicates that the acceptability of results of certain components range from only 60 to 89%; pH is acceptable in only 89% of all laboratories whereas  $\text{Mg}^{2+}$  and  $\text{SiO}_2$  are acceptable only in 60% of the participating laboratories. The results of all laboratories for the rest of the ions are similarly quite low. Considering the importance of  $\text{Cl}^-$  and  $\text{Mg}^{2+}$  in classifying and determining the sources of water as well as an indicator of the movement of fluids, the accuracy in the measurement of these ions is critical.

While 79% of electrical conductivity results in all labs are accepted, it should be noted that this is the easiest parameter to measure, and its accuracy is always expected. Therefore, the low percentage of acceptability which might be due to factors such as lack of calibration of the EC meter calls for stringent adherence to calibration and careful check of measurements in future analytical activities of those laboratories.

The overall performance of the participating laboratories by means of the percentage of accepted results is represented in Figure 12. The performance of the individual laboratories was, therefore, finally based on these 11 components (pH, EC,  $\text{HCO}_3^-$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{SiO}_2$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and  $\text{NO}_3^-$ ). The scale on the right hand side of the figure reflects the number of measured components (represented as dots) out of the total of eleven. As an example, laboratory 5 reported only ten results out of eleven, while laboratory 24 reported all eleven.

About 30% of the participating laboratories fall below 70% of accepted results (Fig. 12). These laboratories should be extra cautious and invest extra efforts in data interpretation prior to any improvements in the quality of their chemical results.

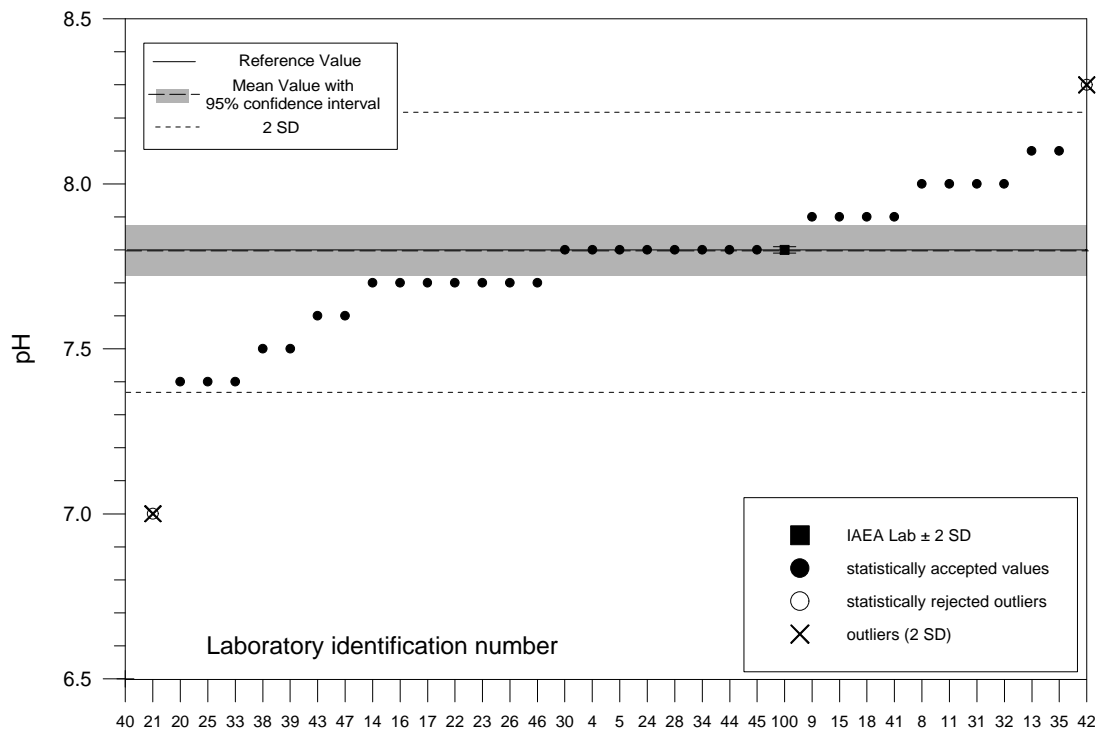


FIG. 1. pH vs. laboratory identification number

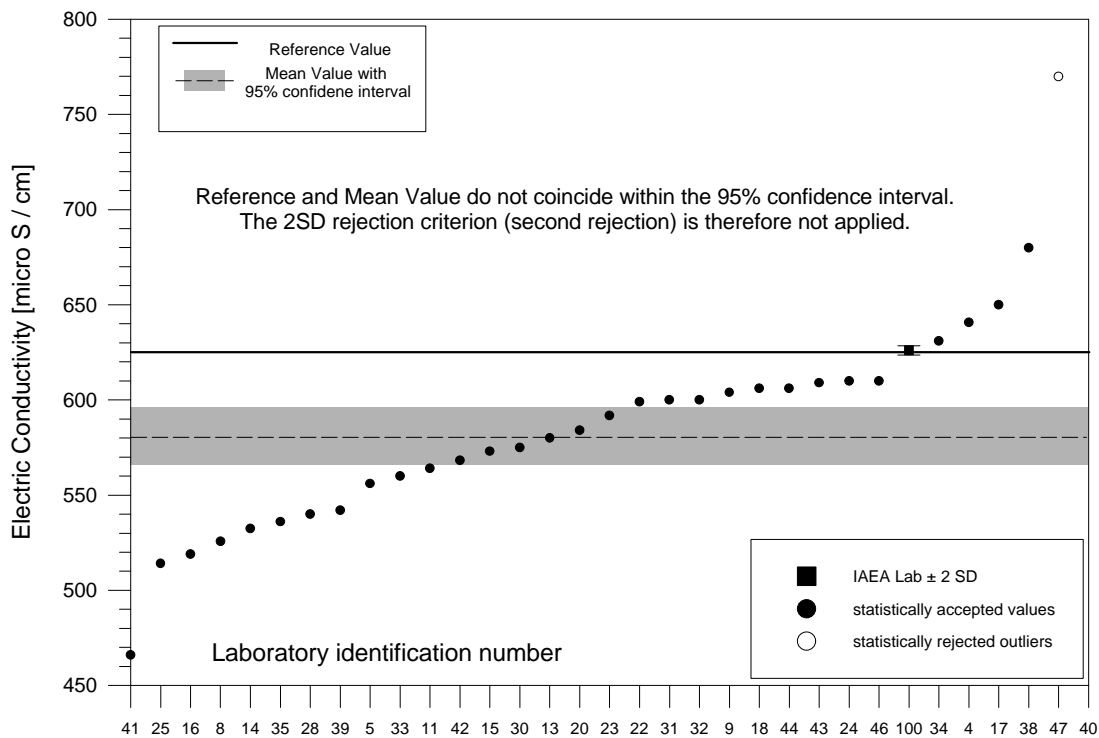


Fig. 2. Electric conductivity vs. laboratory identification number

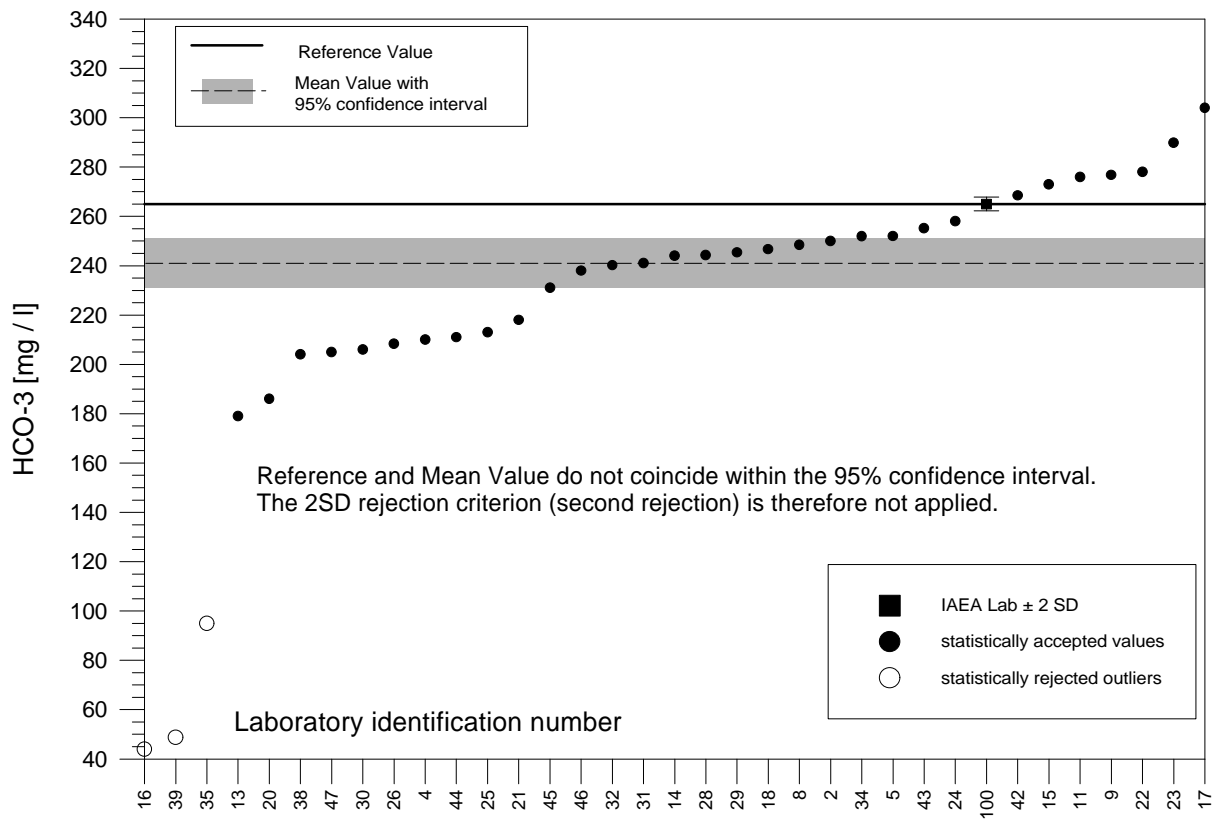


FIG. 3. Bicarbonate concentration vs. Laboratory identification code

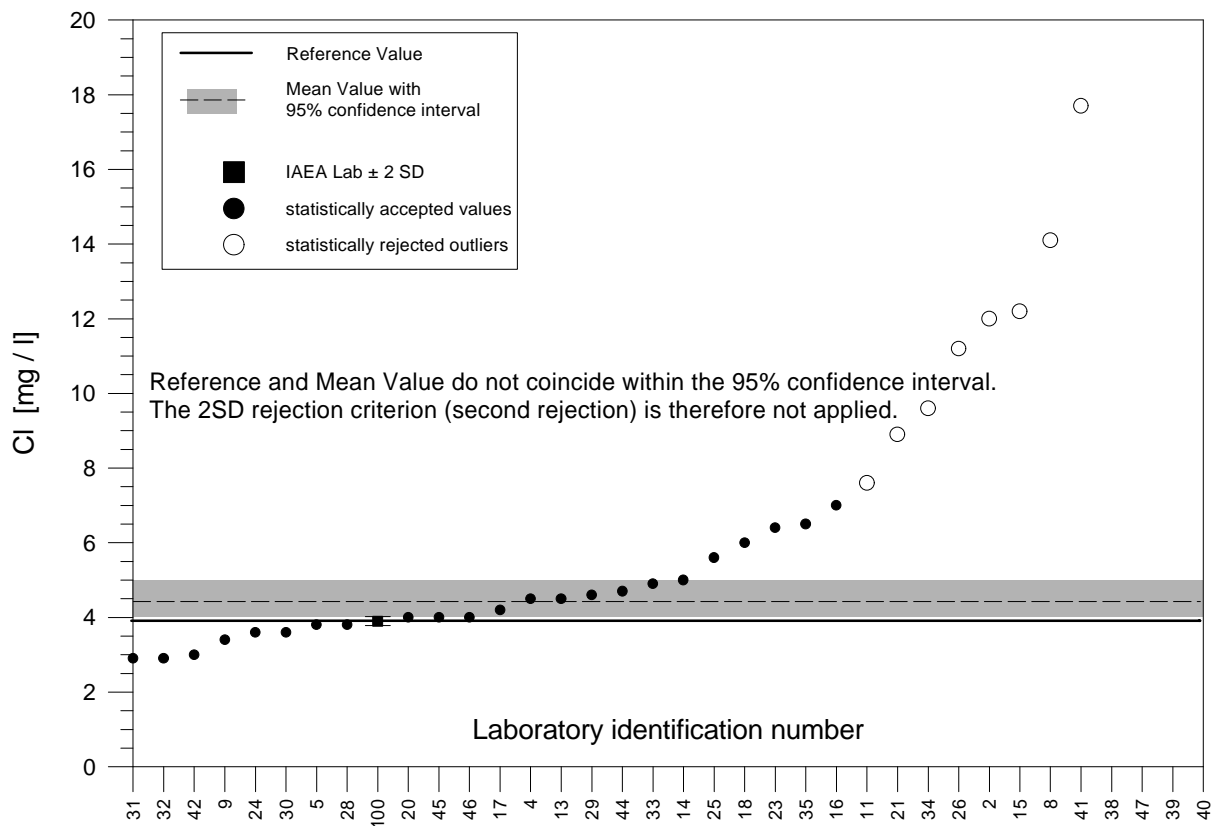


FIG. 4. Chloride concentration vs. Laboratory identification code

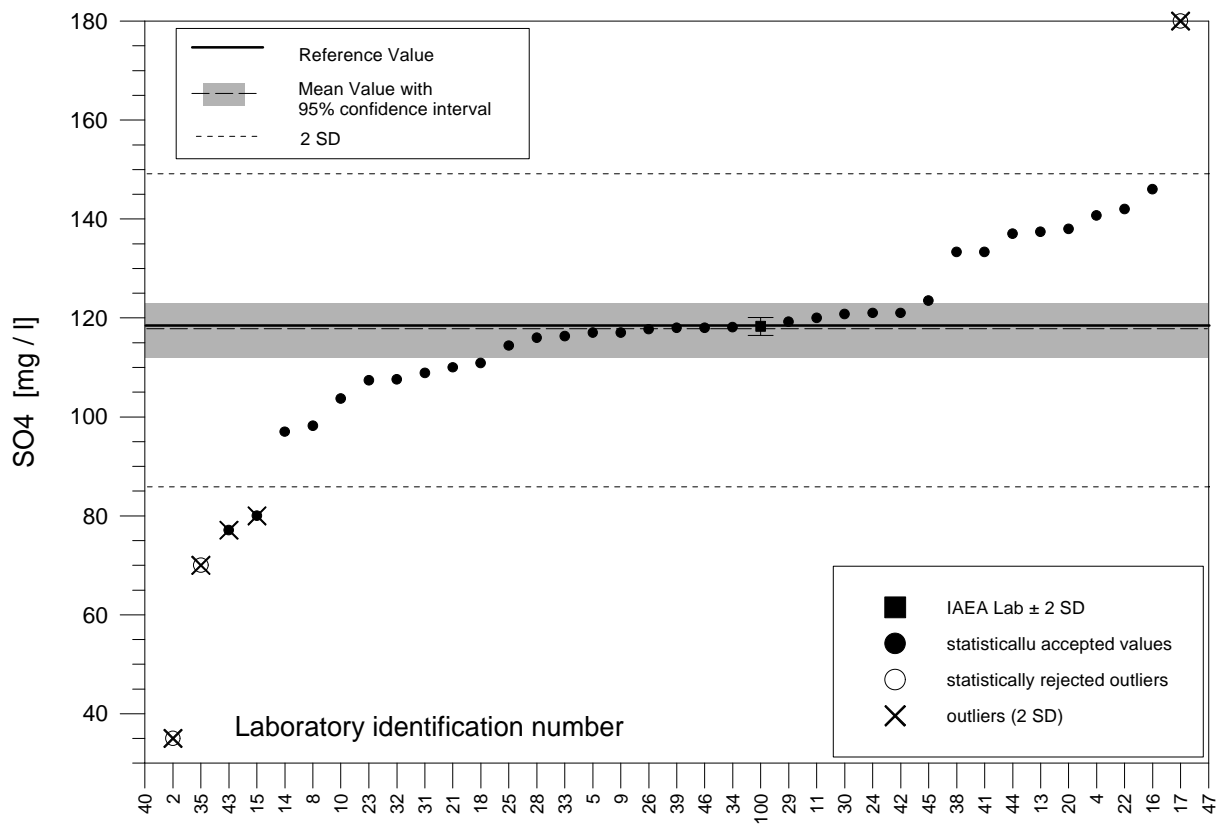


Fig. 5. Sulphate concentration vs. Laboratory identification code

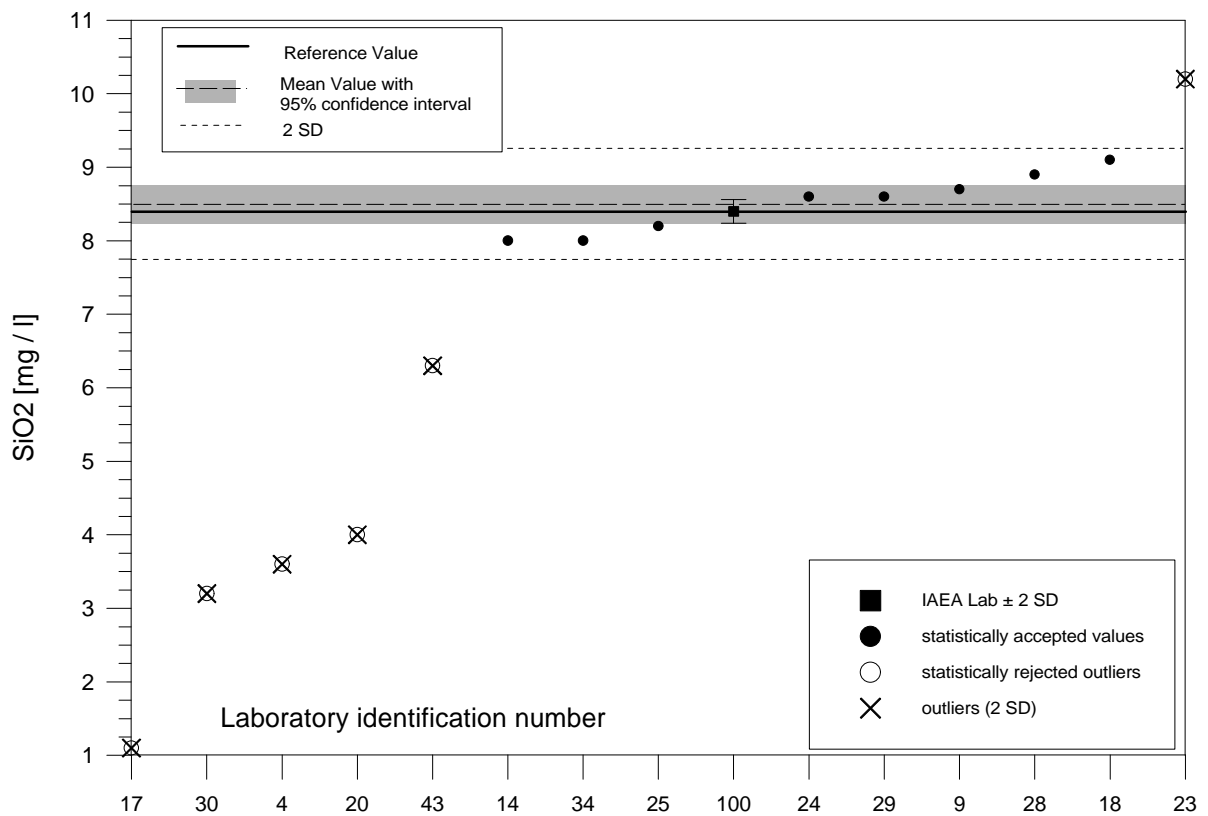


Fig. 6. Silicate concentration vs. Laboratory identification code

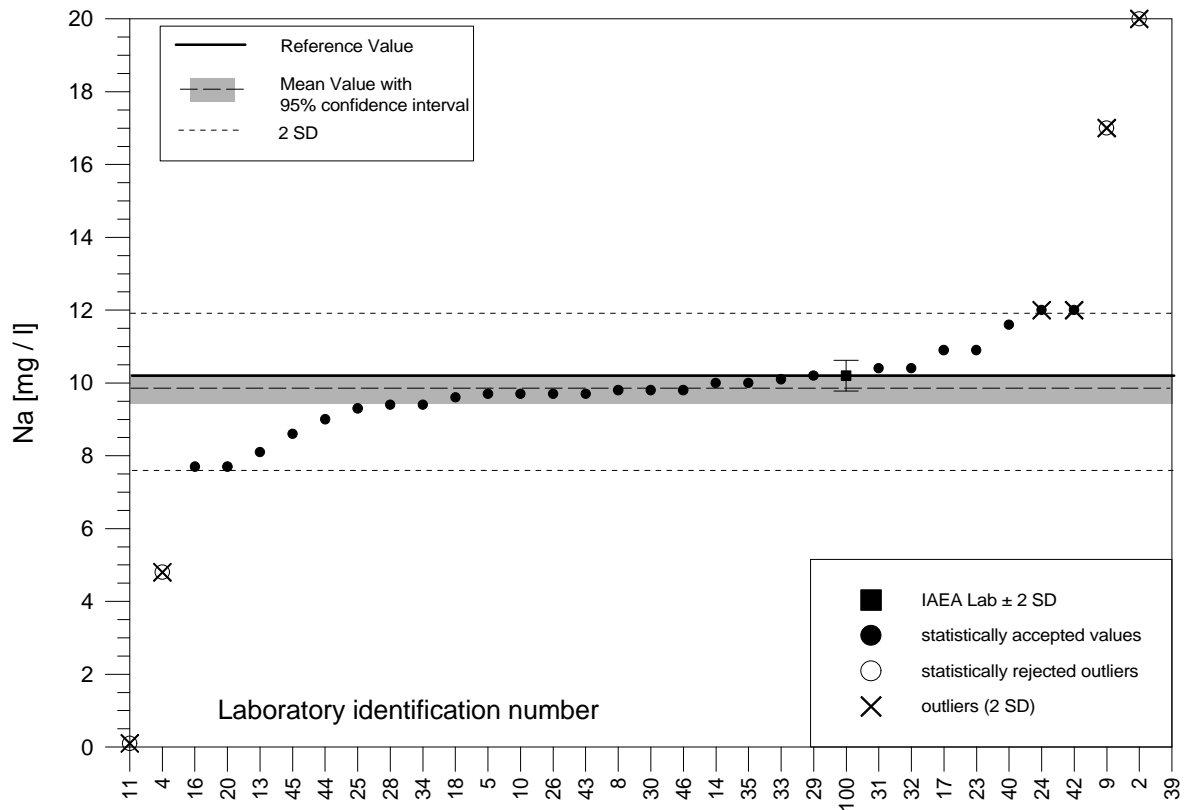


Fig. 7. Sodium concentration vs. Laboratory identification code

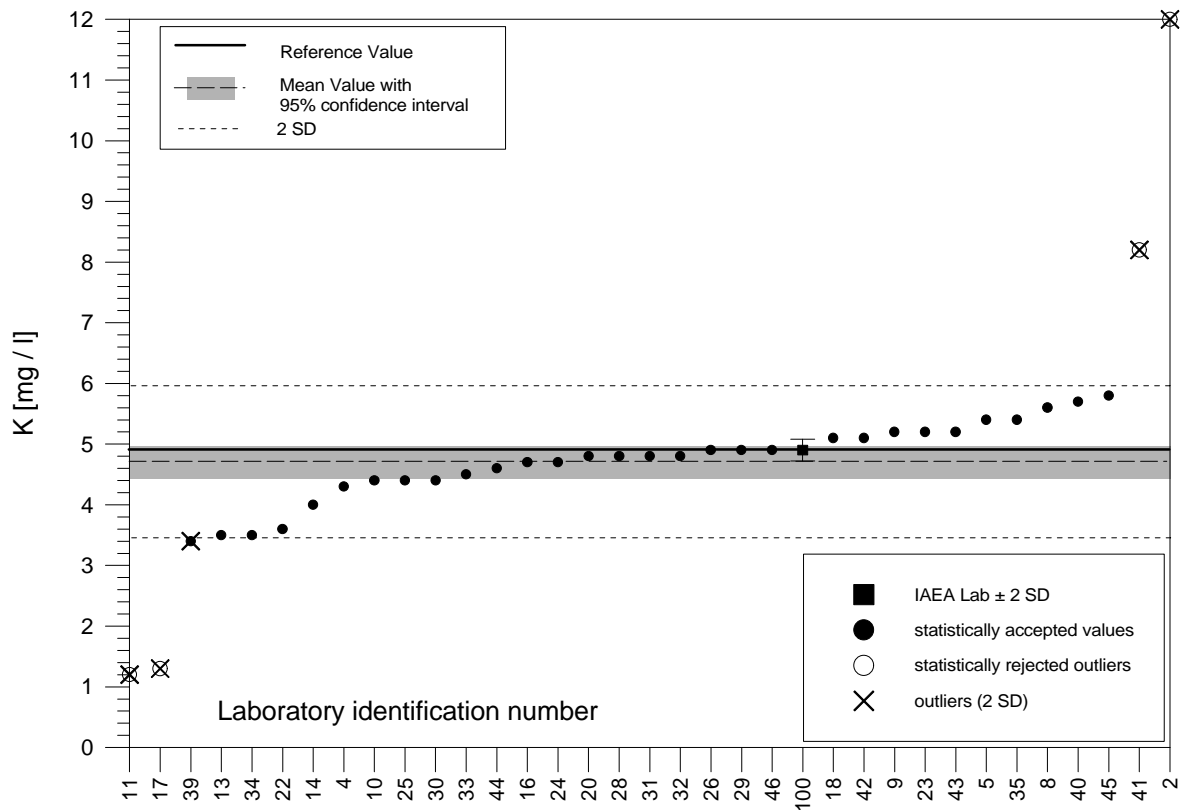


Fig. 8. Potassium concentration vs. Laboratory identification code

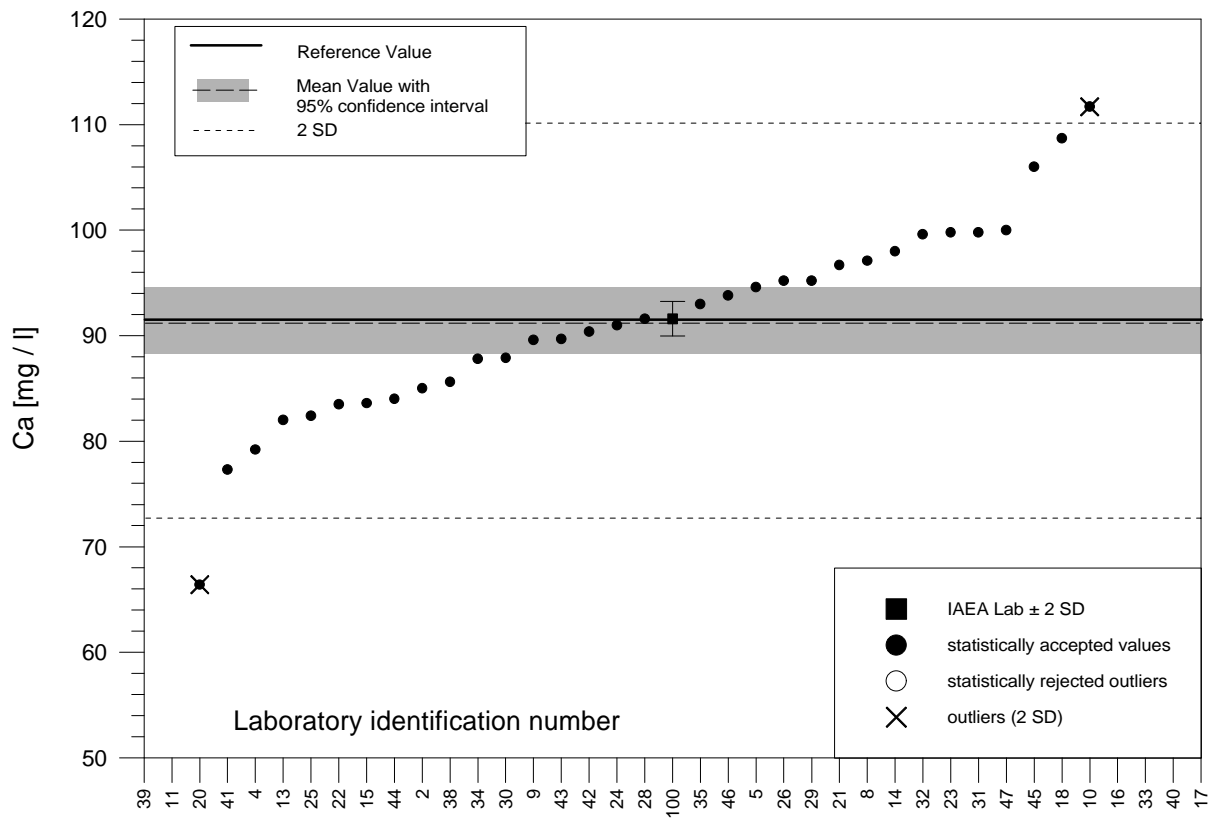


Fig. 9. Calcium concentration vs. Laboratory identification code

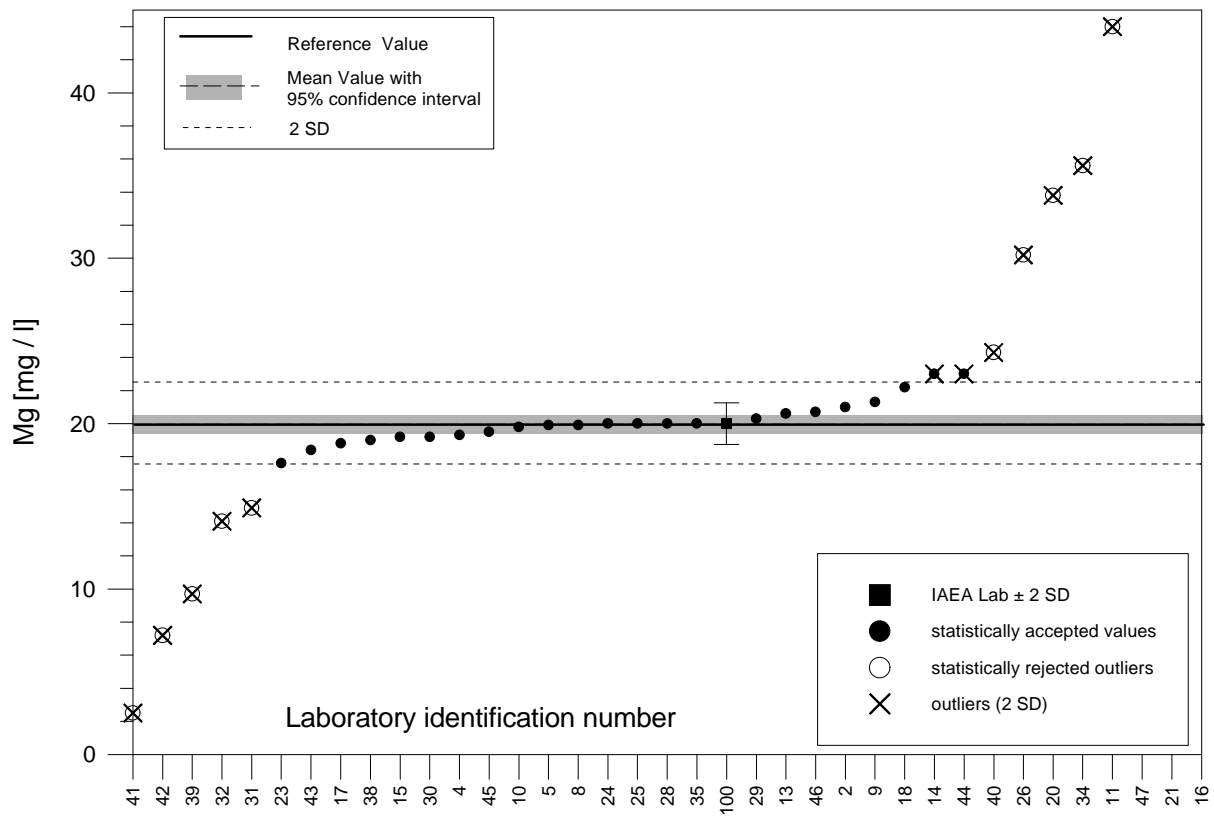


Fig. 10. Magnesium concentration vs. Laboratory identification code

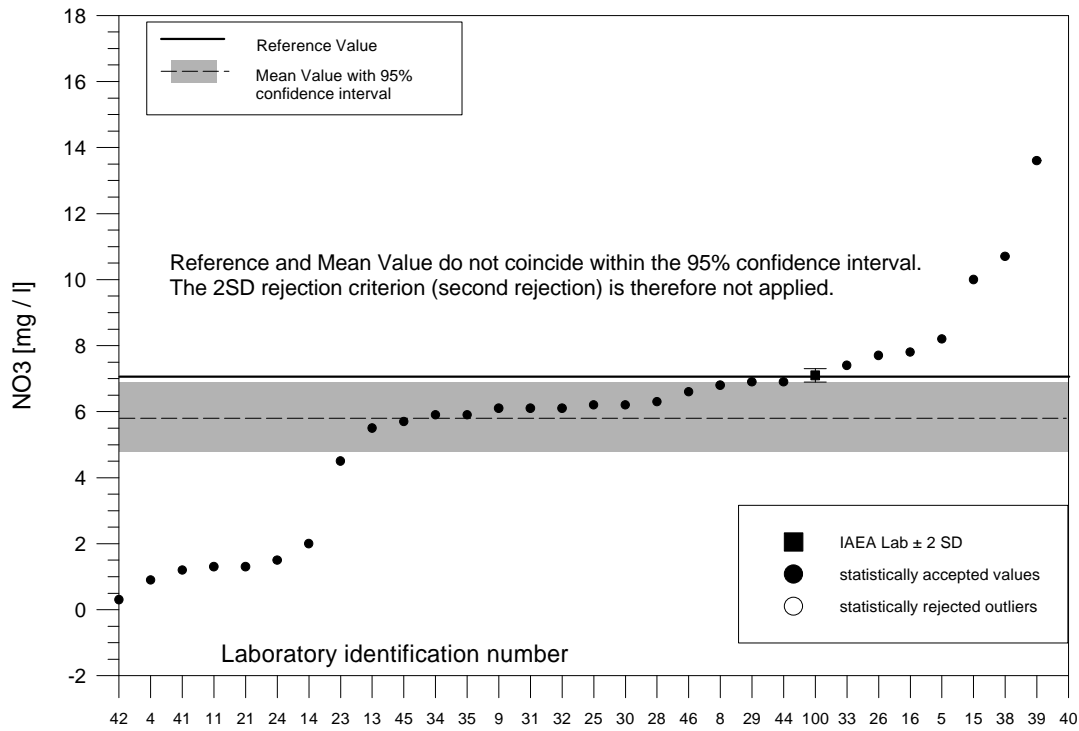


Fig. 11. Nitrate concentration vs. laboratory identification number

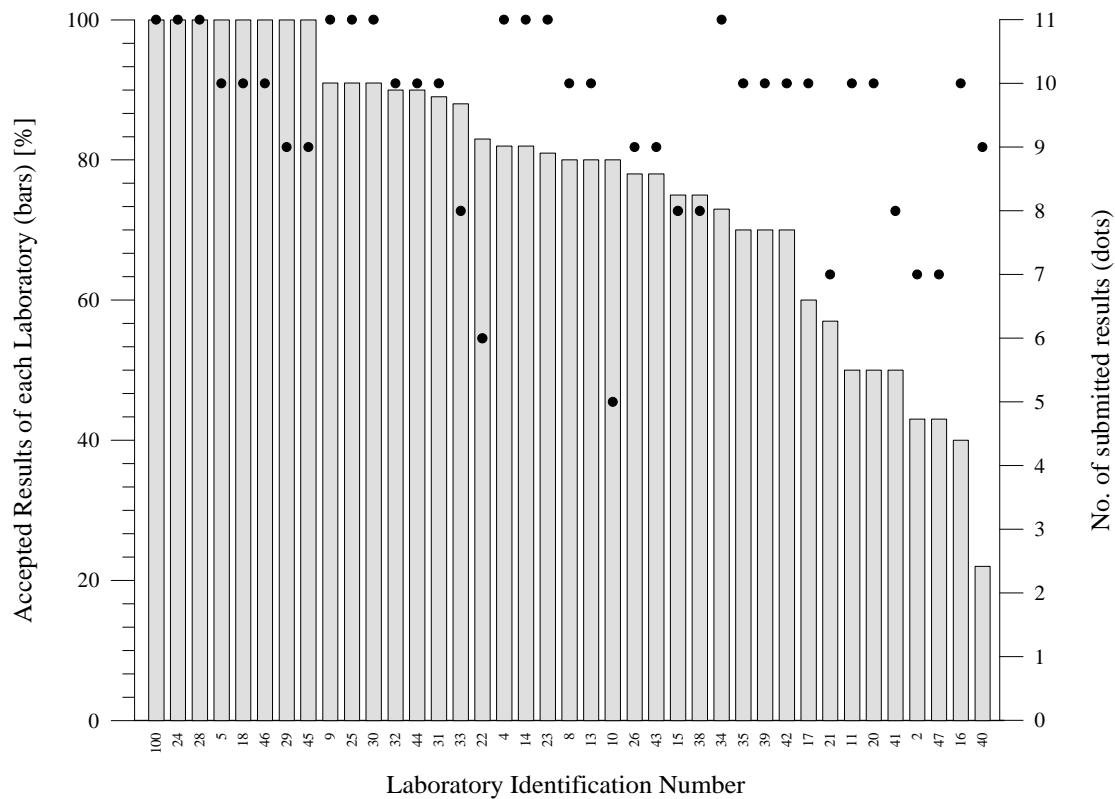


Fig. 12. Accepted results [%] (left axis, bars) and number of submitted results (right axis, dots) versus laboratory identification number

## 6. CONCLUSIONS AND RECOMMENDATIONS

The results of this assessment of chemical results indicate that a number of chemical laboratories need to immediately and thoroughly review their procedures for analysis prior to any interpretation efforts. This is particularly true for laboratories which have <70% accepted results (coded 40, 16, 47, 2, 41, 20, 11, 21, 17, 42, 39 and 35). Other labs have to examine their procedures for analysis of specific ions as well as quality control practices. It should be noted that the quality of analytical results, particularly for Cl<sup>-</sup> is affected by the method employed.

Although a number of laboratories have not measured all the major ions to be able to calculate the ionic balance, it should be noted that the ionic balance is an important way to initially examine the quality of the results. Laboratories should, therefore, always check if the ionic balance is within a 5% range before submitting their results.

As reflected in this exercise, there is ample room for improvement in assuring that chemical data are of acceptable quality before any attempts at interpretation are made. The laboratories are, therefore, encouraged to undertake regular quality assurance exercises, through comparison exercises.

## ACKNOWLEDGEMENT

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## ANNEX I

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## II

### INTERLABORATORY COMPARISON REPORT Major Water Chemistry

Name of Institute / Laboratory: \_\_\_\_\_

Laboratory Manager / Supervisor: \_\_\_\_\_

Sample Name: \_\_\_\_\_

Parameter	Date of Analysis	Method Used In Codes (*)	Units	Result 1	Result 2	Result 3	Mean Result	Std. Dev.
pH			pH units, ____ °C					
Conductivity			uS/cm, 25°C					
HCO <sub>3</sub> <sup>-1</sup>			mg/L					
Cl <sup>-</sup>			mg/L					
SO <sub>4</sub> <sup>2-</sup>			mg/L					
SiO <sub>2</sub>			mg/L					
B			mg/L					
Na <sup>+</sup>			mg/L					
K <sup>+</sup>			mg/L					
Ca <sup>2+</sup>			mg/L					
Mg <sup>2+</sup>			mg/L					
Li <sup>+</sup>			mg/L					
NH <sub>3</sub>			mg/L					
NO <sub>3</sub> <sup>-</sup> (optional)			mg/L					
Ionic Balance								

**Note that sample contains some NO<sub>3</sub> which could affect the ionic balance.**

**REMARKS, if any:** \_\_\_\_\_

*CODE	Method
AA	Atomic Absorption methods
PE	Plasma emission methods
FE	Flame emission method
CP	Complexometric Ca and Mg
IC	Ion chromatographic method
CO	Colorimetric methods (UV-vis spectrophotometry)
TM	Titrimetric Alkalinity determination
VD	Volumetric determination
GM	Gravimetric determination
IS	Ion selective electrode
TU	Turbidity method
PO	Potentiometric determination
pH	pH meter
CM	Conductivity meter