



DHV CONSULTANTS &
DELFT HYDRAULICS with
HALCROW, TAHAL, CES,
ORG & JPS

*Findings of
Second Inter-Laboratory AQC Exercise*

March 2001

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1 Background

Analytical Quality Control (**AQC**) is one of the main components of a Quality Assurance system, wherein the quality of analytical data being generated in any laboratory is controlled through minimising or controlling errors to achieve a target accuracy. A particular water quality study or any organised water quality monitoring programme involves the collection, comparison and interpretation of analytical data, which lead to a decision for the management and use of the water resource. The correctness of the decision or action depends largely upon the accuracy of the analytical results. If the errors of the analytical results are high, the manpower, material and money spent on the monitoring programme or study become futile and further lead to wrong decision and improper action plans. Since the success and usefulness of an information system derived from analysis results depend on the quality of input data, it is essential to ensure that adequate comparability and accuracy of analytical results are achieved.

The need for analytical quality control (AQC) in HP laboratories was first discussed in the 'Water Quality Standardisation Workshop', held at Hyderabad during 9–10 December 1996. It was recommended that AQC exercises should be organised for the HP laboratories to achieve a target accuracy so that the results obtained from different laboratories are comparable. Consequently, the following actions were taken:

- In May 1997 and March 1998, many HP laboratories participated in 'within-laboratory' AQC exercises organised by HP consultants. The results of the first exercise were discussed in two technical meetings, held at Bangalore and Bhopal and a report was issued in February 1998. Results of the second exercise were reported in June 1999.
- Since the 'within-laboratory' AQC exercises evaluate only the precision of the laboratory, an 'inter-laboratory' AQC exercise was conducted in December 1998 to test the bias of the laboratories. Twenty-five (25) laboratories participated in this AQC-1 exercise.
- In continuation of the AQC-1 inter-laboratory exercise, the AQC-2 exercise was conducted in April 2000 for 42 laboratories.

For both of the inter-laboratory AQC exercises, the Central Pollution Control Board (CPCB) laboratory conducted the programme and did the statistical analysis of the data, under the guidance of Dr. S.D. Makhijani and Mr. A. Manoharan.

2 Objectives

The main objectives of an *inter-laboratory* AQC programme are:

- to assess the status of analytical facilities and capabilities of the concerned laboratories
- to identify the serious constraints (random & systematic) in the working environment of the laboratories
- to provide necessary assistance to the concerned laboratories to overcome the short-comings in the analytical capabilities
- to promote the scientific/analytical competence of the concerned laboratories to the level of excellence for better output
- to enhance the internal and external quality control of the concerned laboratories

3 Methodology

3.1 Standard samples

The list of parameters covered under the inter-laboratory AQC exercise is given below:

1. Conductivity (COND)
2. Total Dissolved Solids (TDS)
3. Total Hardness (TH)
4. Sodium (Na)
5. Fluoride (F)
6. Sulphate (SO₄)
7. Nitrate - N (NO₃-N)
8. Phosphate-P (PO₄-P)
9. Boron (B)

The above parameters were selected for the exercise because the procedures for their determination involve various analytical techniques, namely, potentiometric (COND), gravimetric (TDS), titrimetric (TH), absorption-spectrometric (F, NO₃-N, PO₄-P, B), nephelometric (SO₄) and emission-spectrometric (Na), and common laboratory operations such as weighing, heating, filtering, etc. These tests are routinely carried out in the HP laboratories for characterisation of surface and groundwaters. All HP laboratories are expected to be able to carry out these types of analyses. The capability of a laboratory to perform these tests satisfactorily would indicate its preparedness to carry out its assigned HIS functions.

Two synthetic samples, labelled as A & B, were prepared by mixing different volumes of 7 different solutions made from high quality chemicals and distilled water. The list of solutions and their strengths and the volumes used for each sample are given in Annexure I.

The samples were distributed to all the 42 participating laboratories by Courier service to avoid any transport delay. A copy of the instructions for carrying out the analyses is in Annexure II.

3.2 Reference value

The parameter concentrations in each of the samples were determined in three different ways:

- by the recommended analytical procedure in the CPCB laboratory
- from the theoretical considerations, assuming that the solutions were made correctly and the purity of the chemicals used was as displayed on the bottle labels
- from the combined results of analyses of the participating laboratories

Table 1 compares the concentration of the parameters in the test samples estimated by the three procedures. It is seen that there is a close agreement among the values calculated by the three methods. Therefore, the reference mean, calculated from the combined results of analysis of the participating laboratories, was taken as the reference value.

Table 1: Determination of reference value for concentration of various parameters

S. No.	Parameter	Sample-A			Sample-B		
		Reference mean	CPCB analysis	Theoretical value	Reference mean	CPCB analysis	Theoretical value
1	Conductivity	415	416	---	257	260	---
2	TDS	253	250	---	160	163	---
3	Total Hardness	80.5	79.0	---	47.8	48.0	---
4	Sodium	41.1	42.0	42.0	24.7	24.6	26.7
5	Fluoride	1.74	1.78	1.80	1.41	1.42	1.40
6	Sulphate	38.7	39.0	38.4	19.1	20.0	19.2
7	Nitrate-N	2.58	2.93	3.00	1.82	1.95	2.0
8	Phosphate-P	0.291	0.296	0.300	0.192	0.195	0.2
9	Boron	2.13	2.04	2.00	1.58	1.56	1.5

Note: All the parameters are expressed in mg/l except Conductivity which is expressed in $\mu\text{mho/cm}$
 '---' Denotes that theoretical values are not provided

The procedure of estimation of the value of a parameter from the combined analysis results of the participating laboratories is illustrated for the *conductivity* measurements of samples A and B in Annexure III, and is summarised below:

1. The analytical data obtained from the laboratories for each parameter were sorted in increasing order.
2. The data were scrutinised for removal of visual (abnormal) outliers.
3. Of the remaining values, the mean, \bar{X} , and the 95 % confidence limits for the mean were obtained.
4. The values falling within 95 % confidence limits were taken for calculating the Mean and the Standard Deviation (SD_{Ref}) with n-1 degrees of freedom. The Mean is considered as the "Reference value" (X_{ref}).

3.3 Acceptable range for reported values

The acceptable limits for various parameters were arrived at using the "Youden 2 sample plot" method (Youden, 1959¹). The acceptable range for reported values is calculated from the results of the reported values and the reference value, as follows:

The standard deviation (SD_{Ref}) value obtained from the filtered data set (step 4 above) was multiplied by the factor $\sqrt{2}$ (i.e. 1.414) to convert the 'Within Run Precision' to 'Between Day Precision'. This was done to account for the fact that the analyses were performed at different times at different locations. The resulting value is considered to be the 'Adjusted Standard Deviation' (SD_{adj}). The acceptable range was then calculated as $X_{\text{Ref}} \pm 3SD_{\text{adj}}$. The procedure is illustrated for the TDS results in Annex III.

A laboratory was considered to quality for the analysis of a parameter if both the reported analyses results for the two samples A and B were in the acceptable ranges.

1 Youden, W.J., (1959). Graphical diagnosis of inter-laboratory test results, *Industr. Qual. Control*. Vol 15, no. 11, p. 24-28.

4 Findings and discussions

4.1 Findings of AQC-2 exercise

Table 2 gives the reference values and the acceptable ranges for the parameters covered under the exercise. These were calculated according to the procedure described in Sections 3.2 and 3.3.

Table 2: Reference values and acceptable ranges for results of analyses

Parameter	Sample-A		Sample-B	
	Reference mean	Acceptable range	Reference mean	Acceptable range
Conductivity	415	395-435	257	236-278
TDS	253	228-277	160	144-177
Total Hardness	80.5	76.2-84.8	47.8	40.0-55.6
Sodium	41.1	37.3-44.8	24.7	22.2-27.2
Fluoride	1.74	1.54-1.94	1.41	1.32-1.51
Sulphate	38.7	35.8-41.6	19.1	16.2-22.1
Nitrate-N	2.58	2.2-3.0	1.82	1.3-2.3
Phosphate-P	0.291	0.23-0.36	0.192	0.15-0.24
Boron	2.13	1.76-2.5	1.58	1.08-2.07

Note: All the parameters are expressed in mg/l except Conductivity, which is expressed in $\mu\text{mho/cm}$

Based on these values, the performance of the laboratories was evaluated. The reported analysis results for the two samples for each parameter were compared with the respective acceptable ranges. The findings are summarised in Table 3, and are shown in the Youden 2-sample plots (Figures 1-9). Figure 11 shows the number of correctly reported parameters per laboratory code.

The following observations can be made regarding the performance of the laboratories:

- Out of the 42 laboratories that participated in the AQC exercise, 36 laboratories have reported results (i.e. 6 laboratories did not send the results).
- Out of 36 laboratories responding, only 15 laboratories could provide results for all the 9 parameters.
- Out of 36 laboratories responding, the decreasing order of response for various parameters is as follows: Total Hardness, 100 % (i.e. all 36 laboratories responded for Total Hardness); Conductivity, 100%; Sodium, 97%; Total Dissolved Solids, 94%; Sulphate, 89%; Fluoride, 86%; Nitrate - N; 83%; Phosphate-P, 58%; Boron, 52% (see Fig. 10).
- It is not clear why there is such low response rate for the parameters like Phosphate-P (58%) and Boron (52%). It is expected that by this stage all the laboratories under Hydrology Project should have the necessary instruments, chemicals, and standards for analysis of all the parameters in the AQC exercise. The analytical procedures have been documented by the HP consultants in the 'Guidelines on Standard Analytical Procedures' and training modules for the analyses have also been prepared. These documents have all been distributed to the laboratories. The laboratories which are still unable to make the analyses should contact the HP consultants for advice and assistance.
- The percentage of laboratories which reported the stated parameter within acceptable limits is given in Table 4, for both AQC-2 and AQC-1 exercises.

Laboratory Code	Cond	TDS	TH	Na	F	SO4	NO3-N	PO4-P	B	Total Reported	Within Limit
430	OK	OK	X	OK	NR	NR	NR	NR	NR	4	3
431	X	X	OK	OK	NR	NR	NR	NR	NR	4	2
432	OK	OK	OK	X	OK	X	OK	OK	OK	9	7
433	OK	OK	OK	X	OK	OK	OK	OK	OK	9	8
434	OK	X	X	X	OK	OK	X	OK	NR	8	4
435	NR	NR	NR	NR	NR	NR	NR	NR	NR	0	0
436	OK	OK	X	X	X	OK	OK	OK	NR	8	5
437	NR	NR	NR	NR	NR	NR	NR	NR	NR	0	0
438	X	X	X	X	NR	X	X	NR	NR	6	0
439	X	OK	X	X	NR	NR	NR	NR	NR	4	1
440	X	X	OK	X	X	X	X	X	X	9	1
441	X	OK	X	X	OK	X	X	X	X	9	2
442	X	X	OK	X	X	X	X	X	X	9	1
Labs reporting	36	34	36	35	31	32	30	21	19	274	128
No. Acceptable	20	15	14	15	12	16	17	12	7		
% success of reporting	55.6	44.1	38.9	42.9	38.7	50.0	56.7	57.1	36.8		
Ranking (of reporting labs)	3	5	7	6	8	4	2	1	9		

OK Within acceptable range

X Not in acceptable range

NR Not reporting

Note: The eligibility of a particular parameter is arrived based on the values found within acceptable range in both samples A & B.

Table 3: Evaluation of AQC analysis results in comparison with the reference values

Table 4: Percentage of laboratories found within acceptable limits: AQC2 & AQC1

S. No.	Parameters	% of labs within limit AQC-2 (April 2000)	% of labs within limit AQC-1 (Dec. 1998)
1	Phosphate-P	57	38
2	Nitrate-N	57	48
3	Conductivity	56	54
4	Sulphate	50	50
5	TDS	44	43
6	Sodium	43	50
7	Total Hardness	39	52
8	Fluoride	39	32
9	Boron	37	63
Overall performance		46.7	47.2

- The overall performance of the laboratories was below expectation. Only about 50-60 % of the laboratories could perform routine tests such as conductivity, sulphate, NO₃-N and PO₄-P. For other parameters like sodium, Total Dissolved Solids, Total Hardness, fluoride and boron the laboratory performance was even lower (< 50 % in performance). The overall performance of all the parameters was found as 46.7 %.
- Out of the 36 laboratories that reported, only one laboratory could analyse all 9 parameters within acceptable limits. At the other extreme, 5 laboratories identified only 1 parameter correctly, while 4 laboratories did not qualify for even a single parameter.
- Several laboratories have reported values for Nitrate which are ~5 times higher than the reference value. It may be that these laboratories are calculating and/or reporting their results as NO₃ (mg/L) instead of NO₃-N (mgN/L), as requested.
As a conversion: NO₃ (mg/L) x .226 = NO₃-N (mgN/L), where 0.226 = 14/62.

An overall view of the performance of laboratories for each parameter can be obtained from Youden 2-sample plots. Figures 1 to 9 give the plots for the 9 parameters covered under this exercise. For each parameter, the plot shows the value for Sample A against that for sample B reported by a laboratory. Thus, there is one data point for each laboratory. The plots include all reported values, including those removed in the data analysis as outliers.

The acceptable limits for the two samples are also drawn on the plot as two parallel horizontal lines for the samples values plotted on the Y-axis, and two parallel vertical lines for the sample values plotted on the X-axis.

The centre of the rectangular block created by the two sets of parallel lines is the reference value for the parameter. Results close to this point are considered to represent a high degree of accuracy.

The figure can be divided into 4 quadrants by drawing a vertical and a horizontal line through the reference value. If only random error influence the determinations, the points would be expected to be randomly distributed in all the four quadrants. This is rarely seen. The points tend to concentrate in the first (++) or the third (--) quadrant, indicating that the laboratories tend to get either high values or low values, for both samples. This points to the dominant role of systematic error. If a point lies on a line of unit slope passing through the reference value, then the determination has only systematic error.

Though the identity of laboratories is not revealed in the plots, each laboratory can easily recognise its own result. It would be benefiting here to identify the **Geochemical laboratory, PWD Trichi, Tamil Nadu (formerly Thanjavur)**, the only laboratory which reported correct values for all the nine parameters in both the 'inter-laboratory AQC' exercises.

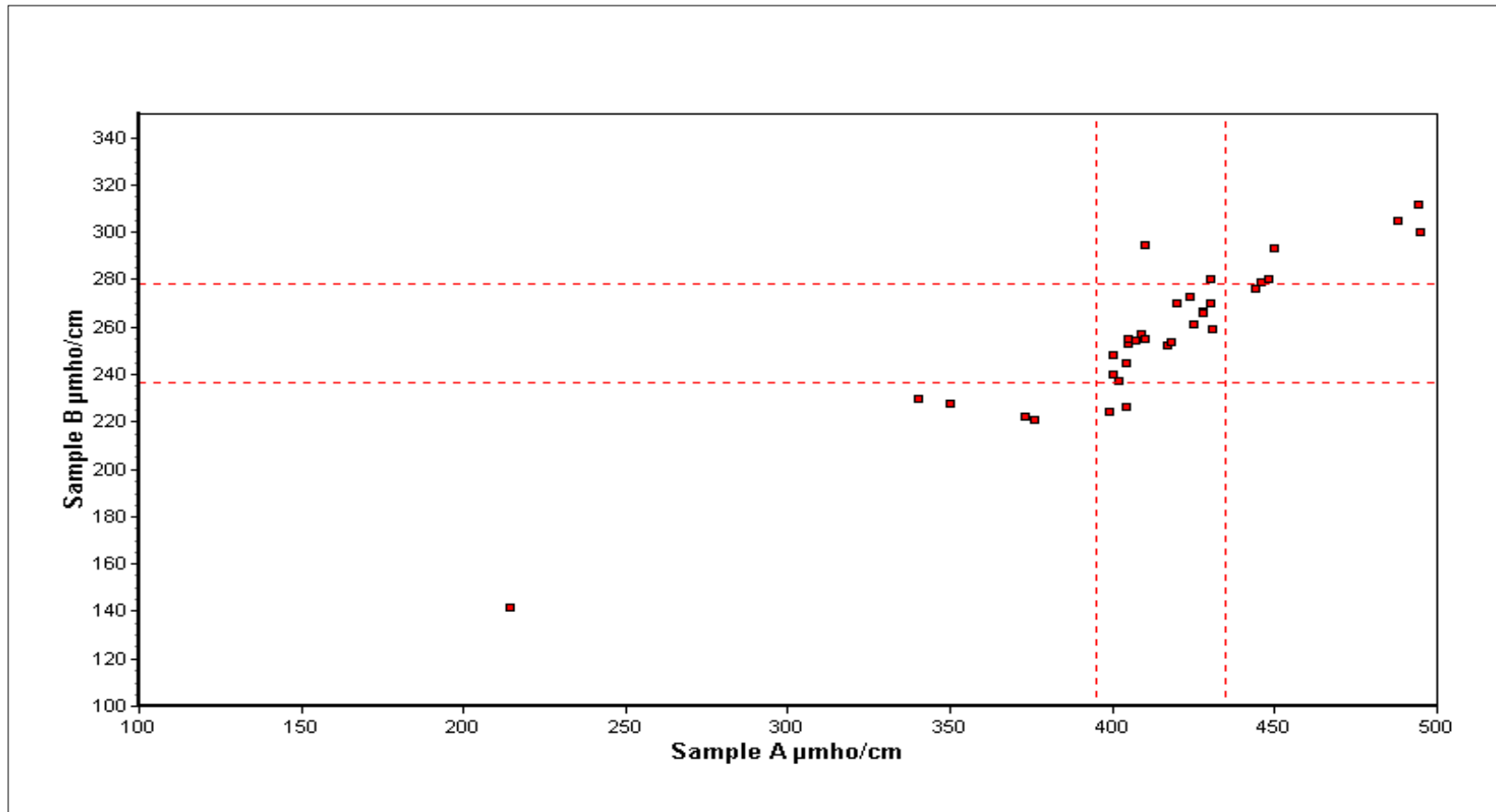


Figure 1: Performance of laboratories for conductivity – Youden 2-sample plot

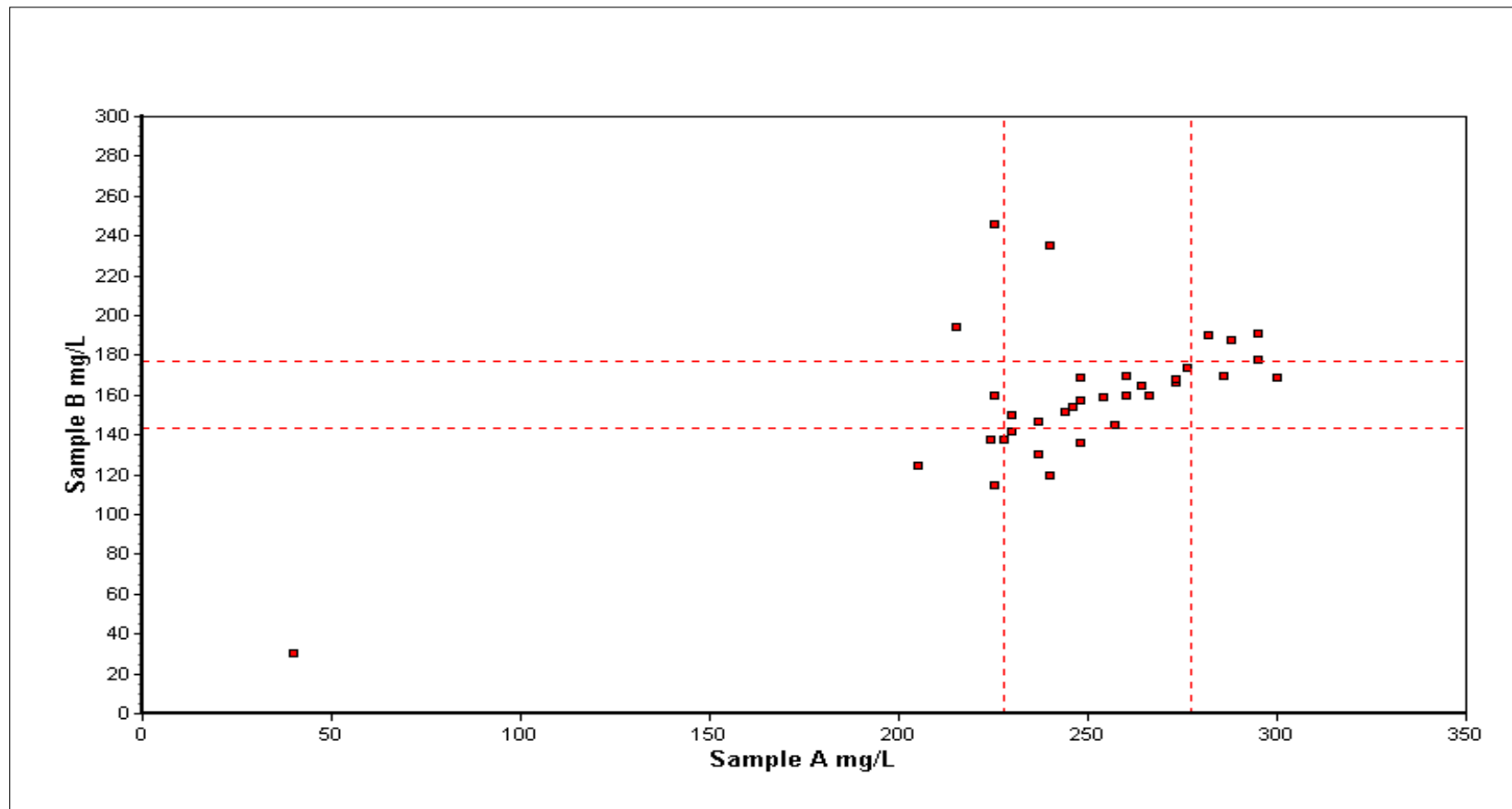


Figure 2: Performance of laboratories for Total Dissolved Solids– Youden 2-sample plot

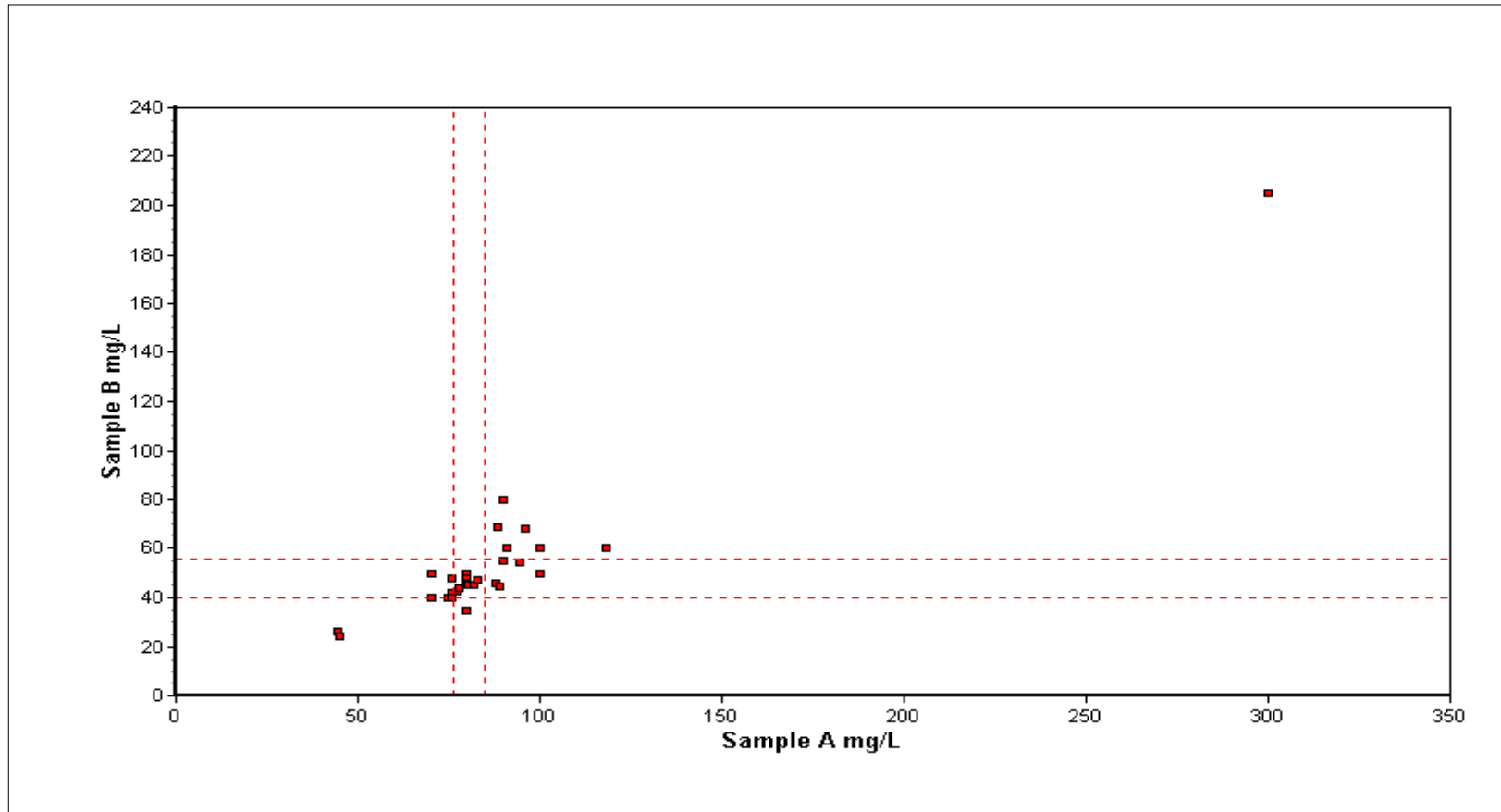


Figure 3: Performance of laboratories for Total Hardness – Youden 2-sample plot

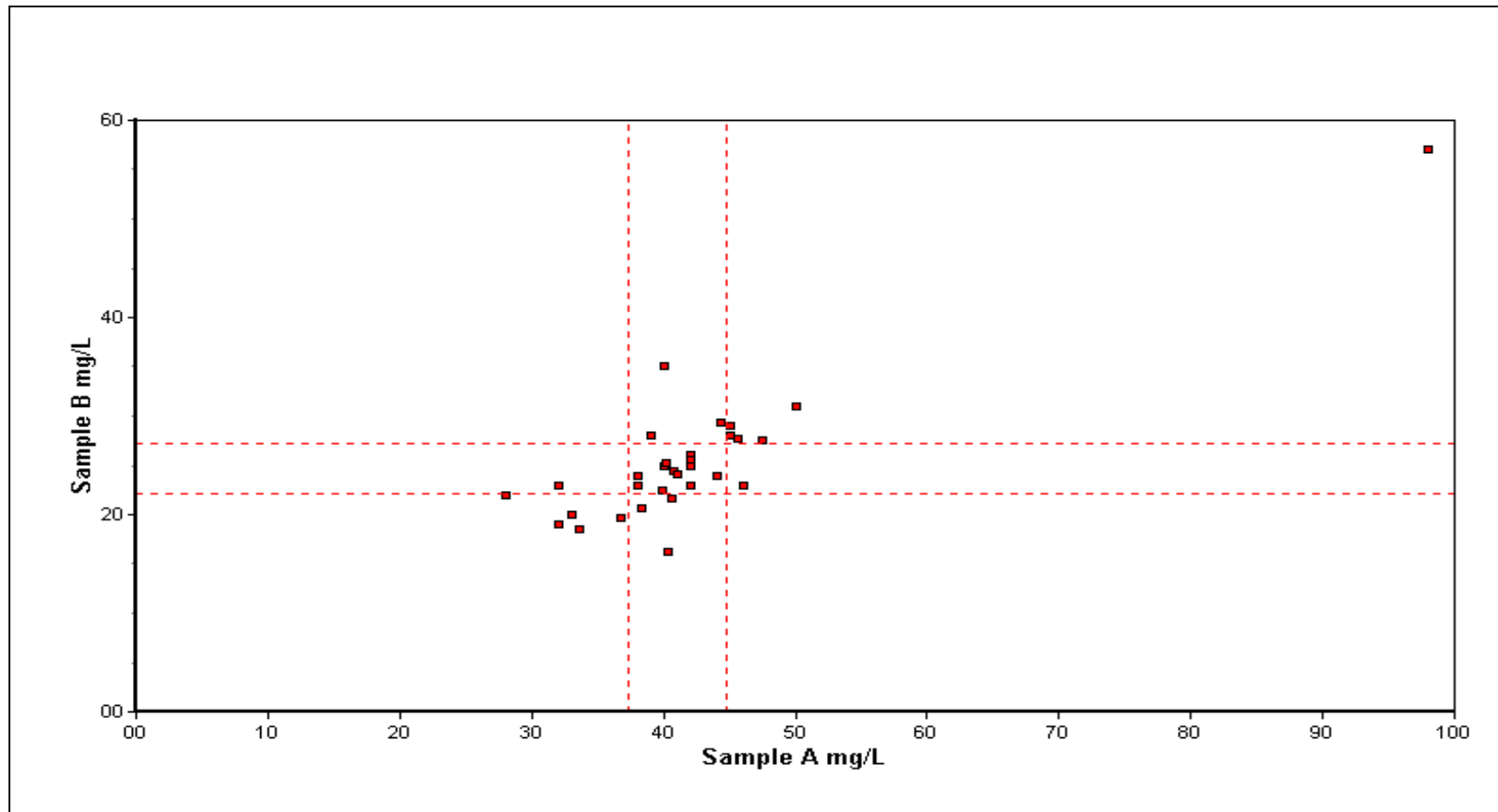


Figure 4: Performance of laboratories for Sodium – Youden 2-sample plot

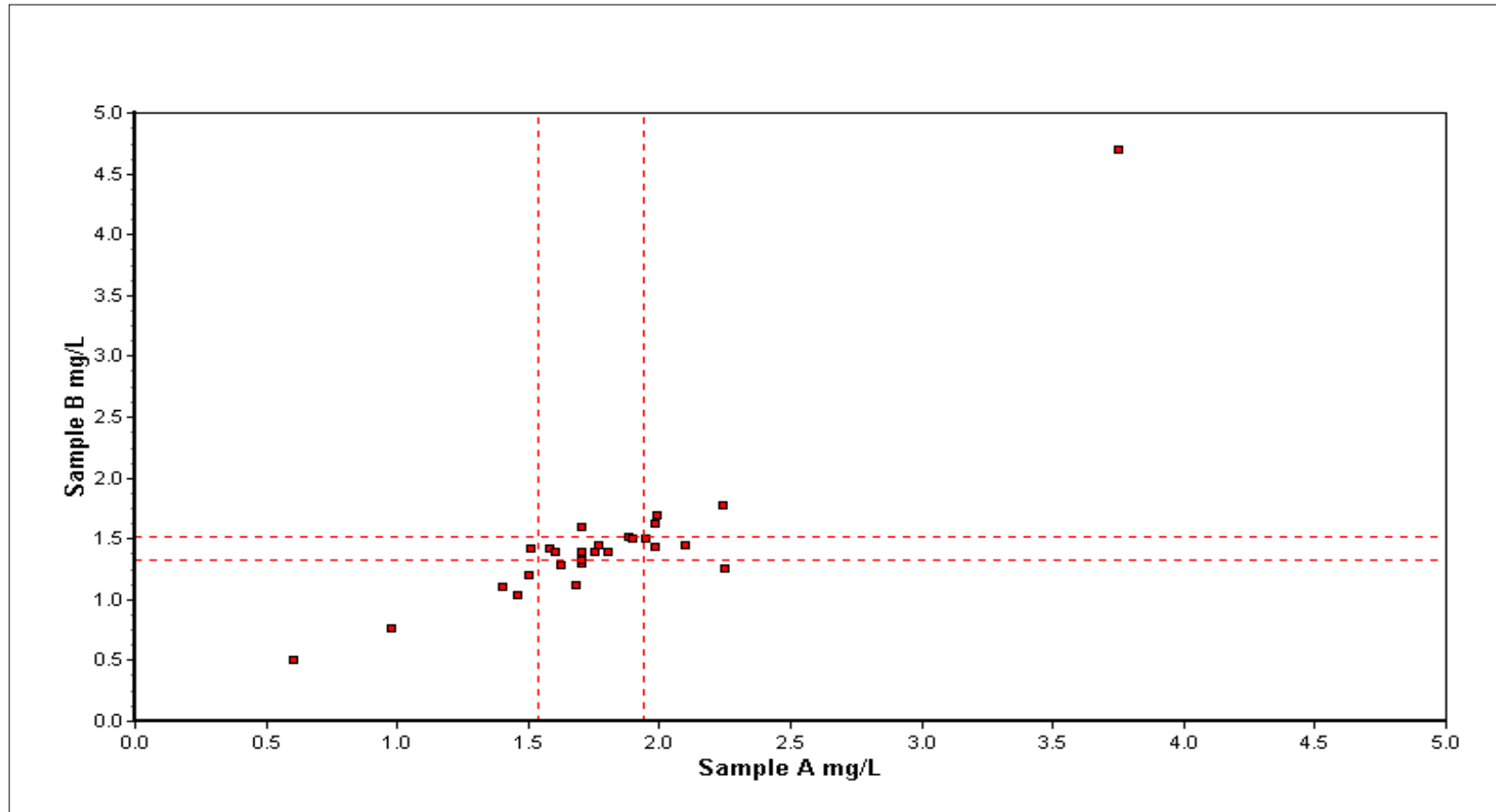


Figure 5: Performance of laboratories for Fluoride – Youden 2-sample plot

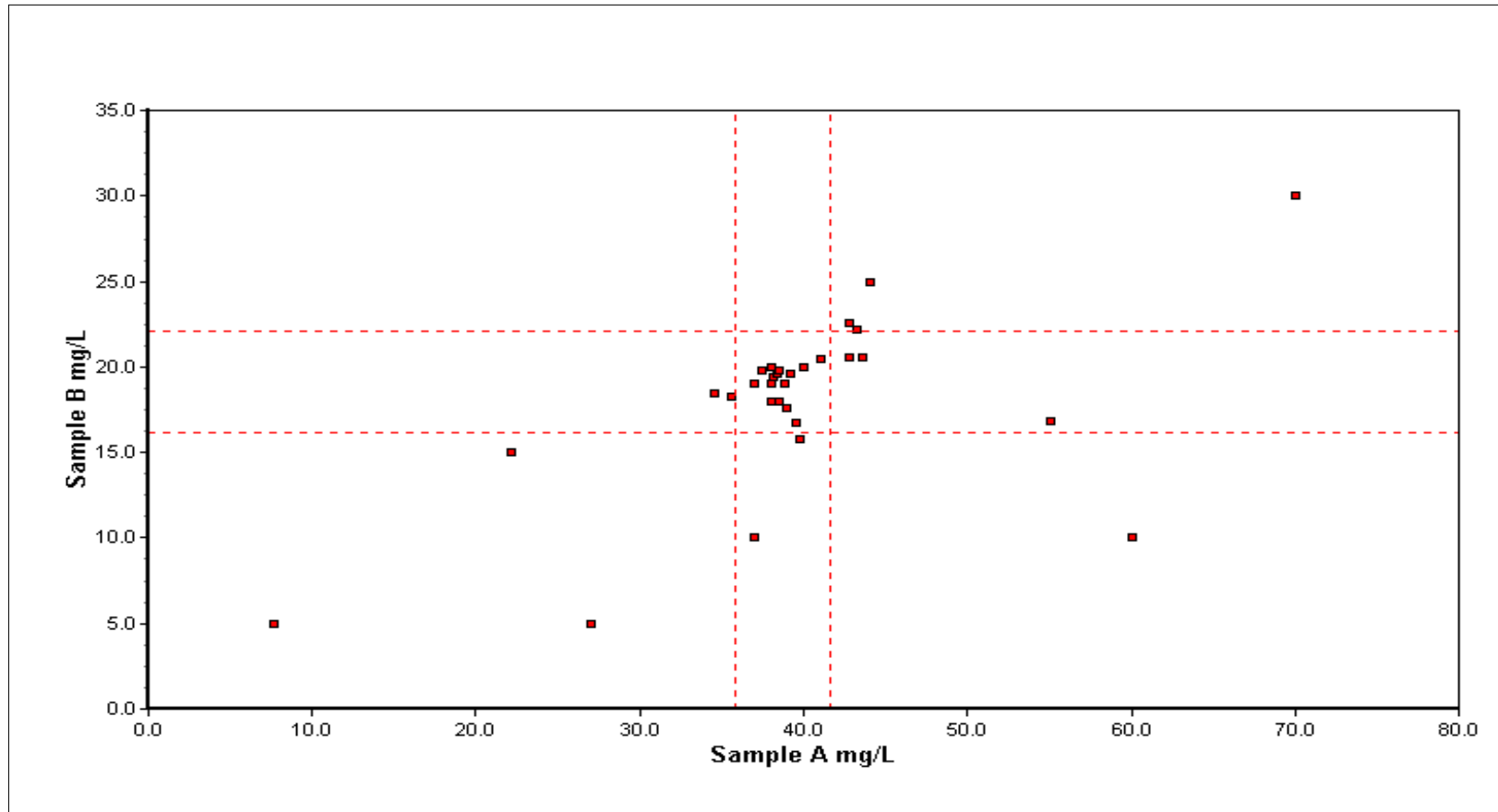


Figure 6: Performance of laboratories for Sulphate – Youden 2-sample plot

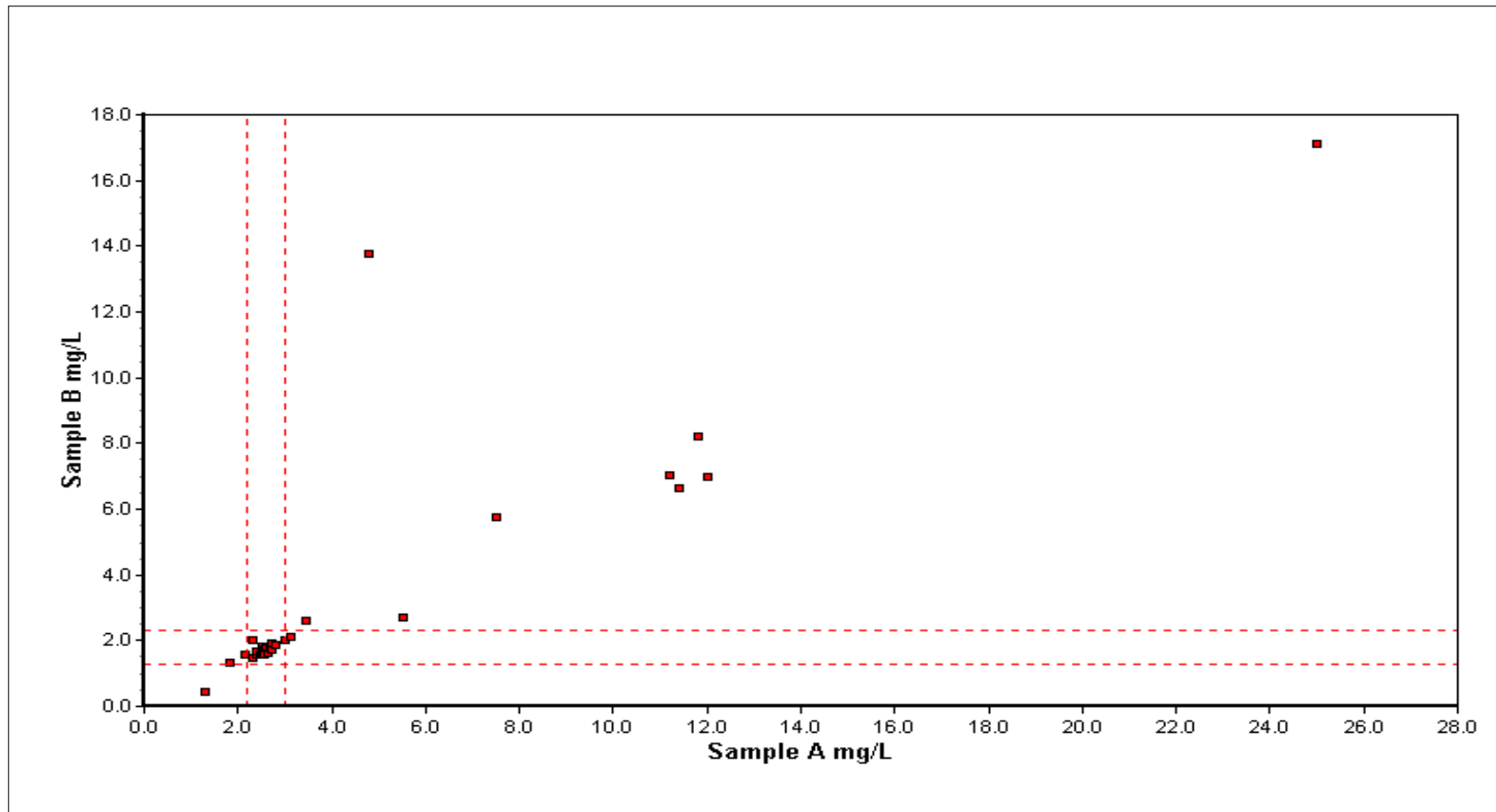


Figure 7: Performance of laboratories for Nitrate – Youden 2-sample plot

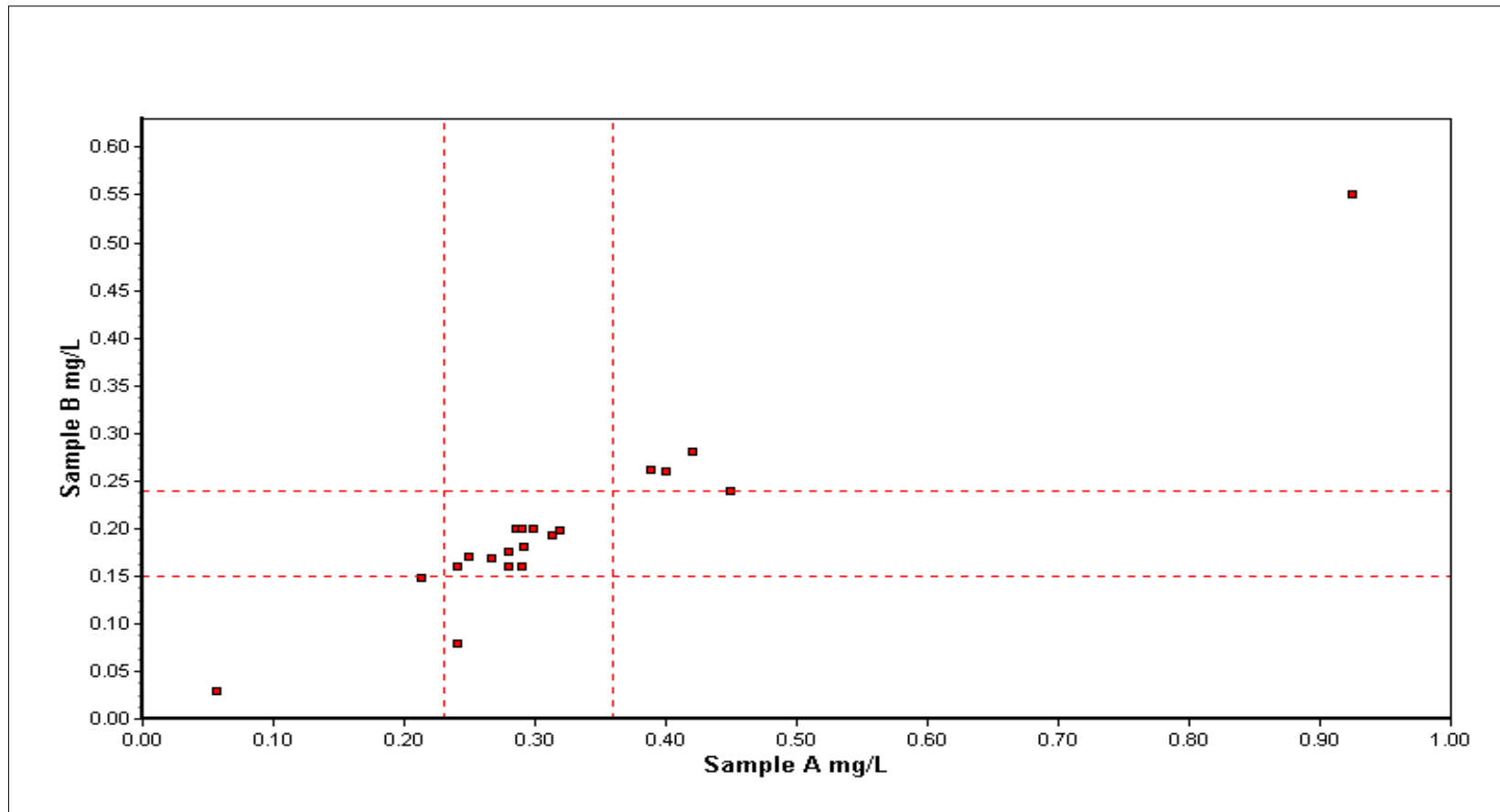


Figure 8: Performance of laboratories for Phosphate – Youden 2-sample plot

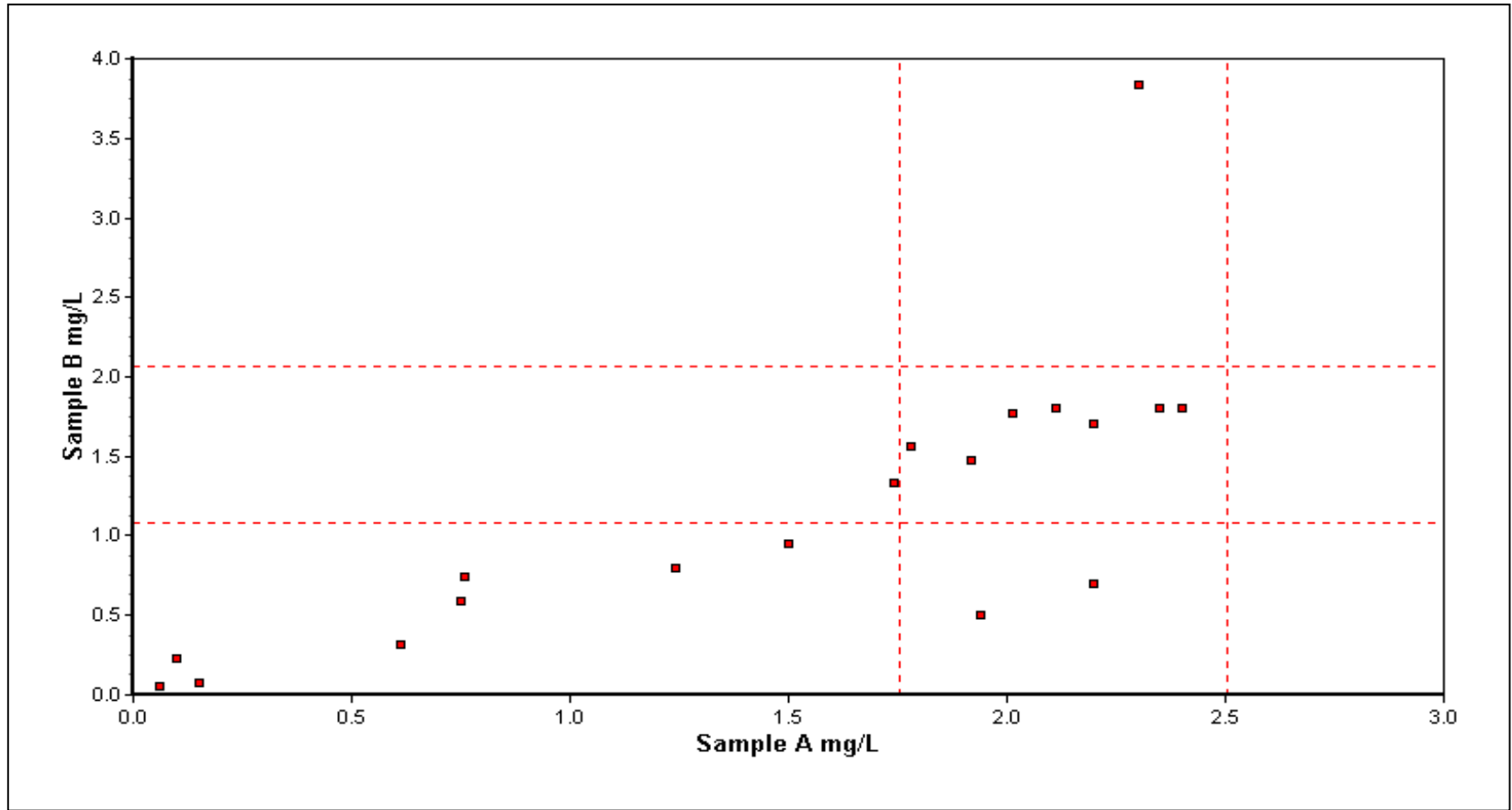


Figure 9: Performance of laboratories for Boron – Youden 2-sample plot

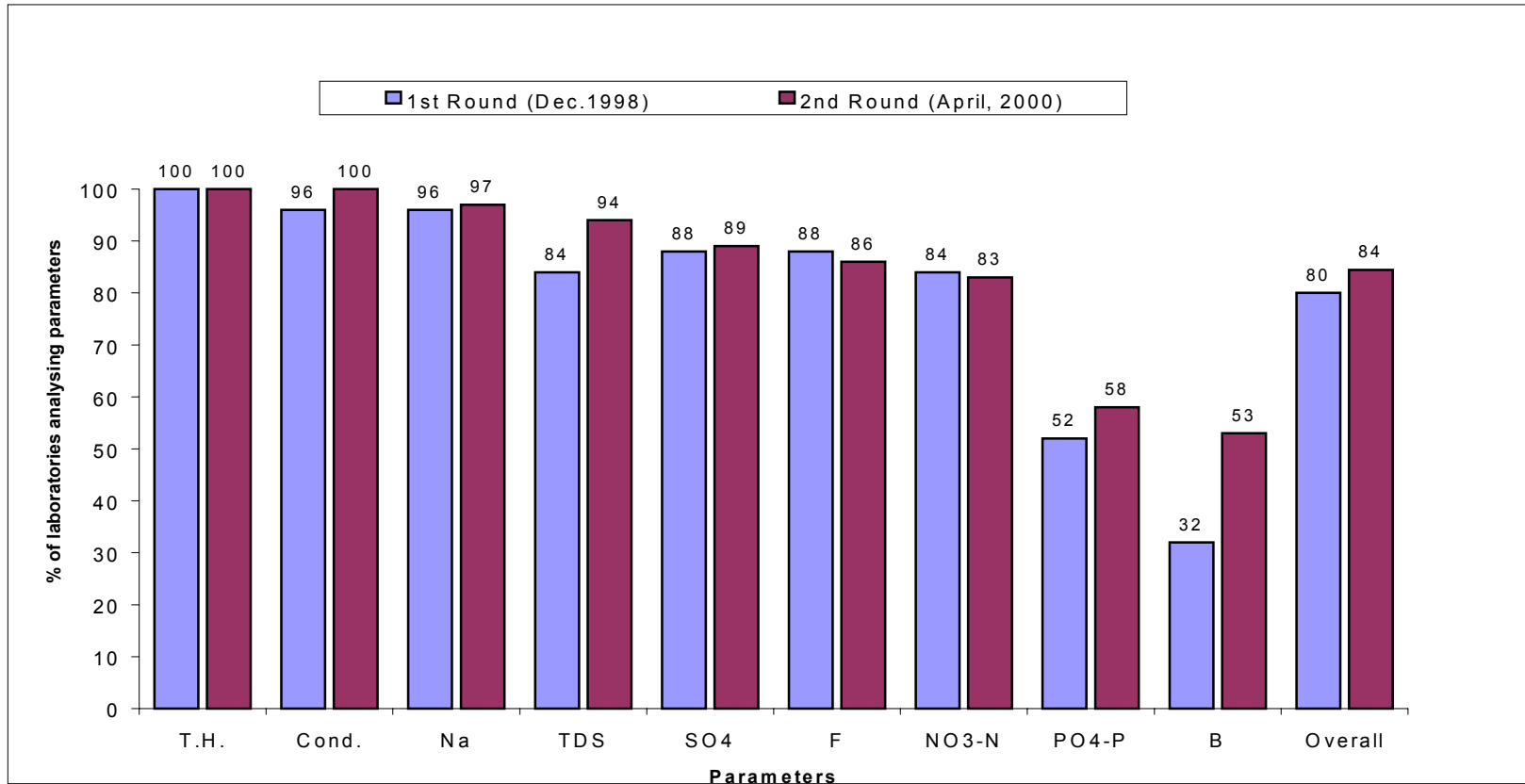


Figure 10: Comparison between AQC-1 and AQC-2 regarding % of laboratories analysing

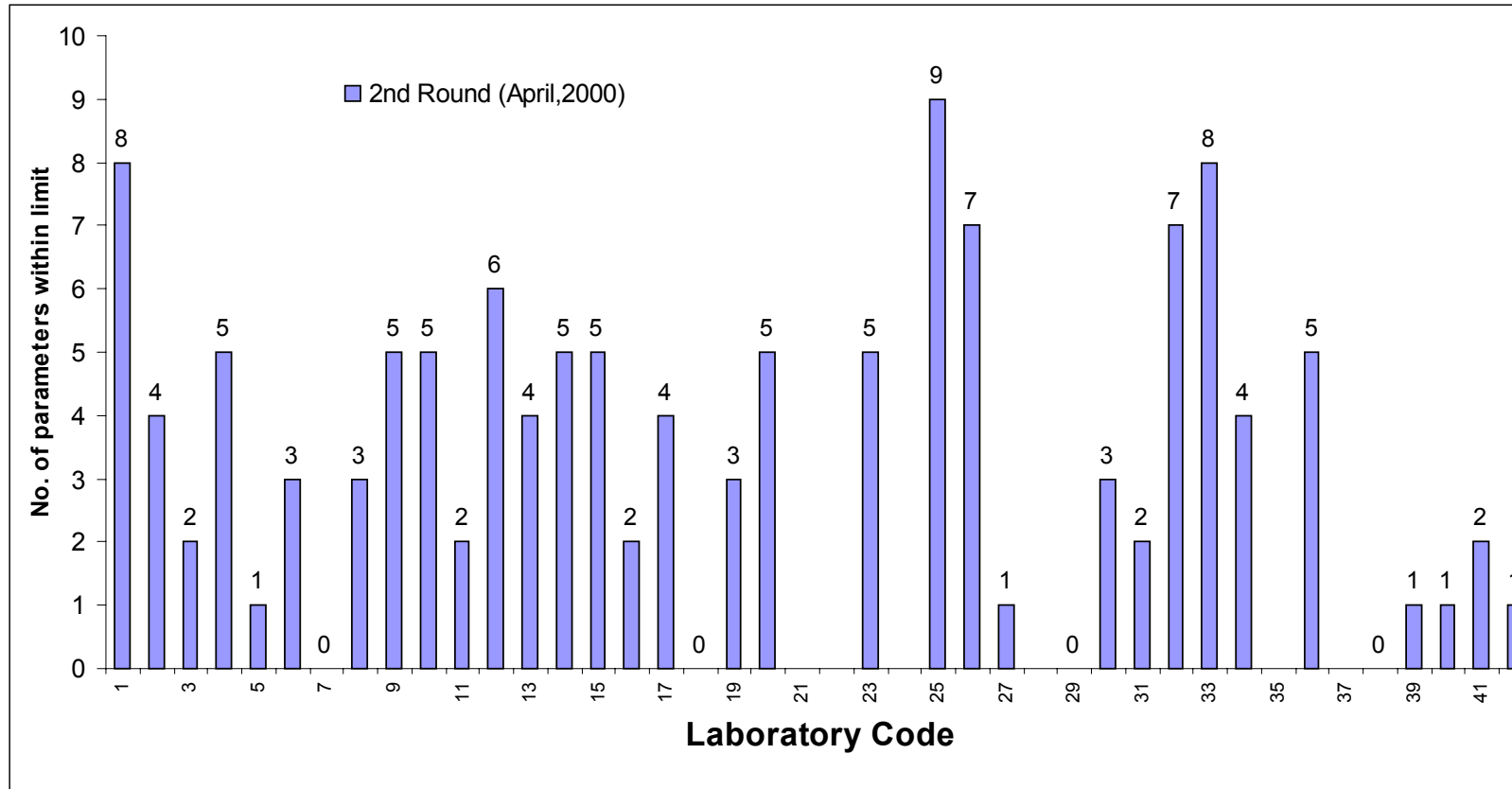


Figure 11: Number of parameters within limit for each laboratory

Note: Lab code '1' = 401, '2' = 402, etc.

4.2 Comparison of AQC-1 and AQC-2 laboratory performance

A comparative analysis on the performance between the 1st and the 2nd round of inter-laboratory AQC exercises has been made and the findings are summarised below:

- The number of laboratories that participated in AQC-2 (April 2000) increased to 42 as compared to 25 that participated in AQC-1 (December 1998). However, 6 laboratories participating in AQC-2 did not send in any result.
- The response, in terms of percent of laboratories reporting various parameters was somewhat better for AQC-2 than AQC-1. The response for the parameters, Total Hardness, Conductivity, Sodium, Sulphate, fluoride, TDS and Nitrate-N were almost similar in both exercises with more than 80% response. For Phosphate-P and Boron, the response in the AQC-2 was only 58% and 53% respectively, but this was higher than AQC-1 (see Figure 10).
- There was no improvement in laboratory performance, measured as percent laboratories within limits, between the first and the second AQC exercise (see Figure 12).

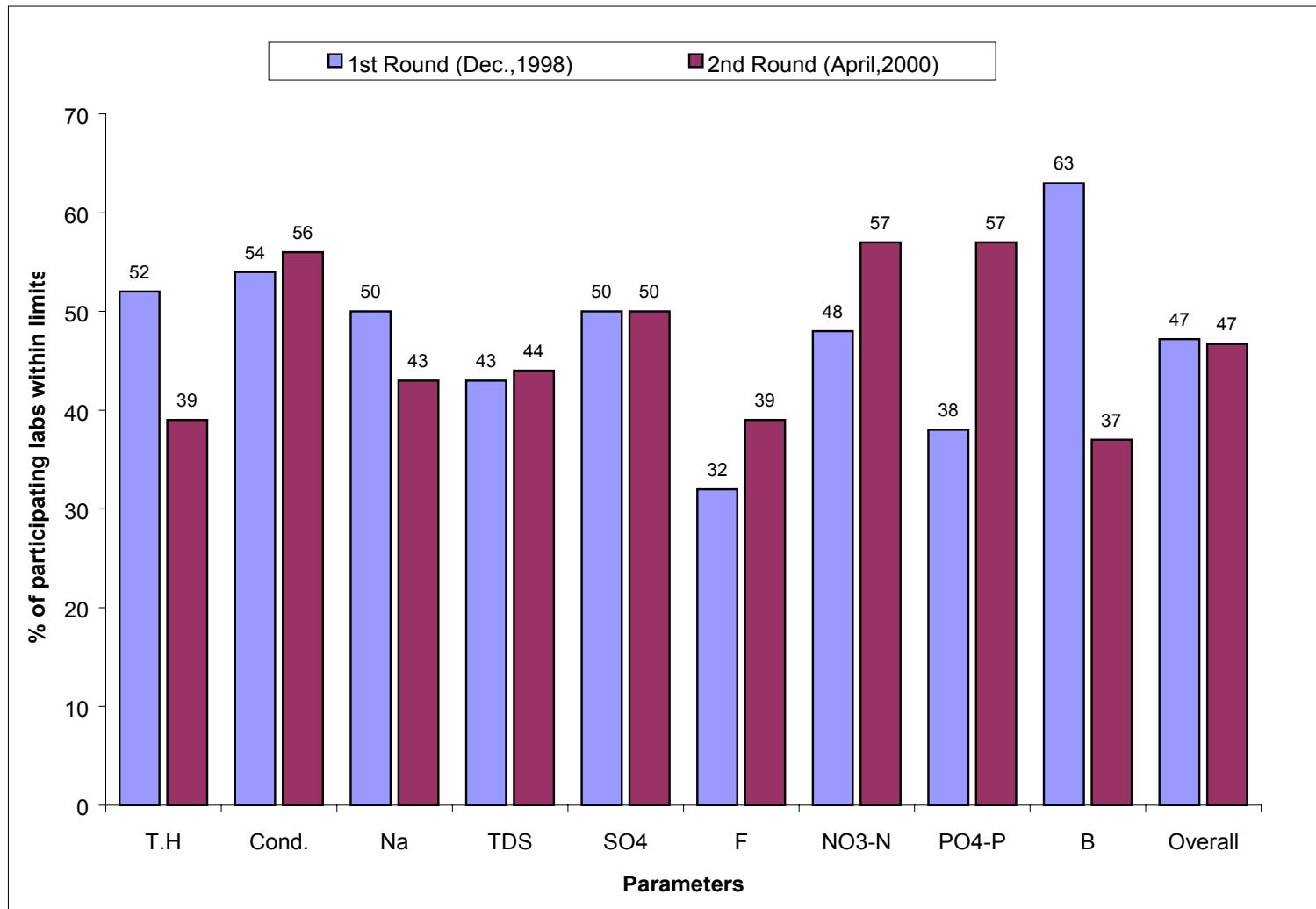


Figure 12: Percentage of laboratories reporting with in acceptable limits

5 Conclusions and recommendations

5.1 Conclusions

- The overall performance of the 42 laboratories participating in the AQC-2 exercise was poor, with only 46.7% of reported parameters being within the acceptable range. Only one laboratory could analyse all 9 parameters within acceptable limits. At the other extreme, 5 laboratories identified only 1 parameter correctly, while 4 laboratories did not qualify for even a single parameter.
- The overall performance of the AQC-2 exercise reveals that many laboratories could not report correct results for many commonly measured water quality parameters. Specifically, many laboratories had difficulty in correctly analysing sodium, Total Dissolved Solids, Total Hardness, fluoride and boron (<45% of laboratories reporting the result were within acceptable range).
- There was fairly low response in the analysis of some parameters, especially phosphate and boron (50 – 60%). The reasons for this are not clear, since all laboratories should have the necessary analytical equipment and chemicals, and have received the 'Guidelines on Standard Analytical Procedures' (HP, 1999).
- Some of the errors in the reported nitrate concentrations may be caused by laboratories reporting results as NO₃ (mg/L) instead of NO₃-N (mgN/L), as requested.
- The results of AQC-2 exercise did not show an improvement compared to results of AQC-1 (held in December 1998), which had 47.2% performance.
- There is a need for laboratories to improve the quality of their analytical procedures so that meaningful data are generated in the laboratories.

5.2 Recommendations

- Since overall performance in AQC-2 has not shown improvement compared to the AQC-1, it is essential to identify the problems affecting each laboratory individually and strategies are to be evolved for improvement. Laboratories which have not qualified for a parameter should give much attention for rectifying problems associated with the concerned parameter and should discuss issues with the HP consultants where there are uncertainties.
- Internal AQC system with Shewart charts is to be introduced in all the laboratories on a regular basis, if not already introduced. Procedures for Quality Assurance and 'Within-laboratory' AQC are given in the Water Quality Training Module number 49.
- In many cases, improvement in performance of laboratories can be brought about by selection of better grade chemicals, glassware, and distilled water. Analytical grade reagents (e.g. AR, Analar, or GR) should be used for preparing all primary standards. All the laboratories should have good distilled water generation facility to have better quality and sufficient quantity of distilled water supply.
- All laboratories should follow standard uniform analytical methods which are described in 'Guidelines for Standard Analytical Procedures' (HP, 1999) which is available at all the laboratories. This will prevent unnecessary errors which may be caused in the calculation or reporting of results, as is suspected for some of the reported errors in case of nitrate.
- It is utmost necessary to calibrate and standardise the instruments periodically to generate good analytical results. Different instruments have different requirements.
- It is suggested to have continuous and regular participation of AQC exercise for the participating laboratories in order to improve the analytical ability.

Composition of standard samples

**CENTRAL POLLUTION CONTROL BOARD-DELHI-32
LABORATORY DIVISION-WATER LABORATORY
ANALYTICAL QUALITY CONTROL, (AQC/WATER) EXERCISE – APRIL, 2000**

FOR THE

LABORATORIES OF SURFACE AND GROUND WATER DEPARTMENTS

OF

**CENTRAL AND STATE GOVERNMENT UNDER
“HYDROLOGY PROJECT”**

INGREDIENT OF SOLUTION, Hydrology Project, April, 2000

S.No.	Name of chemical	Weight in gm.	Final volume	Concentration
1	MAGNESIUM SULPHATE (MgSO ₄ .7H ₂ O)	16.400	2 litres	800 ppm Mg 3200 ppm SO ₄
2	CALCIUM CHLORIDE (CaCl ₂ .2H ₂ O)	14.700	2 litres	2000 ppm Ca 3500 ppm Cl
3	SODIUM FLUORIDE (NaF)	2.210	1 litre	1000 ppm F
4	POTASSIUM NITRATE (KNO ₃)	7.214	1 litre	1000 ppm NO ₃ -N
5	BORIC ACID (H ₃ BO ₃)	5.716	1 litre	1000 ppm Boron
6	SODIUM CHLORIDE (NaCl)	12.717	1 litre	5000 ppm Na
7	POTASSIUM DIHYDROGEN PHOSPHATE (KH ₂ PO ₄)	0.439	1 litre	100 ppm PO ₄ -P

PREPARATION OF SAMPLE – A

600 ml MgSO₄.7H₂O + 375 ml CaCl₂.2H₂O + 90 ml NaF + 150 ml KNO₃ + 100 ml H₃BO₃ + 150 ml KH₂PO₄ + 400 ml NaCl -----> Final Vol. 50 ltrs.

PREPARATION OF SAMPLE – B

300 ml MgSO₄.7H₂O + 250 ml CaCl₂.2H₂O + 70 ml NaF + 100 ml KNO₃ + 75 ml H₃BO₃ + 100 ml KH₂PO₄ + 250 ml NaCl -----> Final Vol. 50 ltrs.

Communication with the despatch of samples

**CENTRAL POLLUTION CONTROL BOARD-DELHI 32
LABORATORY DIVISION – WATER LABORATORY
ANALYTICAL QUALITY CONTROL, (AQC/WATER) EXERCISE – April 2000
FOR THE
LABORATORIES OF SURFACE AND GROUND WATER DEPARTMENTS
OF
CENTRAL AND STATE GOVERNMENT UNDER
“HYDROLOGY PROJECT”**

GENERAL INSTRUCTIONS

Note: Please read the following instructions carefully before starting analysis of samples

Two nos. of synthetic water samples (A & B) of one lit. each labelled with lab code are provided for analysing Conductivity, Total solids, Total Hardness, Sodium, Fluoride, Sulphate, Nitrate-N, Phosphate-P and Boron.

Both labelled liquid samples (A & B) are to be analysed separately for all 9 parameters as shown below.

S.No.	Parameter	Unit
01	Conductivity at 25°C	μ mhos/cm
02	Total Solids	mg/l
03	Total hardness as CaCO ₃	mg/l
04	Sodium	mg/l
05	Fluoride as F	mg/l
06	Sulphate as SO ₄	mg/l
07	Nitrate – N	mg/l
08	Phosphate – P	mg/l
09	Boron	mg/l

Note: Choose appropriate sample volume for each parameter for single run so that analysis can be done within the provided sample volume.

ANALYTICAL METHODS:

1. You may choose any relevant method being followed in your laboratory for various parameters. However, the method is to be mentioned into the data format.
2. In case of colourometric method the standard graph and the factor used for calculation for ample analysis is to be submitted along with the data sheet.
3. Brief outline of the procedures for each analytical parameter is to be provided as annexure along with the data sheets.

Please note the following points:

- All the samples are to be analysed most preferably during 24th April to 5th May 2000 for better comparison purpose of data obtained from various laboratories.
- Report the analysis result in the enclosed Data format sheet only. Kindly avoid using separate typed data sheet.

- Be sure that Lab code & sample code numbers are mentioned in the Data format sheet while sending the report.
- Be sure that all the units of various parameters are properly taken care while reporting data.
- Analysis report should be sent directly to the following address positively latest by 15th May 2000, without fail.

Dr. S.D. Makhijani
Additional Director (Labs)
Central Pollution Control Board
'Parivesh Bhawan'
East Arjun Nagar
NEW DELHI – 110 052

Fax No. (011) 222 0844

**CENTRAL POLLUTION CONTROL BOARD, DELHI-32
LABORATORY DIVISION – WATER LABORATORY**

II AQC/WATER	APRIL, 2000
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LAB CODE	
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**II ANALYTICAL QUALITY CONTROL (AQC/WATER) EXERCISE – APRIL, 2000
FOR THE SURFACE & GROUND WATER LABORATORIES OF CENTRAL AND STATE
DEPARTMENTS UNDER “HYDROLOGY PROJECT”**

01	Name of the organisation	
02	Address of the laboratory with PIN code, phone and fax	PIN
		Phone Fax
03	Sample analysed by: (Name & Designation)	1 2 3 4
04	Date of receipt of sample	

RESULTS

S. No.	Parameter	Sample Code		Method Adopted	Instrument used	Calibration Graph attached (yes/no)@	Date of analysis
		A	B				
01	Conductivity at 25° C (µmhos/cm)						
02	Total Dissolved Solids (mg/l)						
03	Total Hardness (mg/l)						
04	Sodium (mg/l)						
05	Fluoride (mg/l)						
06	Sulphate (mg/l)						
07	Nitrate-N (mg/l)						
08	Phosphate-P (mg/l)						
09	Boron (mg/l)						

@ a copy of the standard Calibration graph, where ever applicable, is to be attached in Annexure.

Dated

Signature of Lab Incharge

Estimation of reference value and acceptable range for TDS for samples A and B

	TDS_A			TDS_B		
	All Data	- Outliers	95%_CI	All Data	- Outliers	95%_CI
	40			30		
	205	205		115		
	215	215		120		
	224	224		125	125	
	225	225		130	130	
	225	225		136	136	
	225	225		137.64	137.64	
	227.53	227.53		138	138	
	230	230		142	142	
	230	230		145	145	
	237	237		147	147	
	237	237		150	150	
	240	240		152	152	
	240	240		154	154	154
	246	246	246	157	157	157
	248	248	248	158.72	158.72	158.72
	248	248	248	160	160	160
	248	248	248	160	160	160
	254	254	254	160	160	160
	257	257	257	165	165	165
	260	260	260	166	166	166
	260	260	260	168	168	
	264	264		169	169	
	266	266		169	169	
	273	273		170	170	
	273	273		170	170	
	276.2	276.2		173.5	173.5	
	282	282		178	178	
	286	286		187.5	187.5	
	288	288		190	190	
	295	295		191	191	
	295	295		194	194	
	300	300		235		
				246		
No. values (N)	33	32		34	29	
Minimum	40	205		30	125	
Maximum	300	300		246	194	
Mean, X	246.1	252.5		158.5	160.1	
Ref. Mean, X_{REF}			252.63			160.09
Std Dev (SD)	44.7	25.6	5.83	36.0	18.3	3.92
X - 1.96 SD/ \sqrt{N}		243.64			153.45	
X + 1.96 SD/ \sqrt{N}		261.35			166.78	
SD _{REF}			5.83			3.92
SD _{ADJ} = $\sqrt{2}$ SD _{REF}			8.24			5.54
Lower limit = X_{REF} - 3 SD_{ADJ}			227.9			143.5
Upper limit = X_{REF} + 3 SD_{ADJ}			277.4			176.7