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Status and Future Trends of Analytical Quality Control Services

by

J.J. LaBrecque, R. Schelenz and E.P. Hardy

International Atomic Energy Agency

Report of the Consultants' Meeting on Status and Future Trends of Analytical Quality Control Services

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Vienna, 18 - 21 November 1986

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INTRODUCTION

An International Atomic Energy Agency (IAEA) Consultants' Meeting on Analytical Quality Control Services (AQCS) was held at the Vienna International Centre 18 - 21 November 1986. Participants from Austria, Denmark, France, Poland and the United States of America were in attendance as well as representatives of the IAEA (RIAL, RIRL and RILS). A listing of the participants (Appendix I) and the Agenda of the meeting (Appendix II) are attached. A previous meeting of this type was held in Vienna on 13-16 October 1981.

The establishment of Analytical Quality Control Services at IAEA took place in the early 1960's with the objective of creating a programme which could assist analytical laboratories of Member States to access and improve their analytical capabilities. Initially, the participating laboratories were primarily interested in radionuclide analyses of nuclear fuel cycle materials and environmental samples. Later on it became clear that determination of stable trace elements, especially those of biomedical and environmental significance was of growing interest to the Member States. Nuclear methods, especially neutron activation analysis, play an important role in trace element analysis and provide a considerable portion of the results used in the process of certification of the candidate reference materials. The programme expanded to include major, minor, and trace elements, stable isotopes, and organic constituents of a wide variety of materials. Currently, the IAEA AQCS programme provides services and expertise that are recognized as unique and valuable to the Member States.

Mr. A.A. Abdel-Rassoul, head of the PCI Laboratory at Seibersdorf, in his introductory remarks, summarized the broad objectives of this meeting:

- to review the present Analytical Quality Control Services (AQCS) programme components in the light of the needs of IAEA Member States for analytical reference materials and intercomparisons.

- to provide guidelines for the direction which the programme should take in the future.

- to identify the type of Analytical Quality Control Services most urgently required by the Member States (which of these are uniquely provided by the IAEA and which could be made available from other sources; which materials, if any, should be phased out and which should be introduced)

The meeting took the form of a one-day plenary session during the course of which Mr. R.M. Parr (IAEA-RILS), Mr. J.J. LaBrecque (IAEA-RIAL), Mr. S. Deron (IAEA Safeguards Analytical Laboratory) and Mr. R. Schelenz (IAEA-RIAL), the Scientific Secretary of the meeting, gave background information presentations. A wide range of topics were discussed and on the second day, these topics were delegated to two sub-groups as follows:

1. Procedures for data evaluation and certification

   1.1 Procedures for homogeneity testing
   1.2 Procedures for interlaboratory testing
   1.3 Procedures for evaluating results and certification

2. Strategies for Producing Reference Materials

   2.1 Selection of new materials and/or new analytes for future studies
   2.2 Preparation techniques for different types of materials
   2.3 Identification of services for future activities

Following the sub-group meetings, the participants had the opportunity to receive a presentation by Ms. C. Houin, representing the Commission D'Etablissement des Methodes D'Analyse (CETAMA). Ms. Houin explained that specific nuclear materials could be made available to the IAEA for distribution to laboratories interested in certified reference samples or intercomparison of isotopic uranium analyses (Appendix III). The results could be collected by AQCS and then transmitted to CETAMA for evaluation.

It was particularly noteworthy that following the April 26, 1986 accident at the Chernobyl nuclear power plant, the Chemistry Unit of the Agency's Laboratories at Seibersdorf seized the opportunity to collect large quantities of various types of environmental samples. These samples should prove to be of considerable value to radioanalytical laboratories throughout the world.

The third and fourth days were spent in reviewing the sub-group recommendations and assembling the draft document.

The Consultants review process provides an opportunity to critically review the IAEA-AQCS programme and to suggest improvements in the services offered. This process may be improved by the following:

- a briefing by the staff that includes changes resulting from the recommendations of the last Consultants' Meeting,

- a rotation of only part of the Consultants to provide continuity to the process.

The substance of this Consultants' Meeting is related in the series of recommendations which follow.

RECOMMENDATIONS

1. Selection of new materials and/or new analytes for future studies

The Consultants have reviewed the results of the questionnaire (Appendix IV) sent to users and incorporated their requests into the list of priority items provided below (Table I). Consideration was also given to the activities of other standards organizations and currently available Reference Materials[1]. Because of the Chernobyl event of 1986, emphasis should be placed on the development of environmental radionuclide samples. Other materials have not been incorporated in the new list. This should be left to the discretion of the IAEA staff.

The priorities assigned should be considered approximate. Availability of staff, materials and facilities should also be taken into consideration to determine the actual ranking of materials.

The freeze dried urine, while ranked high in term of interest among the users (see Appendix IV), presents major problems with regard to preparation, and the Consultants believe that the valuable resources of the IAEA can be more usefully directed elsewhere. This is especially true considering that certified freeze-dried urine materials are available from other standards organizations.

A critically important consideration, distinct from the current priorities is the recommendation that long term storage of irreplacable test samples (Table II) for future evaluation be provided. The panel recognizes the unique and valuable nature of many of the natural matrix materials collected during the past year. For that reason the Consultants strongly recommend the development of a freeze dryer capability and other storage facilities to keep these materials for current/future measurement needs related to the primary mission of the IAEA.

[1] Muramatsu, Y., Parr, R.M. Survey of currently available reference materials for use in connection with the determination of trace elements in biological and environmental materials, IAEA/RL/128, December 1985.

Table I.

Priority list of materials and analytes
for further intercomparison runs and reference materials

Appropr. priority	Material	Elements or nuclides referenced	Remarks
1	hay	radionuclides	~1000 Bq/kg total activity material collected in 1986
2	milk powder	radionuclides	material collected in 1986
3	lignite fly ash	trace elements	
4	spinach	trace elements	material collected in 1986
5	fertilizer	major and trace elements	further information is needed on specific material
6	milk powder	trace elements	when current stocks run low
7	wheat flour	radionuclides	from 1987 harvest
8	lake sediment	fission products and Pu	material should be taken in 1987
9	dried serum	trace elements	non-human
10	animal bone	Sr-90, Cs-137, Ra-226, Pu-239	material collected in 1986
11	soil	radionuclides incl. Pu-239	material should be taken in 1987
12	potatoes	trace elements	

Table II.

Materials collected with elevated levels of radioactivity arising from the Chernobyl nuclear power plant accident

Material	Collected in 1986	To be collected in 1987	Remarks
Milk powder	x		
Whey powder	x		
Meat beef	x		)
calf			) bones,
pork			) internal organs
mutton			)
Spinach	x		
Clover	x		
Hay	x		
Beech leaves	x		
Spruce needles	x		
Fir needles	x		
Sewage sludge	x		
Soil (from the same location as Soil-6/7)		x	
Lake Sediment (from the same location as SL2/3)		x	
Wheat flour		x	

2. Preparation techniques

Sample size:

The Consultants generally conclude that the sample size must be related to the material being evaluated and the measurement being performed. It is recognized that some samples because of their scarcity and difficulty of preparation must be supplied in small quantities. In general, however, it is recommended that, when available, samples should be distributed in 50-70 gram quantities (especially for trace element materials). The size of samples which are to be measured for radioactivity should be selected based on their activity level and use.

Particle size:

The particle size depends on the type of sample. The panel feels that the AQCS-staff is fully qualified to make this judgment.

Freeze-drying:

Freeze-drying is recommended for biological material. A facility should be acquired for handling of large quantities. This is critically important for many of the recently acquired materials uniquely important to the Agency mission.

Blending: the facilities currently available are adequate for the current Agency mission for trace element samples but not for radionuclide materials, as bigger quantities of materials are needed for this kind of sample.

Grinding: current facilities appear adequate but new technologies may suggest the appropriateness of air grinding facilities in the near future (2-4 years)

Sieving: it is suggested that automated equipment be acquired for some applications.

Radiation sterilization for biological materials: this approach should be continued in order to prevent the degradation of biological materials, especially used for trace element measurements.

3. Identification of trends for future services

The Agency through its Technical Co-operation Programme, should assist its Member States in improving the quality of their analytical work by preparing guidebooks, through expert services and training courses.

Radioactivity measurements interest is returning and should be re-emphasized as an IAEA-AQCS assistance in organizing intercomparison runs and in providing reference materials.

The increasing use of multi-element techniques (e.g. NAA, ICP, XRF) is recognized and strengthens the importance of multi-element reference materials. Speciation measurements are of interest although beyond the current scope of the Agency.

There exists an increased demand for the measurement of halogens in natural matrix materials, e.g. I, Br, F, Cl and more reference materials as well as more sensitive measurement techniques. The general trend is to the determination of lower levels of trace elements.

The Consultants are aware of the importance of the determination of organic toxic residues in environmental materials and food e.g. pesticides, organohalides. A great amount of analytical work is done in that field but there are shortcomings in the supply of reference materials and certified reference materials of that kind. The Consultants are of the opinion that, although it would be an extremely important activity to supply relevant materials, this additional workload could not be managed by the AQC group due to lack of manpower and equipment. Nevertheless competent authorities (e.g. Residues Section of IAEA/FAO Joint Division, UNIDO etc.) should be contacted to discuss the feasibility of extending AQC service appropriately in the future.

4. Cost of Reference Materials (RM's)

It is very important that reference materials can be paid for with local currencies or UNESCO coupons as many countries have difficulties in paying with US-$. The cost should be a nominal one, based on the level of service provided and not in excess of other Reference Material producers.

The programme should be considered a technical service of the Agency to the Member States and cost recovery should not be a primary criteria in establishing services.

5. Resources needed

- freeze dryer
- continuous sieving machine
- blender bigger than now available
- appropriate allocation of resources available to accomplish the tasks assigned
- the capability to "contract out" services and to obtain materials through grants, services in kind and other more flexible financial arrangements

6. Intercomarpison/Information Sheet

6.1 Homogeneity

Homogeneity tests should include several elements of different concentration levels that are representative of those elements expected to be determined in the specific materials, using a technique for which the analytical methodology is well under control. The information on the results of the the homogeneity testing should be included in the information sheet, together with the sample size, and may be expressed as sample constants (K). (Reference: ISO Guide 31-1981.)

6.2 Number of samples

- Duplicate samples of the same material should be sent, for intercomparisons, on a trial basis, for which there is a large supply of the material (e.g. hay, soil, lake sediment) with the purpose of obtaining more information on homogeneity.

- A certified material of a similar matrix should be sent, for intercomparisons, on a trial basis, for which there is a large supply of the material with the purpose of checking substantial improvement in the quality of data.

6.3 Results

- Six replicates should be requested in all cases
- Limit of detection should be requested.

6.4 Selection criteria

- The criteria developed in the IAEA over the last few years for assigning recommended values were found to be appropriate and could be refined further. Examples can be found in the following references:

- Dybczynski, R., Tugsavul, A., Suschny, O. Soil-5. A New IAEA Certified Reference Material for Trace Element Determination. Geostandards Newsletter 3 (1979) 61-87.

- Dybczynski, R. Comparison of the effectiveness of various procedures for the reflection of outlying results and assigning recommended values in interlaboratory programs involving determination of trace elements or radionuclides. Anal. Chim. Acta 117 (1980) 53-70.

- Dybczynski, R., Veglia, A., Suschny, O. Milk powder (A-11) - A new IAEA reference material for trace and other element analysis. Trace Element Analytical Chemistry in Medicine and Biology, P. Brätter, P. Schramel (Eds) N. De Gruyter, Berlin, 1980 p. 657-674.

- Pszonicki, L. Evaluation of Analytical Interlaboratory Comparisons and Certification of Reference Materials, Anal. Chim. Acta 176 (1985) 213-227.

- Pszonicki, L., Hanna, A.N., Suschny, O. Report on Intercomparison IAEA/Soil-7 of the Determination of Trace Elements in Soil, IAEA/RL/112, May 1984.

- Parr, R.M. Report No. 2. Intercomparison of Minor and Trace Elements in IAEA Animal Muscle (H-4), IAEA/RL/69, October 1980.

- Parr, R.M. IAEA Biological reference materials, in "Biological Reference Materials: Availability, Uses, and Need for Validation of Nutrient Measurement", (Proc. Symp. Philadelphia, USA, September 1983), Wolf, W.R. (Ed), Wiley, New York (1985) 45-62.

- M'Baku, S., Parr, R.M. Interlaboratory study of trace and other elements in the IAEA powdered human hair reference material, HH-1, Journal Radioanal. Chem. 69 (1982) 171-180.

- Muramatsu, Y., Parr, R.M. Survey of currently available reference materials for use in connection with the determination of trace elements in biological and environmental materials, IAEA/RL/128, December 1985.

7. Report

7.1 Data Evaluation

- The presently employed computer programmes of the Chemistry Unit and Life Science Section for intercomparison studies for chemical analysis and radionuclides data are both valuable and suitable, thus both can continue to be used. All contributors of the AQCS programmes should also apply one or both of these two methods, whichever is more convenient to them.

- The Consultants recommend that further investigation be made on the comparison between the two methods of data evaluation at different significance levels. As much of the available data as possible on materials with known input values should be used.

7.2 Graphs

- Graphs should only be used when sufficient data are available

- They should be in the format of the new Life Science graphs (see Appendix V) and should include:
  - confidence levels
  - linear scale normalized
  - arrow with data value for all points out of the frame (off scale)
  - outliers should be clearly marked as such

- Box plots for comparison of different analytical techniques could be included when sufficient data are available

7.3 Terminology

The terms "ppb" and "ppm" should no longer be used. For the recommended terminology reference can be made to : International Organization for Standardization, SI units and recommendations for the use of their multiples and of certain other units, International Standards, ISO 1000, 1981. (See also Appendix VI, "Definitions and Terms").

7.4 Recommended Values

A list of recommended values should be included - with mean/median, confidence interval and significance level. Other (not recommended) values should only be referred to in the summary table and not be included in this list.

7.5 Selection Criteria

The detailed criteria used for the selection of the recommended values should be included.

8. Certificate

The certificate should include:

- recommended values only, with mean/median, confidence interval, significance level
- source of material
- description of material
- composition of material
- size of sample
- preparation methods
- how moisture content should be determined
- a reference to the full report with a statement that it is available upon request
- a request for any further results

Existing Certificates should be revised accordingly.

9. Further Recommendations

9.1 A project should be set up to support selected outside laboratories to participate in the certification process of reference materials.

9.2 A similar project for outside laboratory services for the preparation of reference materials should also be supported. Emphasis should be placed on homogeneity testing including analytical techniques, particularly those not presently available in the Agency's laboratories, and the statistics thereof.

9.3 To ensure uniformity in the presentation of information sheets/reports and certificates it is recommended that the Chemistry Unit, Seibersdorf, be responsible for the co-ordination of publications.

9.4 The consultants are of the opinion that there is a real need for reference materials (RM) for which the demand is sure to increase in the future, especially regarding an increased demand for radioactivity measurement in food and environmental materials as of April 1986. The Consultants feel that it should be one of the IAEA's service to Member States to provide necessary RMs for these radioactivity measurements. Also the interest of trace element analysis of food, tissue and environmental materials is still increasing. The Consultants are aware that due to (recent) organizational changes the AQCS activities have suffered a reduction in manpower. In view of the continuing interest in AQCS expressed by the Member States, the Consultants are convinced that an increase in capabilities is strongly needed.

9.5 Regarding reliability and economy of the AQCS programme the inhouse activities should be strengthened reasonably. For the workload to be expected a staff of 2 professional staff members, 2 GS staff members (technicians), the availability of part time GS staff members for analytical service in the amount of 2 GS staff members (100%) and an opportunity for temporary assistance would be necessary.

9.6 To ensure continuity in the AQCS programme a change of several staff members simultaneously should be avoided. A short overlapping of the duty periods at least for the professional staff members would be extremely useful to ensure the continuity of ongoing work.

9.7 The AQCS programme is recognized as a critically important programme to Member States and to the overall analytical community based on the use of these services and distribution of reference materials.

APPENDIX I

List of Participants

A. External consultants

Mr. K. Buchtela
Atominstitut d. Oesterreichischen Universitäten
Schüttelstr. 115
A-1020 Vienna, Austria

Mr. L.H. Christensen
MKT Central Laboratory
Vibeholm Elli 22
DK-2605 Broenby, Denmark

Mr. R. Dybczynski
Insitute of Nuclear Research
Dorodna 16
PL-03 195 Warsaw, Poland

Mr. E. Hardy
US Department of Energy
Environmental Measurements Lab.
376 Hudson Street
New York, N.Y. 10014, USA

Mr. L. Pszonicki
Institute of Nuclear Research
Dorodna 16
PL-03 195 Warsaw, Poland

Mr. W. Reed
US Department of Commerce
National Bureau of Standards
Washington D.C., 20234, USA

B. Observers

Ms. C. Houin
Centre d'Etudes Nucleaires
B.P. No. 6
F-92260 Fontenay-aux-Roses, France

C. IAEA staff members

Mr. A.A.	Abdel-Rassoul	RIAL, Head PCI Laboratory
Ms. S.	Clements	RILS, Rad.Biol.&Health Related Env. Res.
Mr. R.	Dekner	RIAL, Chemistry Unit
Mr. S.	Deron	RIAL, Head, Safeguards Analytical Laboratory
Mr. J.J.	LaBrecque	RIAL, Chemistry Unit
Mr. R.	Parr	RILS, Rad.Biol.&Health Related Env. Res.
Mr. R.	Rosenberg	RIRL, Ind. Appl. & Chemistry
Mr. R.	Schelenz	RIAL, Head Chemistry Unit
Mr. Z.	Shuzhong	RIAL, Fellow Chemistry Unit

APPENDIX II

AGENDA

CONSULTANTS' MEETING

on status and future trends of
Analytical Quality Control Services (AQCS)

International Atomic Energy Agency
Vienna International Centre (VIC)
Meeting Room C07

18-21 November, 1986

First day (18 November 1986)

1. Organizational and administrative arrangements
2. Opening
3. Election of Chairman and Approval of Agenda
4. Introduction of the AQCS Programme (Scientific Secretary)
5. Brief self-introduction of the consultants
6. General discussion:

   - selection of new materials and/or new analytes for future studies
   - preparation techniques for different types of materials
   - procedures for homogeneity testing
   - procedures for interlaboratory testing
   - procedures for data evaluation and certification criteria
   - identification of services for future activities
   - miscellaneous

Second day (19 November 1986)

1. Forming of sub-groups according to the topics discussed during the first day
2. Internal discussion of the sub-groups on respective topics

Third day (20 November 1986)

1. Sub-groups: preparation of draft papers and recommendations
2. Plenary: discussion of draft papers and recommendations of sub-groups
3. Sub-groups: revising draft papers according to the plenary discussions
4. Plenary: start to prepare the draft documents on the results of the meeting

Fourth day (21 November 1986)

1. Discussion of the draft document of the meeting including recommendations
2. Corrections and/or additions to the draft document of the meeting
3. Final discussion of the document of the meeting
4. Closing

APPENDIX III

Co-operation IAEA/AQCS and CETAMA on Reference Materials

The following certified reference materials could be made available by CETAMA for sale under a co-operative programme with IAEA/AQCS to be defined:

(1) Natural uranium metal MU-2, certified for uranium element assay, calibration to better than ± 0.05% (0.5-1.0g unit in sealed ampoule);

(2) Natural uranium dioxide sintered pellets, certified for uranium element assay;

(3) Natural uranium concentrates certified for impurity content (7 materials are available in 50-200g units);

(4) Natural uranium ores certified for uranium concentration (6 materials are available in 50-200g units, of different physico-chemical form and content between 130 µg/g to 4% of uranium).

Contribution of the CETAMA to the Interlaboratory Comparisons of AQCS

Three well characterized materials can be made available by CETAMA

(1) A solution of natural uranyl nitrate for uranium elemental assay
(2) A uranium ore for uranium analysis
(3) A uranium concentrate for impurity specification control

In all three cases the activities could be distributed as follows:

(a) the IAEA/AQCS collects the requests of potential participants
(b) the CETAMA provides to IAEA/AQCS the number of units required of each material and sends the instructions for analysis and reporting to the participants
(c) the IAEA distributes the sample
(d) the participant acknowledges receipt of samples to IAEA, analyses the samples and reports to CETAMA
(e) CETAMA
- informs the participant of the "true" value, immediately after receipt of the results
- codes the results
- performs and publishes an annual evaluation of the results

The funding of the cost of the material and its certification will need to be discussed between AQCS and CETAMA.

APPENDIX IIIA

2 Février 1987

Additions:

The cost and the certification of uranyl nitrate solution for uranium elemental assay and of uranium concentrate for impurity specification control will need to be discussed between AQCS and CETAMA.

For uranium ore for uranium analysis, CETAMA accepts to contribute to the Interlaboratory comparisons of AQCS and requires to AQCS to pay only the supply of material (about 3.000 FF). The distribution of activities (a, b, c, d, e) mentioned above would be unchanged. The materail is available immediately.

C. HOUIN

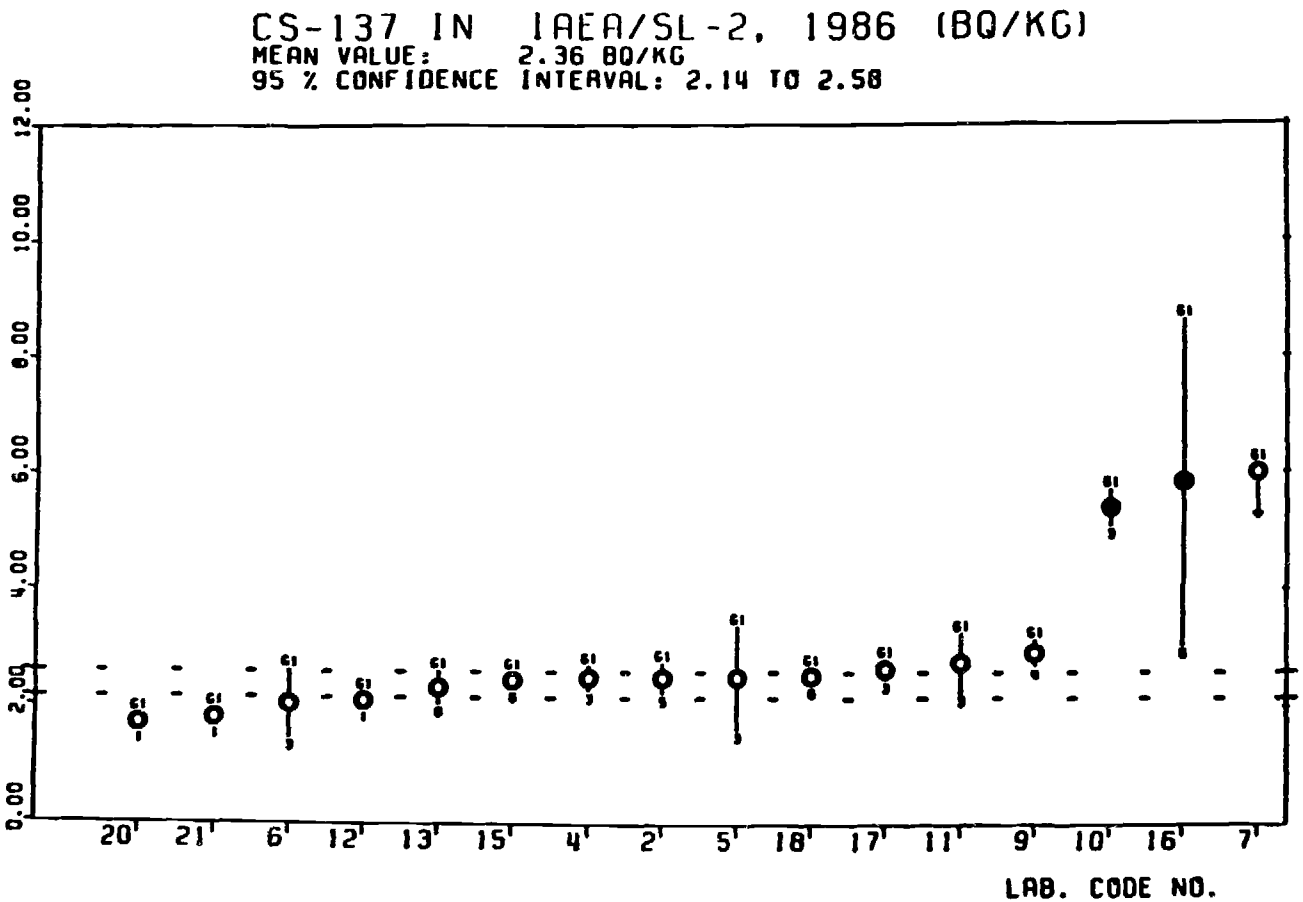
APPENDIX IV

Preliminary Evaluation of AQCS-Questionnaire 1986

Sent to 4800 customers Answers received so far: 237

Ranking	Material	Interested as* Intercomparison sample	Interested as* Reference material	To be determined/certified	Interests (overall)
1	Dried serum	72	74	trace elements	96
2	Dried urine	54	55	trace elements	86
3	Lignite fly ash	58	50	trace elements	76
3	Milk powder	52	59	trace elements	76
4	Wheat flour	53	54	trace elements	75
5	Conifer needles	53	51	trace elements	74
6	Plant fodder, eg. clover	50	55	trace elements	69
7	Coal	55	46	trace elements	68
8	Rice flour	50	42	trace elements	65
8	Sediment	34	35	metal-organics toxic-organics	49
9	Coal	36	32	radionuclides	45
9	Lignite fly ash	38	29	radionuclides	45
10	Fertilizer	30	31	N, P, K and trace elements	40
11	Conifer needles	22	16	radionuclides	28
12	Sintered UO_2	13	12	^{235}U, ^{238}U	17
13	UO_2	9	8	impurities	16
13	Calcium carbonate	13	14	$^{12}C.^{13}C$	15
14	Ammonium salt	13	12	$^{14}N.^{15}N$	15
15	Spent fuel	11	8	U, Pu, isotopic abundance	14
16	Nuclear reactor construction material	4	6	neutron absorbers, eg. Hf and O_2, H_2, N_2	7
16	Sulphur	5	7	S isotopes	7

APPENDIX V


CS-137 IN IAEA/SL-2, 1986 (BQ/KG)
MEAN VALUE: 2.36 BQ/KG
95 % CONFIDENCE INTERVAL: 2.14 TO 2.58
12.00
10.00
8.00
6.00
4.00
2.00
0.00
20' 21' 6' 12' 13' 15' 4' 2' 5' 18' 17' 11' 9' 10' 16' 7'
LAB. CODE NO.

FROM: K. Heyden, Neutron Activation Analysis for Chemical Trace Element Research, Vol. 1-2, CRC Press, 1984, Boca Raton, FLA (USA)

APPENDIX VI

Interdisciplinary communication is often hampered by the traditional use of separate sets of symbols and units for each subject; the adoption of a common system requires a mental effort, and therefore takes time.[9] Nevertheless, the International System of SI units[2] is now increasingly being used in all branches of science, including clinical chemistry,[1] and several international recommendations[10] help to avoid the problem of different concepts having the same symbol or vice versa. Throughout these two volumes, coherent SI units are used in the form of suitable multiples with only one prefix. Trace element data with no information on their chemical form are presented as mass rather than as amount of substance,

mass concentration	1 mg/m^3	=	1 $\mu g/L$
mass content	1 mg/kg	=	1 $\mu g/g$,

and in most cases no conversion factor is needed in relation to the obsolete terms ppm and ppb.

In the text, terms are used that are consistent with internationally accepted usage, whenever possible, and definitions can be found in the publications listed among References 1 to 6. In some cases, however, it is necessary to use terms that have not yet been internationally recognized, or which are defined in a different manner according to the organizations involved. Such terms are listed here with the definition chosen for the present context.

Accuracy—The closeness of agreement between the true value and the mean result which would be obtained by applying the experimental procedure a very large number of times. The smaller the systematic part of the experimental errors which affect the results, the more accurate is the procedure.[3]

Activation Spectrometry—Instrumental Neutron Activation Analysis based on γ-ray spectrometry.[11]

Analysis of Precision—The detection of unexpected sources of variability by comparison of estimated and observed variation of analytical results.[5]

Analytical Method—The set of written instructions completely defining the procedure to be adopted by the analyst in order to obtain the required analytical result.[14]

Analytical Quality Control—The techniques and activities employed to sustain the precision and accuracy of analytical results.[4]

A priori Precision—A set of instructions for the a priori estimation of the standard deviation of a single analytical result.[6]

Carrier—An element added to the sample after activation in order to control losses of determinand during radiochemical separation.

Coefficient of Variation—Standard deviation expressed as a fraction of the mean; the same as relative standard deviation.[6]

Comparator—An irradiated material with exactly known composition from which the specific indicator activity of an element in an unknown irradiated sample can be determined.

Definitive Method—An analytical method in which all possible sources of error have been evaluated and brought in statistical control.[13]

Determinand—The element or chemical species to be determined.

Indicator—A radionuclide indicating the presence of a specified element in an irradiated sample.

Neutron Activation Analysis—Determination of elements by the measurement of characteristic indicators formed by irradiation with neutrons.

Instrumental Neutron Activation Analysis—where a characteristic indicator is determined without any separation from other activity present in the sample.

Radiochemical Neutron Activation Analysis—where a characteristic indicator is determined after a radiochemical separation from the interfering activity in the sample.

Comprehensive Neutron Activation Analysis—where a characteristic indicator is determined after a radiochemical separation, followed by a determination of the yield of the separation.

Precision—The closeness of agreement between the results obtained by applying the experimental procedure several times under prescribed conditions. The smaller the random part of the experimental errors which affect the results, the more precise is the procedure.[3]

Quality Assurance—A comprehensive program designed to establish and maintain statistical control in a measurement system or an analytical method.[12]

Reference Method—The analytical method with the smallest uncertainty for a specified determination.

Sensitivity—In Neutron Activation Analysis the number of counts recorded per unit weight of an element under prescribed conditionns.

Specific Activity—The activity of a radioactive isotope of an element divided by the total mass of the element.

Statistical Control—Full agreement between the estimated and observed variability of analytical results.

Trace—A concentration of the determinand that is lower than 0.01% or 100 mg/kg.

Ultratrace—A concentration of the determinand that is lower than 0.01 mg/kg or equivalent.

Uncertainty—The estimated standard deviation of the difference between the true value and an analytical result after all known corrections have been applied.[7]

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