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Interlaboratory Comparison Radionuclides in Irish Sea Water

IAEA-443

IAEA
International Atomic Energy Agency

Interlaboratory Comparison Radionuclides in Irish Sea Water IAEA-443

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FOREWORD

Our society is giving increasing importance to the study and assessment of the state and health of the environment. Organizations involved in such activities rely on the quality of the information provided and, ultimately, on the precision and accuracy of the data on which the information is based. Many laboratories are involved in the production of environmental data, in many cases leading to wider assessments. These laboratories may develop and validate new analytical methods, study the environmental impact of human activities, provide services to other organizations, etc. In particular, laboratories are providing data on levels of radioactivity in a variety of marine matrixes such as water, suspended matter, sediments and biota. Because of the need to base scientific conclusions on valid and internationally comparable data, the need to provide policy makers with correct information and the need for society to be informed of the state of the environment, it is indispensable to ensure the quality of the data produced by each laboratory.

Principles of good laboratory practice require both internal and external procedures to verify the quality of the data produced. Internal quality is verified in a number of ways, such as the use of laboratory information systems, keeping full records of equipment performance and standardization of analytical procedures. External quality can also be ascertained in a number of ways, notably accreditation by an external body under a defined quality scheme but also, amongst others, the use of internationally accepted calibration standards that are traceable to the SI international system of units, the participation in interlaboratory comparisons or the regular use of Reference Materials to test laboratory performance.

The Radiometrics Laboratory of the International Atomic Energy Agency's Marine Environment Laboratories has been providing quality products for the last 40 years, which include the organization of interlaboratory comparisons, production of Reference Materials and Certified Reference Materials, and training. More than 40 Reference Materials have been produced, which include a wide range of marine sample matrices and radionuclide concentrations.

As part of these activities, a new interlaboratory comparison was organized to provide the participating laboratories with the possibility of testing the performance of their analytical methods on a seawater sample with elevated radionuclide levels due to discharges from a nuclear facility. The material was designed for the analysis of anthropogenic and natural radionuclides in sea water. It is expected that the sample, after successful certification, will be issued as a Certified Reference Material for radionuclides in sea water.

Laboratories were informed that, after the completion of the exercise, an IAEA report describing the results of the interlaboratory comparison would be issued, including their identities, but that the results would not be associated with each laboratory’s identity.

The IAEA officers responsible for this publication were M.K. Pham and J.-A. Sanchez-Cabeza of the IAEA Marine Environment Laboratories in Monaco.

CONTENTS

1. INTRODUCTION

The accurate and precise determination of radionuclide concentrations in marine samples are important aspects of marine radioactivity assessments and the use of radionuclides in studies of oceanographic processes. To address the problem of data quality, the IAEA Marine Environment Laboratories (IAEA-MEL) in Monaco regularly conduct interlaboratory comparisons of radionuclides in marine samples as part of its contribution to the IAEA's Programme of Analytical Quality Control Services (AQCS) [1-2].

In collaboration with IAEA-MEL, the Federal Maritime and Hydrographical Agency, Hamburg, Germany (BSH) collected sea water from the Irish Sea in 1993. A part of the sample was forwarded to IAEA-MEL and was used for the IAEA-381 interlaboratory comparison on anthropogenic and natural radionuclides. The results obtained from 28 laboratories were reported [3-4] and the IAEA-381 Certified Reference Material was issued. In 2005, 1100L of this sample, kept by the Risø National Laboratory, Denmark (Risø), was provided to IAEA-MEL. This sample was used to organize, in collaboration with the Oslo-Paris Commission (OSPAR), an interlaboratory comparison for OSPAR laboratories (13 laboratories from 10 OSPAR contracting parties) to test their performance in analysing radionuclides in sea water. The results of this exercise will allow IAEA-MEL to produce a new Reference Material (RM), replacing IAEA-381 (out of provision) and to test the stability of the sample after 15 years' conservation in high density polyethylene container.

As the sample was collected in the Irish Sea, elevated levels of anthropogenic radionuclides were expected due to discharges from the Sellafield reprocessing plant. Participants were informed that the expected activities for anthropogenic radionuclides would be in the ranges (mBq kg^{-1}):

^{90}Sr : 50–500
^{137}Cs : 100–1000
$^{239+240}Pu$: 1–50
^{241}Am : 1–50

This report describes the results obtained from 12 laboratories on anthropogenic and natural radionuclide determinations in sea water.

2. SCOPE OF THE INTERLABORATORY COMPARISON

This interlaboratory comparison was organized to provide the participating laboratories with the possibility to test the performance of their analytical methods on a seawater sample with elevated radionuclide levels due to discharges from a nuclear facility.

The intercomparison material was designed for the analysis of anthropogenic and natural radionuclides. Participating laboratories were requested to determine as many radionuclides as possible by gamma spectrometry, transuranium radionuclides and other radionuclides requiring radiochemical separation and alpha or beta counting.

It is expected that the sample, after successful certification, will be issued as a Certified Reference Material for radionuclides in sea water [5].

3. DESCRIPTION OF THE MATERIAL

About 3600 litres of surface water were collected by BSH on September 7, 1993, onboard the Research Vessel *Valdivia*. Sampling was performed during a transect between two shallow (*circa* 20 m water depth) stations located at 54°24,89' N - 3°33,62' W and 54°23,2'N - 3°33,45'W. Water was sampled from 5 m water depth, stored in 600 L containers and acidified to pH<1 immediately without prior filtration.

4. HOMOGENEITY TESTS

The sample received in 2005 was transferred into a container of 1500 L and mixed for 4 hours using two pumps, aliquoted into 5 L cubitainers and coded as IAEA-443. Sample homogeneity was checked by measuring ^{137}Cs, ^{40}K ^{90}Sr, ^{238}Pu and $^{239+240}$Pu activities (by using high resolution low background gamma spectrometry, low level beta proportional counter and alpha spectrometry) in 2 L aliquots from 5 cubitainers chosen at random. Homogeneity was tested by using one-way analysis of variance. The coefficient of variation was below 10% for all radionuclides analysed (Table 1, Appendix I). On the basis of the homogeneity tests (Figs 1 and 2, Appendix II for ^{137}Cs and $^{239+240}$Pu, for instance), the sample could be considered sufficiently homogeneous for the assayed radionuclides for volumes of over 2 L.

5. SAMPLE DISPATCH AND DATA RETURN

Each participant received 5 L of the seawater sample. For each radionuclide analysed, the following information was requested:

- Average weight of sample
- Number of analyses
- Massic activity calculated in net values (i.e. corrected for blank, background etc.)
- and expressed in Bq kg^{-1}
- Estimate of the total uncertainty (counting and other uncertainties)
- Description of chemical procedures and counting equipment
- Reference standard solutions used
- Chemical recoveries, counting time, half-life.

The reference date for reporting activities was 1 January 2007.

The samples were distributed to 13 laboratories in June 2007. The deadline for reporting data was set for 1 January 2008. A reminder was sent to late participants. A total of 12 laboratories sent their reports. The list of reported radionuclides is given in Table 2, Appendix I.

Laboratories were informed that, after the completion of the exercise, an IAEA report describing the results of the interlaboratory comparison would be issued, including their identities, but that the results would not be associated to each laboratory identity.

6. EVALUATION OF RESULTS

6.1. DATA TREATMENT

The submitted results are shown under their laboratory code numbers in Tables 3 to 8, Appendix I. Laboratory means were calculated when necessary from individual results and are given either as arithmetic means with corresponding uncertainties when more than two results were reported, or as weighted means with weighted uncertainties in the case of only two results reported. All values have been rounded off to the most significant figure.

6.2. STATISTICAL EVALUATION

The principles and applications of the statistical programme used for the evaluation of data have been described in a previous report [4]. Calculations are based on the assumption of non-parametric distribution of data to which distribution-free statistics are applicable. The "less than" values are segregated from the results and the remaining values are checked for the presence of outliers using a box and whisker plot test. Outliers are identified in the tables with an asterisk. Median values are calculated from all results passing the test. These values are considered to be the most reliable estimates of the true values. Confidence intervals were taken from a non-parametric sample population. They represent a two-sided interval representing 95% confidence limits.

Massic activities for 14 radionuclides were reported and results are shown in Table 2, Appendix I with the number of reporting laboratories for each radionuclide. The number of reported "less than" values are shown in parentheses. The results for the most frequently measured radionuclides can be found in Tables 3 to 8, Appendix I and Figures 3 to 9, Appendix II, while the less frequently measured radionuclides are presented in Table 9, Appendix I. The recommended values and information values obtained after statistical treatment are presented in Table 10, Appendix I.

Following the International Union of Pure and Applied Chemistry (IUPAC) [6] and the International Organization for Standardization (ISO) [7] recommendations for assessment of laboratory performance, the Z-score methodology was used for the evaluation of the intercomparison results. The performance of a laboratory was considered to be acceptable if the difference between the robust mean of the laboratory and the assigned value is less than or equal to two. The analysis is regarded as being out of control when $|Z|>3$.

6.3. EXPLANATION OF TABLES

6.3.1. Laboratory code

Each laboratory was assigned an individual code number to ensure anonymity.

6.3.2. Method code

The analytical techniques employed by participants are specified with following codes:

Alpha spectrometry

Code	*Method*
A	Treatment, evaporation/precipitation, ion exchange, electro-deposition follow by alpha spectrometry.

Beta counting

Code	*Method*
B0	Low level GM counter
B1	LSC (Liquid Scintillation Counter)
B2	Precipitation (oxalate, hydroxide), scavenging, beta counting of Y oxalate follow by beta counting (low level proportional gas counter)

Gamma spectrometry

Code	*Method*
G	High resolution Ge spectrometry

Mass spectrometry

Code	*Method*
ICPMS	Treatment, ion exchange, electro-deposition, leaching, ICP-MS (Inductively Coupled Plasma Mass Spectrometry).

6.3.3. Number of results

The number of determinations corresponds to the number of individual results from which the laboratory mean was calculated. When no mention was made in a participant's report as to the number of measurements made, it was assumed to be one.

6.3.4. Massic activity

The activity corresponds to the arithmetical or weighted mean computed from all the individual results obtained from the participants with the corresponding standard deviation or weighted uncertainty.

6.4. EXPLANATION OF FIGURES

The figures (Figs 3 to 9, Appendix II) present the data with the corresponding standard deviation or weighted uncertainty in order of ascending massic activity. Also shown are:

(i) the distribution medians (full lines) and corresponding confidence intervals (dashed horizontal lines),

(ii) the limits for accepted laboratory means (vertical lines).

The performance of laboratories in terms of accuracy was expressed by Z-scores, which were calculated for each radionuclide. Figures 10 to 16 in Appendix III present the Z-scores for accepted values only. The distributions of Z-scores are symmetric which indicates that the overall performance of the laboratories was satisfactory.

6.5. CRITERIA FOR RECOMMENDATION

Median values and confidence intervals (95% significance level) were calculated as estimations of true massic activities. The median values of the data within the confidence interval were considered as the **recommended values** when:

1. At least 5 laboratory means were available, calculated from at least 3 different laboratories.
2. The relative uncertainty of the median did not exceed ± 5% for activities higher than 100 Bq kg^{-1}, ± 10% for activities from 1-100 Bq kg^{-1} and ± 20% for activities lower than 1 Bq kg^{-1}.

An activity value was classified as an **information value** when it satisfies condition 1, but not condition 2.

7. RESULTS AND DISCUSSION

7.1. ANTHROPOGENIC RADIONUCLIDES

Results of the analysis of ^{3}H, ^{90}Sr, ^{137}Cs, ^{238}Pu, $^{239+240}Pu$, and ^{241}Am reported by participants are presented in Table 3, Tables 5 to 8, Appendix I, Figure 3 and Figures 5 to 9, Appendix II.

7.1.1. ^{3}H

Data were reported from seven laboratories (Table 3, Appendix I, Fig. 3, Appendix II). The data showed good homogeneity and all data passed the outlier test. The Z-score (Fig. 10, Appendix III) is below 1.7, showing good performance. The median, given as the information value, is 37 Bq kg^{-1} (95% confidence interval is 33–41 Bq kg^{-1}).

7.1.2. ^{90}Sr

Data were reported from seven laboratories (Table 5, Appendix I, Fig. 5, Appendix II). All the data passed the outlier test and showed good homogeneity. Z-score values are below 1.6, showing good performance by the laboratories (Fig. 12, Appendix III). The median, given as the information value, is 107 mBq kg^{-1} (95% confidence interval is 89–115 mBq kg^{-1}).

7.1.3. ^{137}Cs

Data were reported from 11 laboratories (Table 6, Appendix I, Fig. 6, Appendix II). The laboratories mainly used direct gamma spectrometry for ^{137}Cs analysis. The data is homogenous within two standard deviations of the distribution mean. Z-score values are below 1.7, showing good performance by the laboratories (Fig. 13, Appendix III). The median, given as the recommended value, is 0.36 Bq kg^{-1} (95% confidence interval is 0.34–0.37 Bq kg^{-1}).

7.1.4. ^{238}Pu

Six data sets were reported (Table 7, Appendix I, Fig. 7, Appendix II), one of them reported a value as LLD (Lower Limit of Detection). Five results did pass the outlier test and showed good homogeneity, within two standard deviations of the distribution mean. Z-score values are below 1.5, showing good performance by the laboratories (Fig. 14, Appendix III). The median, given as the recommended value, is 3.1 mBq kg^{-1} (95% confidence interval is 2.9–3.3 mBq kg^{-1}).

7.1.5. $^{239+240}Pu$

Six data sets were reported (Table 7, Appendix I, Fig. 8, Appendix II), one of them reported a value as LLD. The majority of participants used a conventional method based on sample treatment, ion-exchange separation followed by electrodeposition and alpha spectrometry. The data is homogeneous within two standard deviations of the distribution mean. Z-score values are below 2, showing good performance by the laboratories (Fig. 15, Appendix III). The median, given as the recommended value, is 14 mBq kg^{-1} (95% confidence interval is 12–15 mBq kg^{-1}).

7.1.6. ^{241}Am

Data from 5 laboratories were reported (Table 8, Appendix I, Fig. 9, Appendix II). All the data passed the outlier test and they all fall less than 2 standard deviations from the distribution mean. Z-score values are below 1.2 (Fig. 16, Appendix III). The median, given as the recommended value, is 20.1 mBq kg^{-1} (95% confidence interval is 19.0–20.2 mBq kg^{-1}).

7.2. NATURAL RADIONUCLIDES

^{40}K

Data were reported from 11 laboratories (Table 4, Appendix I, Fig. 4, Appendix II). All results passed the outlier test. The data showed good homogeneity. Results are between two standard deviations from the distribution mean. Z-score values are below 2.0, showing good performance by the laboratories (Fig. 11, Appendix III). The median, given as the recommended value, is 11.4 Bq kg^{-1} (95% confidence interval is 10.7–11.7 Bq kg^{-1}).

7.3. LESS FREQUENTLY REPORTED RADIONUCLIDES

The results for the less frequently reported radionuclides are listed in Table 9, Appendix I.

7.3.1. ^{99}Tc

Three results were reported, ranging from 159 to 250 mBq kg^{-1}.

7.3.2. ^{234}U, ^{235}U and ^{238}U

Four laboratories reported results for ^{234}U and ^{238}U, three of them reported for ^{235}U. Data were rather homogeneous and ranged from 40 to 46 mBq kg^{-1} for ^{234}U, and from 35 to 45 mBq kg^{-1} for ^{238}U. The three values for ^{235}U are (1.4 ± 0.5), (1.8 ± 0.2) and (54 ± 7) mBq kg^{-1}.

7.3.3. ^{237}Np

One laboratory analysed this radionuclide by using ICPMS (7 ±3 mBq kg^{-1}).

7.3.4. ^{239}Pu and ^{240}Pu

One laboratory analysed ^{239}Pu and ^{240}Pu by ICPMS. The ^{239}Pu and ^{240}Pu massic activities reported were (10 ± 2) mBq kg^{-1} and (8 ± 2) mBq kg^{-1}, respectively. The derived $^{239+240}Pu$ concentration is 18 ± 2 mBq kg^{-1}, higher than the value determined by the same laboratory by alpha spectrometry (15 ± 3 mBq kg^{-1}).

8. FINDINGS AND CONCLUSIONS

In this interlaboratory comparison, 12 laboratories reported concentrations of natural and anthropogenic radionuclides in a sea water sample from the Irish Sea (IAEA-443). The median concentrations for the sets of individual data – after rejection of outliers – were chosen as the most reliable estimates of the true values and are reported as recommended and information values.

A summary of the recommended and information values with confidence intervals for the most frequently reported anthropogenic and natural radionuclides can be found in the summary table below as well as in Table 10, Appendix I.

SUMMARY TABLE: RECOMMENDED AND INFORMATION VALUES FOR THE IAEA-443 REFERENCE MATERIAL (Reference date: 1 January 2007, unit: Bq kg^{-1})

Radionuclide	Median	Confidence interval ($\alpha = 0.05$)
Recommended value		
^{40}K	11.4	10.7–11.7
^{137}Cs	0.36	0.34–0.37
^{238}Pu	0.0031	0.0029–0.0033
$^{239+240}Pu$	0.014	0.012–0.015
^{241}Am	0.0201	0.0190–0.0202
Information value		
^{3}H	37	33–41
^{90}Sr	0.107	0.089–0.115

Appendix I

DATA REPORT - TABLES

TABLE 1. HOMOGENEITY TESTS (*) FOR RADIONUCLIDES IN IAEA-443

Sample	^{137}Cs	^{40}K	^{90}Sr	^{238}Pu	$^{239+240}$Pu
1	0.97	0.88	0.95	0.89	0.90
2	1.00	1.00	1.02	0.97	0.97
3	1.01	1.01	1.03	1.01	1.03
4	1.01	1.02		1.02	1.05
5	1.02	1.09		1.12	1.06
Minimum	0.97	0.88	0.95	0.89	0.90
Maximum	1.02	1.09	1.03	1.12	1.06
Mean	1.00	1.00	1.00	1.00	1.00
Median	1.01	1.01	1.02	1.01	1.03
Std. Dev.	0.02	0.07	0.04	0.08	0.07
Coef. Var. (%)	2	7	4	8	7

(*) Normalized activity = x/X (individual/mean value): initially expressed in this manner to ensure confidentiality of results.

TABLE 2. RADIONUCLIDES REPORTED FOR IAEA-443

Radionuclide	Number of results	Radionuclide	Number of results
^{3}H	14	^{238}U	9
^{40}K	28	^{237}Np	6
^{90}Sr	17	^{238}Pu	18 (1)
^{99}Tc	6	^{239}Pu	4
^{137}Cs	27	^{240}Pu	4
^{234}U	9	$^{239+240}$Pu	18 (1)
^{235}U	9 (1)	^{241}Am	16
		Gross alpha	1

(*) "Less than" values are shown in parenthesis.

TABLE 3. RESULTS FOR ^{3}H IN IAEA-443
(Reference date: 1 January 2007, unit: Bq kg^{-1})

Lab Code	Method Code	No. of Results	Weight (g)	$^{3}H^{\#}$
2	B2	3	500	32.91 ± 0.02
4	B2	2	8	41 ± 5
5	B1	1	10	38 ± 3
6	B1	2	250	34.9 ± 1.3
10	B2	1	10.2	36.9 ± 3.7
11a	B2	3	8.047	38.0 ± 1.2
11b	B2	2	8.025	37.4 ± 1.3
Number of reported lab. means				7
Number of accepted lab. means				7
Median				37
Confidence interval (α = 0.05)				33–41

Uncertainties at 2σ

TABLE 4. RESULTS FOR ^{40}K IN IAEA-443
(Reference date: 1 January 2007, unit: Bq kg^{-1})

Lab Code	Method code	No. of Results	Weight (kg)	$^{40}K^{\#}$
1	G	1	0.3	9 ± 3
2	G	3	0.06; 1	12 ± 3
3	G	6	1	11.7 ± 1.2
4	G	2	2.4	11.5 ± 0.9
5	G	1	1.75	11.4 ± 0.6
6	G	3	0.5	11 ± 2
7	G	2	1	11.0 ± 1.6
9	G	5	2	10.7 ± 0.9
10	G	1	3.069	11.5 ± 0.8
11	G	3	1	10.9 ± 0.7
12	G	3	0.27	12.6 ± 2.2
Number of reported lab. means				11
Number of accepted lab. means				11
Median				11.4
Confidence interval (α = 0.05)				10.7–11.7

Uncertainties at 2σ.
* Result rejected by the test for outliers.

TABLE 5. RESULTS FOR ^{90}Sr IN IAEA-443
(Reference date: 1 January 2007, unit: Bq kg^{-1})

Lab Code	Method Code	No. of Results	Weight (kg)	$^{90}Sr^{\#}$
2	B1	2	1	0.089 ± 0.008
3	B0	6	0.5	0.11 ± 0.02
4	B1	3	1	0.10 ± 0.03
6	B2	2	0.2	0.09 ± 0.02
9	B1	3	2	0.11 ± 0.03
10	B1	1	3.115	0.107 ± 0.016
11	B1	2	0.7	0.115 ± 0.012
Number of reported lab. means				7
Number of accepted lab. means				7
Median				0.107
Confidence interval (α = 0.05)				0.089–0.115

Uncertainties at 2σ.

TABLE 6. RESULTS FOR ^{137}Cs IN IAEA-443
(Reference date: 1 January 2007, unit: Bq kg^{-1})

Lab Code	Method code	No. of Results	Weight (kg)	$^{137}Cs^{\#}$
1	G	1	0.3	0.32 ± 0.14
2	G	3	0.06; 1	0.39 ± 0.08
3	G	6	0.5 -1	0.37 ± 0.04
4	G	2	2.4	0.36 ± 0.03
5	G	1	1.75	0.34 ± 0.03
6	G	3	0.5	0.35 ± 0.08
7	G	2	1	0.34 ± 0.07
9	G	5	2	0.36 ± 0.06
10	G	1	3.069	0.37 ± 0.03
11	G	3	0.7-1	0.38 ± 0.03
12	G	3	0.27	0.32 ± 0.09
Number of reported lab. means				11
Number of accepted lab. means				11
Median				0.36
Confidence interval (α = 0.05)				0.34–0.37

Uncertainties at 2σ.
* Result rejected by the test for outliers.

TABLE 7. RESULTS FOR ^{238}Pu AND $^{239+240}$Pu IN IAEA-443
(Reference date: 1 January 2007; unit: Bq kg^{-1})

Lab.	Method Code	No. of results	Weight (kg)	^{238}Pu#	$^{239+240}$Pu#
3	A	6	0.5	0.0033 ± 0.0007	0.015 ± 0.003
4	A	2	0.997; 1	0.0031 ± 0.0008	0.014 ± 0.003
6	A	1	0.2	<0.01	<0.01
9	A	5	2	0.0031 ± 0.0006	0.014 ± 0.001
10	A	1	0.5	0.0029 ± 0.0006	0.012 ± 0.002
11	A	2	0.994; 1.017	0.0030 ± 0.0001	0.014 ± 0.001
Number of reported lab. means				5	5
Number of accepted lab. means				5	5
Median				0.0031	0.014
Confidence interval (α = 0.05)				0.0029–0.0033	0.012–0.015

Uncertainties at 2σ.

TABLE 8. RESULTS FOR ^{241}Am IN IAEA-443
(Reference date: 1 January 2007, unit: Bq kg^{-1})

Lab Code	Method code	No. of Results	Weight (kg)	^{241}Am#
3	A	8	0.5	0.02 ± 0.004
4	A	4	0.7-1	0.020 ± 0.004
9	G	1	2	0.020 ± 0.004
10	A	1	0.5	0.020 ± 0.003
11	A	2	0.994; 1.017	0.019 ± 0.002
Number of reported lab. means				5
Number of accepted lab. means				5
Median				0.0201
Confidence interval (α = 0.05)				0.0190–0.0202

Uncertainties at 2σ.

TABLE 9. RESULTS FOR THE LESS FREQUENTLY MEASURED RADIONUCLIDES REPORTED IN IAEA-443
(Reference date: 1 January 2007, unit: Bq kg^{-1})

Isotope	Lab. code	Method Code	No. of results	Weight (kg)	Activity (Bq kg^{-1})
^{99}Tc	3	B0	2	0.5	0.20 ± 0.04
-	6	B1	2	0.2	0.25 ± 0.04
-	8	B2	2	0.745; 0.754	0.159 ± 0.003
^{234}U	4	A	4	0.997-1.0	0.040 ± 0.006
-	6	A	1	0.2	0.045 ± 0.011
-	7	A	2	1.034	0.045 ± 0.001
-	10	A	1	0.5	0.046 ± 0.007
^{235}U	4	A	4	0.997-1.0	0.0014 ± 0.0005
-	6	A	1	0.2	0.0018 ± 0.0002
-	7	A	2	1.034	0.054 ± 0.007
^{238}U	4	A	4	0.997-1.0	0.035 ± 0.006
-	6	A	1	0.2	0.045 ± 0.011
-	7	A	2	1.034	0.039 ± 0.001
-	10	A	1	0.5	0.040 ± 0.007
^{237}Np	3	ICPMS	4	0.01	0.007 ± 0.003
^{239}Pu	3	ICPMS	4	0.01	0.010 ± 0.002
^{240}Pu	3	ICPMS	4	0.01	0.008 ± 0.002

TABLE 10 SUMMARY OF RECOMMENDED AND INFORMATION VALUES FOR IAEA-443 (Reference date: 1 January 2007, unit: Bq kg^{-1})

Radionuclide	Median	Confidence interval (α = 0.05)	Expanded uncertainty (%) (k=2)	Number of results*
	Recommended value			
^{40}K	11..4	10.7 - 11.7	8.8	11
^{137}Cs	0..36	0.34 - 0.37	10.3	11
^{238}Pu	0..0031	0.0029 - 0.0033	12.9	5
$^{239+240}$Pu	0..014	0.012 - 0.015	19.7	5
^{241}Am	0..0201	0.0190 - 0.0202	6.0	5
	Information value			
^{3}H	37	33 - 41	22	7
^{90}Sr	0..107	0.089 - 0.115	24.5	7

* Number of accepted laboratory means which were used to calculate the recommended values and the confidence intervals.

Appendix II

DATA EVALUATION – FIGURES

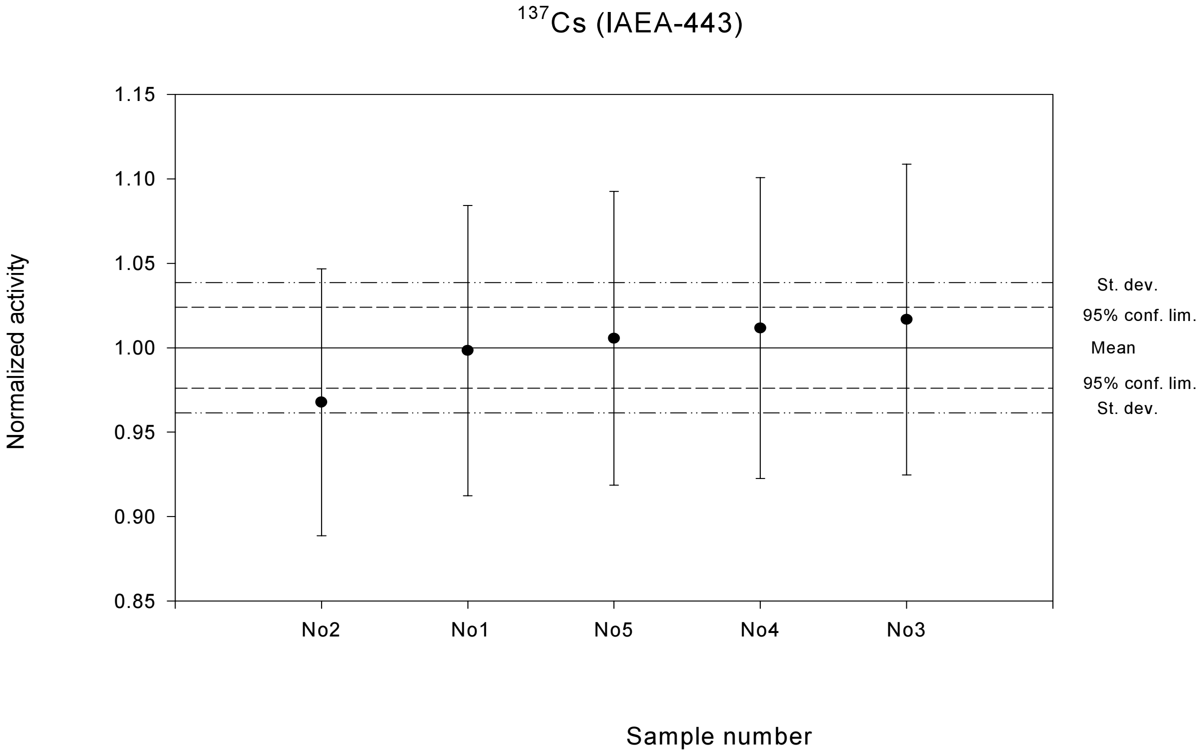

FIG.1. Homogeneity test for ^{137}Cs in IAEA-443.

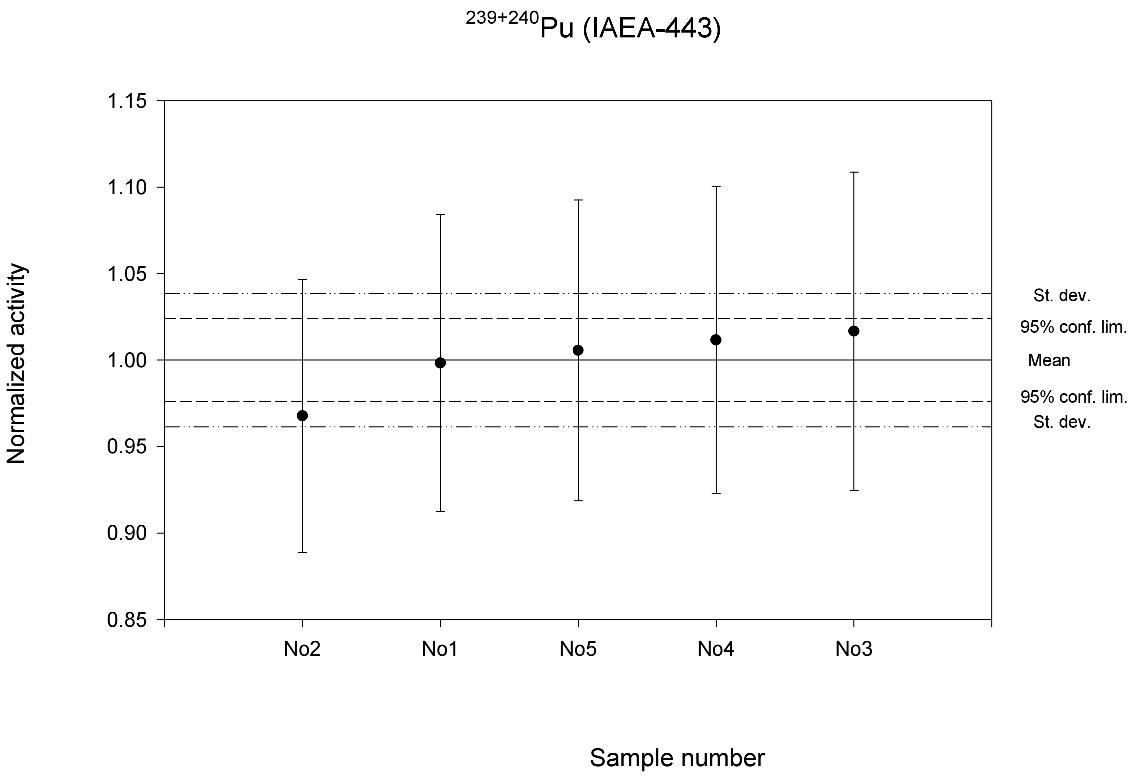

FIG.2. Homogeneity test for $^{239+240}$Pu in IAEA-443.

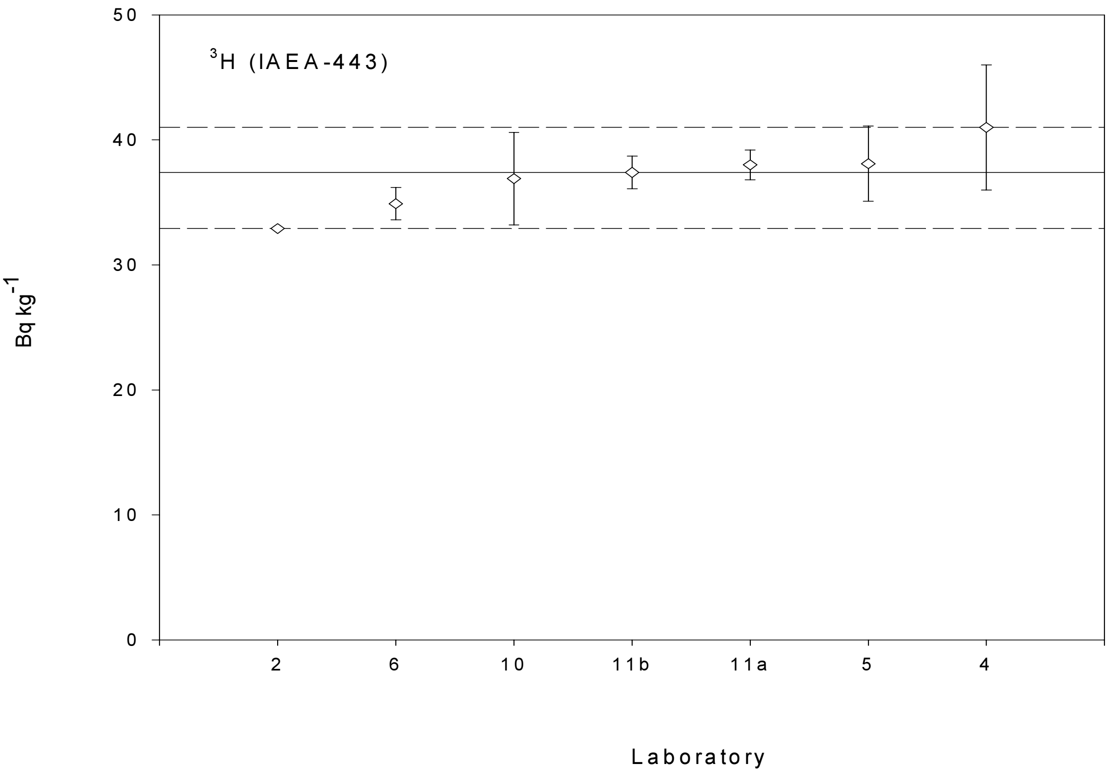

FIG. 3. Data evaluation for ^{3}H.

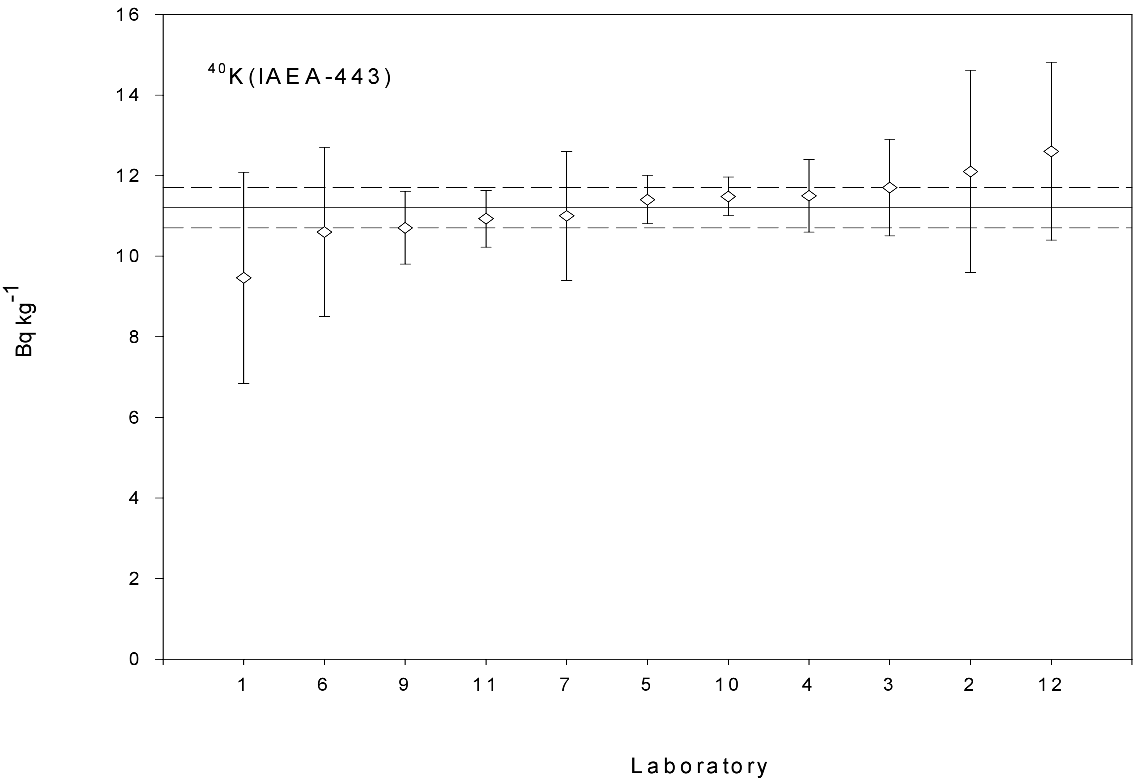

FIG. 4. Data evaluation for ^{40}K.

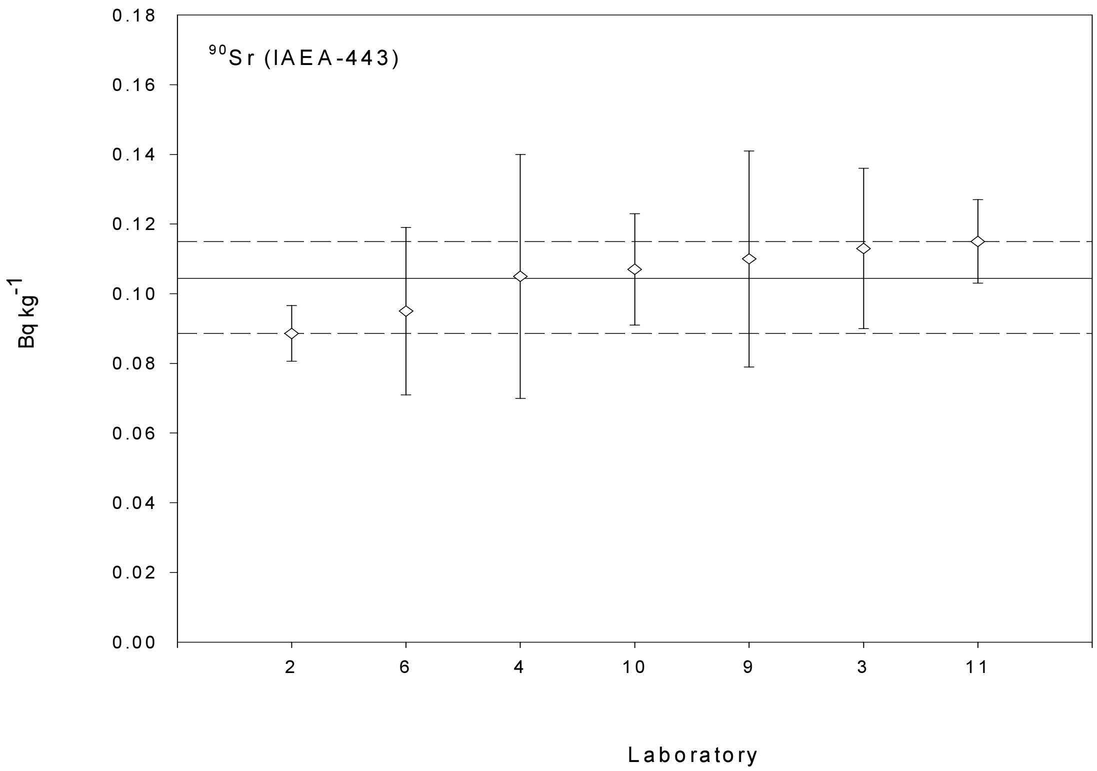

FIG.5. Data evaluation for ^{90}Sr.

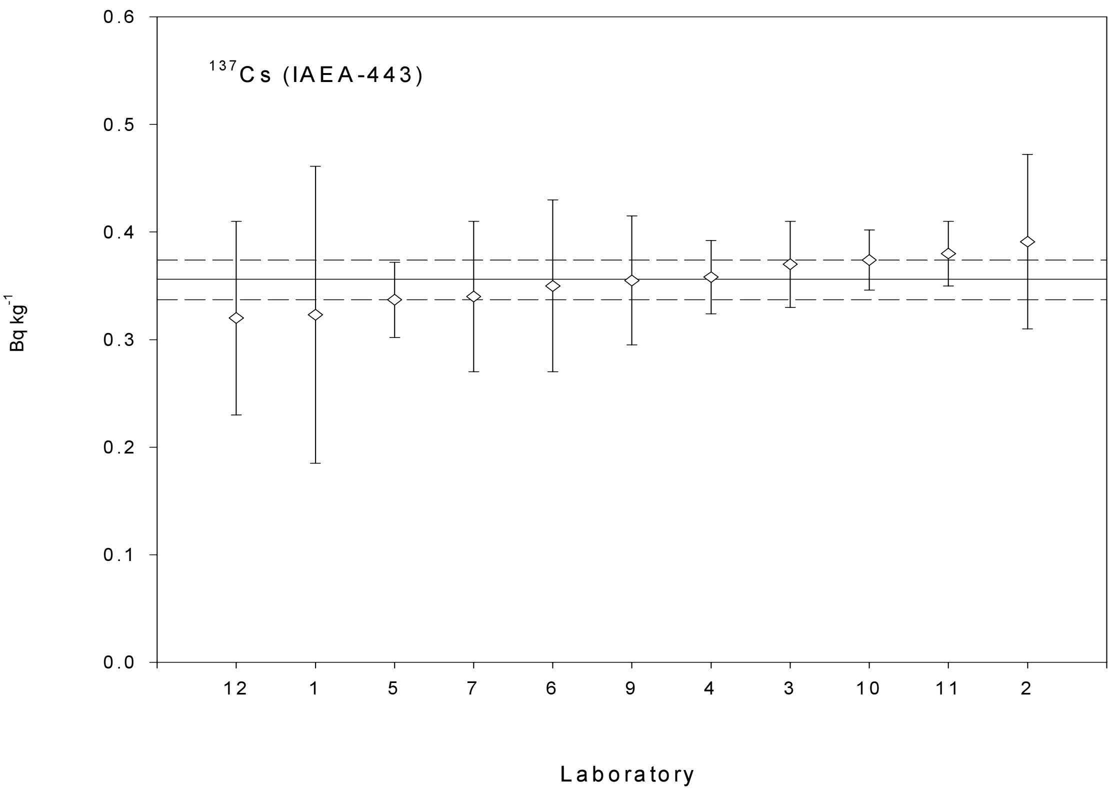

FIG. 6. Data evaluation for ^{137}Cs.

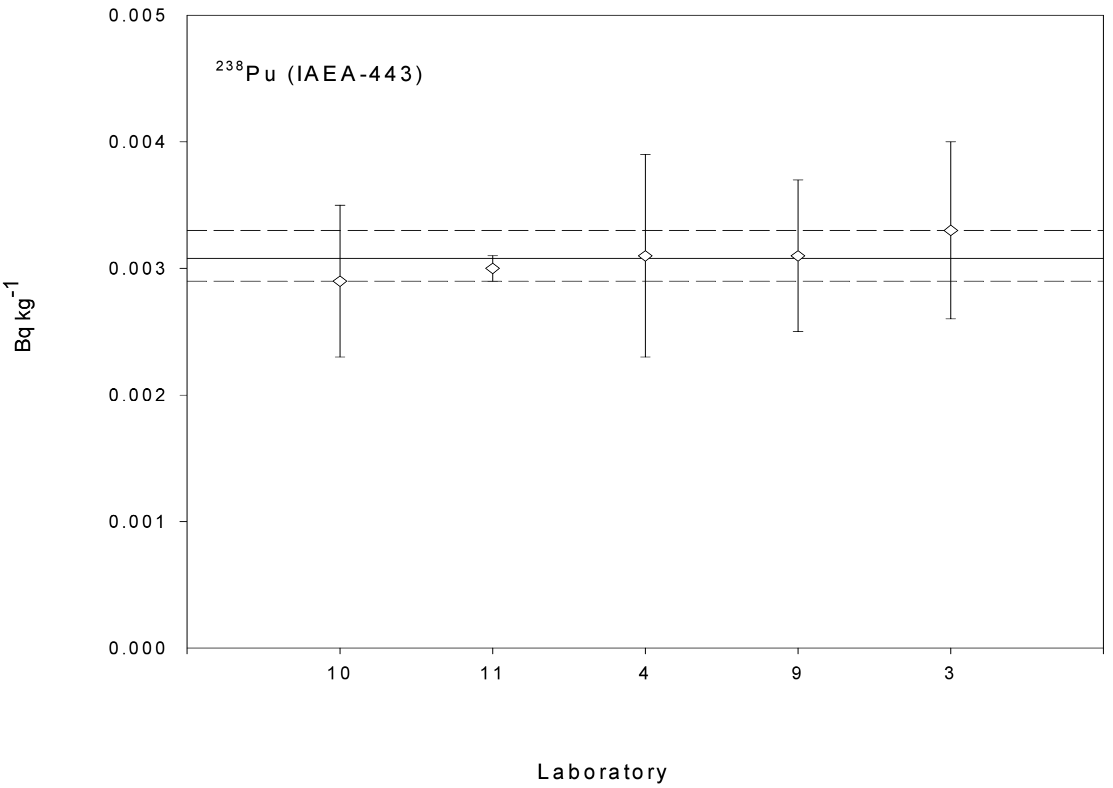

FIG. 7. Data evaluation for ^{238}Pu.

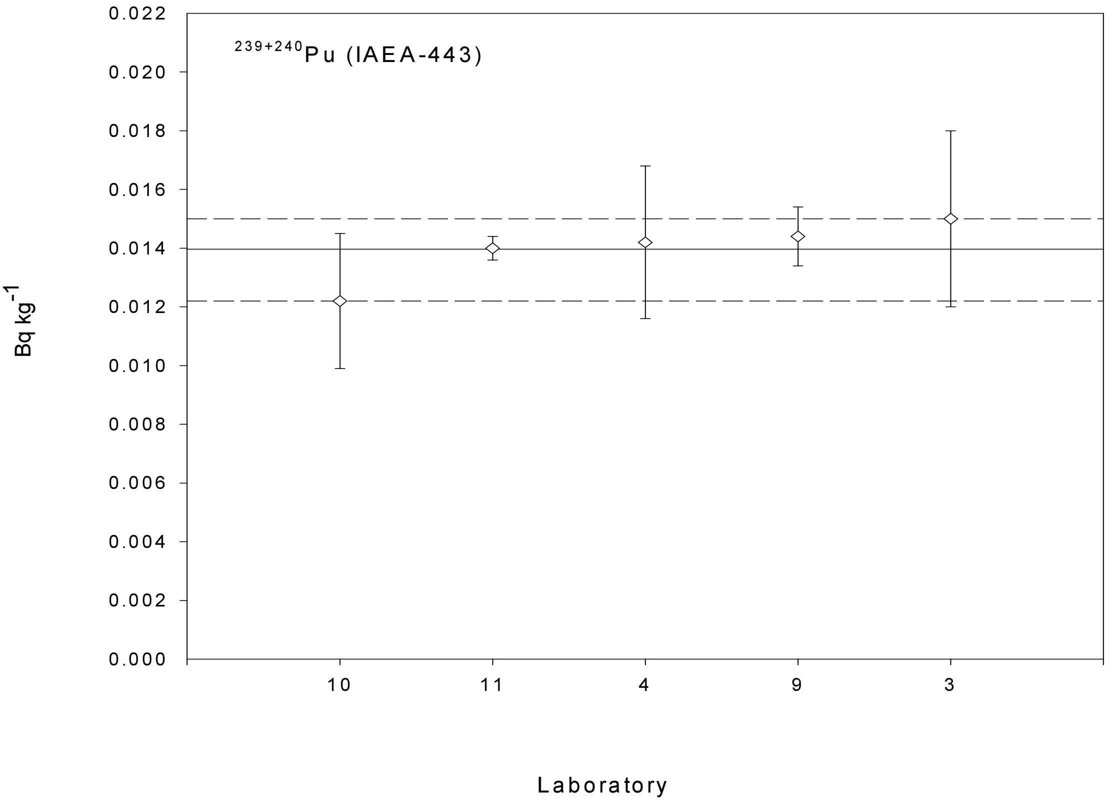

FIG. 8. Data evaluation for $^{239+240}$Pu.

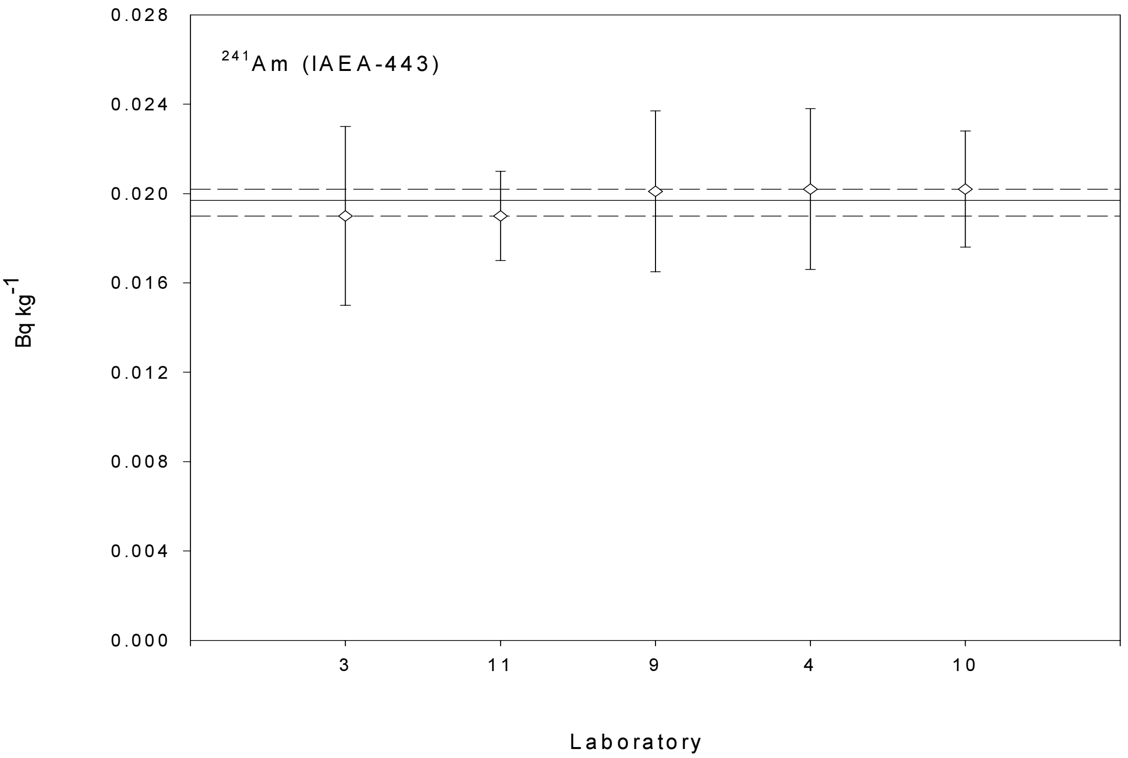

FIG. 9. Data evaluation for ^{241}Am.

Appendix III

Z-SCORES – FIGURES

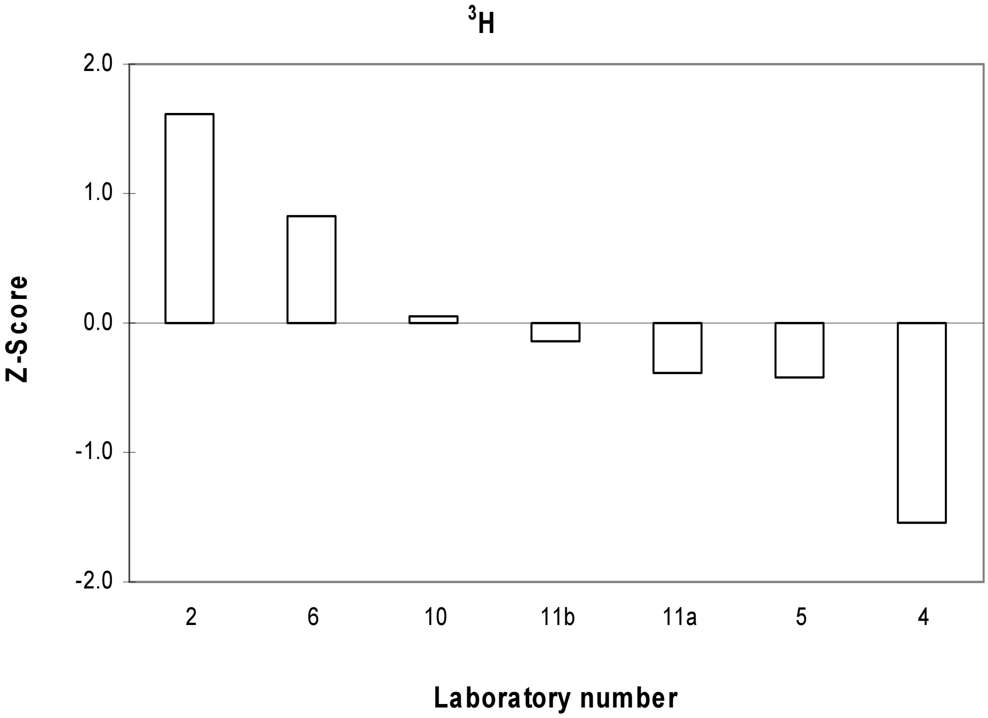

FIG.10. Z-score values for ^{3}H.

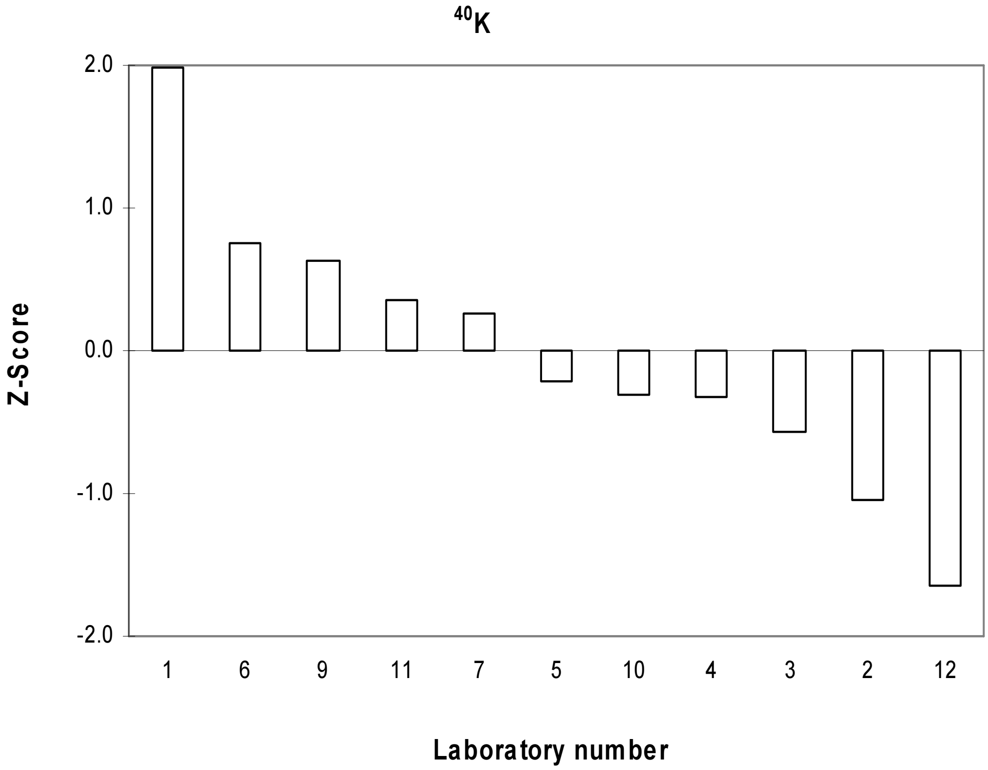

FIG.11. Z-score values for ^{40}K.

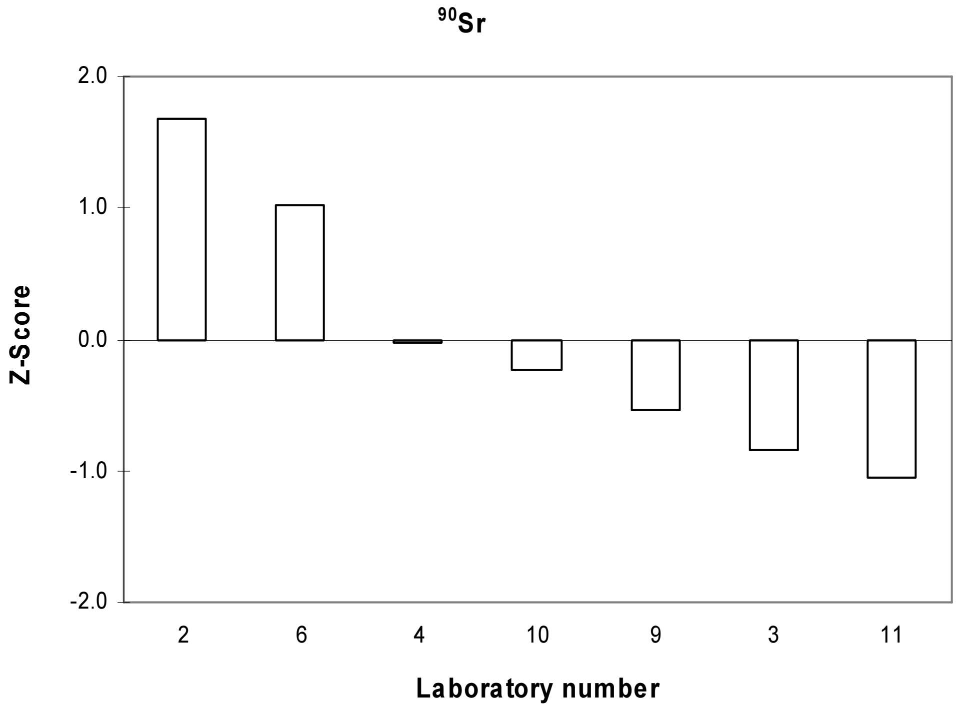

FIG.12. Z-score values of ^{90}Sr.

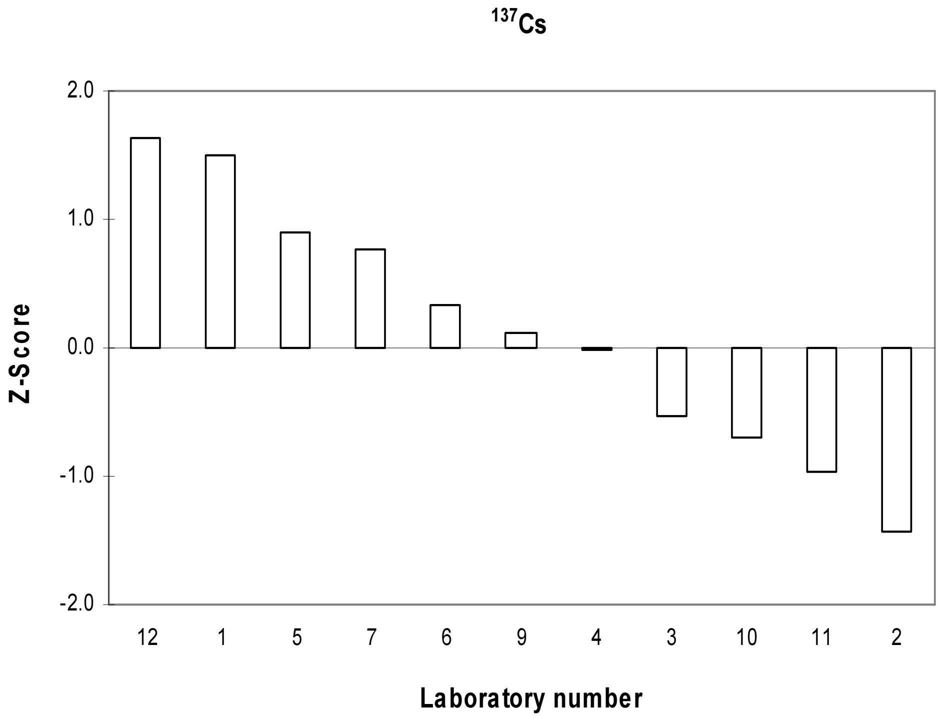

FIG.13. Z-score values of ^{137}Cs.

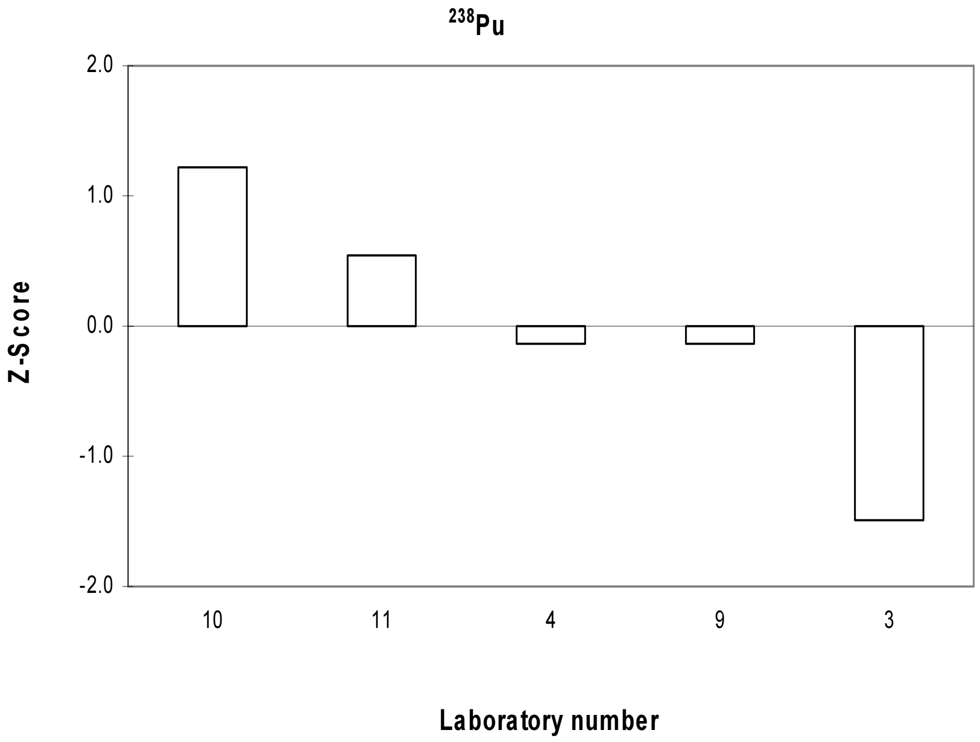

FIG.14. Z-score values of ^{238}Pu.

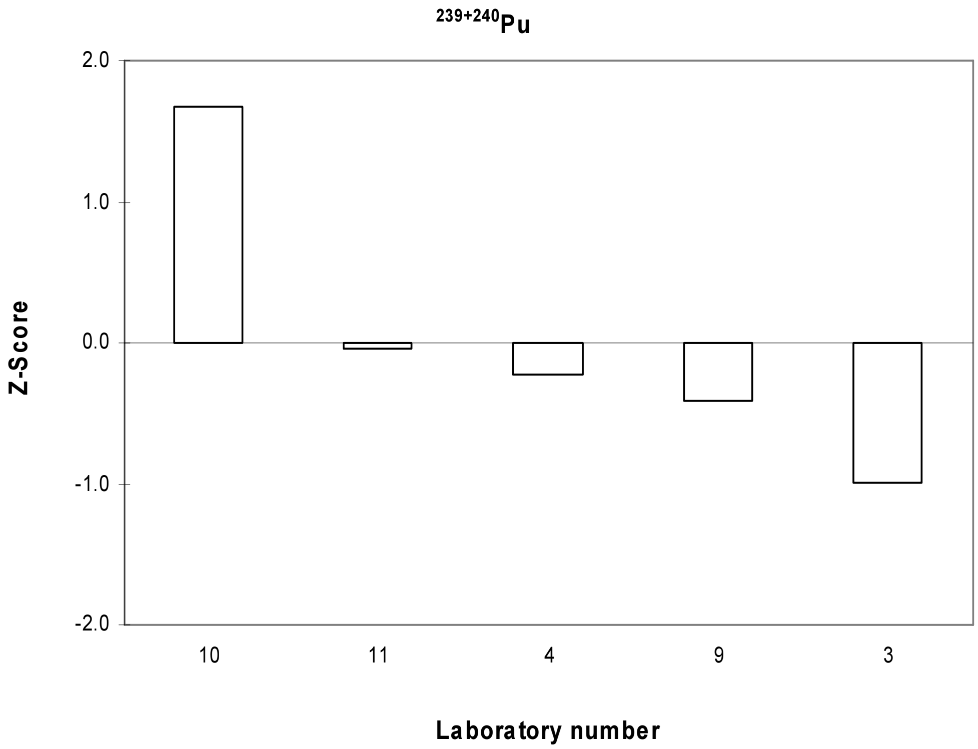

FIG.15. Z-score values of $^{239+240}$Pu.

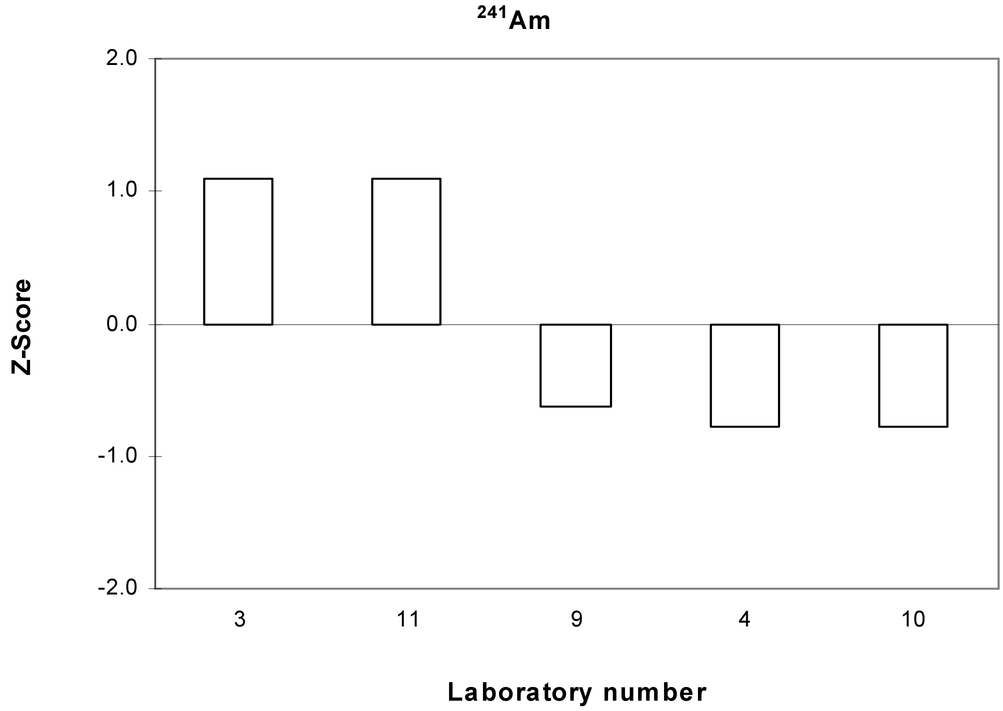

FIG.16. Z-score values of ^{241}Am.

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