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IAEA-RML-2014-01 Proficiency Test for Determination of Radionuclides in Sea Water

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IAEA-RML-2014-01 PROFICIENCY TEST FOR DETERMINATION OF RADIONUCLIDES IN SEA WATER

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INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

The Radiometrics Laboratory of the IAEA Environment Laboratories (NAEL) has been providing quality support products and services for the past 50 years. These include the organization of proficiency tests and laboratory comparisons, and the production of certified reference materials, including a wide range of marine sample matrices and radionuclide levels.

As part of these activities, a proficiency test was organized at the request of the Nuclear Regulation Authority (NRA) of Japan to test the performance of participating laboratories in an analysis of radionuclides in a seawater sample. This exercise was initiated to support laboratories in seawater analyses of tritium, strontium-90 and caesium isotopes in relation to the accident at the Fukushima Daiichi nuclear power plant, in March 2011, and subsequent contamination of the marine environment.

The IAEA wishes to thank all the participants and laboratories who took part in this proficiency test. The IAEA is also grateful to the Government of Monaco for its support.

The IAEA officers responsible for this publication were A.V. Harms, I. Osvath and D. Osborn of the IAEA Environment Laboratories.

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1. INTRODUCTION

The IAEA Environment Laboratories (IAEA-EL) in Monaco and Seibersdorf regularly organize proficiency tests (PT) for radionuclides in environmental samples to support laboratories in IAEA Member States. The organization and the results of a PT organised in cooperation with the Nuclear Regulation Authority (NRA) in Japan are described in this report.

2. MATERIAL AND METHODS

2.1. PROFICIENCY TEST OBJECTIVES

This proficiency test was initiated to support laboratories in seawater analyses of tritium, strontium-90 and caesium isotopes. The results of this exercise allowed the participating laboratories to evaluate their performance in the analysis of these radionuclides for this sample type.

2.2. PARTICIPANTS

A total of 30 laboratories from 15 countries participated in this exercise during the period June – August 2014. This included 12 laboratories from Japan and 18 laboratories from IAEA Member States in Europe and the USA. The full list of participants is given on pages 41–44.

2.3. MATERIAL DISTRIBUTION AND REPORTING REQUIREMENTS

A sample containing 5 L of filtered and acidified Mediterranean seawater spiked by the IAEA with the radionuclides ^{3}H, ^{90}Sr, ^{134}Cs and ^{137}Cs was distributed to the participants, with the massic activities only known to the IAEA. The massic activities were traceable to a standard provided by Czech Metrology Institute ČMI. The combined massic activities in the exercise samples were lower than the natural activity level of ^{40}K in seawater (which is approximately 12 Bq kg^{-1}). The ^{3}H, ^{90}Sr, ^{134}Cs and ^{137}Cs massic activities for the samples were approximately 2.8, 0.35, 0.12 and 0.31 Bq kg^{-1}, respectively. The sample also contained a non-active Cs-carrier at 10 mg kg^{-1} in order to stabilise the solution and to avoid adsorption of Cs to the container walls. No Sr was added to the sample as non-active Sr present naturally in seawater will act as a carrier for ^{90}Sr.

The participants were required to report to the IAEA the ^{3}H, ^{90}Sr, ^{134}Cs and ^{137}Cs massic activities (in Bq kg^{-1}) of the proficiency test sample combined with the associated uncertainties (also in Bq kg^{-1}). Additionally, the participants were asked to submit the following:

- A short description of the analytical method used for the sample analysis. The Information Sheet sent to the participants suggested for ^{3}H distillation followed by liquid scintillation counting. For ^{90}Sr precipitation ^{90}Sr precipitation from seawater as mixed Ca/Sr oxalate or carbonate follow by a standard ^{90}Sr procedure (e.g. a radiochemical procedure such as precipitation with fuming nitric acid, liquid-liquid extraction or extraction chromatography followed by a measurement technique such as gas-flow proportional counting or liquid scintillation counting). For ^{134}Cs and ^{137}Cs three methods were suggested: (i) direct gamma spectrometry, (ii) adsorption on AMP (ammonium molybdophosphate, $(NH_4)_3PO_4Mo_{12}O_{36}$) and subsequent gamma spectrometry or (iii) adsorption on copper hexacyanoferrate ($Cu_2[Fe(CN)_6]$) and subsequent gamma spectrometry;
- Type of calibration and software used for gamma ray spectrometry;
- Nuclear data used;
- An uncertainty budget for the measurement results.

The reference date for reporting massic activities was set at 1 August 2014. At this date, the ranges for the traceable massic activities in the proficiency test exercise samples sent to the participants were 2.78–2.83 Bq kg^{-1} ^{3}H, 0.3453–0.3515 Bq kg^{-1} ^{90}Sr, 0.1154–0.1175 Bq kg^{-1} ^{134}Cs and 0.3064–0.3118 Bq kg^{-1} ^{137}Cs, respectively (see Table 1).

TABLE 1. IAEA ASSIGNED VALUES

Participant	^{3}H massic activity (Bq kg^{-1})	^{90}Sr massic activity (Bq kg^{-1})	^{134}Cs massic activity (Bq kg^{-1})	^{137}Cs massic activity (Bq kg^{-1})
1*	2.82 ± 0.06	0.3502 ± 0.0021	0.1171 ± 0.0005	0.3107 ± 0.0019
2*	2.79 ± 0.06	0.3472 ± 0.0021	0.1161 ± 0.0005	0.3080 ± 0.0019
3*	2.80 ± 0.06	0.3484 ± 0.0021	0.1165 ± 0.0005	0.3091 ± 0.0019
4*	2.81 ± 0.06	0.3492 ± 0.0021	0.1167 ± 0.0005	0.3098 ± 0.0019
5*	2.79 ± 0.06	0.3463 ± 0.0021	0.1158 ± 0.0005	0.3072 ± 0.0019
6*	2.80 ± 0.06	0.3475 ± 0.0021	0.1162 ± 0.0005	0.3083 ± 0.0019
7*	2.80 ± 0.06	0.3481 ± 0.0021	0.1164 ± 0.0005	0.3088 ± 0.0019
8*	2.81 ± 0.06	0.3489 ± 0.0021	0.1166 ± 0.0005	0.3095 ± 0.0019
9*	2.80 ± 0.06	0.3480 ± 0.0021	0.1163 ± 0.0005	0.3087 ± 0.0019
10*	2.79 ± 0.06	0.3470 ± 0.0021	0.1160 ± 0.0005	0.3079 ± 0.0019
11*	2.82 ± 0.06	0.3500 ± 0.0021	0.1170 ± 0.0005	0.3105 ± 0.0019
12*	2.81 ± 0.06	0.3492 ± 0.0021	0.1168 ± 0.0005	0.3098 ± 0.0019
13	2.82 ± 0.06	0.3502 ± 0.0021	0.1171 ± 0.0005	0.3106 ± 0.0019
14	2.82 ± 0.06	0.3509 ± 0.0021	0.1173 ± 0.0005	0.3113 ± 0.0019
15	2.79 ± 0.06	0.3465 ± 0.0021	0.1159 ± 0.0005	0.3074 ± 0.0019
16	2.80 ± 0.06	0.3486 ± 0.0021	0.1165 ± 0.0005	0.3092 ± 0.0019
17	2.81 ± 0.06	0.3486 ± 0.0021	0.1166 ± 0.0005	0.3093 ± 0.0019
18	2.78 ± 0.06	0.3453 ± 0.0021	0.1154 ± 0.0005	0.3064 ± 0.0019
19	2.79 ± 0.06	0.3468 ± 0.0021	0.1160 ± 0.0005	0.3077 ± 0.0019
20	2.79 ± 0.06	0.3468 ± 0.0021	0.1159 ± 0.0005	0.3077 ± 0.0019
21	2.82 ± 0.06	0.3500 ± 0.0021	0.1170 ± 0.0005	0.3105 ± 0.0019
22	2.81 ± 0.06	0.3490 ± 0.0021	0.1167 ± 0.0005	0.3097 ± 0.0019
23	2.81 ± 0.06	0.3498 ± 0.0021	0.1169 ± 0.0005	0.3103 ± 0.0019
24	2.80 ± 0.06	0.3485 ± 0.0021	0.1165 ± 0.0005	0.3091 ± 0.0019
25	2.80 ± 0.06	0.3475 ± 0.0021	0.1162 ± 0.0005	0.3083 ± 0.0019
26	2.81 ± 0.06	0.3492 ± 0.0021	0.1167 ± 0.0005	0.3098 ± 0.0019
27	2.83 ± 0.06	0.3515 ± 0.0021	0.1175 ± 0.0005	0.3118 ± 0.0019
28	2.79 ± 0.06	0.3470 ± 0.0021	0.1160 ± 0.0005	0.3078 ± 0.0019
29	2.81 ± 0.06	0.3499 ± 0.0021	0.1170 ± 0.0005	0.3104 ± 0.0019
30	2.81 ± 0.06	0.3493 ± 0.0021	0.1168 ± 0.0005	0.3099 ± 0.0019

* Participant from Japan

3. PERFORMANCE CRITERIA

The methodology adopted for this exercise was slightly updated from the existing IAEA methodology. The scoring system took into account the accuracy, precision and trueness of the reported data and included in the evaluation both the combined standard uncertainty of the IAEA value and the combined standard uncertainty reported by the participating laboratories. The IAEA values, which were used for the data evaluation, were the certified values of radionuclides at the reference date. A result must pass three tests to be assigned the status "Accepted", otherwise it was assigned the status "Warning" or "Not accepted".

3.1. ACCURACY

The first step in producing a score for a result $Value_{Analyst}$ was the estimation of the bias. The relative bias between the Analyst's value and the IAEA target value was calculated as follows and expressed as a percentage:

$$Bias_{relative} = \frac{Value_{Analyst} - Value_{IAEA}}{Value_{IAEA}} \times 100\% \quad (1)$$

The absolute value of the relative bias was compared to the Maximal Accepted Relative Bias (MARB). Participants' results were scored as "Pass" for accuracy when:

$$|Bias_{relative}| \leq \text{MARB} \quad (2)$$

The MARB values used in this evaluation were 20% for both ^{134}Cs and ^{137}Cs and 25% for both ^{3}H and ^{90}Sr.

3.2. PRECISION AND TRUENESS

The precision *P* for each result was calculated according to the following equation:

$$P = \sqrt{\left(\frac{unc_{IAEA}}{Value_{IAEA}}\right)^2 + \left(\frac{unc_{Analyst}}{Value_{Analyst}}\right)^2} \times 100\% \quad (3)$$

The precision *P* was compared to the Limit of Accepted Precision (LAP). The participants' results were scored as "Pass" for precision when:

$$P \leq \text{LAP} \quad (4)$$

The Limit of Accepted Precision (LAP) values used in this evaluation were 20% for both ^{134}Cs and ^{137}Cs and 25% for both ^{3}H and ^{90}Sr.

The participants' results for trueness were scored as "Pass" when:

$$|Bias_{relative}| \leq \frac{Value_{Analyst}}{Value_{IAEA}} 2.58\, P \quad (5)$$

3.3. FINAL EVALUATION

For the final evaluation, all three scores were combined (see Table 2). The result was considered as "Accepted" if it passed all three tests. If the accuracy test was failed, the result was considered as "Not accepted". If the accuracy test was passed but one of the other two tests was failed, the result was assigned the "Warning" status. The "Warning" status will reflect cases in which the reported result was close enough to the assigned property value, but its associated uncertainty was deemed to be either too small or too large.

TABLE 2. PERFORMANCE EVALUATION CRITERIA

Accuracy	Precision	Trueness	Final evaluation
Pass	Pass	Pass	Accepted
Pass	Fail	Pass	Warning
Pass	Pass	Fail	Warning
Fail	Pass/Fail	Pass/Fail	Not accepted

These evaluation criteria can also be illustrated by plotting the relative bias against the relative uncertainty of the participants' result (see Figure 1). In the illustrated case, a relative uncertainty of 1% for the IAEA value is assumed with MARB and LAP limits of 20%.

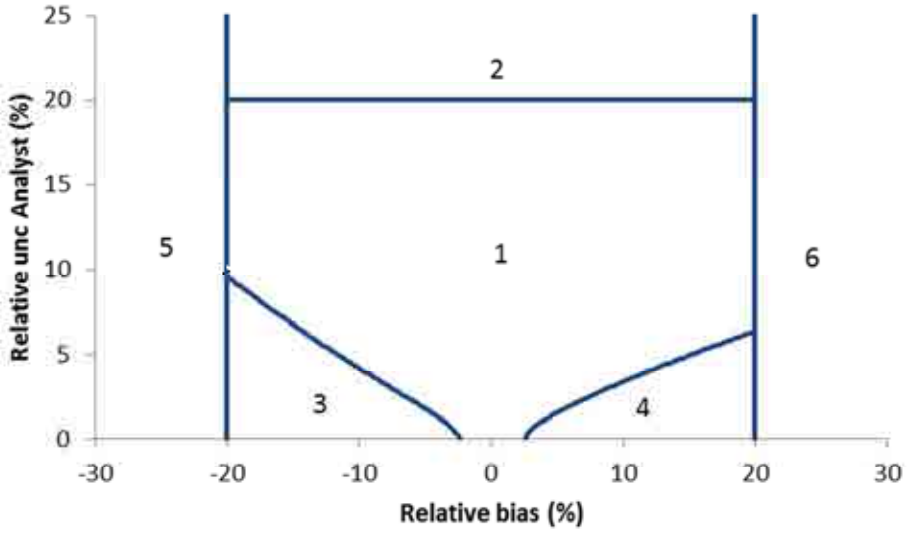

FIG. 1. Visualisation of performance evaluation criteria.

The plot consists of six zones (Zone 1 "Accepted"; Zones 2, 3 and 4 "Warning"; Zones 5 and 6 "Not accepted"), whose areas are defined by the three tests used above to evaluate the data. The areas of Zones 1, 3 and 4 are finite, while the areas of Zones 2, 5 and 6 are infinite. A result located in Zone 1 passes all three tests (evaluation "Accepted"). A result located in Zone 2 fails only the precision test as its associated uncertainty is deemed to be too large (evaluation: "Warning"). A result located in Zones 3 and 4 fails only the trueness test as its associated uncertainty is deemed to be too small (evaluation: "Warning"). A result located in Zones 5 and 6 fails (at least) the accuracy test as its relative bias is larger than the MARB (evaluation: "Not accepted").

3.4. COMPARISON OF PARTICIPANTS' VALUES WITH THE IAEA VALUES

The means and the uncertainties for the combined participants' results were calculated according to a method developed by Cox (i.e. the weighted mean of the largest consistent subset containing *p* results)[1] and subsequently compared with the IAEA values. The mean of the combined participants' results, $Value_{Combined}$, was tested against the IAEA value, $Value_{IAEA}$, using this equation:

$$t = \frac{Value_{Combined} - Value_{IAEA}}{\sqrt{(unc_{Combined})^2 + (unc_{IAEA})^2}} \quad (6)$$

The effective degrees of freedom v_{eff} were determined with the Welch-Satterthwaite equation. The effective degrees of freedom v_{eff} were rounded and the critical value t_{crit} for this value was identified.

[1] Cox, M.G., 2007. The evaluation of key comparison data: determining the largest consistent subset. Metrologia 44 187-200

The criterion for passing the *t* test was:

$$|t| < t_{crit} \quad (7)$$

If the absolute value of *t* was greater than the critical value t_{crit}, this indicates there was a significant difference between the combined participants' results and the IAEA value.

4. RESULTS AND DISCUSSION

In total 90 measurement results were reported by 30 laboratories from 15 countries for ^{3}H, ^{90}Sr, ^{134}Cs and ^{137}Cs. The evaluation of these results showed that 74% of all reported results were "Accepted", while 13% of the individual measurement results were "Not accepted" with the remaining 13% having the "Warning" status. The performance evaluation for ^{3}H, ^{90}Sr, ^{134}Cs and ^{137}Cs is summarised in Table 3. The subset of the 12 Japanese participants' results showed that 86% of all reported results were "Accepted", while 3% of the results were "Not accepted", with the remaining 11% having the "Warning" status.

TABLE 3. SUMMARY EVALUATION OF THE RADIONUCLIDES REPORTED

Radionuclide	Number of submitted results	Accepted	Warning	Not accepted
^{3}H	17 (7)	12 (7)	1 (0)	4 (0)
^{90}Sr	17 (6)	12 (5)	4 (1)	1 (0)
^{134}Cs	27 (11)	20 (9)	3 (2)	4 (0)
^{137}Cs	29 (11)	22 (9)	4 (1)	3 (1)

NOTE: The numbers in brackets represent the subset of Japanese results

For ^{134}Cs there was a significant negative bias of the combined participants' results (–9.4%), while there was no significant bias for ^{3}H (–0.3%), ^{90}Sr (–0.4%) and ^{137}Cs (1.2%) (see Table 4). For ^{3}H, ^{90}Sr and ^{137}Cs about half of the participants' results showed a negative bias (53%, 47% and 48% of the results, respectively), while for ^{134}Cs the 19 of participants' results (70% of the results) showed a negative bias. Coincidence summing is a problem for ^{134}Cs as it leads to signal loss and hence underestimation of the activity levels for this radionuclide. It is clear from the results that some participants did not make a sufficient correction for coincidence summing. For the combined Japanese results, there were no significant relative differences with the IAEA values for all four radionuclides. Table 5 summarises the data evaluation sorted by laboratory code.

TABLE 4. COMPARISON OF THE COMBINED PARTICIPANTS' RESULTS WITH THE IAEA VALUE

Nuclide	Combined participants' result (Bq kg^{-1})	IAEA value (Bq kg^{-1})	Size of the LCS* (%)	t-value	Critical t-value	Bias (%)
^{3}H	2.80 ± 0.03	2.807 ± 0.010	14 (82%)	–0.25	2.12	–0.3
^{90}Sr	0.347 ± 0.006	0.3486 ± 0.0017	13 (76%)	–0.20	2.16	–0.4
^{134}Cs	0.1055 ± 0.0013	0.1165 ± 0.0005	26 (96%)	–7.81	2.04	–9.4
^{137}Cs	0.3128 ± 0.0024	0.3092 ± 0.0013	26 (90%)	1.30	2.02	1.2

*Size of the LCS (largest consistent subset) denotes the percentage of the returned results contributing to combined participants' results

TABLE 5. SUMMARY EVALUATION

Lab Code	^{3}H	^{90}Sr	^{134}Cs	^{137}Cs
1*	A	A	A	A
2*		A	A	A
3*	A			
4*			A	A
5*	A	A	A	W
6*			A	NA
7*	A	A	A	A
8*			A	A
9*			A	A
10*	A	A	A	A
11*	A	W	W	A
12*	A		W	A
13	NA		NA	A
14		NA		W
15		A	A	A
16	A		A	A
17	NA		A	A
18			W	A
19		A	A	A
20				NA
21			A	A
22	NA	A	NA	W
23	A	A	NA	NA
24			A	A
25		W	NA	W
26	NA	W	A	A
27	W	A	A	A
28	A	A	A	A
29	A	A	A	A
30	A	W	A	A

* Participant from Japan

The performance evaluation sorted by radionuclide and the bias plots are presented in Appendix I (see Tables 6–9 and Figures 2–9). In the bias plots, the 'Accepted' results are represented by dark blue points. 'Warning' and 'Not accepted' results are represented by the yellow and red points, respectively. The error bars represent the standard uncertainties of the bias (with a coverage factor of $k = 1$). The dotted lines represent a relative bias of ± 25% or ± 20% (Maximum Accepted Bias for $^{3}H/^{90}Sr$ and $^{134}Cs/^{137}Cs$, respectively). The performance evaluation sorted by laboratory code is presented in Appendix II. All laboratories reported their values with standard uncertainties ($k = 1$). However, a large spread in the submitted uncertainties was observed with relative uncertainties (at $k = 1$) ranging from 1.1% to 31% for ^{3}H, from 1.2% to 21% for ^{90}Sr, from 1.1% to 38% for ^{134}Cs and from 0.6% to 38% for ^{137}Cs. However, most reported relative uncertainties were in the range of 4% – 10% for ^{90}Sr and ^{137}Cs and 4% – 15% for ^{3}H and ^{134}Cs.

For ^{3}H, practically all participants performed a distillation of the seawater samples, followed by liquid scintillation counting (LSC). Two participants (3 and 16) performed electrolytic enrichment after distillation (and obtained excellent results with small uncertainties of less than 2% at $k = 1$). The direct measurements after distillation yielded slightly larger uncertainties between 4% – 15%.

For ^{90}Sr, all participants used gas-flow proportional counting (GPC) of chemically separated ^{90}Y as the analysis technique, except Participants 26 and 27 who used LSC. Chemical separation techniques used included precipitations of Sr-oxalate or Sr-carbonate, barium chromate precipitations, nitric acid precipitations, cation-exchange chromatography, Sr-extraction chromatography and direct liquid-liquid extraction of ^{90}Y with HDEHP. No significant difference between the performances of the chemical separation techniques is apparent.

For ^{134}Cs and ^{137}Cs, a large majority of the participants measured the seawater samples directly with gamma spectrometry, while a small minority of laboratories either used a pre-concentration technique (e.g. adsorption on either ammonium molybdophosphate or hexacyanoferrates containing either copper, nickel or cobalt) to separate the caesium radionuclides from the seawater matrix followed by gamma spectrometry (Participants 1, 5, 18 and 23) or they used a combination of the two techniques (Participant 19). No significant difference in the performance between the two techniques is apparent although in general the reported relative uncertainties (at $k = 1$) for the direct measurements were somewhat larger, typically between 5% – 15% for the direct measurements and between 2% – 8% for the pre-concentration methods.

APPENDIX I. PERFORMANCE EVALUATION TABLES SORTED BY RADIONUCLIDE

TABLE 6. EVALUATION RESULTS FOR ^{3}H

Lab Code	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Rel. bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
1*	2.83	0.16	2.82	0.06	0.5	6.0	16	Pass	Pass	Pass	Accepted
2*	< 1.6	–	2.79	0.06	–	–	–	–	–	–	Not evaluated
3*	2.780	0.031	2.80	0.06	–0.9	2.3	6.0	Pass	Pass	Pass	Accepted
4*	–	–	2.81	0.06	–	–	–	–	–	–	Not reported
5*	3.04	0.45	2.79	0.06	9.0	15	41	Pass	Pass	Pass	Accepted
6*	–	–	2.80	0.06	–	–	–	–	–	–	Not reported
7*	2.70	0.20	2.80	0.06	–3.6	7.7	19	Pass	Pass	Pass	Accepted
8*	–	–	2.81	0.06	–	–	–	–	–	–	Not reported
9*	–	–	2.80	0.06	–	–	–	–	–	–	Not reported
10*	2.43	0.16	2.79	0.06	–13	6.9	16	Pass	Pass	Pass	Accepted
11*	2.90	0.17	2.82	0.06	3.0	6.2	16	Pass	Pass	Pass	Accepted
12*	2.90	0.29	2.81	0.06	3.2	10	27	Pass	Pass	Pass	Accepted
13	6.32	0.56	2.82	0.06	124	9.1	51	Fail	Pass	Fail	Not accepted
14	–	–	2.82	0.06	–	–	–	–	–	–	Not reported
15	< 5.35	–	2.79	0.06	–	–	–	–	–	–	Not evaluated
16	2.910	0.055	2.80	0.06	3.8	2.8	7.3	Pass	Pass	Pass	Accepted

continues

continued											
Lab Code	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Rel. bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
17	1.75	0.45	2.81	0.06	–38	26	42	Fail	Fail	Pass	Not accepted
18	–	–	2.78	0.06	–	–	–	–	–	–	Not reported
19	–	–	2.79	0.06	–	–	–	–	–	–	Not reported
20	–	–	2.79	0.06	–	–	–	–	–	–	Not reported
21	–	–	2.82	0.06	–	–	–	–	–	–	Not reported
22	2.03	0.31	2.81	0.06	–28	15	29	Fail	Pass	Pass	Not accepted
23	2.9	0.4	2.81	0.06	3.1	14	37	Pass	Pass	Pass	Accepted
24	–	–	2.80	0.06	–	–	–	–	–	–	Not reported
25	–	–	2.80	0.06	–	–	–	–	–	–	Not reported
26	1.71	0.15	2.81	0.06	–39	9.0	15	Fail	Pass	Fail	Not accepted
27	2.6	0.8	2.83	0.06	–8.0	31	73	Pass	Fail	Pass	Warning
28	2.85	0.12	2.79	0.06	2.0	4.7	12	Pass	Pass	Pass	Accepted
29	2.2	0.3	2.81	0.06	–22	14	28	Pass	Pass	Pass	Accepted
30	2.72	0.11	2.81	0.06	–3.2	4.5	11	Pass	Pass	Pass	Accepted

TABLE 7. EVALUATION RESULTS FOR ^{90}Sr

Lab Code	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
1*	0.305	0.025	0.3502	0.0021	–13	8.2	18	Pass	Pass	Pass	Accepted
2*	0.37	0.02	0.3472	0.0021	6.6	5.4	15	Pass	Pass	Pass	Accepted
3*	–	–	0.3484	0.0021	–	–	–	–	–	–	Not reported
4*	–	–	0.3492	0.0021	–	–	–	–	–	–	Not reported
5*	0.358	0.020	0.3463	0.0021	3.4	5.6	15	Pass	Pass	Pass	Accepted
6*	–	–	0.3475	0.0021	–	–	–	–	–	–	Not reported
7*	0.343	0.019	0.3481	0.0021	–1.5	5.6	14	Pass	Pass	Pass	Accepted
8*	–	–	0.3489	0.0021	–	–	–	–	–	–	Not reported
9*	–	–	0.3480	0.0021	–	–	–	–	–	–	Not reported
10*	0.345	0.029	0.3470	0.0021	–0.6	8.4	22	Pass	Pass	Pass	Accepted
11*	0.3000	0.0037	0.3500	0.0021	–14	1.4	3.1	Pass	Pass	Fail	Warning
12*	–	–	0.3492	0.0021	–	–	–	–	–	–	Not reported
13	–	–	0.3502	0.0021	–	–	–	–	–	–	Not reported
14	0.52	0.08	0.3509	0.0021	48	15	59	Fail	Pass	Pass	Not accepted
15	0.34	0.02	0.3465	0.0021	–1.9	5.9	15	Pass	Pass	Pass	Accepted
16	–	–	0.3486	0.0021	–	–	–	–	–	–	Not reported
17	–	–	0.3486	0.0021	–	–	–	–	–	–	Not reported
18	–	–	0.3453	0.0021	–	–	–	–	–	–	Not reported

continues

continued

Lab Code	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
19	0.296	0.023	0.3468	0.0021	–15	7.8	17	Pass	Pass	Pass	Accepted
20	–	–	0.3468	0.0021	–	–	–	–	–	–	Not reported
21	–	–	0.3500	0.0021	–	–	–	–	–	–	Not reported
22	0.38	0.08	0.3490	0.0021	8.9	21	59	Pass	Pass	Pass	Accepted
23	0.38	0.04	0.3498	0.0021	9.8	10	28	Pass	Pass	Pass	Accepted
24	–	–	0.3485	0.0021	–	–	–	–	–	–	Not reported
25	0.390	0.011	0.3475	0.0021	12	2.9	8.3	Pass	Pass	Fail	Warning
26	0.386	0.010	0.3492	0.0021	11	2.5	7.2	Pass	Pass	Fail	Warning
27	0.36	0.02	0.3515	0.0021	2.4	5.6	15	Pass	Pass	Pass	Accepted
28	0.359	0.016	0.3470	0.0021	3.5	4.5	12	Pass	Pass	Pass	Accepted
29	0.342	0.016	0.3499	0.0021	–2.3	4.7	12	Pass	Pass	Pass	Accepted
30	0.310	0.012	0.3493	0.0021	–11	3.9	9.0	Pass	Pass	Fail	Warning

TABLE 8. EVALUATION RESULTS FOR ^{134}Cs

Lab Code	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
1*	0.113	0.009	0.1171	0.0005	–3.5	8.0	20	Pass	Pass	Pass	Accepted
2*	0.114	0.013	0.1161	0.0005	–1.8	11	29	Pass	Pass	Pass	Accepted
3*	–	–	0.1165	0.0005	–	–	–	–	–	–	Not reported
4*	0.127	0.013	0.1167	0.0005	8.8	10	29	Pass	Pass	Pass	Accepted
5*	0.104	0.005	0.1158	0.0005	–10	5.2	12	Pass	Pass	Pass	Accepted
6*	0.135	0.019	0.1162	0.0005	16	14	42	Pass	Pass	Pass	Accepted
7*	0.131	0.026	0.1164	0.0005	13	20	58	Pass	Pass	Pass	Accepted
8*	0.137	0.022	0.1166	0.0005	17	16	49	Pass	Pass	Pass	Accepted
9*	0.106	0.018	0.1163	0.0005	–8.9	17	40	Pass	Pass	Pass	Accepted
10*	0.116	0.016	0.1160	0.0005	0.0	14	36	Pass	Pass	Pass	Accepted
11*	0.110	0.029	0.1170	0.0005	–6.0	26	64	Pass	Fail	Pass	Warning
12*	0.10	0.03	0.1168	0.0005	–14	30	66	Pass	Fail	Pass	Warning
13	0.093	0.004	0.1171	0.0005	–21	4.3	8.9	Fail	Pass	Fail	Not accepted
14	<0.3	–	0.1173	0.0005	–	–	–	–	–	–	Not evaluated
15	0.107	0.006	0.1159	0.0005	–7.6	5.2	12	Pass	Pass	Pass	Accepted
16	0.118	0.008	0.1165	0.0005	1.3	6.8	18	Pass	Pass	Pass	Accepted
17	0.110	0.016	0.1166	0.0005	–6.1	15	36	Pass	Pass	Pass	Accepted
18	0.105	0.002	0.1154	0.0005	–9.1	1.9	4.6	Pass	Pass	Fail	Warning

continues

continued											
Lab Code	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
19	0.106	0.005	0.1160	0.0005	–8.6	4.7	11	Pass	Pass	Pass	Accepted
20	–	–	0.1159	0.0005	–	–	–	–	–	–	Not reported
21	0.117	0.013	0.1170	0.0005	0.0	11	29	Pass	Pass	Pass	Accepted
22	0.071	0.027	0.1167	0.0005	–39	38	60	Fail	Fail	Pass	Not accepted
23	0.093	0.007	0.1169	0.0005	–20	7.5	15	Fail	Pass	Fail	Not accepted
24	0.120	0.009	0.1165	0.0005	3.0	7.5	20	Pass	Pass	Pass	Accepted
25	0.1590	0.0017	0.1162	0.0005	37	1.1	3.9	Fail	Pass	Fail	Not accepted
26	0.098	0.010	0.1167	0.0005	–16	10	22	Pass	Pass	Pass	Accepted
27	0.107	0.010	0.1175	0.0005	–9.0	9.4	22	Pass	Pass	Pass	Accepted
28	0.119	0.009	0.1160	0.0005	2.6	7.6	20	Pass	Pass	Pass	Accepted
29	0.116	0.011	0.1170	0.0005	–0.8	9.5	24	Pass	Pass	Pass	Accepted
30	0.110	0.008	0.1168	0.0005	–5.8	7.3	18	Pass	Pass	Pass	Accepted

TABLE 9. EVALUATION RESULTS FOR ^{137}Cs

Lab Code	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
1*	0.326	0.015	0.3107	0.0019	4.9	4.6	13	Pass	Pass	Pass	Accepted
2*	0.304	0.017	0.3080	0.0019	–1.3	5.6	14	Pass	Pass	Pass	Accepted
3*	–	–	0.3091	0.0019	–	–	–	–	–	–	Not reported
4*	0.312	0.016	0.3098	0.0019	0.7	5.1	13	Pass	Pass	Pass	Accepted
5*	0.279	0.010	0.3072	0.0019	–9.2	3.6	8.4	Pass	Pass	Fail	Warning
6*	0.372	0.030	0.3083	0.0019	21	8.1	25	Fail	Pass	Pass	Not accepted
7*	0.322	0.033	0.3088	0.0019	4.3	10	28	Pass	Pass	Pass	Accepted
8*	0.286	0.024	0.3095	0.0019	–7.6	8.3	20	Pass	Pass	Pass	Accepted
9*	0.321	0.024	0.3087	0.0019	4.0	7.5	20	Pass	Pass	Pass	Accepted
10*	0.297	0.024	0.3079	0.0019	–3.5	8.1	20	Pass	Pass	Pass	Accepted
11*	0.290	0.037	0.3105	0.0019	–6.6	13	31	Pass	Pass	Pass	Accepted
12*	0.350	0.024	0.3098	0.0019	13	6.9	20	Pass	Pass	Pass	Accepted
13	0.281	0.022	0.3106	0.0019	–9.5	7.9	18	Pass	Pass	Pass	Accepted
14	0.29	0.11	0.3113	0.0019	–6.8	38	91	Pass	Fail	Pass	Warning
15	0.310	0.025	0.3074	0.0019	0.8	8.1	21	Pass	Pass	Pass	Accepted
16	0.275	0.021	0.3092	0.0019	–11	7.7	18	Pass	Pass	Pass	Accepted
17	0.327	0.017	0.3093	0.0019	5.6	5.3	14	Pass	Pass	Pass	Accepted
18	0.295	0.006	0.3064	0.0019	–3.7	2.1	5.3	Pass	Pass	Pass	Accepted

continues

continued

Lab Code	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
19	0.309	0.014	0.3077	0.0019	0.4	4.6	12	Pass	Pass	Pass	Accepted
20	0.23	0.02	0.3077	0.0019	–25	8.7	17	Fail	Pass	Fail	Not accepted
21	0.309	0.014	0.3105	0.0019	–0.5	4.5	11	Pass	Pass	Pass	Accepted
22	0.27	0.06	0.3097	0.0019	–13	22	50	Pass	Fail	Pass	Warning
23	0.247	0.018	0.3103	0.0019	–20	7.3	15	Fail	Pass	Fail	Not accepted
24	0.330	0.024	0.3091	0.0019	6.7	7.3	20	Pass	Pass	Pass	Accepted
25	0.318	0.002	0.3083	0.0019	3.1	0.9	2.3	Pass	Pass	Fail	Warning
26	0.322	0.018	0.3098	0.0019	3.8	5.5	15	Pass	Pass	Pass	Accepted
27	0.298	0.014	0.3118	0.0019	–4.4	4.7	12	Pass	Pass	Pass	Accepted
28	0.330	0.021	0.3078	0.0019	7.2	6.4	18	Pass	Pass	Pass	Accepted
29	0.333	0.025	0.3104	0.0019	7.3	7.5	21	Pass	Pass	Pass	Accepted
30	0.340	0.017	0.3099	0.0019	9.7	5.0	14	Pass	Pass	Pass	Accepted

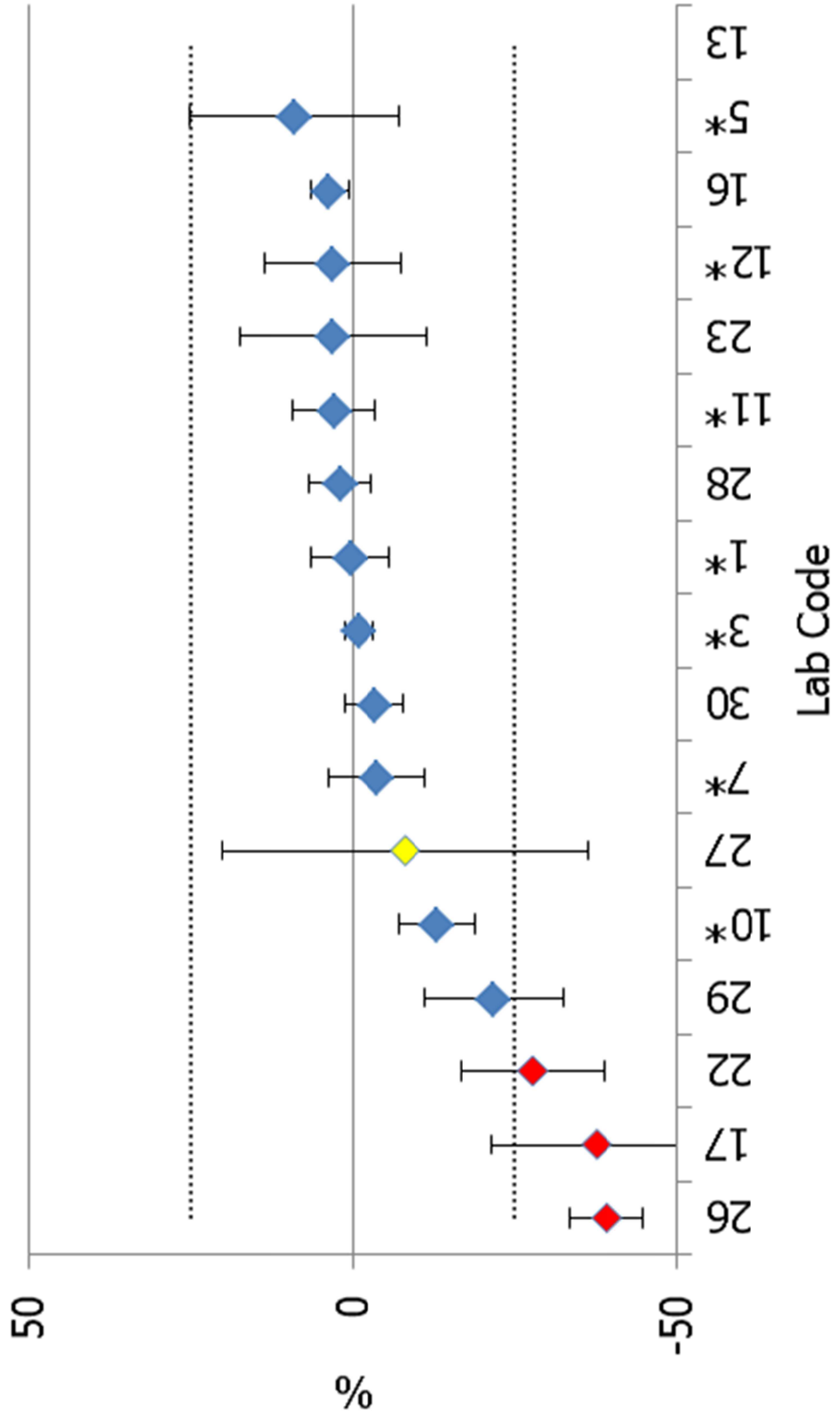

FIG. 2. H-3 bias.

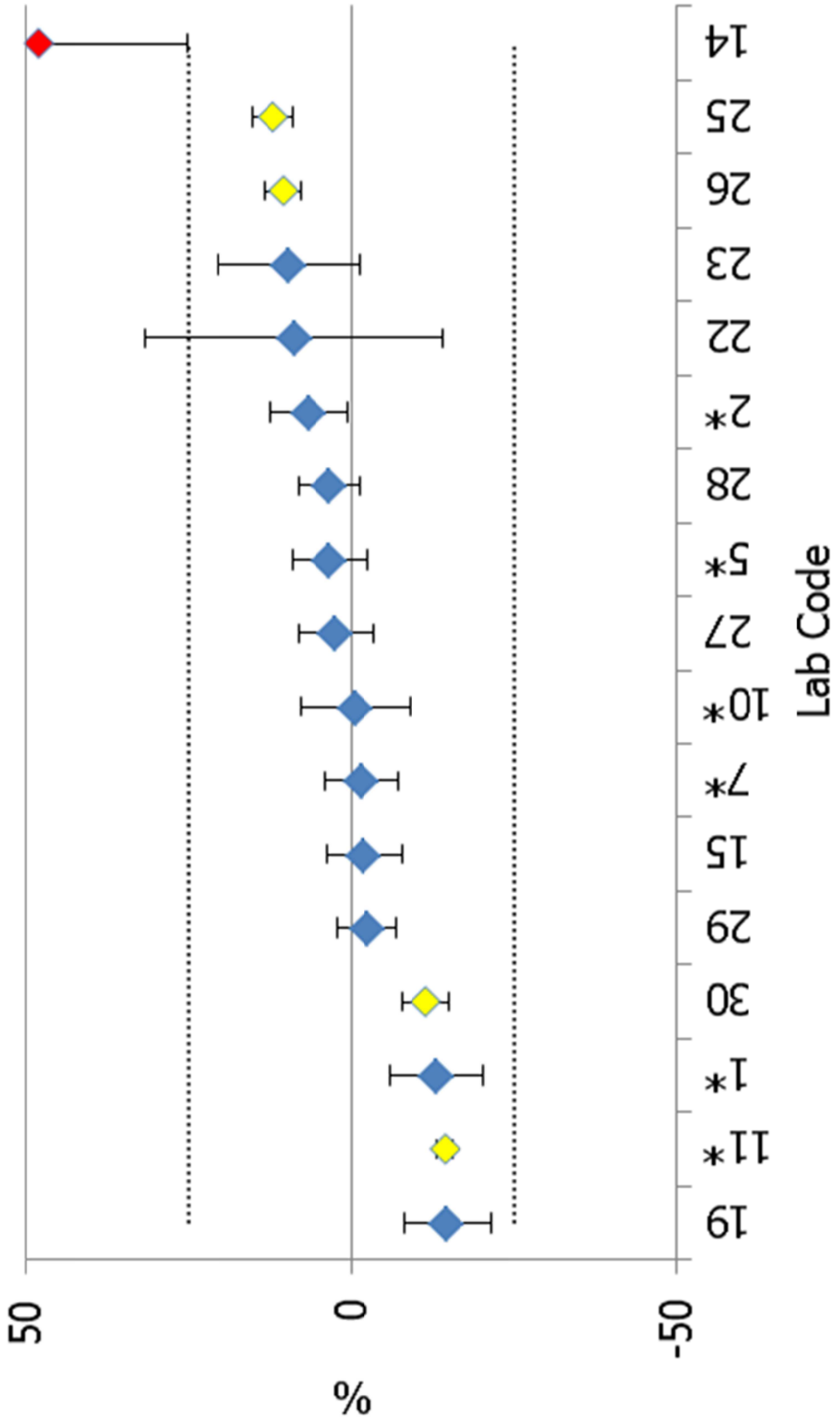

FIG. 3. Sr-90 bias.

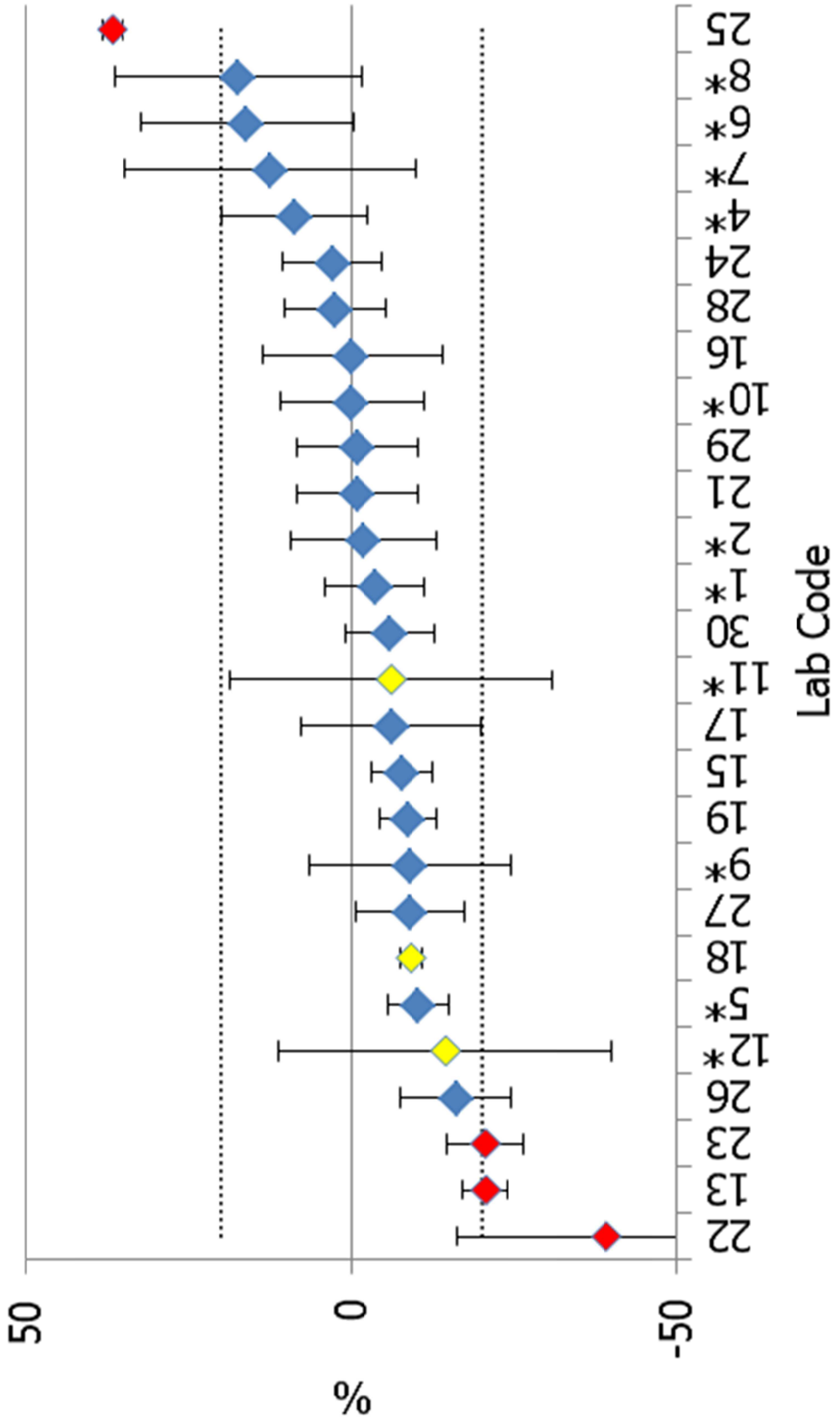

FIG. 4. Cs-134 bias.

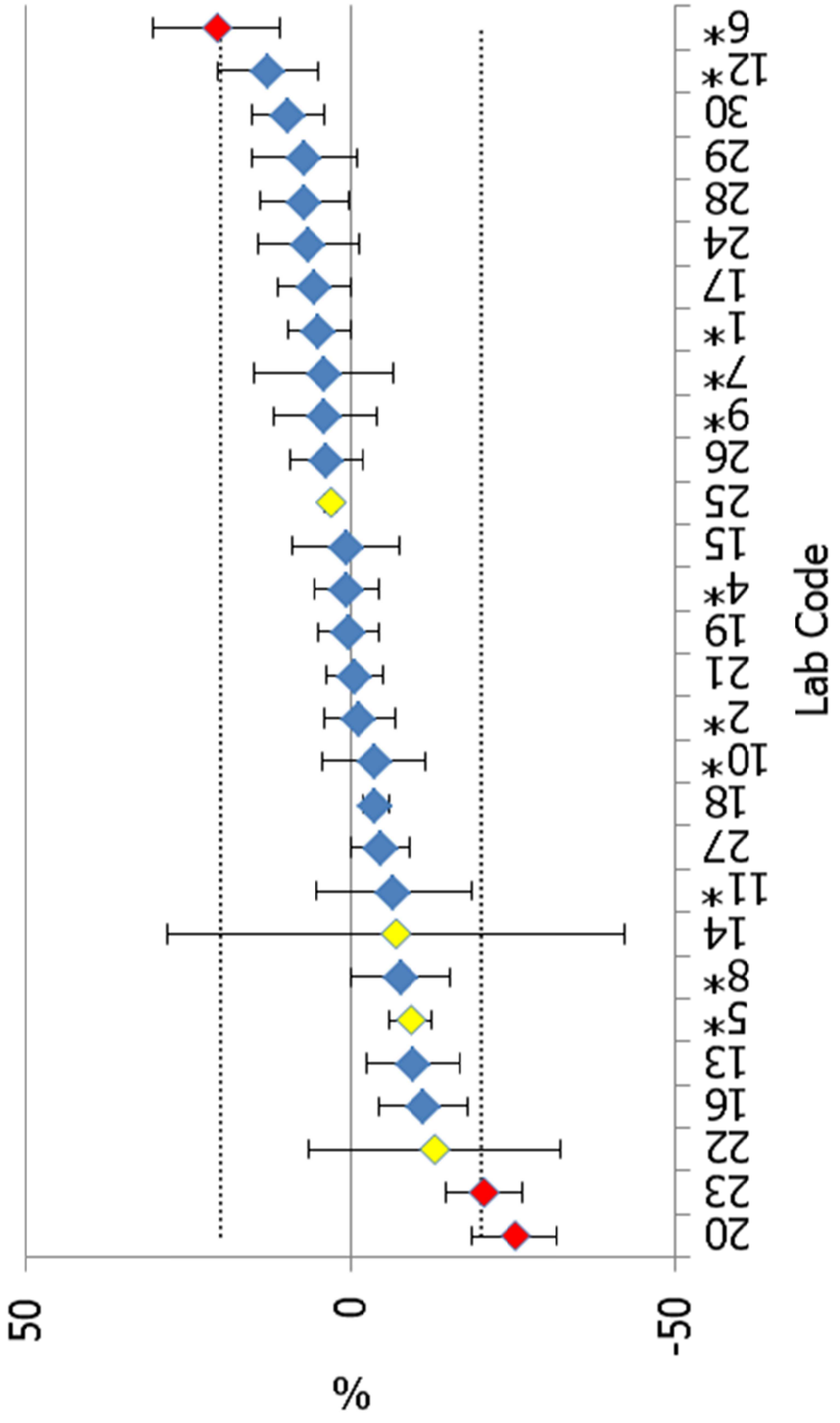

FIG. 5. Cs-137 bias.

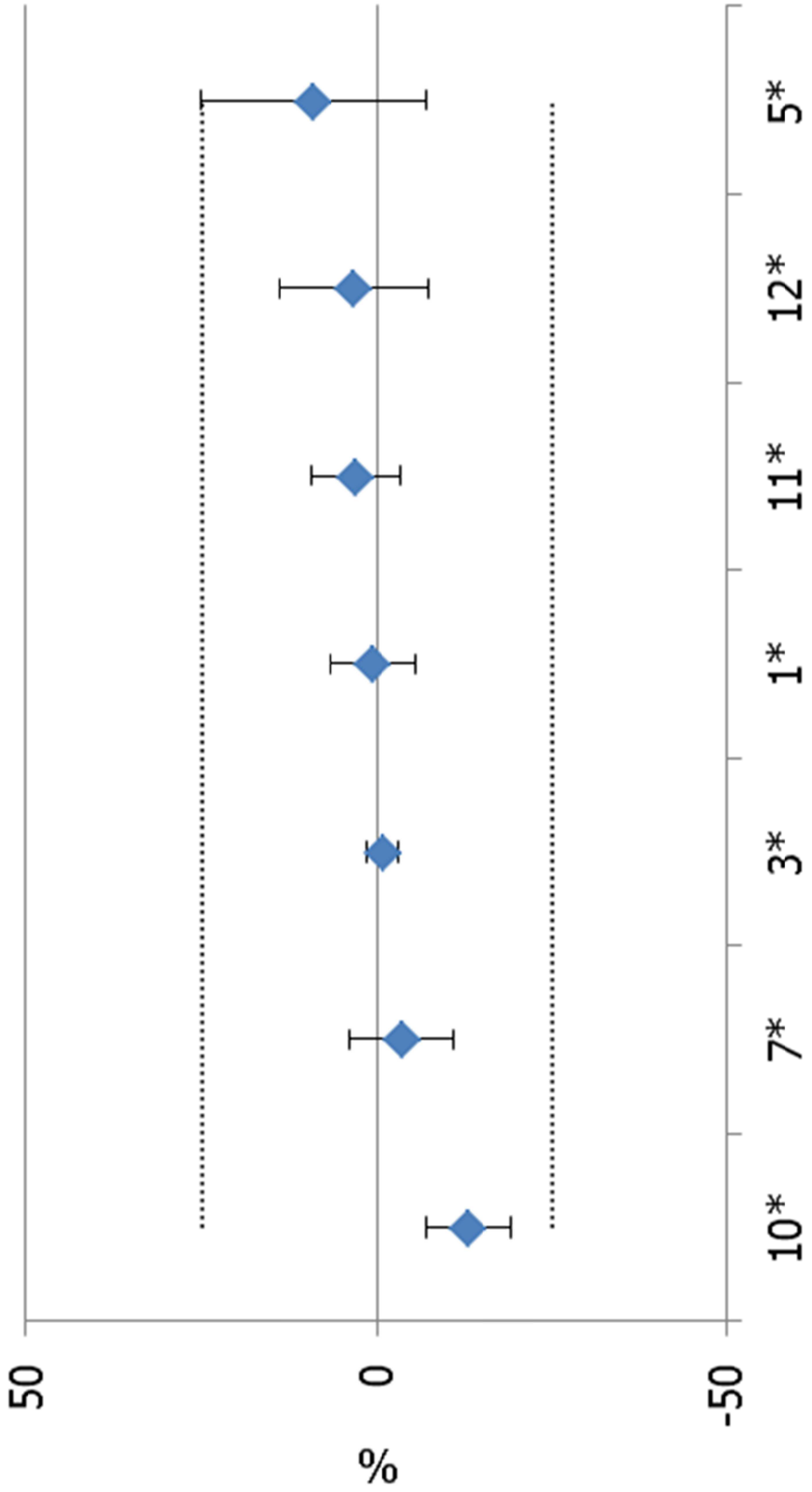

FIG. 6. H-3 bias Japanese participants.

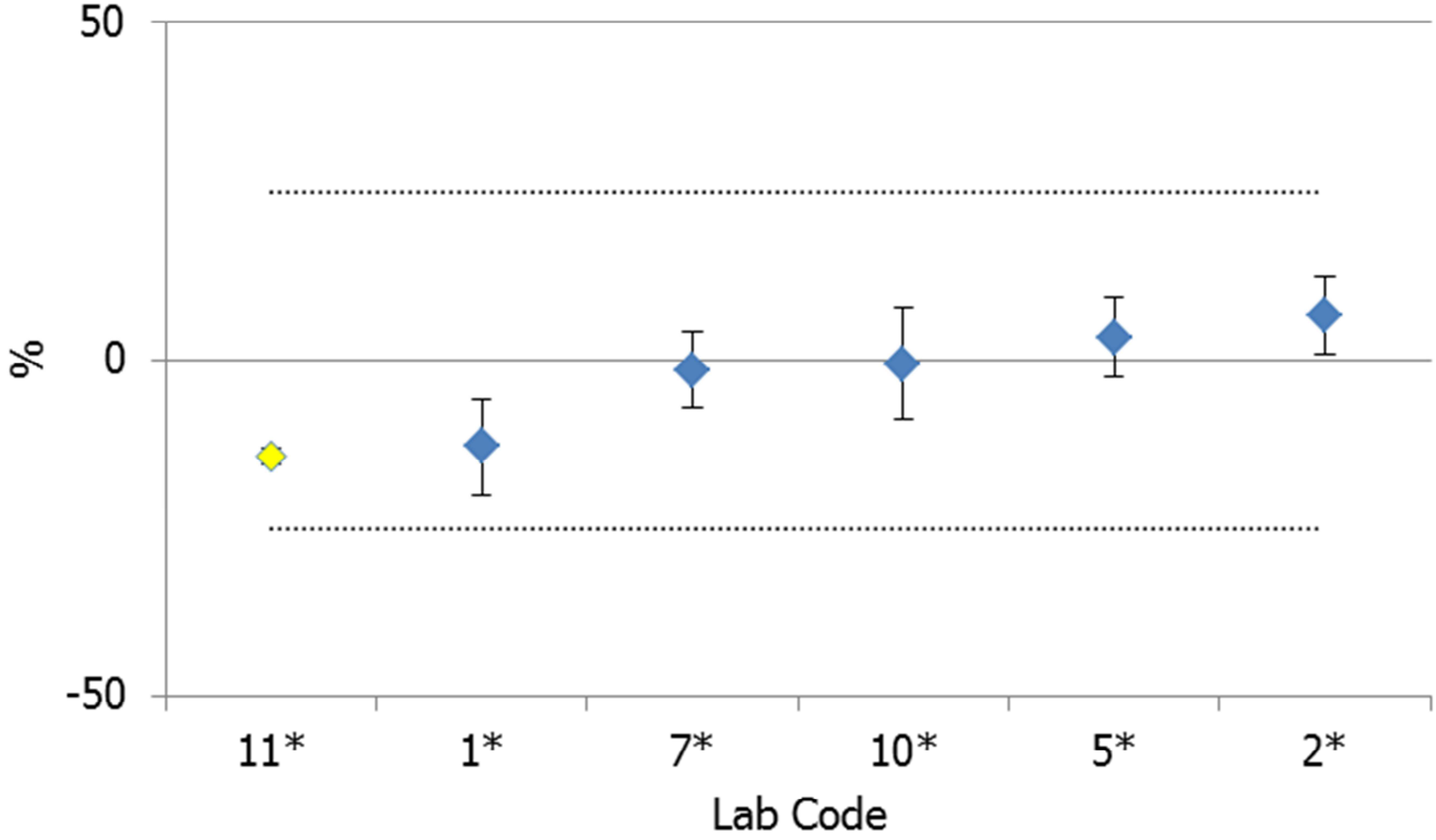

FIG. 7. Sr-90 bias Japanese participants.

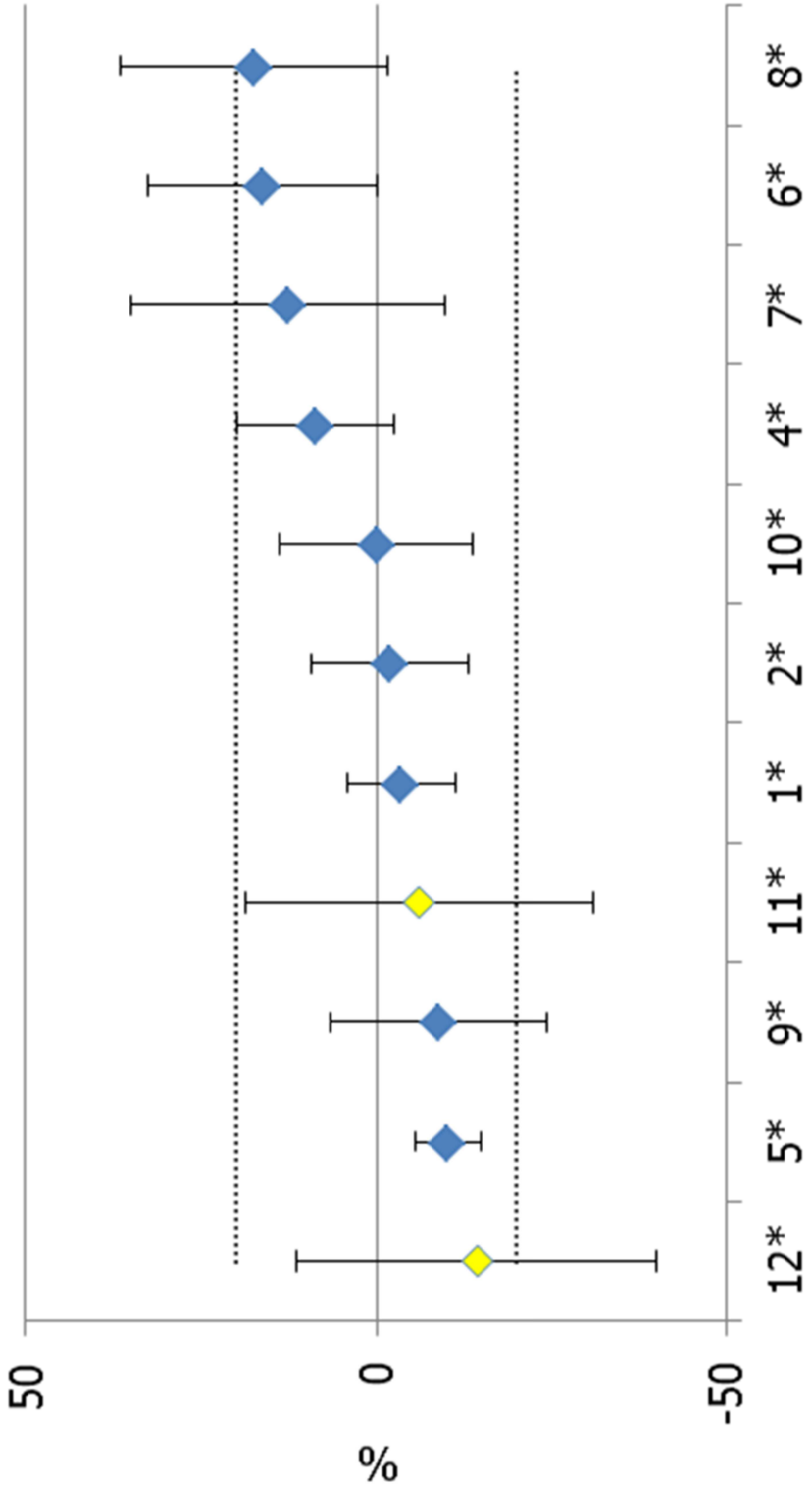

FIG. 8. Cs-134 bias Japanese participants.

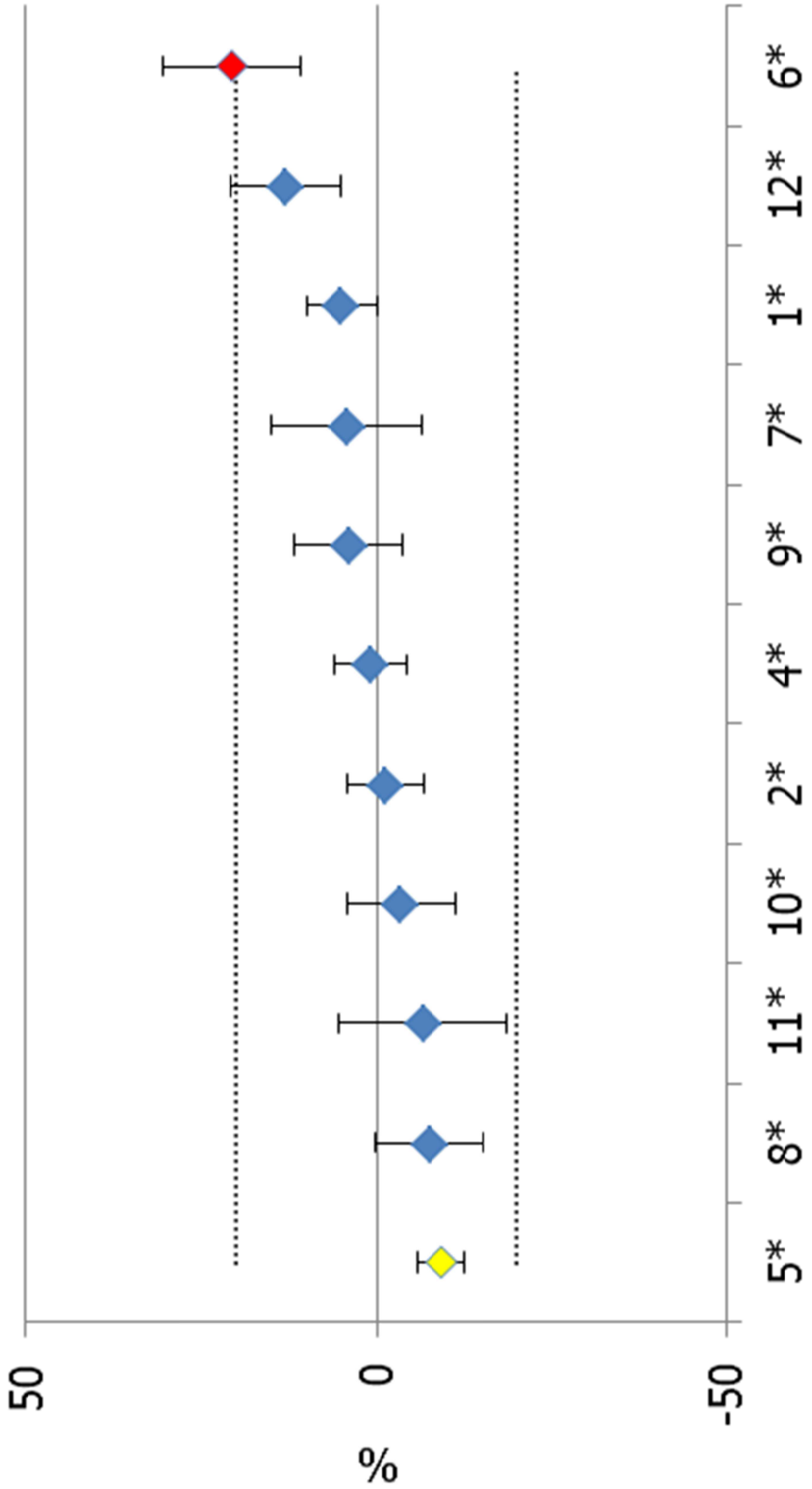

FIG. 9. Cs-137 bias Japanese participants.

APPENDIX II. PERFORMANCE EVALUATION TABLES SORTED BY LABORATORY CODE

LABORATORY CODE 1*.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	2.83	0.16	2.82	0.06	0.5	6.0	16	Pass	Pass	Pass	Accepted
^{90}Sr	0.305	0.025	0.3502	0.0021	–13	8.2	18	Pass	Pass	Pass	Accepted
^{134}Cs	0.113	0.009	0.1171	0.0005	–3.5	8.0	20	Pass	Pass	Pass	Accepted
^{137}Cs	0.326	0.015	0.3107	0.0019	4.9	4.6	13	Pass	Pass	Pass	Accepted

LABORATORY CODE 2*.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	< 1.6	–	2.79	0.06	–	–	–	–	–	–	Not evaluated
^{90}Sr	0.37	0.02	0.3472	0.0021	6.6	5.4	15	Pass	Pass	Pass	Accepted
^{134}Cs	0.114	0.013	0.1161	0.0005	–1.8	11	29	Pass	Pass	Pass	Accepted
^{137}Cs	0.304	0.017	0.3080	0.0019	–1.3	5.6	14	Pass	Pass	Pass	Accepted

LABORATORY CODE 3*.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	2.780	0.031	2.80	0.06	–0.9	2.3	6.0	Pass	Pass	Pass	Accepted
^{90}Sr	–	–	0.3484	0.0021	–	–	–	–	–	–	Not reported
^{134}Cs	–	–	0.1165	0.0005	–	–	–	–	–	–	Not reported
^{137}Cs	–	–	0.3091	0.0019	–	–	–	–	–	–	Not reported

LABORATORY CODE 4*.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	–	–	2.81	0.06	–	–	–	–	–	–	Not reported
^{90}Sr	–	–	0.3492	0.0021	–	–	–	–	–	–	Not reported
^{134}Cs	0.127	0.013	0.1167	0.0005	8.8	10	29	Pass	Pass	Pass	Accepted
^{137}Cs	0.312	0.016	0.3098	0.0019	0.7	5.1	13	Pass	Pass	Pass	Accepted

LABORATORY CODE 5*.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	3.04	0.45	2.79	0.06	9.0	15	41	Pass	Pass	Pass	Accepted
^{90}Sr	0.358	0.020	0.3463	0.0021	3.4	5.6	15	Pass	Pass	Pass	Accepted
^{134}Cs	0.104	0.005	0.1158	0.0005	–10	5.2	12	Pass	Pass	Pass	Accepted
^{137}Cs	0.279	0.010	0.3072	0.0019	–9.2	3.6	8.4	Pass	Pass	Fail	Warning

LABORATORY CODE 6*.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	–	–	2.80	0.06	–	–	–	–	–	–	Not reported
^{90}Sr	–	–	0.3475	0.0021	–	–	–	–	–	–	Not reported
^{134}Cs	0.135	0.019	0.1162	0.0005	16	14	42	Pass	Pass	Pass	Accepted
^{137}Cs	0.372	0.030	0.3083	0.0019	21	8.1	25	Fail	Pass	Pass	Not accepted

LABORATORY CODE 7*.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	2.70	0.20	2.80	0.06	–3.6	7.7	19	Pass	Pass	Pass	Accepted
^{90}Sr	0.343	0.019	0.3481	0.0021	–1.5	5.6	14	Pass	Pass	Pass	Accepted
^{134}Cs	0.131	0.026	0.1164	0.0005	13	20	58	Pass	Pass	Pass	Accepted
^{137}Cs	0.322	0.033	0.3088	0.0019	4.3	10	28	Pass	Pass	Pass	Accepted

LABORATORY CODE 8*.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	–	–	2.81	0.06	–	–	–	–	–	–	Not reported
^{90}Sr	–	–	0.3489	0.0021	–	–	–	–	–	–	Not reported
^{134}Cs	0.137	0.022	0.1166	0.0005	17	16	49	Pass	Pass	Pass	Accepted
^{137}Cs	0.286	0.024	0.3095	0.0019	–7.6	8.3	20	Pass	Pass	Pass	Accepted

LABORATORY CODE 9*.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	–	–	2.80	0.06	–	–	–	–	–	–	Not reported
^{90}Sr	–	–	0.3480	0.0021	–	–	–	–	–	–	Not reported
^{134}Cs	0.106	0.018	0.1163	0.0005	–8.9	17	40	Pass	Pass	Pass	Accepted
^{137}Cs	0.321	0.024	0.3087	0.0019	4.0	7.5	20	Pass	Pass	Pass	Accepted

LABORATORY CODE 10*.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	2.43	0.16	2.79	0.06	–13	6.9	16	Pass	Pass	Pass	Accepted
^{90}Sr	0.345	0.029	0.3470	0.0021	–0.6	8.4	22	Pass	Pass	Pass	Accepted
^{134}Cs	0.116	0.016	0.1160	0.0005	0.0	14	36	Pass	Pass	Pass	Accepted
^{137}Cs	0.297	0.024	0.3079	0.0019	–3.5	8.1	20	Pass	Pass	Pass	Accepted

LABORATORY CODE 11*.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	2.90	0.17	2.82	0.06	3.0	6.2	16	Pass	Pass	Pass	Accepted
^{90}Sr	0.3000	0.0037	0.3500	0.0021	–14	1.4	3.1	Pass	Pass	Fail	Warning
^{134}Cs	0.110	0.029	0.1170	0.0005	–6.0	26	64	Pass	Fail	Pass	Warning
^{137}Cs	0.290	0.037	0.3105	0.0019	–6.6	13	31	Pass	Pass	Pass	Accepted

LABORATORY CODE 12*.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	2.90	0.29	2.81	0.06	3.2	10	27	Pass	Pass	Pass	Accepted
^{90}Sr	–	–	0.3492	0.0021	–	–	–	–	–	–	Not reported
^{134}Cs	0.10	0.03	0.1168	0.0005	–14	30	66	Pass	Fail	Pass	Warning
^{137}Cs	0.350	0.024	0.3098	0.0019	13	6.9	20	Pass	Pass	Pass	Accepted

LABORATORY CODE 13.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	6.32	0.56	2.82	0.06	124	9.1	51	Fail	Pass	Fail	Not accepted
^{90}Sr	–	–	0.3502	0.0021	–	–	–	–	–	–	Not reported
^{134}Cs	0.093	0.004	0.1171	0.0005	–21	4.3	8.9	Fail	Pass	Fail	Not accepted
^{137}Cs	0.281	0.022	0.3106	0.0019	–9.5	7.9	18	Pass	Pass	Pass	Accepted

LABORATORY CODE 14.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	–	–	2.82	0.06	–	–	–	–	–	–	Not reported
^{90}Sr	0.52	0.08	0.3509	0.0021	48	15	59	Fail	Pass	Pass	Not accepted
^{134}Cs	<0.3	–	0.1173	0.0005	–	–	–	–	–	–	Not evaluated
^{137}Cs	0.29	0.11	0.3113	0.0019	–6.8	38	91	Pass	Fail	Pass	Warning

LABORATORY CODE 15.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	< 5.35	–	2.79	0.06	–	–	–	–	–	–	Not evaluated
^{90}Sr	0.34	0.02	0.3465	0.0021	–1.9	5.9	15	Pass	Pass	Pass	Accepted
^{134}Cs	0.107	0.006	0.1159	0.0005	–7.6	5.2	12	Pass	Pass	Pass	Accepted
^{137}Cs	0.310	0.025	0.3074	0.0019	0.8	8.1	21	Pass	Pass	Pass	Accepted

LABORATORY CODE 16.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	2.910	0.055	2.80	0.06	3.8	2.8	7.3	Pass	Pass	Pass	Accepted
^{90}Sr	–	–	0.3484	0.0021	–	–	–	–	–	–	Not reported
^{134}Cs	0.118	0.008	0.1165	0.0005	1.3	6.8	18	Pass	Pass	Pass	Accepted
^{137}Cs	0.275	0.021	0.3092	0.0019	–11	7.7	18	Pass	Pass	Pass	Accepted

LABORATORY CODE 17.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	1.75	0.45	2.81	0.06	–38	26	42	Fail	Fail	Pass	Not accepted
^{90}Sr	–	–	0.3486	0.0021	–	–	–	–	–	–	Not reported
^{134}Cs	0.110	0.016	0.1166	0.0005	–6.1	15	36	Pass	Pass	Pass	Accepted
^{137}Cs	0.327	0.017	0.3093	0.0019	5.6	5.3	14	Pass	Pass	Pass	Accepted

LABORATORY CODE 18.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	–	–	2.78	0.06	–	–	–	–	–	–	Not reported
^{90}Sr	–	–	0.3453	0.0021	–	–	–	–	–	–	Not reported
^{134}Cs	0.105	0.002	0.1154	0.0005	–9.1	1.9	4.6	Pass	Pass	Fail	Warning
^{137}Cs	0.295	0.006	0.3064	0.0019	–3.7	2.1	5.3	Pass	Pass	Pass	Accepted

LABORATORY CODE 19.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	–	–	2.79	0.06	–	–	–	–	–	–	Not reported
^{90}Sr	0.296	0.023	0.3468	0.0021	–15	7.8	17	Pass	Pass	Pass	Accepted
^{134}Cs	0.106	0.005	0.1160	0.0005	–8.6	4.7	11	Pass	Pass	Pass	Accepted
^{137}Cs	0.309	0.014	0.3077	0.0019	0.4	4.6	12	Pass	Pass	Pass	Accepted

LABORATORY CODE 20.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	–	–	2.79	0.06	–	–	–	–	–	–	Not reported
^{90}Sr	–	–	0.3468	0.0021	–	–	–	–	–	–	Not reported
^{134}Cs	–	–	0.1159	0.0005	–	–	–	–	–	–	Not reported
^{137}Cs	0.23	0.02	0.3077	0.0019	–25	8.7	17	Fail	Pass	Fail	Not accepted

LABORATORY CODE 21.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	–	–	2.82	0.06	–	–	–	–	–	–	Not reported
^{90}Sr	–	–	0.3500	0.0021	–	–	–	–	–	–	Not reported
^{134}Cs	0.117	0.013	0.1170	0.0005	0.0	11	29	Pass	Pass	Pass	Accepted
^{137}Cs	0.309	0.014	0.3105	0.0019	–0.5	4.5	11	Pass	Pass	Pass	Accepted

LABORATORY CODE 22.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	2.03	0.31	2.81	0.06	–28	15	29	Fail	Pass	Pass	Not accepted
^{90}Sr	0.38	0.08	0.3490	0.0021	8.9	21	59	Pass	Pass	Pass	Accepted
^{134}Cs	0.071	0.027	0.1167	0.0005	–39	38	60	Fail	Fail	Pass	Not accepted
^{137}Cs	0.27	0.06	0.3097	0.0019	–13	22	50	Pass	Fail	Pass	Warning

LABORATORY CODE 23.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	2.9	0.4	2.81	0.06	3.1	14	37	Pass	Pass	Pass	Accepted
^{90}Sr	0.38	0.04	0.3498	0.0021	9.8	10	28	Pass	Pass	Pass	Accepted
^{134}Cs	0.093	0.007	0.1169	0.0005	–20	7.5	15	Fail	Pass	Fail	Not accepted
^{137}Cs	0.247	0.018	0.3103	0.0019	–20	7.3	15	Fail	Pass	Fail	Not accepted

LABORATORY CODE 24.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	–	–	2.80	0.06	–	–	–	–	–	–	Not reported
^{90}Sr	–	–	0.3485	0.0021	–	–	–	–	–	–	Not reported
^{134}Cs	0.120	0.009	0.1165	0.0005	3.0	7.5	20	Pass	Pass	Pass	Accepted
^{137}Cs	0.330	0.024	0.3091	0.0019	6.7	7.3	20	Pass	Pass	Pass	Accepted

LABORATORY CODE 25.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	–	–	2.80	0.06	–	–	–	–	–	–	Not reported
^{90}Sr	0.390	0.011	0.3475	0.0021	12	2.9	8.3	Pass	Pass	Fail	Warning
^{134}Cs	0.1590	0.0017	0.1162	0.0005	37	1.1	3.9	Fail	Pass	Fail	Not accepted
^{137}Cs	0.318	0.002	0.3083	0.0019	3.1	0.9	2.3	Pass	Pass	Fail	Warning

LABORATORY CODE 26.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	1.71	0.15	2.81	0.06	–39	9.0	15	Fail	Pass	Fail	Not accepted
^{90}Sr	0.386	0.010	0.3492	0.0021	11	2.5	7.2	Pass	Pass	Fail	Warning
^{134}Cs	0.098	0.010	0.1167	0.0005	–16	10	22	Pass	Pass	Pass	Accepted
^{137}Cs	0.322	0.018	0.3098	0.0019	3.8	5.5	15	Pass	Pass	Pass	Accepted

LABORATORY CODE 27.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	2.6	0.8	2.83	0.06	–8.0	31	73	Pass	Fail	Pass	Warning
^{90}Sr	0.36	0.02	0.3515	0.0021	2.4	5.6	15	Pass	Pass	Pass	Accepted
^{134}Cs	0.107	0.010	0.1175	0.0005	–9.0	9.4	22	Pass	Pass	Pass	Accepted
^{137}Cs	0.298	0.014	0.3118	0.0019	–4.4	4.7	12	Pass	Pass	Pass	Accepted

LABORATORY CODE 28.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	2.85	0.12	2.79	0.06	2.0	4.7	12	Pass	Pass	Pass	Accepted
^{90}Sr	0.359	0.016	0.3470	0.0021	3.5	4.5	12	Pass	Pass	Pass	Accepted
^{134}Cs	0.119	0.009	0.1160	0.0005	2.6	7.6	20	Pass	Pass	Pass	Accepted
^{137}Cs	0.330	0.021	0.3078	0.0019	7.2	6.4	18	Pass	Pass	Pass	Accepted

LABORATORY CODE 29.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	2.2	0.3	2.81	0.06	–22	14	28	Pass	Pass	Pass	Accepted
^{90}Sr	0.342	0.016	0.3499	0.0021	–2.3	4.7	12	Pass	Pass	Pass	Accepted
^{134}Cs	0.116	0.011	0.1170	0.0005	–0.8	9.5	24	Pass	Pass	Pass	Accepted
^{137}Cs	0.333	0.025	0.3104	0.0019	7.3	7.5	21	Pass	Pass	Pass	Accepted

LABORATORY CODE 30.

Radio-nuclide	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	IAEA Value (Bq kg^{-1})	IAEA uncert. (Bq kg^{-1})	Relative bias (%)	P (%)	Trueness limit (%)	Accuracy	Precision	Trueness	Final Score
^{3}H	2.72	0.11	2.81	0.06	–3.2	4.5	11	Pass	Pass	Pass	Accepted
^{90}Sr	0.310	0.012	0.3493	0.0021	–11	3.9	9.0	Pass	Pass	Fail	Warning
^{134}Cs	0.110	0.008	0.1168	0.0005	–5.8	7.3	18	Pass	Pass	Pass	Accepted
^{137}Cs	0.340	0.017	0.3099	0.0019	9.7	5.0	14	Pass	Pass	Pass	Accepted

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