IAEA/AQ/40

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IAEA-RML-2012-01 Proficiency Test for Determination of Radionuclides in Sea Water

IAEA
International Atomic Energy Agency

IAEA-RML-2012-01 PROFICIENCY TEST FOR DETERMINATION OF RADIONUCLIDES IN SEA WATER

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IAEA Analytical Quality in Nuclear Applications Series No. 40

IAEA-RML-2012-01 PROFICIENCY TEST FOR DETERMINATION OF RADIONUCLIDES IN SEA WATER

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2015

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For further information on this publication, please contact:

IAEA Environment Laboratories, Monaco
Radiometrics Laboratory
International Atomic Energy Agency
4a Quai Antoine 1er, MC 98000
Principality of Monaco

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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 new proficiency test was organized in the framework of the technical cooperation project entitled Marine Benchmark Study on the Possible Impact of the Fukushima Radioactive Releases in the Asia-Pacific Region, to test the performance of participating laboratories in the analysis of radionuclides in a seawater sample. This exercise was initiated to support Member States in seawater analyses of 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, M.K. Pham, H. Nies and S. Tarjan 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 the frame of the IAEA Technical Cooperation project RAS/7/021 entitled Marine Benchmark Study on the Possible Impact of the Fukushima Radioactive Releases in the Asia-Pacific Region are described in this report.

2. MATERIAL AND METHODS

2.1. PROFICIENCY TEST OBJECTIVES

This proficiency test was organized in the frame of the IAEA Technical Cooperation project RAS/7/021 entitled Marine Benchmark Study on the Possible Impact of the Fukushima Radioactive Releases in the Asia-Pacific Region. This exercise was initiated to support Member States in seawater analyses of caesium isotopes, in relation to the Fukushima Daiichi nuclear power station accident in Japan (March 2011) and subsequent contamination to the marine environment. The results of this exercise allowed the participating laboratories to evaluate their performance in the analysis of the radionuclides for this sample type.

2.2. PARTICIPANTS

A total of 23 laboratories from 17 countries have participated in the exercise. In addition to the 16 laboratories from 10 countries in the Asia-Pacific region (China, India, Indonesia, Republic of Korea, Malaysia, Pakistan, Philippines, Sri Lanka, Thailand and Viet Nam), 7 laboratories from OSPAR and HELCOM contracting parties also took part in the exercise. The ten laboratories associated with the RAS/7/021 project are indicated with the symbol * following their laboratory code (i.e. Participants 3*, 4*, 6*, 7*, 8*, 10*, 17*, 18*, 22* and 23*). The full list of participants is given on pages 27–30.

2.3. MATERIAL DISTRIBUTION AND REPORTING REQUIREMENTS

Each participant received two ampoules (a proficiency test exercise sample and a QC sample) each containing 10 g of a 1 M HCl solution containing ^{134}Cs and ^{137}Cs (with 454 mg kg^{-1} Cs carrier). The ^{134}Cs and ^{137}Cs massic activities for the undisclosed proficiency test sample were approximately 0.7 and 1.0 Bq g^{-1}, respectively, and 2.0 Bq g^{-1} for both ^{134}Cs and ^{137}Cs in the disclosed QC sample. The QC sample could be used by the participants to check their analytical procedures or could be used as a calibration source. The ampoules were meant to be diluted with exactly 100 L of local seawater, resulting in relatively low massic activities for the radionuclides mentioned above (although considerably higher than a 'natural' background level in the Pacific Ocean due to global weapon fallout for ^{137}Cs or potential discharges from nuclear installations).

The participants were required to report to the IAEA the ^{134}Cs and ^{137}Cs massic activities (in Bq kg^{-1}) of the diluted proficiency test sample. Additionally, the participants were asked to submit the following:

- Details for the local seawater used to dilute the original proficiency test sample such as the date of collection, position, salinity, temperature and background level of ^{137}Cs;
- A short description of the analytical method used for the sample analysis. The Information Sheet sent to the participants suggested three methods: (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 ferrocyanide ($Cu_2[Fe(CN)_6]$) and subsequent gamma spectrometry;
- Type of calibration used for gamma ray spectrometry;
- Software used in the gamma spectrometric system;
- Nuclear data used;
- An uncertainty budget for the measurement results.

The reference date for reporting massic activities was set at 5 January 2012. At this date, the traceable massic activities in the proficiency test exercise ampoule samples were (0.730 ± 0.011) Bq g^{-1} ^{134}Cs and (0.997 ± 0.010) Bq g^{-1} ^{137}Cs, respectively. The range for the weights of the proficiency test exercise samples sent to the participants was 10.30678–10.36186 g (see Table 1). The massic activities of ^{134}Cs and ^{137}Cs in the samples diluted by local seawater were calculated for each participant separately by dividing the total activity content of the supplied PT ampoule [for instance (7.52 ± 0.11) Bq ^{134}Cs and (10.28 ± 0.10) Bq ^{137}Cs for participant 1] by the weight of the 100 L of seawater diluent [i.e. (102.5 ± 0.6) kg, which expanded uncertainty covers seawater density uncertainty and gravimetric dilution uncertainty].

TABLE 1. IAEA ASSIGNED VALUES

Lab code	Weight of the PT ampoule received (g)	^{134}Cs massic activity in diluted sample (Bq kg^{-1})	^{137}Cs massic activity in diluted sample (Bq kg^{-1})
1	10.31057	0.0734 ± 0.0013	0.1003 ± 0.0011
2	10.33766	0.0736 ± 0.0013	0.1006 ± 0.0011
3*	10.35542	0.0737 ± 0.0013	0.1007 ± 0.0012
4*	10.31839	0.0735 ± 0.0013	0.1004 ± 0.0011
5	10.36186	0.0738 ± 0.0013	0.1008 ± 0.0012
6*	10.30967	0.0734 ± 0.0013	0.1003 ± 0.0011
7*	10.30678	0.0734 ± 0.0013	0.1003 ± 0.0011
8*	10.32291	0.0735 ± 0.0013	0.1004 ± 0.0011
9	10.31627	0.0734 ± 0.0013	0.1004 ± 0.0011
10*	10.36028	0.0738 ± 0.0013	0.1008 ± 0.0012
11	10.32472	0.0735 ± 0.0013	0.1005 ± 0.0011
12	10.32465	0.0735 ± 0.0013	0.1005 ± 0.0011
13	10.32680	0.0735 ± 0.0013	0.1005 ± 0.0011
14	10.31648	0.0734 ± 0.0013	0.1004 ± 0.0011
15	10.31130	0.0734 ± 0.0013	0.1003 ± 0.0011
16	10.34373	0.0736 ± 0.0013	0.1006 ± 0.0011
17*	10.33407	0.0736 ± 0.0013	0.1005 ± 0.0011
18*	10.31591	0.0734 ± 0.0013	0.1004 ± 0.0011
19	10.31645	0.0734 ± 0.0013	0.1004 ± 0.0011
20	10.33152	0.0736 ± 0.0013	0.1005 ± 0.0011
21	10.30943	0.0734 ± 0.0013	0.1003 ± 0.0011
22*	10.32878	0.0735 ± 0.0013	0.1005 ± 0.0011
23*	10.31418	0.0734 ± 0.0013	0.1003 ± 0.0011

3. PERFORMANCE CRITERIA

The performance criteria take into account the trueness and the precision of the reported data and includes in the evaluation both the combined standard uncertainty of the target value and the combined standard uncertainty reported by the participating laboratories. The IAEA target values, which will be used for data evaluation, were the certified values of radionuclides at the reference date of reporting activities at 5 January 2012. A result must pass both criteria for accuracy and precision to be assigned the status "Accepted", otherwise it will acquire the status "Warning" or "Not accepted".

3.1. RELATIVE BIAS

The first step in producing a score for a result $Value_{Analyst}$ (either a single measurement or a mean value of two or more measurements of analyte concentration in a test material) is the estimation of the bias. The relative bias (RB) between the Analyst's value and the IAEA target value is calculated as follows and expressed as a percentage:

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

3.2. PT EVALUATION CRITERIA

The PT results were evaluated against the acceptance criteria for trueness and precision, and were assigned an "Accepted", "Warning" or "Not accepted" status accordingly.

3.2.1. Trueness

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

$$A1 \leq A2 \quad (2)$$

where:

$$A1 = \left|Value_{IAEA} - Value_{Analyst}\right| \quad (3)$$

$$A2 = 2.58 \times \sqrt{unc_{IAEA}^2 + unc_{Analyst}^2} \quad (4)$$

3.2.2. Precision

The precision *P* for each participant was calculated according to the following formula:

$$P = \sqrt{\left(\frac{unc_{IAEA}}{Value_{IAEA}}\right)^2 + \left(\frac{unc_{Analyst}}{Value_{Analyst}}\right)^2} \times 100\% \quad (5)$$

P directly depended on the measurement uncertainty reported by participants. The Limit of Accepted Precision (LAP) for each analyte was defined for the respective exercise in advance, including any adjustment due to massic activity level of the analyte concerned and the complexity of the analytical problem. Participants' results were scored as "Pass" for precision when $P < LAP$. The LAP value used in the evaluation was 25% for both radionuclides.

For the final evaluation, both scores for trueness and precision were combined. The result was considered as "Accepted" if it passed both trueness and precision criteria. In cases where either precision or trueness was "Fail", a further check was applied. The Relative Bias (RB) of the reported result was compared with the Maximum Accepted Bias (MAB). If RB < MAB, the final score was "Warning". The "Warning" status did reflect two situations. The first situation was that the result was

reported with a small measurement uncertainty; however its bias was still within MAB. The second situation appeared when the reported result was close to the assigned property value, but the associated uncertainty was too large. If RB > MAB, the result will be "Not accepted". The MAB values used in the evaluation was 25% for both radionuclides.

3.2.3. Comparison of the 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 ν_{eff} were determined with the simplified Welch-Satterthwaite equation (it was assumed that the degrees of freedom for IAEA uncertainty, unc_{IAEA}, were infinite).

$$\nu_{eff} = \frac{\left((unc_{Combined})^2 + (unc_{IAEA})^2\right)^2}{(unc_{Combined})^4}(p-1) \quad (7)$$

The effective degrees of freedom ν_{eff} were rounded and the critical value t_{crit} for this value was identified. The criterion for passing the t test was:

$$|t| < t_{crit} \quad (8)$$

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.

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

4. RESULTS AND DISCUSSION

Measurement results were reported by 23 laboratories from 17 countries for ^{134}Cs and ^{137}Cs. The overall evaluation of these results showed that 59% of all reported measurement results fulfilled the PT criteria of acceptability, while 24% of the individual measurement results were not accepted with the remaining 17% having the warning status. The performance evaluation for ^{134}Cs and ^{137}Cs is summarised in Table 2. For the subset of subset of RCA RAS/7/021 results, the values were: 60% 'Accepted', 20% 'Not accepted' and 20% 'Warning'.

TABLE 2. SUMMARY EVALUATION OF THE RADIONUCLIDES REPORTED

Radionuclide	Number of laboratories reporting	Accepted	Warning	Not accepted
^{134}Cs	23 (10)	13 (5)	4 (3)	6 (2)
^{137}Cs	23 (10)	14 (7)	4 (1)	5 (2)

NOTE: The numbers in brackets represent the subset of RCA RAS/7/021 results

For ^{134}Cs the majority of participants' results (83% of the results) showed a negative bias, while for ^{137}Cs 30% of the results showed a negative bias. For ^{134}Cs there was a significant negative bias of the combined participants' results (–5.5%), while there was a significant positive bias (3.3%) for ^{137}Cs (see Table 3). 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.

TABLE 3. 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 (%)
^{134}Cs	0.0695 ± 0.0013	0.0735 ± 0.0013	61	–4.43	2.68	–5.5
^{137}Cs	0.1037 ± 0.0015	0.1004 ± 0.0011	70	3.43	2.72	3.3

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

Table 4 summarises the data evaluation sorted by laboratory code. Ten laboratories (Labs 7*, 8*, 11, 12, 13, 14, 15, 18*, 20 and 23*) scored 'Accepted' ratings for both ^{134}Cs and ^{137}Cs. Six laboratories (Labs 1, 2, 3*, 4*, 6* and 10*) scored an 'Accepted' rating and a 'Warning' rating. One laboratory (Lab 16) scored an 'Accepted' and a 'Not accepted' rating. One laboratory (Lab 9) scored 'Warning' ratings for both radionuclides. Finally, five laboratories (Labs 5, 17*, 19, 21 and 22*) scored 'Not accepted' ratings for both radionuclides.

TABLE 4. SUMMARY EVALUATION OF THE IAEA RCA RAS/7/021 PROFICIENCY TEST 2012

Lab code	^{134}Cs	^{137}Cs
1	A	W
2	A	W
3*	W	A
4*	W	A
5	NA	NA
6*	W	A
7*	A	A
8*	A	A
9	W	W
10*	A	W
11	A	A
12	A	A
13	A	A
14	A	A
15	A	A
16	NA	A
17*	NA	NA
18*	A	A
19	NA	NA
20	A	A
21	NA	NA
22*	NA	NA
23*	A	A

The performance evaluation sorted by radionuclide and the bias plots are presented in Appendix I (see Tables 6–7 and Figures 1–4). 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 $k = 2$). The dotted lines represent a relative bias of ± 25% (Maximum Accepted Bias). The performance evaluation sorted by laboratory code is presented in Appendix II. All laboratories reported their values with expanded uncertainties ($k = 2$). However, a large spread in the submitted uncertainties was observed with relative uncertainties (at $k = 2$) ranging from 3.2% to 29% for ^{134}Cs and from 1.8% to 22% for ^{137}Cs. However, most reported relative uncertainties were in the range 4% to 15%.

The majority of the laboratories used a pre-concentration technique (e.g. adsorption on AMP or copper ferrocyanide) to separate the caesium radionuclides from the seawater matrix followed by gamma spectrometry, while 7 laboratories (Labs 1, 5, 8*, 9, 12, 14 and 19) measured the diluted seawater samples directly with gamma spectrometry. No significant difference in the performance between the two techniques is apparent (see Table 5), although in general the reported relative uncertainties (at $k = 2$) for the direct measurements were larger, ranging from 5.9% to 29% for ^{134}Cs and from 5.4% to 22% for ^{137}Cs, with the majority of the uncertainties larger than 10%.

TABLE 5. COMPARISON OF THE COMBINED PARTICIPANTS' RESULTS PER METHOD WITH THE IAEA VALUE

Nuclide (method)	Combined participants' result (Bq kg^{-1})	IAEA value (Bq kg^{-1})	Size of the LCS* (%)	t-value	Critical t-value	Bias (%)
^{134}Cs (direct)	0.0718 ± 0.0036	0.0735 ± 0.0013	57	–0.88	5.84	–2.3
^{134}Cs (preconc.)	0.0691 ± 0.0014	0.0735 ± 0.0013	63	–4.64	2.75	–5.9
^{137}Cs (direct)	0.1048 ± 0.0037	0.1004 ± 0.0011	57	2.24	5.84	4.4
^{137}Cs (preconc.)	0.1035 ± 0.0017	0.1004 ± 0.0011	75	3.01	2.81	3.1

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

APPENDIX I. PERFORMANCE EVALUATION TABLES SORTED BY RADIONUCLIDE

TABLE 6. EVALUATION RESULTS FOR ^{134}Cs IN IAEA-RCA RAS/7/021 PT 2012

Lab Code	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	Target Value (Bq kg^{-1})	Target uncert. (Bq kg^{-1})	Relative Bias (%)	A1	A2	Trueness	P (%)	Precision	Final Score
1	0.0667	0.0080	0.0734	0.0013	–9	0.007	0.010	Pass	6.1	Pass	Accepted
2	0.0707	0.0040	0.0736	0.0013	–4	0.0029	0.0054	Pass	3.0	Pass	Accepted
3*	0.066	0.003	0.0737	0.0013	–10	0.008	0.004	Fail	2.4	Pass	Warning
4*	0.066	0.005	0.0735	0.0013	–10	0.0075	0.0067	Fail	3.9	Pass	Warning
5	0.046	0.006	0.0738	0.0013	–38	0.028	0.008	Fail	6.6	Pass	Not accepted
6*	0.056	0.004	0.0734	0.0013	–24	0.017	0.005	Fail	3.7	Pass	Warning
7*	0.0715	0.0030	0.0734	0.0013	–3	0.0019	0.0042	Pass	2.3	Pass	Accepted
8*	0.071	0.019	0.0735	0.0013	–3	0.002	0.025	Pass	13	Pass	Accepted
9	0.058	0.004	0.0734	0.0013	–21	0.015	0.005	Fail	3.6	Pass	Warning
10*	0.0757	0.0028	0.0738	0.0013	3	0.0019	0.0040	Pass	2.0	Pass	Accepted
11	0.0713	0.0038	0.0735	0.0013	–3	0.0022	0.0052	Pass	2.8	Pass	Accepted
12	0.078	0.017	0.0735	0.0013	6	0.004	0.022	Pass	11	Pass	Accepted
13	0.067	0.013	0.0735	0.0013	–9	0.006	0.017	Pass	10	Pass	Accepted
14	0.0729	0.0043	0.0734	0.0013	–1	0.0006	0.0058	Pass	3.1	Pass	Accepted
15	0.067	0.005	0.0734	0.0013	–9	0.0064	0.0067	Pass	3.8	Pass	Accepted
16	0.0450	0.0060	0.0736	0.0013	–39	0.029	0.008	Fail	6.7	Pass	Not accepted

continues

continued

Lab Code	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	Target Value (Bq kg^{-1})	Target uncert. (Bq kg^{-1})	Relative Bias (%)	A1	A2	Trueness	P (%)	Precision	Final Score
17*	0.0432	0.0074	0.0736	0.0013	–41	0.030	0.010	Fail	8.6	Pass	Not accepted
18*	0.0730	0.0081	0.0734	0.0013	–1	0.000	0.011	Pass	5.6	Pass	Accepted
19	0.14	0.04	0.0734	0.0013	91	0.067	0.052	Fail	14	Pass	Not accepted
20	0.0599	0.011	0.0736	0.0013	–19	0.0137	0.0143	Pass	9.2	Pass	Accepted
21	0.0354	0.0011	0.0734	0.0013	–52	0.038	0.002	Fail	1.8	Pass	Not accepted
22*	0.27	0.03	0.0735	0.0013	267	0.20	0.04	Fail	5.6	Pass	Not accepted
23*	0.0707	0.0043	0.0734	0.0013	–4	0.003	0.006	Pass	3.2	Pass	Accepted

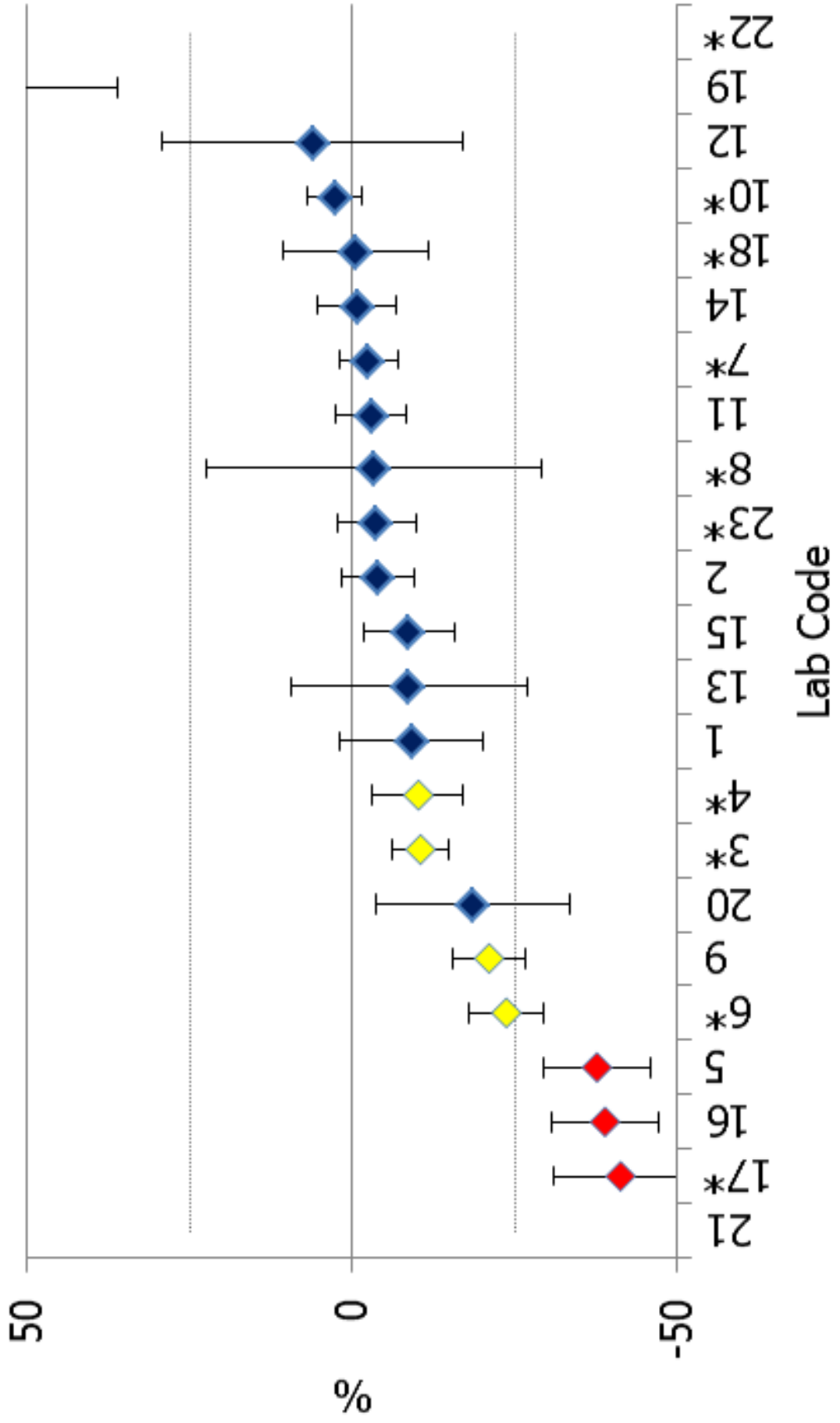

FIG. 1. Cs-134 bias.

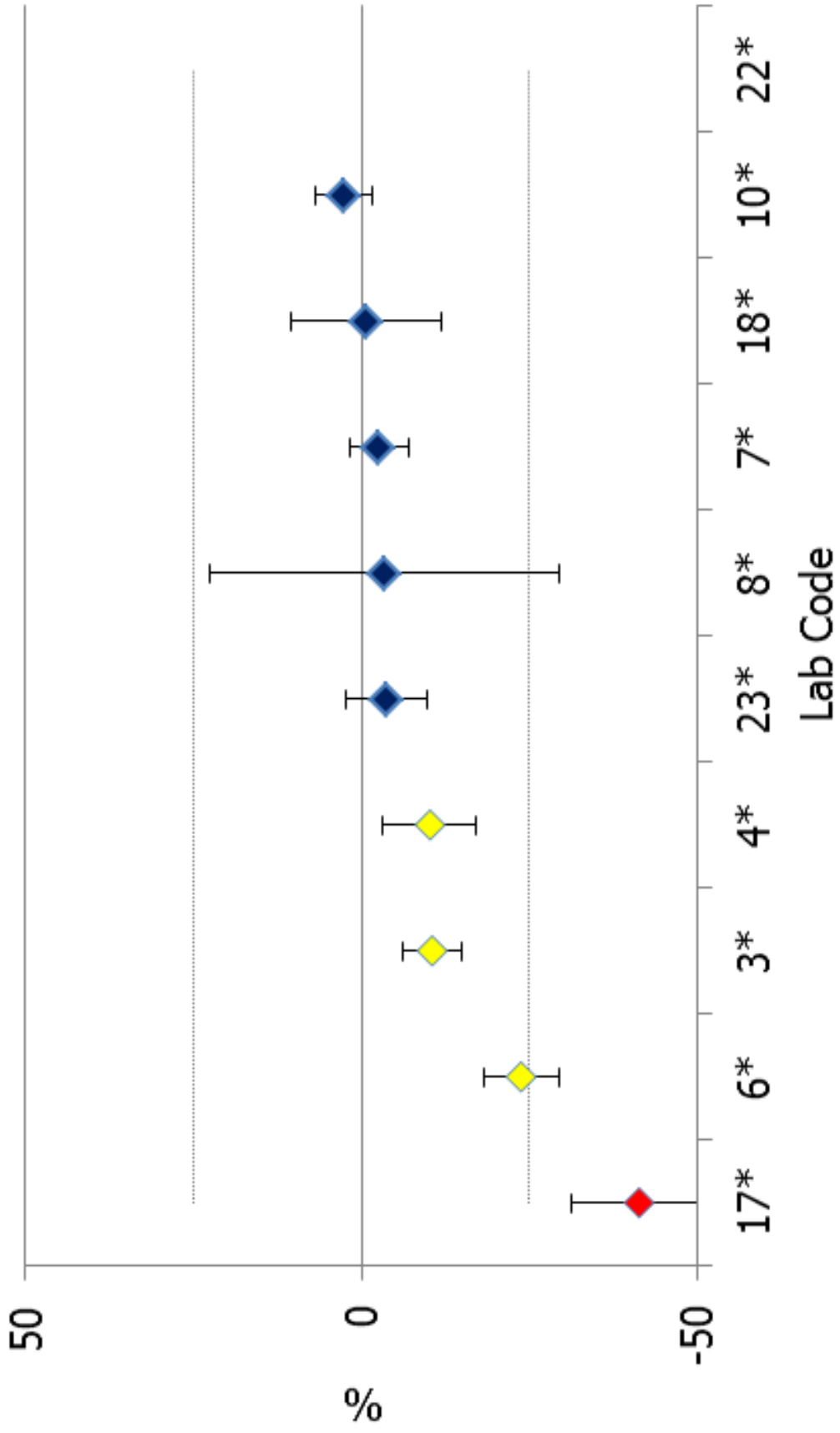

FIG. 2. Cs-134 bias RCA RAS/7/021 participants.

TABLE 7. EVALUATION RESULTS FOR ^{137}Cs IN IAEA-RCA RAS/7/021 PT 2012

Lab Code	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	Target Value (Bq kg^{-1})	Target uncert. (Bq kg^{-1})	Relative Bias (%)	A1	A2	Trueness	P (%)	Precision	Final Score
1	0.1167	0.0087	0.1003	0.0011	16	0.016	0.011	Fail	3.8	Pass	Warning
2	0.1077	0.0032	0.1006	0.0011	7	0.0071	0.0044	Fail	1.5	Pass	Warning
3*	0.100	0.004	0.1007	0.0012	–1	0.0007	0.0054	Pass	2.1	Pass	Accepted
4*	0.105	0.006	0.1004	0.0011	5	0.0046	0.0079	Pass	2.9	Pass	Accepted
5	0.0651#	0.0080	0.1008	0.0012	–35	0.036	0.010	Fail	5.5	Pass	Not accepted
6*	0.102	0.010	0.1003	0.0011	2	0.002	0.013	Pass	4.9	Pass	Accepted
7*	0.103	0.003	0.1003	0.0011	3	0.0027	0.0041	Pass	1.6	Pass	Accepted
8*	0.105	0.019	0.1004	0.0011	5	0.005	0.025	Pass	9.1	Pass	Accepted
9	0.117	0.011	0.1004	0.0011	17	0.017	0.014	Fail	4.7	Pass	Warning
10*	0.1093#	0.0020	0.1008	0.0012	8	0.0085	0.0030	Fail	1.1	Pass	Warning
11	0.096	0.008	0.1005	0.0011	–4	0.004	0.010	Pass	4.2	Pass	Accepted
12	0.090	0.015	0.1005	0.0011	–10	0.010	0.019	Pass	8.4	Pass	Accepted
13	0.105	0.021	0.1005	0.0011	4	0.004	0.027	Pass	10	Pass	Accepted
14	0.1030	0.0056	0.1004	0.0011	3	0.0026	0.0074	Pass	2.8	Pass	Accepted
15	0.107	0.008	0.1003	0.0011	7	0.007	0.010	Pass	3.8	Pass	Accepted
16	0.090	0.017	0.1006	0.0011	–11	0.011	0.022	Pass	9.5	Pass	Accepted
17*	0.0552#	0.0082	0.1005	0.0011	–45	0.045	0.011	Fail	7.2	Pass	Not accepted
18*	0.110	0.016	0.1004	0.0011	10	0.010	0.021	Pass	7.3	Pass	Accepted

continues

continued											
Lab Code	Lab Value (Bq kg^{-1})	Lab uncert. (Bq kg^{-1})	Target Value (Bq kg^{-1})	Target uncert. (Bq kg^{-1})	Relative Bias (%)	A1	A2	Trueness	P (%)	Precision	Final Score
19	0.18	0.04	0.1004	0.0011	79	0.080	0.052	Fail	11	Pass	Not accepted
20	0.104	0.017	0.1005	0.0011	3	0.003	0.022	Pass	8.2	Pass	Accepted
21	0.0507	0.0050	0.1003	0.0011	–50	0.050	0.007	Fail	5.0	Pass	Not accepted
22*	0.51	0.02	0.1005	0.0011	408	0.41	0.03	Fail	2.0	Pass	Not accepted
23*	0.1027	0.0064	0.1003	0.0011	2	0.002	0.008	Pass	3.1	Pass	Accepted

corrected for ^{137}Cs background in local seawater diluent

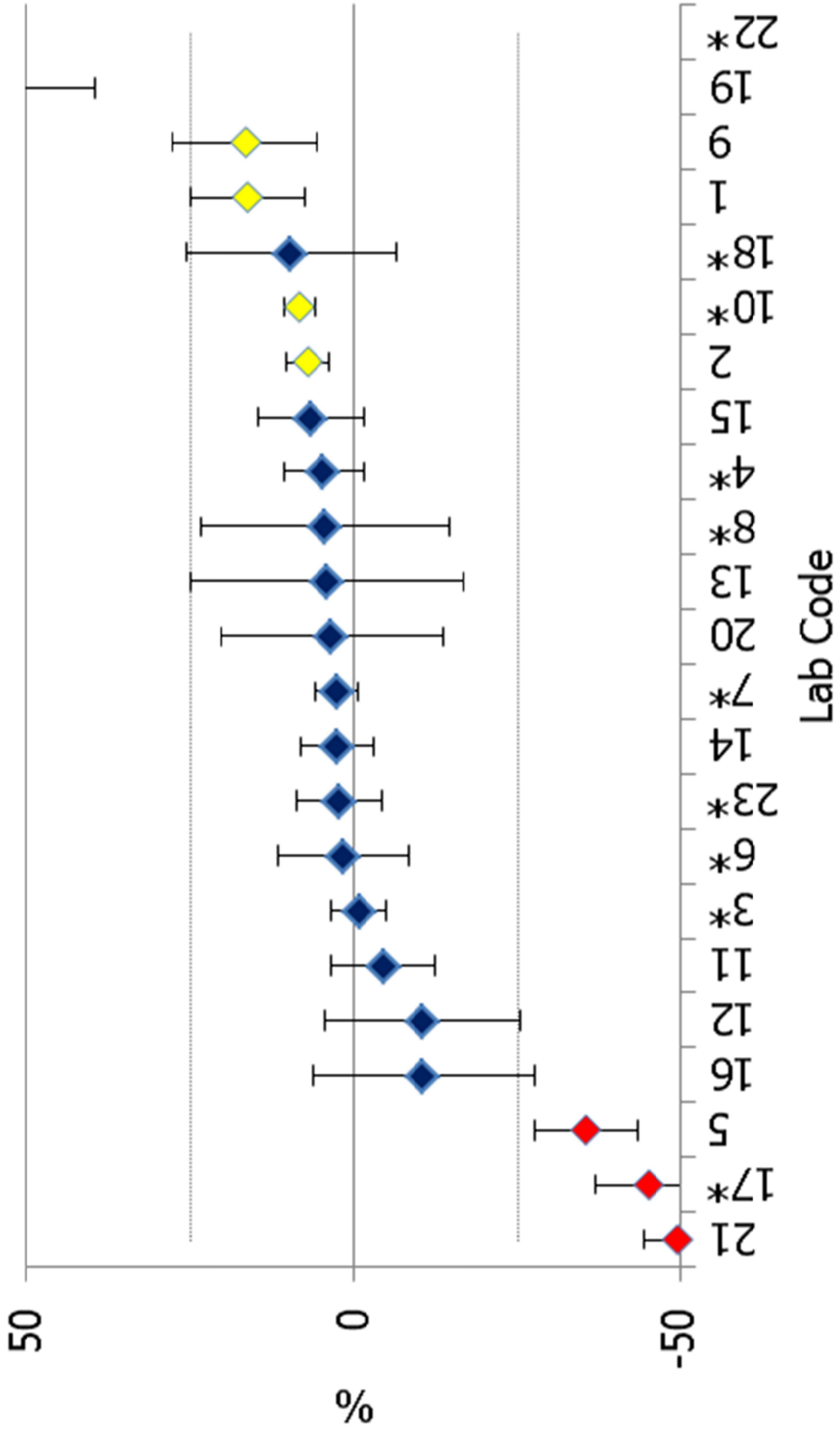

FIG. 3. Cs-137 bias.

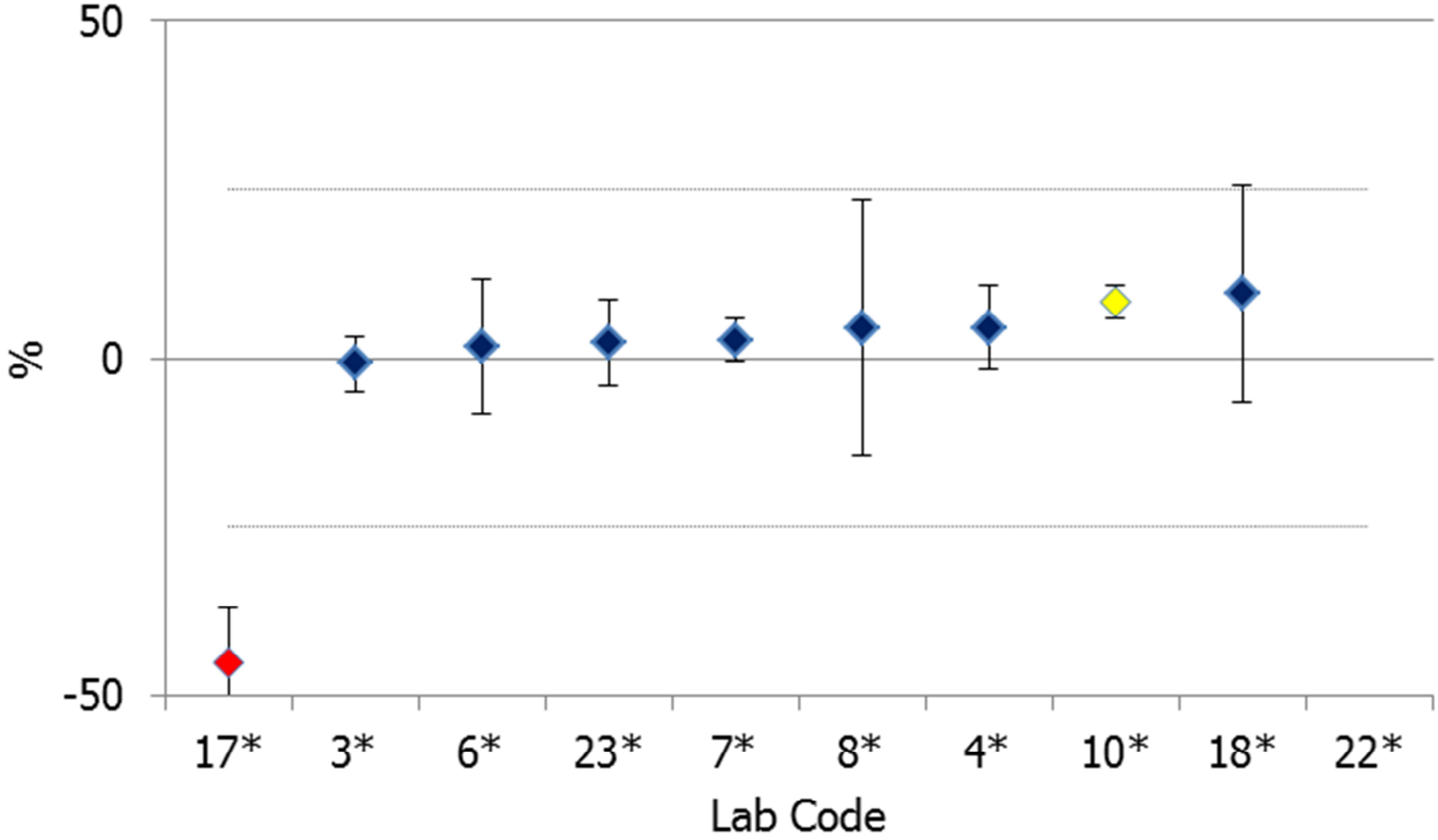

FIG. 4. Cs-137 bias RCA RAS/7/021 participants.

TABLE 8. BACKGROUND ^{137}Cs IN LOCAL SEAWATER DILUENT

Lab Code	Background ^{137}Cs massic activity (Bq m^{-3})	Date of collection	Salinity (PSU)	Temperature (°C)
2	2.6 ± 0.3	13 June 2012	–	30
3*	1.30 ± 0.16	20 June 2012	25	25.4
4*	1.3 ± 0.7	5 April 2012	33.08	24
5	7.91	–	32	–
7*	1.46 ± 0.10	1 June 2012	34.5	23
10*	1.027 ± 0.048	23 May 2012	30.8	27
13	5.5	31 May 2012	34.3	18
15	23.4 ± 2.0	14 June 2012	7.21	13.6
17*	2.21 ± 0.55	20 June 2012	32.5	28.15
18*	2.08 ± 1.16	2 April 2012	30.6	24
20	3.8 ± 0.5	4 March 2004	–	–
21	10.25	25 May 2012	32.8	17.6
22*	1.26	–	–	–
23*	0.62 ± 0.03	7 August 2012	20.5	27.9

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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.0667	0.0080	0.0734	0.0013	–9	0.007	0.010	Pass	6.1	Pass	Accepted
^{137}Cs	0.1167	0.0087	0.1003	0.0011	16	0.016	0.011	Fail	3.8	Pass	Warning

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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.0707	0.0040	0.0736	0.0013	–4	0.0029	0.0054	Pass	3.0	Pass	Accepted
^{137}Cs	0.1077	0.0032	0.1006	0.0011	7	0.0071	0.0044	Fail	1.5	Pass	Warning

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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.066	0.003	0.0737	0.0013	–10	0.008	0.004	Fail	2.4	Pass	Warning
^{137}Cs	0.100	0.004	0.1007	0.0012	–1	0.0007	0.0054	Pass	2.1	Pass	Accepted

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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.066	0.005	0.0735	0.0013	–10	0.0075	0.0067	Fail	3.9	Pass	Warning
^{137}Cs	0.105	0.006	0.1004	0.0011	5	0.0046	0.0079	Pass	2.9	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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.046	0.006	0.0738	0.0013	–38	0.028	0.008	Fail	6.6	Pass	Not accepted
^{137}Cs	0.0651#	0.0080	0.1008	0.0012	–35	0.036	0.010	Fail	5.5	Pass	Not accepted

corrected for ^{137}Cs background in local seawater diluent

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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.056	0.004	0.0734	0.0013	–24	0.017	0.005	Fail	3.7	Pass	Warning
^{137}Cs	0.102	0.010	0.1003	0.0011	2	0.002	0.013	Pass	4.9	Pass	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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.0715	0.0030	0.0734	0.0013	–3	0.0019	0.0042	Pass	2.3	Pass	Accepted
^{137}Cs	0.103	0.003	0.1003	0.0011	3	0.0027	0.0041	Pass	1.6	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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.071	0.019	0.0735	0.0013	–3	0.002	0.025	Pass	13	Pass	Accepted
^{137}Cs	0.105	0.019	0.1004	0.0011	5	0.005	0.025	Pass	9.1	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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.058	0.004	0.0734	0.0013	–21	0.015	0.005	Fail	3.6	Pass	Warning
^{137}Cs	0.117	0.011	0.1004	0.0011	17	0.017	0.014	Fail	4.7	Pass	Warning

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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.0757	0.0028	0.0738	0.0013	3	0.0019	0.0040	Pass	2.0	Pass	Accepted
^{137}Cs	0.1093#	0.0020	0.1008	0.0012	8	0.0085	0.0030	Fail	1.1	Pass	Warning

corrected for ^{137}Cs background in local seawater diluent

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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.0713	0.0038	0.0735	0.0013	–3	0.0022	0.0052	Pass	2.8	Pass	Accepted
^{137}Cs	0.096	0.008	0.1005	0.0011	–4	0.004	0.010	Pass	4.2	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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.078	0.017	0.0735	0.0013	6	0.004	0.022	Pass	11	Pass	Accepted
^{137}Cs	0.090	0.015	0.1005	0.0011	–10	0.010	0.019	Pass	8.4	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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.067	0.013	0.0735	0.0013	–9	0.006	0.017	Pass	10	Pass	Accepted
^{137}Cs	0.105	0.021	0.1005	0.0011	4	0.004	0.027	Pass	10	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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.0729	0.0043	0.0734	0.0013	–1	0.0006	0.0058	Pass	3.1	Pass	Accepted
^{137}Cs	0.1030	0.0056	0.1004	0.0011	3	0.0026	0.0074	Pass	2.8	Pass	Accepted

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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.067	0.005	0.0734	0.0013	–9	0.0064	0.0067	Pass	3.8	Pass	Accepted
^{137}Cs	0.107	0.008	0.1003	0.0011	7	0.007	0.010	Pass	3.8	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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.0450	0.0060	0.0736	0.0013	–39	0.029	0.008	Fail	6.7	Pass	Not accepted
^{137}Cs	0.090	0.017	0.1006	0.0011	–11	0.011	0.022	Pass	9.5	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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.0432	0.0074	0.0736	0.0013	–41	0.030	0.010	Fail	8.6	Pass	Not accepted
^{137}Cs	0.0552#	0.0082	0.1005	0.0011	–45	0.045	0.011	Fail	7.2	Pass	Not accepted

corrected for ^{137}Cs background in local seawater diluent

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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.0730	0.0081	0.0734	0.0013	–1	0.000	0.011	Pass	5.6	Pass	Accepted
^{137}Cs	0.110	0.016	0.1004	0.0011	10	0.010	0.021	Pass	7.3	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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.14	0.04	0.0734	0.0013	91	0.067	0.052	Fail	14	Pass	Not accepted
^{137}Cs	0.18	0.04	0.1004	0.0011	79	0.080	0.052	Fail	11	Pass	Not 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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.0599	0.011	0.0736	0.0013	–19	0.0137	0.0143	Pass	9.2	Pass	Accepted
^{137}Cs	0.104	0.017	0.1005	0.0011	3	0.003	0.022	Pass	8.2	Pass	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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.0354	0.0011	0.0734	0.0013	–52	0.038	0.002	Fail	1.8	Pass	Not accepted
^{137}Cs	0.0507	0.0050	0.1003	0.0011	–50	0.050	0.007	Fail	5.0	Pass	Not 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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.27	0.03	0.0735	0.0013	267	0.20	0.04	Fail	5.6	Pass	Not accepted
^{137}Cs	0.51	0.02	0.1005	0.0011	408	0.41	0.03	Fail	2.0	Pass	Not accepted

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 (%)	A1	A2	Trueness	P (%)	Precision	Final Score
^{134}Cs	0.0707	0.0043	0.0734	0.0013	–4	0.003	0.006	Pass	3.2	Pass	Accepted
^{137}Cs	0.1027	0.0064	0.1003	0.0011	2	0.002	0.008	Pass	3.1	Pass	Accepted

APPENDIX III. LIST OF PARTICIPATING RCA RAS/7/021 LABORATORIES

CHINA

Yu, W.
Marine Isotope Research and Analysis Laboratory
Third Institute of Oceanography
State Oceanic Administration
184# Daxue Rd
Xiamen 361005

INDIA

Jha, S.K.
Environmental Assessment Division
Bhabha Atomic Research Centre
Department of Atomic Energy
Mumbai 400085

INDONESIA

Suseno, H.
Radioactive Waste Technology Center (PTLR)
National Nuclear Energy Agency (BATAN)
Gedung 71 lantai 3 Kawasan
Puspiptek Serpong
Tangerang 15311

KOREA, REPUBLIC OF

Byun, J.-I.
Korea Institute of Nuclear Safety
62 Gwahak-ro
Yuseong-Gu
Daejeon 305-338

MALAYSIA

Kadir bin Ishak, A.
Radiochemistry and Environment Laboratory, Building 23
Malaysian Nuclear Agency
Bangi
43000 Kajang

PAKISTAN

Mashiatullah, A.
Radiation and Isotope Applications Division (RIAD) Pinstech
P.O. Box 1482, Nilore
Islamabad

PHILIPPINES

Enriquez, E.B.
Health Physics Research Section
Philippine Nuclear Research Institute
Commonwealth Avenue, Diliman
1101 Quezon City

SRI LANKA

Waduge, V.A.
Life Sciences Division
60/460, Baseline Road
Orugodawatte
Wellampitiya (Colombo)

THAILAND

Udomsomporn, S.
Office of Atoms for Peace
16 Vibhavadi Rungsit Road
Chatuchak
Ladyao
Bangkok 10900

VIET NAM

Lê, N.S.
Centre for Analytical Techniques and Environmental Monitoring
Nuclear Research Institute (NRI)
Vietnam Atomic Energy Institute
1 Nguyen Tu Luc Street
Dalat

APPENDIX IV. LIST OF OTHER PARTICIPATING LABORATORIES

BELGIUM

Sneyers, L.
Unit Low-level Radioactivity Measurements
Environment Health & Safety
Belgian Nuclear Research Centre SCK CEN
Boeretang 200
2400 Mol

GERMANY

Herrmann, J.
Bundesamt für Seeschifffahrt und Hydrographie (BSH)
Wüstland 2
22589 Hamburg

IRELAND

McKittrick, L.
Radiological Protection Institute of Ireland
3 Clonskeagh Square
Clonskeagh Road
Dublin 14

NETHERLANDS

Engeler, C.
Rijkswaterstaat Centre for Water Management
Zuiderwagenplein 2
8224 AD Lelystad

NORWAY

Lind, B.
Norwegian Radiation Protection Authority (NRPA)
Grini Næringspark 13
1361 Østerås

PHILIPPINES

Pabroa, P.C.B.
Nuclear Analytical Techniques Applications Section
Philippine Nuclear Research Institute
Commonwealth Avenue, Diliman
1101 Quezon City

POLAND

Zalewska, T.
Institute of Meteorology and Water Management
Maritime Branch
National Research Institute
Waszyngtona 42
81-342 Gdynia

THAILAND

Chanyotha, S.
Department of Nuclear Engineering Faculty of Engineering
Chulalongkorn University
Bangkok 10330

Pakkong, P.
Department of Applied Radiation and Isotopes
Kasetsart University
50 Phahon Yothin Rd.
Chatuchak, Ladyao
Bangkok 10900

Kessaratikoon, P.
Thanksin University Songkhla Campus
Muang District
Songkhla 90000

Srisuksawad, K.
Nuclear Research and Development Group
Thailand Institute of Nuclear Technology
9/9 Saimoon, Ongkharak
Nakorn Nayok 26120

VIET NAM

Nguyen, Q.L.
Institute for Nuclear Science and Technology
179 Hoang Quoc Viet Street
Cau Giay
Hanoi

UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

Leonard, K.
CEFAS
Pakefield Road
Lowestoft, Suffolk
NR33 0HT

CONTRIBUTORS TO DRAFTING AND REVIEW

Harms, A.V.	International Atomic Energy Agency
Nies, H.	International Atomic Energy Agency
Pham, M.K.	International Atomic Energy Agency
Tarjan, S.	International Atomic Energy Agency

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FINLAND
Akateeminen Kirjakauppa
PO Box 128 (Keskuskatu 1), 00101 Helsinki, FINLAND
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Lavoisier SAS
14 rue de Provigny, 94236 Cachan CEDEX, FRANCE
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Willstätterstrasse 15, 40549 Düsseldorf, GERMANY
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