The IAEA-TERC-2025-01 worldwide proficiency test on the determination of anthropogenic and natural radionuclides in water, soil, vegetation and contaminated surface samples

Laboratory's Individual Evaluation Report
Laboratory Code: 2 (CuNo: 13949)
Total Pages (with cover): 14

Certificate of Participation

in the IAEA-TERC-2025-01 Worldwide Proficiency Test Exercise

Christos Maramathas and Iason Mitsios

from

teleDOS Laboratories S.M. P.C., teleDOS Nuclear Tech

Corinth, Greece

has been participating in the IAEA-TERC-2025-01 Worldwide Proficiency Test Exercise with laboratory code 2

IAEA-TERC-2025-01 Worldwide Proficiency Test Exercise
Individual Evaluation Report for Labcode 2

January 28, 2026

Abstract

The IAEA Terrestrial Environmental Radiochemistry (TERC) Laboratory provided the Worldwide Proficiency Test Exercise on the determination of anthropogenic and natural radionuclides in water, soil, vegetation and simulated contaminated surface samples.

1 Description of Samples

- Sample 1: Water spiked with naturally occurring and anthropogenic radionuclides
- Sample 2: Water sample containing environmentally occurring radionuclides
- Sample 3: Soil containing environmentally occurring radionuclides
- Sample 4: Vegetation containing environmentally occurring radionuclides
- Sample 5: Printed contaminated surface containing a mixture of Ba-133 and Sr-90

1.1 Sample 1, Drinking Water (spiked)

Drinking water was gravimetrically spiked with a known amount of a standard solution, prepared from individual solutions with a certified activity concentration of radionuclides. The batch of water was acidified to pH < 2 (0.05M HNO3) for stabilization, and thoroughly mixed prior to bottling. Each bottle contains approximately 500 g of water.
The target values for activity concentration and corresponding uncertainties were assigned by formulation, and control measurements were performed by gamma-ray spectrometry, alpha-particle spectrometry and liquid scintillation counting.

1.2 Sample 2, Natural mineral water (non-spiked)

Natural mineral water was acidified to pH < 2 (0.05M HNO3) for stabilization, and thoroughly mixed prior to bottling. Each bottle contains approximately 500 g of water.
The water contains naturally occurring radionuclides at low levels. Specifically, uranium is present at a mass fraction between 0.1 ng/g and 15 ng/g.
The water contains elevated mass concentrations of certain inorganic ions compared to typical drinking water, including:

- Calcium (Ca): between 100 and 500 mg /L
- Magnesium (Mg): between 20 and 200 mg/L

- Sulphate (SO_4): between 100 and 500 mg/L
- Sodium (Na): between 10 and 100 mg/L

The determination of target values and associated uncertainties of the radionuclides has been carried-out using alpha-particle spectrometry and ICP-MS.

1.3 Sample 3, Soil

Approximately 200 g of soil is provided for gamma-ray spectrometry measurement. The bottled samples were sterilized (25 kGy gamma dose) and the related irradiation certificate is available on the exercises website. It contains environmentally occurring radionuclides.
The determination of activity concentration target values and associated uncertainties of the radionuclides has been carried-out using high precision semiconductor gamma-ray spectrometry measurements in compliance with ISO/IEC 17025. The sample was characterized for gamma-emitting radionuclides only.

1.4 Samples 4, Vegetation

Approximately 100 g of vegetation sample is provided for gamma-ray spectrometry measurement. The bottled samples were sterilized (25 kGy gamma dose) and the related certificate is available on the PT website. It contains environmentally occurring radionuclides.
The determination of target values and associated uncertainties of the radionuclides has been carried-out using high precision semiconductor gamma-ray spectrometry measurements in compliance with ISO/IEC 17025. The samples are characterized for gamma-emitting radionuclides only.

1.5 Samples 5, Simulated contaminated surface sample (white envelope)

A set of printed canvas circles for contamination surface monitoring have been included in this proficiency test (Figure 1). They were prepared using an in-house printing technique. One blank sample of the same size, outlined with black ink (non-spiked) is also added for correction (Blank).
The simulated contaminated surface sample (purple) is printed with a combination of magenta ink (Sr-90) and blue ink (Ba-133), and the activity of both radionuclides should be reported (Sample 05).
The simulated contaminated surface sample (blue) is a QC sample (QC-1) and was spiked with a known activity of Ba-133 (see Table 3).The simulated contaminated surface sample (magenta) is a QC sample (QC-2) and was spiked with a known activity of Sr-90 (see Table 3).
The provided QC samples are intended to support the validation and/or calibration of measurement instruments to facilitate the determination of an unknown Sample 05.

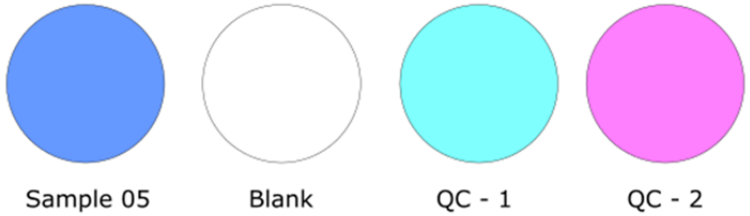

Figure 1. Simulated contaminated surface samples

TABLE 1. Radionuclide content in simulated contaminated surface QC samples.

Sample	Sr-90, Bq/sample	Ba-133, Bq/sample
QC – 1	-	7.36 ± 0.25*
QC – 2	4.39 ± 0.08*	-

* Uncertainty is expressed as a combined standard uncertainty with coverage factor k=1

1.6 Reference date for decay correction

The reference date for decay correction in all samples is 2025-01-01.

1.7 Codes for analytical techniques in evaluation tables

Due to the limited space available in the evaluation tables, the analytical techniques are abbreviated in the tables as shown in the following list:

- alpha: Alpha Spectrometry
- beta: Beta Counting
- gamma: Gamma-ray Spectrometry
- ICP-MS: Inductively Coupled Plasma Mass Spectrometry.

2 Evaluation of results

The reported results were evaluated according to current IAEA procedures for proficiency testing. Reported results were compared to a target value. Criteria to evaluate each participant's performance take into consideration the relative bias of reported values (trueness) as well as the reported uncertainty of measurement (precision).
Target values were assigned independently for most parameters, either by formulation or characterization measurements. In case of results for gross-alpha and gross-beta activity concentrations, a consensus value from reported results was used.

2.1 Evaluation of parameters with independently assigned target values

Each reported result was evaluated according to the following steps:
The relative bias between the reported and the target value (the best estimate of the true value) is expressed by the following equation:

$$Bias_{relative} = \frac{Value_{reported} - Value_{target}}{Value_{target}} * 100\%$$

The relative bias was compared to the Maximum Acceptable Relative Bias (MARB) which is determined for each analyte, considering the radioanalytical methods, the level of radioactivity and the complexity of the analysis.

If $|Bias_{relative}| \leq MARB$, the result will be rated "Accepted (A)" for trueness.

Based on fit-for-purpose and good laboratory practice principles, the relative expanded uncertainty should cover the relative bias:
The P statistic is calculated using the below equation:

$$P = \sqrt{\left(\frac{u_{target}}{A_{target}}\right)^2 + \left(\frac{u_{reported}}{A_{reported}}\right)^2} * 100\%$$

The relative bias is then compared to the P value:

$$|Bias_{relative}| \leq k * P$$

where k is the coverage factor, $k = 2.58$ corresponding to a confidence level of 99%.
When the above criterion is fulfilled, the reported result is not significantly different from the target values considering the uncertainties associated with both values. The reported uncertainty of measurement is large enough to cover the bias of the result.
In addition, the P statistic is compared to the MARB.

$$P \leq MARB$$

When this criterion is fulfilled, the measurement uncertainty is not overestimated and fit-for-purpose in relation to the MARB criterion of this PT exercise.
When both criteria related to the measurement uncertainty are fulfilled, the reported result is rated "accepted (A)" for precision (measurement uncertainty). The result is rated "Not Accepted (N)" for precision if either of the two conditions are not fulfilled. The final score is assigned according to the detailed evaluation described above. The possible scores are listed below:

- "Accepted (A)" when both, trueness and precision were rated "Accepted"
- "Not Accepted (N)" when the trueness rating is "Not Accepted"
- "Warning (W)" when the trueness rating is “Accepted” but the precision rating is "Not Accepted"

A z score is provided in addition to above mentioned parameters due to requests by several participants.

$$z = \frac{Value_{reported} - Value_{target}}{\sigma_{PT}}$$

Where σ_{PT} is the standard deviation for proficiency assessment. The standard deviation for proficiency assessment is determined for each analyte, considering the radioanalytical methods, the level of radioactivity and the complexity of the analysis. In case of independently assigned target values, it is connected to the MARB as follows:

$$\sigma_{PT} = \frac{MARB.Value_{target}}{3}$$

2.2 Evaluation of parameters without independently assigned target value (“intercomparison” approach)

When no independently assigned target value is available for a parameter, the consensus from all reported results from PT participants is applied as the target value. Robust statistical methods are applied to derive the target value and the robust standard deviation.
This approach was applied to gross alpha / beta measurement results.
The evaluation includes calculation of relative bias, z scores and ζ (zeta) scores according to the following steps:
The relative bias is calculated as described in Section 2.1.
A z score is calculated using the following general equation:

$$z = \frac{Value_{reported} - Value_{target}}{\sigma_{PT}}$$

Where σ_{PT} is the standard deviation for proficiency assessment.
In this case, the standard deviation for proficiency assessment is the robust standard deviation of the population.
Here, the z score provides information on the deviation of the reported value from the consensus value derived from participants’ results, expressed in multiples of the (robust) standard deviation of the population.
It should be emphasized that a z score derived this way is a parameter which depends on the population of reported results, i.e. on the performance of participants.
The following criteria apply for performance ratings based on obtained z scores:

- $|z| \leq 2$ ... accepted (A)
- $2 < |z| < 3$ ... questionable (Q)
- $|z| \geq 3$ ... not accepted (N)

A ζ (zeta) score is calculated using the following general equation:

$$\zeta = \frac{Value_{reported} - Value_{target}}{\sqrt{(u_{reported})^2 + (u_{target})^2}}$$

The ζ score allows a combined assessment of the reported value and the reported uncertainty of measurement.
The following criteria apply for performance ratings based on obtained ζ scores:

- $|\zeta| \leq 2$ ... accepted (A)
- $2 < |\zeta| < 3$ ... questionable (Q)
- $|\zeta| \geq 3$ ... not accepted (N)

3 Data Evaluation Tables

Target Values for activity concentration of radionuclides in Sample 1, Spiked Water

TABLE 2. Target values

Sample	Analyte	Technique	Target Value	Uncertainty ($k = 1$)	Unit	MARB in %
1	Po-210	alpha	29.9	1.5	Bq/kg	30
1	H-3	beta	46.8	2.4	Bq/kg	30
1	Sr-90	beta	39.5	2.0	Bq/kg	30
1	Pb-210	beta	29.4	1.2	Bq/kg	30
1	Na-22	gamma	19.9	1.2	Bq/kg	20
1	Co-60	gamma	35.6	1.5	Bq/kg	20
1	Ba-133	gamma	34.3	2.1	Bq/kg	20
1	Cs-134	gamma	24.6	1.0	Bq/kg	20
1	Cs-137	gamma	17.1	0.7	Bq/kg	20

Evaluation Table for Sample 1

TABLE 3. Evaluation Results for Sample 1

Analyte	Technique	Target Value	Unc. of the TV	MARB in %	Reported value in Bq/kg	Reported uncertainty ($k = 1$) in Bq/kg	Relative bias in %	P-Test in %	Trueness evaluation	Precision evaluation	Final Score	Z Score
Na-22	Gamma-Ray Spectrometry	19.9	1.2	20	17.9	1.6	-10.1	10.78	A	A	A	-1.51
Co-60	Gamma-Ray Spectrometry	35.6	1.5	20	34.8	2.7	-2.2	8.83	A	A	A	-0.34
Ba-133	Gamma-Ray Spectrometry	34.3	2.1	20	31.5	2.1	-8.2	9.05	A	A	A	-1.22
Cs-134	Gamma-Ray Spectrometry	24.6	1.0	20	24.3	2.2	-1.2	9.92	A	A	A	-0.18
Cs-137	Gamma-Ray Spectrometry	17.1	0.7	20	15.9	1.2	-7.0	8.59	A	A	A	-1.05
Pb-210	Gamma-Ray Spectrometry	29.4	1.2	30	31.5	2.9	7.1	10.07	A	A	A	0.71

Target Values for activity concentration of radionuclides in Sample 2, Natural Water

TABLE 4. Target values

Sample	Analyte	Technique	Target Value	Uncertainty ($k = 1$)	Unit	MARB in %
2	Ra-226	alpha	0.0962	0.0058	Bq/kg	30
2	U-234	alpha	0.0891	0.00446	Bq/kg	30
2	U-235	alpha	0.00372	0.00031	Bq/kg	30
2	U-238	alpha	0.0818	0.0041	Bq/kg	30

Evaluation Table for Sample 2

TABLE 5. Evaluation Results for Sample 2

Analyte	Technique	Target Value	Unc. of the TV	MARB in %	Reported value in Bq/kg	Reported uncertainty ($k = 1$) in Bq/kg	Relative bias in %	P-Test in %	Trueness evaluation	Precision evaluation	Final Score	Z Score
U-234	Alpha-Particle Spectrometry	0.0891	0.00446	30	0.083	0.011	-6.8	14.17	A	A	A	-0.68
U-238	Alpha-Particle Spectrometry	0.0818	0.0041	30	0.0728	0.0095	-11.0	13.98	A	A	A	-1.10

Target Values for Uranium Isotopes by ICP-MS in Sample 2, Natural Water

TABLE 6. Target values

Sample	Analyte	Technique	Target Value	Uncertainty ($k = 1$)	Unit	MARB in %
2	U-235	ICP-MS	0.0470	0.0017	ng/g	20
2	U-238	ICP-MS	6.56	0.21	ng/g	20
2	Total U	ICP-MS	6.60	0.21	ng/g	20

Evaluation Table for Sample 2, Natural Water, Uranium Isotopes by ICP-MS

No data reported.

Target values for activity concentration of radionuclides in Sample 3, Soil

TABLE 7. Target values

Sample	Analyte	Technique	Target Value	Uncertainty ($k = 1$)	Unit	MARB in %
3	K-40	gamma	485	11	Bq/kg	20
3	Cs-137	gamma	10.3	0.3	Bq/kg	20
3	Tl-208	gamma	12.9	0.4	Bq/kg	20
3	Pb-210	gamma	43.4	1.7	Bq/kg	20
3	Bi-212	gamma	39.6	1.7	Bq/kg	20
3	Pb-212	gamma	36.8	1.1	Bq/kg	20
3	Bi-214	gamma	47.9	1.3	Bq/kg	20
3	Pb-214	gamma	47.9	1.3	Bq/kg	20
3	Ra-226	gamma	47.9	1.3	Bq/kg	20
3	Ac-228	gamma	36.4	1.7	Bq/kg	20
3	Th-232	gamma	36.4	1.7	Bq/kg	20
3	Pa-234m	gamma	27.0	1.8	Bq/kg	20
3	Th-234	gamma	27.0	1.8	Bq/kg	20
3	U-235	gamma	1.24	0.08	Bq/kg	20
3	U-238	gamma	27.0	1.8	Bq/kg	20

Evaluation Table for Sample 3

TABLE 8. Evaluation Results for Sample 3

Analyte	Technique	Target Value	Unc. of the TV	MARB in %	Reported value in Bq/kg	Reported uncertainty ($k = 1$) in Bq/kg	Relative bias in %	P-Test in %	Trueness evaluation	Precision evaluation	Final Score	Z Score
K-40	Gamma-Ray Spectrometry	485	11	20	492	56	1.4	11.61	A	A	A	0.22
Cs-137	Gamma-Ray Spectrometry	10.3	0.3	20	10.3	1	0.0	10.14	A	A	A	0.00
Tl-208	Gamma-Ray Spectrometry	12.9	0.4	20	12.7	1.4	-1.6	11.45	A	A	A	-0.23
Pb-210	Gamma-Ray Spectrometry	43.4	1.7	20	40.8	4	-6.0	10.56	A	A	A	-0.90
Bi-212	Gamma-Ray Spectrometry	39.6	1.7	20	36.5	2.1	-7.8	7.18	A	A	A	-1.17
Pb-212	Gamma-Ray Spectrometry	36.8	1.1	20	36.5	2.1	-0.8	6.48	A	A	A	-0.12
Bi-214	Gamma-Ray Spectrometry	47.9	1.3	20	48.5	5.5	1.3	11.66	A	A	A	0.19
Pb-214	Gamma-Ray Spectrometry	47.9	1.3	20	51	3.9	6.5	8.11	A	A	A	0.97
Ra-226	Gamma-Ray Spectrometry	47.9	1.3	20	50.1	4.5	4.6	9.38	A	A	A	0.69
Ac-228	Gamma-Ray Spectrometry	36.4	1.7	20	37.8	3.9	3.8	11.33	A	A	A	0.58
Th-232	Gamma-Ray Spectrometry	36.4	1.7	20	36.7	1.5	0.8	6.21	A	A	A	0.12
Th-234	Gamma-Ray Spectrometry	27.0	1.8	20	27.7	2.9	2.6	12.41	A	A	A	0.39
U-235	Gamma-Ray Spectrometry	1.24	0.08	20	1.27	0.13	2.4	12.10	A	A	A	0.36
U-238	Gamma-Ray Spectrometry	27.0	1.8	20	27.7	2.9	2.6	12.41	A	A	A	0.39

Target values for activity concentration of radionuclides in Sample 4, Vegetation

TABLE 9. Target values

Sample	Analyte	Technique	Target Value	Uncertainty ($k = 1$)	Unit	MARB in %
4	K-40	gamma	2029	69	Bq/kg	20

Evaluation Table for Sample 4

TABLE 10. Evaluation Results for Sample 4

Analyte	Technique	Target Value	Unc. of the TV	MARB in %	Reported value in Bq/kg	Reported uncertainty ($k = 1$) in Bq/kg	Relative bias in %	P-Test in %	Trueness evaluation	Precision evaluation	Final Score	Z Score
K-40	Gamma-Ray Spectrometry	2029	69	20	2140	200	5.5	9.95	A	A	A	0.82

Target values for activity of radionuclides in Sample 5, Printed Surface

TABLE 11. Target values

Sample	Analyte	Technique	Target Value	Uncertainty ($k = 1$)	Unit	MARB in %
5	Sr-90	beta	3.22	0.16	Bq/sample	30
5	Ba-133	gamma	10.1	0.51	Bq/sample	30

Evaluation Table for Sample 5 (surface sample)

TABLE 12. Evaluation Results for Sample 5

Analyte	Technique	Target Value	Unc. of the TV	MARB in %	Reported value in Bq/sample	Reported uncertainty ($k = 1$) in Bq/sample	Relative bias in %	P-Test in %	Trueness evaluation	Precision evaluation	Final Score	Z Score
Sr-90	Other	3.22	0.16	30	3.31	0.54	2.8	17.05	A	A	A	0.28
Ba-133	Gamma Ray Spectrometry	10.1	0.51	30	10.53	0.77	4.3	8.89	A	A	A	0.43

Intercomparison parameters for activity concentration of radionuclides

TABLE 13. ILC values

Sample	Analyte	Technique	Robust Mean	Robust Standard Deviation	Unit	MARB in %
2	Gross Alpha	alpha	0.319	0.188	Bq/kg	30
2	Gross Beta	beta	0.417	0.294	Bq/kg	30
2	Ra-228	beta	0.656	0.703	Bq/kg	30
4	Cs-137	gamma	0.500	0.382	Bq/kg	30
4	Bi-214	gamma	4.37	3.63	Bq/kg	30
4	Pb-214	gamma	3.50	2.33	Bq/kg	30
4	Ra-226	gamma	4.40	3.59	Bq/kg	30
4	Ac-228	gamma	4.86	4.18	Bq/kg	30

Evaluation Table for Sample 2 and 4

No data reported.

4 Contributors to evaluation and report

I. Davies, M. Horsky, B. Seslak, A. Trinkl, I. Vukanac: Terrestrial Environmental Radiochemistry Laboratory, Division of Physical and Chemical Sciences, Department of Nuclear Sciences and Applications, International Atomic Energy Agency

5 Disclaimer

This report is generated automatically and intended solely for the recipient's personal use. While every effort is made to ensure accuracy, we acknowledge that discrepancies may occur. Should you identify any incorrect information, please notify us promptly so we can address the issue. Your vigilance helps us maintain the highest standard of correctness.