IMPROVING ANALYTICAL PERFORMANCE THROUGH PROFICIENCY TESTS ACTIVITY

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Abstract
One of the most important parts of the environmental monitoring program worldwide is the measurement of radionuclides activity concentrations in order to be able to assess the human and biota exposure due to radiation. For the external quality control, the participation in the proficiency tests is an important tool providing opportunity to improve analytical skills and to validate the techniques in the field of radioactivity measurements. At the same time, it represents an essential requirement of ISO 17025 standard. The aim of this paper was to present the results obtained by the Radiation, Environmental and Civil Protection Laboratory (LRPMPC), RATEN ICN Pitesti, from the latest five environmental radioactivity proficiency tests organized by IAEA ALMERA network.

Keywords: *Proficiency test, Gamma spectrometry, ALMERA network*

Introduction

ALMERA is a network of Analytical Laboratories for the Measurement of Environmental Radioactivity coordinated by the International Atomic Energy Agency (IAEA). The network aims to enhance the capability and performance of participating laboratories with a view to providing timely and reliable measurement results in emergency situations [1]. Participation of the national environmental radioanalytical laboratories in the network's activities is quite important and among the benefits of joining ALMERA the following can be mentioned:

- demonstration of technical competences in the field of measuring environmental radioactivity;
- adopt the application of recommended validated methods leading to methodological harmonization and increased worldwide comparability of results of environmental radioactivity measurement;
- improving the analytical capabilities of personnel to meet global standards;
- development of collaborations with other similar laboratories in the region and elsewhere.

The Radiation, Environmental and Civil Protection Laboratory (LRPMPC) from RATEN ICN Pitesti, became an ALMERA network member in 2005, annually participating in the environmental radioactivity proficiency tests organized by the network. These tests are designed to identify analytical problems, to help IAEA member states to maintain their accreditation and to provide knowledge and technology transfer in this area. Yearly, IAEA prepares and distributes the samples to the national participating laboratories, after which it collects and interprets analysis results and compiles a comprehensive report. The proficiency tests organized by IAEA are prepared according to international standards and recommendation [2].

The set for PTs contains more samples having liquid or solid matrix with different density. Usually, the liquid matrix consists in water which is acidified for stability reasons and the solid matrix was varied from year to year (e. g. soil, shrimps, fish and bamboo). The samples can be un-spiked (natural radioactivity) or spiked with anthropogenic gamma-ray emitting radionuclides (e. g. ^{241}Am, ^{60}Co, ^{58}Co, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{133}Ba, ^{110m}Ag), beta emitter isotopes (^{90}Sr, ^{3}H) and/or natural radionuclides.

Beside these samples, the PT material also includes the quality control (QC) samples (in water matrices) spiked with known radionuclides activity concentrations for calibration check purpose. All information regarding the origin and characterization of samples and reporting requirements are provided in *Instruction to Participants Sheet* received with the PT samples set.

The latest five ALMERA PTs are briefly summarized in the following:

- IAEA-TEL-2021-04 ALMERA - *PT on determination of anthropogenic and natural radionuclides in water, Japanese bamboo and simulated swipe samples.*

The PT consisted of five water samples, including two QC water samples, one Japanese Bamboo sample and four swipe samples (two identical simulated swipe samples containing γ emitters and transuranic isotopes - TRU, one QC sample with γ emitters and TRU, and one blank sample). Three water samples were spiked with anthropogenic gamma and alpha emitting radionuclides, ^{3}H and ^{90}Sr, and the other two additional water samples have contained transuranic isotopes.

- ***IAEA-TEL-2020-04 ALMERA*** - *PT on determination of anthropogenic and natural radionuclides in water and fish samples and gross alpha and beta estimation on simulated aerosol filter.*

The PT consisted of three water samples, including one QC water sample, one fish sample and three simulated aerosol filter. One water sample and fish sample contained radionuclides from the broken decay chain of the (^{232}Th)-^{228}Ra-… in disequilibrium.

- ***IAEA-TEL-2019-04 ALMERA*** - *PT on determination of anthropogenic and natural radionuclides in water, shrimp and simulated filters.*

The PT consisted of three water samples, including one QC water sample, one shrimp sample and three simulated aerosol filter. The water samples were spiked with anthropogenic gamma emitters and natural radionuclides, one of these having low activity concentration.

- ***IAEA-TEL-2018-04 ALMERA*** - *PT on determination of anthropogenic and natural radionuclides in water, milk powder and calcium carbonate.*

The PT consisted of three water samples, including one QC water sample, one agricultural soil sample and three large surface samples for the determination of surface contamination. One of the water sample was spiked with anthropogenic gamma emitter radionuclides, ^{210}Pb and two beta emitters, ^{89}Sr and ^{90}Sr, and other water sample was spiked with a primary coolant of the nuclear reactor.

- ***IAEA-TEL-2017-04 ALMERA*** - *PT on the determination of anthropogenic and natural radionuclides in water, milk powder and Ca-carbonate of natural origin.*

The PT consisted of three simulated paper filters, three water samples, including one QC water sample, one milk powder sample, and one NORM sample, i.e. Ca-carbonate from a spring water source.

More information about the PT organized by IAEA ALMERA can be found by accessing the following link https://nucleus.iaea.org/sites/ReferenceMaterials/Pages/ALMERA-Proficiency_Tests.aspx.

Evaluation of proficiency test results

The first parameter to be determined is the *relative bias between the reported and the target value* and is expressed by Eq. (1). This is an indicator of the closeness of reported value to the target value, being expressed as a percentage.

$$Bias_{relative} = \frac{value_{reported} - value_{target}}{value_{reported}} \times 100\% \qquad (1)$$

The relative bias is compared to the Maximum Acceptable Relative Bias (MARB), which is predefined by the IAEA, considering the radioanalytical methods, the radioactivity level and the complexity of the analysis. Usually, MARB is settled to be typically 15% – 30% for gamma-ray emitting radionuclides, and 20% – 35% for radionuclide for which the determination of mass activity requires radiochemistry [1]. The results will be "Accepted" for accuracy if $|Bias_{relative}| \leq$ MARB.

If the reported value passes the accuracy test, the *precision score*, *P*, is calculated according to Eq. (2):

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

$$\left|Bias_{relative}\right| \leq k \times P \qquad (3)$$

where *k* is the coverage factor; for the 99% confidential level, $k = 2.58$.

If the result is between the ± MARB values, but is not overlapping the target value, within the uncertainty, this equation is used to decide if the values are significantly different or not.

The P value is also compared to the MARB. If both relations: $P \leq$ MARB and $|Bias_{relative}| \leq$ k × P are fulfilled, the reported results will be "Accepted" for precision. The result will be assigned "Not accepted" for precision if either condition is not fulfilled. The final score is assigned according to the detailed evaluation described above, the possible scores being listed below:

- "Accepted" when both accuracy and precision achieved "Accepted" status
- "Not Accepted" when the accuracy is "Not accepted"
- "Warning" when accuracy is "Accepted", but the precision is "Not accepted".

The process of evaluation of the results is schematically represented in Fig. 1.

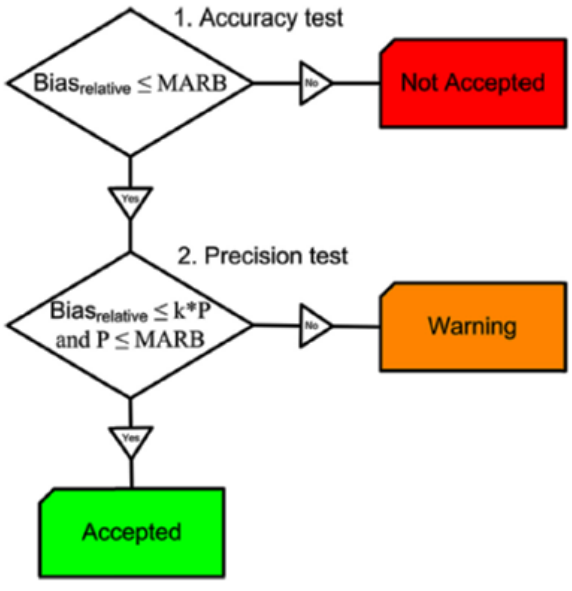


Fig.1 Process of results evaluation

As additional information, a *z-score* parameter is shown in the evaluation report; it is calculated by using the robust standard deviation given below:

$$z = \left|\frac{value_{reported} - value_{target}}{robustSD}\right| \qquad (4)$$

If the analyte is included in the proficiency test evaluation scheme, the stated target value is used to calculate the *Z-score*. For the analytes which are subject of an intercomparison only, the robust mean of the values reported is used instead.

Material and methods

Equipment

The equipment used for radiological monitoring of the environment by means of gamma spectrometry was a coaxial p-type HPGe detector (Canberra, model GC2518) having a relative efficiency of 25% and an energy resolution of 1.8 keV (FWHM) at 1332.5 keV and 0.850 keV (FWHM) at 122 keV. The detector is shielded with 10 cm of lead lined on the inner face with a 2 mm Copper foil. The detector is linked to an appropriate data acquisition system InSpector Desktop Canberra. The software used for spectra analysis and calculation of activity concentration was Genie 2000 from Canberra. The HPGe detector calibration (energy and efficiency) was performed using certified calibration source containing ^{60}Co, ^{133}Ba, ^{137}Cs and ^{241}Am, respectively.

The measurements of beta emitters activity concentration, such as ^{3}H or ^{90}Sr, were carried out using a TRI-CARB 4900 TR Liquid Scintillation Counter.

For gross alpha and beta measurements, a gas-flow proportional counter, model MPC 9300, was used. This equipment is a counting system that provides true ultra-low background performance for applications with low sample throughput requirements. Simultaneous or separate alpha plus beta counting modes provide high efficiency detection in a single counting cycle [4].

Samples preparation

Tested and validated analytical procedures availability is extremely important in order to produce valid and reliable analytical measurements. LRPMPC disposes of a series of analytical procedures in which the methods of analysis are described (including the samples preparation step). The water samples for the PTs were about 500 ml each, the solid matrix samples mass ranging from 200 g to 400 g.

The samples were prepared according to the chosen analytical method. For example, the water samples for gross beta and gross alpha were prepared by evaporation, and then analysed using the gas proportional counter. In order to perform gamma spectrometry measurements, samples were prepared for measurement and placed into relatively large volume plastic containers of cylindrical shape (usually known as SARPAGAN geometry) having 73 mm inner diameter and 37 mm in height.

In case of solid matrix samples, other preparation steps may be required, such as drying of the sample. For LSC measurements, small volumes of water samples were mixed with different types of scintillators, depending on the radionuclide to be measured.

For the mass activity determination of radionuclides which requires radiochemistry, the samples preparation step is more complex, and depends on the radionuclide, sample matrix type or analytical method used.

Self-attenuation correction

The most accurate method to determine the activity of each radionuclide is to use an adequate standard source with very similar geometrical dimensions, density, and chemical compositions as the sample under study. In practice, the samples differ from the chosen calibration sources in terms of matrix, density, geometry, and, consequently, corrections for different self-absorption effects are needed.

For gamma spectrometric measurements, in order to perform the accurate determination of the activity concentrations in the samples for which no appropriate standard exists in LRPMPC, LabSOCS software was used.

Self-attenuation corrections were also applied for gross alpha and beta measurements, the attenuation correction curves being determined from the measurement of standard sources prepared with different known thicknesses [5].

Results and discussion

The target values, reported results and evaluation criteria for the before mentioned five annual proficiency tests (performed between 2017 and 2021) are summarized in Tables 1 and 2.

Table 1 Evaluation Report (values and uncertainties are expressed in Bq/kg)

Year of PT	Sample code	Analyte	Target Value	Target Uncert.	MARB	Rep. Value	Rep. Uncert.	Accuracy	Precision	Final Score
2021	1- Spiked water	Am^{241}	60.9	2.7	20 %	55.9	5.0	A	A	A
		Co^{60}	74.2	3.3	20 %	77.9	4.1	A	A	A
		Cs^{134}	113.2	5.1	20 %	120.6	6.2	A	A	A
		Cs^{137}	69.2	3.1	20 %	77.4	4.3	A	A	A
	2- Spiked water	Am^{241}	108.3	4.9	20 %	107.2	8.9	A	A	A
		Ba^{133}	147.3	6.6	20 %	136.3	7.0	A	A	A
		Cs^{137}	147.4	6.6	20 %	155.8	8.3	A	A	A
		Sr^{90}	146.8	8.4	30 %	145.9	14.6	A	A	A
	4 - Japanese bamboo	Cs^{134}	86.6	4	25 %	83.0	4.4	A	A	A
		Cs^{137}	2063	93	20 %	1959.2	103.2	A	A	A
		K^{40}	97.9	7.2	30 %	67.8	17.1	N	A	N
	5- Spiked water	Cs^{134}	19.05	0.86	30 %	20.0	1.1	A	A	A
		Cs^{137}	26.02	1.17	25 %	28.1	1.7	A	A	A
	7 - Simulated swipe samples	Cs^{137}	11.2	0.6	20 %	10.8	0.8	A	A	A
		Pu^{239}	8.47	0.5	40 %	7.9	2.0	A	A	A
2020	1- Spiked water	Cs^{134}	33.5	0.5	20 %	33.8	2.4	A	A	A
		Cs^{137}	64.4	0.9	20 %	66.3	4.8	A	A	A
		Na^{22}	76.8	1.2	20 %	72.2	5.1	A	A	A
		Sr^{90}	23.9	0.3	30 %	30.7	4.6	A	A	A
	2- Spiked water	Ac^{228}	24.7	1	25 %	22.7	1.7	A	A	A
		Bi^{212}	6	0.5	60 %	8.4	2.8	A	A	A
		Pb^{212}	6	0.5	35 %	8.5	0.7	N	N	N
		Tl^{208}	2.2	0.2	40 %	4.2	0.5	N	N	N
	4 - Dried fish	Ac^{228}	34.9	2	30 %	32.8	2.5	A	A	A
		Bi^{212}	11.5	0.8	60 %	19.6	3.8	N	N	N
		Bi^{214}	13.5	0.8	30 %	9.0	1.1	N	A	N
		Cs^{134}	119.4	5	20 %	122.2	8.6	A	A	A
		Cs^{137}	18.9	1	25 %	20.6	1.6	A	A	A
		K^{40}	369	18	25 %	354.4	27.3	A	A	A
		Pb^{210}	95.8	5	30 %	121.9	56.6	A	N	W
		Pb^{212}	11.5	0.8	30 %	15.6	1.2	N	N	N
		Pb^{214}	13.5	0.8	30 %	5.6	0.8	N	N	N
		Po^{210}	97.4	5	30 %	90.9	11.8	A	A	A
		Ra^{226}	13.5	0.8	30 %	15.4	3.1	A	A	A
		Ra^{226}	13.5	0.8	30 %	23.9	5.9	N	N	N
		Tl^{208}	4.1	0.3	40 %	6.1	0.7	N	N	N
	5 - Printed disk samples	Ag^{110m}	55.1	4	30 %	55.6	3.9	A	A	A
		Se^{75}	18.1	1	25 %	17.6	1.2	A	A	A
	6 - Printed disk samples	Ag^{110m}	35.1	3	30 %	35.6	2.5	A	A	A
		Se^{75}	31.3	1.5	25 %	30.9	2.2	A	A	A
	7 - Printed disk samples	Ag^{110m}	19.2	1.4	30 %	19.8	1.4	A	A	A
		Se^{75}	113.4	2	25 %	107.9	7.6	A	A	A

Table 1 Evaluation Report (values and uncertainties are expressed in Bq/kg) – *continued*

Year of PT	Sample code	Analyte	Target Value	Target Uncert.	MARB	Rep. Value	Rep. Uncert.	Accuracy	Precision	Final Score
2019	1 - Spiked water	Ac^{228}	22.08	1	20 %	23.8	1.4	A	A	A
		Cs^{134}	9.3	0.3	20 %	9.9	0.5	A	A	A
		Cs^{137}	8.92	0.25	20 %	9.7	0.9	A	A	A
		Ra^{226}	7.5	0.25	25 %	7.8	1.0	A	A	A
		Sr^{90}	9.4	0.31	30 %	8.7	1.3	A	A	A
	2 - Spiked water	Ac^{228}	3.98	0.12	40 %	6.6	0.6	N	N	N
		Cs^{134}	5.05	0.15	40 %	4.4	0.2	A	A	A
		Cs^{137}	4.19	0.12	40 %	4.6	0.4	A	A	A
		Ra^{226}	1.4	0.07	40 %	1.4	0.2	A	A	A
		Sr^{90}	2.7	0.13	60 %	2.4	0.6	A	A	A
	4 - Shrimps	Ac^{228}	17.7	0.9	25 %	17.9	1.5	A	A	A
		Cs^{137}	0.21	0.04	60 %	3.8	1.9	N	N	N
		K^{40}	335	12	15 %	308.5	49.2	A	N	W
		Po^{210}	57.8	1.1	25 %	16.1	2.1	N	N	N
		Ra^{226}	6	0.6	40 %	3.2	0.8	N	A	N
	5 - Simulated Air Filters	Cs^{134}	10.71	0.32	20 %	9.4	1.0	A	A	A
		Cs^{137}	13.25	0.4	20 %	13.8	1.6	A	A	A
	6 - Simulated Air Filters	Cs^{134}	20.28	0.61	20 %	17.5	1.8	A	A	A
		Cs^{137}	13.02	0.4	20 %	12.9	1.5	A	A	A
	7 - Simulated Air Filters	Cs^{134}	6.37	0.25	25 %	5.6	0.6	A	A	A
		Cs^{137}	24.93	0.75	20 %	24.7	2.8	A	A	A
2018	1 - Spiked water	Am^{241}	29.3	0.2	15 %	16.4	1.6	N	N	N
		Ba^{133}	28.6	0.2	15 %	23.5	1.5	N	N	N
		Co^{60}	97.6	0.8	15 %	99.3	5.5	A	A	A
		Cs^{134}	58.2	0.3	15 %	58.9	3.4	A	A	A
		Cs^{137}	29	0.2	15 %	33.2	2.5	A	A	A
		Po^{210}	86.6	4	30 %	244	29	N	N	N
		Sr^{89}	93.8	1.4	25 %	87.0	11.3	A	A	A
		Sr^{90}	9.7	0.1	25 %	9.8	1.3	A	A	A
	2 - Spiked water	Br^{82}	224	8	30 %	216.1	13.0	A	A	A
		Co^{58}	15.5	1.2	30 %	14.2	1.0	A	A	A
		Co^{60}	14.3	0.6	30 %	16.2	1.4	A	A	A
		Cs^{134}	3010	60	15 %	3156.4	160.7	A	A	A
		Cs^{136}	29.2	0.7	30 %	23.4	2.2	A	A	A
		Cs^{137}	2010	40	15 %	2220.9	122.4	A	A	A
		I^{131}	241	7	20 %	202.0	13.3	A	A	A
		I^{133}	2760	70	30 %	3319.0	219.3	A	N	W
		Mn^{54}	61.3	1.4	20 %	63.7	3.8	A	A	A
		Mo^{99}	470	15	30 %	467.5	36.4	A	A	A
		Na^{24}	21900	600	25 %	22189.	1236.1	A	A	A
		Sb^{124}	33.5	0.7	30 %	31.2	2.9	A	A	A
		Tc^{99m}	470	15	30 %	449.5	52.4	A	A	A
	4 - Agricultural soil	Ac^{228}	32.6	1.3	25 %	36.3	3.5	A	A	A
		Am^{241}	53.1	0.9	20 %	31.7	2.5	N	N	N
		Ba^{133}	56.8	0.9	20 %	60.0	7.2	A	A	A
		Bi^{214}	31.2	1.5	20 %	19.4	1.6	N	N	N
		Co^{60}	141.8	2.7	20 %	148.0	7.8	A	A	A
		Cs^{134}	112.2	1.6	20 %	117.1	6.2	A	A	A
		Cs^{137}	64.9	1.2	20 %	73.1	4.2	A	A	A
		Pb^{210}	485	11.6	20 %	77.5	20.2	N	N	N
		Pb^{212}	32.6	1.3	25 %	32.2	5.3	A	A	A
		Pb^{214}	31.2	1.5	20 %	16.1	1.1	N	N	N
		Ra^{226}	31.2	1.5	20 %	24.6	7.2	N	N	N
		Tl^{208}	11.7	0.4	25 %	12.5	1.1	A	A	A
		U^{235}	1	0.1	30 %	1.5	0.7	N	N	N

Table 1 Evaluation Report (values and uncertainties are expressed in Bq/kg) – *continued*

Year of PT	Sample code	Analyte	Target Value	Target Uncert.	MARB	Rep. Value	Rep. Uncert.	Accuracy	Precision	Final Score
2017	1 - Spiked water	H^{3}	29.8	0.6	25	28	4.2	A	A	A
		Sr^{90}	11.2	0.3	20%	11.6	0.3	A	A	A
		Ba^{133}	16.9	0.5	15%	16.3	0.3	A	A	A
		Cs^{137}	13.1	0.4	15%	13.8	0.2	A	A	A
	2 - Spiked water2	Zr^{95}	8	0.22	30%	7.3	0.3	A	A	A
		Mo^{99}	55.9	1.9	25%	55.1	14.6	A	N	W
		Ru^{103}	3.94	0.12	40%	4.8	0.5	A	A	A
		Ba^{140}	37.1	1.1	30%	50.4	4.9	N	N	N
		Ce^{141}	15.7	0.4	30%	18.5	1.3	A	A	A
		Nd^{147}	15	0.5	30%	16.2	3.1	A	A	A
		Np^{239}	3100	70	20%	2022	210	N	N	N
	4 - Milk powder	Sr^{90}	99.9	5	15%	119.3	6	N	N	N
		Ba^{133}	137.4	5	15%	137.7	4.5	A	A	A
		Cs^{137}	98,6	5	15%	99.7	3.5	A	A	A
	5 - Ca-carbonate	Ra^{226}	6970	200	20%	6856.47	822.78	A	A	A
		Ra^{228}	90	4	30%	120	30	N	A	N

Table 2. Intercomparison Parameter Evaluation
(values and uncertainties are expressed in Bq/kg for water samples and fish samples)

Year of PT	Sample Code	Analyte	Robust Man	Robust SD	Rep. Value	Rep. Uncert.	Z-Score	Z-Score Evaluation
2021	1 - Spiked water	gross_α	105	26	69.9	17.5	1.35	A
		gross_β	159	45	163.4	40.9	0.10	A
	2 - Spiked water	H^{3}	1653.6	98.2	1429	129	2.29	W
		gross_β	457	112	437.9	109.5	0.17	A
		gross_α	97	28	74.7	18.7	0.80	A
	5- Spiked water	Pu^{239}	5.93	2.27	7.5	1.90	0.69	A
		Cm^{244}	7.02	2	5.7	1.5	0.66	A
		gross_β	33	9	26.8	6.7	0.69	A
		gross_α	16.4	5.4	13.7	3.4	0.50	A
	7 - Simulated swipe samples	gross_β	10.18	2.69	8.8	2.2	0.51	A
		gross_α	7.64	1.34	10.0	2.5	1.76	A
	2 - Spiked water	Eu^{152}	3.01	0.37	4.0	1.2	2.68	W
2020	1- Spiked water	gross_β	170	27	152.7	22.9	0.64	A
	2- Spiked water	gross_α	40	14	29.7	4.5	0.74	A
		gross_β	38	7	40.3	6.0	0.33	A
	4 - Dried fish	gross_α	169	126	297	89	1.02	A
		gross_β	597	186	488	146	0.59	A
	5 - Printed disk samples	gross_β	12.4	3.5	11.8	1.1	0.17	A
	6 - Printed disk samples	gross_β	8.6	2.5	8.1	0.7	0.20	A
	7 - Printed disk samples	gross_β	7.6	2.5	7.3	0.7	0.12	A

Table 2. Intercomparison Parameter Evaluation – *continued*
(values and uncertainties are expressed in Bq/kg for water samples and fish samples)

Year of PT	Sample Code	Analyte	Robust Man	Robust SD	Rep. Value	Rep. Uncert.	Z-Score	Z-Score Evaluation
2019	1 - Spiked water	gross_α	21.06	8.33	18.3	3.7	0.33	A
		gross_β	59.45	10.54	57.7	11.5	0.17	A
	2 - Spiked water	gross_α	4.2	1.58	2.7	0.8	0.95	A
		gross_β	17.32	4.15	7.8	2.3	2.29	W
	5 - Simulated Air Filters	gross_β	24	3.89	7.9	0.8	4.14	N
	6 - Simulated Air Filters	gross_β	33	5.04	9.8	1.0	4.60	N
	7 - Simulated Air Filters	gross_β	31	5.41	11.7	1.2	3.57	N
2018	1 - Spiked water	gross_α	104.5	34.1	133.3	20.0	0.84	A
		gross_β	242	76	392.3	58.8	1.98	A
	5 – Contaminated surface	β_emission _rate	1.1	0.5	1.233	0.026	0.27	A
	6 – Contaminated surface	α_emission _rate	0.3	0.2	0.428	0.018	0.64	A
	7 - Contaminated surface	α_emission _rate	0.2	0.1	0.277	0.014	0.77	A
		β_emission _rate	2	0.9	2.104	0.035	0.12	A
2017	1 - Spiked water	gross_α	42.3	6.5	43	6	0.84	A
		gross_β	38.1	10	59	9	1.98	W

For few radionuclides (such as ^{226}Ra and other radionuclides from natural series) the reported values have not been accepted, and corrective actions are needed.

In general, as can be observed from Table 1, for the most "Not accepted" results the target value of the specific activity in the samples is low (few Bq only), which makes the analysis process more complex. The presence of dynamic radioactive decay system (^{228}Ra – ^{228}Ac – ^{228}Th - …) has made the decay correction to be a little "tricky", some samples having similar isotopes, but different equilibrium status.

As it can be noticed, ^{241}Am is one of the radionuclides for which few results have been "Not accepted". The failure could be due to inaccurate efficiency calibration in gamma-ray spectrometry for the low energy range (less than 100 keV), difficult to obtain due to the lack of suitable radionuclide standards. Also, the high background of the detector recorded in this low energy region easily could lead to this failure.

In case of ^{226}Ra, the fail result is due to the interference with ^{235}U isotope, and necessary actions are taken for a better calculation of this radionuclide activity.

Conclusions

Ensuring accurate and reliable data in a radiation measurement laboratory requires specific high-performance equipment, calibrated detectors, the use of appropriate reference standards, corrections when necessary, and well-trained personnel with good expertise.

Regularly participation of LRPMPC in the proficiency tests organized by IAEA has helped to assess the laboratory performance, to identify the analytical problems and the source of errors, and to improve the overall laboratory performance including analytical protocols and personnel expertise by implementation of corrective actions and development of new analytical procedures.

The results of the presented proficiency test exercises organized by IAEA ALMERA network between 2017 and 2021 were satisfactory, more than 80% of the reported results being accepted. The performance evaluation in the IAEA proficiency tests confirmed the reliability and traceability of the analytical measurement results obtained by the LRPMPC.

"Not accepted" results and the relevant corrective actions implemented by the RATEN ICN above mentioned laboratory contributed to gain experience and knowledge, and also to strength the existing protocols and develop new ones.

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