Proficiency Test of calibration of surface contamination monitors with Brazilian Network – 2022/2023

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Abstract. This work reports the results obtained from the proficiency test involving 7 laboratories in Brazil. This exercise is about the calibration service of surface contamination monitors. The monitor has been calibrated to BS ISO 7503-3, the calibration factor in terms of surface emission rate. The proficiency test was conducted by the Brazilian National Laboratory of Ionizing Radiation Metrology (LNMRI / IRD) from December 2022 to May 2023. The extensive sources used were ^{14}C, ^{137}Cs, ^{60}Co, $^{90}Sr/^{90}Y$, ^{36}Cl and ^{241}Am. The result of this proficiency test was excellent, proving its need and the capacity of the Brazilian network in the calibration service for surface contamination monitors.

Keywords. Comparison, contamination monitor, calibration factor.

1. Introduction

The use of calibrated instrumentation for radiation protection purposes is one of the requirements that ensure the safe use of ionizing radiation sources. When unsealed sources are handled, there is a possibility of dispersion of radioactive solutions in the work areas. In such circumstances, the use of a calibrated contamination monitor is very important. Laboratories performing this contamination monitor calibration service follow written procedures and must be should be performed using Standard Sources (ABNT BR ISO 8769:2017)[2].

The participation in comparisons is necessary to increasing the credibility of measurement results and establishing mutual trust between laboratories. Participation in this type of program is also a requirement of ABNT BR ISO / IEC 17025: 2017[1].

The Brazilian National Laboratory of Ionizing Radiation Metrology (LNMRI/IRD/CNEN) organized and conducted this comparison exercise from December 2022 to May 2023. The protocol was structured according to the ISO/IEC 17043-1[5].

1.1. Participating Laboratories.

- Laboratório de Calibração de Monitores de Radiação – LCMR/LNMRI/IRD
- Instituto de Pesquisas Energéticas e Nucleares - IPEN
- Centro de Desenvolvimento de Tecnologia Nuclear- CDTN
- Departamento de Energia Nuclear da UFPE - DEN/UFPE
- Laboratório de Ciências Radiológicas da UERJ - LCR/UERJ
- Eletronuclear – Eletrobrás Termonuclear S.A.
- MRA Comércio de Instrumentos Eletrônicos Ltda.

The Brazilian National Laboratory of Ionizing Radiation Metrology (LNMRI/IRD) determined the calibration factor reference. It been the mean of the calibrations performed during the exercise.

2. Objective

The purpose of the comparison exercise was:
a) Calculate the calibration factor of the following radionuclides: ^{14}C, ^{137}Cs, ^{60}Co, $^{90}Sr/^{90}Y$, ^{36}Cl and ^{241}Am, and compares them;
b) Determine the performance of the calibration of participating laboratories;
c) Identify problems.

1. Instrument submitted for comparison

The item in this comparison is a monitor and its probe with the following characteristics:

Manufacturer: Thermo Electron Corporation
Monitor Model: Eberline E-600 serial number 3679
Probe: SHP-360 serial number 3704
Type: Geiger-Müller

4. Materials and Methods Used

Participants provided all the information requested to identify sources of error for the correct analysis of the results. This exercise only covered the calibration service for surface contamination monitors. Participants used the sources available at their facilities, covering as many radionuclides as possible. The sources belonging to LNMRI used in this exercise are in table 1.

Table 1: Characteristics of sources calibrated for comparison exercise.

Source	Fluxo (s^{-1})	Date	Área (cm^2)	Calibration
Am^{241}	1540	08/03/1994	100*	PTB/DKD Germany
Sr^{90}/Y^{90}	2620	02/03/1994	150*	
Cl^{36}	3170	02/03/1994	150*	
C^{14}	2540	03/03/1994	150*	
Cs^{137}	2840	04/03/1994	150*	
*Rectangular sources				

The calibration factor (emission) was chosen because it does not require the detector or probe area, thus decreasing a variable in the calculations. The percentage difference (D%) between the calibration factors calculated by LNMRI and the participants must be within 15% for the results LNMRI to be considered acceptable.

The most used reference documentation for contamination monitoring is ISO 7503-1[3], IEC ISO 8769[2], IAEA Safety Report Series No. 16[6] and comparison exercise articles[7,8,9,10,11,12]. The documents recommend that the instrument be calibrated for efficiency or calibration factor. Both procedures are correct and conversion from one to another is possible if the detector window area and calibration measurements are stated in the calibration certificate.

4.1. Determination of the calibration factor

For comparison purposes the instrument was calibrated according to ISO 7503-3[4] using the instrument calibration factor in terms of the surface emission rate FC(E) which is:

$$FC(E) = \frac{(R_c / S_c)}{n - n_B} \qquad (1)$$

Where:

n = average monitor readings (s^{-1})

n_B = average of background readings (s^{-1})

R_C = reference source emission rate (s^{-1})

S_c = reference source area (cm^2).

4. 2. Irradiation Geometry

The instruments were positioned with the detector windows parallel to the active surface of the radioactive source, keeping both detector and origin geometric centers aligned at a distance of 3 mm.

4. 3. Uncertainties

The measured uncertainties were calculated according to the ISO "Guide to the expression of measurement uncertainty". Total uncertainty was obtained by combining type A and B uncertainties concerning measurements and standard sources, multiplied by the factor k = 2, which corresponds to the 95.45% confidence level.

The components of uncertainty that contributed to the combined standard uncertainty of the calibration of surface contamination monitors are raised in positioning, irradiation distance, uncertainty of the calibration standard source (certified standard source), uniformity of the source, repeatability of measurements made with the monitor, reproducibility of measurements taken with the monitor, source

area, half life and monitor resolution, resolutions depending on the equipment and set up some more, and should take most of the components into account again when calibrating the surface contamination monitors.

5. Results

The Calibration Factors calculated by the participating Laboratories were compared with the factors calculated by LNMRI/IRD. Only one laboratory sent two results, because it has a set from 1984 and purchased another set of sources in 2016.

Table 2. The calibration factors and uncertainties determined by the participating laboratories.

SOURCES	Calibration Factors - FC (E) (β s-1 cm-2/s-1) ± U							
	LNMRI/IRD	LCR/UERJ	ETN	DEN	MRA	IPEN	CDTN 1	CDTN 2
Am-241	0,1702 ± 0,0085	0,158 ± 0,01485	0,172 ± 0,0234	0,207 ± 0,01304	0,177 ± 0,0135	0,170 ± 0,0158	0,1692 ± 0,0015	0,1544 ± 0,0071
Cs-137	0,1253 ± 0,0073		0,144 ± 0,0147	0,157 ± 0,0094		0,140 ± 0,01414		
Co-60	0,1939 ± 0,0262			0,197 ± 0,0205				
Sr-90/Y-90	0,106 ± 0,0055	0,118 ± 0,0104	0,107 ± 0,0105	0,137 ± 0,0086	0,114 ± 0,00855	0,120 ± 0,0085	0,11976 ± 0,0009	0,1105 ± 0,0049
Cl-36	0,1219 ± 0,0081	0,128 ± 0,0113	0,113 ± 0,0110	0,144 ± 0,00864	0,133 ± 0,01556	0,140 ± 0,0087	0,1218 ± 0,00064	0,1184 ± 0,00978
C-14	0,315 ± 0,0154	0,355 ± 0,0323	0,332 ± 0,0342		0,361 ± 0,0650		0,31195 ± 0,0061	0,3128 ± 0,02195

In the graph below, figures 1, we can observe the variation of the factors obtained by all participating laboratories and the LNMRI.

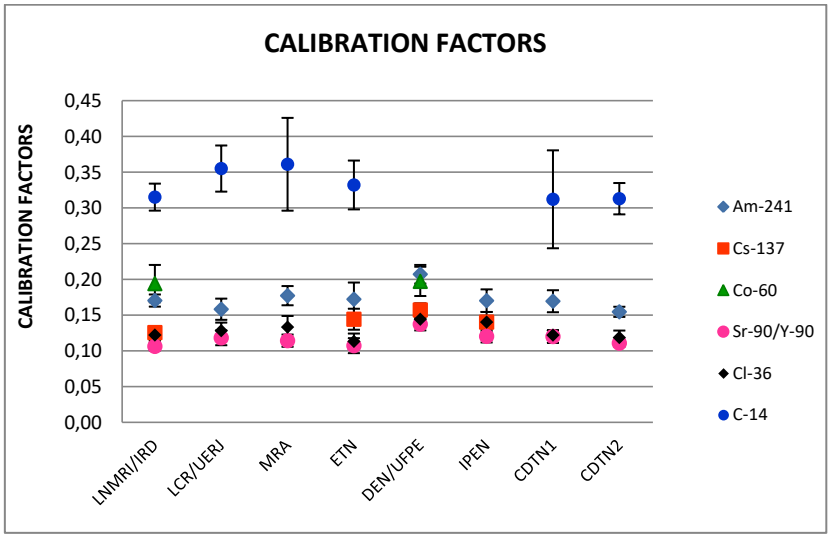

Figure 1 - Radionuclide Calibration Factors

5.1 Percentage Difference

Results were evaluated by percentage difference, D%, using the methodology recommended in ISO 17043-1.The percentage difference is calculated by the equation:

$$D_{\%} = \frac{FC_{participante} - FC_{LNMRI}}{FC_{LNMRI}} .100 \quad (2)$$

Where:

FC_{LNMRI} is the Calibration Factor obtained by LNMRI and

FC_{part} is the Calibration Factor obtained by the participating Laboratory.

Table 3: Percentage Difference of Participating Laboratories Factors with LNMRI Factor

Radionuclides	Percentage Difference- D(%)						
	LCR/UERJ	**ETN**	**DEN**	**MRA**	**IPEN**	***CDTN 1***	***CDTN 2***
Am-241	7,1	-1,1	-21,7	-4,0	0,1	0,6	9,3
Cs-137		-14,9	-25,3		-11,7		
Co-60			-1,6				
Sr-90/Y-90	-11,3	-0,9	-29,2	-7,5	-13,2	-13,0	-4,3
Cl-36	-5,0	7,3	-18,1	-9,1	-14,8	0,1	2,9
C-14	-12,7	-5,4		-14,6		1,0	0,7

Only one lab showed a percentage difference greater than 15 % in their results, the greater was 29,2 % in Sr-90 factor, outside the acceptance limits.

6. Conclusions and Comments

The calibration proficiency test for surface contamination monitors was carried out with a selected instrument sent to participants, allowing visualization of the practices carried out by laboratories and their equipment.

The Percentage Difference of the calibration coefficients was used as a criterion for evaluating the results of this proficiency test.

As can be seen from the results obtained in Table 3, the laboratories were within the 15% acceptance limit established by LNMRI in the protocol, only one laboratory result showed a percentage difference greater than 15% in four of its calculated factors, showing that there is a problem in the system. All other Labs remained within the stipulated value.

The result of this test proves the capacity of the laboratories to perform the calibration service of surface contamination monitors and also the need to apply comparisons carried out and improved at intervals to be discussed with the laboratories, which results in more accurate responses in the Test of Proficiency and greater reliability in the services provided by Brazilian laboratories.

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