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Comparison of calibration of surface contamination monitors with Brazilian Network - 2018/2019

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Abstract. This work reports the results obtained from the comparison 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 comparison was conducted by the Brazilian National Laboratory of Ionizing Radiation Metrology (LNMRI / IRD) from October 2018 to July 2019. 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 and proved the calibration 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 to assess the situation through reliable measurements. Laboratories performing such calibrations follow written procedures and should be performed based on standard sources.

Performing intercomparison is critical 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: 2005.

The Brazilian National Laboratory of Ionizing Radiation Metrology (LNMRI/IRD/CNEN) organized and conducted this comparison exercise from October 2018 to July 2019. The protocol was structured according to the ISO 17043.

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This exercise also aimed to apply the methodology resulting from previous works and analyze the results obtained to make improvements in the next comparisons of contamination monitors calibration performed with the Brazilian network.

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: ¹⁴C, ¹³⁷Cs, ⁶⁰Co, ⁹⁰Sr/⁹⁰Y, ³⁶Cl and ²⁴¹Am, and compares them;

b) Determine the performance of the calibration of participating laboratories;

c) Identify problems and propose corrective action.

3. Instrument submitted for comparison

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

Manufacturer: Ludlum Monitor Model: 2241-3 s/n 311330 Probe: 44-9 s/n PR341297 Type: Geiger-Müller

4. Materials and methods used

Participants committed to providing as much relevant information as possible that could be useful in identifying sources of error when the results were analyzed. This exercise covered only the calibration of surface contamination monitors and did not include the calibration of extensive reference sources. Reference sources for monitor calibration were not provided; participants used sources available at their facilities, covering as many radionuclides as possible. The extensive sources belonging to LNMRI used in this exercise are in table 1.

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

Table 1: Characteristics of sources calibrated for comparison exercise

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The calibration factor (emission) was chosen because it does not require the detector or probe area, thus decreasing an important variable in the calculations.

The most commonly used reference documentation for contamination monitoring are ISO 7503-1,2 and 3, IEC ISO 8769, IAEA Safety Report Series No. 16 and two NPL comparison exercise articles. The documents recommend that the instrument be calibrated for efficiency and / 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:

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

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 (cm²).

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 found by the laboratories were compared with the average of the factors found by LNMRI / IRD, only one laboratory sent two results, because it bought a new set of sources and sent the factors found with both sets of sources.

In the graph below, figure 1, we can observe the variation of the factors obtained by all participating laboratories and the LNMRI in table 2.

Radionuclides	Calibration Factor - FC (E) (β s ⁻¹ cm ⁻² /s ⁻¹) ± U							
	LNMRI/IRD	LCR/UERJ	ETN	DEN	MRA	IPEN	CDTN 1	CDTN 2
Am-241	0,2569 ±	0,24 ±	0,286 ±	0,289 ±	0,254 ±	0,24 ±	0,2761	0,238 ±
	0,013	0,02	0,036	0,018	0,018	0,015	±0,012	0,0122
Cs-137	0,16677 ±		0,182 ±	0,1899 ±		0,17 ±	0,1951	
	0,008		0,018	0,011		0,011	±0,017	
Co-60	0,2867 ±			0,2802 ±				
	0,013			0,022				
Sr-90/Y-90	0,148 ±	0,151 ±	0,136 ±	0,1696 ±	0,149 ±	0,14 ±	0,1619	0,1638 ±
	0,008	0,01	0,013	0,011	0,011	0,009	± 0,009	0,012
CI-36	0,1599 ±	0,158 ±	0,141 ±	0,1816 ±	0,168 ±	0,17 ±	0,1784	0,1905 ±
	0,008	0,01	0,014	0,011	0,019	0,010	± 0,009	0,0079
C-14	0,4918 ±	0,519 ±	0,482 ±		0,474 ±		0,4989	0,4912 ±
	0,027	0,05	0,049		0,081		±0,026	0,0264

Table 2. The calibration fact6r and uncertainties determined by the participating laboratories.





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:

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

Where:

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

In the table 3, we can observe the percentage difference obtained by all participating laboratories with LNMRI factor.

Radionuclides	Percentage Difference- D(%)						
	LCR/UERJ	ETN	DEN	MRA	IPEN	CDTN 1	CDTN 2
Am-241	6,58	-11,33	-12,50	1,13	6,58	-7,47	7,36
Cs-137		-9,13	-13,87		-1,94	-16,99	
Co-60			2,27				
Sr-90/Y-90	-2,03	8,11	-14,59	-0,68	5,41	-9,39	-10,68
Cl-36	1,19	11,82	-13,57	-5,07	-6,32	-11,57	-18,82
C-14	-5,53	2,00		3,62		-1,44	0,13

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

The largest percentage difference was 18.8% in chlorine factor and 17% in cesium factor, only these two results from the same laboratory were outside the acceptance limits.

6. Conclusions and Comments

In the previous exercise, in 2016, a positioning system was sent along with a surface contamination monitor and was verified by 3 laboratories that performed the measurements on the system sent and on the laboratory positioning system itself and there was no significant variation, so in this exercise no positioning system was sent, only the surface contamination monitor.

Based on the results of this exercise and others already performed^{7, 8, 10, 11, 12}, a comparison of calibration of surface contamination monitors should be performed with a selected instrument sent to participants. This avoids the use of detectors with varied characteristics influencing the results and has a better view of the practices performed by the laboratories.

These comparison exercises were also useful for "quality control" of the extensive sources used by the Brazilian radiation monitor calibration network, since in Brazil there is no laboratory with the technology to calibrate the sources. Comparisons allow you to evaluate sources over time and although some have more than 10 years of use they are still fit for the calibration service as the results are compared to sets of sources purchased in 2007, 2016 and 2017 and these are kept satisfactory. In the evaluation a serious problem of homogeneity was observed in several sources including newer sources, 2016 and 2017, due to this observation it is important that when purchasing a set or a new source is made a survey of their homogeneity.

The uniform response of services provided between participating laboratories is to verify that they perform calibrations with an acceptable tolerance level. The Percentage Difference of calibration coefficients was used as a criterion to evaluate the results of this proficiency test.

Most results were within the limite15% acceptance limit established by the LNMRI in the protocol, as can be seen from the values obtained in Table 3, only two results obtained by the same laboratory

presented a percentage difference of up to almost 19%. , this difference may stem from the extensive source homogeneity.

This result proves the ability of laboratories to perform the calibration service of surface contamination monitors being excellent and proving that over the years the applied exercises have been improved, which results in more accurate answers compared to the services provided by Brazilian laboratories.

The Comparison Exercise tests the real measurement capability of laboratories performing radiation monitor calibration services in Brazil, as measurements are performed on premises and with laboratory procedures and gives greater reliability to measurements and services performed by the Brazilian calibration network.

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