LATIN AMERICAN AND CARIBBEAN INTERCOMPARISON OF SURFACE CONTAMINATION MONITORING EQUIPMENT

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Abstract: In October 2009 the IAEA sponsored an intercomparison exercise of surface contamination monitoring equipment which was held at the Laboratório Nacional de Metrologia das Radiações Ionizantes (LNMRI), from the Instituto de Radioproteção e Dosimetria, IRD/CNEN, Rio de Janeiro. This intercomparison was performed to evaluate the calibration accessibility in Latin America and the Caribbean. Thirteen countries within the region and IAEA have sent instruments to be compared, but only 5 countries and IAEA were considered apt to participate. Analysis of instruments results and discussions are presented and recommendations are drawn.

Key words: intercomparison, contamination monitor, radiation protection.

1. INTRODUCTION

The use of calibrated instrumentation for radiation protection purpose is one of the requirements to assure the safe use of ionizing radiation sources. When unsealed sources are handled, there is a possibility of dispersion of radioactive solutions in the working areas. In such circumstances, the use of a calibrated contamination monitor is very important to evaluate the situation through confident measurements. Laboratories that perform such calibrations must be traceable to measuring standards and follow written procedures.

In order to evaluate the calibration accessibility in Latin America and the Caribbean, the International Atomic Energy Agency (IAEA) has organized an intercomparison exercise of surface contamination monitoring equipment. This exercise was recommended in a former IAEA project[1] and could be performed within the Project RLA9066/9001/01 "Optimization of radiation protection programmes in practices that lead to intakes of radio nuclides".

The exercise was performed from 05 to 09 October 2009, in the the Brazilian Secondary Standard Dosimetry Laboratory (SSDL), which is the Laboratório Nacional de Metrologia das Radiações Ionizantes (LNMRI), from the Instituto de Radioproteção e Dosimetria, IRD/CNEN, Rio de Janeiro. Reports to the participants were sent for their revision and comments during 2010.

2. MATERIALS AND METHODS

The Project RLA9066 gathers 19 countries within the region of interest. Thirteen participants and IAEA has sent instruments to be compared. Some are representing SSDL's, and some are clinics or hospital users. Two of them had already performed a bilateral comparison for the same type of instrument[2].

All contamination sources used in the intercomparison belong to LNMRI/IRD, and are listed on Table 1. They all comply with ISO 87693 standard, and are traceable to LMRI, now named LNHB, France, or PTB/DKD, Germany.

Table 1: Characteristics of the calibrated sources used for comparison exercise

Source	Flux s^{-1}	Ref. date	Area cm^2	Cal.
Sr^{90}/Y^{90}	2926	08/08/1989	63*	LMRI (LNHB) France
Cl^{36}	3153	29/08/1989	63*	
Cs^{137}	3531	17/08/1989	63*	
C^{14}	2902	23/08/1989	63*	
Am^{241}	1666	28/08/1989	305*	PTB 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**	

*Circular sources **Rectangular sources

Table 2 presents a list of participants with a description of instruments brought for the comparison exercise and their calibration condition as received.

No instrument from Brazil participated in the comparison as the contamination sources used were from the same laboratory. For the purpose of this comparison the instruments were tested according to LNMRI procedures, which are based on the ISO 75034 standard. On this, the instrument efficiency (ε_i) relative to the size of the sensitive window of the monitor is calculated as in equation 1:

$$\varepsilon_i = \frac{n - n_B}{E_{sc} \, . W} \qquad (1)$$

Where:

n = monitor readings [s^{-1}]
n_B = background readings [s^{-1}]
E_{sc} = surface emission rate per unit area of the reference source [$s^{-1}cm^{-2}$]
W = area of the detector window [cm^2].

Table 2: Project RLA9066 list of participants with associated instruments

Country	Instrument	Probe Type	Calib.
Nicaragua	Tech. Associates TBM3	GM-W	no
Paraguay	Berthold LB122	PC.	no
Cuba	LAMSE RM1001	GM-W	yes
Venezuela	Ludlum 44-9	GM-W	yes
Chile	Automess 6150AD6	PC.	yes
El Salvador	BICRON 2000 Probe PGM	GM-W	no
IAEA	Berthold LB124	SC	yes
Argentina	Automess AD1	GM-W	yes
Uruguay	Automess 6150AD6	PC.	yes
Guatemala	Tech. Associates TBM-15C	GM-W	no
México	Ludlum 14C Probe 44-9	GM-W	no
Bolivia	TechAssoc TBM-3	GM-W	no
Colombia	Victoreen 450B	IC	no
Costa Rica	Fluke- ASM 990	GM-W	no

GM-W - End Window GM tube, IC - Ionization chamber, PC – Proportional counter, SC – Scintillation crystal

If participants instruments were brought calibrated in terms of calibration factor (CF) in Bq/cm^2 per cps of the meter, the efficiency of the instrument would be obtained using the correlation shown in equation 2.

$$CF = \frac{1}{\varepsilon_i \,.\, W \,.\, \varepsilon_s} = \frac{E_{sc}}{\varepsilon_s \,.\, (n - n_B)} \qquad (2)$$

Where:
ε_s = efficiency of the contamination source

Conservative values of ε_s were taken from ISO 7503-1[4], as shown in Table 3, and used in this experiment.

Table 3: Values of ε_s according to radiation type and energy

Radiation type	ε_s
Alpha emitters	0.25
Beta emitters	
E_{max} < 400 keV (C-14)	0.25
All other beta emitters	0.5

Measurement uncertainties were calculated according to LNMRI/IRD procedure, which is based and detailed on the ISO Guide to the Expression of Uncertainty in Measurement[5].

3. RESULTS AND COMMENTS

All instruments were calibrated and left the LNMRI/IRD with a calibration certificate suitable for the detector type. Some instruments listed on Table 2 could not be compared because they were not brought calibrated against contamination sources. Besides this, one instrument had also a detector unsuitable for contamination measurements, i.e., ionization chamber, which detector's wall was too thick for alpha and beta measurements. Therefore only instruments from Argentina, Chile, Cuba, IAEA, Uruguay, and Venezuela could participate in the comparison. Their results were coded by a letter to protect their confidentiality, and are presented on Table 4.

Table 4: Results of comparison exercise with coded participants

		Efficiency ± U (%)			
Code	Source	LNMRI	Participant	Dev. (%)*	E_n
A	Sr-90	48.4±8.1	67±3.2	38	1.6
	Am-241	20.8±15.8	19±3.16	9	0.1
B	C-14	11.9±12.3	3.77±18	68	0.7
	Cl-36	44.0±7.1	29±18	34	0.6
	Sr-90	47.5±8.2	58.8±18	24	1.0
	Cs-137	38.4±8.5	26.53±18	31	0.6
	Am-241	21.2±15.7	8.94±18	58	0.5
C	C-14	15.3±30.9	14.3±14	7	0.0
	Cl-36	41.2±18.4	27.2±14	34	0.6
	Sr-90	47.3±22.5	27.6±14	42	0.7
	Am-241	25.7±70.5	20.7±22	19	0.1
D	C-14	14.2±18.5	14.5±7.1	2	0.0
	Cl-36	45.3±10.7	42.9±8.9	5	0.2
	Sr-90	49.0±13.1	50.0±10.0	2	0.1
	Cs-137	40.7±13.0	38.1±8.0	6	0.2
	Am-241	21.9±44.7	23.6±7.1	8	0.0
E	C-14	27.0±8.8	18.8±20	30	0.4
	Cl-36	67.4±6.4	60.3±20	11	0.3
	Sr-90	63.9±7.5	57.8±20	10	0.3
	Am-241	37.9±11.9	31.1±20	18	0.3
F	C-14	21.6±15.2	19.9±4.1	8	0.1
	Cl-36	61.9±9.5	58.0±5.0	6	0.4
	Sr-90	64.5±11.7	64.0±6.0	1	0.0
	Am-241	38.9±37.0	34.4±3.7	12	0.1

*Dev.(%) – Absolute percentual deviation of efficiencies

Efficiency shown on participant column in Table 4 is according to the calibration certificate they presented, including significant digits.

The results were evaluated using the methodology recommended in the ISO/IEC guide 43-1[6], where a number En is used for evaluation. The number En combines the influence of the difference between the values of □i reported by participants and its uncertainties. This number is calculated by equation 3.

$$E_n = \frac{\varepsilon_{i,LNMRI} - \varepsilon_{i,participant}}{\sqrt{U^2_{i,LNMRI} + U^2_{i,participant}}} \qquad (3)$$

Where:
$\varepsilon_{i,LNMRI}$ = efficiency reported by LNMRI
$\varepsilon_{i,participant}$ = efficiency reported by participant
$U_{i,LNMRI}$ = combined expanded uncertainty reported by LNMRI at 95% of confidence level.
$U_{i,participant}$ = combined expanded uncertainty reported by participant at 95% of confidence level.

Values of $E_n \leq 1$ are considered satisfactory and $E_n > 1$ are unsatisfactory.

Participant A presented the smallest uncertainty values among all. Their result for Sr-90 was the only unacceptable result according to En calculation. LNMRI results for participant C show a large uncertainty due to the size of the instrument's detector window, which is very small when compared to the size of the sources used, as listed on Table 1.

The results for participant D, shown on table 4, are corrected results that consider their bulk data sent together with their certificate. It was found that their reported efficiencies were incorrectly calculated. Nevertheless, their uncertainties remain as reported on the certificate.

There is a doubt concerning the results of participant F with a Cl-36 source. Their certificate present results for efficiency and calibration factor for all sources, except for this one, which has only efficiency values.

4. CONCLUSIONS

This intercomparison exercise was useful to all participants and helped them to recognise their laboratory's actual situation in order to introduce improvements. Participant D was contacted and had to review their calibration procedure. They were issuing certificates with incorrectly calculated efficiency values.

In a first look into Table 4, the intercomparison results assessed by E_n were almost all acceptable, as they were smaller than 1. As the number E_n combines the difference between the values of ε_i and its uncertainties, as reported by participants. This somehow hides instrument unsatisfactory efficiency results with high uncertainty values.

Uncertainty figures for contamination calibrations and measurements are normally high, mainly for low energy beta emitting radionuclides, i.e. C-14, and alpha emitters. Such values depend also on the uncertainty components considered by each participant. The absolute percentual deviation between LNMRI and participant efficiencies, presented on table 4, is a direct comparison of calculated efficiencies that give an idea of the spread of values that can be found. Nevertheless, such deviations are very influenced by different parameters like: source traceability, source detector calibration distance, detector window size and thickness, among others, and, therefore, cannot be considered conclusive.

The authors recommend that this type of activity should continue in the region, gathering SSDL´s preferentially, but understand that ideally an intercomparison of contamination instruments should be performed with a set of selected instruments that could be circulated to the participants, as already realized by other authors[7,8] in a regular basis. This would avoid the use of detectors with small windows that would badly influence the results.

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