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Activimeter “in situ” calibration methodology to ^{111}In and ^{123}I

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ABSTRACT

The activimeter calibration has the purpose of ensure greater reliability in measurement results, hence the activimeters used are commonly installed in controlled areas and, in some cases, with difficult access. The activimeter “in situ” calibration methodology presented in this work allows its execution only with the displacement of the radioactive samples and not of the activimeter itself, which simplifies the procedure of nuclear medicine services and at radiopharmaceuticals production centers, without affecting the quality and accuracy of measurements. After the application of the methodology by qualified technicians, the obtained results of the tested activimeters showed its importance since the calibration factors can present correction of up to 5% for ^{111}In and greater than 5% for ^{123}I.

Keywords: **activimeter, calibration, methodology “in situ”.**

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1. INTRODUCTION

In a Nuclear Medicine Service (NMS), for therapy or diagnostics, it is necessary to have reliability in the radiopharmaceutical activity value before it is given to the patient. For this purpose, the activitimeter must be appropriately calibrated, otherwise it can raise uncertainty around the measurements, resulting in doubtful diagnostics or improper therapies. Usually, the activimeters are located in controlled areas, hot rooms, of difficult access both for handling and for sending to a Calibration Laboratory. Based on this the Instruments Calibration Laboratory of IPEN has developed a methodology of "in situ" calibration of activimeters where there is not need of equipment transportation, but only the radiopharmaceutical used as reference source [1].

The objective of this study was to implement this methodology exclusively for the control and calibration of the activimeters of the radiopharmaceutical production laboratory of the Radiopharmacy Center of IPEN (CERAF) using the radionuclides ^{111}In and ^{123}I.

2. MATERIALS AND METHODS

Since the new methodology development and the execution of the present study, all the steps for the Activimeter calibration had as reference the applied methodology at the National Primary Physical Standardization (NPL), England [2]. The secondary standard activimeter owned by the LCI (Instruments Calibration Laboratory) has traceability to NPL.

2.1. Activimeters Used

Twelve activimeters were used: activimeter reference standard model CRC-25R, series 252669 presented in Figure 1 and tested eleven activimeters belonging to CERAF listed on Table 1.

Figure 1: Reference activimeter - LCI

Table 1: Activimeters used in this study - CERAF

Activimeter	Model	Série
1	CRC-15 BT	510191
2	CRC-25 R	252537
3	CRC-15 R	157874
4	CRC-15 R	157173
5	CRC-15 R	157816
6	CRC-15 R	158945
7	CRC-15 R	158944
8	CRC-15 R	154896
9	CRC-15 R	155183
10	CRC-35 R	350181
11	CRC-35 R	350373

2.2. Preparation of the Radioactive Samples

The samples were produced by CERAF, diluted and storaged in the IPEN's vials with volume of 6ml each. The samples handling was done by an authorized CERAF's technician. The radionuclides produced were ^{111}In e ^{123}I, and their characteristics are presented in Table 2 and the characteristics of the two types of vials used, IPEN's vial and the 10R Schott, are on Table 3.

Table 2: Characteristics of samples supplied by production sector of CERAF

Radionuclide	Half-Life (hours)	Energy (keV)	Volume (ml)
^{111}In	67.3128 ± 0.010	860	6.0
^{123}I	13.2231 ± 0.002	1228	6.0

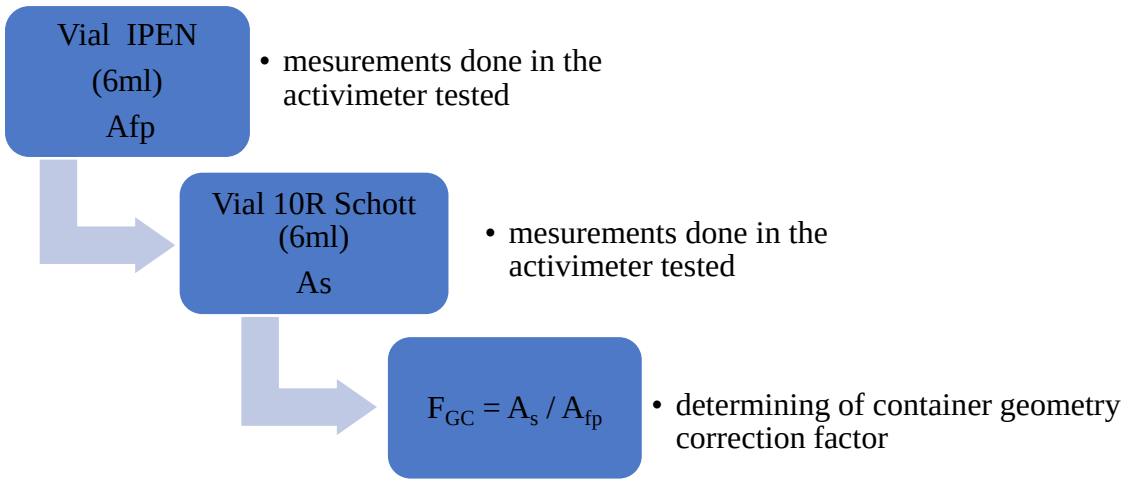
Table 3: Main characteristics of the used glass vials

Containers	10R Schott		IPEN	
Height (mm)	45.0 ± 0.5		57.7 ± 0.02	
Diameter (mm)	24.0 ± 0.2		26.05 ± 0.02	
Wall Thickness (mm)	1.00 ± 0.04		1.2 ± 0.02	
Maximum Volume (ml)	13.5		22.9 ± 0,02	

2.3. Determination of container geometry correction factor

Initially the determining of container geometry correction factor was done for each activimeter tested. The samples were provided on IPEN container and 10R Schott in volume of 6,0 ml each. In order to determine the container geometry correction factor, the steps followed are shown in the diagram below:

Phase 1: Determination to vial geometry correction factor



The vial geometry correction factor, F_{GC}, is calculated by equation 1 [3].

$$F_{GC} = \frac{\bar{A}_s}{\bar{A}_{fp}} \quad (1)$$

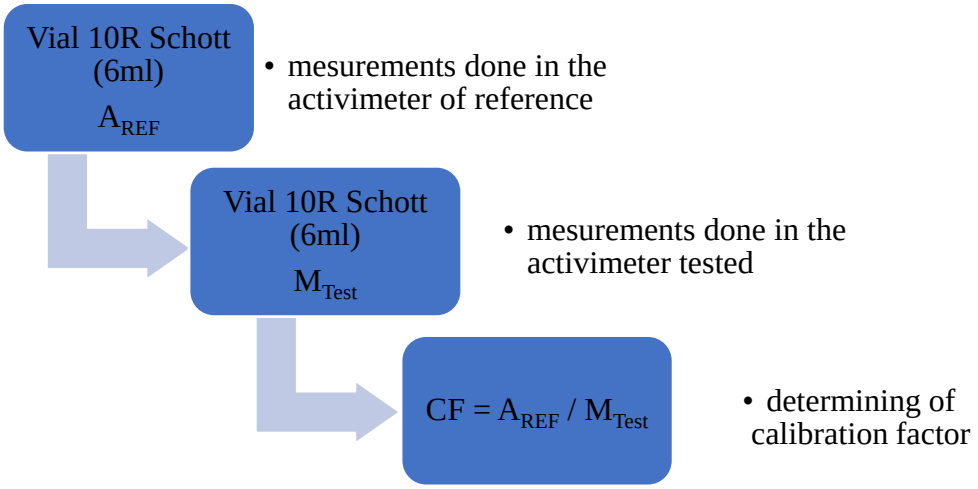
Where: $\bar{A}_s$ = Average of activities measured in the 10R Schott

$\bar{A}_{fp}$ = Average of activities measured in the IPEN

2.4. Determination of calibration factor

In order to apply the calibration methodology, the reference container 10R Schott was used. The tests were done respecting identical measurement conditions. In each activimeter were done 10 consecutive measurements, with 30 seconds interval between them. The diagram below shows every step of the methodology applied.

Phase 2: Determination to calibration factor



The measurements were done in all activimeters and calibration factor (CF) was obtained by ration between measurements on the reference activimeter (A_{REF}) and test activimeters (M_{Test}), as shown in the equation 2.

$$CF = \frac{A_{REF}}{M_{Test}} \tag{2}$$

2.5. Uncertainty Calculations

The uncertainty calculation was obtained based on the estimates of type A and type B, possibly for a 95% confidence level (k=2). The type A uncertainty were estimated by standard deviation and average deviation standard, type B information were based on a set of variables of each activemeter. The uncertainty of calibration factor was calculated based on variables error propagation correlated on equation 3:

$$\frac{\sigma_{CF}}{FCF} = \sqrt{\left(\frac{\sigma_{\bar{A}_{REF}}}{\bar{A}_{REF}}\right)^2 + \left(\frac{\sigma_{\bar{M}_{Test}}}{\bar{M}_{Test}}\right)^2 - 2\frac{\mathrm{cov}(\bar{A}'_{REF}, \bar{M}'_{Test})}{\bar{A}_{REF} .* \bar{M}_{Test}}} \tag{3}$$

Were: $\sigma_{CF} = uncertainty\ of\ calibration\ factor$

$CF = calibration\ factor$

$$\sigma_{\bar{A}_{REF}} = \frac{\sqrt{\frac{\overline{A'_{REF}}}{T_{sample}} + \frac{\overline{BG}}{T_{BG}}}}{\sqrt{n}} \quad (4)$$

$$\sigma_{\bar{M}_{Test}} = \frac{\sqrt{\frac{\overline{M'_{Test}}}{T_{sample}} + \frac{\overline{BG}}{T_{BG}}}}{\sqrt{n}} \quad (5)$$

$$cov(\bar{A}_{REF}, \bar{M}_{Test}) = \sqrt{\frac{\overline{BG}}{T_{\overline{BG}}}} \quad (6)$$

$\sigma_{\bar{A}_{REF}}$ $= propagation\ of\ uncertainty\ of\ measurement\ average\ in\ the\ reference\ activimeter$

$\sigma_{\bar{M}_{Test}}$ $= propagation\ uncertainty\ of\ measurement\ average\ in\ the\ test\ activimeter$

$\bar{A}'_{REF}$ $= liquid\ activity\ (background\ discounted)\ reference\ activimeter$

$\overline{M'}_{Test}$ $= liquid\ activity\ (background\ discounted)\ test\ activimeter$

$T_{amostra} = time\ of\ sample\ measured$

T_{BG} $= time\ of\ background\ measurement$

n $= sample\ size\ or\ measurement\ quantity$

3. RESULTS AND DISCUSSIONS

Table 4 and 5 show the results found to the radionuclides ^{111}In and ^{123}I using the methodology proposed. The calibration factors were obtained using the equation 2 and are reported on Table 6 and 7.

Table 4: Tests accomplished with radionuclide ^{111}In to vial geometry correction factor

Activimeter	IPEN vial, A1 Initial Activity (GBq)	10R Schott vial, A_2 (GBq)	F_{GC}
1	0.200 ± 0.039	0.191 ± 0.032	0.955 ± 0.9 %
2	0.200 ± 0.037	0.192 ± 0.048	0.955 ± 1.4 %
3	0.193 ± 0.050	0.185 ± 0.033	0.959 ± 0.7 %
4	0,202 ± 0.072	0.194 ± 0.032	0.960 ± 0.5 %
5	0.208 ± 0.038	0.197 ± 0.050	0.947 ± 1.4 %
6	0,196 ± 0.049	0.188 ± 0.049	1.000 ± 1.0 %
7	0.198 ± 0.031	0.188 ± 0.032	0.949 ± 1.1 %
8	0.202 ± 0.040	0.193 ± 0.067	0.955 ± 1.8 %
9	0.195 ± 0.049	0.188 ± 0.046	0.964 ± 1.0 %
10	0.192 ± 0.048	0.185 ± 0.031	0.964 ± 0.7 %
11	0.198 ± 0.052	0.191 ± 0.026	1.037 ± 0.5 %

Table 5: Tests accomplished with radionuclide ^{123}I to vial geometry correction factor

Activimeter	IPEN vial, A1 Initial Activity (GBq)	10R Schott vial, A_2 (GBq)	F_{GC}
1	0.740 ± 0.008	0.737 ± 0.001	0.996 ± 1.5 %
2	0.737 ± 0.049	0.731 ± 0.007	0.992 ± 0.1 %
3	0.687 ± 0.005	0.724 ± 0.005	1.054 ± 0.2 %
4	0,784 ± 0.006	0.718 ± 0.001	0.916 ± 0.2 %
5	0.747 ± 0.021	0.712 ± 0.018	0.953 ± 0.8 %
6	0,679 ± 0.012	0.705 ± 0.019	1.038 ± 1.5 %
7	0.729 ± 0.008	0.699 ± 0.008	0.959 ± 1.0 %
8	0.755 ± 0.008	0.693 ± 0.011	0.918 ± 1.5 %
9	0.803 ± 0.011	0.687 ± 0.010	0.856 ± 1.1 %
10	0.705 ± 0.012	0.681 ± 0.012	0.966 ± 0.6 %
11	0.874 ± 0.015	0.675 ± 0.007	0.772 ± 0.6 %

Table 6: Calibration factors obtained with radionuclide ^{111}In for the activimeters under test. Activity on the reference: 0.195 ± 0.029 GBq

Activimeter	**Measured activity in activimeter under test M_{Test} (GBq)**	**Calibration Factor A_{REF}/M_{test}**
1	0.191 ± 0.032	1.019 ± 0.038
2	0.192 ± 0.152	1.013 ± 0.013
3	0.185 ± 0.033	1.052 ± 0.069
4	0.194 ± 0.032	1.002 ± 0.047
5	0.197 ± 0.050	0.990 ± 0.013
6	0.188 ± 0.049	1.036 ± 0.037
7	0.188 ± 0.032	1.035 ± 0.071
8	0.193 ± 0.067	1.007 ± 0.069
9	0.188 ± 0.046	1.036 ± 0.097
10	0.185 ± 0.031	1.054 ± 0.068
11	0.191 ± 0.026	1.020 ± 0.049

Table 7: Calibration factors obtained with radionuclide ^{123}I for the activimeters under test. Activity on the reference: 0.669 ± 0.013 (GBq)

Activimeter	**Measured activity in activimeter under test M_{Test} (GBq)**	**Calibration Factor A_{REF}/M_{Test}**
1	0.737 ± 0.001	0.908 ± 0.143
2	0.731 ± 0.007	0.916 ± 0.137
3	0.724 ± 0.005	0.924 ± 0.241
4	0.718 ± 0.001	0.932 ± 0.162
5	0.712 ± 0.018	0.941 ± 0.841
6	0.705 ± 0.019	0.949 ± 1.570
7	0.699 ± 0.008	0.957 ± 1.000
8	0.693 ± 0.011	0.966 ± 1.387
9	0.687 ± 0.010	0.974 ± 0.925
10	0.681 ± 0.012	0.983 ± 0.587
11	0.675 ± 0.007	0.991 ± 0.483

4. CONCLUSIONS

The results show that the calibration methodology applied in the radiopharmaceutical center production, although presenting dificulties in its execution, shows its importancy considering that the calibration factors may present correction until 5% for ^{111}In and greater than 5% for ^{123}I.

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REFERÊNCIAS

[1] KUAHARA, L. T.; CORREA, E. L.; POTIENS, M. P. A. Análise da distribuição de radiofármacos para serviços de medicina nuclear no Brasil. **International Nuclear Atlantic Conference**, Recife. 2013.

[2] NATIONAL PHYSICAL LABORATORY. Protocol for establishing and maintaining the calibration of medical radionuclide calibrators and their quality control. **A National Measurement Good Practice**. Middlesex, United kingdom: 2006 (Guide n.93).

[3] LABORATOIRE NATIONAL HENRI BECQUEREL. Guide d'utilisation et de controle qualité dês activimètres**.** Societé française de radiopharmacie, França, 2006.

[4] INTERNATIONAL ELECTROTECHNICAL COMISSION. Medical electrical equipment – **Dosimeters with ionization chambers andlor semi- conductor detectors as used in X-ray diagnostic imaging**. Geneva, 1997.