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PERFORMANCE EVALUATION OF THE REFERENCE SYSTEM FOR CALIBRATION OF IPEN ACTIVIMETERS

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ABSTRACT

The formation of good quality image in nuclear medicine services depends on several factors, including the radiopharmaceutical activity, which must be well determined by a specific apparatus, in perfect operating condition, called activimeter. Therefore, the establishment of a quality control program for measuring the radiopharmaceuticals radioactivity before being administered to the patient is crucial to the safe and effective use of the radiopharmaceuticals used in diagnostic and therapeutical procedures. Two activimeters, belonging by the Laboratório de Calibração do Instrumentos (LCI) of Instituto de Pesquisas Energéticas e Nucleares (IPEN), were evaluated: the secondary standard system NPL-CRC® *radionuclide calibrator*, manufactured by *Southern Scientific,* and the work standard system CRC®-15BT with traceability to *National Institute of Standard and Technology (NIST).* A set of standard sources of the radionuclides ^{133}Ba, ^{57}Co and ^{137}Cs was used as reference to perform the quality control tests. The precision, accuracy and repeatability tests were in agreement with those established by the CNEN-NE 3.05 Brazilian standard, which recommends the variation limit of up to 10%, 5% and 5% respectively. The results obtained for the reproducibility tests presented a variation always below 1,5%, which means it is within the IEC 61674 international standard recommendation of up to 3%. Activimeters response regarding linearity showed concordance between the measured activities and the theoretical curve for both activimeters.

1. INTRODUCTION

Due to the large number of procedures performed with the use of ionizing radiation in medicine, it is necessary to use a substantial number of activity meters in order to cover all NMS, and concerns about the development of quality control programs as well as radiological safety are inevitable.

These two factors have often been studied, and they are a requisite for the national and international standards, since their main objective is to ensure the precise measurement of radiopharmaceuticals activity before being administered to patients.

The activimeter needs to be in perfect operation conditions, otherwise it may present values smaller or larger than the real one, resulting in unnecessary high doses to patients without any benefit, or repeated procedures leading to radiation exposure to the patient as well as individuals involved in the process, thus failing to meet the radioprotection principles [1,2].

The activimeter has a unique feature compared to other systems which use ionization chambers, the electronic circuit which allows response to be showed directly in units of activity [3].

Several factors influence the accuracy of the dose given by activimeters. Before becoming available for sale, the activimeter, after its manufacture, is submitted to calibration measurements using a set of certified radiation sources. The manufacturer limits its initial accuracy to a range between +/- 1% and +/- 5%. Over time this accuracy can vary due to pressure changes in the gas of its chamber and electronic attraction. To ensure the proper operation of the instrument, due to these variations, regular tests were established to be applied at specific intervals.

There are three types of tests which are part of a quality control program: (I) acceptance tests, (II) reference tests, (III) operational tests.

(I) Acceptance tests should be performed after the acquisition of a new activimeter by NMS. Some of the acceptance tests are: physical inspection (display lighting, battery, support, wiring, etc), precision, accuracy, activity response linearity and background radiation.

(II) To verify the apparatus performance, reference tests are periodically performed, as listed in Table 1, including accuracy, precision, linearity and background radiation tests. Those tests must conform to acceptance limits established by the CNEN standard [1].

TABLE 1: Tests established by CNEN for quality control of activimeters.

Test	Frequency	Recommended sources	Acceptance limits
Precision	Bianual	^{57}Co, ^{133}Ba or ^{137}Cs	10%
Accuracy	Bianual	^{57}Co, ^{133}Ba or ^{137}Cs	5%
Linearity	Bianual	^{99m}Tc	20%
Reproducibility	Anual	^{57}Co or ^{133}Ba	5%

(III) Operational tests include reproducibility and background radiation tests [4].

2. MATERIALS AND METHODS

In this study the following activimeters were tested: the reference system, the secondary standard, NPL-CRC® radionuclide calibrator, and the tertiary system, Capintec basic CRC®-15BT. They consist of two parts: the console in which the electrometer is situated, and the ionization chamber, both by Capintec, as presented in Figure 1.

The reference system is a secondary standard, model NPL-CRC® radionuclide calibrator, serial number 111113, manufactured by Southern Scientific plc, with traceability to National Physical Laboratory (NPL). The system to be used as work standard is a model CRC®-15BT,

serial number 180020, calibrated by Accredited Dosimetry Calibration Laboratory of Medical Radiation Research Center – University of Wisconsin, with traceability to National Institute of Standard and Technology (NIST).

Figure 1. a) Reference system: NPL-CRC®, b) Work system: CRC®-15 BT.

For the quality control tests, a set of standard sources were used as reference, provided by the Centro de Tecnologia das Radiações (CTR) of IPEN. Three sealed sources: ^{133}Ba, ^{57}Co e ^{137}Cs, are presented in Figure 2.

Figure 2: Set of standard Eckert & Ziegler sources.

Each standard source is supplied in a 27 ml polyethylene vials with uniform distribution of the active element in 20 ml of epoxy resin, composed of a density of approximately 1,0 g/cm^3. These sources were manufactured by the German company Eckert & Ziegler Isotope Products (E&Z), with traceability certificates to National Institute of Standards and Technology (NIST). In Table 2 its characteristics are related.

TABLE 2: Main characteristics of sources *E&Z.*

Radionuclides	Primary photon energy (keV)	Activity (MBq)	Uncertainty (%)	$T_{1/2}$ (days)	Reference date
^{133}Ba	81; 356	9.55	± 3.0	3853.6	01/11/09
^{57}Co	122	206.8	± 3.0	272.11	01/03/10
^{137}Cs	662	7.26	± 3.0	110.15	01/11/09

Precision and accuracy tests were applied after stabilization of the device, 10 readings were performed with a 30 seconds time interval between them. The precision test was calculated using the percentage deviation (P) between individual activity measure (A_i) and the measurements mean ($\overline{A}$) according to equation 1.

$$\mathbf{P\ (\%) = 100\ x} \frac{(A_i - \overline{A})}{\overline{A}} \qquad (1)$$

In which: $\overline{A}$ = Arithmetic mean of the activity measures
A_i = Activity of the individual source

The accuracy test (E) was calculated using the percentage deviation between the average of the activity measures ($\overline{A}$) relative to the mean of the first ten measurements in the standard system with correction for the decay ($\overline{A}_{10}$), given by the equation 2 [1,3,5,6].

$$\mathbf{E\ (\%) = 100\ x}\ \frac{(\overline{A} - \overline{A}_{10})}{\overline{A}_{10}} \qquad (2)$$

In which:

$\overline{A}$ = Arithmetic mean of the activity measurements
$\overline{A}_{10}$ = Arithmetic mean of the first ten measurements in the standard system with correction for the decay on the date in which the test was realized.

The repeatability and reproducibility tests were applied equally in both activimeters to ensure the quality control of each apparatus regarding stability, using a ^{137}Cs source. For the linearity test a ^{99m}Tc source was used, in a homogeneous mixture of 4 ml of saline solution into a penicilin vial with maximum volume of 20 ml and initial activity of 5.1 GBq.

3. RESULTS

Precision: the maximum percentage deviation between the individual activity measure (A_i) with respect to the measured mean activities ($\bar{A}$) was less than 0.32% for all the tests performed, not exceeding the recommended limit of ± 5%, thus showing satisfactory results with reliability of 95%.

Accuracy: the acceptance limit is ± 10% with a reliability of 90% recommended by CNEN standard [1]. All tests performed were satisfactory, not exceeding the recommended limit. In Table 3, it is possible to observe the results of accuracy test, that is the percentage deviation between mean of activity measured (10 measurements) and the standard source activity with the application of the decay correction factor.

TABLE 3: Results obtained for the accuracy test with reference sources in both activimeters.

	NPL-CRC®			CRC®-15BT		
	Ā (MBq)	A (MBq)	Accuracy (%)	Ā (MBq)	A (MBq)	Accuracy (%)
Bário -133	8.03	8.01	0.27	7.93	7.90	0.29
Césio -137	6.93	6.92	0.14	7.40	7.38	0.26
Cobalto – 57	169.3	169.2	0.06	170.0	169.9	0.06

For the stability test a sequence of measurements was performed. 10 first measurements were employed to determine the value to be used as reference, the maximum coefficient of variation obtained was 1% (acceptable variation is 5%) [7]. Figure 3 shows the reference and work system stability over time (standard deviation of the average), respectively. For the reference system, maximum variation of the results was 1% throughout the testing period and for the work system, 1.5%, both within the acceptance limits recommended by international protocols [8,9].

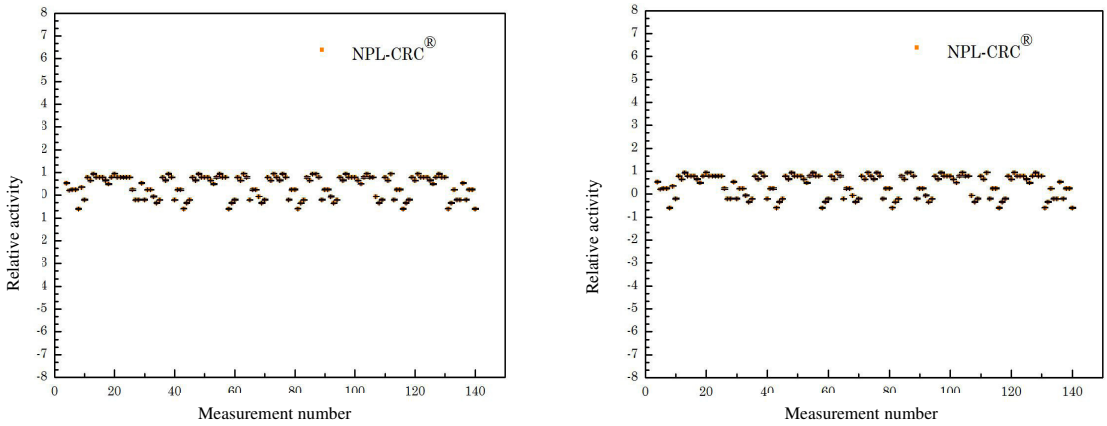

Figure 3: Stability test using ^{137}Cs standard source.
a) Reference system: NPL-CRC®, b) Work system: CRC®-15 BT.

Linearity: activimeters response was accompanied by the decay of a ^{99m}Tc source, with initial activity of 5,01 (GBq), as shown in Figure 4. Date and time of the measurements were registered in time intervals of one hour between them for a period of 56 hours.

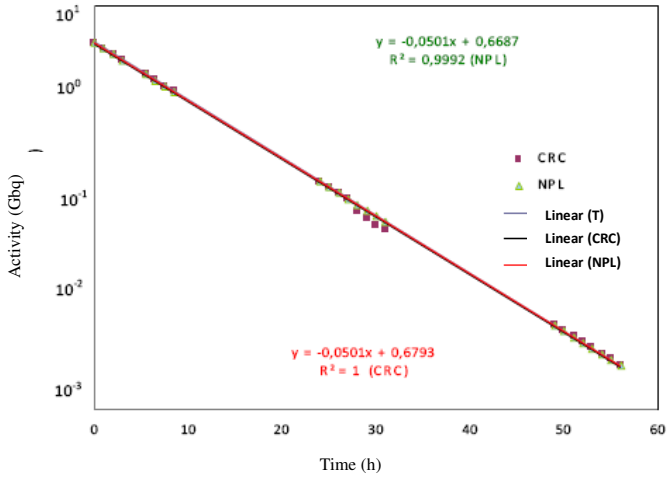

Figure 4: Linearity test

The reference system (NPL-CRC®) and the work system (CRC®-15BT) presented results within the acceptance limit recommended by the manufacturer's manual (± 10%), so both activimeters revealed linear responses between the values of measured activity which is in accordance with the experimental values.

4. CONCLUSIONS

For the precision, accuracy and reproducibility tests, the Brazilian standard for nuclear medicine services, CNEN-NE 3.05, was used as reference, which recommends variation limits of up to 10%, 5% and 5% respectively. Results obtained for repeatability presented a variation lower than 1,5%, within the recommendation of up to 3% of IEC 61674 international standard [7]. Activimeters response regarding linearity showed concordance between measured activities and the theoretical curve for both activimeters. Therefore, the quality control program implemented for the LCI activimeters demonstrated that both instruments are in good operation condition and the CRC® - 15 BT apparatus can be used as work standard, employing the appropriate corrections.

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