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QUALITY CONTROL TESTS OF AN ACTIVITY METER TO BE USED AS REFERENCE FOR AN *IN SITU* CALIBRATION METHODOLOGY

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ABSTRACT

The Nuclear Medicine is a medical specialty involving the application of radioactive isotopes in diagnosis and/or treatment of disease. In order to ensure that the radiation dose applied to the patient is adequate, the radiopharmaceutical activity must be adequately measured. This work was performed to analyze the behavior of an activity meter Capintec NPL-CRC to be used as a reference for the implementation of a methodology for *in situ* calibration of nuclear medicine equipment. It were made the daily quality control tests, such as auto zero, background, system test, accuracy test and constancy test, and determination of repeatability and intermediate measurement precision using ^{137}Cs, ^{57}Co and ^{133}Ba sources. Furthermore, this equipment was used to confirm the check sources activities produced at IPEN and used by the laboratory that produces the radiopharmaceuticals sent to the nuclear medicine services. The results showed a good behavior of this equipment. The maximum variation obtained in the accuracy test was of 1.81 % for the ^{57}Co source. For ^{137}Cs this variation was of 4.59 %, and for ^{133}Ba, 11.83 %. The high value obtained for the last case, indicates the needs of a correction that can be obtained by calibration methods. The result obtained using different reference sources showed a great repeatability, with a maximum variation of 1.38 %.

1. INTRODUCTION

The Nuclear Medicine is a medical specialty involving the application of radioactive isotopes in diagnosis and/or treatment of disease. In both cases the radioactive source activity is a critical parameter to obtain satisfactory results. In a therapeutic procedure, lower doses may not treat the cancer efficiently. In diagnostic procedures, a lower amount of radiation in a typical nuclear imaging won’t be enough to identify a possible pathology. Moreover, a very high dose, in both cases, can be harmful for the patient.

In Brazil, there is no obligation of calibration procedures application in activity meters, which makes the results obtained by some nuclear medicine services unreliable, generating many variations in the results [1]. Because of the lack of traceability in the activity meter, it is difficult to guarantee that the activity of the material to be injected is adequate to obtain a good image. The Brazilian regulations only recommend periodic quality control tests [2].

Previous studies showed the need to establish a calibration methodology for a activity meter [3,4].

The objective of this study is to present the quality control tests for an activity meter that will be used as reference in the establishment of an *in situ* calibration methodology. This reference equipment has been used to measure the activity of check sources employed for quality control tests of the activity meters at Centro de Radiofarmácia (CR), of Instituto de Pesquisas Energéticas e Nucleares (IPEN).

2. MATERIALS AND METHODS

The quality control tests were made according to the Brazilian standards [2] and the manufacturer manual. It was not made the linearity test, due to impossibility of using a ^{99m}Tc source, as recommended, in the laboratory where the activity meters are located.

2.1. Materials

The LCI reference system is a secondary standard Capintec NPL-CRC radionuclide calibrator (Fig. 1).

Figure 1: Activity meter Capintec NPL-CRC used in this study.

The quality control tests were made using the ^{57}Co, ^{137}Cs and ^{133}Ba reference radioactive sources (Fig. 2). Their main characteristics are in table 1.

Figure 2: From left to right, ^{57}Co, ^{137}Cs and ^{133}Ba radioactive sources used in this study.

Table 1. Main characteristics of the isotopes used in the activity meter quality control tests. [5]

Isotope	Half-life	Decay type	Main decay energy (keV)
^{57}Co	271.79 days	Electron capture	836
^{137}Cs	30.07 years	Beta	1176
^{133}Ba	10.51 years	Electron capture	517

2.2. Repeatability and intermediate measurement precision

According to the International Vocabulary Metrology [6] the repeatability is defined as a measurement precision test made under a set of repeatability conditions of measurement. These conditions include the same measurement procedure, same measuring system, same operator, same operating conditions and same location. In this case the measurements are made in a short period of time. In this test, for each source, it were taken 10 measurements every 30 seconds.

The intermediate measurement precision has almost the same definition as the repeatability. Though, the measurements are made over an extended period of time. In this case, the same procedure used in the repeatability test was made during a period of 20 days, with the same radiation sources.

2.3. Measurement accuracy

VIM 2008 [6] defines accuracy as the “closeness of agreement between a measured quantity value and a true quantity value of a measurand”. To obtain the accuracy the activities measured in the activity meter were compared with the nominal activity, corrected for the source decay. The accuracy D is obtained according to the equation 1:

$$D = \frac{(1-A_i)}{A_v} \text{ x } 100\ \% \quad (1)$$

where A_i is an individual measurement and A_v is the conventional activity value [2].

2.4. Measurement precision

According to the VIM 2008 [6] the precision is defined as the “closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions”. The precision P is obtained according to the equation 2:

$$P = \frac{(A_i-A)}{A} \text{ x } 100\ \% \quad (2)$$

where A_i is an individual measurement and A is the mean of the activities measured [2].

In this case the measurement precision was determined using the standard deviation of the 10 measurements, obtained for each radiation sources during the 20 days of measurements.

2.5. CR radiation check sources quality control tests

This test was made using nine ^{137}Cs sources. The objective was to verify these sources accuracy and precision so the CR could use them to make the quality assurance tests on its activity meters.

The procedures used here were the same of those presented previously for the reference activity meter.

3. RESULTS

3.1. Activity meter quality control tests

In the table 2 are shown the results of the repeatability and intermediate precision tests. According to the IEC standard [7], the maximum variation allowed for the repeatability test is 3 %, and the CNEN-NN-3.05 standard states that the maximum variation must be less than

5 % for the intermediate precision. From the table 2 it is possible to note that the results are within these limits.

Table 2. Results obtained for the repeatability and intermediate precision tests. The presented values are the maximum variation obtained in each test.

Isotope	Maximum variation	
	Repeatability	Intermediate precision
^{133}Ba	0.74 %	1.61 %
^{137}Cs	0.80 %	0.78 %
^{57}Co	0.52 %	0.97 %

In the table 3 are shown the results for the accuracy and precision tests. According to the CNEN-NN-3.05 standard, the maximum variation allowed for these tests are 10 % (accuracy) and 5 % (precision). It is possible to note that the results are within these limits in all cases except for the ^{133}Ba accuracy test, in which were obtained values of up to 11.83 %. However the standard deviation of this value was less than 2.5 %, which indicates that this variation may be corrected with a calibration procedure

Table 3. Results obtained for the accuracy and precision tests. The presented values are the maximum variation obtained in each test.

Isotope	Maximum variation	
	Accuracy	Precision
^{133}Ba	11.83 %	0.86 %
^{137}Cs	4.59 %	1.54 %
^{57}Co	1.81 %	1.09 %

3.2. CR radiation check sources measurements

In table 4 is shown the results obtained for the quality control tests of the CR radiation check sources. The sources accuracy test varied from 1.13 % to 9.03 %, which indicates that they probably were not calibrated by the same activity meter. The values presented in table 4 show the necessity of a calibration methodology, in order to attend not only the nuclear medicine services, but also the center that produces the radioisotopes for these services.

Table 4. Results obtained in the quality control tests of the CR ^{137}Cs radiation check sources. The values presented in "accuracy" show the variation between the nominal and the measured activity.

Source number	01	02	03	04	05	06	07	08	09
Accuracy (%)	6.28	6.23	6.22	5.89	6.34	7.38	6.86	9.03	1.13

4. CONCLUSION

The activity meter NPL-CRC presented a good behavior in the tests. The large variation obtained in the accuracy test presented a small standard deviation, which indicates the necessity of a recalibration of this system. A comparison with a similar new reference system will be made in order to determine new calibration coefficients.

The results obtained for the CR sources presented a large variation in different measurements made in the accuracy test, which shows the necessity of calibrate these equipments, not only in medical services but also in the radiopharmaceuticals production.

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