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BEHAVIOR ANALYSIS OF THE ACTIVITY METER IN STANDARD FIELDS

Letícia K. Bueno[1], Elaine W. Martins, Adilson Abolafio e Maria da P. A. Potiens

Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP, Brazil
lebueno222@gmail.com/leticia.bueno@ipen.br[1]

ABSTRACT

The measurements good practices consists in the periodic control of the results obtained by the instruments, the main objective of the quality control in the activity meter is to guarantee that its response is being constant over time and, the results are trustable in relation to the references. The objective of this study was to perform a comparison of the behavior of 12 activity meters that are located inside of the IPEN's Radiopharmacy Center. These equipment were submitted to periodic tests using the reference sources of ^{57}Co, ^{133}Ba and ^{137}Cs. To evaluate their behavior the accuracy and precision tests were applied individually to the well-type ionization chamber. Based on the survey accomplished, we can verify through the failures presented on the accuracy performance that the activity meters are instruments that need a periodic verification, requesting adjusts and recalibration.

1. INTRODUCTION

The Nuclear Medicine (NM) is a medical specialty that uses marked compounds with the function of tracing or mapping, organic functions, denominated as radiopharmaceuticals. These radionuclides are associated to a drug, which is administrated on the patient, making possible to get a physiologic images to diagnostics or the accomplishment of a treatment with the radioactive substances accumulation on the pathologic region, resulting in death of malignant cells. The drug aims to direct the radioactive substance to the organ/region of interest, thus, the correct choice for each type of studied region is fundamental to obtain an appropriate concentration and image as well. The proper choice of radionuclide and its activity in important to determine the radiation dose which is being deposited on the region of interest [1].
In order to assure the adequate amount and the quality of the radiopharmaceuticals to a patient, ensuring the quality and avoid the overdose a patient, the Nuclear Medicine Services (SMN) to use an activity meter that is good operational condition. To guarantee the precise and trustable operation routine in the SMN, it is important to establish a quality control program for all the instrumentation. Quality control tests can be performed daily, semiannual, quarterly or annual, testing for example, the accuracy, precision, reproducibility and the linearity of response, according to periodic test established by the CNEN-NN-3.05 [2].

2. MATERIALS AND METHODS

The activity meters are measurements instruments composed by a well-type ionization chamber coupled to an appropriate electronic circuit. The chamber is filled by argon, nitrogen or even different gases mixture that are at a pressure higher than the atmosphere, in order to achieve good measurement efficiency, moreover, the chamber has two coaxial cylindrical electrodes, causing the ions to be collected and measured when getting the application of a potential difference between the central electrode and the chamber's wall made of aluminum that confines a volume of gas, therefore the number of produced ions in the chamber is related to the energy deposited in the chamber by radiation. The data are exhibited on the display in units being either becquerel (Bq) or curie (Ci), represented in figure 1 [3].

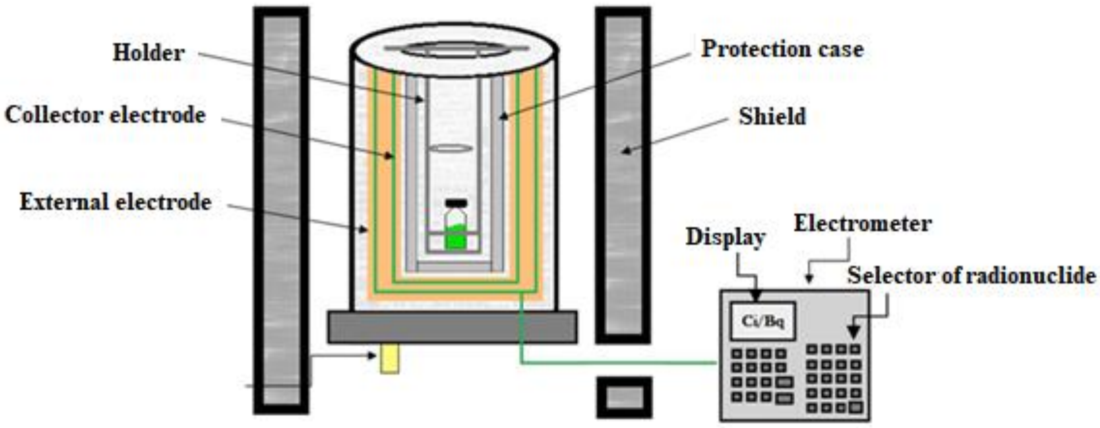

Figure 1: Representation of a well-type activity measuring instrument.

Initially it was done through the calibration certificates issued annually by the Instrument Calibration Laboratory (LCI), a retrospective analyze of the quality control results, of the 12 activities meters were analyzed in a period of 4 year period. The instruments under studies are located inside of IPEN's RC.

In order to establish safety and precision standard in the activity measurements of the activities of determined radiopharmaceuticals used in nuclear medicine, the norm of CNEN-NE-3.05 "Radioprotection and Safety for Services of Nuclear Medicine", establishes that all service of nuclear medicine must have references sources of ^{57}Co, ^{133}Ba and ^{137}Cs, for proper evaluation of their radiation detectors or activities meters [4].

The tests of quality control applied in the equipment under study were performed with the reference sources shown in Table 1 and 2. They are provided by IPEN's Radiations Technology Center (RTC), in a 27mL recipient of polyethylene with uniform distribution of the active element in 20mL of epoxy resin, composed by a density of approximately 1,0g/cm³.

Table 1: Reference sources used in 2015.

Certificate Number	Radionuclide	Activity (MBq)	Reference Date
CTR 012/12	^{137}Cs	7.718	20/02/2012
CTR 014/12	^{133}Ba	8.99	20/02/2012
CRTR 011/12	^{57}Co	153.85	20/02/2012

Table 2: Reference sources used in the year of 2016, 2017 and 2018.

Certificate Number	Radionuclide	Activity (MBq)	Reference Date
CTR 012/12	^{137}Cs	8.144	01/01/2012
CTR 014/12	^{133}Ba	9.239	01/01/2012
181630-18	^{57}Co	196.4	01/06/2015

All activity meters under studies are from the manufacturer Capintec. They are divided in four distinct models shown in Table 3.

Table 3: Activities meters used in CR.

Manufacturer	Model	Measure Of Instrument
Capintec	CRC-15R	7
Capintec	CRC-25R	2
Capintec	CRC-15Dual	1
Capintec	CRC-712MH	1

3. ANALYSIS

The final analysis of the quality control was defined by the results of the accuracy and precision tests, individually performed in the well of the ionization chamber. 10 measurements with 30 seconds intervals were registered, considering the average of the ten readings obtained.
The zero adjust tests, background radiation and high voltage were daily performed, before the start of the tests operations, the results obtained were satisfactory within the manufacturer's recommendations.
The precision was estimated through the difference between the individual activities and the average value. The accuracy was calculated by the difference of the activities average value measured and the certified activity of the corrected source by radioactive decay until the measurement's day. The norm CNEN-NN-3.05 establishes the limits of acceptation and periodicity for the test according to the Table 4 [5].

Table 4: Quality control test of activity meter according CNEN-NN-3.05.

Tests	Periodicity	Objective
Repeatability	Daily	Verify the constancy in the equipment response for different reference sources. The measurements must be within an interval of ± 5% (five per cent).
Accuracy	Weekly	Verify the accuracy in the measurements of an activity meter through the utilization of reference sources. The measurement must be within an interval of ± 10% (ten per cent).
Precision	Weekly	Verify the precision in the measures of an activity meter through the utilization of reference sources. The measures must be within an interval of ± 5% (five per cent).
Linearity	Yearly	Verify the linearity in the measurements of an activity meter through the utilization of a short half-life source. The measurement must be within an interval of ± 10% (ten per cent).

4. RESULTS AND DISCUSSION

The Table 5 presents the results of the accuracy test performed in the year of 2015. Using the acceptation limit of ± 10% from the CNEN's standards which establishes the requirements of radioprotection and safety for NMS, the results show a much higher percentage of the limit for the instrument 6 in the measurement using the ^{57}Co source and, for the ^{133}Ba source in the instrument 9.

Table 5: Accuracy test performed in 2015.

Instrument	Accuracy (%)		
	^{137}Cs	^{133}Ba	^{57}Co
1	9.06	2.47	-4.42
2	4.9	2.90	-------
3	0.56	-3.45	-3.84
4	3.21	2.76	-1.65
5	3.07	0.28	-10.15
6	-6.15	-3.58	-15.91
7	3.64	0.28	-1.52
8	-0.28	-7.87	-4.97
9	3.08	-12.86	2.69
10	3.09	-0.97	-1.56
11	5.03	1.38	-1
12	4.48	3.18	-0.28

The Table 6 shows the results of the accuracy tests applied in 2016, the instrument 1 was above the acceptable limit for more than one tested source. The instrument 9 that was above the limit in the year of 2015 with -12.86 passes to -13.14 with a ^{133}Ba source, increasing much more its percentage out of the acceptable limit.

Table 6: Accuracy test performed in 2016.

Instrument	Accuracy (%)		
	^{137}Cs	^{133}Ba	^{57}Co
1	12.96	15.62	7.56
2	0.41	-4.82	-3.74
3	-1.63	-3.76	-1.65
4	2.72	0.29	-1.32
5	0.54	-1.59	-1.01
6	-3.67	-3.18	-1.86
7	-1.9	-1.01	-2.64
8	-0.55	-4.67	-2.87
9	-5.44	-13.14	-0.53
10	-1.5	-3.04	-2.61
11	-0.82	-1.3	-1.6
12	-0.28	0.72	-1.3

The Table 7 presents the data obtained from 2017. It can be observed that the instrument 1 increases more than 10% compared to the previously year for the ^{133}Ba source and, approximately 4% for the ^{137}Cs. The instrument 9 that had been showing problems with the ^{133}Ba source. Therefore, the user decided not to use it to this source measurement this year.

Table 7: Accuracy test performed in 2017.

Instrument	Accuracy (%)		
	^{137}Cs	**^{133}Ba**	**^{57}Co**
1	16.67	-26.54	7.33
2	0.42	-8.27	0.15
3	-1.67	4.19	-2.27
4	-7.37	-2.78	-3.71
5	1.39	-0.47	-1.28
6	7.66	-9.3	4.5
7	-1.9	-1.16	-2.64
8	-2.37	-7.64	-3.95
9	-5.58	-------	-0.63
10	-0.28	-1.85	-1.01
11	0	-0.31	-3.87
12	-0.28	1.39	-0.68

Finally, the Table 8 shows that the results of the accuracy tests performed in 2018 obtained satisfactory results within the acceptance limits for all chambers and tested sources, with the exception of the instrument 9 that for one more consecutive year, after presenting failures with the ^{133}Ba did not show the results for this source.

Table 8: Accuracy test performed in 2018.

Instrument	Accuracy (%)		
	^{137}Cs	**^{133}Ba**	**^{57}Co**
1	-3.44	-0.50	-4.34
2	-3.57	-6.48	-2.69
3	-3.14	-5.32	-4.52
4	-0.29	1.16	-1.14
5	1.86	0.17	-0.56
6	-3.29	-7.32	-3.69
7	-2.14	-2.38	-5.14
8	-2.15	-5.31	-4.84
9	-5.29	--------	-0.81
10	0.57	0.16	-3.85
11	0.57	0	-3.49
12	1.00	3.63	-0.08

5- CONCLUSION

It has been a common practice to use activity meters as soon as they come from the manufacture. Many medical installation and radiopharmacy employees that has used this kind of equipment daily, do not have the specific knowledge of the operational features and, the tests should be applied to maintain the equipment efficiency. Independently of the purpose of the measurement, either for radiopharmacy or radionuclide to be administrated in a patient or for a standard source utilized in the tests of quality control, or to calibrate a meter instrument, the methods and instrumentation used to perform the measurement must be documented and has to be proper for the pretended task. As the others instruments, the activity meters are the equipment that require a periodic verification, and the quality control tests recommended by the norm CNEN-NN-3.05 as a key point to guarantee the equipment maintain its periodicity.
After the analysis, it can be verified the need of adjust and recalibration through the failures showed in the accuracy performance in 3 chambers that are daily used in the RC. The availability of set-ups with metrological traceability to calibrate instruments and verify the performance in the activities measurements, allows the establishment of quality control programs in the utilization of radiopharmaceuticals products. In the NMS, a practical method to assure the traceability to the national standard is to calibrate the activity meter annually, being a working instrument against the reference instrument [6].

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