Radionuclide Calibrators Performance Evaluation

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Abstract. Radionuclide calibrators are used to estimate accurately activity prior to administration to a patient, so it is very important that this equipment meets its performance requirements. The purpose of this paper is to compare the commercially available "Calicheck" (Calcorp. Inc), used to assess linearity, versus the well-known source decay method, and also to show our results after performing several recommended quality control tests. The parameters that we wanted to evaluate were carried on using the Capintec CRC-15R and CRC-15 βeta radionuclide calibrators. The evaluated tests were: high voltage, display, zero adjust, background, reproducibility, source constancy, accuracy, precision and linearity. The first six tests were evaluated on the daily practice, here we analyzed the 2007 recorded data; and the last three were evaluated once a year. During the daily evaluation both calibrators performance were satisfactory comparing with the manufacture's requirements. The accuracy test show result within the ± 10% allowed for a field instrument. Precision performance is within the ± 1 % allowed. On the other hand, the linearity test shows that using the source decay method the relative coefficient is 0.9998, for both equipments and using the Calicheck the relative coefficient is 0.997. However, looking the percentage of error, during the "Calicheck" test, its range goes from 0.0 % up to -25.35%, and using the source decay method, the range goes from 0.0 % up to -31.05 %, taking into account both instruments. Checking the "Calicheck" results we can see that the results varying randomly, but using the source decay method the percentage of error increase as the source activity decrease. We conclude that both devices meet its manufactures requirements, in the case of the linearity using the decay method, decreasing the activity source, increasing the percentage of error, this may happen because of the equipment age.

KEYWORDS: Radionuclide calibrators; Quality control procedures; Linearity test; Calicheck test, Stability test.

1. Introduction

The nuclear medicine is a diagnostic technique based on the introduction of radio-isotopes into the human body; these radioactive materials are bind to pharmaceutical products which are specific of the studied target organ, which means, that when the introduction of these radio-pharmaceutical products occurs, the physiological behaviour of the organs can be studied [1]. In order to deliver the correct amount of activity per patient, prior to administration, the radio-pharmaceutical products have to be measured accurately and determination of the amount of activity is carry on using a radionuclide calibrator [2] or dose calibrator [3], so it is very important that this equipment meets its performance requirements.

The dose calibrator is an ionization chamber consists essentially of two electrodes at a potential difference of several hundred volts and insulated from each other by an envelope of gas. The radioactive sample is place into a cavity surrounded by the chamber. The passage of ionising radiation through the sensitive volume of the calibrator ionises the gas, producing an electrical current, the magnitude of which is proportional to the activity of radionuclide being assayed [2].

There have been publications [4, 5, 6, 7] trying to determinate the radionuclide settings for different isotopes or different geometries, this is because dose calibrators are commercially available for performing assays of radioactivity in nuclear medicine [8]. In fact some others have published their results for determination of its efficiency when β-emitters are used [9, 10] or even in the presence of contaminants [11].

The Nuclear Medicine Department at the San Juan de Dios Hospital has a quality assurance program applied to the dose calibrators based on the recommendations given by the International Atomic Energy Agency (IAEA) [12]. The quality assurance program has several quality control test, for instance, high voltage, display, zero adjust, background, reproducibility, source constancy, accuracy,

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precision and linearity, some of them are carried on the daily practice, others quarterly or annually. The source constancy and reproducibility tests are to check the response of the overall system (chamber + electrometer) against the benchmark value, which is established when the system is first installed [2].

The purpose of this paper is to compare the commercially available “Calicheck” (Calcorp. Inc) [13], used to assess linearity, versus the well-known source decay method, and also to show our results after performing several recommended quality control tests.

2. Materials and methodology

Our nuclear medicine department has two dose calibrators; one is the CRC-15 βeta, which includes one well counter for measurements of β radio-isotopes emitters; the other one is the CRC-15R; both from Capintec manufacture’s. The study was carried on using 2007 data.

2.1 Daily quality control tests

Every morning before the journey begins, one member of our staff starts the quality control tests, here we follow the manufacture’s instructions. The daily test consists of: auto zero test, checking the background, the system test, the data check test, the source constancy test and the reproducibility test. The member of the staff has to follow the displayed instructions in the dose calibrator, after finish the first test the data is recorded and one needs accept (or dismiss) the result to keep going. The source constancy test consist of evaluated the ^{137}Cs activity measurement (source reference) versus the current activity, this value is automatically estimated by the dose calibrator and also the equipment shows a deviation between those results. The reproducibility test consist of evaluated the ^{137}Cs source reference for the available settings or isotopes in the equipment; therefore by pressing each isotope button one can record the activity measurement obtained.

2.2 Annually quality control tests

Once a year the accuracy, precision and linearity tests are performed. The accuracy and precision measurements are carried on using ^{137}Cs source reference; for each measurement the standard is placed in the dose calibrator holder and waiting to measure the activity; therefore removing the holder with the standard and waiting for no activity displayed, and repeating this cycle in order the get the new measurement. To assess precision, calculation for the percentage of differences between the individual measured activities, A_i , and their mean $\overline{A}$, as follows [12]:

$$\% P = \frac{\left(A_i - \overline{A}\right)}{\overline{A}} * 100 \quad (1)$$

To assess accuracy, calculation for the percentage of differences between the mean measured activity, $\overline{A}$, and the certified activity of the source corrected for radioactive decay to the day of measurement, C, as follows [12]:

$$\% Acc = \frac{\left(\overline{A} - C\right)}{C} * 100 \quad (2)$$

To assess linearity, taking the first eluation from the ^{99m}Tc generator and place it into an eluation vial, and performing two different methodologies, first using the Calicheck and following this procedure [13]: Place the source into the chamber liner and measure the activity. Remove the chamber liner from the dose calibrator. Set the dose calibrator to measure ^{99m}Tc. Verify background levels. Place the source into the black tube and insert it into the dose calibrator. Place the red tube into the dose calibrator over the black tube. Replace the red tube with the orange tube. Replace the orange tube with the yellow tube. Replace the yellow tube with the green tube. Replace the green tube with the blue tube. Replace the blue tube with the purple tube.

Using the same eluation and carrying on the well-known source decay method, the measurements times were at: 4, 14, 18, 22, 39, 42, 44, 46, 50, 52, 54, 65 and 71 hours.

3. Results

3.1 Daily quality control tests

The auto zero test, checking the background, the system test, the data check test were all of them satisfactory. The source constancy test, for CRC-15 βeta dose calibrator, is showing a percentage of error varying from -0.79 % up to -4.85%, looking at figure 1, the maximum difference occurs at day 56, the minimum difference occurs at day 71. For CRC-15R dose calibrator, is showing a percentage of error varying from -0.86 % up to -2.63%, looking at figure 2, the maximum difference occurs very often and is quite stable for some periods of time, the minimum difference occurs at day 68. We do not see an ongoing trend, which indicates that the response is continually rising (or falling), indicating either a leak in the pressurised ionisation chamber or a progressive of the electrometer, also for both system the percentage of error is less than 5 %, so apparently no repairs have to be done [2].

Figure 1: Source constancy test for CRC-15 βeta dose calibrator, using the ^{137}Cs source reference.

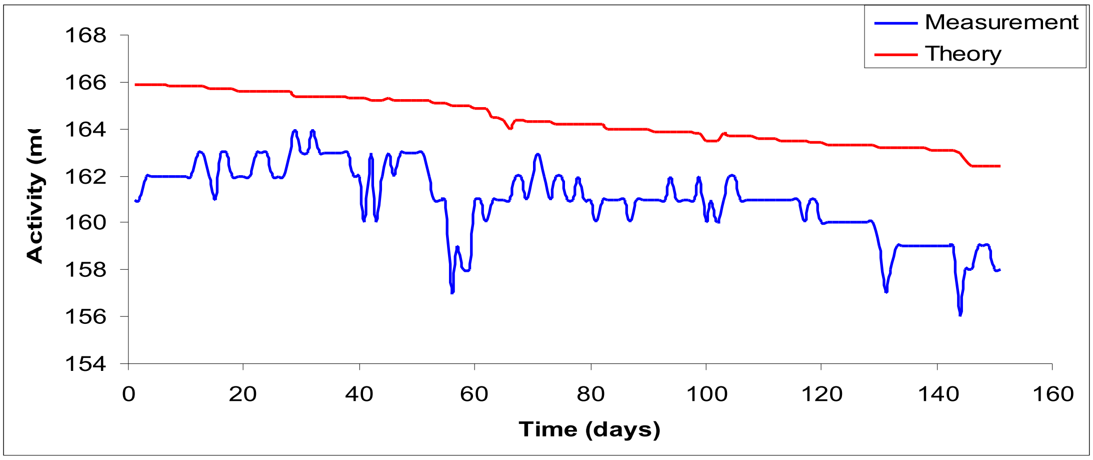
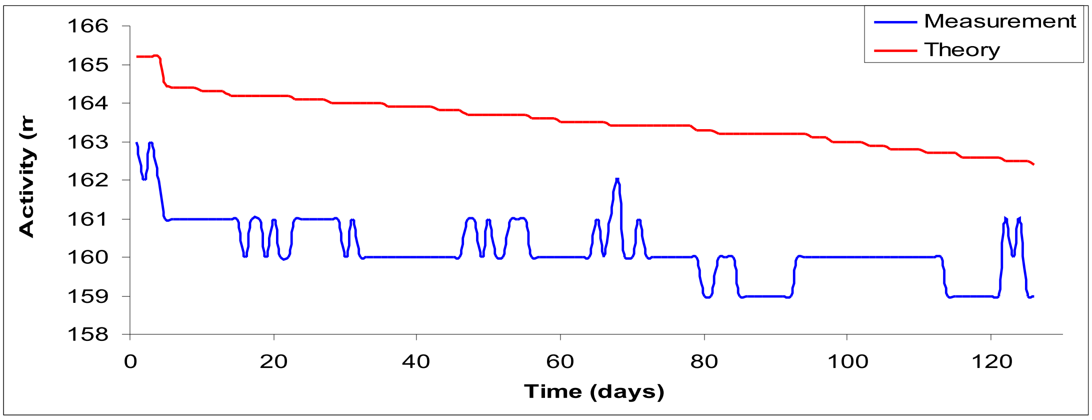


Figure 2: Source constancy test for CRC-15R dose calibrator, using the ^{137}Cs source reference.



The reproducibility test results can be seen in figures 3 and 4. Both figures also are showing the upper and lower limits of acceptability, in our case this limits are at ± 5 %. Here we do not perform any decay correction because the source reference used was the ^{137}Cs, so there is not necessary this correction because of its long half-live. Looking at ^{57}Co results, both systems were measured almost the same result, which is the reason to see a straight line. On the other hand, looking at the ^{99m}Tc results, results are not very constants, we do see an ongoing trend, for CRC-15 βeta dose calibrator that could not be appreciate previously [2]. We have to plot this result for other settings to check the falling trend in it. This dose calibrator has more than 10 years working, so this effect can be related with the its aging. However results are between the limits of acceptability are satisfactory.

Figure 3: Reproducibility for CRC-15 βeta dose calibrator, using the ^{99m}Tc and ^{137}Cs operating settings.

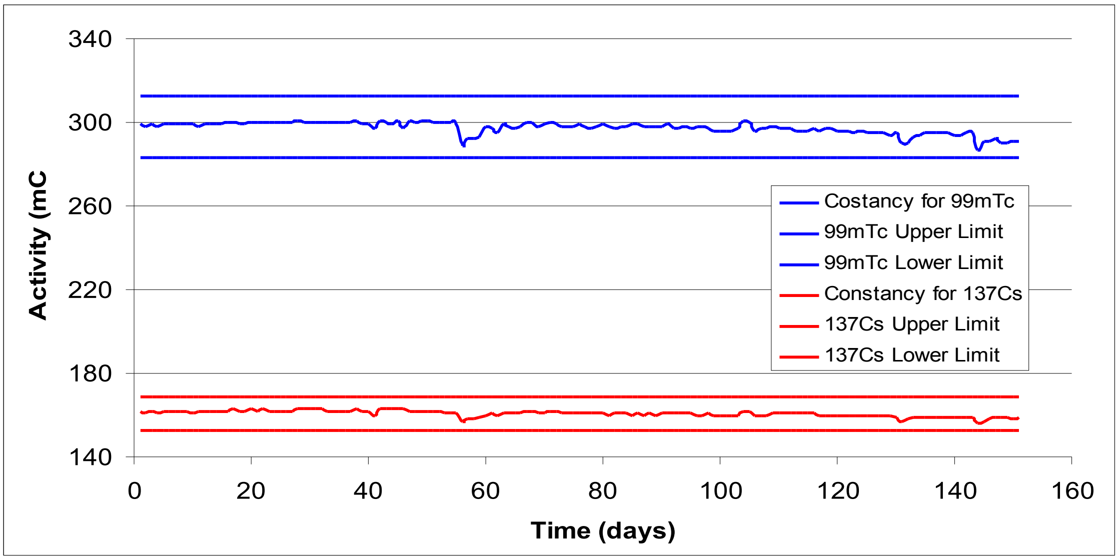
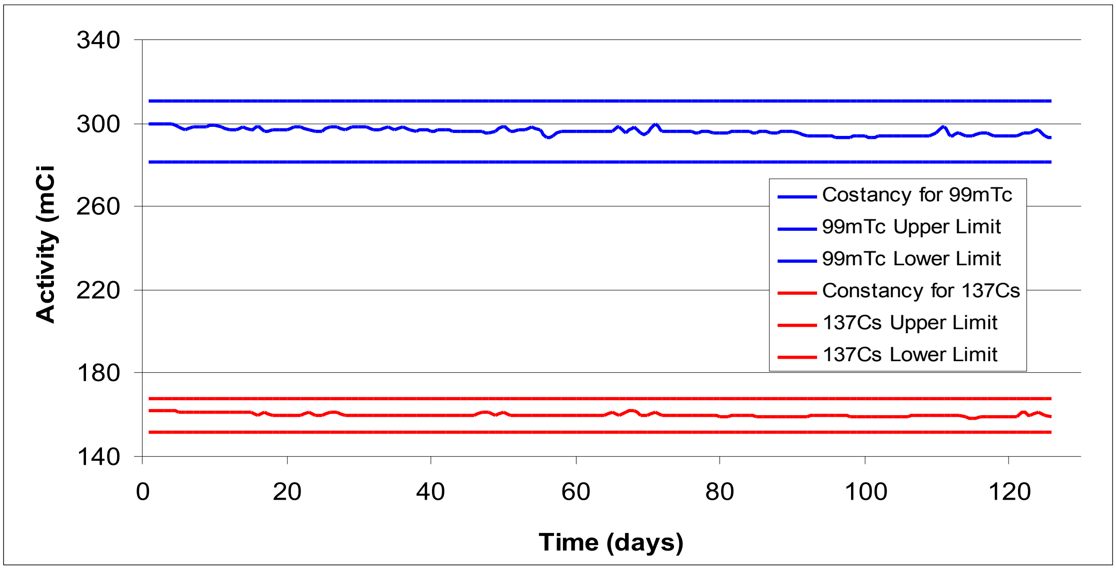


Figure 4: Reproducibility for CRC-15R dose calibrator, using the ^{99m}Tc and ^{137}Cs operating settings.



3.2 Annually quality control tests

The accuracy test show results within the ±10% allowed and the precision performance is within the ±1 % allowed, both for a field instrument [2, 13]. From figures 5 and 7 results of linearity can be seen for the Calicheck methodology considering both dose calibrators. For both plots the relative coefficient is 0.997, in the measurement case, and the slopes are very similar to the theory one. On the other hand, considering each individual measurement, the percentage of error is varying randomly, in the case of the CRC-15 βeta dose calibrator, from 0.0% up to -24.17% and in the case of the CRC-15R dose calibrator, from 0.0% up to -25.35%. Looking at figures 6 and 8 results of linearity can be seen for the decay methodology considering both dose calibrators. For both plots the relative coefficient is 0.999, in the measurement case, and the slopes are very similar to the theory one. On the other hand, considering each individual measurement, the percentage of error is increasing as the activity measured decrease, the percentage of error raise up to 16 % for a current activity of 17 mCi and the same value raise up to 30 % for a current activity of 0.58 mCi, in the case of the CRC-15 βeta dose calibrator. The CRC-15R dose calibrator shows similar results for the same range of current activity. We think that these results are due to the dose calibrators aging, one of them has 11 years working and the other one has 13 years. Although both linearity curves are not showing range change effects and non-linearity effects, the inaccuracy can be seen at the end of the curve, for low activity measurements.

Figure 5: Linearity results using the Calicheck for CRC-15 βeta dose calibrator

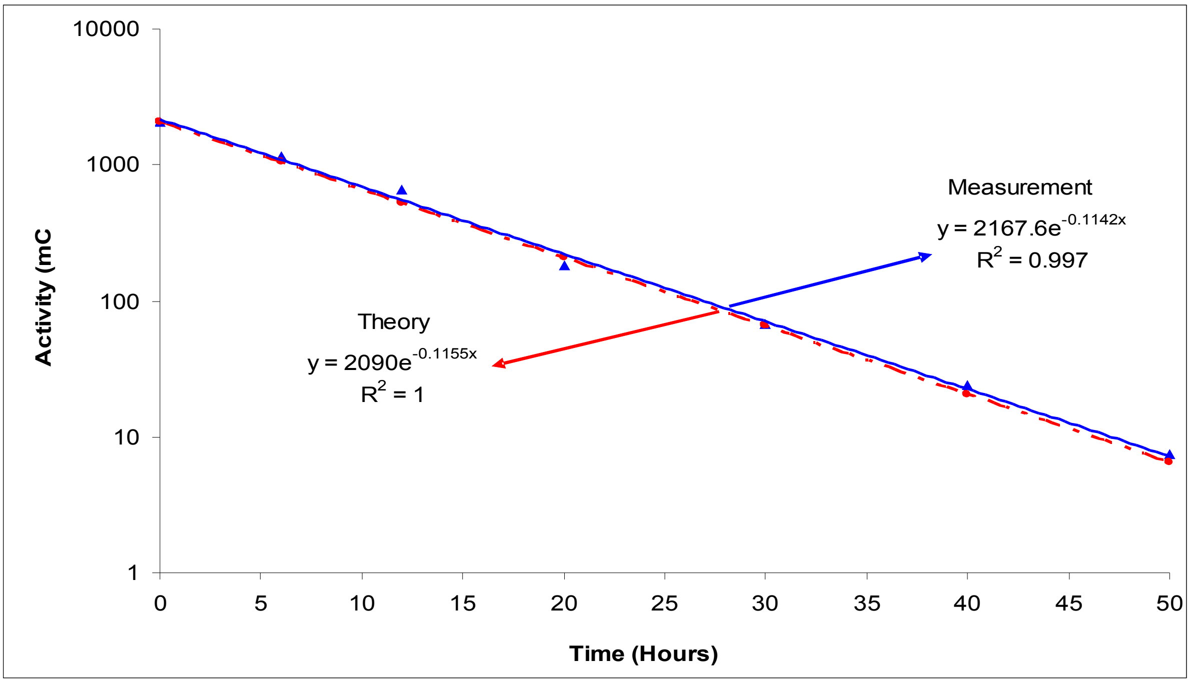


Figure 6: Linearity results using the decay method for CRC-15 βeta dose calibrator.

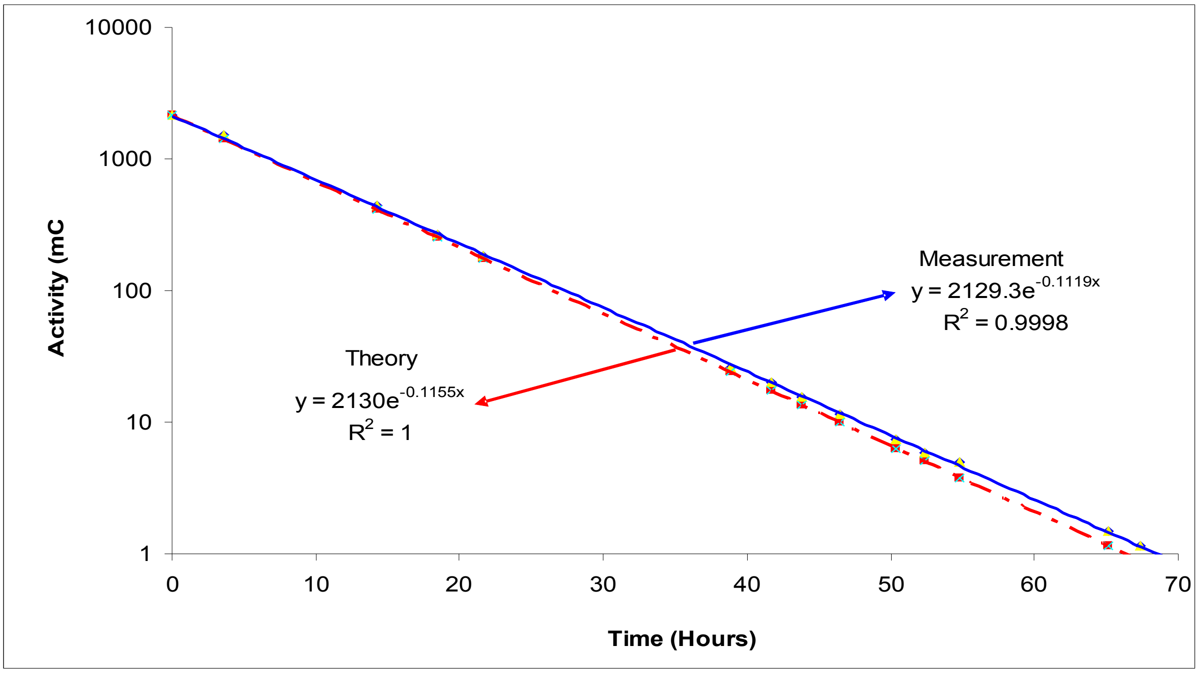


Figure 7: Linearity results using the Calicheck for CRC-15R dose calibrator.

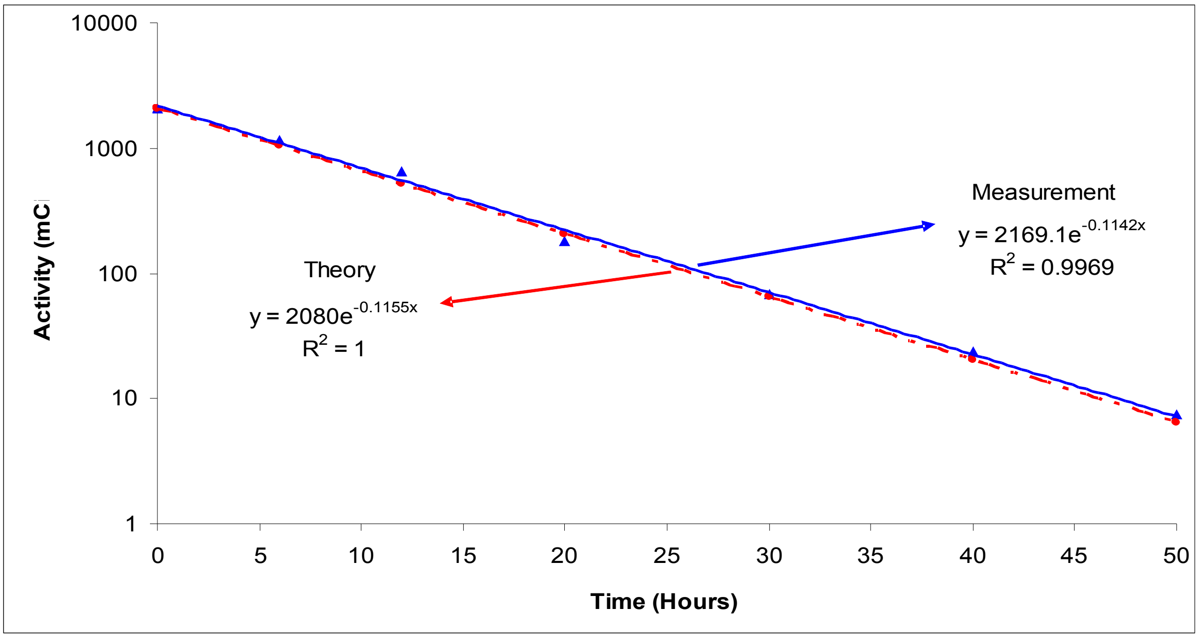
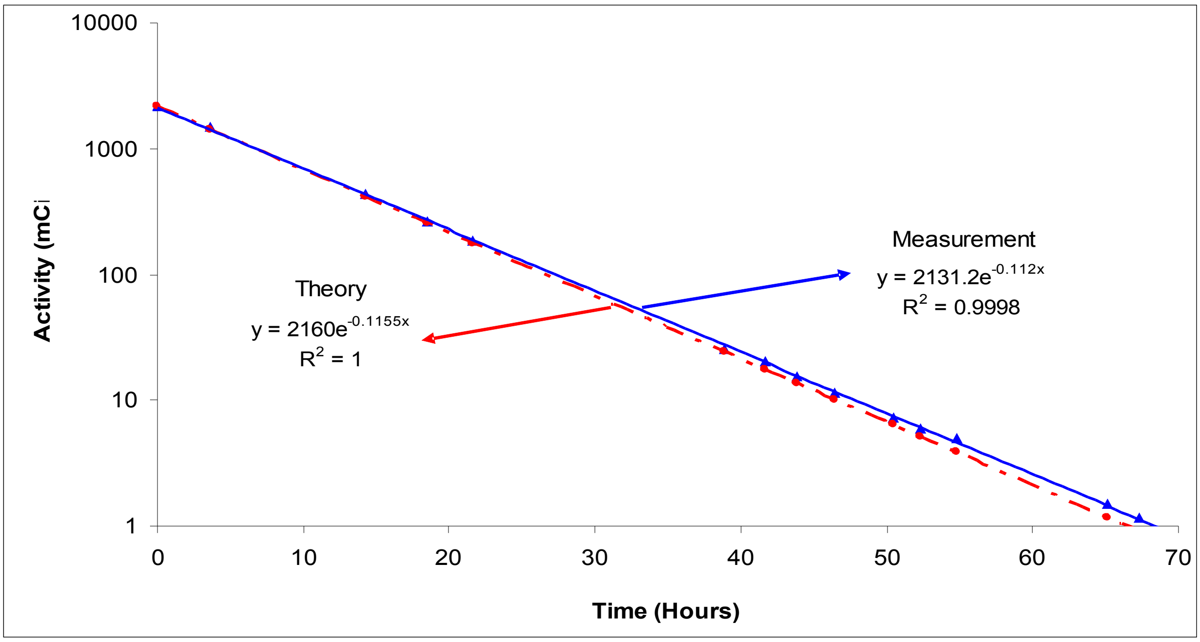


Figure 8: Linearity results using the decay method for CRC-15R dose calibrator.



4. Conclusion

We conclude that both devices meet its manufactures requirements, in the case of the linearity using the decay method, decreasing the activity source, increasing the percentage of error, this may happen because of the equipment age.

Acknowledgements

The author wish to thank his workmates from the Nuclear Medicine Department at the San Juan de Dios Hospital, for their collaboration performing this quality control test; to the Heads of the Department and to the "Comité Local de Bio-ética en Investigación (CLOBI)" from the Hospital for allowing me to develop this paper this paper.

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