

Calibration of two $^{90}\text{Sr}+^{90}\text{Y}$ dermatological applicators

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Abstract. The $^{90}\text{Sr}+^{90}\text{Y}$ applicators need to be periodically calibrated, but in Brazil the service is not offered yet. The recommended method for the calibration of this kind of applicators is the use of extrapolation chambers. An alternative method for the calibration of clinical applicators is the use of thermoluminescent dosimeters. A dosimetric method of these applicators was already developed at Instituto de Pesquisas Energéticas e Nucleares (IPEN) and several types of thermoluminescent dosimeters were studied in previous works. The aim of this work was the application of this method to calibrate two dermatological applicators. Thin $\text{CaSO}_4:\text{Dy}$ pellets, with and without 10% of graphite were utilized. The reproducibility of these pellets was studied, and calibration curves were obtained using a standard applicator calibrated at the National Institute of Standards and Technology (NIST), USA. Both applicators showed similar results. The TL materials tested showed usefulness for dosimetry and calibration of this kind of applicators.

KEYWORDS: *Clinical applicators, beta radiation, beta dosimetry, $^{90}\text{Sr}+^{90}\text{Y}$ source, thermoluminescent dosimeters*

1. Introduction

Over the last five decades, $^{90}\text{Sr}+^{90}\text{Y}$ beta radiation sources have been commonly used in brachytherapy procedures, in the treatment of superficial injuries of eyes and skin. This kind of therapy can be used for post-operative treatment of pterygia, to reduce the rate of relapse, and to reduce the chances of formation of keloids, for example. These sources were developed by Friedell and collaborators in 1950^[1], and the procedure diffused quickly for the whole world. Approximately 10 different manufactures produced some hundred of sources, in the 1990's decade^[2]. $^{90}\text{Sr}+^{90}\text{Y}$ sources are very utilized due to their long half-life (28.8 years).

The special sources used in brachytherapy are the clinical applicators. Since some years $^{90}\text{Sr}+^{90}\text{Y}$ dermatologic and ophthalmic applicators are not commercialized anymore, but many of them are still very utilized in Brazilian radiotherapy clinics. These applicators may be plane or concave; generally, the dermatologic applicators are plane and the ophthalmic applicators are concave.

The $^{90}\text{Sr}+^{90}\text{Y}$ sources were delivered with usually calibration certificates of the manufacturers, but some of them were recalibrated by standard laboratories. The sources have not been periodically calibrated, because no such services are available in the Brazilian calibration laboratories yet. Moreover, it is difficult to remove these applicators from the radiotherapy clinics to send them for calibration, because this fact it would interrupt the treatments in progress. Recommendations as of the International Atomic Energy Agency^[3] and De Almeida et al.^[4] showed the need for periodic measurements and calibrations in secondary standard laboratories, hospitals and clinics that use these kinds of sources.

The recommended method for calibration of clinical applicators in laboratory involves the use of special ionization chambers, called extrapolation chambers. These instruments allow variation of their sensitive volumes. These ionization chambers are metrological instruments that may be utilized for the detection of beta radiation and low energy X-rays. They are very useful for the determination of superficial absorbed dose rates of beta radiation sources, by the extrapolation technique. At the Calibration Laboratory of Instituto de Pesquisas Energéticas e Nucleares (IPEN), extrapolation chambers were developed for the calibration of dermatologic and ophthalmic applicators^[5,6,7]. These

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chambers are used only in laboratory, because they are not appropriate for field measurements, because they are not portable.

The dosimetry of the clinical applicators can also be made using thermoluminescent dosimeters (TLD). In 1990, Reft et al. demonstrated already the ability to calibrate ophthalmic applicators of $^{90}\text{Sr}+^{90}\text{Y}$, flat or curved, with the use of the phenomenon of thermoluminescence^[8]. The best response for beta radiation was obtained for thin $\text{CaF}_2:\text{Mn}$ and $\text{CaSO}_4:\text{Dy}$ pellets. This method of calibration was also developed at IPEN in previous studies, using several types of thermoluminescent dosimeters (TLDs)^[9]. Due to the low penetration power in the matter by beta radiation, the thin dosimeters are more appropriate for beta dosimetry^[9]. For the calibration of a $^{90}\text{Sr}+^{90}\text{Y}$ concave applicator, studies by Oliveira and Caldas showed the usefulness of thin $\text{CaSO}_4:\text{Dy}$ pellets^[10].

The Calibration Laboratory of IPEN has two $^{90}\text{Sr}+^{90}\text{Y}$ dermatological applicators (named A and B) of different activities. The aim of this work was the calibration of these applicators using thermoluminescent dosimeters against a dermatological applicator calibrated by National Institute of Standards and Technology (NIST), as reference.

2. Materials and Methods

The calibration of applicators was realized using the method of thermoluminescent dosimetry. Initially, twenty thin $\text{CaSO}_4:\text{Dy}$ pellets were utilized: ten pellets with and ten pellets without 10% of graphite. Both the thin $\text{CaSO}_4:\text{Dy}$ pellets present dimensions of 6.0 mm in diameter and 0.2 in thickness. These pellets were produced by the Dosimetric Materials Laboratory of IPEN. A reproducibility study of TL response was performed and the result allowed the selection of the pellets in groups, with similar characteristics in relation to their TL sensitivity. One group of five $\text{CaSO}_4:\text{Dy}$ pellets and one group of five $\text{CaSO}_4:\text{Dy} + 10\%$ of graphite pellets were chosen for the calibration curve using the NIST standard applicator and for the calibration of both dermatological applicators A and B.

In this work, a $^{90}\text{Sr}+^{90}\text{Y}$ dermatological applicator calibrated by the primary standard laboratory of NIST, $^{90}\text{Sr}+^{90}\text{Y}$ Beta-Particle Source, Atlantic Research Corporation, Model B-1 S/N 233, was utilized to calibrate two $^{90}\text{Sr}+^{90}\text{Y}$ dermatological applicators: A, from Amersham, with nominal activity of 1.49 GBq and nominal average water absorbed-dose rate of 0.40 Gy/s (11/08/1968) and B, from Amersham, with unknown activity. The NIST calibration certificate presents a combined uncertainty, \dot{D}_w , of 6.0%. All three applicators were used in the same calibration conditions.

Irradiations of the TL dosimeters using the NIST, A and B applicators were performed at a null source-detector distance. The applicators were fixed vertically by a support, inside of an acrylic box, and the pellets were placed on the source. The TL measurements were taken using a Harshaw Nuclear System, model 2000A/B, with a linear heating rate of $10^\circ\text{C}.\text{s}^{-1}$, and a constant flux of N_2 . The light emission was integrated in the temperature interval of 50°C to 200°C . The thermal treatments for re-utilization of the TL pellets were made at 300°C during 1 hour.

3. Results

3.1. Reproducibility of TL Response

Initially, the reproducibility of the TL response of the samples was checked using ten pellets of each kind. The reproducibility was obtained after five series of irradiations measurements and thermal treatments, using $^{90}\text{Sr}+^{90}\text{Y}$ source, 1850 MBq (1981), at 11 cm, dose of 1 Gy, without the use of the flattening filter. The maximum percentual deviation obtained was 4.6% for the thin $\text{CaSO}_4:\text{Dy} + 10\%$ of graphite pellets, and 4.3% for the thin $\text{CaSO}_4:\text{Dy}$ pellets. The associated uncertainties in this case were equal to 6.12% for $\text{CaSO}_4:\text{Dy}$ pellets and to 7.11% for $\text{CaSO}_4:\text{Dy} + 10\%$ of graphite pellets.

3.2. Calibration Curves (NIST Applicator)

The TL response as a function of absorbed dose was measured for six absorbed doses, in the interval of 5 Gy to 100 Gy. The measurement uncertainty obtained for the thin CaSO₄:Dy pellets was equal to 11.6%, and for the thin CaSO₄:Dy + 10% of graphite it was equal to 13.4%.

For the calibration of the A and B applicators, three pellets of each kind were chosen, with similar TL characteristics. The calibration curves for the TL response, in function of the absorbed dose, are shown in Figures 1 and 2. These calibration curves show the usefulness of both kinds of TL dosimeters, thin CaSO₄:Dy pellets and CaSO₄:Dy + 10% of graphite, for calibration of dermatological applicators.

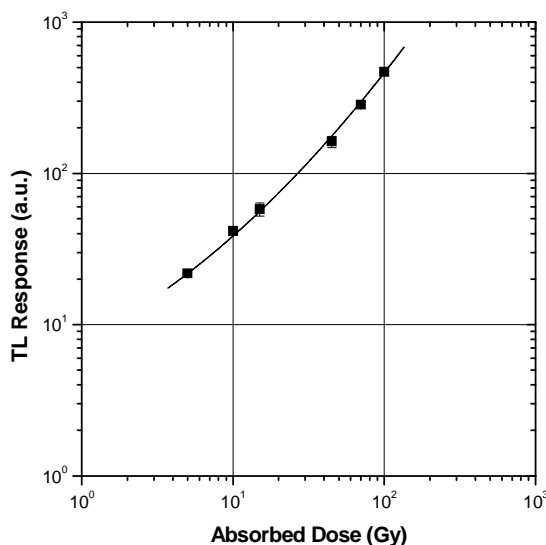


Figure 1: Calibration curve of the thin CaSO₄:Dy pellets, for beta radiation, using the reference ⁹⁰Sr+⁹⁰Y NIST applicator.

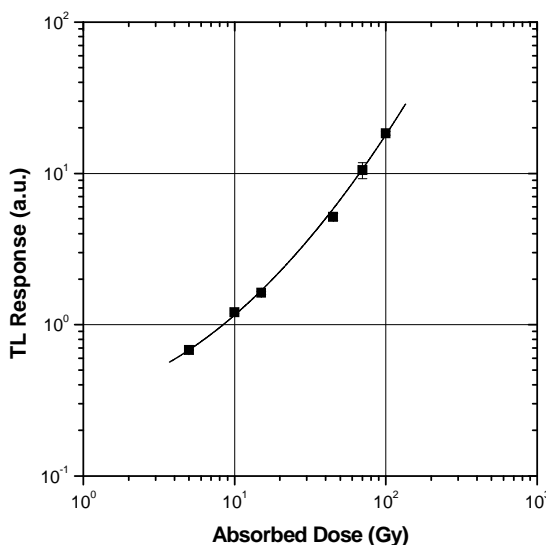


Figure 2: Calibration curve of the thin CaSO₄:Dy + 10% of graphite pellets, for beta radiation, using the reference ⁹⁰Sr+⁹⁰Y NIST applicator.

The calibration curves show a linear behaviour until 15 Gy. After this dose, the curves present supralinear characteristics. The fitting of the data was obtained using the Origin 7.5 software.

3.3. Calibration of Dermatological Applicators

3.3.1. Applicator A and B

In the case of applicator A, all TL samples were irradiated four times, during 5, 10, 15 and 20 min. After each irradiation, the samples were evaluated and then thermally treated. The absorbed dose, relative to each time of irradiation was determined, through the calibration curve of the NIST applicator. The maximum percentual deviations obtained for the CaSO₄:Dy (without and with 10% of graphite) pellets were 1.1% and 5.8%, respectively.

In the case of the calibration of the dermatological applicator B, the samples were irradiated five times, during 5, 10 (twice), 15 and 20 min. The maximum percentual deviations obtained for the CaSO₄:Dy (without and with 10% of graphite) pellets were 5.8% and 5.1%, respectively.

The absorbed-dose rates were obtained from the calibration curves of the NIST applicator for both kinds of pellets. The results for applicators A and B are shown in Table 1. The difference between the results obtained for the applicator A was 4.6%, and for the applicator B it was only 0.41%. These results were considered satisfactory, because the NIST calibration certificate presents 6.0% as uncertainty for the absorbed dose rate of the standard applicator used in this work as the reference source.

Table 1: Absorbed-dose rates obtained for the two dermatological applicator.

Applicator	Pellets	Absorbed-Dose Rate (Gy/h)
A	CaSO ₄ :Dy	107.47 ± 17.01
	CaSO ₄ :Dy + 10% of graphite	102.79 ± 15.70
B	CaSO ₄ :Dy	125.12 ± 19.24
	CaSO ₄ :Dy + 10% of graphite	124.61 ± 19.31

4. Conclusion

The results obtained for the reproducibility study of the thin CaSO₄:Dy pellets with and without graphite are within the expected values. The pellets have similar dosimetric characteristics, which is of great importance. From the calibration curve of both materials, obtained with a standard dermatological applicator calibrated by NIST, the calibration of the two dermatological applicators of IPEN was possible. The results obtained for applicator A could be compared with results of previous work and from its certificate, but for applicator B this was not possible, because its nominal activity was unknown. As the absorbed-dose rates and uncertainties obtained for the applicator A were satisfactory, it is possible to conclude that the values obtained for the applicator B are real, because the same calibration procedures were utilized. Therefore, the results of the calibration of the applicators A and B show that the TL materials present great usefulness for dosimetry and calibration of dermatological applicators.

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