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Performance of thin $CaSO_4$: Dy pellets for calibration of a $^{90}Sr + ^{90}Y$ source

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Abstract

Because of the radionuclide long half-life, $^{90}Sr + ^{90}Y$, plane or concave sources, utilized in brachytherapy, have to be calibrated initially by the manufacturer and then routinely while they are utilized. Plane applicators can be calibrated against a conventional extrapolation chamber, but concave sources, because of their geometry, should be calibrated using relative dosimeters, as thermoluminescent (TL) materials. Thin $CaSO_4$:Dy pellets are produced at IPEN specially for beta radiation detection. Previous works showed the feasibility of this material in the dosimetry of $^{90}Sr + ^{90}Y$ sources in a wide range of absorbed dose in air. The aim of this work was to study the usefulness of these pellets for the calibration of a $^{90}Sr + ^{90}Y$ concave applicator. To reach this objective, a special phantom was designed and manufactured in PTFE with semi spherical geometry. Because of the dependence of the TL response on the mass of the pellet, the response of each pellet was normalized by its mass in order to reduce the dispersion on TL response. Important characteristics of this material were obtained in reference of a standard $^{90}Sr + ^{90}Y$ source, and the pellets were calibrated against a plane applicator; then they were utilized to calibrate the concave applicator.

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1. Introduction

Weakly penetrating beta radiation sources, as $^{90}Sr + ^{90}Y$ sources, are commonly utilized in brachytherapy procedures, specially in treatments of superficial lesions. These sources, called applicators, can be plane or concave to better fit the injured surface. The calibration of this kind of source is very difficult because of the great dose gradient near the source surface, and the source dimensions. According to international recommendations, plane sources can be accurately calibrated using an extrapolation chamber. By utilizing an extrapolation chamber it is possible to determine the absorbed dose rate at the source surface or at a reference point. The calibration of concave plaques is more difficult because of the source geometry: plane extrapolation chambers cannot be put in contact with the source surface. In this case, the use of calibrated relative dosimeters is recommended, such as thermoluminescent (TL) dosimeters, positioned on a suitable phantom [1,2].

Thin $CaSO_4$: Dy pellets are produced at IPEN. The usefulness of these pellets for the detection of beta radiation was showed in a previous work where the TL response as a function of beta radiation dose was studied up to 10 mGy [3]. More recently, Oliveira and Caldas [4] studied the performance of this material in comparison with different pellets commercially available (LiF, CaF_2: Mn, CaF_2: Dy) and produced at IPEN (conventional and thin $CaSO_4$: Dy, and $CaSO_4$: Dy + 10%C). The results obtained showed the adequate behavior of the $CaSO_4$: Dy pellets as a TL dosimetric material for $^{90}Sr + ^{90}Y$ sources in a higher dose range (1–70 Gy); due to the low penetration in matter of beta particles, the thinner dosimeters, as thin $CaSO_4$: Dy, and $CaSO_4$: Dy + 10%C, proved to be more adequate than the conventional dosimeters for beta

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dosimetry. However, the $CaSO_4$: Dy + 10%C, although presenting a reduced energy dependence, is less sensitive to radiation than the thin $CaSO_4$: Dy pellets [5].

The aim of this work was to study the dosimetric characteristics of thin $CaSO_4$: Dy pellets, produced at IPEN, to verify the possibility of their use to calibrate concave $^{90}Sr + ^{90}Y$ applicators. In the present work, the TL response of each pellet was normalized by its mass; this normalization reduced the TL response dispersion.

2. Materials and methods

In the present work, thin $CaSO_4$: Dy pellets were utilized. The samples were irradiated using a standard $^{90}Sr + ^{90}Y$ source (1005 MBq, 2006), a plane (600 MBq, 2006) and a concave (300 MBq, 2006) $^{90}Sr + ^{90}Y$ applicators. The irradiations with the standard source were performed positioning the samples on a rectangular acrylic phantom, covered by a thin plastic foil; irradiations with the plane applicator were performed in disc-phantoms, with the same thickness. For the calibration of the concave source, the TL samples were positioned on semi-spherical acrylic phantoms.

Prior to each irradiation, the samples were thermally treated (300 °C/3 h). The readout system was a Harshaw Nuclear System, Model 2000A/B. The individual mass of each pellet was determined by utilizing a high resolution digital balance.

3. Results

The main dosimetric characteristics of $CaSO_4$: Dy pellets were studied exposing the pellets to a $^{90}Sr + ^{90}Y$ standard source and a $^{90}Sr + ^{90}Y$ plane applicator. The response reproducibility, calibration curves, TL response as a function of the source–detector distance, and the linearity of the sample response were obtained as a function of irradiation time.

3.1. Reproducibility

The reproducibility of the TL response of the pellets was obtained by their TL evaluation after 5 readout cycles of standard annealing and irradiation with both $^{90}Sr + ^{90}Y$ sources: the standard source, at 11 cm, and the plane applicator, at 1 mm (to simulate the geometry of use). The TL response spread of each pellet, after 10 readout cycles, was less than 2.8%. The measurement uncertainties (coverage factor k equal to 2) were equal to 6.5% and 5.5% for the measurements performed with the standard source and the applicator, respectively.

3.2. Calibration curves

The TL response of the samples as a function of absorbed dose in air was obtained using the $^{90}Sr + ^{90}Y$ standard source at 11 cm, in the dose interval of 1–70 Gy; up to this dose no saturation of response was achieved, as showed in Fig. 1a. The measurement uncertainties were equal to 9.3% ($k = 2$). The thin $CaSO_4$: Dy pellets show a linear behavior up to 15 Gy, and then the TL response becomes supralinear.

In a different geometry, the same pellets were irradiated with the $^{90}Sr + ^{90}Y$ plane applicator; the distance between source and samples was equal to 1 mm and the dose interval was from 1 up to 16 Gy. The result (Fig. 1b) shows a linear behavior similar to that exhibited in Fig. 1a. In this

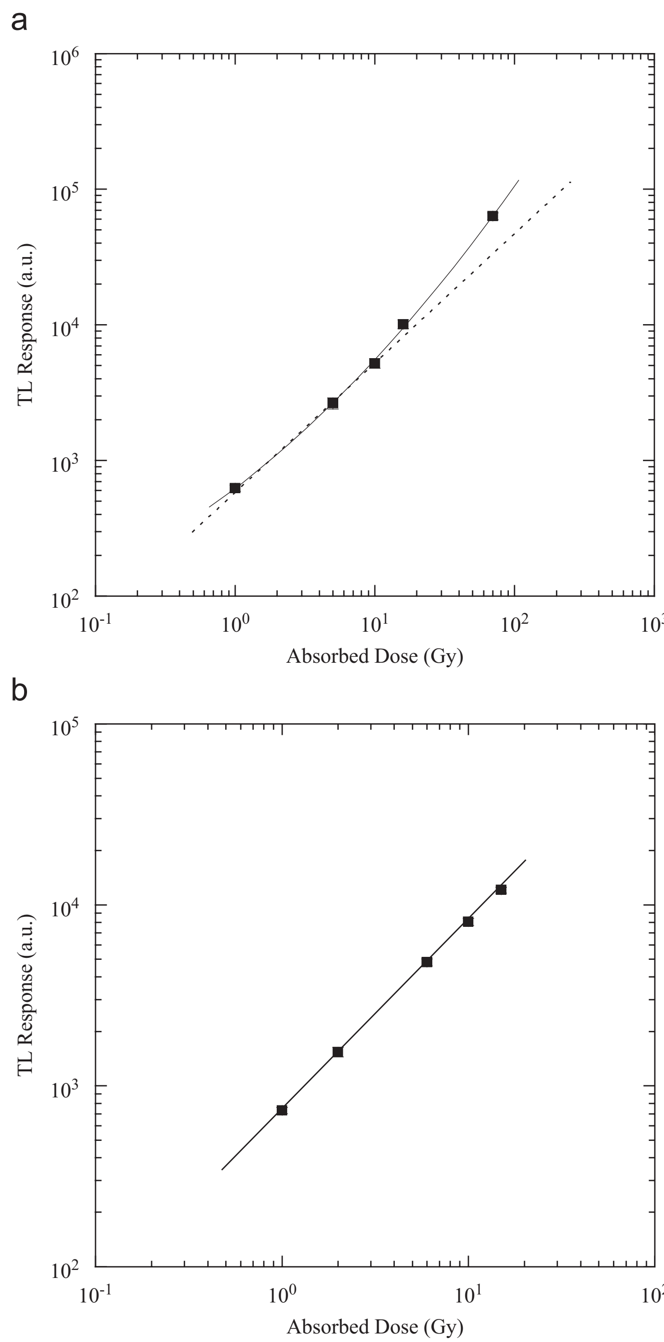

Fig. 1. Calibration curves for: (a) $^{90}Sr + ^{90}Y$ standard source, at 11 cm (the dashed line shows the linear region of this curve), and (b) $^{90}Sr + ^{90}Y$ plane applicator, at 1 mm.

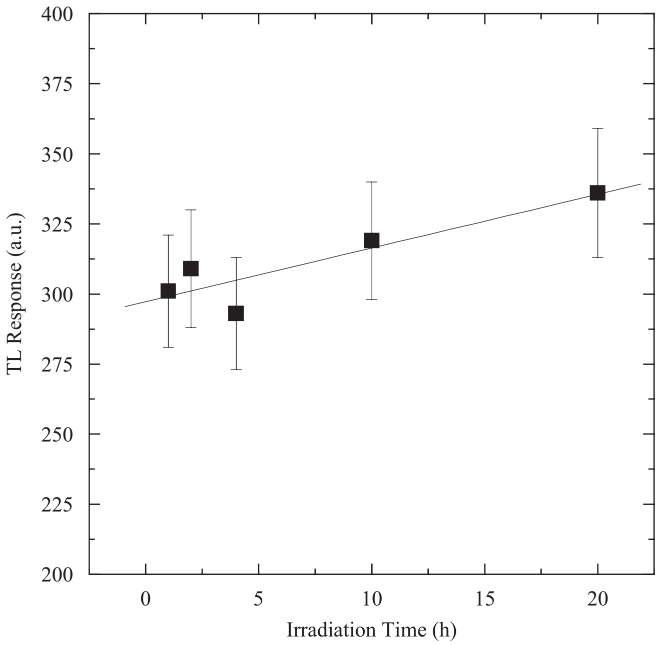

Fig. 2. TL response (normalized by irradiation time) of $CaSO_4$: Dy pellets as a function of irradiation time, at 11 cm from the plane applicator.

case, the measurement uncertainties were equal to 6.6% ($k = 2$).

The TL response of thin $CaSO_4$: Dy pellets is presented in Fig. 2; in this figure the response of the pellets, irradiated with the plane applicator, was studied as a function of the irradiation time (which was varied from 1 up to 20 h). The TL response of the pellets were normalized by the irradiation time, and, as shown in Fig. 2, the pellets exhibited a supralinear behavior, confirming the results showed in Fig. 1. The measurement uncertainties were equal to 6.8% ($k = 2$).

3.3. *Calibration of a $^{90}Sr + ^{90}Y$ Concave Applicator*

A concave applicator was utilized to irradiate thin $CaSO_4$: Dy pellets; the pellets were positioned on a semi-spherical phantom to simulate the real condition of utilization. The irradiation time was calculated in order that the absorbed dose was equal to 10 Gy. By utilizing the curve showed in Fig. 1b, the TL response could be converted to absorbed dose; the result obtained was (9.18 ± 0.60) Gy, which results in a difference of 8.2% from the nominal value.

4. Conclusions

The results obtained show the usefulness of the thin $CaSO_4$: Dy pellets for the calibration of a $^{90}Sr + ^{90}Y$ concave applicator. The percentual difference between the value obtained and the nominal value is nearly equal to the uncertainties in the determination of calibration curves.

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