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ABOUT TLD-100 GLOW CURVE MANIPULATION TO ACHIEVE DOSIMETRIC PARAMETERS OF I-125 SEEDS USED FOR BRACHYTHERAPY

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ABSTRACT

Brachytherapy with ^{125}I sources is applied, mainly, to the treatment of prostate, cerebral and ophthalmologic cancers. For experimental measurements, thermoluminescence dosimeters (like TLD-100) are widely used for brachytherapy dosimetry requests. The TLD-100 is a LiF:Mg,Ti crystal and its thermoluminescence response, the glow curve, has some peaks registered during the reading. In order to establish the direct relationship between dose and TL response, the total or partial integration of the glow curve could be used, or simply the size of a peak. If not using the size of this peak, the integration of a temperature interval containing it, is normally used. The aim of this work is to analyze the influence on dosimetric properties whether the main peak is selected to the measurements or the entire integration of the glow curve. A batch of TLD-100 micro-cube, with dimensions 1 mm x 1 mm x 1 mm and a Harshaw 2000 A/B TLD reader were used. For TLD-100 irradiations and positioning, Iodine-125 sources and a Solid Water phantom were used. With the appropriate electronic acquisition devices, connected to the Harshaw 2000 A/B, it was possible to read each signal individually. Both measurements methods presented acceptable regularity in the results. Therefore, for the dosimeters positioned distant from the source, large relatives differences among selected region (55 – 70 %) were observed.

1. INTRODUCTION

Briefly, the brachytherapy can be defined as a treatment where sealed radioactives sources are put in a short distance or inside the tumor, for a specific time or permanent implants. The main treatment purposes are to deliver a high radiation dose, in tumor cells and to minimize the dose contribution on the surrounding healthy tissues with a rapid dose fall, related to the distance. Some radionuclides are used for the treatment; the main ones are ^{125}I, ^{192}Ir and ^{106}Pd [1-3].

For dose treatment prescription it is fundamental to analyze the characteristics of radionuclides, as well as the materials that are incorporated on the sealed source, to perform an accurate dosimetry. Basically, this dosimetry is realized with two methods: computer simulation methods (using Monte Carlo codes) and experimental methods, using detectors to measure the dose directly or indirectly. In brachytherapy, the thermoluminescence dosimetry

(TLD) using LiF crystals, is an experimental method that has been extensively applied with relative success [4].

TLD-100 (developed by Harshaw Chemical Company, which named the LiF:Mg,Ti as TLD-100 and became the most used name in literature) is composed by LiF:Mg,Ti; with approximately 180 ppm of Mg and 10 ppm of Ti to create luminescence centers in crystal. LiF:Mg,Ti has a variety of physical forms, like, powder, PTFE discs and rods. TLD-100 has some advantages, like relative tissue equivalence (important for medical purposes), various dimensions and formats and fully available information in the literature [5-7].

The TL response of TLD-100 gives several characteristic peaks in a large range of temperature. According to the literature [8,9], at room temperature, five main peaks appear in the spectra. The peaks 4 and 5 have a long half-life and are more convenient for dosimetric purposes. Therefore it is usual, on practice, to eliminate the other peaks. This method selects a certain region of interest, or chooses a temperature interval where these main peaks appear.

Generally, these peaks are not “very well situated” in the spectra and sometimes the dose is not sufficient to identify them. Due to these facts, it is a complex task to analyze and discriminate these peaks, requiring some additional equipments or other methods, like computerized glow curve deconvolution [10]

This work studies the influence on the choice of these peaks (4 and 5) in TLD-100 micro-cube or the entire glow curve measurements, with ^{125}I sources applied for brachytherapy.

2. MATERIALS AND METHODS

2.1. I-125 Sources

For this work, an ^{125}I sealed source, usually called *I-125 seed* (due to small sizes), model IMC6711 manufactured by Oncura GE Healthcare Ltd, was used. This model is a cylindrical welded titanium capsule with 4.5 mm in length and 0.8 mm in external diameter. Inside this capsule there is a silver rod with 3.0 mm in length and 0.5 mm in external diameter which contains ^{125}I adsorbed on the silver rod surface.

^{125}I seeds has a half-life of 59.43 days and emits photons of 27.4 to 35.5 keV; these seeds are available with air kerma strength values between 0.243 and 7.92 $\mu Gym^2/h$ ($\pm 7\%$ with 2σ) and apparent activity values between 7.07 and 230.88 MBq ($\pm 7\%$ with 2σ) [11].

2.2. TLD-100 Irradiation

A batch of TLD-100 micro-cube (1 mm^3) manufactured by Thermo Scientific Corporation was utilized. For this work, 28 pre-selected dosimeters were chosen to perform the relative measurements. These dosimeters were selected because they showed more reproducibility compared with the whole batch. More details escape from the scope of this work, but they are found in the reference [12].

For the measurements with TLD-100, three irradiation series, for approximately 2 hours of exposure and fade time (time fade for small half-lives peaks) around 17 hours, were carried out. To avoid spurious signals deriving from TLD Reader, three measurements with no dosimeter inside the reader were performed. These measurements were not significant, compared with the measurements, and this influence was despised in the measurements.

The dosimeters were irradiated in a solid phantom (30 x 30 x 2 cm) of Solid Water model RW1, manufactured by PTW-Freiburg. This water equivalence is important to simulate the scatter radiation, like in the human tissue. During the irradiation, other phantoms were put over and under the measurement phantom, to guarantee the same scatter observed in human body.

Annealing procedures adopted for the dosimeters was 400 ^{0}C, for 1 hour and 100 ^{0}C, for 2 hours, with a homogeneous temperature for pre-irradiation annealing. Due to relative low time of exposure used in the measurements, no post-irradiation annealing was carried out, to avoid any influence in the measurements [12-13].

Figure 1 illustrates the phantom utilized for irradiation measurements of TLD-100. This figure shows a phantom of solid water with 108 spaces, distributed in three circular discs (each disc with 36 spaces) with 2, 5 and 7 cm in disc 1, 2 and 3, respectively; the ^{125}I seed was positioned in the geometric center of the discs.

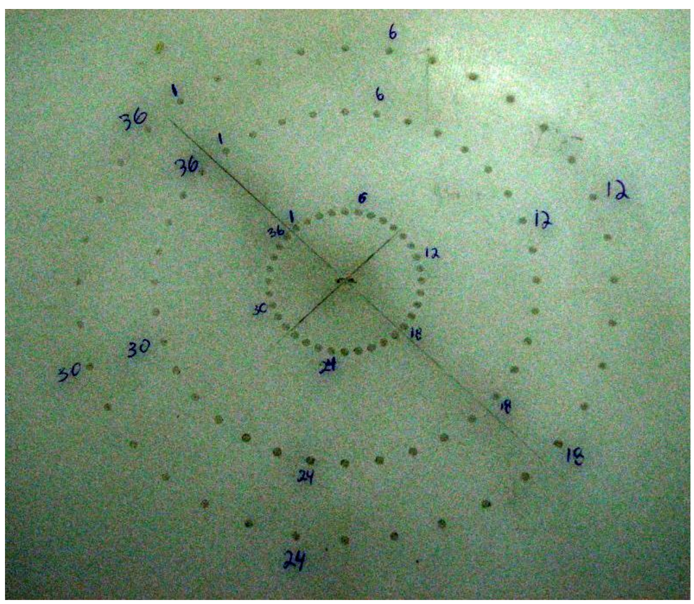


Figure 1: Phantom utilized for TLD-100 irradiations, the numbers beside space represent the spaces order to identify and locate each dosimeter.

The positions for the 28 TLD dosimeters were chosen with the same dosimetric methodology established in the reference [12]. This dosimetric methodology denominates each space with the number of the circular discs (1 to 3), followed by the number of the space (1-36) in each circular disc. For example, the dosimeter positioned in the disc one and space 20 was denominated by 1D20; another positioned in the disc 3 and space 7 was represented by 3D7, where the capital letter D represents discs. Table 1 presents the spaces and circular discs utilized in this work.

Table 1. Positions and number order of TLD-100 in the phantom

TLD-100 number order	Irradiation position	TLD-100 number order	Irradiation position
1	1D5	15	1D33
2	1D6	16	1D34
3	1D7	17	1D35
4	1D8	18	2D15
5	1D9	19	2D16
6	1D10	20	2D17
7	1D11	21	2D18
8	1D12	22	2D19
9	1D13	23	2D21
10	1D14	24	2D22
11	1D29	25	2D23
12	1D30	26	3D2
13	1D31	27	3D3
14	1D32	28	3D4

2.3. TLD-100 Responses

Each dosimeter was measured individually in a TLD reader manufactured by Harshaw, model 2000 A/B, with purified nitrogen (N_2) gas flow, located in the Centro de Metrologia das Radiações CMR-IPEN/CNEN – SP. The oven inside the TLD reader increases the temperature from approximately 40 ^{o}C up to 280 ^{0}C.

This TLD reader presents the TLD-100 response in the unit of electric charge (nC), the value supplied from the reader is the sum of all luminescence signals registered by TLD Reader; therefore, with an electronic acquisition plate, connected to the TLD reader, it was possible to acquire the responses in each reader channel. This electronic plate, altogether, presents two hundred reader channels, which were obtained in each dosimeter.

With the individual reader channels and the temperature rise in each reader channels, it was possible to plot the glow curve. Consequently, at the glow curve, the analysis in the spectra can be performed to select the region of interest of the dosimetric measurements. Figure 2 shows an experimental measurement of the TL Response vs. Temperature, for the entire integration of the peaks and an arbitrary selected region. In a first approximation, the selected region (red area in figure 2) "belongs" to area formed under the dosimetric peaks (peak 4 and peak 5).

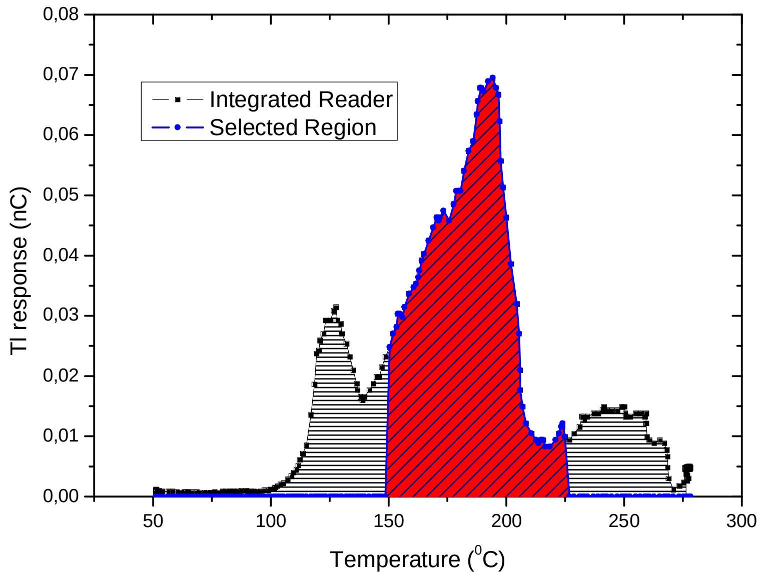


Figure 2: TL Response (nC) vs. Temperature (^{0}C) for an integrated reader (horizontal black lines plus red area) and an arbitrary selected region (red area only).

To facilitate the comparisons between the TLD-100, a fixed temperature interval (ΔT = 75 ^{0}C) was selected to make the choice of the area under the main peaks (selected region). These peaks are subjected to changes in the temperature profiles, hence, a manual peak area selection enabled to maximize the measurement inside the region of interest, in each measurement dosimeter.

2.4. Uncertainty Analysis

Uncertainty analyses in TLD-100 measurements are fundamental to trace the possible uncertainty sources associated to the experiments, aiming to diminish them as much as possible. Uncertainty analysis methodologies available in the literature are insufficient to establish reliable procedures to estimate them on TLD values.

A method suggested by Zeituni [12] was used to treat the data with an approach of weighed mean of the measurements, as it follows:

a) On each measurement sequence, the simple arithmetic mean was calculated to the 28 TLD, equation (1).

$$Mean_k = \frac{\sum Measurement_i}{28} \quad (1)$$

Where: k is the measurement sequences (1 to 3 irradiation sequences) and i is the TLD number order (1 to 28).

b) Weighed mean was determined by equation (2).

$$Weighed\ Mean = \frac{\sum\left(Measurement_i \cdot Mean_k\right)}{\sum Mean_k} \quad (2)$$

c) With these weighed means, the sample standard deviations can be expressed by equation 3.

$$Standard\ Deviations = \left(\frac{\sum\left(Measurement_i - Weighed\ Mean\right)^2}{\left(n\text{ - }1\right)}\right)^{1/2} \quad (3)$$

The method described above was based on the assumption that the measured background has a relative small value, compared to the TLD response values. As the values measured for the background were not considered relevant, compared with TL responses, they were not took into account.

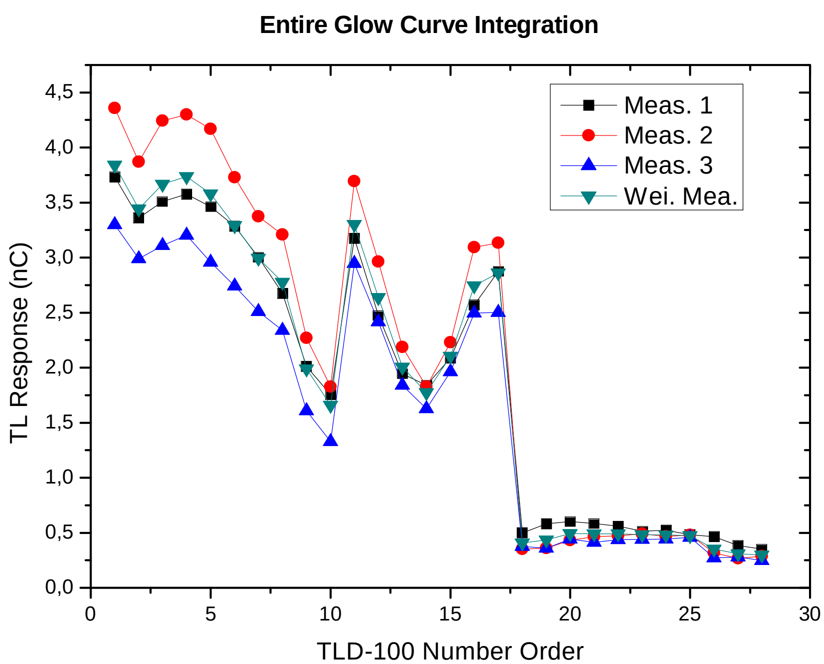
3. RESULTS AND DISCUSSION

For the entire integration of glow curve and selected region of interest, about three measurements and the weighed mean value, were plotted in figure 3. Figures 3(a) and 3(b) present the points obtained from three series of irradiations and weighed mean of measurements obtained from equation (2). Except to the intensity of TL Response, more intense for the entire integration of glow curve, graphs have shown a similar aspect that indicates no significant difference between measured values.

Table 2 gives the weighed mean measurements for the entire integration glow curve and selected region of interest of the measurements, with respective uncertainties (1σ) calculated by equation (3). In general, the differences tend to increase proportionally with the distance. Due to the rapid fall of dose, with the increase of the distance to the ^{125}I seed, it becomes more complex to distinguish the peaks caused by ^{125}I source irradiation and the background radiation or external luminescence process, as room lights, for example.

Nevertheless, these differences have a “regular” value in each disc spaces. Such trend suggests that a fixed temperature interval selection of the area under the peaks does not change the proportionality of the TL response. The difference between TL response values in each disc, that represents the mean value obtained for the difference between entire integration and selected region, were 32.02 ($\pm$2.38), 55.14 ($\pm$3.36) and 69.09 ($\pm$1.27) % for disc 1, 2 and 3 respectively.

a)



b)

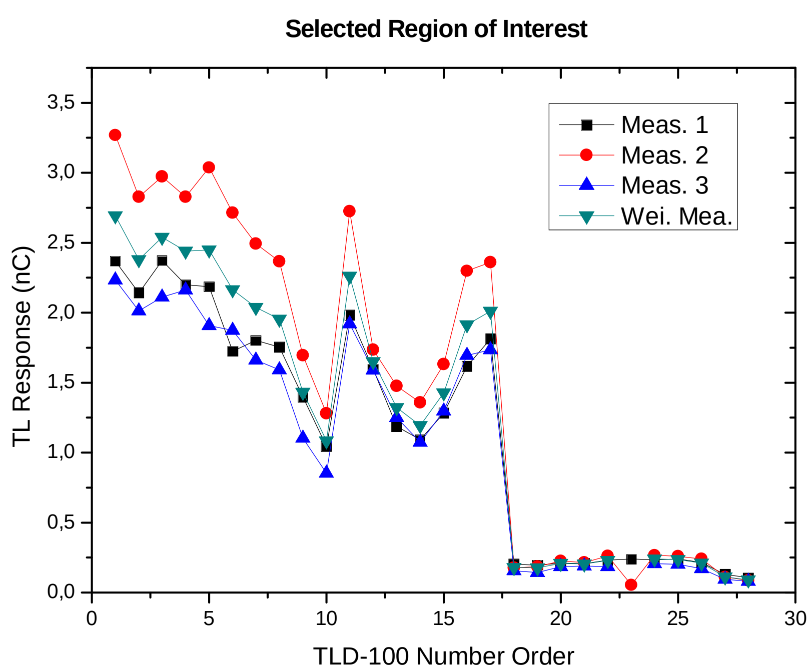


Figure 3: Three measurements (Meas.1; Meas.2 and Meas.3) and weighed means (Wei. Mea.) for a) Entire glow curve integration and b) Selected region of interest.

Table 2. Weighted mean to three series measurements.

TLD-100 Number Order	Entire integration glow curve (nC)	Selected region of interest (nC)	Difference between entire integration and selected region [a] (%)
1 – 1D5	3.84 ± 0.54	2.69 ± 0.57	29.90
2 – 1D6	3.44 ± 0.44	2.38 ± 0.44	30.88
3 – 1D7	3.67 ± 0.58	2.54 ± 0.45	30.76
4 – 1D8	3.74 ± 0.56	2.44 ± 0.38	34.68
5 – 1D9	3.58 ± 0.61	2.45 ± 0.60	31.60
6 – 1D10	3.29 ± 0.50	2.17 ± 0.54	34.23
7 – 1D11	3.00 ± 0.44	2.04 ± 0.45	31.98
8 – 1D12	2.78 ± 0.44	1.95 ± 0.41	29.65
9 – 1D13	1.99 ± 0.34	1.43 ± 0.30	28.09
10 – 1D14	1.66 ± 0.27	1.08 ± 0.22	34.62
11 – 1D29	3.30 ± 0.39	2.26 ± 0.45	31.52
12 – 1D30	2.64 ± 0.30	1.65 ± 0.08	37.48
13 – 1D31	2.01 ± 0.18	1.32 ± 0.15	34.06
14 – 1D32	1.77 ± 0.12	$1,19 \pm 0.16$	32.71
15 – 1D33	2.10 ± 0.13	1.43 ± 0.20	32.18
16 – 1D34	2.74 ± 0.33	1.91 ± 0.38	30.25
17 – 1D35	2.86 ± 0.32	2.01 ± 0.34	29.76
18 – 2D15	0.41 ± 0.08	0.18 ± 0.02	56.27
19 – 2D16	0.43 ± 0.13	0.18 ± 0.03	59.22
20 – 2D17	0.49 ± 0.10	0.21 ± 0.02	57.61
21 – 2D18	0.49 ± 0.09	0.21 ± 0.01	58.16
22 – 2D19	0.49 ± 0.06	0.23 ± 0.04	53.16
23 – 2D20	0.48 ± 0.04	0.24 ± 0.03	50.41
24 – 2D21	0.48 ± 0.04	0.24 ± 0.03	50.73
25 – 2D22	0.48 ± 0.01	0.21 ± 0.04	55.58
26 – 2D23	0.35 ± 0.10	0.11 ± 0.02	68.27
27 – 3D2	0.31 ± 0.06	0.09 ± 0.01	70.55
28 – 3D3	0.30 ± 0.05	0.09 ± 0.02	68.46

a. Normalized to 100% for entire integration of glow curve.

4. CONCLUSIONS

The entire integration of glow curve and the selected region of interest show a relative similarity to the ^{125}I source, indicating proportionality between TL responses. For long distances from the source (disc 2 and disc 3), significant differences were found out, due to small contributions of the dose in these regions, the peaks spectra profile seem to vanish, increasing the difference in the selected regions. A manual analysis of the glow curve demands much time to be done, therefore, mainly for long distances from ^{125}I source, it is a hard task to guarantee a trustful result just by the entire integration of glow curve.

Further works should include more measurements and calibration of ^{125}I seed with a calibrated dose profile inside the phantom.

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