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COMPARING THE RESPONSES OF TLD 100, TLD 600, TLD 700 AND TLD 400 IN MIXED NEUTRON-GAMMA FIELDS

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ABSTRACT

The dosimetry in mixed fields neutron and gamma, using small dosimeters known as TLD is commonly done using pairs of dosimeters with different sensitivity to neutrons. The purpose of this work is to compare the response obtained with the pair of TLD 700 and TLD 600 with the response obtained with the pair of TLD 700 and TLD 100 in a mixed field neutron gamma. The pair of TLD 700 and TLD 600 is amply used to obtain the information of dose gamma and neutron in mixed neutron-gamma fields due to present difference in the concentration of isotopes of ^{6}Li. In this work was used thirty TLDs of four different types: TLD 100, TLD 400, TLD 600 and TLD 700. The TLDs were irradiated in an experimental setup using a ^{241}AmBe source coated by a moderator material, polyethylene. The composition of the dose in different types of TLDs was evaluated through computer simulation with the radiation transport code MCNP5 (Monte Carlo N-Particle Radiation Transport Code). In this work was compared the composition of the dose in different types of TLDs and compared also the pair use TLD 700 and TLD 600 with the pair TLD 700 and TLD 100 in the mixed field dosimetry.

1. INTRODUCTION

Some tumors such as high grade gliomas, brain metastasis of melanoma and head and neck cancer can be treated based on the nuclear reaction energy obtained suffered by boron (^{10}B) when a beam of thermal neutrons irradiates it. This treatment is known as Neutron Capture Therapy (NCT) and is a type of radiotherapy technique in which the useful energy for treatment comes from the energy released in a nuclear reaction differently of conventional radiotherapy. When this radiotherapy technique gets the useful energy of reaction boron neutron capture reaction, this technique is referred as BNCT (Boron Neutron Capture Therapy) [1,2].

In BNCT technique is first administered to the patient a compound borated, which in turn should preferably concentrate in tumor cells. Afterwards the region of treatment must be subjected to a thermal neutron beam to promote the desired reaction. With the irradiation of ^{10}B by thermal neutrons occur predominantly following nuclear reaction:

$$^{10}B\ (n,\alpha)^{7}Li \tag{1}$$

In these reactions are released heavy and highly energetic particles, alpha particles and ^{7}Li atom. In 94% of the reactions ^{7}Li is generated in the excited state (Eq.1) [3].
There is in IPEN a research facility in BNCT using one of beam extractors (BH - Beam Hole) of the research reactor IEA-R1 / IPEN-SP [4].

The development of this facility aims to conduct research in physics of radiation and radiobiology to study in BNCT. [4] Biological studies were performed in vitro and in vivo in partnership with the Instituto Butantan [5] and research in dosimetry with UNICAMP [6] that will enable the optimization of beam obtained in the BNCT facility.
The radiation beam obtained in the BNCT facility is a mixed beam consisting of neutrons and gamma. For to characterize, the radiation beam is under development a methodology using thermoluminescent dosimeters, TLD. [7] These TLDs are used in pairs, by having different sensitivities to the components of the beam, because to differences in the concentration of lithium isotopes. The study proposed here will contribute to analysis of an alternative methodology using the pair TLD 700 and TLD 100. Although the TLD 100 also contains the ^{6}Li, its concentration is smaller, it is sufficient for the intensity of the beams studied, avoiding the loss of linearity in high flux. [8]

2. MATERIAL

The TLDs were irradiated in a mixed field irradiator in an experimental setup using a polyethylene cylinder and a source of ^{241}AmBe of 2Ci used in previous works. [7]

2.1. Irradiation fields

In this arrangement TLDs were positioned with a styrofoam support at the cylinder surface polyethylene in average height. The source 241AmBe was positioned in the inside the cylinder polyethylene in the average height.

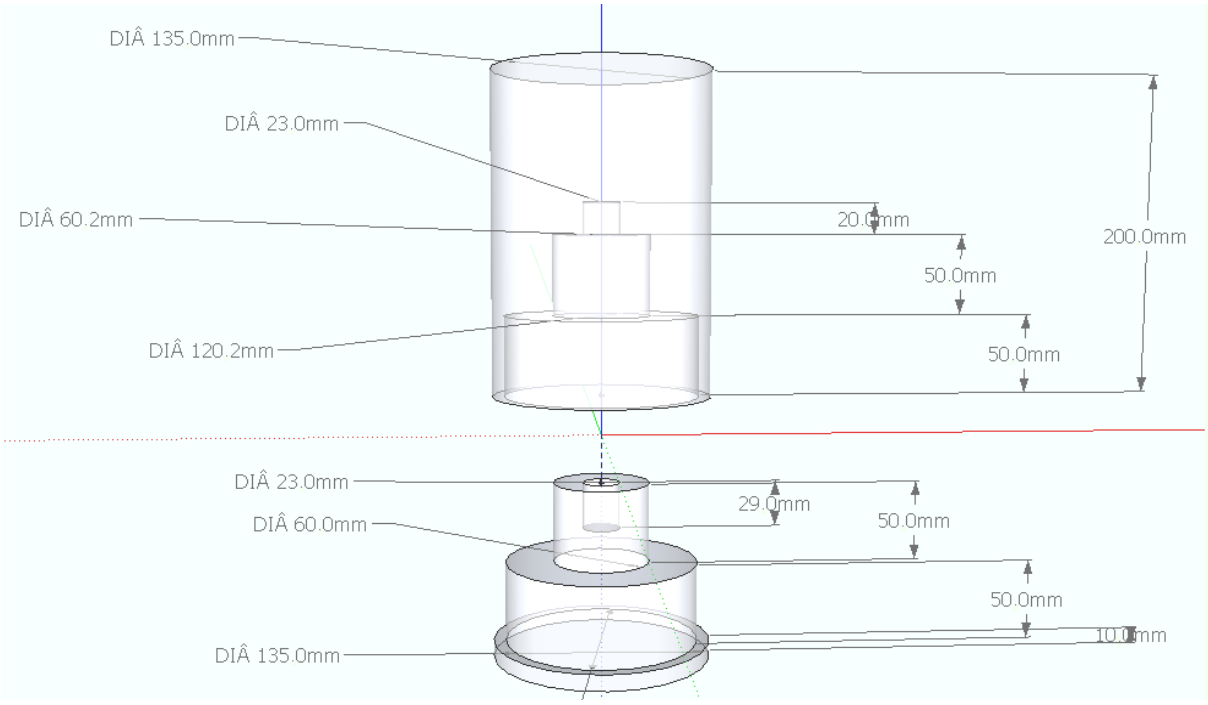

Figure 1: Cylinder dimensions used. The source was positioned on the inside of the cylinder in the average height.

2.2. Termoluminescent Dosimeters

This work utilized 120 TLDs, 30 TLDs of each type:
TLD 100: LiF:Mg,Ti - natural isotopic composition of ^{7}Li and ^{6}Li.
TLD 400: CaF_2:Mn
TLD 600: LiF:Mg,Ti - enrichment with ^{6}Li.
TLD 700: LiF: Mg, Ti - enrichment with ^{7}Li.

2.3. MCNP5 - Monte Carlo N-Particle transport code

For the evaluation of the deposited dose in TLD, was used radiation transport simulation code (MCNP) version 5. Through the calculations made with the help of MCNP5 it was possible to discriminate the dose deposited by photons and neutrons in the mixed field gamma and neutron.

3. METHODS

The TLDs were irradiated for 24 hours and the reading of the data made the day after the end of irradiation. Before each irradiation the TLDs were thermally treated according to the type of TLD. The LiF TLDs were placed in a oven at 400 °C for one hour, then was transferred to a second oven at 100 °C for two hours. The TLD 400 was submitted only to the first step of heat treatment, that is, 400 °C for one hour.

The glow curve was obtained in the TLDs, Harshaw 3500 reader. The resulting glow curve contains peaks that are in areas of interest represented by channels (ROI).
For LiF TLDs when irradiated in the mixed field, there are two regions of interest (ROI 1 and ROI 2), around 195 °C and 250 °C. The TLD 400 has only one region of interest (ROI 3) with dosimetric peak around 260 °C.

4. RESULTS

The data obtained are referred to four irradiation of 24 hours made the experimental arrangement using the source ^{241}AmBe.

Table 1: Response average of 30 TLDs for four radiations in mixed neutron-gamma fields obtained in TLD Harshaw 3500 Reader.

TLD 100		TLD 600		TLD 700		TLD 400
ROI 1 μC	ROI 2 μC	ROI 1 μC	ROI 2 μC	ROI 1 μC	ROI 2 μC	ROI 3 μC
4.65	0.85	9.89	2.33	3.94	0.28	340.59

The Table 1 shows the average of the responses of 30 TLDs of each type, for four irradiations. The LiF TLDs showed different answers for two regions of interest, and the TLD 600 had the highest response in the two regions of interest, due to the higher concentration of ^{6}Li.

The TLD 700 has the lowest concentration of ^{6}Li, which explains the lowest response in the two regions of interest. As LiF TLDs have different ^{6}Li isotopes concentrations, your answers for mixed field, must varied in function of the Li isotope concentration.
As the TLD 400 is little sensitive to neutrons, its high response, is a parameter indicating a high flux gamma.

4.1 Study with MCNP5

A study done with MCNP5 established a profile of the flux of photons and neutrons by energy range. Table 2 and Table 3 shows the estimated flux neutrons and photons calculated with MCNP.

Table 2: Estimated flux neutral.

	Neutrons	Uncertainty %
Flux (1/cm².s)	8.32E4	2
Thermal %	26	2
Epithermal %	16	2
Fast %	58	2

Table 3: Estimated flux photons

Photons	Uncertainty %
8.32E4	1,8

It was calculated MCNP5 the contribution of neutrons and photons at a total dose of composition deposited in the TLD.

Table 4: Percentage contribution of the total dose in each type of TLD.

Particle	TLD 100	TLD 600	TLD 700	TLD 400
Photons %	4.68	0.79	79.3	83.7
Neutrons %	95.32	99.21	20.7	16.3

The results showed in Table 4 show that the TLD 600 is the more neutrons sensitive between the LiF TLD. Among the LiF TLDs the TLD 700 has the highest sensitivity to photons, but 20.7% of the dose deposited in this type of TLD is due to the neutrons.
In the dosimetry of mixed neutron-gamma fields using TLDs, the dose value due to neutrons is obtained by subtracting the response of TLD 700 the value of response of other TLD with different sensitivity, for example, TLD 100 or TLD 600. The use of this methodology without take into account the contribution of neutrons in 700 TLD responses implies an underestimation in the dosimetry of neutrons or overestimation the gamma dose. The TLD 400 shows the highest sensitivity to photon and a lower sensitivity to neutrons.
The Table 5 Shows the contribution due to neutron dose per energy range.

Table 5: Percentage of dose due to neutrons by energy range

Energy	TLD 100	TLD 600	TLD 700	TLD 400
Thermal %	94.34	91.50	86.35	0.07
Epithermal%	3.83	7.80	3.17	0.05
Fast %	1.84	0.70	10.49	99.89

The results presented in Table 4 show that the LiF TLDs are more sensitive to thermal neutrons, this due to the 6Li have high cross-section for thermal neutrons. [9] These results are in in harmony with Table 1 where it is observed that the LiF TLDs with higher concentrations of 6Li have greater response to the mixed field (gamma and thermal neutrons). Based on the calculation of the composition of the dose in the TLD 400, it can observed that the TLD 400 is sensitive to gamma and fast neutrons, and the doses due to thermal neutrons and epithermal added together do not reach 0.5% this type of TLD.

5. CONCLUSIONS

This study contributed to understanding the dose composition in each type of TLD. Through this study it was verified that each type of TLD has a distinct sensitivity to photons and neutrons in the three energy range considered. So when varying the energy spectrum of a mixed field (neutron and gamma) the responses of TLDs may vary significantly. Therefore, when the TLD is calibrated in a mixed neutron-gamma field, this calibration will not be valid for monitoring other mixed field with different energy spectrum.

The monitoring in mixed fields using TLD can be made using the pair TLD 700 and TLD 600 or the pair TLD 700 and TLD 100. For a mixed field of low flux., as obtained from ^{241}AmBe source in this work, the pair of TLD 700 and TLD 600 can be more appropriate due to TLD 600 be more sensitive to neutrons than the TLD 100. On the other hand for a mixed field with high thermal neutron flux, like those achieved in installation BNCT, the pair TLD 700 and TLD 100 can be more appropriate because the TLD 100 present the loss of linearity less rapidly than the TLD 700. [7]

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