Thermoluminescence Dosimetry Measurements of Brachytherapy Seeds in Liquid Water

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Purpose:

The goal of this project was to design a system for measuring TG-43 dosimetry parameters of a brachytherapy seed in liquid water and to measure SW correction factor at ^{125}I and ^{131}Cs energies.

Introduction:

The brachytherapy dosimetry protocol TG-43 recommends that dose distributions be related to a water medium.[1] For dosimetric measurements, most investigators [2-8] have resorted to water-equivalent plastic materials such as Solid Water™ (SW). The results of measurements in SW phantoms have been related to the dose in liquid water through the use of SW correction factors based on Monte Carlo (MC) calculations.[4-6,9,10] Several publications have presented results showing MC based correction factors depend not only on the chemical composition and density of the SW, but also on the distance from the brachytherapy source.[11,12] Uncertainties in the SW correction factor will affect determination of the dose rate constant (Λ) and the radial dose function g(r), when these parameters are based on measurements in SW.

Method and Materials:

Irradiation system for liquid water: Two plastic jigs were designed and constructed to position TLD capsules at specific radial distances (r) and angles (θ) around a brachytherapy source. The design allows positioning of TLD capsules with high geometric precision (< 0.1 mm). The two jigs are identical (Fig.1) in all respects except for the pattern of TLD positioning holes.

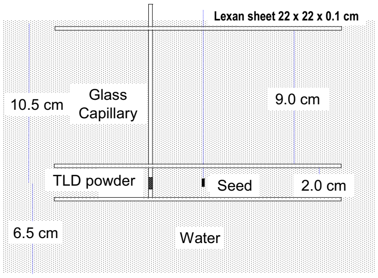

Fig.1: Schematic of jig for TLD measurement in liquid water.

The basic jig-design consists of 3 identical lexan sheets (each 0.1 cm thick) separated by spacer rods. Each sheet has an identical pattern of TLD positioning holes or indentations.

Jig-A (Fig.2) is designed to facilitate measurement of Λ and F(r,θ). It has 24 TLD-positioning holes spaced 15^0 apart along each of the 5 concentric circles (radii 1-7 cm).

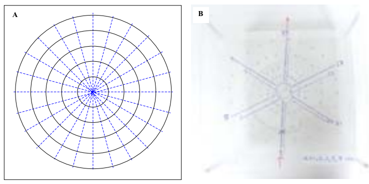

Fig. 2: Jig for measurement of Λ and F(r,θ). (A) is schematic showing circles along which TLD are placed, while (B) shows the jig's picture.

Jig-B (Fig.3) is designed to facilitate measurement of g(r). The jig has TLD-positioning holes, arranged in 3 spiral arms, each 120^0 apart around the seed. Each spiral arm has 15 TLD-positioning holes at distances r = 0.5-10 cm from the center of the seed.

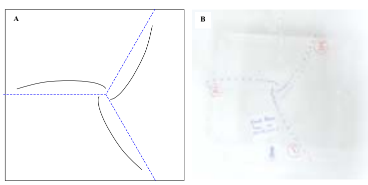

Fig. 3: Jig for measurement of g(r). (A) is schematic showing TLD pattern, and (B) shows the jig's picture.

TLD capsules: TLD capsules were constructed for dosimetric measurements. Each TLD capsule (Fig.4) consists of a glass capillary (length 12.8 cm, inner diameter 1.4 mm, wall 0.15 mm). The capillary, sealed with a 6-mm long polystyrene rod at its bottom, is filled with ~ 13 mg of TLD-100 powder (7 mm length of the capillary). The remaining space above the TLD powder is filled by a polystyrene rod which extends ~1 cm beyond the open end of the capillary. Even though the capsule's wall is extremely thin, it does offer a measurable extra attenuation over water. A correction factor 1.039 was measured using ^{131}Cs seed to account for it.

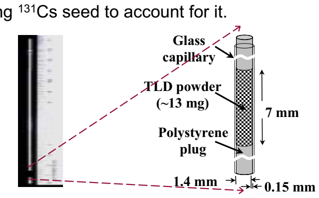

Fig.4: Schematic and photo of TLD capsule.

Seed mounting: The seed-support assemblies are shown in Fig.5. The assembly (Fig.5A) designed for measurement of Λ and g(r), holds a seed in vertical position, parallel to and at the exact center of the TLD array. The other assembly (Fig.5B) designed for measurement of F(r,θ) holds a seed in the horizontal position at the center of the TLD array. The seed is glued to tip of the graphite rod with a touch of super glue employing special jigs (not shown) for alignment.

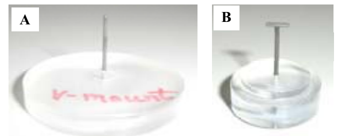

Fig. 5: Seed-support assemblies showing the seed mounted on tip of graphite rod.

Alignment check: Prior start of irradiation, alignment test of the seed-support assembly is performed employing a test-jig (Fig.6A). The test jig's top and bottom plates both have a hole at precise geometric center. A graphite rod held by the upper plate's hole, extends to the middle of the 2 cm gap between the plates. The seed-support assembly is inserted through an entry hole in the bottom plate. Axial alignment of the seed support is assured by rotating the support assembly and observing any motion relative to the upper graphite rod. The seed is in the correct vertical position when it almost touches the upper graphite rod.

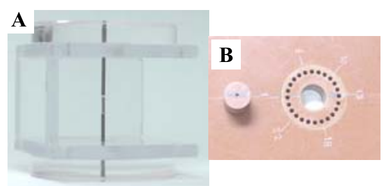

Fig. 6: Here A) is test-jig for checking seed's alignment, and B) shows parts of SW phantom for measurement of SW correction factor.

Irradiation in water: Prior to irradiation, TLD capsules are loaded into the jig and the source-support assembly is inserted through an entry hole in the bottom plate. The jig is then submerged in water.

Irrad. system for SW: In order to measure SW correction factor, a SW phantom (15 x 15 x 15 cm) was designed. The phantom consists of of several slabs. The 1 cm thick central slab (Fig. 6B) carries two coaxial slip-in circular cylinders at its center. The central cylinder has an axial hole for loading a brachytherapy seed. This cylinder fits coaxially into the annular cylinder which contains 24 equidistant TLD capsules in a circular pattern of radius 1.000 cm around the seed hole.

TLD reading: The TLD capsules are identical in design to those used for measurements in water, except the length is 1.00 cm to match the SW slab thickness. TLD were read (Harshaw reader 4500) employing RPC's standard procedure and settings.[13,14] For each irradiated TLD, both the mass and the TLD reading were recorded. The average TL signal was corrected for linearity, fading, and the reader sensitivity. Correction for seed's radioactive decay was applied to determine effective seed strength over the course of TLD irradiation.

Results & Conclusions:

Typical plot of TL signal (TLD reading / mass) with respect to TLD's angular position is shown in Figs.8. The shaded region includes 95% of the data, and therefore corresponds to an uncertainty of two standard deviations.

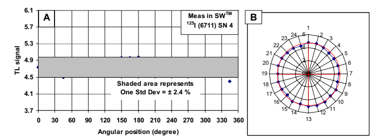

Fig. 8: Typical data in SW^{TM} plastic at r = 1 cm from the seed.

As expected for each seed, the measured TL signal per unit effective source strength was found to be higher for irradiation in liquid water than for irradiation in SW. The ratio of the former to the latter (SW correction factor), was measured using both ^{125}I (model 6711) and ^{131}Cs (model Cs-1) seeds. Results of measurements, performed with different seeds as well as repeated with same seed, are shown in Table-I.

Seed	Seed's ID	Dose-Conversion Factor: SW to H_2O			Literature[11] Value
		Individual	Mean ± SD	Average ± SD	
^{125}I (6711)	002	1.056			
	002	1.020	1.040 ± 0.018		
	004	1.043		1.039 ± 0.015	1.031
^{131}Cs (Cs-1)	001	1.036			
	002	1.022			
	002	1.038	1.038 ± 0.014		
	003	1.056			

Table-1: Measured SW correction factor.

Experiment and theory serve a vital role of mutual check and balance. Measurements are important, especially in light of MC calculations which predict the SW correction factor to depend significantly on distance.

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