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A New TLD Holder for External Radiotherapy Beam Audit

Doğan Yaşar[1,*], Bayram Demir[2], Erol Kam[1], Gürsel Karahan[1], Murat Okutan[3]

[1] *TAEK, Çekmece Nuclear Research and Training Center, Metrology Unit, Secondary Standard Dosimetry Laboratory, Yarımburgaz Mah. ÇNAEM Yolu - 34303, Istanbul, Turkey*
[2] *University of Istanbul, Science Faculty, Department of Physics, Vezneciler / Fatih, Istanbul, Turkey*
[3] *University of Istanbul, Oncology Institute, Department of Medical Physics, Çapa / Fatih, Istanbul, Turkey*
**Corresponding author e-mail: dogan.yasar@taek.gov.tr; doganyasar@yahoo.com*

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Abstract: In present study, a special TLD holder inserted to a solid water phantom for TLD irradiation was designed and results were compared with the TLD results irradiated in a plastic bucked using International Atomic Energy Agency (IAEA), standard TLD holder as recommended by IAEA. Powder TLD-100 was used in the study and the capsules filling powder TLD were irradiated using Co-60 beams in RW3 type solid phantom with new holder. The absorbed dose measurements for TLD were performed by Harshaw 4500 model TLD reader and the results were confirmed using a 0.6 cc ionization chamber in RW3 plastic phantom. For different irradiation setup, the closest dose values to the prescribed dose of 2 Gy were only obtained with using the new TLD holder (2.022± 0.017cGy) with lowest error value. The average and standard deviation for standard IAEA water phantom and plastic bucked set-up were 2.014±0.024 cGy and 1.948±0.062cGy respectively. While the maximum average absolute difference (%3.5) and the maximum % error (%3.16) were found in the hospital condition with bucket filled with water, the minimum average absolute difference and the minimum % error were **%**1.32 and %0.86 respectively, with our new TLD holder in the solid water phantom . In our opinion, the reason of this good consistency is the reproducibility of TLD position that created by means of our TLD holder. This study shows that non-standard conditions may cause important differences between SSDL (Secondary Standard Dosimetry Laboratory) and hospital dose results.

***Key words**:* Radiotherapy, TLD, quality audit.

Eksternal Radyoterapide Işın Denetimi İçin Yeni Bir TLD Tutucu

Özet: Bu çalışma da radyoterapi doz kontrolü amacıyla yapılan TLD ışınlamalarında kullanılmak üzere özel bir TLD tutucu dizayn edilmiş ve elde edilen sonuçlar IAEA (International Atomic Energy Agency) tarafından tavsiye edilen yöntem olan plastik kova içerisine yerleştirilmiş IAEA TLD tutucu sonuçları ile karşılaştırılmıştır. Çalışmada toz TLD-100 kullanılmış ve TLD tozu ile doldurulmuş kapsüller önerdiğimiz yeni TLD tutucu ile RW3 tipi katı fantomda Co-60 ışınları ile ışınlanmıştır. TLD absorbe doz ölçümleri Harshaw 4500 model TLD okuyucu sistemi ile okunmuş ve sonuçlar 0.6 cc iyonizasyon odası ile doğrulanmıştır. Farklı ışınlama şartlarında verilen 2 Gy radyasyon dozuna en yakın değerlerin yeni TLD tutucu (2.022± 0.017cGy) ile elde edildiği görülmüştür. Standard IAEA su fantomu, plastik kova set-up' ları için ortalama ve standart sapma değerleri sırası ile 2.014±0.024 cGy, 1.948±0.062cGy, olarak tespit edilmiştir. Hastane şartlarında plastik kova set-up'ı için maksimum ortalama mutlak fark (%3.5) ve maksimum % hata (% 3.16) iken, yeni TLD tutucu set-up'ın da bu değerler sırası ile %1.32 ve % 0.86 dır. Bizim düşüncemize göre, değerlerimiz arasındaki bu uyum yeni TLD tutucu sayesinde tekrar edilebilen TLD pozisyonlarıdır. Bu çalışma standart olmayan ışınlama koşulları olması durumunda SSDL (Secondary Standard Dosimetry Laboratory) ve hastane doz sonuçları arasında önemli farklar olabileceğini gösterrmiştir.

Anahtar kelimeler: Radyoterapi, TLD, kalite denetimi.

1. Introduction

In 1969 the International Atomic Energy Agency (IAEA), together with the World Health Organization (WHO), established the IAEA/WHO TLD postal programme to verify the calibration of radiotherapy beams in developing countries [1, 2, 3]. The main purpose of this programme is to provide an independent quality audit of the dose delivered by radiotherapy treatment machines using a Thermoluminescent Dosimeter (TLD) as transfer dosimeter. The IAEA/WHO TLD postal dose quality audit service has also monitored the performance of Secondary Standard Dosimetry Laboratories (SSDLs) in therapy dose quality since 1981. TLD postal programme was applied first for Co-60 energy beam and then it was extended to high energy photon beams produced by clinical accelerators in 1991 [2].

The hospital staffs of participated TLD intercomparison programme have to irradiate TLD capsules in the non-standard conditions. They have to irradiate TLDs vertically in the classical water instead of standard water phantom (e.g. IAEA water phantom). Water filled plastic buckets or similar water containers are used for this purpose. The procedure starts with putting IAEA standard TLD holder with TLD capsule in the plastic bucket. There should be 5 cm distance between TLD capsule centre and water surface. In these conditions, TLD irradiation set-up isn't practically easy for medical physicist. For the TLD irradiations in above-mentioned phantom, geometrical errors are inevitable. Moreover, radiotherapy centres are already working at high capacity for cancer treatment and might try to irradiate TLD in a short time. Also, the water in the container might not have the same temperature as the irradiation room. These factors causes the TLD irradiation doses to be out of the acceptance limits of the IAE/WHO TLD audits which are ±5% in non reference conditions for hospitals and ±3.5% in reference conditions for SSDLs. It has been observed that sometimes mistakes were made in the calculation of the dose given to the TLDs or in the geometry set-up for the TLD irradiation [2]. But, both mistakes can be prevented, especially for the latter; it is possible to remove the geometrical error in external dose quality audits.

In present study, a special TLD holder inserted to the solid water phantom for TLD irradiation was designed and results were compared with the TLD results irradiated in a plastic bucked using IAEA standard TLD holder.

2. **Materials and Methods**

2.1. Materials: Thermoluminescent Dosimeter (TLD) System

Lithium fluoride powder was used as a TLD material in this work. Its effective atomic number ($Z_{eff.}$: 8.14) makes it close to tissue equivalence ($Z_{eff/tissue}$: 7.42). The grain size of the material is between 80 and 200 µm. The powder is annealed before it is used for dose measurements in order to optimize its characteristics and to achieve better stability of powder sensitivity and lower fading. The annealing is performed at 400 ^{o}C for 1 hour followed by fast cooling and subsequent annealing at 100 ^{o}C for 2 hours [2,3]. The powder TLDs are closed in black polyethylene capsules of 19 mm inner length, 3 mm inner diameter and 1 mm wall thickness. The outer length, including the plug, is 28 mm.

Every capsule contains about 160 mg of powder that provides nine identical portions to be read after the powder is dispensed. Harshaw 4500 model TLD manual reader was used for readouts. In order to determine a reader calibration factors (RCF), reference dosimeters are irradiated to 2 Gy in Co-60 beam at SSDL. The irradiation is performed under reference conditions using a standard IAEA holder in IAEA water phantom (30 cm x 30 cm x 30 cm). The absorbed dose is determined with SSDL's therapy level working standard according to IAEA Technical Reports Series No-398 (TRS-398) dosimetry code of practice [4]. The TLD dosimeter is positioned at the depth of 5 cm, at the distance of 100 cm from the source within the irradiation field of 10 cm x 10 cm.

In order to calculate the absorbed dose to water from irradiated TLDs, a TLD system calibration has to be performed and several correction factors determined: the dose response (non linearity) factor, the energy correction factor, the fading correction and holder correction factors. The absorbed dose to water (D_w) at the location of the TLD is calculated according to follow formula;

$$D_w = M*N*f_{lin}*f_{engy}*f_{fad}*f_{hol}$$

Where M is the TLD response, N is the calibration coefficient of the TLD system, f_{lin} is the non-linearity dose response correction factor, f_{engy} is the energy correction factor, f_{fad} is the fading correction factor, and f_{hol} is the standard holder correction factor [5, 6].

2.2. Measurements

To determine the user effects arisen from geometric errors on the measurements, three different set-ups for TLDs were separately irradiated using Co-60 irradiation system, Picker C-9 in SSDL. All measurements were performed ten times by ten different medical physicists. TLD irradiations were performed in usual geometrical conditions: in the depth of 5 cm, at 100 cm source to axis distance (SAD) and in the size of 10 cm x 10 cm.

In the first group of measurement set-up, TLD measurements were performed in SSDL conditions using a standard IAEA water phantom. For this purpose, an irradiation set-up was arranged as shown is Figure 1 and the 2 Gy radiation dose was given to the TLD using Co-60 beams.

In the second group of measurements, to create the non-standard conditions of hospitals and to determine the user effect on the measurements in these conditions, a plastic bucked was used. The plastic bucked was filled with water and an IAEA TLD holder manufactured with plastic material was placed to the centre of the bucket [5]. And then, 3 TLD capsules for every irradiation were placed in the holes drilled on plastic holder as shown in Figure 2.

Finally, measurements were repeated by using our new TLD holder under the irradiation conditions as shown in Figure 3. The proposed new holder was designed to simulate the shape of the 0.6 cc ionization chamber and to be used for the TLD irradiation in the solid water phantoms (RW3).

Figure 4 illustrates our new TLD holder and a farmer type ionization chamber. The total length of TLD holder applicator is 159 mm and it is made of plexiglass. Its thimble section is different from ionization chamber. It is designed to have 23 mm outer length, 5 mm inner diameter and 1 mm wall thickness. TLD capsule can be put inside the holder with ease.

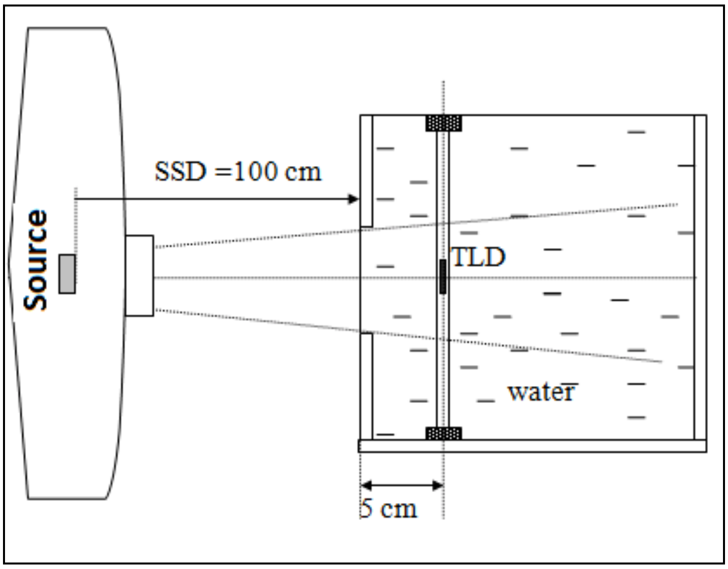

Figure1. TLD irradiation set-up using standard IAEA water phantom (30cmx30cmx30 cm)

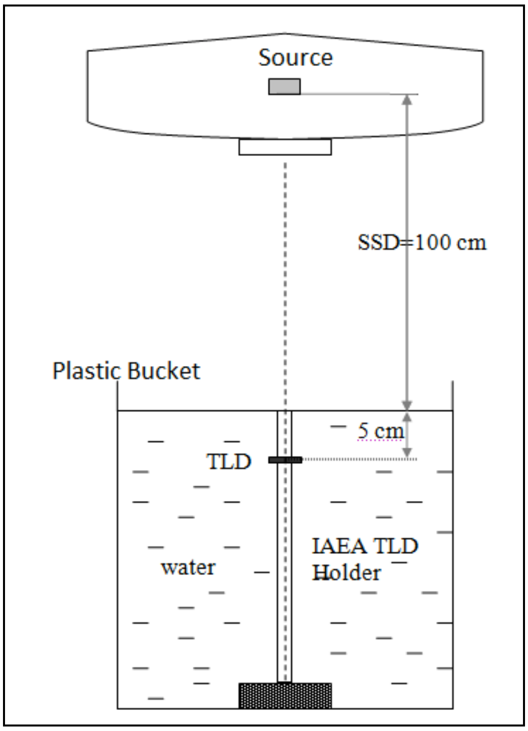

Figure 2. TLD irradiation set-up using a plastic bucket in hospital conditions.

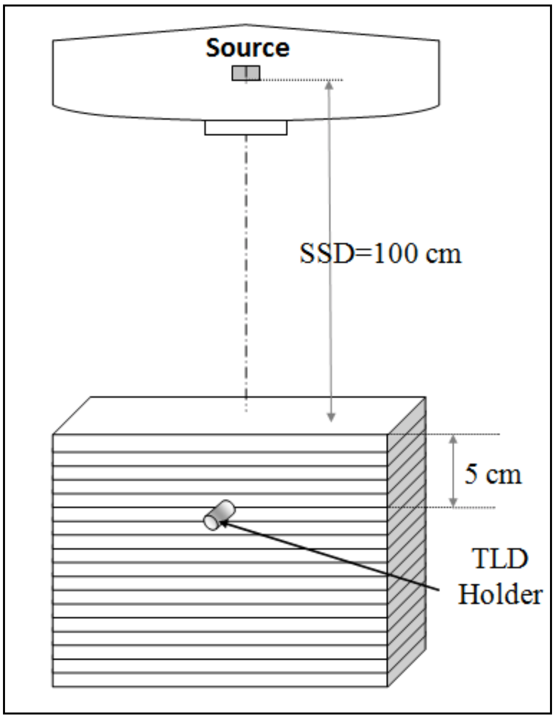

Figure 3. TLD irradiation set-up using new TLD holder in solid water phantom (RW3).

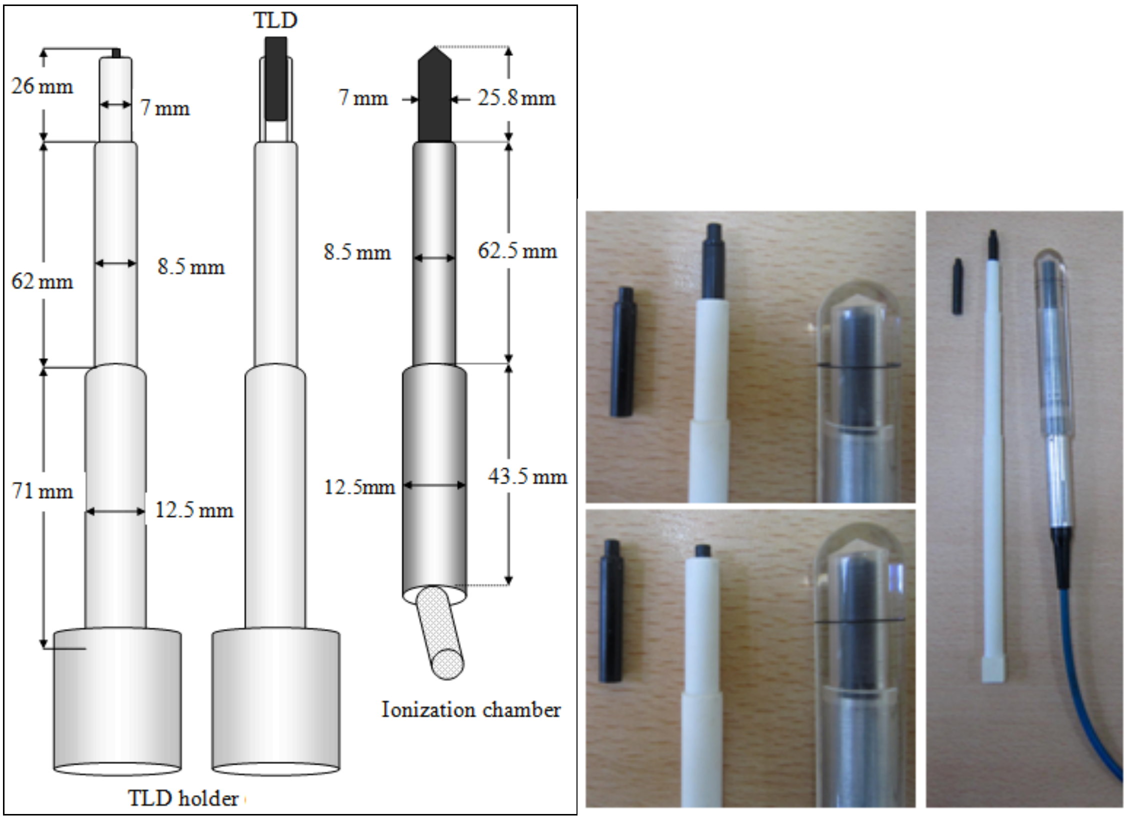

Figure 4. TLD irradiation holder designed (RW3) with the similar shape of Farmer type ionization chamber.

3. Results and Discussion

National and international quality assurance networks are performing dosimetry inter-comparison between radiotherapy centres functioning at the present time in the world [1, 2, 3, 7]. All radiotherapy centres participated in external audit with TLD has suitable dosimeters. In the hospital, TLDs are vertically irradiated in the plastic water bucket instead of IAEA standard water phantom. Because they have to make two studies in different arrangements for TLD irradiation, TLD measurement uncertainty increases and also the latter procedure is a time loss for the radiotherapy centres. National and international organizations have been preparing TLD postal dose inter-comparisons between SSDLs and radiotherapy centres for years. Also, Turkish radiotherapy centres have participated in external TLD quality audit for Co-60 energy beam since 1989. According to the results of the comparisons organized between 1989 and 2012, geometrical error has the biggest percentage within total error.

This study shows that non-standard conditions may cause important differences between SSDL and hospital dose results. As can be seen from Table 1, we determined that the most closed results to the prescribed dose (2 Gy) are our TLD holder results. For different irradiation setup, the closest dose values to the prescribed dose of 2 Gy were only obtained with using the new TLD holder (2.022± 0.017cGy) with lowest error value. The average and standard deviation for standard IAEA water phantom and plastic bucked set-up were 2.014±0.024 cGy and 1.948±0.062cGy respectively. While the maximum average absolute difference (%3.5) and the maximum % error (%3.16) were found in the hospital condition with bucket filled with water, the minimum average absolute difference and the minimum % error were **%**1.32 and %0.86 respectively, with our new TLD holder in the solid water phantom (Table 1) . As can be clearly understood from these results, the reason of this good consistency is the reproducibility of TLD position that created by means of our TLD holder. On the other hand, plastic bucked or similar material may cause a non standard irradiation conditions and different material such as plastic used in the TLD holder may cause in-homogeneous dose in the water. Izewska et al. [5] showed in their study, when an IAEA holder is used in the hospital, the error between hospital and SSDL could be reduced by applying a correction factor to the TLD results of hospital. As stated in their study, we also applied a correction factor to the TLD results irradiated in this step mentioned above. Since an acceptance limit of 3% was chosen for the Pan-European Radiation Oncology Programme for Assurance of Treatment Quality (EROPAQ) intercomparisons, any systematic error in dose evaluation by the measuring centre should be minimized. But, geometric errors cannot completely prevent in this non standard conditions when using an IAEA TLD holder in a plastic bucked.

In conclusion, medical physicist has to measure dose out-put of irradiation system very carefully and the centre should have a suitable dosimeter system with valid calibration factor and also with stability and repeatability of the response. Furthermore, to eliminate the user effect caused by geometrical errors, it is suggested to perform both ionization chamber measurements and TLD irradiations in the same material and in the same geometrical set-up in hospital.

Table 1. The measured values of irradiated TLDs for 3 different set-up conditions. Difference (%) shows the value between measurement and prescribed dose of 2Gy.

Measurements No	Set-up :1 in the SSDL conditions with IAEA water phantom		Set-up :2 in the Hospital conditions with bucket filled with water		Set-up :3 With our New TLD holder in the solid water phantom	
	TLD Measurement (Gy)	Difference (%)	TLD Measurement (Gy)	Difference (%)	TLD Measurement (Gy)	Difference (%)
1	2.011	%0.55	2.080	%4.00	2.024	%1.20
2	1.950	%-2.50	1.930	%-3.50	2.036	%1.80
3	2.011	%0.55	1.920	%-4.00	2.005	%0.25
4	2.017	%0.85	1.960	%-2.00	2.032	%1.60
5	2.040	%2.00	1.860	%-7.00	2.026	%1.30
6	2.024	%1.20	1.960	%-2.00	1.980	%-1.00
7	2.022	%1.10	1.890	%-5.50	2.026	%1.30
8	2.015	%0.75	2.010	%0.50	2.034	%1.70
9	2.025	%1.25	1.930	%-3.50	2.029	%1.45
10	2.026	%1.30	1.940	%-3.00	2.033	%1.65
Average Measurement (Av)	**2.014**		**1.948**		**2.022**	
Standard Deviation (SD)	**0.024**		**0.062**		**0.017**	
% Error = (SD/Av)x100	**%1.19**		**%3.16**		**%0.86**	
Average Absolute Difference (%)		**%1.20**		**%3.50**		**% 1.32**

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Bayram Demir e-posta: bayramdemir69@yahoo.com
Erol Kam e-posta: kam@nukleer.gov.tr
Gürsel Karahan e-posta: karahang@cnaem.nukleer.gov.tr
Murat Okutan e-posta: mokutan@istanbul.edu.tr