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Measurement of the Ambient and Extremity Doses in Clinical Oncology Hospital, Menoufia University, Egypt

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Abstract

The ambient dose of radiation therapy and nuclear medicine units of Clinical Oncology Hospital, Menoufia University were investigated using thermoluminescence dosimeter MTS-700 and surveymeter (Inspector Radiation Alert). The maximum% difference between read out of both MTS-700 (TLD) and surveymeter did not exceed 6% and 8% for the two hospital units respectively. Values of the annual ambient dose received in both hospital units were found to be incompliant with radiation protection regulations. In addition, the extremity effective dose Hp (0.07) of staff in nuclear medicine unit was measured using wrist and finger techniques. Results indicate in-homogenies distribution of fingertips doses. Radiation doses received by the wrists and fingertips of radiopharmaceutical staff preparing ^{99m}Tc syringe were observed to be higher by a factor of about 1.41 and 1.44 respectively than those for the administrating staff whom injecting patients by ^{99m}Tc syringe, but also still in congruent with international radiation protection regulations.

Keywords

Ambient Dose, Extremity Dose, Thermoluminescence, Lithium Fluoride Dosimeter

1. Introduction

The use of ionizing radiations widely applied, especially in the context of medical diagnostics and therapy as well as for material testing and many other purposes [1] [2]. Radiation has been used in medicine. Between 30 and 50 percent of medical decisions, especially the critical ones, are made after studying the results of radiological examinations [3] [4]. In medicine, the most important requirement is the radiation dosimetry for surveillance of radiation workers in radiology, nuclear medicine and radiation oncology. In addition, its importance was defined for quality assurance (*i.e.* Precise estimation of delivering dose to the patient) in both external beam radiation therapy and brachytherapy as well [5]. Because of the large and growing number of patients undergoing radiation therapy and the multiple nuclear medicine procedures, continued efforts are required to improve the quality of treatment, diagnosis and to reduce the associated radiological risk [6]. So, multiple therapeutic and diagnostic procedures in radiation therapy and nuclear medicine units of Clinical Oncology Hospital, Menoufia University, Egypt require proper attention.

In the present work, an ambient radiation monitoring program is assessed. Knowledge of ambient dose values is relevant to the occupational exposure personnel who may limit the time spent at high dose areas. Recommendations were given to the departmental authorities to implement actions in order to reduce doses at high dose sites in order to comply with the ALARA principle [7]. This will be discussed whether the exposed doses at the work places are acceptably and safe or not. The investigated sites at radiation therapy unit are a radiation therapy clinic, ^{60}Cocontrol, patient waiting, long hall, worker path room, linear accelerator control, simulator control and ^{60}Co treatment room. Moreover, other selected sites in the nuclear medicine unit are chosen, physician station, technician station, X-ray room, injection room, preparing material, patient path room, external hall and patient waiting room. In addition, determination and investigation of the effective skin dose at depth 0.07 mm (Hp (0.07)) of the body of medical and paramedical staff in the nuclear medicine unit will be done using wrist and finger MTS-700 (TLD). Special attention has been paid to the exposure of nuclear medicine worker hands. The radio pharmacists who label various ligands can be exposed to high radiation doses to their fingertips (primarily of the thumb, index finger and middle finger). Quite frequently, the Hp (0.07) to the fingertips of those three fingers may exceed the dose limit, *i.e.* value of 500 mSv/y for the skin of human fingers; this dose limit refers to the maximum dose recorded [8].

2. Methodology

2.1. Experimental Procedure for Ambient Dose Measurements

In radiation therapy unit some radiation sources are in use; these are ^{60}Co (Cobalt-60) gamma source (Theratronics 780-E (1.25 MeV). This teletherapy unit was manufactured in Canada by Theratronics International Limited for Oncology System and used for radiation therapy treatment of cancer patients. X-ray Photon beam from medical linear accelerator (Varian Clinac 600-C with nominal energy 6 MeV) was used in radiation therapy unit for radiation therapy treatment of cancer patients. This device provides rectangular, symmetric and asymmetric fields and generates therapeutically useful megavoltage X-rays with exceptional flexibility, control, precision, and reproducibility). In addition, X-ray beam from radiotherapy simulator(Ximatron C-series) with an energy range of (40 - 150 kVp) and serial number 99,599 manufactured in the U.S.A. by VARIAN Associated Limited for Oncology System was used in radiation therapy unit. It was used for simulating the treatment radiation fields before and during radiation therapy treatment of cancer patients). In nuclear medicine unit, ^{99m}Tc (Technetium-99) generator with activity of 50 GBq (1351.35 mCi) and energy of gamma 140 keV and X-ray machine (General Electric Healthcare)with energy range (40 - 120 kVp)are also in use. For many years the most commonly used TLDs were LiF detectors doped with Mg and Ti [9]. Sintered pellets of the same chemical composition produced in Poland from natural LiF are referred under the trade name MTS-N [10] [11]. MTS-700 (TLD) referred to that produced from enriched 7Li isotopes will be used in the measurements. MTS-700 indicates the accumulated dose, which divided by the number of measurement hours to give dose rate. MTS-700 is tissue equivalent, its Z_{eff} (effective atomic number) is 8.13 [12]. In order to investigate the dosimetric characteristics of MTS-700 (TLD), ^{60}Co γ-source with dose rate = 48.08 cGy/min and radiation field size of $10 \times 10\ cm^2$ was used. MTS-700 (TLD) readings will be compared with results read out directly by surveymeter (Inspector Radiation Alert) manufactured by SE International, INC serial number (21,083) underwent mandatory annual calibration by National Institute of Standard, NIS Egypt. The inspector is a Geiger-Müller detector, the most useful and famous radiation detector consists of a microprocessor controlled radiation measuring instrument which offers excellent sensitivity to low levels of alpha, beta, gamma and X-rays. The digital readout is displayed with a red count light and audible beep. Providing instant indications of the radiation level. Other benefits include an adjustable timer and external calibration control [13]. The exposure rate in mR/h was converted into absorbed dose rate in mG/h using a standard conversion. Figure 1 and Figure 2 show,

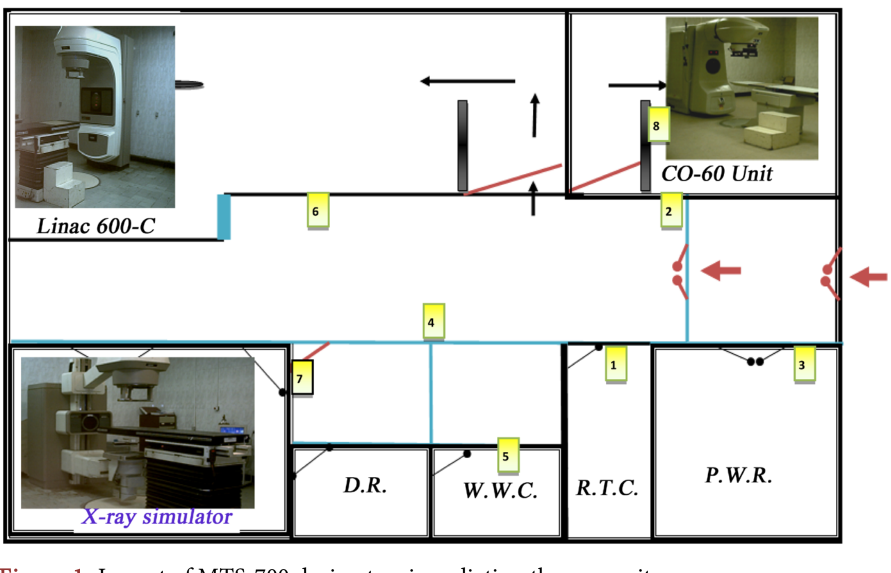

Figure 1. Layout of MTS-700 dosimeters in radiation therapy unit.

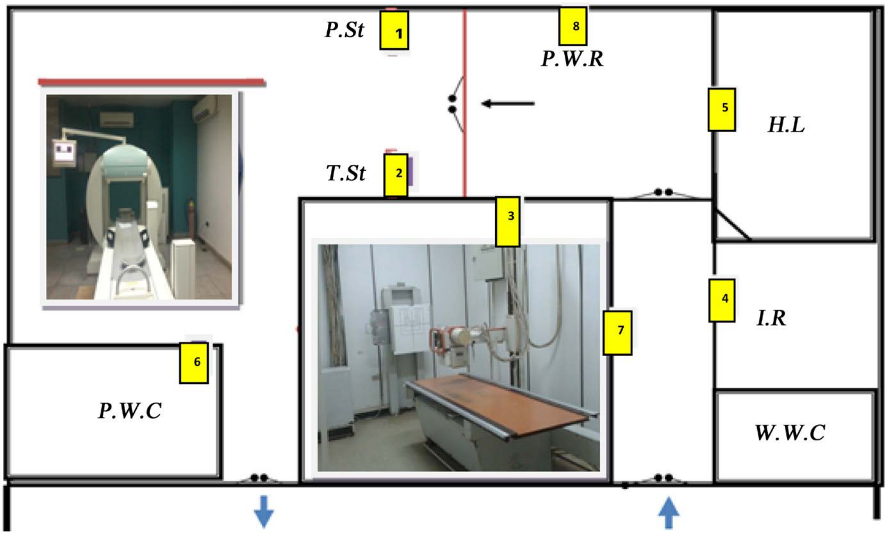

Figure 2. Layout of MTS-700 dosimeters in nuclear medicine unit.

respectively the layout of MTS-700 dosimeters in radiation therapy and nuclear medicine units. The surveymeter and TL dosimeters were fixed on 120 cm height from the ground, at 8 different locations, two chips of MTS-700 (TLD) in each defined position. TLD read out was taken after exposure by one day to fade the low temperature peaks using Harshaw bicorn model 3500 TL reader

2.2. Experimental Procedure for Extremity Dose Measurements of Medical and Paramedical Staff in Nuclear Medicine Unit

Nuclear medicine implies the manipulation of unsealed radioactive sources. Labelle ^{99m}Tc in hospital divided into three steps kit preparation, dispensing syringes and administration as described in Table 1. The two steps No. 1 and 2 were performed by physicists or technologists and step No. 3 performed by physicians or nurses, according to a department rotation periodic work table for nuclear medicine unit workers. In this research, the workers did so by volunteering for their colleague, the second author, to complete his Ph.D. They were divided into two groups, the first group called preparing radiopharmaceuticals group (physicists) and the second group called injecting radiopharmaceuticals group (nurses). In nuclear medicine procedures, radiation exposure of hands, especially in fingertips, is much higher than that of the thorax. [14] [15]. If the dose to any part of the extremities of a worker is likely to exceed three tenths of the annual dose limit, an additional dosimeter should be placed on the part of the extremity where the dose is expected to have its highest value. In practice, extremity monitoring is carried out by measuring the personal dose equivalent Hp (0.07) [16]. The work load includes numbers of patients and the scan type during one week the period of investigation described in Table 2. Two pairs of gloves equipped with eight chips of MTS-700 (TLD) were fixed in a certain position as in Figure 3 in a palm side of the two hands of the two groups at the centers of the wrists and fingertips of middle, index, and thumb fingers.

Table 1. Steps of ^{99m}TcLabelle in the nuclear medicine unit at Menoufia University, Egypt.

Steps of ^{99m}Tc Labelle No.	Process and Procedures in the nuclear medicine unit at Menoufia University, Egypt	
	Process	Procedures
1	Kit Preparation	1) Eluting ^{99m}Mo-^{99m}Tc generator in elute vial (50 GBq). 2) Determining specific activity in dose calibrator. 3) Drawing from elution vial and adding saline
2	Dispensing Syringes	1) Dispensing in syringes from kit vial. 2) Checking activity in dose calibrator. 3) Transfer of unshielded syringes to lead transport box.
3	Administration	1) Remove needle and mounting syringe shield. 2) Inject patient with 10 mm saline to check the cannula before inject with radiopharmaceutical and again injected with 10 mm saline after radiopharmaceutical for washing.

Table 2. Number of patients and the scan type during the investigation, one week in the nuclear medicine unit at Menoufia University, Egypt.

No.	Number of patients and the scan type during the investigation	
	Number of patients	Scan type
1	55	Bone scan
2	18	Cardiac scan
3	4	Thyroid scan
4	11	Renal scan

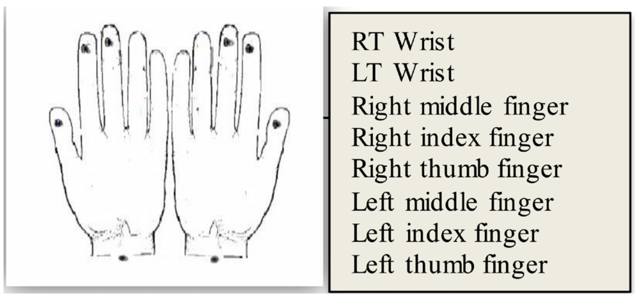

Figure 3. Distribution and Positions of MTS-700 (TLDs) in the palm side of the right and the left hands during preparing and injecting ^{99m} Tc persons.

3. Results

The element correction coefficient (ECC) was calculated for a set of measurements carried out on 15 pieces from MTS-700 (TLD) irradiated at dose of 2 Gy The mean value of relative ECF was found to be ranged between 0.96 and 1.04 with standard deviation (SD) 0.02 and coefficient of variance (CV) 2.28% (see Table 3). In order to assess the repeatability of the dose measurements attainable using the MTS-700 (TLD) a set of repeated readouts, 15 chips for each cycle,

Table 3. The range, mean, SD, and CV of relative ECC for MTS-700 (TLD).

MTS-700 (TLD) No.	Element Correction Coefficient
1	1.018
2	0.988
3	1.003
4	0.981
5	0.977
6	1.004
7	1.022
8	1.030
9	1.008
10	0.970
11	1.015
12	1.036
13	0.955
14	1.004
15	1.007
Range	0.995 - 1.036
Mean	1.001
SD	0.02
CV	2.28%

was carried out at dose 2 Gy. The mean value of relative sensitivity in seven cycles of irradiations was found to be ranged between 0.98 and 1.01 with (SD) range 0.022 - 0.047. This indicates good stability of the crystals in the TLD batch. Therefore, reproducibility with (SD) 0.03 and (CV) 3.21% over 105 TL signal readings became satisfactory regarding to the International Electrotechnical Commission, IEC requirements for environmental and personal dosimetry [17] [18]. The dosimeters showed high resistance to adverse effects caused by handling procedures (see **Table 4**). Variance in sensitivity of a typical batch of TL dosimeters is unavoidable but can be reduced from 10% - 15% to 1% - 2% when dosimeters are calibrated [19]. A calibration factor (nC/mGy) was assigned to each one. This process of calibration was repeated for two times to seven groups of MTS-700 (TLD). Each group contains two dosimeters irradiated with different radiation doses from 100 mGy up to 2000 mGy at the constant time, temperature profile (TTP) equal 10˚C/s to check the linearity and reproducibility of MTS-700 (TLD) response. Linear response was observed within the irradiated doses the coefficient of determination (R^2) obtained from a linear regression analysis was 0.9983 (see **Figure 4** and **Figure 5**).

The results of ambient dose measurements using MTS-700(TLD) and inspector radiation alert (surveymeter) for radiation therapy and nuclear medicine

Table 4. The mean, ±SD and Coeff. of Var. of relative TL signals for MTS-700 (TLD) as irradiated seven cycles at 2 Gy Co-60 γ-rays.

Cycle No.	The Mean, ± Standard Deviation and Coefficient of Variation of relative TL signals for MTS-700(TLD) as irradiated seven cycles at 2 Gy ^{60}Co γ-rays.		
	Mean	±SD	CV
1	0.980	0.027	2.79
2	1.000	0.039	3.89
3	1.010	0.025	2.44
4	1.010	0.047	4.65
5	1.000	0.023	2.29
6	1.010	0.022	2.21
7	1.000	0.042	4.21

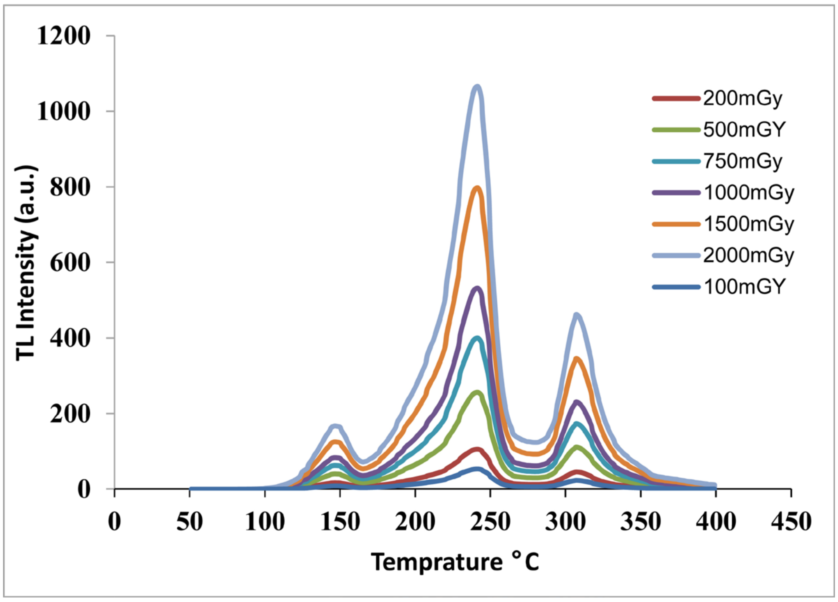

Figure 4. MTS-700 (TLD) glow curve at different doses (100, 200, 500, 750, 1000, 1500 and 2000 mGy) at 10˚C/s TTP.

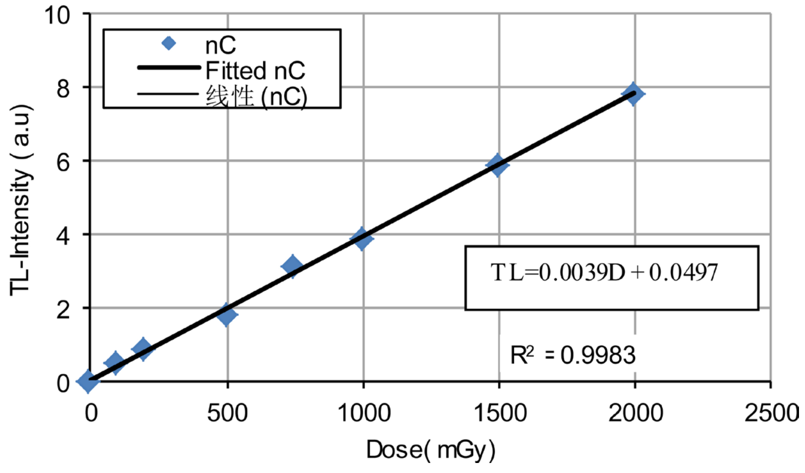

Figure 5. MTS-700 (TLD) conversion factor from (nC) to (mGy).

units of Clinical oncology hospital, Menoufia University, Egypt shown in Table 5 and Table 6, respectively.

The results of extremity dose measurements using MTS-700 (TLD) for nuclear medicine workers shown in Table 7 and Table 8 respectively.

4. Discussion

A comparison between the values of the annual ambient doses measured with surveymeter and MTS-700 (TLD) in the radiation therapy working area is shown in Table 4. The working areas are radiation therapy clinic, ^{60}Co Control room, patient waiting, long hall, worker path room, linear control, simulator control and ^{60}Co room. Values obtained by MTS-700 (TLD) are slightly higher than those obtained by surveymeter. The maximum% difference between read out of both the surveymeter and MTS-700 (TLD) did not exceed 6%, which indicates good agreement between both of them. In addition, doses measured in the nuclear medicine unit were gathered in Table 5. Measuring sites are physician

Table 5. Comparison between radiation therapy unit annual ambient doses measured by Surveymeter and MTS-700 (TLD).

No.	Site	Dose (mSv\y)			
		Survey meter	TLD (MTS-700)	Mean value ±SD	% Diff.
1	Rad.Thera.Clinac	1.094 ± 0.021	1.134 ± 0.089	1.114 ± 0.014	3.591
2	^{60}Co Control	4.402 ± 0.021	4.494 ± 0.175	4.448 ± 0.033	2.068
3	Patient waiting	0.601 ± 0.021	0.610 ± 0.031	0.606 ± 0.003	1.484
4	Long hall	0.927 ± 0.021	0.995 ± 0.096	0.941 ± 0.010	2.976
5	Worker path room	0.839 ± 0.021	0.884 ± 0.051	0.861 ± 0.016	5.223
6	Linear Control	1.460 ± 0.022	1.053 ± 0.131	1.418 ± 0.015	2.902
7	Simulator control	4.857 ± 0.022	5.112 ± 0.187	4.985 ± 0..91	5.116
8	^{60}Co Room	76.536 ± 0.114	79.588	78.062 ± 1.087	3.910

Table 6. Comparison between nuclear medicine unit Annual ambient doses measured by Surveymeter and MTS-700 (TLD).

No.	Site	Dose (mSv\y)			
		Survey meter	TLD(MTS-700)	Mean value ±SD	% Diff.
1	physician station	2.421 ± 0.021	2.584 ± 0.102	2.503 ± 0.058	6.513
2	technician station	2.752 ± 0.021	2.866 ± 0.002	2.809 ± 0.040	4.058
3	x-ray room	3.126 ± 0.022	3.207 ± 0.094	3.167 ± 0.029	2.558
4	injection room	2.980 ± 0.022	3.098 ± 0.065	3.039 ± 0.042	3.883
5	preparing material	3.718 ± 0.022	3.792 ± 0.124	3.775 ± 0.026	1.971
6	patient path room	2.561 ± 0.021	2.754 ± 0.112	2.658 ± 0.069	7.262
7	external hall	1.938 ± 0.021	2.076 ± 0.035	2.007 ± 0.049	6.876
8	patient waiting room	5.503 ± 0.023	5.732	5.615 ± 0.082	4.077

Table 7. Wrist doses (mSv) in nuclear medicine unit for preparing and injecting99m Tc persons using MTS-700 (TLD) per one week.

TLD position	Fingertip doses (mSv) in nuclear medicine unit for preparing and injecting ^{99m}Tc persons using MTS-700 (TLD) per week.	
	Preparing	Injecting
Right middle finger	2.053	1.485
Right index finger	2.960	2.106
Right thumb finger	2.160	1.566
Left middle finger	1.885	1.374
Left index finger	2.847	2.063
Left thumb finger	2.102	1.524
Mean value ± SD	2.381 ± 0.450	1.686 ± 0.315

Table 8. Fingertip doses (mSv) in nuclear medicine unit for preparing and injecting ^{99m}Tc persons using MTS-700 (TLD) per week.

TLD position	Wrist doses (mSv) in nuclear medicine unit for preparing and injecting ^{99m}Tc persons using MTS-700 (TLD) per one week	
	Preparing	Injecting
Right Wrist	0.458	0.314
Left Wrist	0.287	0.204
Mean value ± SD	0.373 ± 0.121	0.259 ± 0.078

station, technician station, X-ray room, injection room, preparing material, patient path room, external hall and patient waiting room. The maximum% difference between measurements with the above mentioned techniques not exceed 8%.This difference between two different measurement methodologies may be resulted from the fact that only fifteen measurements were taken in a month with surveymeter, while MTS-700 (TLD) responded for whole time exposure. Results given in both Table 5 and Table 6 exhibit that the ambient dose values measured in this work are in compliance with the local radiation protection regulations. The design of structural shielding for radiation therapy and nuclear medicine units in the clinical oncology departmental Menoufia University, Egypt achieve the requirements and follow the guidelines of national and international commission in radiological protection.

The dose values of wrists and fingertips personal dose Hp (0.07) for nuclear medicine unit worker using MTS-700 (TLD) are displayed in Table 7 and Table 8.

Table 7 shows radiation doses to right and left wrists of group one (preparing ^{99m}Tc) and group two (injecting ^{99m}Tc). Radiation doses received by the wrists of radiopharmaceutical staff preparing, dispensing syringe were observed to be higher by a factor of about 1.41 than those for the administrating staff whom injected patients by ^{99m}Tc. The annual wrists doses were calculated for group 1 and

2 by multiplying one week dose in 52.2 times (No. of weeks in one year).

Table 8 shows radiation doses to three main used fingers middle, index, and thumb of the two group workers. Radiation doses received by index fingertip of both hands were higher than radiation doses received by thumb's and middle's fingertips, these results are in agreement with the findings of Wrzesien, M. *et al.* [15] and indicates in-homogenies distribution of doses received by fingertips of nuclear medicine unit workers. Dose recorded by fingertips dosimeters for radiopharmaceutical staff preparing and dispensing syringe were observed to be higher by a factor of about1.44than those of the administration staff whom injected patients. The annual fingers doses for group 1 and 2 can be estimated by multiplying a factor y/wk. = 52.2.

The average values of doses recorded by dosimeters placed on fingertips of middle, thumb and index fingers in one week for the two groups 1 and 2 which equal 2.381 and 1.712 mSv respectively, the annual dose can be calculated to be 124.29 and 89.37 mSv, respectively in which the most likely equivalent dose limit 500mSv [20] [21] [22]. If we from the point of view consider the maximum fingertips doses which equal 2.960 mSv and 2.106 mSv in one week, then the annual dose will be 154.51 and 109.93 mSv/y for the two groups, respectively *i.e.* staff preparing will receive dose more than $3/10^{th}$ of the limit, which legally require routinely monitoring. With this work conditions, the equivalent dose limit will not be reached. These results are in agreement with the findings of Gauri, S. *et al.* [23] and Chruscielewski, W. *et al.* [24]. The maximum expected annual dose to the fingers appeared to be less than the annual limit (500 mSv/y) because all of workers are on rotation and do not constantly handle radioactivity throughout the year but if the workload is increased and the protection measures stays as they are doses can reach the equivalent dose limit. So, we recommend increase the radiation protection precautions as, using the automatic injector, increasing the patient waiting area and adding a new patient bathrooms. The extent of the annual radiation exposure of the workers depends on several factors within the workplace [25] [26] [27]. These factors include, but are not limited to, the annual workload, the distribution of the workload among workers, the radiation protection practices followed by the workers, and the radiation safety facilities provided by the employers. An evaluation of how such factors affect occupational exposure will be our future study after the development of radiation therapy and nuclear medicine units of Clinical Oncology Hospital Menoufia University, Egypt.

5. Conclusions

MTS-700 (TLD) was subjected to several systematic investigations carried out using γ–ray doses range from 100 to 2000 mGy. These TLDs were applied in clinical radiotherapy and nuclear medicine dose measurements. Results showed that MTS-700 (TLD) has a good reproducibility, an extended range of linearity, high sensitivity, and no significant variation in response over a wide range of doses typically used in clinical exposures with applying the appropriate quality factor. Therefore, MTS-700 (TLD) dosimeters are capable of determining the ambient dose in radiation therapy and nuclear medicine units that received by workers.

Values of the ambient dose measured in this work are in compliance with the international radiation protection regulations. This means that design of structural shielding for radiation therapy and nuclear medicine units in these two units fulfill the requirements and follow the guidelines of national and international commission in radiological protection. Comparison between average wrists and fingertips of the thumb, index and middle finger exposure doses using MTS-700 (TLD) indicates that the fingertips can receive 6.38 and 6.51 times higher dose than those recorded by the wrist dosimeters for ^{99m}Tc preparing and injecting radiopharmaceutical groups respectively. The radiation dose distributions on the hands of nuclear medicine unit workers are in-homogenies and complex. Measuring dose depends strongly on the position of the dosimeter, successive procedures, and an ensemble of workers. Strong variations of measuring dose are also attributed to differences in individual experiences and working habits. Herein, it can be said that this study was so important to be performed in order to provide a virtual radiation protection maps for workers, patients and visitors, in clinical oncology center at Menoufia University, Egypt this study is the first study in Egypt and the first Clinical Oncology center in Egypt has radiation protection maps for worker, patients and visitors.

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