Experimental study of individual thermoluminescent dosemeters performances for measuring the dose equivalents in skin and eye lens

E.N. Sheleenkova

Saint-Petersburg Research Institute of Radiation Hygiene after Professor P.V. Ramzaev, Saint-Petersburg

The article gives a comparative analysis of existing and newly developed thermoluminescent detectors DTG-4, TTLD-580, TLD-1011(TM) and DTVS-01 and dosemeters MKD-A and MKD-B for the purposes of individual dosimetric control of skin and eye lens exposure to radiation. The dependence of sensitivity of different thermoluminescent dosemeters, designed for dose equivalents measurements in skin and eye lens on the type (photons and β-particles) and energy of radiation was determined experimentally.

There are conclusions about the limits of applicability of existing detectors and dosemeters under different radiation exposure conditions.

*The article evaluates the possib*ility of different dosimeter use for specific radiation exposure conditions.

Key words: *individual dosimetric control, thermoluminescent method, weakly penetrating radiation, individual dose equivalent in skin and eye lens.*

Introduction

Radiation safety standard NRB-99/2009 [1] specifies the principle radiation dose limit for skin, hands, foots and eye lens equal to the dose equivalent 500 mSv/year and 150 mSv/year, respectively, but in our country inadequate attention is given to the problems of measuring the doses of radiation exposure to skin and eye lens by weakly penetrating radiation [2], as well as to the dosimetry in mixed radiation fields.

Considering that thermoluminescent (TL) dosemeter manufacturers provide the general information, indicating only types of radiation and limits of energy range, without any detailed data about detector response changing due to the energy value, it is necessary to study the characteristics and possibilities of application for existing and newly developed detectors for the purposes of individual dosimetric control (IDK) of skin and eye lens exposure to radiation.

Objective

To determine experimentally the dependence of the sensitivity of different TL dosemeters, designed for measuring the dose equivalents in hand skin and eye lens, Hp(0,07) and Hp(3), respectively, on the type (photons and β-particles) and energy of radiation.

To achieve this objective, the following tasks have been solved:

1. Characteristics analysis of weakly penetrating radiation dosimetry.
2. Experimental study of thermoluminescent detectors and dosemeters performance under different radiation conditions.
3. Assessment of capabilities for application of different dosemeters in action.

Weakly penetrating radiation dosimetry characteristics

NRB-99/2009 [1] specifies that dose equivalent in skin correlates with critical basal layer of epidermis 5 mg/cm2 thickness, that lies on 5 mg/cm2 depth, excluding the palm skin with screening layer thickness of 40 mg/cm^2. Dose equivalent in skin, according to NRB-99/2009, correlates with it at 0,07 mm depth, so, from mentioned above, the assumption can be made, that it is an average depth of basal layer plus the horny layer thickness.

It is believed, that the most radiation-sensitive area of eye lens is an epithelial growth zone close to the surface of the lens. Dose equivalent in eye lens, according to NRB-99/2009, correlates with it at 300 mg/cm^2 depth.

Operating dosimetry values for individual radiation monitoring is an equivalent of individual dose, Hp(d) [3-4]. This is a dose equivalent in soft biological tissue under specified body point at corresponding depth, d. One of the possible approaches for Hp(d) measurement can be using the detector, carried at the body surface and covered with the tissue equivalent material of adequate thickness.

The indication of reference depth, d, in millimeters, should be included at every determination of individual dose equivalent.

International Commission on Radiological Units (ICRU) (1993) established, that Hp(10) values were designed only for strongly penetrating radiation monitoring, for instance, the photons with energy over 30 keV and neutrons, while Hp(0,07) values were used for monitoring of weakly penetrating radiation: photons with energy less than 30 keV and β-particles. In addition, Hp(0,07) is also used for the monitoring of dose in hands and foots under the exposure of radiation of any type and energy value, although in particular cases other depth values can also be used (e.g, for eye lens it is 3 mm, Hp(3)) [3].

This distinction comes from the fact, that dose forming manners for external strongly and weakly penetrating radiation are different: strongly penetrating radiation basically has an effect on the internals and produces doses in it, whereas the dose of weakly penetrating radiation is produced only in the externals and body tissues, such as eye lens and skin. Weakly penetrating radiation produces maximum doses in radiation sensitive basal layer of skin at the depth 0,05 to 0,1 mm and in eye lens at 3 mm depth.

The difficulties of β-radiation dosimetry are accounted for the features of the process of radiation-substance interaction, namely the abrupt changes of flows and energies from point to point over the absorber depth [5].

For photon radiation with 1–10 keV energy the cross-section of interaction with the substance enlarges drastically due to photoeffect with decreasing the radiation energy. Gamma-radiation low energy losses per unit length are by one-two order bigger, that for high energy radiation, and, thus, the strong dependence of dose equivalent distribution on the depth of propagation is observed. These conditions do define the difficulties of direct measurement of this type of radiation.

Materials and study techniques

Within the study of TL detectors, designed for measuring the dose equivalents in skin, Hp(0,07), and in eye lens, Hp(3), the following detectors were used:

• DTG-4 – single-crystal detector, that contains LiF(Mg, Ti). Thickness is ≈ 1,05 mm, diameter is 4,5 mm. For this study the lot of detectors with sensitivity spread at least ± 15% was used.

• TTLD-580 by NPP «Doza» (including MKD dosemeters, A and Б types) – detectors from homogenous composition of fine thermoluminophore MgB4O7 and polyimide resin PM-1 grade. Thickness is ≈10 mg/cm^2 (≈100 μm), diameter is 9 mm for MKD-B dosemeter, diameter is 15 mm for MKD-A dosemeter.

- MKD-A is a dosemeter for dose equivalents measurement of photon- and β-radiation in eye lens and face skin. It is a composite cartridge from impact-proof chemically and radiation stable tissue equivalent material. Inside there are pad-absorbers 50, 100 и 110 mg/cm^2 thickness, rotating in line, at which TTLD-580 detectors with 15 mm diameter are mounted. The thickness of shielding entrance window, beyond which the first detector is situated, is about 2 mg/cm^2. The last detector DTG-4 is a single crystal of lithium fluoride is mounted at 300 mg/cm^2 depth and is used for measuring of doses in eye lens.

- MKD-B – is a dosemeter for dose equivalents measurement of photon- and β-radiation in finger skin. It contains the set of TTLD-580 detectors, separated by tissue equivalent absorbers with thicknesses, which are chosen in such a manner so the first two detectors will measure the dose at 35 and 45 mg/cm^2 depth, respectively, and other detectors – at 95 and 155 mg/ cm^2. The set of detectors is sealed into polyethylene jacket and placed at flexible support, by which it is attached to the inner side of finger phalanges. The number of the dosemeter is on the back.

• TLD-1011(TM) by NTC «Praktika» (Moscow) – polycrystall detector, that contains LiF(Mg,Cu,P). The thickness of crystallophosphorus is 5-7mg/cm2, diameter is 5 mm. Crystallophosphorus is applied at the reference surface of aluminum cup with 21mg/cm2 thickness.

• DTVS-01 by JSC «AEKhK» (Angarsk) – detectors on the base of thermoluminophore LiF(Mg,Ti) in polyimide film. The thickness of crystallophosphorus is 5 mg/cm^2, diameter is 12 mm.

For all detectors the following parameters have been used:

- sensitivity factors against radiation type and energy (K, [imp/mSv]);

- ergonomical characteristics (usability);

Dosimetric thermoluminescent instrument DVG-02TM, with capability of heating profile adjustment and automatic subtraction of detector own background, was used to readout the dosemetric information.

Detectors radiation exposure was performed at reference units of FGUP «Mendeleev All-Russian Research Metrology Institute (VNIIM)» in the β-radiation fields of the source Sr^{90}/Y^{90} and Pm^{147}, and in X-ray field at N40 mode (according to ISO 4037 [6]) with average spectrum energy of 33 keV.

The part of series of radiation exposure was performed on irradiators of FBUN «Professor P.V.Ramzaev Saint Petersburg Research Institute of Radiation» (FBUN NIIRG):

- in the β-radiation fields of the source Sr90/Y90. Field uniformity was measured using DTG-4 detector. It was determined, that the field is uniform within 8 cm diameter.

- at the mobile X-ray unit PRDU-02 (CJSC «ELTEKh-Med»), equipped with N40 mode (according to ISO 4037) with average spectrum energy 33 keV.

During the radiation exposure all detectors were covered by the layer of tissue equivalent material with 0,07 mm or 3 mm thickness, using water phantom (9 cm diameter and 15 cm height) for scattering simulation, that is equivalent to human body scattering.

Before the exposure in the field of the source of ionizing radiation (III) all TL detectors were heat treated under conditions, specified by the manufacturers, to remove the residual information.

Study results and discussion

When choosing the type of detectors for IDK, depending on the dosimetry task, it is necessary to be aware of comparative performances of different types of detectors, i.e. the same-type parameters, obtained under the same conditions on the same instrument. Foremost, this is due to the fact, that the values of detector parameters largely depend on the instrument, from which they are readout. It is also important to note, that specific values of the parameters of actual lot of detectors either unknown, or specified in its technical data sheets by the limit values, that these parameters do not exceed. For instance, the sensitivity of detectors in the lot does not specified in technical documentation, and the coefficient of variation is set by its maximum, thus, it is necessary to experimentally determine the most critical parameters of the lot of TL detectors of different types.

Radiation detectors should simulate the energy absorbing in the sensitive layers of tissue and should meet the following requirements:

- tissue-equivalent: the compliance of effective atomic number of the detector, $Z_{эфф}$, with effective atomic number of soft biological tissue (МБТ), $Z_{эфф}$(МБТ), is 7,4. All available detectors are tissue-equivalent within the range of energy over 100 keV, for lower energy an additional validation of sensitivity is assumed to be done.

- wide range of registered doses of photon- and β-radiation over the “practical” energy range;

- measurement bias, acceptable for chronic and emergency radiation;

- self-containment;

- the comfort of wearing on open skin areas, while performing the production operations;

- repetitive in use (depending on price).

DTG-4

Tissue equivalent material with $Z_{эфф}$ = 8,3

After the series of DTG-4 detectors radiation exposure in VNIIM it becomes possible to calibrate it against the type of radiation. Then, during radiation exposures within this study, the reference dose value was estimated by DTG-4 readings with applied adjustments depending on the tape of radiation.

Obtained results and its description are shown below (see Table 1).

It is obvious, from the obtained data, that Hp(0,07) for X-ray radiation with Ecp.=33 keV has an upward bias an average 35%, and for Sr^{90}/Y^{90} radiation it has a downward bias an average 29%.

Thus, during the simultaneous radiation exposure of DTG-4 detectors and detectors of other types, it is possible to determine the reference dose value, compare the other detectors readings with it and calculate their sensitivity factors.

It should be mentioned, that DTG-4 detectors, based on LiF(Mg, Ti), is 100 mg/cm^2 thickness, that does not meet NRB-99/2009 requirements and recommendation of International Commission on Radiological Protection (ICRP) – 5 mg/cm^2. While using such a «thick» detectors, it is possible to measure only an averaged dose for skin layer, that corresponds to the thickness of detector used. When the components with low or medium β-radiation energy or low-energy gamma-radiation are in the radiation spectrum, the dose, measured using these detectors, can be underestimated by several times in comparison with the reference dose value in critical skin layers with 5 mg/cm^2 thickness. Therefore, DTG-4 detectors can be used only as indicators of β-radiation or low-energy β-radiation presence.

Table 1

DTG-4 detectors sensitivity for different types and energy levels of radiation

Radiation type, energy	Detector	K_1, [imp/mSv]	Hp(0,07), [mSv]	Reference dose, $H^0p(0,07)$, [mSv]	K_2, [imp/mSv]
X-ray radiation Ecp.=33 keV	DTG-4	841	2,43	1,617	1135
			2,15		
			2,32		
			1,94		
			2,31		
			2,42		
			2,05		
			2,11		
			2,18		
			1,93		
		Hp(0,07)cp.= 2,184±0,058		Upward bias 35%	
Sr^{90}/Y^{90} E cp.= 0,196/0,8 MeV	DTG-4	841	7,98	10	597
			7,52		
			8,46		
			7,94		
			6,22		
			6,75		
			6,25		
			7,21		
			5,75		
		Hp(0,07)cp.= 7,12±0,31		Downward bias 29%	

In this table K_1 – is a sensitivity factor, used for the calculation of individual dose equivalent, Hp(10), when the radiation exposure is within Cs^{137} source field (VNIIM verification), K_2 – is a new sensitivity factor, experimentally obtained depending on the type of radiation.

TLD-1011(TM)

Tissue equivalent material with $Z_{эфф}$ = 8,3

The radiation exposure of TLD-1011(TM) detectors was performed in VNIIM in the field of certified source of weakly penetrating radiation of Sr^{90}/Y^{90} (by 10 mSv dose) and Pm147 (by 5 mSv dose), and then the sensitivity factors were calculated separately for each detector. Detector lot used was a test one, and vendors do not provide yet the technique for application of exactly the same crystallophosphorus layers at the working surface, thus sensitivity factors has to be determined for each detector separately, because there is a strong dependence of sensitivity on crystallophosphorus thickness. The thicker layer means the higher sensitivity and light output of detector (see Table 2).

Thermoluminescence curve of TLD-1011(TM) detector has 4 dosimetric peaks. The quantity measured is a light sum after luminescence of low temperature peak: the sum of 3rd and 4th peaks.

In accordance with State standard, the verification of dosemeters for Hp(0,07) measurement is performed only for β-radiation exposure from the source of Sr^{90}/Y^{90}.

Table 2

TLD-1011(TM) detectors sensitivity for different energy levels of radiation

Detector No.	Light sum under peak, [imp] Sr^{90}/Y^{90}	Light sum under peak, [imp] Pm^{147}	K,[imp/mSv] Sr^{90}/Y^{90}	K, [imp/mSv] Pm^{147}
101	676	180	67,2	36,0
102	1037	225	103,7	45,0
103	1444	136	144,4	27,2
104	1488	443	148,8	88,6
105	810	71	81,0	14,2
106	1461	246	146,1	49,2
107	819	100	81,9	20,0
108	1402	639	140,2	127,8
109	962	66	96,2	13,2
110	1775	625	177,5	125,0
111	813	315	81,3	63,0
112	1992	336	199,2	67,2
113	755	94	75,5	18,8
114	1071	391	107,1	78,2

In the table K – is a sensitivity factor, depending on the radiation source.

From the listed data it is obvious, that for TLD-1011(TM) detectors there is a strong dependence of the sensitivity on β-particles energy (Sr^{90}/Y^{90} E cp.= 0,196/0,8 MeV, Pm^{147} Ecp.= 0,062 MeV).

Three months later the repetitive radiation exposure of TLD-1011(TM) detectors was performed in VNIIM in the field of β-radiation source of Sr^{90}/Y^{90} (by 10 mSv dose). Results are shown in Table 3, where K1 – is a sensitivity factor, that was obtained when detector has been calibrated during the initial radiation, and K2 – is a sensitivity factor, obtained 3 months later. Radiation was made by 10 mSv dose both.

From the data presented it is clear, that detectors' sensitivity decreased by an average 2 times with the course of time.

Then, taking into account new K2 values, it is possible to determine TLD-1011(TM) detector sensitivity to the X-ray radiation (Ecp.=33keV). The reference dose is taken from DTG-4 (3 mSv) detector data, that was exposed to radiation simultaneously with TLD-1011(TM). Results are shown in Table 4.

Table 3

TLD-1011(TM) detectors sensitivity after 3 months of use

Detector No.	Light sum under peak, [imp] Sr^{90}/Y^{90}	K1, [imp/mSv] Sr^{90}/Y^{90}	K2, [imp/mSv] Sr^{90}/Y^{90}	K_1/K_2, per unit value
101	293	67,2	29,3	2,29
102	457	103,7	45,7	2,27
103	656	144,4	65,6	2,20
104	791	148,8	79,1	1,88
105	329	81,0	32,9	2,46
106	750	146,1	75,0	1,95
107	392	81,9	39,2	2,09
108	810	140,2	81,0	1,73
111	393	81,3	39,3	2,07
112	1060	199,2	106,0	1,88
113	311	75,5	31,1	2,43
				(K_1/K_2) cp. = 2,11±0,07

Table 4

TLD-1011(TM) sensitivity to X-ray radiation

Detector No.	Light sum under peak, [imp]	K_2, [imp/mSv]	$Hp(0,07)_{TLD-1011(TM)}$, [mSv]	Reference dose, $H^0p(0,07)$ DTG-4, [mSv]
101	46	29,30	1,56	3,00
102	94	45,70	2,06	
103	83	65,60	1,27	
105	67	32,90	2,04	
			Hp(0,07)cp.= 1,73 ± 0,19	Correction required + 42%

In the table $Hp(0,07)_{TLD-1011(TM)}$ – is an individual dose equivalent in hand skin, obtained using TLD-1011(TM) detector.

During the examination of TLD-1011(TM) detectors it emerged, that it did not register the doses less than 2 mSv, even though the manufacturer declared the dose equivalent measurement range (linearity range) as 0,03÷30000 mSv. For X-ray radiation Hp(0,07) values, obtained using TLD-1011(TM) readings, were reduced by an average 42%.

New detectors has a limitation, that is more or less typical to all the detectors, bases on LiF:Mg,Cu,P, that is an unacceptability of long-term detector overheating over specific temperature [7].

Detectors (including housings, developed in Radiation control laboratory) were used in one of the medical organizations of Saint Petersburg, and no apparent inconveniencies were mentioned by the personnel, using it.

DTVS-01

Tissue equivalent material with $Z_{эфф}$ = 8,3

The radiation was performed using mobile X-ray unit PRDU-02, equipped with N40 mode (according to ISO 4037). Also detectors were radiated in the field of β-radiation source of Sr90/Y90, and calibrated against it. The reference value of dose equivalent, Hp(0,07), was determined using DTG-4 detectors data, considering corrections (see Table 1). Measurement results for DTVS-01 detectors are shown in Table 5.

Based on the data obtained it is possible to conclude, that calibration results against Sr90/Y90 agree with the further radiation at the X-ray unit. The reference dose and the obtained one have a discrepancy no more than 30%.

TTLD-580

Tissue equivalent material with Zэфф = 8,4

Radiation of TTLD-580 detectors was performed as a part of MKD-A (K = 403 imp/mSv) and MKD-B (K = 129 imp/mSv) dosemeters in the fields of β-radiation source of Sr^{90}/Y^{90} and Cs^{137} and in N40 mode (within verification by VNIIM).

Dose equivalent in skin is estimated by:

- readings of first two detectors (MKD-A dosemeters)
- readings of the first detector (MKD-B dosemeters)

Results are shown in Table 6, where

Hф(0,07) – reading of background dosemeter;

H0p(0,07)– reference dose;

Hip (0,07) =(H1p(0,07)+ H2p(0,07))/2 – Hф(0,07);

Δ, % – Hp(0,07) measurement bias;

Table 5

DTVS-01 detectors sensitivity for different types and energy levels of radiation

Detector No.	Radiation type, energy	Light sum under peak value, [imp]	Reference dose, H0p(0,07)DTG-4, [mSv]	K, [imp/mSv]	Hp(0,07)DTVS-01, [mSv]
1		418		63,33	
2	Sr^{90}/Y^{90}	451		68,33	
3	E cp.= 0,196/	339	6,60	51,36	
4	0,8 MeV	404		61,2	
5		485		73,48	
				Kcp.=63,54±3,71	
1		185	2,30	63,54	2,91
2	X-ray radiation	181		63,54	2,84
3	Ecp.=33 keV	169		63,54	2,66
4		170		63,54	2,68
5		179		63,54	2,82
					(Hp(0,07)DTVS-1)cp. = 2,78±0,05

Hp(0,07)DTVS-01 – individual dose equivalent in hand skin, obtained using DTVS-01 detectors.

Таблица 6

Чувствительность детекторов ТТЛД-580 при различных энергиях и типах облучения

Detector No.	Radiation type, energy	Readings of cartridge with filters, [mSv]		Hip (0,07) – Hф(0,07), [mSv]	H0p(0,07), [mSv]	Δ, %
		$H^1p(0,07)$	$H^2p(0,07)$			
MKD-A						
872		2,44	2,58	2,02	2,0	1
871		2,9	3,67	2,80	3,0	-7
876		5,07	4,58	4,34	5,0	-13
877	Sr^{90}/Y^{90}	6,48	6,24	5,87	6,0	-2
887	E cp.= 0,196/0,8 MeV	10,49	10,33	9,68	10	-3
886		8,85	11,00			
879		87,22	89,73	91,49	90	2
884		93,12	97,88			
856	Cs^{137} Ecp.= 660 keV	7,77	9,39	8,14	10	-19
865		7,33	10,04			
868	N40 Ecp.= 33 keV	2,56	4,04	2,81	1,93	46
869		2,39	3,35	2,38	2,11	13
MKD-B						
121	Sr^{90}/Y^{90} E cp.= 0,196/0,8 MeV	12,36			10	24
123		12,49				25
164		10,57				6
174		13,62				36
177		9,59				-4
178		9,00				-10

From the data, shown in Table 6, it is clear, that all obtained results for TTLD-580 detectors, irrespective of the fact, what dosemeter they are a part of, are in good agreement with reference values of Hp(0,07) for all types of radiation (β-, gamma-radiation and soft X-ray 33keV).

During getting these detectors into actual practical use, as a part of MKD-B dosemeters, within the medical organizations of Saint Petersburg, these detectors attract a good deal of criticism from the personnel: contact tape has sharp edges and do not come tightly in contact with the finger, that makes impossible to use those dosemeters under gloves, while performing production operations. There is no point in wearing it above the gloves, as it can be contaminated by radioactive substances.

There is also a series of practical faults:

- while packing, detectors (4 pc.) and absorbers (6 pc.+foil) are strongly electrified, that makes the dosemeter assemble and disassemble process quite a labour-consuming.

- detectors are sensitive to UV radiation (even with its installation into the dosemeter the light influence is really substantial for MKD-B dosemeter. MKD-A dosemeter housing is more «enclosed» for UV radiation), that essentially complicates its application for environmental, as well as individual, monitoring.

Examination of dose performances of detectors for measurement of individual dose equivalent for eye lens Hp(3)

To measure individual dose equivalent, Hp(3), DTG-4 detector is used. Sensitivity factor K = 841 imp/mSv.

DTG-4 detectors radiation was performed in VNIIM in the field of β-radiation source of Sr^{90}/Y^{90} and Cs^{137} and in N40 mode, as a part of MKD-A dosemeter, i.e. at 300mg/cm^2 depth (see Table 7).

As well as at PRDU-02 X-ray unit, equipped with N40 mode, without and under the layer of tissue equivalent material with 3 mm thickness (see Table 8).

Using MKD-A dosemeters, by Hp(3)/H0p(0,07) ratio, it is possible to determine the percentage of hitting dose, that is absorbed by covering layer of 300mg/cm^2.

When calculating the dose from Sr90/Y90 source for DTG-4 detectors, sensitivity factor K = 597 imp/mSv was used (see Table 1).

During the analysis of data obtained (see Table 7), it is possible to conclude, that for eye lens radiation exposure by β-radiation of Sr^{90}/Y^{90} over 70% of hitting dose is absorbed by 300 mg/cm^2 layer, that does not agree with conversion factors ratio, indicated in IS0 12794:2000, Table E.3 [8], where Hp(3)/H0p(0,07) = 0,48. As the result, for the measurement of individual dose equivalent in eye lens from Sr^{90}/Y^{90} source, using MKD-A dosemeter, the measurement bias will be over 45%.

Table 7

DTG-4 detectors sensitivity for measuring the dose equivalent in eye lens for different types of radiation

Detector No.	Radiation type, energy	Readings of DTG-4 detector in MKD-A housing with filters, Hp(3), [mSv]	Reference dose, $H^0p(0,07)$, [mSv]	$\frac{Hp(3)}{H^0p(0,07)}$
872		0,46	2,0	0,23
871		0,52	3,0	0,17
876		1,20	5,0	0,24
877	Sr^{90}/Y^{90}	1,62	6,0	0,27
887	Ecp.= 196 /0,8 MeV	2,59	10	0,26
886		2,96		0,30
879		22,40	90	0,25
884		25,96		0,29
				Ср.зн.= 0,25 ±0,04
856	Cs^{137}	11,37	10	1,14
865	Ecp.= 660 keV	13,46		1,35
868	N40	2,37	1,93	1,23
869	Ecp.= 33 keV	3,03	2,11	1,44
				Average = 1,29±0,07

Table 8

DTG-4 detectors sensitivity under different radiation conditions

Detector No.	Readings of DTG-4 detectors under the layer of tissue equivalent substance, h=3 мм, Hp^1, [mSv]	Readings of DTG-4 detectors without tissue equivalent substance, Hp^2, [mSv]	Hp^1/Hp^2
1	2,79	2,49	1,12
2	2,72	2,42	1,12
3	2,10	1,83	1,15
4	2,49	2,41	1,03
5	2,41	2,71	0,89
			$\langle Hp^1/Hp^2 \rangle$ = 1,06±0,05

For radiation of MKD-A dosemeters in the fields of gamma-radiation and soft X-ray (Ecp.= 33 keV) there is no attenuation (see Tables 7, 8), that agrees with conversion factors ratio, indicated in ISO12794:2000, Table E.2 [8].

During getting these detectors into actual practical use (as a part of MKD-A dosemeters) within the medical organizations of Saint Petersburg, no substantive remarks about its usability were made.

Summary

Performed study of detectors for hand skin and eye lens dosimetry reveals that:

1. TLD-1011(TM) detectors sensitivity essentially decrease with the course of time, thus, an adequate estimation of radiation doses in hand skin can be done only by time-stable detectors and with information about the type and energy of skin effecting radiation available.

2. The estimation of radiation doses in eye lens in the fields of photon radiation, performed on the base of the measurements of individual dose equivalent in eye lens (Hp(3)) using specific dosemeters, is acceptable. Measurement bias an average is up to 25%, but for 33 keV energy range an upward bias of results is observed as an average 35%.

3. Dosemeters sensitivity for the measurement of individual dose equivalent in eye lens (Hp(3)) by β-radiation does not meet the requirement of International standard IS0 12794:2000. Thus, the possibility of MKD-A dosemeter application for Hp(3) measuring in the fields of β- and mixed radiation warrants further study.

4. Today the most advanced detector to control the hand skin dose equivalent is a slim DTVS-01 detector on the base of LiF(Mg,Ti). This thermoluminophore is tissue equivalent, easy in use, has a good sensitivity to β-radiation and soft-radiation, and time-stable. Dosimetry using this detector in the mixed fields is possible, that is required for skin dosimetry purposes.

5. After completing the series of practical studies in medical organizations of Saint Petersburg, it became obvious, that dosemeters, placed on the inner side of palms should be ergonomic (slim and flexible) and not interfere the work of personnel, thus, besides developing of adequate thermoluminophore, it is also important to thoroughly consider the dosemeter housing.

List of references

1. Radiation safety standard (NRB-99/2009): Sanitary rules and norms (SanPiN 2.6.1.2523-09): appr. and put into effect on 07.07.09, – M. : Federal center of hygiene and epidemiology, 2009. – 100 p.
2. Gimatoda T.I. Individual dosimeters for measurement of equivalent dose in the skin of the fingers, face and eye lens for chronic and emergency exposure/ Gimadova T. I., Shax A. I.// Equipment news of radiation measurements. – 2001. No. 3. – p. 21-27
3. Assessment of Occupational Exposure Due to Intakes of Radionuclides. Safety guide – Vienna: IAEA, 1999. № RS-G-1.2. – p. 87.
4. Occupational Radiation Protection. Safety guide. – Vienna: IAEA, 1999.- № RS-G-1.1. – S. 78.
5. Control equivalent doses of photon and beta radiation in skin and eye lens. HOWTO (MU 2.6.1.56-2002). – M.: Russian Ministry of Health, 2002.
6. ISO 4037-1: 2006, X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy -- Part 1: Radiation characteristics and production methods.
7. Agrinenko S. D., "Development of complex monitoring on the base of detectors LiF. Mg, Cu, P for the handling of RAO" dissertation VAK 05.17.02, candidate of Technical Sciences.
8. ISO 12794:2000, Nuclear energy – Radiation protection – Individual thermoluminescence dosemeters for extremities and eyes