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Estimation of ambient dose equivalent from environmental radiation using a ^{7}LiF:Mg,Cu,P thermoluminescence dosemeter

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This paper aims to present the characterization of the dosimetric system based on ^{7}LiF:Mg,Cu,P dosemeter used for environmental radiation monitoring and workplace monitoring. In order to characterize this dosimetric system, the main influence quantities of the dosimetric response must be analyzed. This study presents the results for the energy dependence response of Harshaw ^{7}LiF:Mg,Cu,P (TLD-700H) dosemeter. Calibrations were done in secondary standard laboratory condition at the Czech Metrology Institute – Inspectorate for Ionizing Radiation. The energy dependence of dosemeter response was studied by irradiating the thermoluminescent dosemeters at the same value, in terms of air kerma, at 2.00 mGy, for 11 radiation quality, from N-40 to S-Co.

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1. Introduction

One of the primary purposes of environmental radiation monitoring is to provide information and data for evaluation of human radiation exposure. Environmental monitoring is always dependent on the site specific features of the environment to be monitored and it's done to detect changes in long term trends of dose rates in the environment.

Thermoluminescent dosemeters are widely used for environmental radiation monitoring or workplace monitoring. The advantages of thermoluminescent dosemeters are their high sensitivity, their linear response with dose, their good energy response (materials have the effective atomic number Z close to that of tissue), and their reusability.

Lithium fluoride doped with magnesium, copper and phosphorus (LiF:Mg,Cu,P) had been shown to exhibit better dosimetric properties then the lithium fluoride doped with magnesium and titanium (LiF:Mg,Ti), which is the most widely used material in thermoluminescence dosimetry. The sensitivity of LiF:Mg,Cu,P it is reportedly 30 times greater than LiF:Mg,Ti, [1].

The principle of application of thermoluminescent materials to the dosimetry of ionizing radiation relies on the relationship between the dose absorbed and the intensity of emitted light. This light results from the release of electrons that were excited and trapped when the material was irradiated, the amount of light released being directly related to the radiation dose received by the material.

In thermoluminescent dosimetry, the relationship between the relevant signal and the dose equivalent to be measured must be determined by calibration.

2. Experimental part

Materials and methods

The dosimetric system used for environmental radiation monitoring consists of:

- Thermoluminescent reader Harshaw 4500
- Harshaw Environmental Dosemeter Assemblies (7777H card and 8855 holder).
- Winrems software, 8.2.1.0
- Algorithm "Win Algorithm 8855", 1.0.0.0
- Time – Temperature – Profile (TTP)

The TLD card consists of four LiF:Mg,Cu,P sintered pellets mounted between two PTFE sheets on an aluminum substrate. The holder covers each TL chip with its own filter on both sides. This provides different radiation absorption thickness to allow estimation of directional and ambient doses.

All four of the TL elements are fabricated from ^{7}LiF:Mg,Cu,P (TLD-700H). They are 0.38 mm thick and 3.6 mm diameter. The specific TL materials and filters are described in Table 1 and shown in Fig. 1.

Table 1. Description of the 7777H dosemeter.

Element position	Material	Filtration
i	^{7}LiF: Mg,Cu,P (TLD 700H)	ABS + Cu 331 mg/cm^2
ii	^{7}LiF: Mg,Cu,P (TLD 700H)	ABS + PTFE 1000 mg/cm^2
iii	^{7}LiF: Mg,Cu,P (TLD 700H)	Al Mylar 6.8 mg/cm^2
iv	^{7}LiF: Mg,Cu,P (TLD 700H)	ABS + Sn 704 mg/cm^2

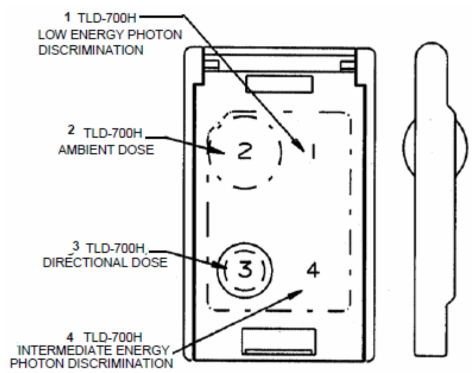

Fig. 1. 7777H card with 8855 holder filtration.

The two operational quantities recommended by the ICRU for environmental monitoring are the ambient dose equivalent *H*(d)* and the directional dose equivalent *H'(d,Ω)*. These are appropriate for monitoring strongly penetrating and weakly penetrating radiation fields respectively, for which the recommended depths are 10 mm and 0.07 mm respectively. These quantities measured in the workplace can provide, along with appropriate occupancy data, the basis for an adequate estimation of the effective dose and skin dose.

The algorithm used for dose evaluation has available the following options: "General", if the energy range from 20-1250 keV is covered, "Low Energy", if only low energy photons (E < 80 keV) are expected in the field, "High Energy", if only high energy photons (80 keV < E <1.250 keV) are expected, and "Cs137 Only", if the system was calibrated with a Cs137 Source [2].

The Time – Temperature – Profile (TTP) used is: Preheat: up to 165 ^{0}C, 0 s, Acquire rate 15 ^{0}C/s, up to 260 ^{0}C, acquire time 13 1/3 s; Anneal: 260 ^{0}C, for 10 s [3].

Results

The energy dependence of dosemeter response

The energy dependence of dosemeter response was studied by irradiating the thermoluminescent dosemeters at the same value, in terms of air kerma (K_{air}), at 2.00 mGy, for 11 radiation quality, from N-40 to S-Co [4,5,6].

The quantity air kerma was used for calibrating thermoluminescent dosemeters in the reference photon radiation fields, without any phantom present, i.e. free in air. Conversion coefficients from air kerma to *H*(10)* are [7]:

$$k(E) = \frac{H^*(10)}{K_{air}}$$

For this experiment, a number of 60 thermoluminescent dosemeters were irradiated (two dosemeters per radiation quality) in secondary standard conditions (at the Czech Metrology Institut – Inspectorate for Ionizing Radiation).

The conventional true values for ambient dose equivalent $H^*_{c.a.}(10)$ was obtained by air kerma value using the conversion coefficients for radiation qualities. The measured ambient dose equivalent *H*(10)* was made using the dose calculation algorithm for environmental dosemeter - "Cs137 Only". The ratio of measured ambient dose equivalent $H^*_{meas.}(10)$ and the conventional true values $H^*_{c.a.}(10)$ was obtained for each radiation quality. The results are presented in Table 2.

Table 2. Energy dependence of dosemeter response (algorithm „Cs-137only").

Quality Rad.	*Mean energy keV*	*$K_{air,}$ mGy*	*conv. coef. k(E) mSv/mGy*	*H*(10) c.a. mSv*	*$H^*(10)_{meas.}$ mSv*	Ratio $\frac{H^*meas.}{H^*c.a.}$
N-40	33	2.00	1.18	2,36	2,41	1,02
N-60	48	2.00	1.59	3,18	2,52	0,79
N-80	65	1.99	1.73	3,44	2,33	0,68
N-100	83	2.00	1.71	3,42	2,06	0,60
N-120	100	2.00	1.64	3,28	2,05	0,62
N-150	118	2.00	1.58	3,16	2,03	0,64
N-200	164	1.99	1.46	2,90	2,13	0,73
N-250	208	2.00	1.39	2,78	2,20	0,79
N-300	250	2.00	1.35	2,70	2,26	0,84
S-Cs	662	2.00	1.20	2,42	2,42	1,01
S-Co	1125	2.00	1.16	2,32	2,61	1,12

c.a. - conventional true value with an uncertainty < 5.1 %

Fig. 2 present the dosimetric response of thermoluminescent dosemeters as a function of irradiation energy, for dose calculation using „Cs-137only" algorithm's option.

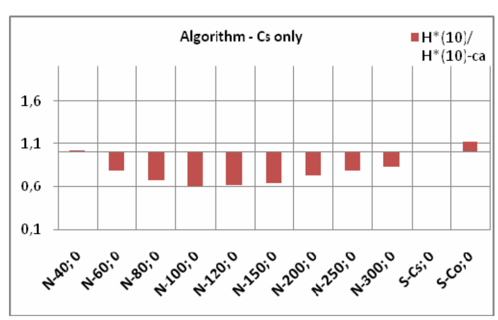

Fig. 2. Dosimetric response as a function as energy, for dose evaluation using „Cs-137only" algorithm's option.

It can be seen that the dosimetric response is near 1 at N-40 and S-Cs and there is a constant underestimation between N-60 and N-300.

By using the "General" option of the algoritm, the values for measured ambient dose equivalent are different. The results are presented in Table 3.

Table 3. Energy dependence of dosemeter response (algorithm „General").

Quality Rad.	*Mean energy keV*	$K_{air,}$ *mGy*	*conv. coef. k(E) mSv/mGy*	*H*(10) c.a. mSv*	*H*(10)$_{meas.}$ mSv*	Ratio $\frac{H^{*}meas.}{H^{*}c.a.}$
N-40	33	2.00	1.18	2,36	2,72	1,15
N-60	48	2.00	1.59	3,18	3,66	1,15
N-80	65	1.99	1.73	3,44	3,87	1,12
N-100	83	2.00	1.71	3,42	3,28	0,96
N-120	100	2.00	1.64	3,28	2,95	0,90
N-150	118	2.00	1.58	3,16	2,82	0,89
N-200	164	1.99	1.46	2,90	3,10	1,07
N-250	208	2.00	1.39	2,78	2,78	1,00
N-300	250	2.00	1.35	2,70	2,69	1,00
S-Cs	662	2.00	1.20	2,42	2,31	0,96
S-Co	1125	2.00	1.16	2,32	3,08	1,33

Fig. 3 present the dosimetric response of thermoluminescent dosemeters as a function of irradiation energy, for dose calculation using „General" algorithm's option.

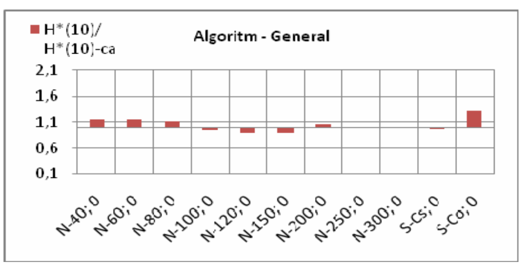

Fig. 3. Dosimetric response as a function as energy, for dose evaluation using „General" algorithm's option.

The obtained results are improved using this algorithm's option. For energy range 33 keV to 661 keV, the response is in (0.89–1.15) interval, with an overestimation of the response for S-Co.

3. Results and discussions

For improving the quality of the results, the dependence on radiation energy, direction of incidence, and other influence quantities must be taken into account.

The subject of environmental monitoring/workplace monitoring is discussed to the extent that such monitoring is used in the assessment of individual dose.

In a workplace, where the energy spectrum and orientation of the radiation field are generally not well known, the uncertainties in measurements made with thermoluminescent dosemeters can be reduced if the energy response is established and compensated.

4. Conclusions

This study is part of a larger one aimed to establish criteria for the parameters that influence the performance of the thermoluminescent dosemeter (radiation type, directional distribution and environmental influences), in order to satisfy the performance criteria according to ICRP recommendation on overall accuracy.

Thermoluminescent dosemeters used for environmental radiation monitoring are designed to measure quantities defined in free air, for improving the quality of the results is very important to have information about the radiation field (mixed beta–photons field, photons only), in order to choose the best algorithm's option.

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