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New personal dosimetry services in Romania for mixed fields gamma-neutrons using ^{6}LiF:Mg, Ti – ^{7}LiF:Mg, Ti pairs detectors

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Dozimed – Personal Monitoring Service starts to use since 2010 a TLD albedo dosemeter as standard neutron personal dosemeter, consisting of 2 pairs of ^{6}LiF:Mg, Ti-^{7}LiF:Mg, Ti detectors. The main problem in albedo dosimetry is to optimize the readout procedures and to calibrate the dosemeter in the environment of each neutron source by applying survey measurement, phantom calibrations or special field data. All albedo neutron dosimeters are energy-dependent, becoming less sensitive as the energy of the neutrons is increased. In this paper the energy dependence and the effect it has on the evaluation of the dose are discussed. The measurements show the limits imposed by the energy dependence on the evaluation of the dose determined by albedo neutron dosimeters. In most cases evaluation of an individual's dose occurring in a single facility can be reasonably accurate, but it must be known in which facility the person was exposed. The capabilities of TLD albedo dosemeter applied in personnel dosimetry are discussed, with emphasis on the dose range, reproductibility, energy dependence and the detector-to-body distance.

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1. Introduction

If neutron are incident on the human body, they will be moderated and scattered as a result of interactions with the nuclei atom in the body and there will be a flux of thermal and low energy neutrons leaving from surface of the body. These neutrons are called albedo neutrons; and by making appropriate measurements of these albedo neutrons, using a dosimeter worn close to the surface of the body, it is possible to estimate the dose equivalent in the body due to the original incident neutrons. This process is called albedo neutron dosimetry.

Unfortunately, the number of albedo neutrons leaving the body depends not only on the flux of incident neutrons, but on their energy [1].

The attraction of albedo dosimeters is that they can provide a reasonable estimate of dose equivalent in a very wide variety of practical situations [2].

TLD gamma dosimeters, which are combined with any neutron sensitive TL detector to indicate albedo neutrons and/or slow neutrons from the field, are the simplest type of albedo dosimeters, with the advantage of using a plastic encapsulation, flat cadmium filters and dosemeter card for automatic readout [3]. Disadvantages are, however, additional capture gamma rays which increase the apparent gamma dosimeter reading, the variation of response to thermal field neutrons with radiation incidence, and a large detector-to-body distance effect.

Because of sensitivity of TLDs to both neutrons and gamma rays the random statistical uncertainty of the neutron measurement in mixed neutron and gamma rays fields depends on the dose equivalent ratio (H_γ/H_a) and because of the energy dependence of the albedo response it depends also on the neutron energy distribution in the actual stray neutron field [4].

The albedo neutron fluence changes significantly with the direction of radiation incidence and the distance of the albedo dosimeters from the body, resulting in a decrease of albedo reading with increasing dosimeter-to-body distance. The reading contribution of scattered low energy neutrons, on the other hand, increases with increasing distance depending on the type, size and shape of the neutron absorber in the dosimeter encapsulation [5].

2. Experimental part

Standard calibration technique

The routine application of the albedo neutron dosimeter is based on a standard field calibration technique to be performed in the stray radiation field at workplace of interest.

Calibration using Am-Be neutrons or ^{252}Cf sources do not provide calibration factors for stray neutron fields. For an application in personal monitoring, therefore, the neutron response of the albedo dosimeter design must preferably be estimated in each stray neutron field, i.e., for each facility at different work locations. The contribution of the scattered neutron background, mainly in the lower energy range, may change the calibration factor by up to one order of magnitude [6].

The standard field calibration technique results in the estimation of an albedo response in personnel dosimetry which is sufficiently independent of the direction of the radiation incidence. Moreover, a conservative indication of the neutron dose equivalent H'(10) desirable for personnel dosimetry is also obtained.

Results of field calibrations

The calibrations in a variety of neutron fields finally resulted in a classification of four typical areas of application N1 to N4 [7]. The corresponding application areas are specified as follows:

N1: Reactors and accelerators, heavy shielding.
N2: Fuel element cycle, critically, low shielding.
N3: Radionuclide sources.
N4: Accelerators for research inside shielding.

Within the application areas N1 to N2 a constant calibration factor for each area can be applied. For N3 and N4, the use of the reading ratio may reduce local and workplace dependent changes of the neutron response in most cases to about ±30%. An albedo dosimeter may be worn in both application areas N3 and N4 but it must not be used in the application areas N1 or N2.

Table 1. Classification of workspace according to DIN-6802-4.

Workplace category	Neutron calibration factor (relative to ^{137}Cs)
N1: Reactors, strong shielding	0.17 – 0.47
N2: Fuel element cycle	0.88
N3: Radionuclide sources	3.0 – 6.0
N4: High – energy accelerators	?

The neutron response depends on the neutron spectrum. Neutron spectra vary widely in workplaces. However, site specific correction factors can be used to correct for this, provided that the neutron spectrum is known and remains constant.

Albedo dosimeter system

The TLD albedo dosimeter used for personal dosimetry at workplace in Romania is presented in Fig. 1. It consists of a dosimeter badge made of tissue equivalent plastic (ABS) with a cadmium filter in combination with a four element TLD card (Harshaw type 6776 with TLD-600/700 chips - LiF:Mg, Ti, chip size 3.2 × 3.2 × 0.4 mm).

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Fig. 1. Albedo dosimeter system used at Dozimed personal Monitoring Service.

Albedo dosimeters use thermoluminescent detectors such as 6LiF which separate the albedo neutrons from incident thermal neutrons. Because of the photon sensitivity of TLDs, the neutron dose reading is given by the difference between 6LiF and 7LiF detector readings.

Table 2. Description of the dosimeter used.

Element position	Material	Filtration
i	^{6}LiF: Mg, Ti (TLD 600)	465 mg/cm^2 (0.7 mm ABS + 0.5 mm Cd)
ii	^{7}LiF: Mg, Ti (TLD 700)	465 mg/cm^2 (0.7 mm ABS + 0.5 mm Cd)
iii	^{7}LiF: Mg, Ti (TLD 700)	300 mg/cm^2 (3.0 mm ABS)
iv	^{6}LiF: Mg, Ti (TLD 600)	300 mg/cm^2 (3.0 mm ABS)

For evaluation, a Harshaw TLD reader 4500 is used with a special Time – Temperature – Profile (TTP): Preheat: 175 ^{o}C, 10 s, Acquire 15 ^{o}C/s, 300 ^{o}C max., 10 s; Anneal: 300 ^{o}C, 10 s. The main advantage of this TTP is that the usage of an oven for pre- or post-annealing procedures can be avoided.

The albedo dosimeter has entrance windows made of ABS at the front size for the direct neutron signal and at the back side for the albedo neutron signal. The dosimeter is based on the reaction ^{6}Li(n,α)t. The ^{6}LiF detector is also gamma sensitive and therefore the difference to the neutron insensitive ^{7}LiF has to be calculated to determine the neutron signal.

The strong energy dependence of the dosimeter can be compensated by correction the calibration with the ratio of the direct neutron signal to the albedo neutron signal. This method is described in detail in DIN 6802-4.

In practice, we use Harshaw Win8806, a special developed dose calculation algorithm, which divide the neutron energy range in three categories:

- Moderated Cf-252
- Unmoderated Cf-252
- Unknown

When "Moderated Cf-252" or "Unmoderated Cf-252" is selected, there are built-in factors that are applied to the algorithm. When "Unknown" is selected, additional fill-in information is needed, provided from irradiation at a similar neutron source to the source of radiation expected in normal use, including geometry [8].

3. Results and discussions

For the purpose of neutron dosimetry, the neutron and gamma dose contribution must be separated by using the difference in the readings of two detectors of different neutron sensitivity (for instance TLD 600 and TLD 700) rather than a separate glow peak evaluation in a single detector.

In practice, all workplaces were neutron doses can occur, are divided into four categories (N1 – N4), due to the dominant neutron spectrum.

The strong energy dependence of the dosimeter can be compensated by using a special developed dose calculation algorithm, which divides the neutron energy range in three categories.

4. Conclusions

In personal dosimetry, TLD systems are widely used for assessing body and skin doses at personnel dosimetry services. The merits of the thermoluminescence technique are the excellent dosimetric properties of TL dosimeters such as nearly tissue equivalent, high sensitivity, large dose range and excellent low standard deviation of measurement. Disadvantages of this technique may be the complexity of readout, annealing and calibration procedures and the influence of ambient parameters.

Establishing this new service it's a forward step in personal dosimetry in Romania, covering the area of mixed fields gamma - neutrons applications.

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