INTERCOMPARISON OF ENVIRONMENTAL DOSEMETERS USING VARIOUS TL MATERIALS AND DOSIMETRY SYSTEMS

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INTRODUCTION

External gamma radiation from radionuclides naturally present in the environment or released from man-made practices or events is usually an important component of the exposure of human populations. The measurement of environmental gamma ray doses can provide important information for the evaluation of external irradiation of general population. The natural external radiation can be divided into cosmic radiation, radiation of primordial radionuclides in the earth's crust (^{40}K, ^{232}Th, ^{238}U) and airborne component (radon and its progeny). The man-made external radiation consists of radionuclides generated either for or from nuclear, medical and industrial installations.

For environmental dosimetry different passive solid state dosemeters can be applied [1]. The dosemeter systems have to fulfil the requirement to measure the man-made contribution to environmental radiation under variable environmental conditions (UV sunlight, humidity, temperature). To reach international standards and to improve the environmental dosimetry methods there is a need for intercomparisons.

The aim of the present work was to compare the ambient dose equivalent ($H^*(10)$) values determined at 20 sites around NPP Krško, using thermoluminescence (TL) dosemeters with different TL materials and radiophotoluminescence (RPL) dosimetry system.

MATERIAL AND METHODS

Dosemeter systems

The Jožef Stefan Institute (JSI), Ljubljana, Slovenia applied CaF_2:Mn (TLD-400) TL detectors developed in JSI. These dosemeters were read out

by an in–house semiautomatic TL dosemeter reader (TLD-MR-200 C), which has been used successfully for almost 20 years in personal and environmental dosimetry [2]. The measuring parameters can be easily changed, which makes the MR-200 C system suitable for experiments with different thermoluminescent materials. The working procedures for reading the doses and the preparation of the dosemeters are exactly explained elsewhere [3].

The Ruđer Bošković Institute (RBI), Zagreb, Croatia applied LiF:Mg,Cu,P (TLD-100H), CaF_2:Mn and Al_2O_3:C TL detectors as well as radiophotoluminescence (RPL) glass dosemeters type SG1 [4]. TL detectors were evaluated with a TOLEDO 654 (Vinten) reader [5] while for RPL FGD-202 reader was used [4].

All dosemeters provided by JSI were calibrated by ^{137}Cs source in the ambient dose equivalent $H^*(10)$, a quantity which is widely used in environmental dosimetry. The calibrations were performed in the Laboratory for dosimetry standards at JSI [6].

The dosemeters provided by RBI were calibrated in air kerma using ^{137}Cs source in the Secondary Standard Dosimetry Laboratory of RBI [7]. The $H^*(10)$ values were calculated according to [8].

Protocol

Two groups of dosemeters were prepared for field dose measurements. The dosemeters from the Group 1 were deployed at 10 locations in Slovenia and the sites were labelled from 11 to 20. The dosemeters from the Group 2 were deployed at 10 locations in Croatia. They were labelled from 1 to 10. On all locations routine environmental monitoring is carried out continuously for the Krško nuclear power plant. At each location JSI had 2 dosemeters, each contained 2 TLD-400 detectors, RBI applied at each location one TL dosemeter with three detectors and one RPL dosemeter.

The dosemeters were placed at the same locations in as much as possible same conditions, packed in plastic bags or similar material, 1 m above the ground, and away from buildings and other objects that could influence, block or veil the flux of the external radiation to the detector.

The calibration, control and transport detectors (not deployed in the environment) were held in dark storage containers with known dose rate and used to determine the transport and background radiation which was subtracted from the measured values for the dosemeters set outside [9]. The TL responses were also corrected for individual sensitivity of the detectors.

All ambient dose equivalents in this intercomparison were calculated to the monitoring time of the dosemeters in the environment.

RESULTS

Table 1 shows the summarised experimental results for the Group 1, i.e. the mean value of results reported by JSI and by RBI at the locations in Slovenia. The accumulated ambient dose equivalent $H^*(10)$ for the IJS dosemeters (Mean SLO) and the RBI dosemeters (Mean TL+RPL) averaged over the sites labelled by 12 to 20 was (0.40 ± 0.03) mSv. These doses were obtained from the dosemeters which are deployed in the countryside. The average ambient dose equivalent obtained by the dosemeters at the location 11 was (0.29 ± 0.01) mSv, which was placed above the area where the soil was removed and re-filled with the gravel.

Table 1. $H^*(10)$ at various locations in Slovenia reported by JSI and RBI (Group 1). Monitoring time: 176 days

Location SLO	**Mean CRO TL**	**Mean CRO (TL+RPL)**	**Mean SLO TLD-400**
	***H**(10)** [mSv]		
11	0.30 ± 0.05	0.30 ± 0.05	0.28 ± 0.04
12	0.46 ± 0.07	0.44 ± 0.07	0.43 ± 0.06
13	0.41 ± 0.05	0.36 ± 0.05	0.38 ± 0.06
14	0.46 ± 0.07	0.45 ± 0.07	0.45 ± 0.07
15	0.46 ± 0.06	0.38 ± 0.06	0.44 ± 0.07
16	0.41 ± 0.06	0.38 ± 0.06	0.38 ± 0.06
17	0.40 ± 0.08	0.50 ± 0.08	0.39 ± 0.06
18	0.42 ± 0.06	0.38 ± 0.06	0.37 ± 0.06
19	0.38 ± 0.05	0.33 ± 0.05	0.37 ± 0.06
20	0.44 ± 0.06	0.40 ± 0.06	0.39 ± 0.06

The average $H^*(10)$ for the IJS TLD-400 was (0.43 ± 0.03) mSv while for the combined RBI CaF_2:Mn (TLD-400), LiF:Mg,Cu,P (TLD- 100H), Al_2O_3:C, and RPL dosemeters were (0.47 ± 0.03) mSv, (0.40 ± 0.05) mSv, (0.41±0.04) mSv, and (0.40±0.06) mSv, respectively. From these results it can be seen that the $H^*(10)$ obtained by the dosemeters of various types deployed in the countryside fluctuate less than 10 %. The highest $H^*(10)$ values were measured with CaF_2:Mn detectors reported by RBI. It is well-

known that CaF_2:Mn detectors show enhanced read-out sensitivity for the photon energies below 200 keV. According to the measurement protocol at the JSI the measured results for the CaF_2:Mn were multiplied by a factor of 0.88, thus the values are lower than those reported by the RBI. The ratio between the results reported by the JSI and RBI for the CaF_2:Mn was (0.86 ± 0.02).

The results reported by JSI and RBI for the dosemeters used in the Group 2 are shown in Table 2. The average $H^*(10)$ for the TLD-400 dosemeters for the sites labelled from 1 to 10 was (0.40±0.07) mSv while the average $H^*(10)$ obtained by RBI dosemeters was (0.39±0.06) mSv.

Table 2. $H^*(10)$ at various locations in Croatia reported by JSI and RBI (Group 2). Monitoring time: 174 days

Location CRO	**Mean SLO TLD-400**	**Mean CRO (TL-RPL)**	**Mean CRO TL**
	***H**(10)** [mSv]		
1	0.49 ± 0.07	0.47 ± 0.09	0.48 ± 0.06
2	0.44 ± 0.06	0.40 ± 0.10	0.42 ± 0.08
3	0.45 ± 0.07	0.47 ± 0.08	0.50 ± 0.03
4	0.43 ± 0.06	0.38 ± 0.13	0.37 ± 0.11
5	0.29 ± 0.04	0.31 ± 0.05	0.33 ± 0.05
6	0.36 ± 0.05	0.36 ± 0.06	0.38 ± 0.02
7	0.45 ± 0.06	0.43 ± 0.09	0.46 ± 0.07
8	0.33 ± 0.05	0.32 ± 0.07	0.32 ± 0.05
9	0.45 ± 0.07	0.41 ± 0.09	0.43 ± 0.07
10	0.33 ± 0.05	0.33 ± 0.05	0.34 ± 0.05

From data in Tables 1 and 2 the average ratio of the $H^*(10)$ reported by JSI and RBI for both groups of dosemeters can be calculated. For the Group 1 the average ratio was 0.94, ranging from 0.88 to 0.99. The average ratio for the dosemeters from the Group 2 was 1.00, found in the interval from 0.89 to 1.17.

CONCLUSION

The comparison between the measurement results reported by two independent institutions from Slovenia and Croatia was performed with a satisfactory outcome. All the results reported by the JSI and RBI were found

comparable within the measurement uncertainty. This conclusion is very important from the point of view that the results were obtained by various TL materials, and different dosimetry systems (TL and RPL) which utilize different measurement protocols. The outcome should emphasize also in the manner that the results obtained and reported in the intercomparison can be traceable to the primary standards.

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The aim of the present work was to compare the ambient dose equivalent ($H^*(10)$) values determined at 20 sites around NPP Krško, using different thermoluminescence (TL) materials and various dosimetry systems. The $H^*(10)$ was measured by the CaF_2:Mn (TLD-400) provided by the Jožef Stefan Institute (JSI) Ljubljana, Slovenia. These dosemeters were deployed in the environment in plastic bags and suspended inside the plastic bottles. On the other hand the Ruđer Bošković Institute (RBI), Zagreb, Croatia applied LiF:Mg,Cu,P (TLD-100H), CaF_2:Mn, Al_2O_3:C TL detectors and radiophotoluminescence (RPL) glass dosemeters type SG1. They were placed at the same locations in as much as possible same conditions as JSI detectors.

According to the protocol established for this intercomparison, the control and transport detectors (not deployed in the environment) were held in dark storage containers and used to determine the background radiation. The TL responses were corrected for individual sensitivity of the TL detectors which is an important factor after the calibration irradiations. The calibration irradiations were performed by ^{137}Cs sources provided in Secondary Standard Dosimetry Laboratory facilities at the JSI and RBI.

The results obtained by different TL materials and different dosimetry systems show interesting features especially concerning local environmental peculiarities. The $H^*(10)$ obtained by the dosemeters of various types deployed in the countryside fluctuate less than 10 %. The outcome should emphasize also in the manner that the results obtained and reported in the intercomparison are traceable to the primary standards.