COMPARATIVE RESPONSES OF THERMOLUMINESCENT DOSIMETERS IN ENVIRONMENTAL MONITORING SITUATIONS

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1. INTRODUCTION

Ambient radiation measurements are of importance in defining natural background levels and for determining the extent and significance of additional radioactivity introduced into the environment from man-made sources. Various types of radiation detection equipment and dosimeters have been applied to the evaluation of ambient radiation levels. Recently, Thermoluminescent Dosimeters (TLD's) using various phosphors have been effectively utilized for these types of measurements (1). Although considerable information is available in the literature on Thermoluminescent Dosimetry, data relating to actual response characteristics of the various phosphors, specifically to terrestrial and cosmic radiation, is not readily available.

2. METHODOLOGY

The evaluation of the response characteristics and reliability of TLD's for environmental measurements was performed by simultaneously exposing applicable phosphors to cosmic and various levels of terrestrial and man-made radiation. The locations were selected to cover a variety of situations, which included urban environments, the environs of a nuclear power installation, and a high mountain lake essentially free from terrestrial and man-made radioactivity. The same dosimeters used were included in the Second International Cross Check conducted by the Health Safety Laboratory (HASL) (2) to confirm the validity of the results obtained through this comparative study. Measurements were also undertaken with a Reuter-Stokes Pressurized Ionization Chamber and by using a 7.6 cm by 7.6 cm Sodium Iodide scintillation detector coupled to a gamma spectrometer for comparative purposes (3).

The applicable phosphors used in this comparative study were CaF_2:Dy, CaF_2:Mn and LiF-700; specifically CaF_2:Dy and LiF-700 (3.2 x 3.2 x 0.9 mm) chips and CaF_2:Dy and CaF_2:Mn bulb assemblies manufactured by the Harshaw Chemical Company. Shielding consisting of a 0.9 mm copper capsule providing an effective lower energy cut off at 40 KeV was used to normalize the lower energy response of the CaF_2:Dy chips, figure 1. The CaF_2:Dy and CaF_2:Mn bulb assemblies use an outer tantalum shield and single phosphor chip and heating element encapsulated in glass,in figure 2. The more linear response characteristics of LiF-700 chips allowed encapsulation in unshielded plastic holders. A standard one meter distance was used to obtain the comparative response data in the terrestrial environment. The dosimeters themselves were contained in the arms of a plastic pipe stand as shown in figure 4.

Calibrations of the dosimeter and radiation counting equipment was conducted under controlled conditions similar to the placement and corresponding to exposure levels received in the environment. A 1.0 mg radium source certified by the U.S. National Bureau of Standards was used for this purpose.

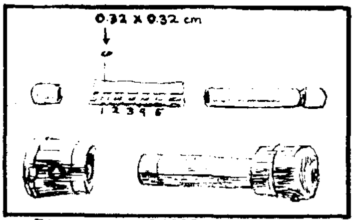

Figure 1 CHIP ASSEMBLY

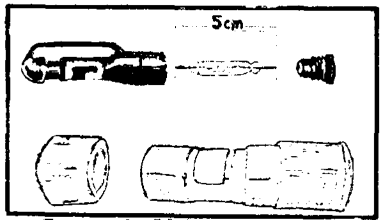

Figure 2 BULB ASSEMBLY

Harshaw 2000 and 2000P systems were used for the processing of the chips and bulbs. These systems consist of a thermoluminescent detector coupled to an automatic integrating picoammeter. Prior to use, all chips were segregated and grouped according to their response characteristics. The five chip per dosimeter capsule initial groupings were maintained throughout the study for each location. Annealing of the chips and bulb assemblies required prior to all exposures followed the Harshaw recommendations (4).

3. OBSERVATIONS

This comparative response study confirmed the TLD phosphor CaF_2:Dy as being the most sensitive to the environmental radiation spectra as stated in the literature (1). This material was observed to be ten times more sensitive than CaF_2:Mn and thirty times more sensitive than LiF-700 phosphors. This high sensitivity is of importance in obtaining statistically significant data using exposure periods as short as thirty days. The data among the various phosphors exposed to various environmental situations as presented in Table 1 showed excellent agreement and internal precision. The long term environmental radiation data and exposures derived through the International Cross Check Study determined by using LiF-700 phosphors were approximately 15% lower when compared to other TLD materials used. Note Table 3.

The use of CaF_2:Dy and CaF_2:Mn phosphors was successfully applied to the measurement of cosmic ray intensities in an environment essentially free of terrestrial and man-made activity, the center of a large lake at an elevation of 968 meters as shown in figure 3. The dose rate determined at the surface using CaF_2:Dy bulb and chip dosimeters was 0.09 mR/day while CaF_2:Mn bulbs indicated a dose rate of 0.08 mR/day. These values compare favorably with the exposure rate value for absolute cosmic ray intensities of 0.11 mR/day at this elevation for latitude North 50 degrees as published by Lowder and Beck (5).

Using the same types of TLD dosimeters, sealed in plastic pipe, additional underwater measurements at 20 meter increments extending to the bottom of this lake were undertaken to determine the phosphor responses to a harder cosmic spectra. The decrease in the exposure rates observed with increasing depth is presented in graphical form in figure 5 and corresponds to the attenuation of cosmic rays in water as detailed by Rossi (6). The dose rates on the bottom, however, were higher resulting from the natural and fallout origin radioactivity contained in the sediments. The intercomparison of the CaF_2:Dy chip and bulb dosimeters over extended periods of six months underwater showed the same overall trends. The chip dosimeters were approximately 20% more sensitive to the cosmic spectrum than the equivalent phosphor bulb assemblies as displayed in figure 6. The exposure rates determined at appropriate sites using a pressurized ionization chamber and gamma spectrometer compared favorably with quarterly data accumulated using TLD dosimeters. This information presented in table 2 showed similar trends among sampling locations.

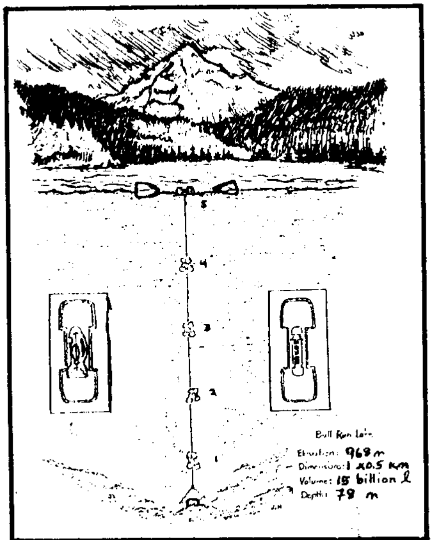

Fig. 3 HIGH MOUNTAIN LAKE

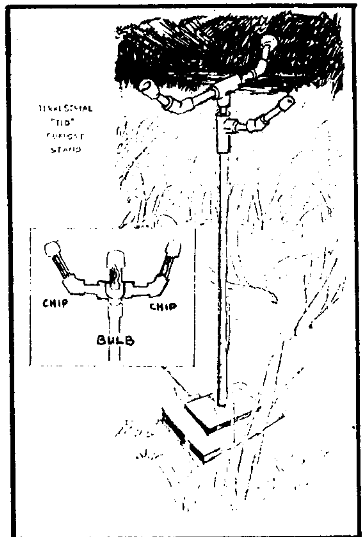

Fig. 4 TLD SUPPORT STAND

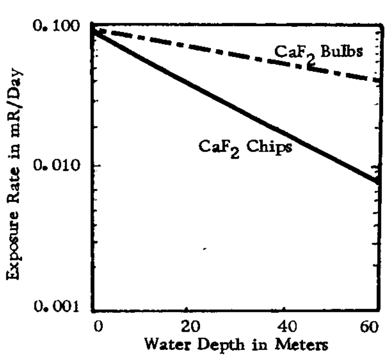

Figure 5 Cosmic Ray Attenuation in Water

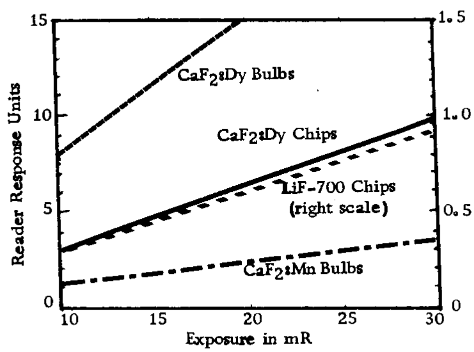

Figure 6 Dosimeter Sensitivities

4. CONCLUSION

Thermoluminescent Dosimetry can be effectively used to monitor environmental exposure rates. Using applicable phosphors and procedures it was concluded that variations of less than 10 mR/year from established ambient levels can be detected with statistical confidence when the normal seasonal variations have been determined. Of the dosimeters evaluated the preferred choice for this purpose due to their high sensitivity, was CaF_2:Dy chips although their handling, shielding and processing involved complex procedures. The CaF_2:Dy bulb dosimeters were comparable in response to these chips for this type of monitoring. However, their easier handling and processing procedures are somewhat compromised by the larger capital investment in the dosimeters themselves.

Ambient radiation measurements using gamma spectrometers or pressurized ionization chambers were observed to be comparable with accumulated exposure rate data obtained using TLD dosimetry when appropriate calibration procedures are utilized. Additional ambient measurements of this type are considered to be useful in confirming the validity of the TLD data being accumulated over extended periods.

Table 1: Comparative Responses of TLD's in Various Environmental Monitoring Situations. Results Expressed in mR/Day				
Environmental Situation	LiF-100 Chips	CaF_2:Dy Chips	CaF_2:Dy Bulbs	CaF_2:Mn Bulbs
Nuclear Facility	-	0.16 ± 0.01	0.17 ± 0.01	0.15 ± 0.01
	-	0.16 ± 0.01	0.18 ± 0.01	0.15 ± 0.01
	-	0.14 ± 0.01	0.17 ± 0.01	0.16 ± 0.01
	-	0.18 ± 0.01	0.17 ± 0.01	0.16 ± 0.01
	-	0.19 ± 0.01	0.19 ± 0.01	0.17 ± 0.01
High Mountain Lake (4 Depths 20m increments)	-	0.09 ± 0.003	0.09 ± 0.003	0.08 ± 0.003
	-	0.03 ± 0.001	0.08 ± 0.002	0.06 ± 0.002
	-	0.02 ± 0.001	0.06 ± 0.002	0.04 ± 0.001
	-	0.01 ± 0.001	0.05 ± 0.002	0.04 ± 0.001
Urban Environment	0.17 ± 0.01	0.20 ± 0.01	-	-
	0.16 ± 0.01	0.18 ± 0.01	-	-

Table 2: Comparative Responses of TLD's to Other Radiation Detection Equipment. Results Expressed in mR/Day			
	Type of Detector		
Location	CaF_2:Dy Chips	7.6cm x 7.6cm NaI:Tl Crystal	Reuter-Stokes Pressurized Ion Chamber
1	0.21	0.22	0.19
2	0.17	0.14	0.16
3	0.19	0.18	0.18
4	0.19	0.15	0.17
5	0.10	0.07	0.10
6	0.20	0.16	0.18
7	0.21	0.19	0.18
8	0.18	0.14	0.17

Table 3: Comparative Responses of TLD's in International Cross Check. Results Expressed in Total mR				
	CaF_2:Dy Chips	CaF_2:Dy Bulbs	LiF-700 Chips	Mean of All Participants
Field Exposure	15.8 ± 0.9	14.8 ± 1.5	11.4 ± 0.6	16.4 ± 3.8
Lab Exposure	17.8 ± 0.9	15.7 ± 1.6	14.3 ± 1.0	18.8 ± 3.8

References

(1) Denham, D.H., Kathren R.L., Corley J.P., A CaF_2:Dy Thermoluminescent Dosimeter for Environmental Monitoring, Battelle Northwest Laboratory Report #SA-4191, (1972).

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