Letter to the Editor

Intercomparison of Environmental Gamma doses Measured with A NaI (Tl) Survey Meter and Thermoluminescent Dosimeters (TLDs) in the Poonch Division of Azad Kashmir, Pakistan

Muhammad Rafique[1,2,#], Kimberlee J Kearfott[1], Khalil Ahmad[3], Jabeen Akhter[3], Abdul Razzaq Khan[2], Raja Azhar Saeed[2], Saeed Ur Rahman[4], Matiullah[5], and Muhammad Usman Rajput[6]

This study presents the intercomparison of the outdoor environmental gamma dose rates measured using a NaI (Tl) based survey meter along with thermoluminescent dosimeters (TLDs) and estimation of excess lifetime cancer risk (ELCR), for the inhabitants of Poonch division of the Azad Kashmir, Pakistan. CaF_2: Dy (TLD-200) card dosimeters were installed at height of 1 m from ground at fifteen different locations covering the entire Poonch division comprising of three districts. During three distinct two month time periods within the six month study period, all the installed dosimeters were exposed to outdoor environmental gamma radiations, retrieved and read out at Radiation Dosimetry Laboratory, Health Physics Division, PINSTECH laboratory, Islamabad. The ambient outdoor gamma dose rate measurements were also taken with NaI (Tl) based portable radiometric instrument at 1 m above the ground. To estimate the annual gamma doses, NaI (Tl) based survey data were used for one complete year following the deployment of the dosimeters. The mean annual gamma dose rates measured by TLDs and survey meter were found as 1.47±0.10 and 0.862±0.003 mGy/y respectively. Taking into account a 29% outdoor occupancy factor, the annual average effective dose rate for individuals was estimated as 0.298±0.04 and 0.175±0.03 mSv/y by TLDs and survey meter, respectively. For outdoor exposure, the ELCR was calculated from the TLD and survey meter measurements. The environmental outdoor average annual effective dose obtained in present study are less than the estimated world average terrestrial and cosmic gamma ray dose rate of 0.9 mSv/y reported in UNSCEAR 2000. The possible origins of gamma doses in the area and incompatibilities of results obtained from the two different measurement techniques are also discussed.

TLDs were used to assess gamma doses in outdoor environment of Poonch division of the Azad Jammu and Kashmir, Pakistan. TLDs are widely used for environmental monitoring of gamma dose levels due to their attractive features of low cost, small size, lack of requirements for power and electronics, integrating nature, reusability, and large useful dose range (0.1 μGy to 10^4 Gy). In addition, the required calibrations are readily accomplished[1], environmental signal fading effects are reproducible and correctable[2-4], measurements are suitably accurate and precise[5]. This study intercompares data obtain using a survey meter with integrated TLD results while also establishing baseline background radiation levels and estimates ELCR for inhabitants. It is also a continuation of efforts to determine baseline background radiation data for Azad Kashmir and other parts of Pakistan[6-7].

TLD cards with two 3×3×0.89 mm^3 CaF_2: Dy chips (i.e. TLD-200, Thermo Scientific/Harshaw, 6801 Cochran Road, Solon, OH 44139, USA) encapsulated between Teflon sheets were used for measurements. The dosimeters were annealed before field deployment. These TLDs were covered with black paper and placed in Polyethylene bags to protect them from ultraviolet (UV) light and moisture. Polyethylene boxes containing dosimeters were installed at 15 different locations away from buildings at 1 m heights above the ground using iron

doi: 10.3967/bes2014.138

1. University of Michigan, Department of Nuclear Engineering and Radiological Sciences, 2355 Bonisteel Boulevard, Ann Arbor, MI 48109-2104, USA; 2. Department of Physics University of Azad Jammu and Kashmir Muzaffarbad, 13100, Azad Kashmir, Pakistan; 3. Radiation Dosimetry Laboratory, Health Physics Division, PINSTECH, 45650, Nilore Islamabad, Pakistan; 4. Department of Medical Physics, Nuclear Medicine, Oncology and Radiotherapy Institute, 44000, Islamabad, Pakistan; 5. Directorate of Systems and Services, PINSTECH, 45650, Nilore Islamabad, Pakistan; 6. Physics Division, Pakistan Institute of Nuclear Science and Technology (PINSTECH), 45650, Nilore Islamabad, Pakistan

bars, as shown in Figure 1.

The outdoor dose rate measurement using TLDs commenced in September 2012 and was completed in March 2013. The installed numbers of TLDs were proportionate to the local population. Since the subdivision Rawalakot is highly populated six TLDs were installed in this subdivision, while three TLDs each were placed in the Hajira, Abbaspur, and Thorar subdivisions.

After each deployment interval, the exposed dosimeters were retrieved and read out on a semiautomatic tabletop hot gas TLD reader (Model 4500 TLD Reader, Thermo Scientific/Harshaw, 6801 Cochran Road, Solon, OH 44139, USA). Data were collected and processed using commercial software provided with the reader (WinREMS, Thermo Scientific/Harshaw, 6801 Cochran Road, Solon, OH 44139, USA). All dosimeters were calibrated with 10×10 cm^2 radiation field size and a 1 m distance from a ^{137}Cs source in a laboratory that is part of the network of approved IAEA/WHO secondary standard dosimetry laboratories (Radiation Dosimetry Laboratory, PINSTECH, Nilore Islamabad, Pakistan).

All the readings were corrected for the fading effect. Environmental background gamma radiation dose rates at each location were determined by multiplying the TLD response by a calibration factor.

To compare passive integrating with active instantaneous measurement techniques, a recently calibrated sensitive portable gamma ray survey meter containing an internally mounted 2.54 cm diameter x 2.54 cm long NaI (Tl) scintillator (Model 19,

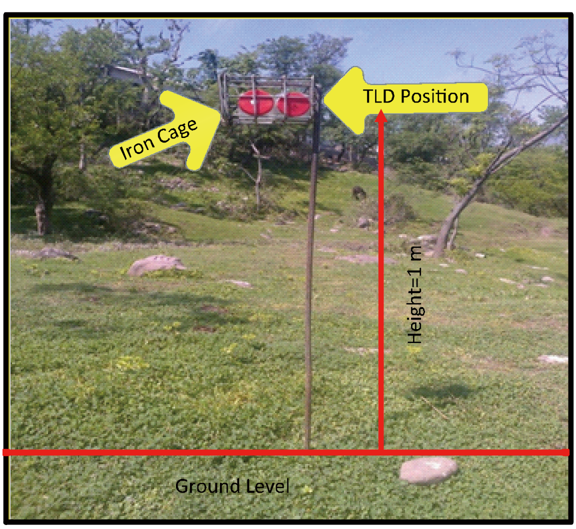

Figure 1. A glimpse of installed detector (TLD-200) in study area.

Ludlum Measurements Inc., 501 Oak Street, Sweetwater, TX 79556 USA) was used for ambient outdoor gamma dose measurements. Measurements were taken in air 1 m above ground at 15 different locations. Based upon ^{137}Cs, the sensitivity of the survey meter is 175 cpm/micro R/hr. For every location five measurements were taken on different days within each month, with each measurement was spanning over a time period of 2 min. The exposure rate was converted into absorbed dose rate using a standard conversion. Measurements were taken for one complete year.

Gamma dose rates (GDR) obtained from yearly measurements with the survey meter were subsequently used to find a value for annual gamma dose measured by TLDs. An empirical relation was developed to get the estimate, namely:

$$AGDR_{TLDs}=6\ months\ GDR_{TLDs}\times\left(\frac{A+B}{A}\right) \quad (1)$$

Where $AGDR_{TLDs}$ is annual gamma dose rates measured by TLDs and 'A' represents the 6 months survey meter gamma doses measurements during which TLDs were deployed, and 'B' represents the 6 months during which only the survey meter was used.

For the purpose of determining the annual effective dose equivalent (AEDE) interviews of the population living in the regions were conducted to determine the amount of time spent outdoors. More than 150 individuals, distributed evenly across the regions being surveyed, were contacted during four seasons, spanning over the year.

The results obtained in current study with TLDs for all three exposure rounds are shown in Table 1. As may be seen in this table, for first exposure round minimum and maximum gamma dose rate were 0.20±0.04 and 0.41±0.29 mGy/y, respectively. The arithmetic mean, geometric mean and geometric standard deviation were 0.27±0.07, 0.27±0.049, and 1.078±0.06 mGy/y, respectively. Minimum gamma dose rate was found at location L-4 whilst maximum was found at L-12. For the second round of monitoring, minimum and maximum gamma dose rates were found to be 0.18±0.04 and 0.30±0.04 mGy/y at the L-5 and L-15 locations, respectively. Corresponding arithmetic mean, geometric mean, and geometric standard deviation were 0.24±0.05, 0.238±0.039, and 1.068±0.07 mGy/y respectively. For the third time period, minimum and maximum gamma dose rates were 0.14±0.03 and 0.24±0.03 mGy/y at locations of L-5 and L-15, respectively. The arithmetic mean, geometric mean, and geometric standard deviation were computed to be 0.18±0.04, 0.179±0.034, and 1.080±0.06 mGy/y, respectively.

The results of the monthly survey meter monitoring are shown in Figure 2. Five readings were taken and they were averaged to get single value for each month of the year. The annual gamma dose measured with the survey meter was 0.862 mGy/y.

Gamma doses obtained by the TLDs over the three time periods (September-October, November-December, and January-February) were compared to the complete year of survey meter data, which had sampling of 5 days per month. As may be seen in Figure 2, the maximum average outdoor gamma dose rate, in June, was 0.132 µGy/h, while the minimum was 0.0696 µGy/h during February. Since in June temperatures rise to their maximum value, the increased dose rate may be attributed due to reduction in soil moisture, as soil moisture can attenuate gamma radiations to in appreciable amounts. Similarly seasonal variation of radon and its progenies also affects the gamma dose rates. February is quite a cold month and the area of study is often covered with snow that minimizes the contributions of radon progeny (^{214}Pb and ^{214}Bi, both β-decay accompanied with gammas) to the total gamma dose rates. The annual average gamma dose measured with the survey meter was 0.862 mGy/y.

Table 1. Gamma dose Rates for First Three Round Measurements

Location	September-October (mGy/y)	November-December (mGy/y)	January-February (mGy/y)
L-1	0.26±0.06	0.25±0.06	0.15±0.05
L-2	0.22±0.03	0.27±0.10	0.21±0.08
L-3	0.27±0.02	0.24±0.01	0.19±0.03
L-4	0.20±0.04	0.21±0.04	0.20±0.04
L-5	0.25±0.05	0.18±0.04	0.14±0.02
L-6	0.25±0.06	0.20±0.03	0.15±0.03
L-7	0.29±0.06	0.29±0.07	0.16±0.04
L-8	0.25±0.05	0.21±0.03	0.16±0.02
L-9	0.31±0.02	0.29±0.03	0.16±0.02
L-10	0.35±0.20	0.25±0.10	0.23±0.03
L-11	0.25±0.03	0.21±0.02	0.14±0.03
L-12	0.41±0.29	0.28±0.11	0.23±0.05
L-13	0.25±0.05	0.22±0.05	0.19±0.05
L-14	0.28±0.04	0.24±0.01	0.19±0.02
L-15	0.28±0.03	0.30±0.04	0.24±0.03
Maximum	0.41±0.29	0.30±0.04	0.24±0.03
Minimum	0.20±0.04	0.18±0.04	0.14±0.03
A.M	0.27±0.07	0.24±0.05	0.18±0.04
G.M	0.270±0.049	0.238±0.039	0.179±0.034
G.S.D	1.078	1.068	1.080

Using Equation (1), an estimate for annual gamma dose rates measured by TLDs was obtained by using survey meter data to fill in the missing six months of TLD data. In effect, a seasonal correction was being performed. The resulting annual gamma dose obtained from the measurements of TLDs was found as 1.469 mGy/y.

People living in the studied area spent almost 7 h outdoors and 17 h indoors, corresponding to occupancy factors of 0.71 (17/24), and 0.29 (5/24), respectively. Using a dose conversion factor of 0.7 Sv/Gy from absorbed doses in air to effective dose received by adults[8], the annual effective dose equivalent (AEDE) was determined to be:

AEDE (Outdoor) (mSv/y)=Absorbed dose rate (nGy/h)×8760 h×0.7 Sv/Gy×0.29×10^{-6} (2)

The mean value for outdoor exposure measured by TLDs was 167.8 nGy/h, and so by applying equation (2), the value obtained is 0.298 mSv/y.

Based upon calculated values of AEDE, Excess lifetime cancer risk (ELCR) for outdoor gamma exposure was calculated from:

Excess Lifetime Cancer Risk (ELCR)=AEDEx Average duration of life (DL) x Risk Factor (RF) (3)

Where AEDE, DL, and RF is the annual effective dose equivalent, duration of life (66 y)[9] and the risk factor (Sv^{-1}), fatal cancer risk per Sievert. For low dose background radiations that are considered to produce stochastic effects, ICRP 60 uses values of 0.05 for the public exposure[10]. For outdoor exposure, mean value of ELCR measured by TLDs and survey meter were 9.85×10^{-4} and 5.77×10^{-4}. Average value of ELCR measured by TLDs and survey meter are less than the world average value of 0.29×10^{-3}.

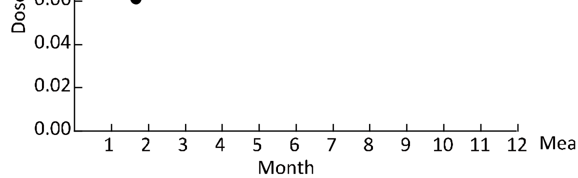

Figure 2. Gamma Dose rates, measured by Ludlum microR meter-19.

The annual mean gamma dose measured by TLDs (1.469 mGy/y) is greater than that determined using the survey meter measurements (0.862 mGy/y). This difference between two different measurement methodologies may be resulted from the fact that only five measurements were taken in a month at particular location, whilst TLDs responded for whole time exposure. TLDs have registered the diurnal effects and have registered night and day time variations in gamma dose rates as well.

In summary, our findings shows that the outdoor average annual effective gamma dose measured for the current study is less than the UNSCEAR 2000 average value of 0.9 mSv/y. Also, mean value of ELCR 9.85×10^{-4} and 5.77×10^{-4} obtained from TLDs and the survey meter, respectively, for this study is less than the world average value of 0.29×10^{-3}. Gamma doses obtained by TLDs are higher than those measured by the survey meter. The data obtained in this study can serve as baseline data for future investigations and can also be useful for natural radioactivity mapping. There was no known prior TLD data in the area of study and these data can be utilized as a reference data for monitoring of possible radioactivity pollution in the future. One of the authors, Muhammad Rafique is thankful to Higher Education Commission of Pakistan for providing postdoctoral fellowship through grant No. Ref: 2-6(22)/PDFP/HEC/2013/14.

[#]Correspondence should be addressed to Dr. Muhammad Rafique, E-mail: mrafique@gmail.com; kmir@umich.edu; mrafique@ajku.edu.pk; rafi_722002@ yahoo.com

Biographical note of the first author: Muhammad Rafique, male, born in 1972, PhD, professor, major in reactor physics, radiation dosimetry, radiation shielding, environmental radiations and fluid dynamics.

Received: July 9, 2014;
Accepted: October 29, 2014

REFERENCES

1. Simpkins RW, Kearfott KJ. The Minimum number of observations necessary to develop an average thermoluminescent dosimeter element correction factor. Radiat Prot Manag, 1997; 13, 55-61.
2. Harvey JA, Haverland NP, Kearfott KJ. Characterization of the glow peak fading properties of six common thermoluminescent materials. App Radiat Isot, 2010; 68, 1988-2000.
3. Harvey JA, Kearfott KJ. Reproducibility of glow peak fading characteristics of thermoluminescent dosimeters. Radiat Meas, 2011; 46, 319-22.
4. Harvey JA, Kearfott KJ. Effects of high ambient temperature on glow-peak fading properties of LiF: Mg, Ti thermoluminescent dosemeters. Radiat Prot Dosim, 2012; 149, 109-15.
5. Harvey JA, Thomas EM, Kearfott KJ. Quantification of various factors influencing the accuracy and precision of thermoluminescent detector calibrations for new and used chip sets. Health Phys, 2011; 100, S79-S91.
6. Rafique M. Ambient indoor/outdoor gamma radiation dose rates in the city and at high altitudes of Muzaffarabad (Azad Kashmir). Environ Earth Sci, 2013; 70, 1783-90.
7. Rafique M, Basharat M, Azhar SR, et al. Effect of geology and altitude on ambient outdoor gamma dose rates in district poonch, Azad Kashmir. Carpath J Earth Env, 2013; 8, 165-73.
8. UNSCEAR. Ionizing radiation: Sources and biological effects, report to the general assembly with scientific annexes, United Nations, New York, 2000.
9. Worldstat info, http://en.worldstat.info/Asia/Pakistan, [2014-03-17].
10. Recommendations of the ICRP. Annals of the ICRP, 1990, 21, Publication 60.