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Study of Thermoluminescence Property of Himalayan Stones for Nuclear Radiation Measurement

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Abstract: In this work, the Thermoluminescence (TL) property of Himalayan stones (natural stone) was investigated for their likely applications in nuclear radiation measurement. Twenty six (26) natural stones sample of size varying from 50-100 gm and different colours were selected from the bank of river Ganga at Rishikesh, in a clean carry bag. Powder samples of size 150-212μm were prepared from each stone samples. The prepared powder samples (each weighing 50 mg) were divided into two parts, one part kept for background measurement and the samples from the other part were positioned at 20 cm from the ^{60}Co radiation and irradiated for calculated exposure time 47 min for 300R exposures. The TL integral count and TL glow curve of the samples were recorded by Nucleonix TLD Reader. On the basis of given information by TLD Reader the TL sensitivity of Himalayan stones was discussed in terms of AU/R/mg and Natural Radiation exposure in Himalayan stones was estimated. The future prospects of higher sensitive stones is also discussed.

Keywords: Thermoluminescence, Himalayan stones, Nucleonix TLD Reader, Glow curve, Natural radiation exposure.

1. INTRODUCTION:

Thermoluminescence (TL) is a form of luminescence, exhibited by certain materials, such as some mineral, when some of the previously absorbed energy from electromagnetic or other ionizing radiation is re-emitted as light upon heating of the material. TL characteristics of a material (phosphers) are expressed by a few parameters, such as order of kinetics, activation energy and frequency factors. The knowledge of these parameters is essential for the understanding of TL process occurring in a phosphor. There are many experimental techniques, developed on the basis of glow curve shape, heating rate phosphorescence decay etc [1]. In the TL process, part of energy absorbed by the material is re-emitted during heating, in form of light. The plot of the TL intensity (light output) as a function of rising temperature exhibiting one or more peaks is called a glow curve. The glow curve provides a useful tool for studying the traps and trapping parameter, such as trap depth E, kinetic order b and frequency factor, etc. [2].

2. MATERIALS AND METHODS:

Twenty six (26) natural stone samples were collected from the bank of river Ganga at Rishikesh. Stones sample of size varying from 50-100 gm and of different colours were selected from the river bank in a clean carry bag. After that the sample stones were labeled and then crushed to make fine powder of size varying between 150-212 μm with the help of metal grinder and combination of two sieves respectively. 50 mg of each powder samples were weighed with digital balance and were separated into two sets. One set was kept for background measurement and the other was used for exposure measurement.

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2.1.TL measurement setup:

The PC controlled TLD reader (Model: TL10091, make: M/S Nucleonix System Pvt. Ltd., Hyderabad, India) was used for investigation of TL property of the material under study. This system is comprised of two essential parts (1) the integral TLD reader, (2) Personnel computer system with TL data acquisition and analysis software. The integral TLD reader consists of low voltage and high voltage supplies, temperature controller, thermocouple amplifier circuits, microcontroller based data acquisition circuits, photomultiplier Tube (PMT), heat transformer, PMT current to frequency converter and kanthal strip for sample loading with drawer assembly. All these equipments are kept inside a single enclosure. The TL light output from the sample is detected by the photomultiplier tube (PMT), which is amplified and recorded. Here heating is done by resistive heating method, in which electric current is passed through a planchet so as to raise the sample temperature in a controlled manner.

2.2. Experimental Procedures:

The heating profile of the equipment is adjusted as per measurement requirements. In this study, linear heating profile at the rate of 5^0C/Sec was used with constant heating at temperature 300 ^{0}C for 20 sec and another 20 sec allowed for cooling. The prepared powder samples were irradiated in calibrated gamma radiation field of average energy (1.25 MeV) emitted from ^{60}Co sources of Industrial Gamma Radiation Exposure Device (IGRED), Model: Techops-741 at Defence Laboratory, Jodhpur. The γ radiation from $^{60}\mathbf{Co}_{27}$ is nearly mono-energetic, being made up of two photon energies, 1.17 MeV and 1.33 MeV, giving an average of 1.25 MeV (Technical report, 1987). The desired exposure rate and accordingly the irradiation time for the samples were calculated using the standard and calibrated radiation field data provided by Bhabha Atomic Research Centre (BARC), Mumbai.

Standard Radiation Field data:

- Source: ^{60}Co, $T_{1/2}$ = 5.27 years
- Exposure rate at 33.3 cm from the source: 303.125 R/h as on 25/07/2012

Calculation of exposure data for sample irradiation:

- Date of experiment: 26/06/2018
- Total time elapsed since calibration: 26/06/2018 – 25/07/2012 (06 years)
- Exposure rate $X(t) = X(o).\exp-[(0.693x\ t)/T_{1/2})]$
  $X(t) = 303.125 \text{ x } \exp-[(0.693x6)/5.27] = 137.71$ R/h as on 26/06/2018
- Let us apply inverse square law for calculating exposure rate at 20 cm distance from the source.
- Exposure rate at 20 cm from the source: 137.71 (33.3/20)2 = 381.76 R/h
- Irradiation time for 300 R = 300 / 381.76 h = 0.77 h = 47 min

The prepared samples were divided into two parts, one part kept for background measurement and the samples from the other part were positioned at 20 cm from the ^{60}Co radiation source and irradiated for calculated exposure time 47 min for 300 R exposures.

2.3. Thermoluminescence Measurement:

50 mg of each powder samples were weighed with digital balance, properly immobilized and uniformly spread over the heating element of the TL Reader. The TL measurement sequence was run and the TL output was stored in proper file of the computer system of the unit. This procedure was repeated five times for all the samples (background and exposed).

2.4. Observations:

First we do a run without giving any exposure to the stone samples to determine background (Natural) TL count (AU). Next, we do a run with exposed stone samples to determine TL integral counts (300R) like reading1, reading2….etc. Then we take an average of those TL integral counts (300R). To obtaining net TL integral counts for 300R we subtracted background (Natural) TL counts from average TL integral counts.

We define sensitivity as,

$$Sensitivity = \frac{Net\,TL\,integral\,count}{300\,R}$$

Here unit of sensitivity is AU/R/50mg, where AU is arbitrary unit.

We define,

$$Natural\,radiation\,exposure\,(Roentgen) = \frac{Background\,(Natural)\,TL\,count}{sensitivity}$$

and,

$$Minimum\,exposure\,detection\,(Roentgen) = \frac{512\,R}{sensitivity}$$

Here the factor 512 Roentgen is Minimum Detectable Activity (MDA). It is defined as the activity which will result in a count rate significantly different from background for a given time.

Therefore,

$$MDA = \frac{M_{min.sensitivity} + N_{max.sensitivity}}{2}$$

Where M & N is twice of a standard deviation of an average TL counts of completely annealed stone.

The TL Integral counts of the samples for background and the radiation exposure are shown in Table 1. The glow curves of the samples for background and the radiation exposures measured using the Nucleonix TLD reader are shown in Fig.1 to Fig.3 for three important samples (S-2, S-7, S-15).

Table 1: TL Analysis of Himalayan Stones for Nuclear Radiation Measurement

TL Analysis of Himalayan Stones for Nuclear Radiation Measurement									
Sample ID	Background (Natural) TL Integral count (AU)	TL Integral Counts (300 R)			Average TL Counts	Net TL Integral Counts for 300 R	Sensitivity (AU/R/50mg) A	Natural Radiation Exposure (Roentgen)	Minimum Exposure Detection (Roentgen)-512/A
		Reading-1	**Reading-2**	**Reading-3**					
S-2	74566.00	80893.00	81991.00	81245.00	81376.33	6810.33	22.70	3284.69	22.55
S-6	7413.00	12532.00	19437.00	12250.00	14739.67	7326.67	24.42	303.54	20.96
S-7	16895.00	19551.00	18655.00	19510.00	19238.67	2343.67	7.81	2162.64	65.54
S-8	106888.00	108895.00	105919.00	112536.00	109116.67	2228.67	7.43	14388.15	68.92
S-11	49650.00	49318.00	51143.00	51679.00	50713.33	1063.33	3.54	14007.84	144.445
S-12	22294.00	26511.00	23357.00	24348.00	24738.67	2444.67	8.15	2735.83	62.83
S-14	4358.00	10038.00	8992.00	8811.00	9280.33	4922.33	16.41	265.61	31.20
S-15	24406.00	278444.00	286307.00	286625.00	283792.00	39786.00	132.62	1839.89	3.86
S-17	91321.00	106655.00	114006.00	110633.00	110431.33	19110.33	63.70	1433.59	8.04
S-18	3062.00	3853.00	2893.00	3534.00	3426.67	364.67	1.22	2519.01	421.121
S-19	230771.00	248305.00	236639.00	241641.00	242195.00	11424.00	38.08	6060.16	13.45
S-20	24187.00	23043.00	24063.00	30349.00	25818.33	1631.33	5.44	4447.96	94.16
S-21	26338.00	27972.00	33118.00	30383.00	30491.00	4153.00	13.84	1902.58	36.99
S-22	56613.00	61617.00	67391.00	65033.00	64680.33	8067.33	26.89	2105.27	19.04
S-26	24720.00	29734.00	26651.00	28033.00	28139.33	3419.33	11.40	2168.84	44.92

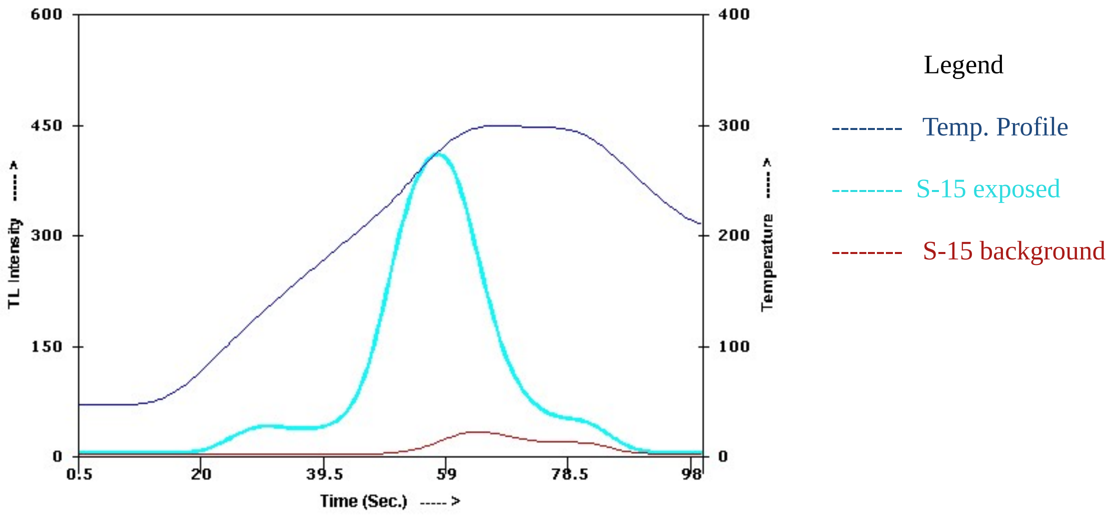

Fig.1: Graph showing Glow Curve of Sample S-15 (Exposed and Background)

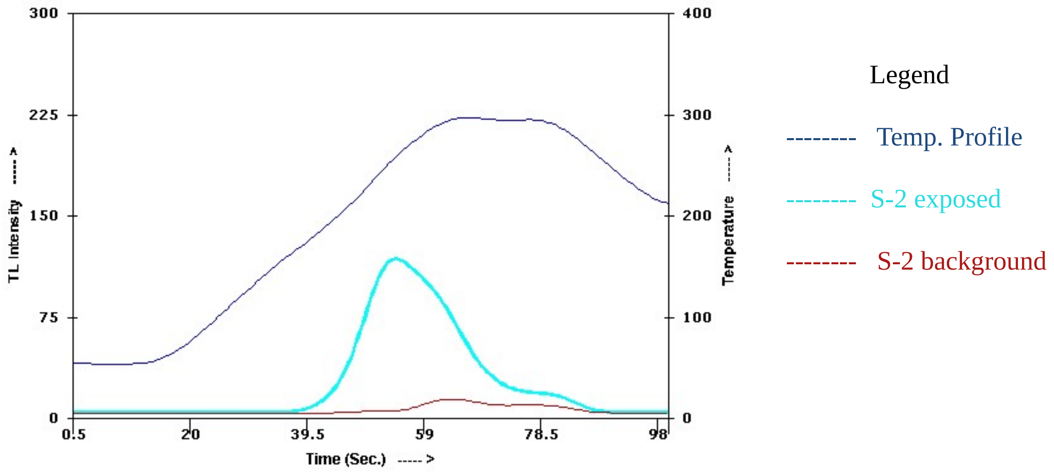

Fig.2: Graph Showing Glow Curve of Sample S-2 (Exposed and Background)

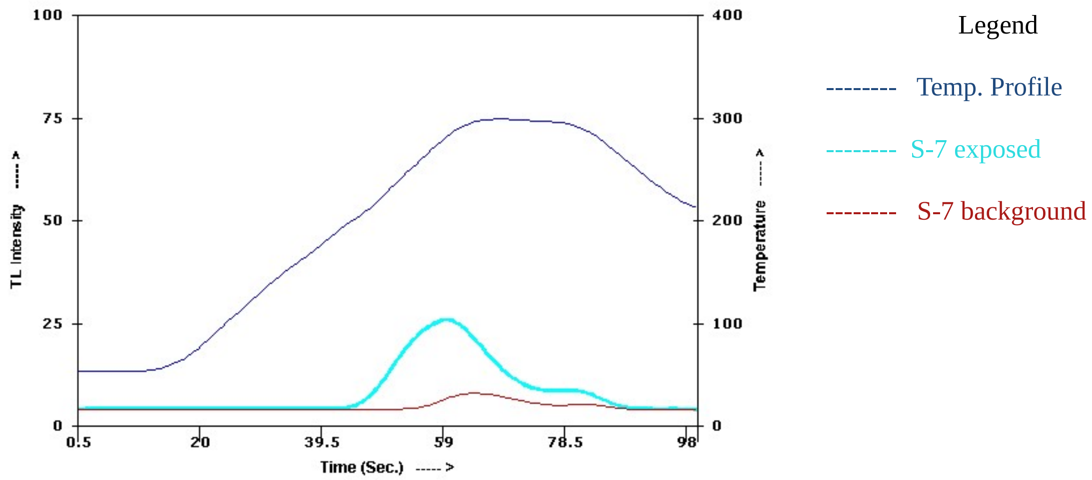

Fig.3: Graph Showing Glow Curve of Sample S-7 (Exposed and Background)

3. RESULTS & DISCUSSIONS:

3.1. TL Sensitivity: Out of 26 studied Himalayan Stones for TL, 15 samples have shown significant TL sensitivity to be used for ionizing radiation measurement in various applications. The variation in TL sensitivity is graphically shown in Fig.4. The TL sensitivity of these 15 samples is found to vary from 1.2 to 132.6 AU/R/50mg, with a minimum radiation detection level from 3.86 to 421.21 R of gamma radiation.

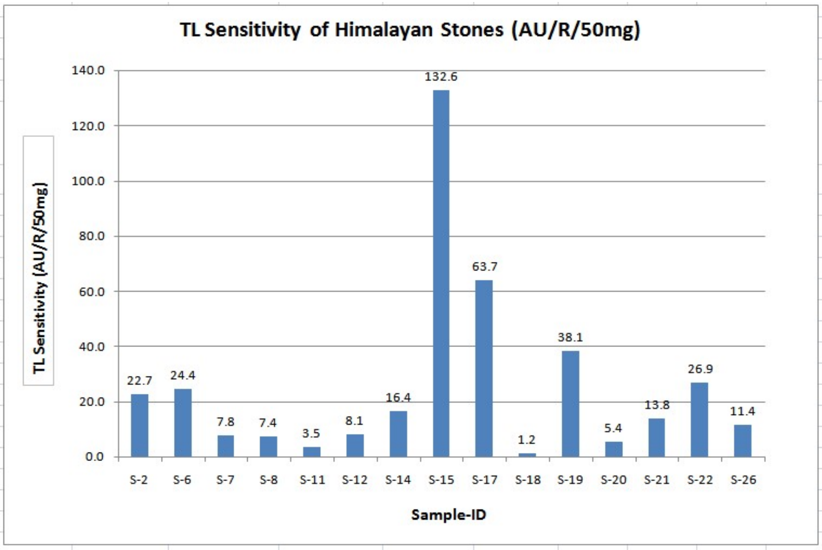

Fig. 4: TL Sensitivity in terms of AU/R/50mg

3.2: Estimation of Natural Radiation Exposure in Himalayan Stones: All materials of the universe are being continuously irradiated form the natural radiation (cosmogenic and terrestrial). TL analysis of the raw stone samples (without annealing) can give approximate estimate of the natural ionizing radiation, which a typical stone has received through exposure to the environment. This has also been explored in this study and the exposure levels in these stones have been found to be in the range of 304 to 14388 R. These estimations have been graphically represented in Fig. 5.

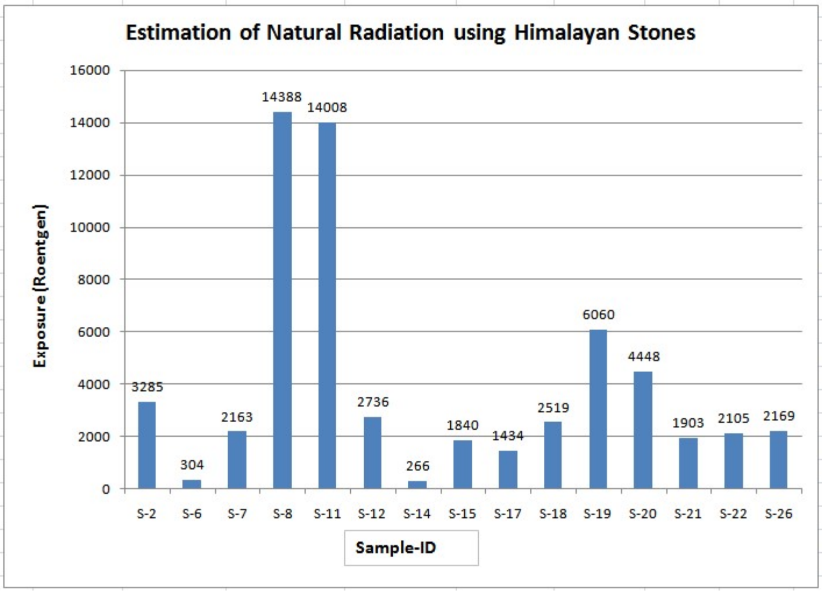

Fig. 5: Estimate of Natural Radiation Exposure

4. CONCLUSIONS:

The TL analysis of the stone samples irradiated by gamma dose has enough TL sensitivity which can be used for ionizing radiation measurement in case of radiological / nuclear emergencies and also medical applications. The glow peak of most of the stones is found below 300 ^{0}C, which is suitable for TL radiation dosimetry also.

5. FUTURE PROSPECTS:

Higher sensitive stones can be further studied for additional radiation dosimetric parameters such as; linearity, reproducibility, repeatability and TL fading etc. for establishing them as TL material for radiation dosimetry.

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