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Thermoluminescence dose Response Study of Natural Salt (NaCl:Cu,Mg,Mn,O,Cu,As) obtained from Mizoram, India

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Abstracts

This paper reports the dose response study of natural salt (local name Dap Chi) extracted from salty water sources in Mizoram, India. XRD and SEM of the sample were done and TL studies have been carried out using TLD reader TL1009I and sample was irradiated with gamma radiation using Theratron machine fitted with cobalt-60 source. Chen and Mckeever method has been applied to analyze linearity, sub-linearity and super linearity properties of the sample. The corrections for zero dose reading were done. The fifth degree polynomial dose responses had also been investigated. From the investigations, it may be concluded that the natural salt extracted from Mizoram shows a linear dose response in the range of 0.5 Gy – 2.0 Gy and may be a candidate for low radiation dose-meter, however further studies are needed for confirmation in this regard.

Keywords: Thermoluminescence, dose response, natural salt, dosimetry.

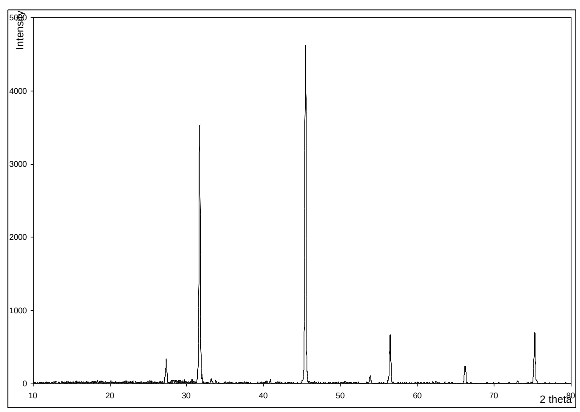
Introduction

Thermoluminescence (TL) is the thermally stimulated emission of light following the previous absorption of energy from radiation [1]. The output of a TL is a glow curve plotted between TL intensity and stimulating temperature.

The TL intensity or area under glow curve depends on the amount of radiations absorbed by the TL materials. There is a linear increase of TL response with dose. Below and above this range, the TL material may over/under response to radiation. The occurance of non-linear region in the dose response curve requires careful calibration and correction from which additional errors may occur [1]. For the applications of TL in dosimertry and dating the desired behaviour of the material is linear dose dependence over as broad a range as possible [2].

Some other TL properties had also been studied recently by the present authors [3-9]. In the present study, we apply the linearity, sub-linearity and super-linearity discussed by Chen and McKeever [2] to analyze the non-linearity of the dose response of natural salt. The corrections for zero dose reading are also carried out. The fifth degree polynomial dose responses have been found. The range of linear dose response has been determined.

Materials and methods



(XRD analysis of Dap natural salt)

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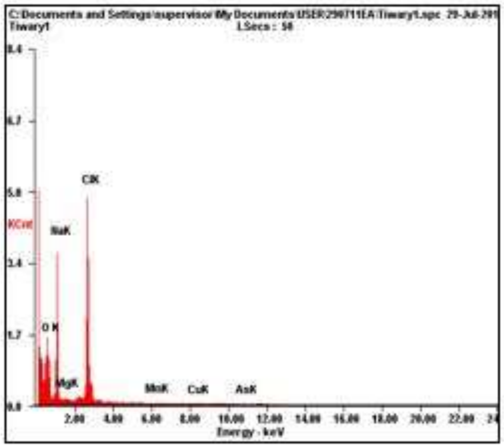

KV:20.01 TILT: 0.00 TAKE-OFF:34.12
AMPT:51.2 DETECTOR TYPE :SUTW-SAPPHIRE
RESOLUTION :131.37

Element	Wt%	At%
O K	28.70	41.80
NaK	31.95	32.38
MgK	00.59	00.57
ClK	38.07	25.02
MnK	00.04	00.02
CuK	00.30	00.11
AsK	00.33	00.10

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The Natural salt Dap Chi (local name) was extracted by evaporation of salty spring water, available in the state of Mizoram. The natural salt was crushed to fine powder, and given thermal treatments at 110 C for 90 minutes followed by slow cooling in oven before irradiation. Samples 20 mgs were prepared by packing properly in light tight black polythene.

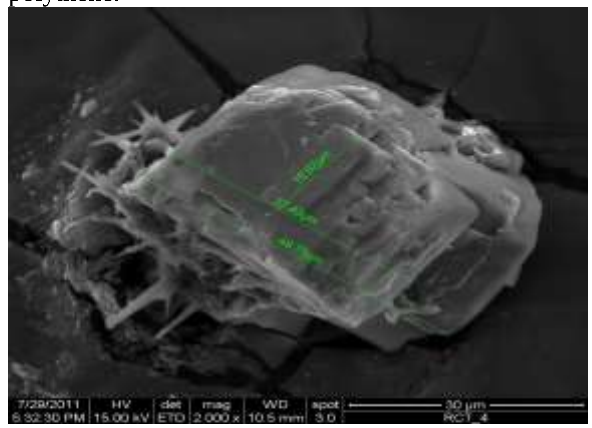

Fig. 1: SEM image of Dap Salt from Bose Institute, Kolkata (M/S AMTEK, USA)

The samples were irradiated from a ^{60}Co gamma source at 0.5, 1.0, 1.5, 2.0 and 2.5 Gy in a Cobalt Th780C machine. The dose rate of the ^{60}Co source at the time of irradiation was 0.0253 Gy/sec. TL measurements of the irradiated samples were carried out within 2 hours of irradiation in a commercial PC based TL reader, model TL1009I photomultiplier tube Hamamatsu/ET make Type No. 6095 (Nucleonix System Pvt. Ltd, Hyderabad, India). The heating rate used was 5 C/sec with the final temperature set to 400 C. An un-irradiated sample was also read in a TL reader for the purpose of zero dose correction. XRD, SEM image and EDAX analysis shows the presence of NaCl and some other impurities in the natural salt.

Theory

The plot of TL intensity against temperature is Glow curve. Since the area *A* under each glow curve is proportional to the number of charge carrier *n* initial trapped. The number of trapped electrons n_0 at time $t = 0$ can also be obtained after Pagonis, Kitis and Furetta [10],

$$n_0 = 1/\beta \int_{T_0}^{T_f} I(T)dT = 1/\beta \sum I(T).\Delta T \text{ .... (1)}$$

where ΔT is the temperature interval between two successive TL intensities, and β is the heating rate.

A plot of TL signal versus dose is a dose response curve. A dose response curve generally consists of different zones; the low dose sub-linear zone, linear zone and high dose super-linear or supra-linear zone. The "super-linearity index" g(D) which gives the change in the slope of the dose response and "supra-linearity index" f(D) for quantifying the corrections required for extrapolation of the linear dose region [11]. Super-linearity indicates an increase of the derivative M = M (D) function, where M is the measured TL signal, both the peak height at the maximum or the peak area. M' indicates the first derivative at the point D and M'' the second derivative.

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$M''(D) > 0$ → $M'(D)$ increases in D → *M(D)* increases and then is super-linear.
$M''(D) < 0$ → $M'(D)$ decreases in D → *M(D)* decreases and then is sub-linear.
$M''(D) = 0$ → $M'(D)$ is constant in D → *M(D)* is linear.

The following function can be used to quantify the amount of super-linearity (or sub-linearity) [3].

$$g(D) = \left[\frac{D.M''(D)}{M'(D)}\right] + 1 \qquad (2)$$

g(D) < 1, indicates sub-linearity
g(D) = 1, signifies linearity
g(D) > 1, means super-linearity

The *f(D)* function concerns the amount of deviation from linearity, that is the quantity needs for extrapolation to the linear region. The *f(D)* function characterize the TL versus dose behavior and is given by [2].

$$f(D) = \frac{\{M(D) - M_0\}/D}{\{M(D_l) - M_0\}/D_l} \qquad (3)$$

where D_l is normalization dose in the linear region, M_0 is the intercept on the TL response axis.

$f(D) < 1$ means *M(D)* values lies below the extrapolated linear region, under-linearity.
$f(D) = 1$ means linearity
$f(D) > 1$ indicates *M(D)* values lies above the extrapolated linear region, supra-linearity.

Results and discussion

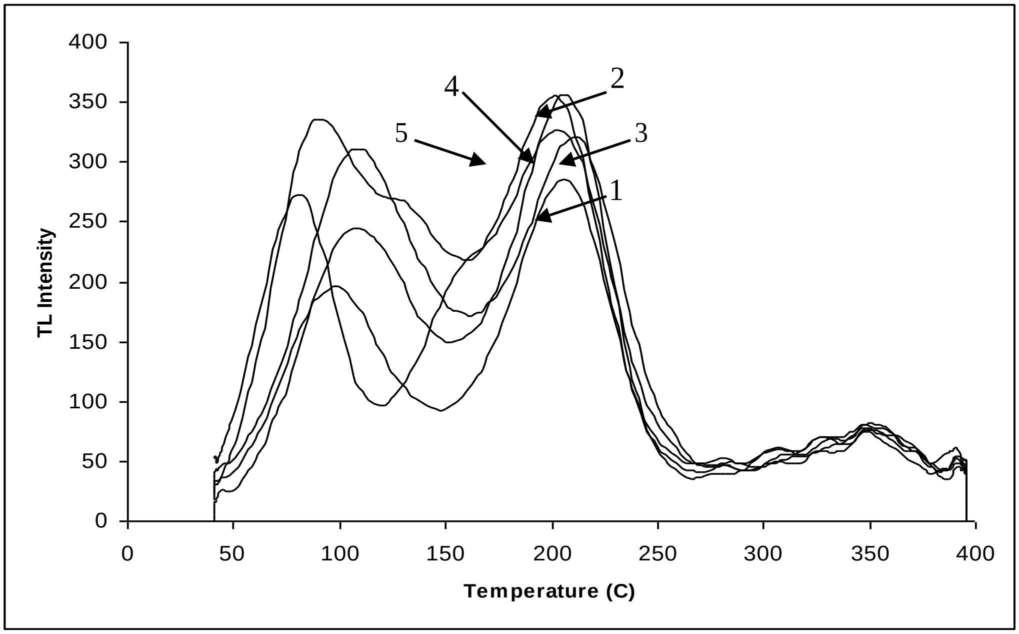

Figure 1: TL glow curves of natural salt irradiated to 0.5 Gy (curve 1), 1.0 Gy (curve 2), 1.5 Gy (curve 3), 2.0 Gy (curve 4) and 2.5 Gy (curve 5). The sample is read within 2 hours of irradiation.

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For the purpose of area measurement, integration zone is taken from 41.2 C to 279.68 C. Beyond 279.68 C, the glow curves seems to contain no useful information.

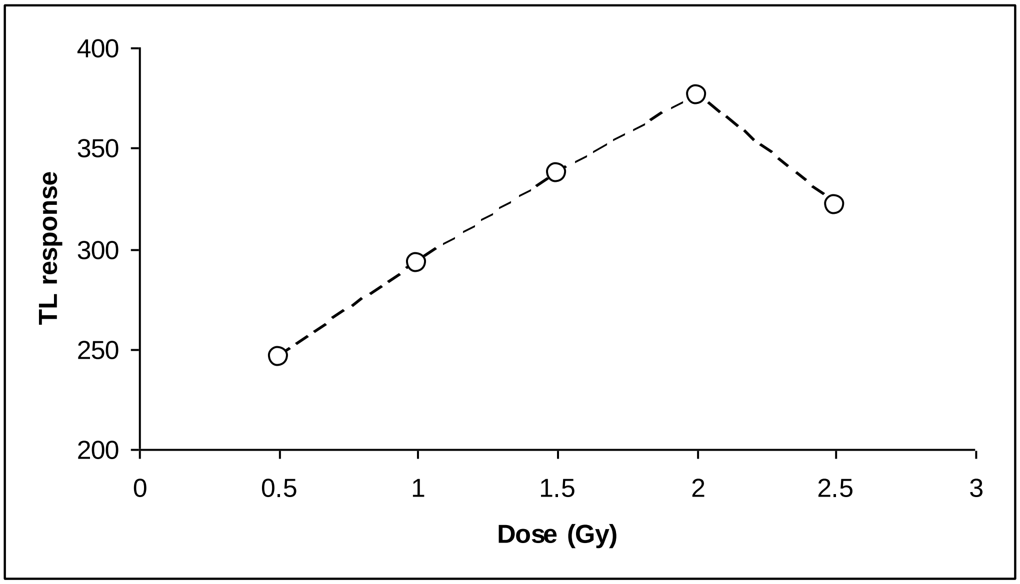

Figure 2: The dose response curve of natural salt irradiated with 0.5 Gy, 1.0 Gy, 1.5 Gy, 2.0 Gy and 2.5 Gy. The sample is read within 2 hours of irradiation.

Corrections for the zero dose reading

As shown in Figure 3 curve 1, the extrapolated linear curve fitting at zero dose give 203.67. On the other hand, a sample without expose to radiation should result zero dose response. Therefore, an un-exposed sample is read in a TLD reader with the same temperature profile; set temperature 400 C, rise time 80 sec, clamp time 20 sec, run time 100 sec and heating rate 5 C/sec. The result of the out was found to be 219. This may be due to the introduction of systematic error of the instrument like PMT dark current. Since this result is included in all the measurements done in this experiment, the zero dose response of 219 is subtracted from all measurements and the new curve is shown in Figue 3 curve 2. The extrapolated zero dose has -15.328 which is much closer to zero response then uncorrected value.

Table 1: The experimental data of TL response (column 2) versus dose (column 1). The corrected TL response is also shown (column 3).

Dose (Gy)	TL response (*curve1*)	TL response – zero dose response (*curve2*)
0	219	0
0.5	245.3007	26.3007
1.0	292.7137	73.7137
1.5	337.4504	118.4504
2.0	375.9712	156.9712
2.5	321.8417	102.8417

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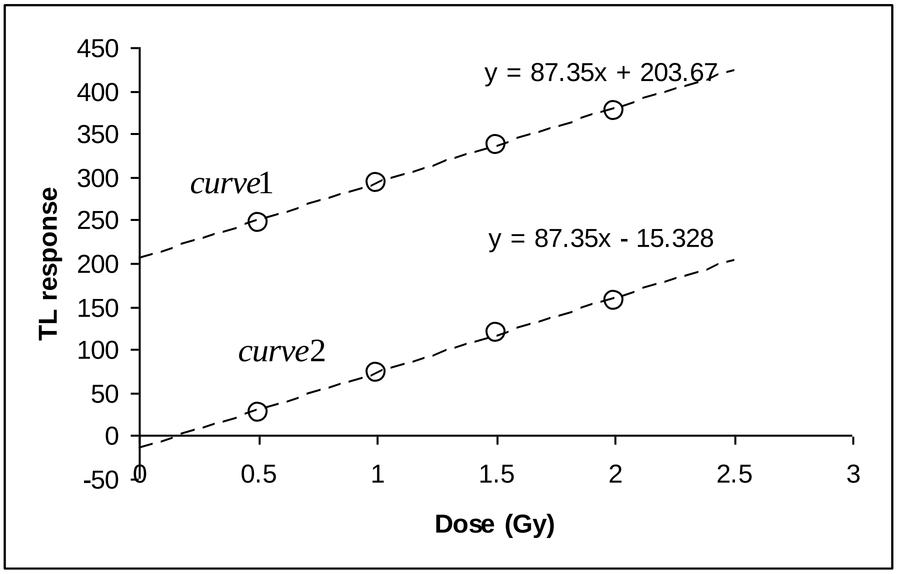

Figure 3: The linear fitting extrapolate to zero dose; curve1 without correction for zero dose and curve2 with correction for zero dose.

The linear region (*curve2*) in Figure 3 is given by $M(D) = 87.35D - 15.328$. Now *M'* is 87.35 and *M''* is zero. Therefore, *g(D)* = 1 from equation (2), showing that the TL response is linear for doses from 0.5 Gy to 2 Gy.

Again the 0 to 2.5 Gy dose dependent curve (*curve2*) in Figure 4 can be analytically expressed by the equation

$$M(D) = -27.505D^5 + 151.02D^4 - 312.88D^3 + 298.83D^2 - 35.752D - 9\times10^{-9}$$

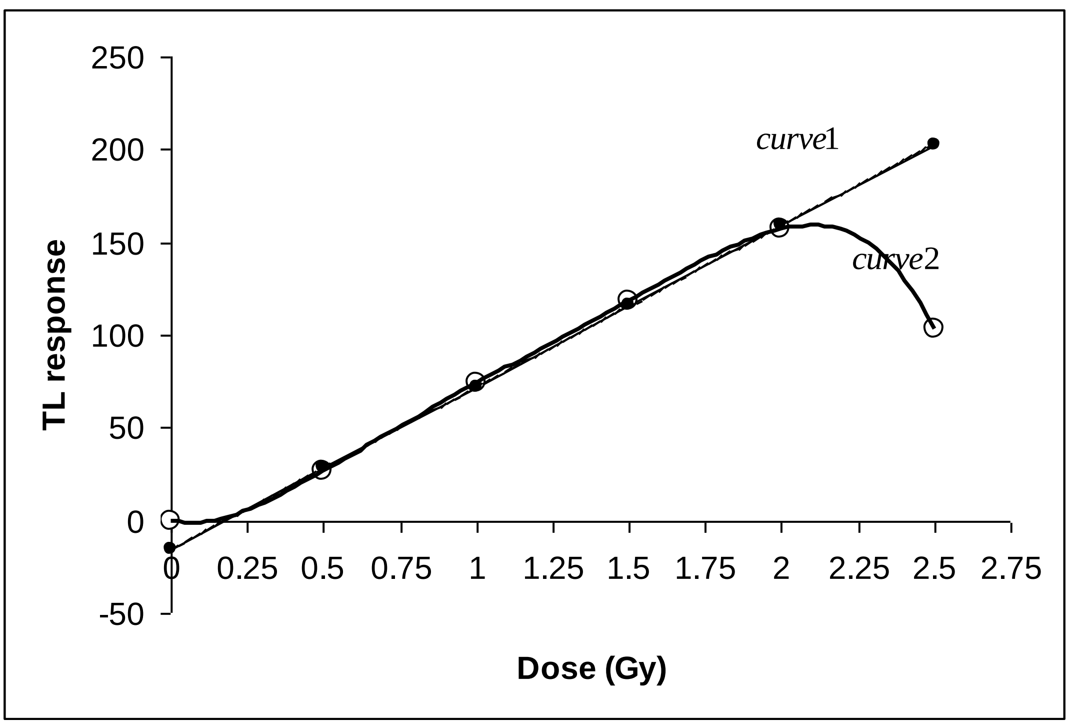

Figure 4: Plot of TL response versus dose showing under response at high dose and over response at low dose.

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Some points of the curve can now be considered from table 2.

Table 2: Calculated values of g(D) and f(D) from equations (2) and (3).

Gy	*M'(D)*	*M''(D)*	*g(D)*	*M(D)*	D_l	*M(D_l)*	M_0	*f(D)*
0.25	63.89954	233.0097	1.911625	5.413187	1.1	82.62512	-6.1312	0.572301
0.5	95.33269	43.3175	1.113596	26.30072	1.1	82.62512	-6.1312	0.803889
0.6	97.59164	4.8768	1.012493	35.97892	1.1	82.62512	-6.1312	0.869818
0.7	96.85609	-17.1227	0.955804	45.7196	1.1	82.62512	-6.1312	0.918017
1	89.823	-17.48	0.951349	73.713	1.1	82.62512	-6.1312	0.989548
1.5	91.34769	2.6925	1.007369	118.4422	1.1	82.62512	-6.1312	1.029265
1.6	90.61344	-19.8632	0.945198	127.559	1.1	82.62512	-6.1312	1.035554
1.7	86.82289	-58.9837	0.830161	136.4633	1.1	82.62512	-6.1312	1.039555
1.8	78.15452	-117.97	0.62264	144.7613	1.1	82.62512	-6.1312	1.038935
1.9	62.45677	-200.122	0.19896	151.8603	1.1	82.62512	-6.1312	1.03056
2	37.248	-308.74	-1.07219	156.936	1.1	82.62512	-6.1312	1.010485
2.5	-341.422	-1364.35	1.999021	102.7411	1.1	82.62512	-6.1312	0.539723

For D = 0.25 Gy: *M'(0.25)* = 63.89 > 1; which means M is an increasing function in D = 0.25 Gy.
M''(0.25) = 233 > 1; M' is increasing and has the concavity facing the top in D = 0.25 Gy.
g(0.25) = 1.91 > 1; indicates super-linearity in the region preceding the linear part of the curve.
f(0.25) = 0.57 < 1; ; indicates supra-linearity in the region preceding the linear part of the curve.
For D = 2 Gy: *M'(2)* = 37.248 > 0; which means M is an increasing function in D = 2 Gy.
M''(2) = -308.74 < 0; M' is decreasing and M(D) has the concavity facing the bottom in D = 2 Gy.
g(2) = -1.07 < 1; indicates sub-linearity at D = 2 Gy. *f(2)* = 1.01 > 1; ; indicates supra-linearity at D = 2 Gy.

Now considering *g(D)* from 0.5 to 1.6 Gy which has got value approximately 1, we can consider that the TL response is linear in this region. The *f(D)* has a wider linear range of 0.6 Gy to 2.0 Gy, where the *f(D)* values are approximately 1.

Conclusion

The present thermoluminescence study shows that Mizoram natural salt (Dap Chi) has linear dose response from 0.5 Gy to 1.6 Gy, however, it may be acceptable up to 2 Gy as shown by the *f(D)* value. Below this dose range the sample shows over response and above this range the sample shows under response. Therefore, it may be concluded from present study that Dap natural salt obtained from Mizoram may be a candidate for TL studies in the low dose region from 0.5 Gy to 2.0 Gy, however further studies are needed for confirmation in this regard.

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