LONG-TERM STABILITY OF HARSHAW LiF:Mg,Cu,P TLDs
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The sensitivity of Harshaw™ magnesium/copper/phosphorus-doped lithium fluoride is shown to be stable over long time periods, even when, as is often the case in practical operations, the TLDs are read out only three times a year.

INTRODUCTION

The UK Health Protection Agency’s (HPA) Radiation Protection Division completed a major modernisation of its thermoluminescence dosimetry (TLD) service in 2006. The new service uses Harshaw™ whole-body and extremity TLDs based on magnesium/copper/phosphorous-doped lithium fluoride (LiF:Mg,Cu,P) material (Figure 1), together with Harshaw 8800™ automated readers (1–3). The material was chosen in view of its high sensitivity and improved tissue equivalence over LiF:Mg,Ti, and in view of its successful use in several applications (4, 5) including that of a large personnel dosimetry service in the USA (6).

The new service has now been operating smoothly and successfully for over 3 y. The various changes, particularly to the read technology (from hot contact to hot gas), readers, holder and material, have delivered both greater reliability and improved dosimetric performance. The decision threshold (7) under laboratory conditions is now so low (a few microsieverts (1, 8)) that it is no longer the dosemeter that determines the reporting level, but rather the size of the natural background. Meanwhile, the adoption of a more tissue-equivalent material together with a tissue-equivalent holder design (1, 3) has resulted in a dosemeter, which realises the physical quantities $H_p(10)$ and $H_p(0.07)$. This has the advantage of a fully additive response for all the rated radiation qualities, so that the dosemeter will accurately measure the above quantities in any fields or any mixture of fields.

Note that the service uses the same heating cycle (‘time–temperature profile’) for both routine reading and annealing, see ref. 2 for details.

STABILITY OF LiF:Mg,Cu,P

Over many, few-minute cycles

Previous work (9) has shown that the sensitivity of the LiF:Mg,Cu,P material, as incorporated in whole-body TLD cards, was stable over as many as one thousand cycles. However, for those particular tests the cycle duration was very short, with repeated dose and read phases following each other immediately (cycle times of a few minutes).

Over a standard quarterly issue period

Work by HPA (8) during commissioning of the new system showed stability of response over a period of 6 months after issue, i.e. after one read (or anneal) cycle. This is the kind of time frame in which the latest returns of quarterly issue dosemeters might reasonably be expected to occur. No change in sensitivity was detected over a period of 6 months.

Over longer periods

The above results gave confidence that (i) dosemeters could be subjected to many read cycles without performance detriment and (ii) individual routine dose measurements could be carried out without concern for ageing effects. However, there remained question of stability in the much longer term. This property was operationally important in deciding on the TLD re-calibration interval. A relatively constant TLD sensitivity allows for infrequent re-calibration, e.g.
every few years, whereas a more variable sensitivity requires re-calibrations to be more frequent. Whilst the (short-term) repeatability of the Harshaw™ TLDs was very good, this might be a consequence of the TLDs receiving frequent reads and anneals. What would happen in routine operational conditions, where there is normally a large time gap between anneal or read cycles? And would a low frequency of annealing/reading lead to any cumulative effects?

For monthly issue TLDs, the gap between successive reads or anneals of a dosemeter will typically lie between 6 and 8 weeks, if the dosemeter is returned promptly. For quarterly (3-month) issue TLDs, this gap between reads will be nearer to 4 months. In the HPA service, a large fraction of users have selected a quarterly change interval. This means that a substantial proportion of TLDs may only receive a few issues a year; in fact, based on a small sample of those dosemeters, which have been in use since the launch of the service, the mean number of issues per year is 3.1.

Furthermore, the service allows for the re-issue of processed dosemeters without any pre-issue annealing, provided that (i) the preceding recorded dose was sufficiently small and (ii) re-issue takes place within 1 week of read. It is therefore possible that individual HPA TLDs receive no more than three read cycles per year (and fewer, if they are not returned promptly after use). Accordingly, the present work assumes that TLDs are read (or annealed) only three times a year.

The test described here was begun in late 2005, prior to the inception of the new service.

METHODS

Given the likelihood that field dosemeters may only be read three times a year, the experiment assessed the sensitivity of each of 20 elements (10 two-element cards) at 4-month intervals. The TLD cards were subjected to one, and only one, standard read cycle every 4 months.

At the mid-point between read-outs, i.e. after 2 months, a reproducible personal dose equivalent of 0.4 mSv was applied to the TLDs, using the dedicated $^{137}$Cs irradiation facility of the HPA service. Traceability of this facility is checked every 6 months, using the dosemeters themselves as transfer standards, an important consideration for an experiment such as this which covers several years. The relatively low dose value was chosen so as to minimise any effects of the residual signal, of around 0.5 %, which is known to affect this material.

After each read-out, the raw results were corrected for the known local natural background, according to the number of days between reads. Lastly, for each individual TL element, the sensitivity (in nanoCoulombs per millisievert) was calculated relative to the original (time zero) sensitivity for that element. The dosemeters were then returned to storage, in dark conditions at ambient temperature.

RESULTS

The results to date are shown in Figure 2. For each data point, the quantity shown is the response ratio, i.e. the sensitivity of the TLD to the applied dose, relative to its original sensitivity, averaged over all 20 TLD elements. The measurement uncertainties, typically of 15 % at the 67 % confidence level, include not only the dispersion of the results amongst the 20 TLD elements, but also the uncertainties in the long-term stability of the TLD readers and in the applied dose over a period of time. The results clearly show the absence of any trend.

This experiment has now accumulated 4 y’ worth of data. The results show the sensitivity of Hashaw™ LiF (Mg,Cu,P) to be stable over that time, within the measurement uncertainties, even though the dosemeters have only received three read cycles per year.

CONCLUSION

Earlier work had shown good stability for Harshaw™ LiF:Mg,Cu,P in rapid-cycle conditions$^{(9)}$, and during a typical issue period (with some allowance for late return)$^{(8)}$. The present result demonstrates clearly for the first time that the sensitivity remains stable in realistic conditions, where dosemeters only receive one read cycle every few months. With as few as three reads per year, dosemeter sensitivity remains stable for at least 4 y.

HPA is currently using a 3-y re-calibration cycle. The experiment is being continued to see whether it is feasible to extend this.

FUNDING

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REFERENCES


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