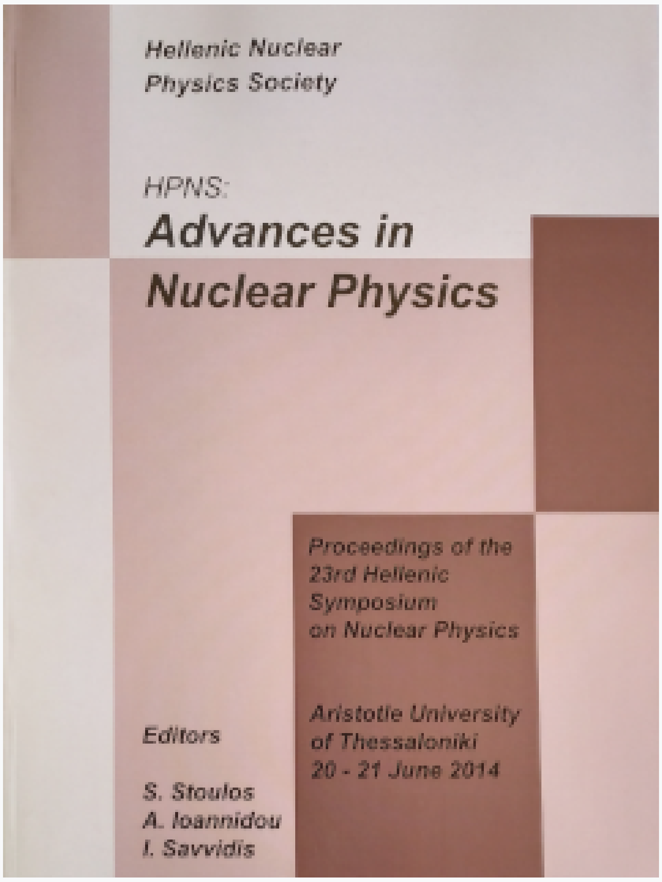
ePublishing
ΕΘΝΙΚΟ ΚΕΝΤΡΟ ΤΕΚΜΗΡΙΩΣΗΣ NATIONAL DOCUMENTATION CENTRE

Annual Symposium of the Hellenic Nuclear Physics Society

Τόμ. 22 (2014)

HNPS2014



Use of everyday materials in retrospective nuclear accident dosimetry

K. Stamoulis, K. G. Ioannides, H. Bakola, C. A. Papachristodoulou, L. M. Tsodoulos

doi: 10.12681/hnps.1941

Βιβλιογραφική αναφορά:

Stamoulis, K., Ioannides, K. G., Bakola, H., Papachristodoulou, C. A., & Tsodoulos, L. M. (2019). Use of everyday materials in retrospective nuclear accident dosimetry. *Annual Symposium of the Hellenic Nuclear Physics Society*, *22*, 113–116. https://doi.org/10.12681/hnps.1941

Use of everyday materials in retrospective nuclear accident dosimetry

Stamoulis K.C.[1], Ioannides K.G.[1], Bakola H.[1], Papachristodoulou C.A.[1], Tsodoulos I.M.[1]

[1]*Department of Physics, University of Ioannina, 45110, Ioannina, Greece.*

ABSTRACT

Following a large-scale nuclear event, a quantitative estimate of the radiation dose to the general population necessitates the availability of adequate procedures for the assessment of doses. The main objectives of dose reconstruction, namely retrospective dosimetry can be synoptically stated as in the following: a) To guide the provision of proper protection for the population that had been exposed to radiation, b) To provide assuring information to the worrying public and c) To provide input data for epidemiological studies. Amongst the methods used for dose estimation are the Thermoluminescence (TL) and the Optically Stimulated Luminescence (OSL). Methods based on TL and OSL have the advantage that they allow the measurement of the integrated absorbed dose. When the irradiation comes from external sources, materials found within the perimeter of the accident area such as bricks, tiles and pottery and certain household chemicals, can be used. The absorbed dose may be evaluated many years after the accident.

INTRODUCTION

After a nuclear accident, huge amounts of radioactive materials are introduced into the environment causing the accumulation of equivalent doses in living organisms as well as in inorganic materials found in the vicinity of the accident. Quantitative estimate of the radiation dose to the general population can be performed with various methods. Amongst the methods applied for dose reconstruction or retrospective dosimetry in relation to the local population after a nuclear accident, are solid state methods based on luminescence, including Thermoluminescence (TL) and Optically Simulated Luminescence (OSL), which can be used to measure the integrated absorbed dose. Various materials can be applied as natural dosimeters in the affected area, such as electronic components of cell phones and common salt (Spooner *et al.,* 2011; Mesterhazy *et al.*, 2012).

In the present work everyday materials - such as common salt, water softener tablets and porcelain – were examined for their suitability and efficiency for natural dosimeters, using TL and OSL measurements. The results of the present study have shown that such materials may be used as dosimeters provided they fulfil specific requirements so to allow a satisfactory assessment of the post-accident situation and facilitate the application of appropriate countermeasures.

MATERIALS AND METHODS

In our preliminary study of their dosimetric properties presented here, the following household materials were selected: Sodium chloride, the main ingredient of cooking salt, potassium chloride used as a substitute in table salt and also as an ingredient of water softeners, water softener salt for washing machines and dish porcelain, were chosen for the study. Samples of these materials were crushed to powder and passed through sieves. Fractions of 100-150 μm were selected and were placed on stainless steel disks of 1 cm diameter. These were submitted to treatments following various protocols in order to investigate thermal stability, thermal sensitivity, TL and OSL signal profiles and finally assess their dose response.

The TL/OSL measurements were conducted using a TL/OSL Riso reader (DA-20 model) equipped with a $^{90}Sr/^{90}Y$ beta source (0.0982 Gy s^{-1} dose rate) and capable in performing TL readings up to 500^o C and OSL measurements with blue light stimulation and preheat at various temperatures and with different rates of heating.

A dose of ~1 Gy was given to 10 aliquots of KCl, NaCl, water softener salt (Calgon) and porcelain. The SAR protocol was followed in order to estimate the dose recovery of these materials. Each aliquot was preheated at 200^o C and the OSL signal was recorded after preheat at 125^o C and blue light stimulation. To construct growth curves, doses up to 8 Gy were delivered progressively to the aliquots and test doses of 4 Gy were provided after each irradiation for normalization.

The dose response of NaCl and KCl at different preheat temperatures ranging from 180^o C to 300^o C was studied. The thermal stability and thermal sensitivity of the OSL signal derived from aliquots of NaCl and KCl, was investigated using the following protocol: All aliquots (18 disks per material) were given a 2 Gy dose and were heated to 200^o C. Afterwards, a normalization OSL reading at 20^o C (OSL1) was performed for 0.1 s and the aliquots were heated to temperatures varying from 200^o to 300^o C. The OSL signal was recorded (OSL2) for 100 s at 160^o C. Finally, a test dose of 1.2 Gy was delivered to the aliquots and the signal was read after preheat to 200^o C for 100 s (OSL3 for sensitivity).

The influence of illumination to the TL properties of NaCl and KCl was investigated as follows: Sets of three aliquots of each material were irradiated with 5 Gy and preheated at 200^o C for 10 s. Subsequently, these sets were stimulated with blue light at reduced power (2%) at 20^o C for time period 0.3 s, 3 s, 30 s, 300 s, 3000 s . Each aliquot was heated to 500^o C (heat rate 2^o C s^{-1}) to measure TL. The final part of the experiment was a dose normalization measurement of 5 Gy and the TL signal was recorded again by rising the temperature to 500^o C. The integral at the temperature range of 200-300^o C was used as a normalization factor for each aliquot.

RESULTS AND DISCUSSION

The dose recovery estimated using the OSL signal from the materials used in the present study was promising for retrospective dosimetry. In the case of KCl the recovery was over 100 %, while for NaCl was about 50 %. Finally, for Calgon the average value was about 86 %. The most promising material was porcelain with a recovery almost near to 100%.

Using the extrapolation of the growth curves to investigate the saturation dose for each material revealed that although porcelain is promising in providing good recovery results, it shows saturation at low doses (<50 Gy), while KCl displays moderate results (saturates in the 50% of the cases at doses <500 Gy). Finally, Calgon and NaCl exhibit a linear response to doses without any sign of saturation in most of the measurements.

Table 1. Dose recovery (signal/given dose)

Material	*Signal/dose*	*1 sd*
KCl	1.19	0.02
NaCl	0.52	0.23
Calgon	0.86	0.03
Porcelain	1.01	0.07

The influence of illumination in various exposure times (0.3-3-30-300-3000 s) to the TL glow curves is presented in Fig. 1 for the case of NaCl. As shown in the inset of Fig. 1, the typical TL glow curve of NaCl exhibits three major thermal peaks, the first from 20-150^o C, the second from 150-350^o C and the final from 350-500^o C. It was observed that the part of the glow curve that is between 150-350^o C is mainly affected by reducing the TL signal more than 2 orders of magnitude, while the range 350-500^o C is reduced up to 80%.

Finally in the range of 20-150^o C, the influence is positive meaning that illumination transfers charge in this range of temperature from other parts of the spectrum instead of decreasing the charges that remain after the initial preheat at 200^o C.

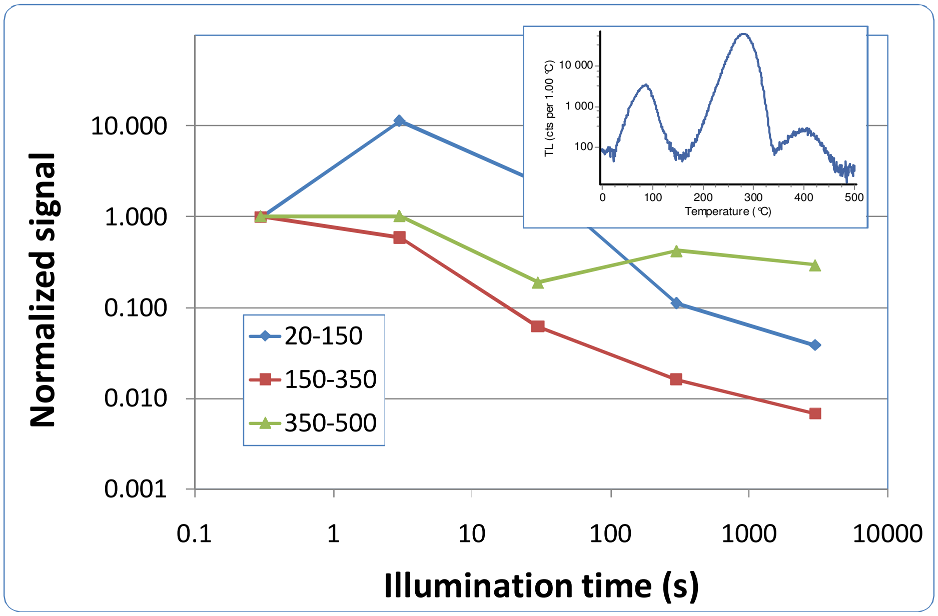


Figure 1. Influence of illumination on TL signal. Typical TL glow curve of NaCl is shown in the inset.

The results of the thermal stability experiments for the case of NaCl are presented in Fig. 2. As the preheat temperature rises from 200° C to 300° C the normalized ratios (of remaining OSL signal (OSL2) to the initial pulse signal (OSL1)), to the initial value of 200° C, decrease rapidly after 240° C by a factor of 100. This means that preheat to temperatures more than 240° C eliminate most of the charge which is responsible for the TL peak with center around 290° C (see inset of Fig. 1) and thus for best results in the case of NaCl preheat temperature should not exceed 200° C. The results of sensitivity experiment are presented in the inset of Fig. 2. The normalized ratio of test dose to initial pulse signal (OSL3/OSL1) is almost stable for the various preheat temperatures and this provides evidence that there is no significant change of sensitivity in the range of 200-300° C preheat. The results for thermal stability as well as the results for illumination agree satisfactorily with previous results (Bailey *et al.*, 2000).

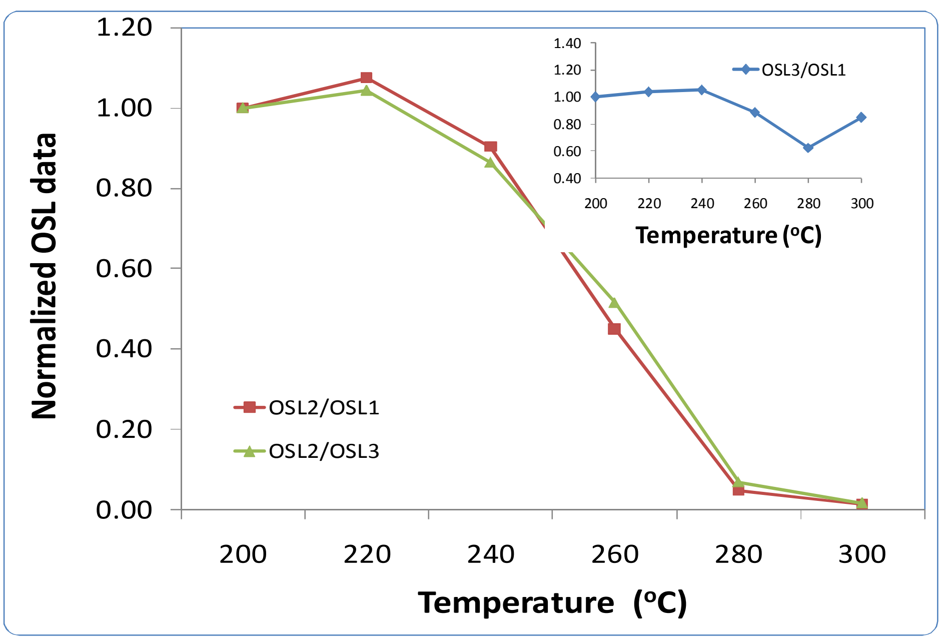


Figure 2. Thermal stability and sensitization.

CONCLUSIONS

Dose recovery tests of every day materials for retrospective dosimetry, provided promising results for KCl, Calgon and porcelain and at a lesser extent for NaCl. Saturation curves have shown that porcelain is less promising for high doses as it saturates with doses up to 50 Gy while best results (linear relation between delivered dose and dose response) exhibit Calgon and NaCl. Studies on the OSL and TL properties of NaCl have shown that best preheat temperature is 200^{o}C. Ongoing experiments for other household materials are expected to add in the knowledge of their properties useful for retrospective dosimetry.

REFERENCES

Bailey R.M., Adamiec G., Rhodes E.J. (2000) Radiation Measurements v32, 717-723.

Mesterhazy, D., Osvay, M., Kovács, A., Kelemen A. Accidental and retrospective dosimetry using TL method. (2012) Radiation Physics and Chemistry, v81, 9, 1525-1527.

Spooner, N.A., Smith, B.W., Williams, O.M., Creighton, D.F., McCulloch, I., Hunter, P.G., Questiaux, D.G., Prescott J.R. Analysis of luminescence from common salt (NaCl) for application to retrospective dosimetry. Radiation Measurements, Volume 46, Issue 12, December 2011, Pages 1856–1861.