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# OSL IN HOUSEHOLD SALT (NaCl) FOR ENVIRONMENTAL, OCCUPATIONAL AND MEDICAL DOSIMETRY

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***Abstract***: The recent progress in our work to implement salt (NaCl) as a dosemeter is presented. Laboratory investigations have indicated a linear dose response from 1 mGy to about 100 mGy and detection limits down to 0.1 mGy. Investigations in the clinic comparing TL-dosimetry in LiF and OSL in NaCl have indicated a similar dose response for the two dosemeters at different photon energies. Field studies with stationary dosemeter kits containing TLDs (LiF) and NaCl suggests that salt is also a good candidate for environmental monitoring of radiation.

***Keywords***: OSLD, TLD, NaCl, LiF, dosimetry

## 1. Introduction

Today there are no direct dosemeter for the general public in case of an accident involving external exposure from ionising radiation. There are however methods for assessing collective, and to some extent also individual, doses in such cases [1, 2]. The drawback with many of the retrospective methods for individual dose estimations is that they are complicated and have a relatively high dose threshold under which they are unreliable. In our search of finding methods and materials for individual dose assessments we have focused on optically stimulated luminescence (OSL) in household salt (NaCl). This particular dosemeter can be found almost everywhere and it has shown several promising dosemetric properties [3, 4] and e.g. a linear dose response between 0.1 mGy to 100 mGy and a low limit of detection, down to 0.1 mGy for some brands of salt [5].

The use of OSL in NaCl is not limited to retrospective dosimetry. Preliminary investigations carried out in different radiation environments in a hospital, shows a similar response for LiF and NaCl for absorbed dose measurements at different photon energies. NaCl dosemeters can also be used as a cheap alternative for environmental dosimetry. Studies that have been carried out in a highly $^{137}$Cs-contaminated village in Belarus during the summer of 2008, suggests that NaCl dosemeters are as good indicators of absorbed dose and its variation, as the particular LiF (TLD-100) dosemeters used in the same village.

## 2. Material and methods

To investigate salt as a dosemeter in different radiation situations, special dosemeter kits have been designed containing NaCl and LiF. These "twin" dosemeter kits were normally assembled with two sections of 30-50 mg NaCl and two chips of LiF (TLD-100, Harshaw). Before the dosemeter kits were assembled, which was carried out the night before the distribution, the salt was exposed to sunlight (bleached) for a few days, in order to get a low background luminescence. The chips and the salt were placed between two 4 mm thick layers of PMMA, this forming a dosemeter kit of two different luminescent materials. To avoid bleaching of the OSL signal, all dosemeter kits were covered with a light tight adhesive tape. Additionally, the environmental dosemeters were placed in plastic bags filled with silica gel, to protect the dosemeters from rain and moist during the measurement period.

After the kits were collected, the TLDs were read out using a TOLEDO TLD reader (VINTEN Instruments, England). The signal in the NaCl dosemeters was assessed using a TL/OSL reader (TL/OSL DA 15; Risø National Laboratory, Roskilde, Denmark) which is an automated equipment that can manage 48 samples (or aliquots) per run. The salt from each dosemeter kit was carefully mixed and divided onto five, or more, different aliquots. To assess the stored signal in the salt, it was optically stimulated by blue light ($\lambda$ = 470±30 nm) for 40 – 100 s. The average signal, $OSL_{signal}$ (counts mg$^{-1}$), for a dosemeter kit was defined as:

$$OSL_{sample} = \frac{\sum_{i=1}^{n}\left(\frac{S_i}{m_i}\right)}{n} \qquad (1)$$

where $S_i$ is the integrated signal, in the beginning of the stimulation, from aliquot $i$ with mass $m_i$ and $n$ is the number of aliquots (normally n = 5). Similarly, an OSL background, $OSL_{bkg}$ (counts mg$^{-1}$) was estimated as the integrated signal during the late phase of the stimulation time. The absorbed dose, $D_{sample}$ (mGy), to the salt was thereafter estimated by applying a calibration coefficient, $c_{specific}$ (counts mGy$^{-1}$ mg$^{-1}$) to the net signal:

$$D_{sample} = \frac{1}{c_{specific}} \cdot \left(OSL_{sample} - OSL_{bkg}\right) \qquad (2)$$

Details on the read out protocol and on the calibration coefficients are described in more detail by Bernhardsson *et al.* [5] and in [6].

### 2.1 Occupational and medical exposures

To test salt as a personal dosemeter and at different photon energies, four staff members working in the radiology and nuclear medicine departments at Malmö University Hospital (UMAS) carried the dosemeter kits during one month. The salt used for the personal dosemeters was Falksalt fint havssalt (Hansson and Möhring, Halmstad, Sweden), a naturally fine grained sea salt consisting of NaCl≥99.6%. The kits were attached to the investigated persons regular TLD (LiF: Mg, Ti) and the TL-readings from these were used for the NaCl/LiF comparison. Similar dosemeter kits were also attached to TLDs that were positioned on the inside walls of a nuclear medicine investigation room. A few other dosemeter kits were placed in the primary radiation field from a mammography X-ray unit and in the primary beam of a $^{60}$Co therapy unit. At the $^{60}$Co unit the dosemeter were given eight successively increasing doses in the range from 1.4 mGy to 4.1 Gy.

### 2.2 Environmental exposure

To test the salt (Falksalt fint bergsalt, Hansson and Möhring, Halmstad, Sweden) during normal environmental conditions, dosemeter kits were positioned in a highly $^{137}$Cs-contaminated village in Belarus, during the summer of 2008. Between 5 and 14 kits were attached to the inside- and outside walls of each one of the 7 houses included in the study. After 2.5 months the dosemeters were re-collected and brought back to Sweden for the read-out. During the distribution and collection of the dosemeters a special radiation protection instrument, GR-110 (NaI(Tl)-detector; Exploranium, Canada) was used to directly determine the dose rate *in situ*. A mean value from these measurements was used to include the GR-110 readings in the comparison between NaCl and LiF.

A few TLDs and direct measurements, using various radiation protection instruments (e.g. SRV-2000; RADOS, Finland), were used during transport and storage to estimate the dose accumulated when the dosemeters were not in position in the village.

## 3. Results and discussion

### 3.1. Occupational and medical exposures

The relation between the OSL-signal in NaCl and the absorbed dose as measured by LiF for measurements on the personnel in diagnostic radiology and nuclear medicine as well as in the primary beam of a mammography X-ray unit is shown in: Fig. 1. The same relation is also shown for similar measurements in a $^{60}$Co beam. At low photon energies (mammography), the OSL-measurements indicate a somewhat higher response relative to the LiF-TL dosemeters. The effect may be attributed to the somewhat higher atomic number of NaCl (Z = 11; 17) compared to LiF (Z = 3; 9).

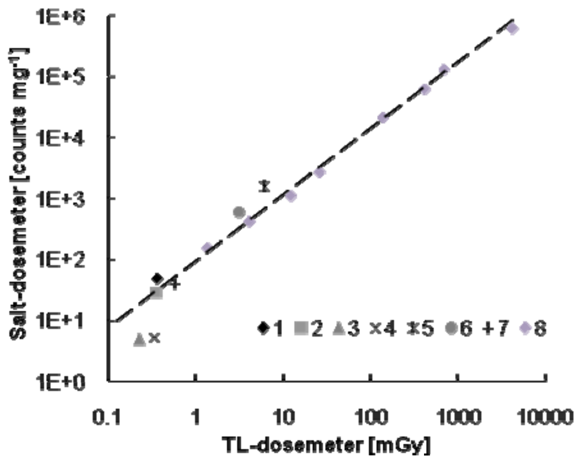


**Fig. 1.** The OSL signal from NaCl as a function of absorbed dose measured by LiF (TLD) for ten “twin” dosemeter kits (OSL and TL) positioned at the following locations; *i.)* on individual staff members in diagnostic radiology (no 1 and 2), *ii.)* on individuals at the nuclear medicine department (no 3 and 4), *iii.)* in the mammography primary radiation field (no 5 and 6), *iv.)* on the interior walls of a nuclear medicine laboratory (no 7). The OSL response vs. absorbed dose determined by LiF-TL dosemeters placed in a $^{60}$Co beam is shown for comparison (no 8).

Although these results are based on a small number of NaCl/LiF dosemeters, the salt shows a similar dose response at different photon energies, compared to ordinary TLDs.

### 3.2. Environmental exposure

The total absorbed dose accumulated under field-conditions in the Belarusian village, between resetting of the luminescence and the read-out in Sweden, is presented in: Fig. 2. The absorbed dose to 54 dosemeter kits as determined by OSL in NaCl is plotted as a function of the corresponding value for TL in LiF. In view of the low signals there is a fairly good correlation ($r^2$ = 0.55) between the two types of dosemeters. There is however a systematic difference, where the NaCl dosemeters on average, show a 0.16 mGy higher absorbed dose compared with the TLDs. This might indicate a too small background subtraction in the NaCl batches or a too high background subtraction in the LiF chips. It could also be an effect of a variation in the sensitivity of the LiF chips during the measuring period, i.e. between calibration and read-out. Another explanation could be that the fading of the signal is more rapid in the LiF chips compared to NaCl, at least during the first 2 – 3 months.

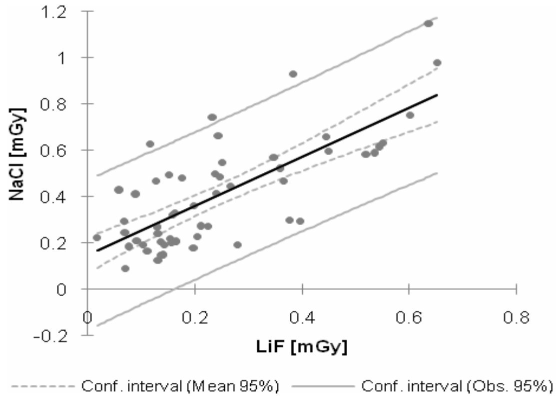


**Fig. 2.** Absorbed dose as determined by OSL in NaCl vs. the absorbed dose as determined by TL in LiF.

In Fig. 3 and 4, is the absorbed dose as determined by LiF and NaCl, respectively, plotted as a function of the corresponding dose obtained from the GR-110 measurements at each position of the luminescent dosemeters. The GR-110 values refer to the average value of the dose rate at the outset and the collection of the luminescent dosemeters minus an estimated background (0.11 µSv $h^{-1}$ and 0.17 µSv $h^{-1}$ for the indoor and outdoor measurements, respectively). Different colors have been used to distinguish the dosemeters that were positioned inside from dosemeters outside the buildings. The regression line is however fitted to all dosemeter readings. The correlation in terms of Pearsons's $r^2$ was higher for the outdoor measurements compared to those inside. The better correlation found for the outdoor dosemeters is probably due to the higher absorbed dose which provide a better signal to noise ratio.

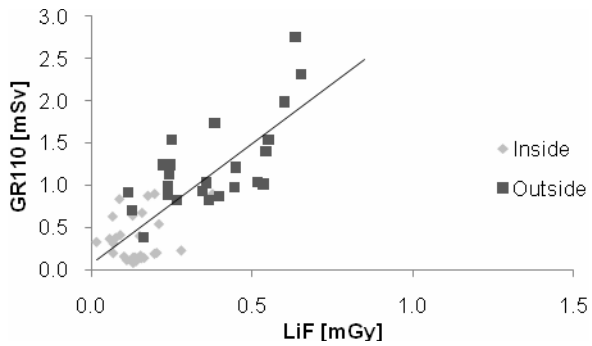


**Fig. 3.** The average effective dose as measured with GR-110 (on outset and collection) as a function of the absorbed dose in LiF at the same position, inside and outside the houses.

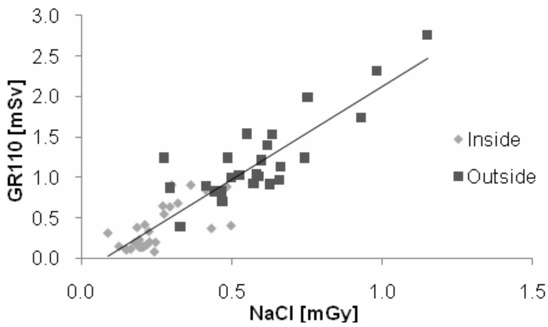


**Fig. 4.** The average effective dose as measured with GR-110 (on outset and collection) as a function of the absorbed dose in NaCl at the same position, inside and outside the houses.

Generally, the estimated dose rate indoors were rather low ($\bar{D}_{NaCl} = 0.14$; $\bar{D}_{LiF} = 0.07$ µGy $h^{-1}$) or comparable to the normal background radiation level in many European countries. Nevertheless, there is a moderately or good correlation between the three dosemeters. The best correlation is observed between GR-110 and NaCl readings ($r^2$ = 0.82), compared to GR-110 and LiF ($r^2$ = 0.55). This may partly reflect the similar responses between NaI(Tl) and NaCl for the photon energies studied. It is however apparent that some of the specific LiF chips used in this study show a larger variation in sensitivity than originally stated by the manufacturer. This might have had a negative influenced on the 0.01 mGy detection limit, as specified by the manufacturer, and should be take into consideration when looking at the indoor measurements where the dose rate was relatively low.

A new expedition to the same village was carried out during the summer of 2009, with the same purpose as in 2008. Then additionally 10 houses (including 72 dosemeter kits) were investigated and the information from these dosemeters will bring more light to the usefulness of salt as a dosemeter for the environment.

## 4. Summary and conclusions

It has been show that household salt can be used to measure absorbed doses down to a few tens of mGy. Measurements also indicate a slightly higher response in NaCl- relative to LiF dosemeters at lower photon energies. The effect may be attributed to the higher atomic number of NaCl compared to LiF, and differences in directional dependence in sensitivity. More studies on salt are required to fully understand the dose response at different photon energies.

It has also been shown that household salt can be used as a dosemeter at absorbed doses from a few tenths of mGy and during field conditions. Even though the detection limit of OSL in salt, as stated in [5], is not yet as low as for the best TL systems using LiF, the use of salt instead of LiF would reduce the cost in both preparation and in read out time, as well as in the cost of manufacturing the dosemeters. The drawback is that the salt must be kept sealed from light and that it is sensitive to moisture. However, the risk of those factors can easily be reduced by a different design of the dosemeter casings.

Hence, both laboratory and field studies demonstrate that household salt is a useful tool for retrospective dosimetry and a good candidate for environmental monitoring. Still, there are some properties that must be investigated and improved before it can be fully used as a dosemeter e.g.

- long- and short term fading properties when exposed to monochromatic light sources and in darkness,
- comprehensive study of the dose response at different radiation qualities from low energy to high energy photons in hospitals and from photons to neutrons in the nuclear industry,
- develop a protocol for individual calibration of each salt sample,
- develop more rigid dosemeter holders.

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