NaCl pellets for prospective dosimetry using optically stimulated luminescence: Signal integrity and long-term versus short-term exposure

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Abstract
Optically stimulated luminescence (OSL) signal properties of pellets from three types of NaCl (two household salts and one analytical grade salt) were investigated for their use in prospective dosimetry. Special attention was given to the OSL signal behaviour with time. The readout protocol was optimised in terms of preheat temperature, and the OSL signal yield of the NaCl pellet with time as well as the fading of the OSL signal with time was investigated. The effects of acute and chronic irradiations were compared. Irradiations and readout were performed using a Risø TL/OSL reader (TL/OSL-DA-15, DTU Nutech, Denmark). The optimal preheat temperature was determined to be 100 ºC, yielding OSL signals similar to a 1 h pause before OSL signal readout. There was no OSL signal fading observed as a function of time, but a decrease in the OSL signal yield of the NaCl pellets with time resulted in an apparent inverse fading when converting the OSL signal to an absorbed dose. For chronic radiation exposures of up to five weeks, the sensitivity of the NaCl pellets was found to be stable. The results of this study show that the use of NaCl pellets for prospective dosimetry is a promising, cost-effective, and accessible complement to commercially available alternatives for accurate absorbed dose determinations.

Keywords OSL · Dosimetry · Salt · Fading · Extended exposures · Preheat

Introduction
Prior studies on optically stimulated luminescence (OSL) dosimetry involving luminescent materials have shown that ordinary household salt (NaCl) has potential applications both in retrospective dosimetry (Bailey et al. 2000; Bernhardsson et al. 2009; Spooner et al. 2011; Hunter et al. 2012; Ademola 2017) and prospective dosimetry (Bernhardsson et al. 2012; Ekendahl et al. 2016; Christiansson et al. 2018; Waldner and Bernhardsson 2018; Majgier et al. 2019). As NaCl is easily accessible all over the world, it could be an available and cost-effective complement to commercially available dosimeters in applications where a large number of dosimeters is needed or when there is a shortage of other available means for in situ or individual dosimetry. Such applications may include personal dosimetry and radiation dose assessments in hospitals, the nuclear industry, or research environments; environmental monitoring; and emergency preparedness. Compressing the NaCl into pellets simplifies handling, improves reproducibility, and further supports the potential use of NaCl for prospective OSL dosimetry. Some of the dosimetric properties of NaCl in pellet form have already been investigated (Elashmawy 2018; Waldner and Bernhardsson 2018; Majgier et al. 2019), but the use of NaCl pellets for long-term measurements outside the laboratory, e.g., for personal dosimetry or environmental monitoring, requires more knowledge and understanding regarding any potential changes in signal properties over time. Until now, most of the studies on NaCl pellets have only included results from acute radiation exposures, e.g., inside the reader. However, under realistic conditions, the dosimeter may be continuously exposed over days or weeks. It is not yet known if and how such chronic exposures affect the radiation-induced OSL signal used for the quantification of absorbed doses in NaCl. Furthermore, the effect on the OSL signal due to compressing the NaCl to pellets have not yet been fully investigated, but initial investigations (Waldner 2017) indicate that the dosimetric properties are affected...
when grains of NaCl are compressed to pellets, yielding higher weight-normalised signals for pellets as compared to grains of salt.

A common practise in OSL for retrospective dosimetry and archaeological dating is to apply a preheat before readout (Bailey 2000; Christiansson et al. 2011); a pause between irradiation and readout, to let the signal stabilise on its own, has also been suggested (Waldner and Bernhardsson 2018). Multiple measures are needed to achieve a stable signal depending on the available readout equipment and labour time. Consequently, further studies are needed to find an optimised preheat temperature for the NaCl pellets and to determine how to achieve a stable and reproducible OSL signal at the readout.

The overall aim of this work was to investigate the dosimetric properties of NaCl pellets over time, both during and after exposure. More specifically, the aim was to investigate the potential OSL signal fading, the OSL signal yield of the NaCl pellets over time, and the effect of chronic vs acute exposures, and to optimise the preheat temperature. Knowledge on these issues is essential for dose applications outside the laboratory where complex measurement conditions may dominate, and when handling a large number of NaCl pellets.

Method

Production of NaCl pellets

The study examined three different salts (NaCl) (Table 1) compressed to pellets (Waldner and Bernhardsson 2018). Salt 1 was a commercially available rock salt while Salt 2 was a commercially available sea salt, both bought in Swedish supermarkets. Salt 3 was an analytical grade salt used for laboratory purposes (Scharlab, 99.5%). The NaCl pellets were produced using a specially-made tool (Promech, Sweden) with a pressure of 0.8 tons per pellet. The pellets were 4 mm in diameter and about 0.8 mm thick, made from about 20 mg of NaCl with grain sizes between 100 and 400 µm. The pellets were produced at least 24 h before they were exposed to ionising radiation unless an exception is noted for the different experiments. After manufacturing the pellets were kept at room temperature in a laboratory with a combination of natural and artificial lighting. No additional optical or thermal bleaching was needed to zero potential background OSL signals. The produced pellets were visually identical and no additional controls were made to ensure that they were physically and dosimetrically identical beyond the properties previously investigated in Waldner and Bernhardsson (2018). In addition, any difference in dosimetric properties between pellets was corrected by the use of the calibration dose.

OSL signal readout

Readout of the OSL signal from NaCl pellets was performed using a Risø TL/OSL reader (TL/OSL-DA-15, DTU Nutech, Denmark), described in detail by Thomsen (2004). The reader was equipped with an internal 90Sr/90Y irradiation source (20 MBq as of 9 April 2009) with an absorbed dose rate of 0.77 ± 0.02 mGy s−1 (as of 1 February 2019) to quartz (calibration quartz, DTU Nutech, Batch 101). The dose rate to NaCl was 0.72 mGy s−1, calculated using a stopping power ratio of 0.938 (Berger et al. 2005) between NaCl and SiO2. Light stimulation was performed using continuous wave (CW) stimulation by means of blue (λ = 470 nm) LEDs. The photomultiplier tube used to detect the luminescence photons was equipped with a 7.5 mm thick Hoya U-340 filter, resulting in a detection window with maximum transmission at 340 nm.

Typically, the first minutes after irradiation the OSL signal decreases rapidly before it starts to stabilise after about 1 h (Waldner and Bernhardsson 2018), due to the emptying of the more shallow and unstable impurity traps in the NaCl. It is desirable to avoid any signal contributions of these shallow traps, which means that the unstable traps need to be emptied before readout of the OSL signal. This can be achieved by either waiting for the signal to stabilise on its own at room temperature or by heating the sample to remove the unstable part of the signal.

To investigate the optimal use of either a preheat or a pause, the readout protocol in Table 2 was used for OSL signal readout. The preheat temperature was kept the same in Steps 2.1 and 5.1 in Table 2 to ensure a reproducible fraction of emptied energy state traps in the crystal lattice after each irradiation.

Pellets of the three types of salt presented in Table 1 were subjected to the two readout protocols described in Table 2. In the assessment of the unknown signal, S′, no background correction was performed as the background...
signal was assumed negligible (all NaCl pellets had been pre-bleached in daylight). After the 1 h pause or preheat after exposure, the radiation-induced signal from each pellet was defined as the integrated number of luminescence counts registered during the first 5 s of the 20-s OSL signal readout with blue light stimulation. The OSL signal decreased rapidly during the first seconds of readout to a background which then decreased slowly. The integrated luminescence during the last 5 s of the recorded OSL signal decay curve was used as a background correction when further irradiations and readouts were performed on the same pellet since any additional induced signal will be added to the remaining background from the former readout. The calibration signal, \( S_c \), was thus defined as the integrated OSL signal between 0 and 5 s of readout corrected for the background of the previous OSL signal readout between 15 and 20 s.

For some experiments, only Steps 1–3 of the readout protocol in Table 2 were used, and the signal was compared to the pre-established signal-dose response curve described in Waldner and Bernhardsson (2018). This curve shows the mean OSL signal from 10 NaCl pellets, read using Steps 1–3 of the protocol in Table 2, for several different increasing absorbed doses up to 300 mGy. Using such a curve provides a quick estimation of the absorbed dose, with uncertainties of about 10% (Waldner and Bernhardsson 2018) in the absorbed dose determination.

The procedure of using only the readout Steps 1–3 in Table 2 was also used to determine the calibration dose when the full readout protocol in Table 2 was used (Section “OSL signal fading and its dependence on preheating conditions”). According to previous work (Waldner and Bernhardsson 2018), a \( D_c \), twice the size of \( D_u \) gives a good estimation of the absorbed dose for all salts at the absorbed dose levels used in the present investigation (<50 mGy).

When using the full protocol in Table 2, the absorbed dose to the NaCl pellets was calculated according to Eq. 1.

\[
D_u = \frac{S_u}{S_c} \cdot D_c, \tag{1}
\]

where \( D_u \) is the unknown dose, \( D_c \) is the calibration dose, \( S_u \) is the signal after exposure to an unknown dose, and \( S_c \) is the calibration signal.

### Optimisation of preheat temperature for NaCl pellets

The preheat temperature was optimised in two steps: first, it was determined whether heating the NaCl pellet affected its dosimetric properties, and second, it was investigated whether the chosen temperature was sufficient to empty the unstable electron traps in the crystal lattice.

### Effects of preheating the NaCl pellet

When using a calibration dose to determine an unknown dose, it is important that the OSL signal per unit dose is the same for both the unknown exposure and the administered calibration dose (or that the relationship between the responses is known and constant). If the dosimetric properties change between the two irradiations, the unknown dose, \( D_u \), in Eq. 1, will not be estimated correctly.

To investigate if the heating of NaCl before readout affects the dosimetric properties, and if so, at what temperature, several measurements were performed using the protocol in Table 2. The preheat was varied between 25 and 225 °C in steps of 25 °C in steps of 25 °C, with all other parameters remained unchanged. The preheat temperature in Step 2.1 was kept the same as that in Step 5.1 (Table 2). For this investigation, the two given doses, \( D_u \) and \( D_c \), had the same value (21.6 mGy); hence, the corresponding signals \( S_u \) and \( S_c \) were expected to be similar. The ratio of the unknown signal \( S_u \) and the calibration signal \( S_c \) was calculated and compared.
for the different preheat temperatures. Any deviation from a value of 1 for this ratio was then interpreted as a change in sensitivity.

**Time delay between preheat and readout**

To investigate if the selected preheat was sufficient to empty the unstable traps in the NaCl, the OSL signal was read at several instances after the preheat. If the signal did not continue to decrease after preheat, then the chosen preheat temperature was considered to be sufficient. Five NaCl pellets were irradiated with an absorbed dose of 21.6 mGy and then preheated. After a pause following the preheat, the OSL signal was read. This was repeated nine times, with pauses between 0 and 400 s introduced between the preheat and readout steps, i.e., between Steps 2.1 and 3 in the readout protocol in Table 2.

**OSL signal fading and its dependence on preheating conditions**

In the present study, fading is defined as the decrease in the read OSL signal, \( S_u \), and estimated dose, \( D_u \), over time. To investigate the fading, the OSL signal was read on multiple occasions from different pellets after exposure to the same absorbed dose. For this, 100 NaCl pellets were irradiated by a \( ^{60}\text{Co} \) gamma radiation source (Gammatron 3, Siemens, Germany) 24 h after production. The NaCl pellets were positioned in a PMMA phantom with a 5 mm build-up layer and then irradiated with an absorbed dose, \( D_u \), corresponding to 5 mGy to water. After this exposure, the pellets were kept in a light sealed plastic container intended for photographic films, to keep the signal from optical bleaching.

The OSL signal from the irradiated pellets was read at various times, from 1 h to 4 weeks after irradiation. Ten pellets were read on each occasion: five at room temperature after being preheated to the temperature determined in Section “Production of NaCl pellets” and five at room temperature without any preheat. After readout, the signal was compared to a pre-established signal-dose calibration curve (Waldner and Bernhardsson 2018) to estimate the absorbed dose from the \( ^{60}\text{Co} \) source. Based on the estimated absorbed dose, a calibration dose, \( D_c \), was determined and administered to the pellets. For all three salts, \( D_c \) was set twice as high as the administered dose, \( D_u \). The calibration signal, \( S_c \), was read after a preheat of 100 °C for the first five pellets and after a 1-h pause for the other five pellets. The estimated absorbed dose was calculated using Eq. 1.

**OSL signal yield over time**

To investigate the OSL signal yield over time, NaCl pellets were irradiated, and the OSL signal read, on several occasions between one hour and one month after production of the pellets. The internal \( ^{90}\text{Sr}^{90}\text{Y} \) source of the TL/OSL reader was used for the irradiations. After the pellets were manufactured they were kept in a transparent plastic container at ambient conditions. The \( D_u \) administered to the NaCl pellets was at the same level (28.8 mGy) for each exposure. Two types of readout (Table 2) were used after irradiation: first, five pellets were read after a preheat (Step 2.1 in Table 2) at a temperature determined in Section “Production of NaCl pellets”, and second, five pellets were read after a pause of one hour using no preheat (Step 2.2 in Table 2). In this way, the OSL signal yield, or radiation sensitivity, of the NaCl pellets was determined as a function of time after pellet production for two types of signal acquisition.

**Acute versus chronic irradiation**

To investigate any potential effects of long-term irradiation and the influence of exposure with varying dose rates, NaCl pellets made from Salt 1 were placed in opaque packages on styrofoam blocks at different distances (40, 60 and 80 cm) from a 20 MBq \( ^{137}\text{Cs} \) point source (Fig. 1). The use of varying distances from the point source was intended to mimic free air exposure with different ambient dose equivalent rates 4, 7, and 13 µSv/h, respectively, as determined using a handheld radiation detector (identifier FLIR, United States). These dose rates resulted in cumulated doses of around 3–10 mGy to the NaCl pellets after 5 weeks which is well above the detection limits of the NaCl pellets but in the relevant range for personal dosimetry. At each distance from the radiation source, five packages of pellets, each containing five NaCl pellets, were placed on individual styrofoam blocks. One package per distance was removed for readout (full readout protocol with pause, Table 2) after 1, 2, 3, 4, and 5 weeks of exposure to achieve five different total absorbed doses with three different dose rates. The dose rate effects were expected to be the same for the three salts (Table 1), which is why only one salt (Salt 1) was investigated. Scattering
Effects were not considered as the aim was only to have a constant dose rate at each styrofoam block for the 5 weeks of measurements.

**Uncertainty calculations**

Uncertainties were calculated using error propagation (Eq. 2). When irradiating and reading the OSL signal twice from the same NaCl pellet, i.e., twice repeating Steps 1–3 in Table 2, all dosimetric properties were assumed to be unchanged. This means that the unknown signal and calibration signal were not independent of each other but were likely correlated. Thus, their covariance needed to be accounted for in the uncertainty estimate.

\[
\left( \frac{\sigma_{D_{NaCl}}}{D_{NaCl}} \right)^2 = \left( \frac{\sigma_{Su}}{Su} \right)^2 + \left( \frac{\sigma_{Sc}}{Sc} \right)^2 + \left( \frac{\sigma_{Dc}}{Dc} \right)^2 - 2 \cdot r \cdot \frac{\sigma_{Su}}{Su} \cdot \frac{\sigma_{Sc}}{Sc},
\]

where \(\sigma\) denotes the uncertainty of the previously described variables and \(r\) is the correlation factor.

Figure 2 shows a graph of \(S_u\) as a function of \(S_c\), read from the same NaCl pellet after two exposures with the same dose, repeated for different absorbed doses. The correlation, \(r\), between \(S_u\) and \(S_c\) is obtained as the square root of the Pearson \(R^2\) value in Fig. 2. For these data, the correlation was 0.9996, and the uncertainty contribution from \(S_u\) and \(S_c\) thus became very small.

**Result and discussion**

**Optimisation of preheat temperature for NaCl pellets**

**Effects of heating**

In Fig. 3, for the same given dose \((D_u = D_c)\), the ratio \(S_u/S_c\) (see Eq. 1) increases above unity at temperatures above 100 °C. This means that the calibration signal became lower than the unknown signal if a higher preheat temperature was used. At the time of the first exposure to \(D_u\), the pellets had not been heated to temperatures above room temperature. Before the second irradiation, however, the pellets had been preheated to obtain \(S_u\). For a correct estimation of the absorbed dose to the NaCl pellets, a preheat must be chosen that does not alter the dosimetric properties of the NaCl.

The aim is thus to preheat the NaCl pellets enough for the unstable energy level traps to be emptied without affecting the properties of the NaCl pellets or emptying the deeper, stable traps in the NaCl crystal. As shown in Fig. 3, 100 °C is the maximum temperature that can be used for the preheat without altering the dosimetric properties of the NaCl pellets.

It is noted that depending on the heat transfer between the heating element of the OSL reader and the NaCl pellet, the optimal temperature might vary slightly with different readout systems. Furthermore, setting the heating element...
to 100 °C might not provide a uniform temperature of the pellet, especially when the heating rate is high and the pellet is only heated for a short period of time.

**Time delay between preheat and readout**

To investigate if a preheat of 100 °C is enough to empty the shallow electron traps, the OSL signal was read at several different occasions after preheat (0–400 s) from different pellets irradiated with the same absorbed dose, 21.6 mGy. The result is shown in Fig. 4. When accounting for the estimated uncertainty (indicated as ± 1 SD uncertainty bars), the signal was observed to be stable after a 100 °C preheat regardless of the pause time (Fig. 4). This means that the unstable traps were sufficiently emptied and the remaining occupied traps were stable and of importance for absorbed dose estimation. Some variation is to be expected, however, as the OSL signals were compared for different NaCl pellets at the different readout times.

Based on these results, a preheat of 100 °C was chosen for all further investigations.

**OSL signal fading and its dependence on preheating conditions**

Figure 5a–d show (a) the OSL signal over time (non-normalised) when either a pause or a preheat protocol was used; (b) the calibration signal after administration of \( D_u \) at different times after the initial \( D_A \) irradiation, which gives the OSL signal yield of the NaCl pellets with time; (c) the apparently absorbed dose with time; and (d) the absorbed dose with time when calculated using a predetermined signal-dose response curve (Waldner and Bernhardsson 2018). The rather large variability in Fig. 5a depends on the mass and amount of signal-inducing material of the NaCl pellets. The readout protocol in Table 2 was used, and both readout procedures are presented in Fig. 5.

The three salts show similar trends in all graphs in Fig. 5: the unknown OSL signal, \( S_u \), remains stable over 30 days within 1 standard deviation of the uncertainty with no indication of signal fading (Fig. 5a), while the calibration signal decreases with time (Fig. 5b). For all three types of NaCl, this resulted in an apparent inverse fading effect when the absorbed dose, \( D_u \), was calculated using Eq. 1 (Fig. 5c). The same trend was obtained and discussed in previous work (Waldner and Bernhardsson 2018). Others have also observed indications of inverse fading of the OSL signal, both for a short time scale of seconds (Biernacka et al. 2016) and a longer time scale of days (Christiansson et al. 2014). However, those observations were related to a different phenomenon than the one observed here. As can be seen in Fig. 5a, there was no fading of the OSL signal itself, and the apparent inverse fading is only attributed to the calibration dose normalisation, \( D_A \), in Eq. 1. When dividing by a number which decreases with time, the estimated dose appears to increase with time. However, when \( D_u \) is calculated using the signal-dose response curve taken from Waldner and Bernhardsson (2018), the estimated absorbed dose appears stable with time (Fig. 5d). Note that the signal-dose response curve does not correct for any fading, as it was produced by reading the OSL signal 1 h after irradiation. Therefore, the estimated \( D_u \) in Fig. 5d will show a similar trend over time as \( S_u \) in Fig. 5a, but with an added conversion factor from the signal to the absorbed dose. Since calculating absorbed doses by means of individual calibration doses (Eq. 1) results in more accurate dose estimates than using a pre-established signal-dose response curve, the decreasing signal yield of \( S_u \) overtime must be adjusted when using Eq. 1. There are two alternatives to achieve this: either a mathematical correction that is calculated from a graph showing the OSL signal yield with time or avoidance of the use of the pellets until the efficiency is stabilised. However, the first step before applying the second adjustment is to investigate if the OSL signal yield stabilises as a function of time after pellet production.

The OSL signals in Fig. 5a and b were read using two different readout protocols (Table 2), one which used a preheat to empty the unstable traps and one which used a pause. The resulting OSL signals differed in magnitude, but when calculating the absorbed doses (Fig. 5c), the differences cancel and the estimated absorbed dose agreed within about 7% for the two readout protocols. This means that either protocol can be used for absorbed dose estimates with a similar accuracy depending on the available readout possibilities.
which in turn may depend on available equipment and time restraints. For example, if only a few samples are to be read, it is faster to use the preheat protocol. However, for a large number of samples, the time difference between a pause or the preheat becomes negligible, and because the heating the samples itself is connected with uncertainties such as heat transfer and uneven heating of the sample (McKeever and Moscovitch 2003), the pause protocol may yield more reliable results.

**OSL signal yield as a function of time**

Figure 6 shows the results of exposing NaCl pellets to ionising radiation at different times after production and reading of the OSL signal. It is evident that the signal from the administrated dose, $S_u$, decreases with time even though the administrated dose, $D_u$, was the same for each exposure. This indicates that the NaCl pellets become less sensitive to ionising radiation with time after production. This effect is large during the first two days but tends to stabilise to a certain level of sensitivity after about three weeks after production. If the NaCl pellets are used for prolonged radiation exposure, then it is either necessary to correct for this sensitivity change, or the NaCl pellets need to be produced several weeks in advance before use to allow time for stabilisation of their radiation sensitivity.

The reason for the change in OSL signal yield is not clear, but the compression of the salt during pellet production might be a factor, with point defects becoming instable due to the compression and then starting to stabilise after
the stress relaxation. This is further supported by the fact that NaCl pellets generally have a higher weight-normalised OSL signal than grains of salt (Waldner 2017). This needs to be further investigated, however, possibly by performing the same measurements with pellets produced with different compression forces to find a cut-off where the weight-normalised signal from the pellets does not differ from that of the grains, or by investigating the TL curves of the NaCl pellets as a function of time to see if they change in shape over time.

**Correcting for decreasing OSL signal yield**

Using a mathematical correction to obtain a better estimation of the absorbed dose is more time efficient than waiting for the NaCl pellets to age and stabilise. When using Eq. 1 to calculate the absorbed dose, \( D_a \) can be adjusted with a time-dependent correction factor that accounts for the time between the first irradiation and the administration of the calibration dose. This correction factor comes from fitting a mathematical function \( f(t) \) to the observed decrease in efficiency with time, \( t \). This can be calculated as \( f(t_1) - f(t_2) \), where \( t_1 \) is the time of the first irradiation and \( t_2 \) is the time of administration of the calibration dose. Fitting bi-exponential functions to the data of each of the salts in Fig. 6 (pause protocol) and using these to correct the decreasing \( S_u \) in Fig. 5b results in the adjusted graphs in Fig. 7. Even after this correction, however, there is still a small increase in the estimated absorbed dose with time, but this increase is significantly smaller compared to that shown in Fig. 5c. With a better fit to the observed OSL yield data and more detailed knowledge of its time dependence, the correction could be further improved.

**Acute versus chronic irradiation**

For the extended irradiations, the average \( S_u/t \) (Fig. 8 top) and \( S_c/t \) (Fig. 8 bottom) appear to be stable over the investigated 5-week period for all three dose rates. There are some values that deviate from the overall trend, which may be attributed to pellets being broken or to any variation in the amount of NaCl in each pellet. For some measurement points, the data deviate from the overall trend for both \( S_u \) and \( S_c \). This supports the possibility of a varying amount of NaCl in each pellet being the reason, as this is cancelled out in the \( D_a \) calculations (Fig. 9). The results in Fig. 8 can be compared to those of the acute irradiations shown in Fig. 5a, b. In Fig. 5b, there is a clear decrease in \( S_c \) with time, while this effect is not seen for \( S_u \) in Fig. 8, even though both Figs. 5b and 8 show the \( S_u \) values obtained after a calibration dose administered by the \( {^{90}}\text{Sr/}^{90}\text{Y} \) source at different times up to at least a month. The estimated \( D_a/t \) remains stable as a function of the measured time interval (Fig. 9). Unlike the situation with acute irradiations (Fig. 5c), there is no observed inverse fading for prolonged irradiations. This may be the result of a continuous fading and stabilisation of the signal over time for extended irradiations.

Additional extended exposure experiments are needed to investigate if the decrease in signal efficiency of the NaCl pellets can also be seen in other exposure situations, for example, in environmental monitoring. If not, there is no need for a correction of extended measurements.
Conclusions

In this study, the OSL signal in NaCl pellets (0.8 mm thick and 4 mm in diameter) has been investigated for its potential use in prospective dosimetry using blue light continuous wave OSL. Of specific importance for dosimetry using such pellets outside the laboratory are the timing between production and irradiation and the timing between irradiation and subsequent readout protocol, including optimised preheat. The results indicate the following:

- A preheat at 100 °C or a pause of 3600 s between irradiation and readout gives a reproducible OSL signal.
- Taking into account the measurement uncertainties, the OSL signal from the NaCl pellets appears to be stable over time, at least over 4 weeks.
- To more accurately estimate absorbed doses, a correction may be considered for the decrease in OSL signal yield with time.
- The change in OSL signal yield with time can be corrected if the rate of change in a particular salt brand is known beforehand.
- If acute irradiation is closely followed by the readout, the OSL signal yield does not need to be corrected.
- For chronic exposures there is no observable change in OSL signal yield for up to at least 5 weeks of exposure, indicating possible stabilisation of traps with time.
- The results obtained in this work can be applied not only for prospective but also for retrospective dosimetry.

The results of this study show that the NaCl pellets can be used for long-term measurements which is essential for personal dosimetry. Using NaCl pellets for prospective dosimetry is a promising, cost-effective, and accessible complement to commercially available alternatives for accurate absorbed dose determinations.

Future work includes investigations of the thermoluminescence signal from different types of NaCl to further optimise the preheat temperature and to explain some of the phenomena addressed in this work, especially in terms of signal response for long-term exposures.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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