*Journal of Electrical Engineering and Information Technologies*, Vol. **8,** No. 1, pp. 5–10 (2023)
Article 202
Received:March 3, 2023
Accepted: May 17, 2023
In print: ISSN 2545–4250
On line: ISSN 2545–4269
UDC: 539.16.073.5:[613:641.881
https://doi.org/10.51466/JEEIT2381202005k

*Original scientific paper*

# DIETARY SALT AS A POTENTIAL DOSIMETER IN RETROSPECTIVE DOSIMETRY

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A b s t r a c t: As a result of the risk that radiological and nuclear disasters and accidents will expose members of the public to unsafe amounts of radiation, numerous emergency dosimetry approaches for triage have been thoroughly explored. The current methods of retrospective dosimetry encompass a variety of biological, physical, and chemical procedures related to the radiation exposure of the human body. Additional items that might be useful as fortuitous dosimeters using luminescence techniques include banknotes, electronic components, table salt, quartz recovered from bricks, and other burnt ceramic materials. In this study, we investigated the usability of the dietary salt supplement for retrospective dosimetry in the dose range related to triage. We studied samples' limit of detection (LOD), dose response, reproducibility, and fading, which are all important elements of the optically stimulated luminescence (OSL) signal and sample's luminescent properties. Measurements were conducted by Riso TL/OSL reader DA-20. The study used potassium chloride tablets and electrolyte powder from different manufacturers that were packaged in standard lightproof containers. The findings of this study demonstrate that these supplements after irradiation provide measurable and satisfactorily reproducible OSL signal. The signal increases linearly with the dose in the triage-related dose range and has low LOD values.

**Key words;** fortuitous dosimeters; retrospective dosimetry; optically stimulated luminescence (OSL)

## ДОДАТОЦИ НА ИСХРАНА КАКО ПОТЕНЦИЈАЛЕН ДОЗИМЕТАР ВО РЕТРОСПЕКТИВНА ДОЗИМЕТРИЈА

А п с т р а к т: Поради ризикот од изложување на широка популација на големи дози јонизирачко зрачење при радиолошки и нуклеарни катастрофи, се истражуваат бројни пристапи за итна дозиметрија со цел брзо спроведување на тријажа. Сегашните методи на ретроспективна дозиметрија опфаќаат различни биолошки, физички и хемиски методи чија крајна цел е да го утврдат степенот на изложеноста на јонизирачко зрачење. Материјалите кои можат да се користат при испитувањето со физички методи на луминисценција се банкнотите, електронските компоненти, готварската сол, кварцот извлечен од тули и други топлински обработени керамички материјали. Во овој труд се истражува применливоста на додатоци на исхраната кои содржат соли за употреба во ретроспективна дозиметрија во опсегот на дози поврзани со тријажа. Целта на истражувањето е да се утврдат лимитот на детекција, одговорот на доза, повторливоста и стареењето на сигналот. Мерењата се извршени со читачот Riso TL/OSL DA-20. Користени се калиумов хлорид и електролити од различни производители. Резултатите од ова истражување покажуваат дека испитуваните материјали по изложеноста на јонизирачко зрачење обезбедуваат мерлив и задоволително повторлив сигнал. Интензитетот на сигналот се зголемува линеарно со дозата во дозниот опсег поврзан со тријажа и има низок лимит на детекција.

**Клучни зборови:** дозиметри; ретроспективна дозиметрија; оптички стимулирана луминисценција (OSL)

## 1. INTRODUCTION

Numerous emergency dosimetry techniques for triage have been thoroughly studied as a result of the concern that radiological and nuclear catastrophes and accidents will expose members of the public to dangerous levels of radiation. Various biological, physical, and computational techniques related to the radiation exposure of the human body are included in the current methods of retrospective dosimetry [1].

Banknotes, chip cards, dust on coins, tobacco, clothing, common table salt, salty foods like crackers and snacks, quartz recovered from bricks, and other fired ceramic materials are additional items that might be useful for testing with luminescence techniques [2, 3]. The category of personal items might include medications and nutritional supplements [4]. Numerous studies were done to determine their dosimetry potential.

In this study, we studied the dietary salt supplement's applicability for retrospective dosimetry in the dose range associated with triage. OSL was chosen as a measurement method. Our attention was drawn to crucial aspects of the OSL signal in the samples, including sensitivity variations over the course of multiple readings, dose response, LOD, and fading.

## MATERIALS AND METHODS

Materials used for this study, including potassium chloride and electrolyte, were purchased at a local pharmacy. Potassium chloride was in the form of tablets of different shapes and sizes, while electrolyte was in the form of a powder. They were enclosed in common lightproof pharmaceutical packaging. All the data were taken from the patient information leaflets or packaging. Table 1 provides a list of the materials used, with details on their composition.

The size and shape of most of the tablets in their intact form were not suitable for OSL measurements. The tablets of all used materials were crushed using a mortar and a pestle. The powder was not sieved and thus contained grains of different size. Powder aliquots for measurements were created by covering cups used within the OSL instrumentation with a thin layer of the powder. The cups used are with an inner diameter of 8 mm. The weight of the powder portions spread on the cups was 9.8 – 10.2 mg. The preparation was performed in darkroom conditions.

Measurements are performed by Riso TL/OSL reader DA-20. The optical stimulation was carried out with blue LEDs with a peak emission at 470 nm. Samples were stimulated and read using continuous-wave OSL, in which the stimulation light intensity is kept constant and the OSL signal is monitored continuously throughout the stimulation period. The light intensity was 50 mW/cm$^2$ at the sample position. The stimulation lasting 60 s was performed at room temperature. All results are obtained as the mean value of the integral in the range from 0 to 1.5 seconds, on 5 samples. Preparation was performed in dark room conditions, as well as the storage of samples. This study was performed on Potassium chloride tablets and powder Electrolyte from different manufacturers, enclosed in common lightproof packaging. The tablets were not acceptable for OSL measurement due to their size and shape in their intact condition. With the aid of a mortar and pestle, the tablets were broken up. The powder had not been sieved, thus it contained granules of all sizes.

T a b l e 1

*List of the medications and food supplements with details on their composition*

| Dietary salt supplement<br>Brand name (manufacturer) | Ingredients |
|---|---|
| Potassium chloride<br>Belupo | Potassium chloride 500 mg<br>Lactose monohydrate 19.75 mg |
| Potassium chloride<br>JADRAN galenski laboratorij - JGL | Potassium chloride 500 mg<br>Lactose hydrate 25 mg |
| Electrolyte (Electrolyte 1)<br>Erba Vita Nature in Science | Maltodextrin, Calcium citrate, Sodium bicarbonate, Fructose, Orange aroma, Sodium chloride, Lemon acid, Magnesium carbonate, Silicon dioxide, L-ascorbic acid (Vitamin C), Betacarbotene, Sucralose, Sodium citrate, Riboflavin (Vitamin B6), Peroxide hydrochloride (Vitamin B1), Cyanocobalmin (Vitamin B12) |
| Hidraton neo Bioecolians ® (gluco-oligosaccharide) (Electrolyte 2)<br>DS natural | Bioecolians (gluco-oligosaccharide), Dextrose, Sodium, Chlorine and Potassium |

## RESULTS AND ANALYSIS

### *OSL signal*

Figure 1 shows the OSL signal obtained after irradiation with different doses. After illumination and test irradiation with dose of 1 Gy, all materials described in Table 1 displayed a clear OSL signal. A similar response is observed in KCl preparations, while in electrolyte mixtures there is a greater difference due to their complex composition. In KCl preparations, the intensity of OSL decreases more slowly and a significant luminescent signal could be observed even after 5 s of illumination.

The specific luminescence values $C_{specific}$ (co-unts·mg$^{-1}$·Gy$^{-1}$) and LOD are given in Table 2 for all used materials. LOD is calculated according to the method reported by Geber-Bergstrand et al. [5, 6]. This method considers the uncertainty of the calibration curves of the dose response.

$$\mathrm{LOD} = \frac{S_0}{k} + 3\left(\sqrt{\left(\frac{\sigma_s}{S_0}\right)^2 + \left(\frac{\sigma_k}{k}\right)^2} \cdot \frac{S_0}{k}\right), \qquad (1)$$

where $S_0$ is the average number of counts of the zero-dose samples, $k$ is the slope of the calibration curve, $\sigma_s$ is the standard deviation of $S_0$, and $\sigma_k$ is the standard deviation of $k$.

LOD was determined using data from OSL measurements on non-irradiated samples. For potassium chloride samples, values of 171 Gy and 593 Gy were obtained, while values of 4.3 mGy and 1.4 mGy were obtained for electrolyte samples.

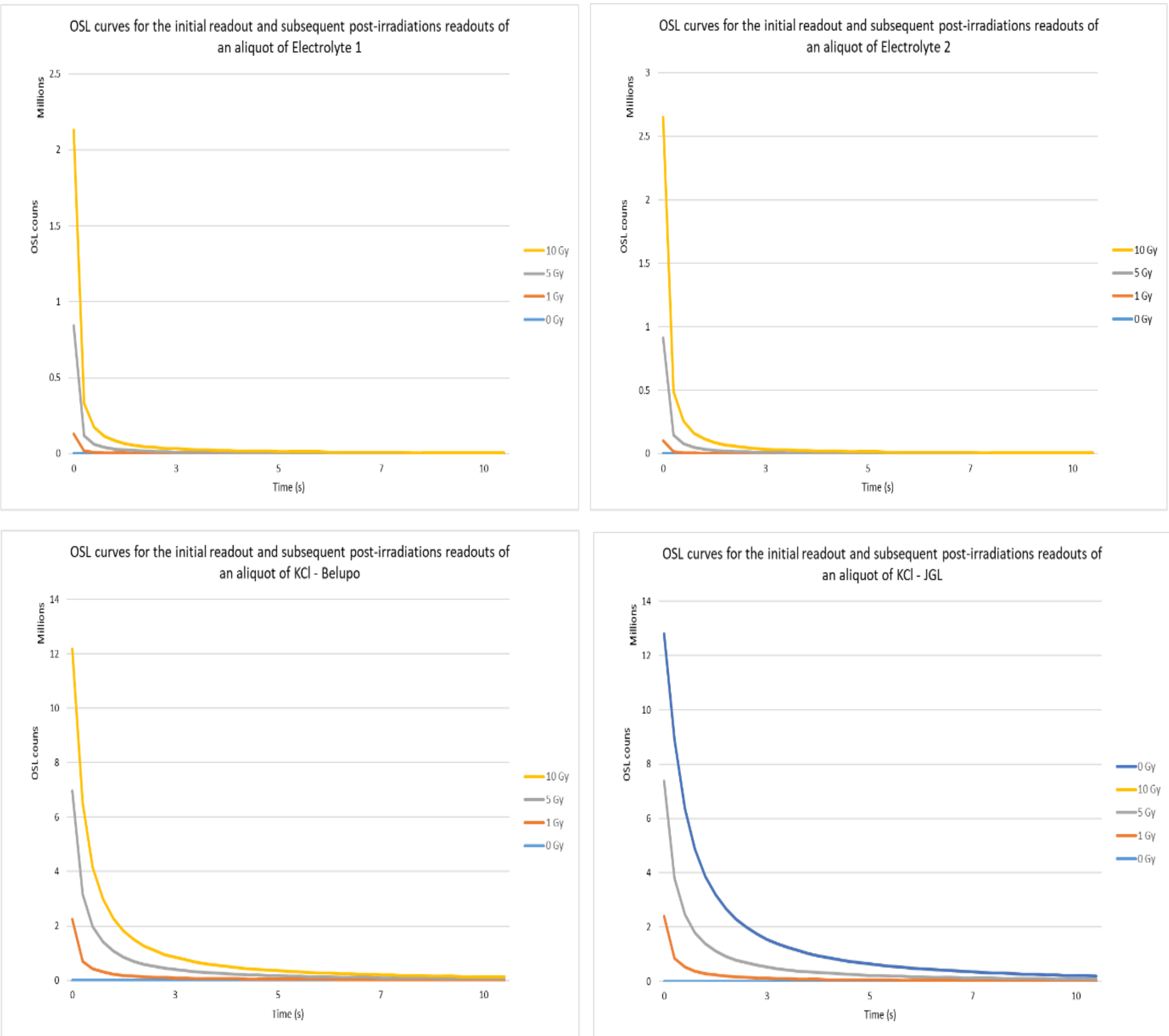


**Fig. 1.** OSL responses

Table 2

*Specific luminescence and LOD*

| Sample | Specific luminescence, $C_{specic}$ (counts / mg · Gy ) | LOD |
|---|---|---|
| KCl – Belupo | 416376±34342 | 171 μGy |
| KCl – JGL | 441032±50903 | 593 μGy |
| Electrolyte 1 | 19365±5506 | 4.3 mGy |
| Electrolyte 2 | 19562±21884 | 1.4 mGy |

*Dose-response*

The OSL response of samples exposed to doses of 0, 1, 2, 3.5, 5, 6.5, 8, and 10 Gy was studied, measuring 5 samples of each material (Figure 2).

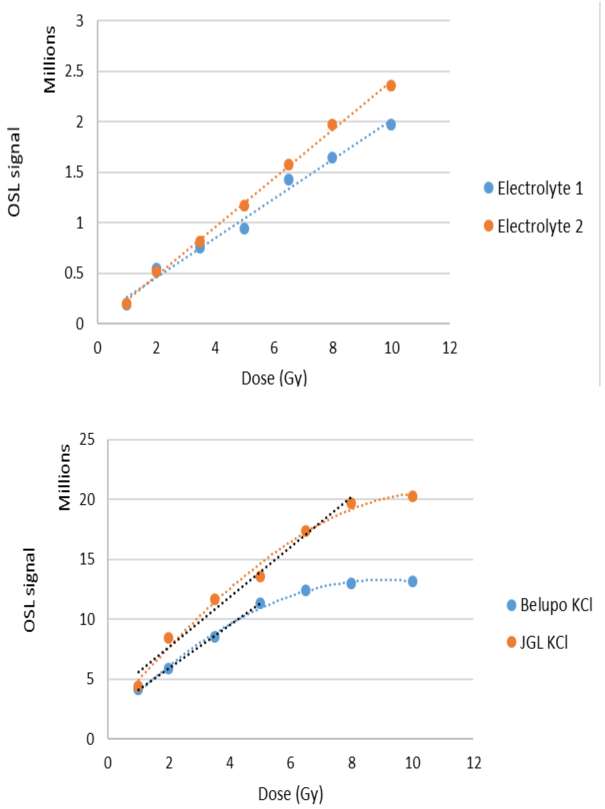


**Fig. 2.** Dose-response and linearity

According to the results for potassium chloride dose-response test, linearity is seen up to 5 Gy for JGL sample and up to 8 Gy for Belupo sample. OSL signal to dose linearity in the electrolyte was attained up to 10 Gy.

*Reproducibility*

For the aim of measuring reproducibility, aliquots of each sample were exposed to radiation at a dose of 5 Gy and read ten times in a row. The OSL signals were normalized to the value found for the first cycle. The dose response must be determined using a Single-Aliquot Regenerative-dose methodology for materials with a high coefficient of reproducibility (>1.1) [8]. In the examined potassium chloride, the reproducibility was obtained from 1.1 to 1.3, while in the case of electrolytes it ranges up to 2.9 (Figure 3).

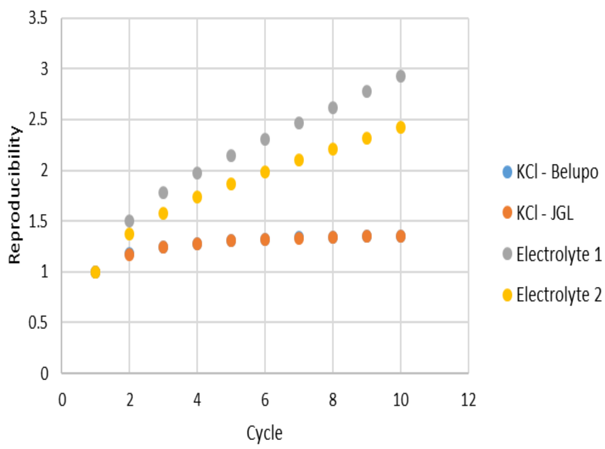


**Fig. 3.** Reproducibility of repeated measurements

However, additional illumination can reduce this factor, which is most likely due to undischarged loops. This can also be explained by the phenomenon named as the regeneration effect characteristic of salt compounds [9]. However, by adding another illumination step with 100% power for 60 s after the reading, the coefficient drops below 10%.

### *Fading*

Over a seven-day period, we identified fading of the OSL signal (Figure 4). After one week, the OSL signal decreased to about 80% of its initial value obtained right after irradiation. The measurements for dose reconstruction ought to be performed as soon as possible after radiation exposure.

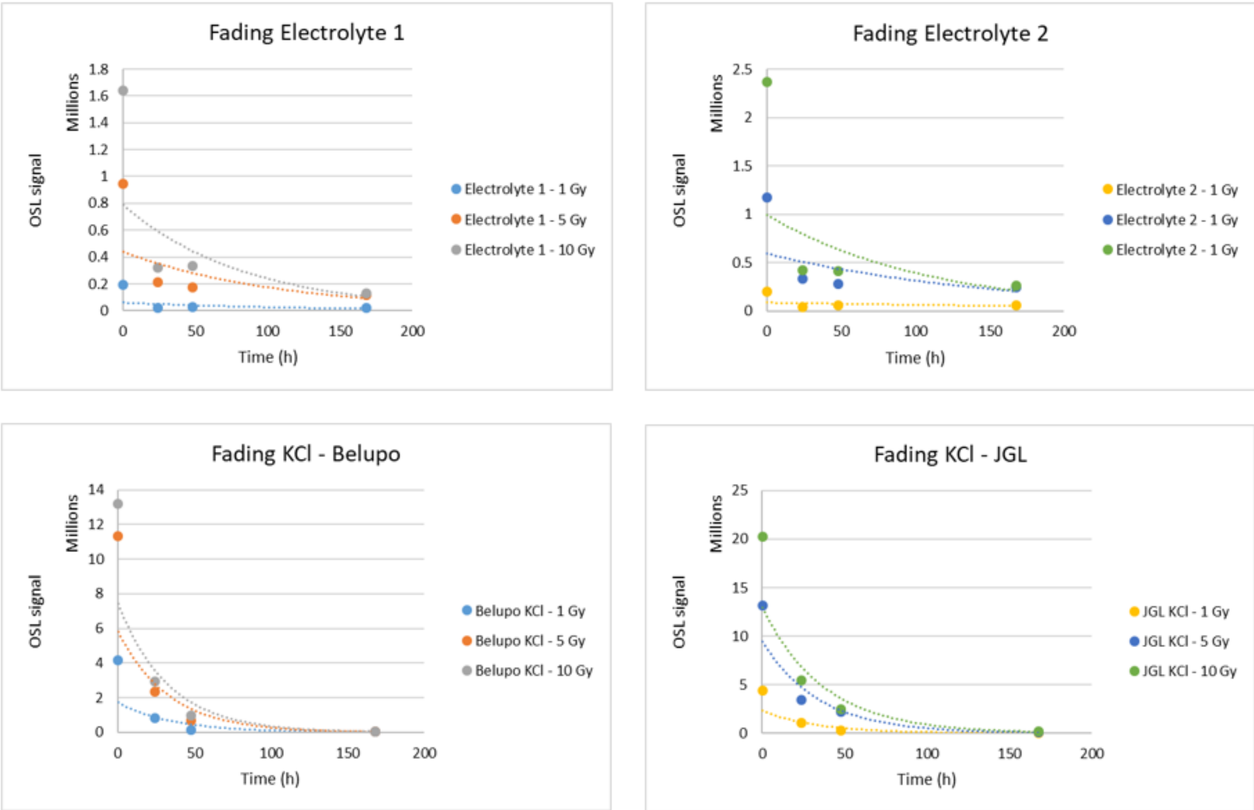


**Fig. 4**. Fading of OSL signal

## CONCLUSION

In this study we performed measurements on potassium chloride and electrolyte by OSL in order to determine crucial aspects of the OSL signal including sensitivity variations over the course of multiple readings, dose response, LOD, and fading. Using data obtained from OSL measurements on non-irradiated samples, the LOD for potassium chloride and for electrolyte samples was determined. Moreover, measurements were done on samples exposed to doses of 0, 1, 2, 3.5, 5, 6.5, 8, and 10 Gy, and their response to optical stimulation was investigated. From the dose-response test, linearity for potassium chloride is observed in aliquots irradiated with doses of up to 5 Gy for one and up to 8 Gy for the other sample. In the electrolyte, linearity of OSL signal vs. dose was obtained in aliquots irradiated with doses of up to 10 Gy. Regarding the interpretation of the subsequent dosimetry experiments that were based on the repeated usage of individual aliquots, it was crucial to examine the reproducibility of the OSL signals. Because of high coefficient of reproducibility the dose response must be determined using a Single-Aliquot Regenerative-dose methodology [7]. In the examined potassium chloride, the reproducibility was obtained in the range 1.1 -1.3, while in the case of electrolytes it ranges up to 2.9. We observed fading over a period of seven days. The OSL signal dropped to about 80% of its initial value after one week. Ideally, the measurements for dose reconstruction should be carried out within a few days of radiation exposure. The investigated materials can be applied for dose determination in nuclear incidents as retrospective dosimeters in the first days after the accident. In addition, the luminescent responses to combined heat and light stimulation that can improve some of the key luminescence parameters should be investigated.

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