



Sintered sand pellets for high-dose dosimetry

M.I. Teixeira, L.V.E. Caldas *

*Instituto de Pesquisas Energéticas e Nucleares, Comissão Nacional de Energia Nuclear, Caixa Postal 11049,
05422-970 São Paulo, SP, Brazil*

Abstract

Sand samples from different Brazilian beaches have been studied in relation to their dosimetric properties for high-dose dosimetry in routine procedures of radiation processing. The powder samples were pressed, and sintered at 300 °C in air. The thermoluminescent glow curves of samples exposed to gamma doses of 5 Gy up to 80 kGy present two peaks at about 110 and 170 °C. The results indicate that sintered sand pellets can be successfully used for high-dose dosimetry in several areas of applications of ionising radiation.

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1. Introduction

Radiation processing using high-doses presents various advantages in industry (water purification, pasteurization), medicine (sterilisation) and agriculture (desinfestation, inhibition of sprouting) [1].

In the industrial area new techniques were developed, the reference and routine dosimeter systems were improved, and the quality-assurance programs were applied to radiation dosimetry, to meet the specific needs of measures and of cost [2].

Sand is a natural material found in great amounts; in the decade of nineties this material awakened interest in its dosimetric properties.

Sand is mainly constituted of quartz and feldspar, which exhibit thermoluminescence (TL). Sand also contains some other elements in minor quantities [3,4]. The class of silicates is one of the most numerous and important in the mineral world.

Vaijapurkar and Bhatnagar [4] studied sand originating from Rajasthan, India, which exhibits two thermoluminescent glow curve peaks at 80 and 220 °C. The first peak is not important for dosimetry because it decays at the ambient temperature (fade-out), while the second TL peak presents an adequate response as a function of absorbed dose. They suggested in this work that sand could be used as a thermoluminescent dosimeter for gamma radiation and X-rays up to 20 Gy.

At the Metrology Laboratory of IPEN, São Paulo, transparent and colored commercial glasses have been studied in relation to their dosimetric properties for high-doses using different techniques [5–7].

* Corresponding author. Tel./fax: +55-11-3816-9118/3816-9117.

E-mail addresses: miteixei@ipen.br (M.I. Teixeira), lcaldas@ipen.br (L.V.E. Caldas).

In the present work the thermoluminescent dosimetric characteristics of sintered sand pellets (reproducibility, response to gamma radiation of ^{60}Co , and lower detection threshold) were determined for use as high-dose dosimeters, because of their extremely low cost and relatively easy characterization.

2. Materials and methods

Sand samples originating from different Brazilian beaches at distances of over 500 km from each other were studied. The sand sources included: Barra do Sahy Beach, São Paulo; Santinho Beach, Santa Catarina and Ponta Negra Beach, Rio Grande do Norte. These samples were called in this work, respectively, samples A, B and C. Sand was bolted to uniform grain between 0.037 and 0.074 mm in diameter. To eliminate organic impurities, the sand samples were washed with a solution of hydrochloric acid 1 N (1 M), and then rinsed with distilled water to remove the HCl. The sand samples were dried in an electric oven (Formitex) at 75 °C for 1 h.

Magnetic particles (mainly iron) were removed from some sand samples of each beach, using a magnetic separator (S.G. Frantz Com. Ind., Iso-dynamic, model L-1). An analysis of the main elements of the sand samples was obtained by neutron-activation analysis technique at the

Radiochemistry Department of IPEN. Results are given in Table 1.

To facilitate easy handling, sintered sand pellets were prepared at the Laboratory for Production of Dosimetric Materials, IPEN, using teflon for the binder. Sintering of the pellets was achieved with a thermal treatment of 300 °C for 1 h followed by another thermal treatment of 400 °C for 1.5 h. The sand pellets were divided into two batches:

A1, B1 and C1: natural sand samples, cleaned with HCl (1 M); and

A2, B2 and C2: natural sand samples, cleaned with HCl (1 M), without Fe.

The thermal treatment for reutilization of the material was 300 °C for 1 h.

The samples were packed in aluminium foils and in black plastic bags for the irradiations. Gamma sources of ^{60}Co were utilized: a Gamma-Cell 220 system (doses from 50 Gy to 80 kGy), and a Panoramic Yoshizawa Kiko Co. Ltd. System (doses from 5 to 50 Gy) of the Center of Radiation Technology, IPEN. The irradiations were made at ambient temperature, and the samples were fixed between 6 mm thick polymethyl meth-acrylate plates (Lucite), to guarantee the occurrence of electronic equilibrium during the irradiations.

The evaluation of the sintered sand pellets was carried out using a thermoluminescent reader (Harshaw Chemical Co., model 2000 A/B) using a heating rate of 10 °C/s. All TL measurements were integrated between 50 and 300 °C. Due to the

Table 1
Neutron activation analysis results of sand samples: concentration of the elements above 2 $\mu\text{g g}^{-1}$

Elements ($\mu\text{g g}^{-1}$)	Barra do Sahy Beach		Santinho Beach		Ponta Negra Beach	
	A1	A2	B1	B2	C1	C2
Al	7015 ± 86	5765 ± 86	4701 ± 51	3760 ± 51	8099 ± 81	5476 ± 70
Ba	86 ± 1	75 ± 1	53.5 ± 0.8	43.3 ± 0.7	87 ± 0.7	102 ± 1
Ca	4075 ± 299	952 ± 70	2999 ± 220	267 ± 20	27,666 ± 2033	2168 ± 159
Ce	92 ± 1	8.5 ± 0.1	5.70 ± 0.07	3.38 ± 0.04	31.1 ± 0.4	15.3 ± 0.2
La	44 ± 1	3.9 ± 0.1	3.3 ± 0.1	2.01 ± 0.06	16.0 ± 0.5	7.3 ± 0.2
Mn	94 ± 3	12.8 ± 0.9	21.7 ± 1.3	5.5 ± 0.6	99,229	2.4 ± 0.2
Na	322 ± 66	141 ± 36	146 ± 15	66 ± 10	444 ± 24	342 ± 10
Nd	37.1 ± 0.9	3.11 ± 0.07	2.79 ± 0.06	1.24 ± 0.03	9.0 ± 0.2	6.9 ± 0.5
Th	18.41 ± 0.08	1.73 ± 0.01	0.83 ± 0.02	0.42 ± 0.01	17.3 ± 0.07	7.03 ± 0.03
Ti	1588 ± 113	286 ± 58	667 ± 57	134 ± 37	28,615 ± 1445	461 ± 54
Fe (%)	0.498 ± 0.009	0.105 ± 0.002	0.207 ± 0.004	0.055 ± 0.001	1.46 ± 0.03	0.039 ± 0.001

thermal fading of the first peak, all measurements in this work were taken exactly one hour after the irradiations.

3. Results

3.1. Glow curves

The thermoluminescent glow curves of sand pellets from the three different origins, with and without Fe, exposed to an absorbed dose of 10.0 kGy are shown in Figs. 1 and 2, respectively. The glow curves of the sand pellets show peaks at 110 and 170 °C. The first TL peak is not considered for dosimetry due to its fast fading nature.

3.2. Reproducibility

Eight sets of the three types of sand pellets were submitted ten times to the same procedure of thermal treatment at 300 °C for 1 h (defined for the reutilization), and irradiation (5 kGy), in order to study the response reproducibility. The maximum standard deviations obtained were approximately

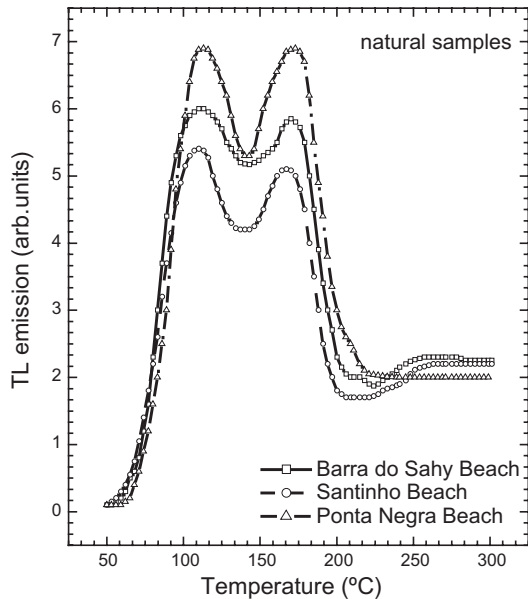


Fig. 1. Thermoluminescent glow curves of sintered sand pellets (natural samples), irradiated (^{60}Co) with 10 kGy.

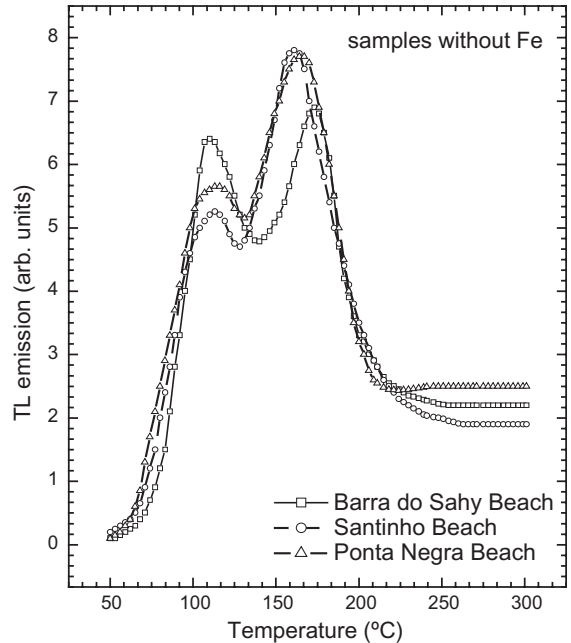


Fig. 2. Thermoluminescent glow curves of sintered sand pellets without Fe, irradiated (^{60}Co) with 10 kGy.

Table 2
Reproducibility of TL response of sintered sand pellets

Beach sand	Standard deviation (%)		
	Barra do Sahy	Santinho	Ponta Negra
Natural samples	6.47	6.59	6.58
Samples without Fe	3.63	3.94	3.85

6.5% for sand pellets with Fe (natural samples) and 3.8% for sand pellets without Fe. The results are given in Table 2.

3.3. Lower detection limits

The lowest detectable value for each sand type was determined by studying the signal variability obtained by evaluating non-irradiated sand pellets. It was taken as being equal to three standard deviations from the mean zero-dose reading of the sand pellets. The lower detection limits obtained were: 30, 20 and 40 mGy for the sand pellets of the Barra do Sahy Beach, Santinho Beach and Ponta

Negra Beach, respectively. These results were the same for samples with and without Fe.

3.4. Calibration curves

The sintered sand pellets were submitted to ^{60}Co radiation from 5 Gy to 80 kGy. Dose response curves were obtained, and they are presented in Figs. 3 and 4 for measurements taken by

using the TL reader. The maximum standard deviation of these measurements was 1.2%. Linearity can be observed in the ranges of 10 Gy up to 1.0 kGy, and saturation effects are clearly evidenced about 10 kGy for all sand pellets.

4. Conclusion

The results obtained on the main dosimetric characteristics (reutilization, reproducibility, dose response up to 10 kGy, and lower detection limits) show that sintered sand pellets can be applied in high-dose dosimetry. The advantages of this kind of material are: very low cost, easy handling, and the fact that sand is a natural substance easily available in large quantities on beaches. Sintered sand pellets may be applied for dosimetry in the main radiation processes of seed stimulation, mutation breeding, industrial radiography, insect population control, pasteurization and water purification.

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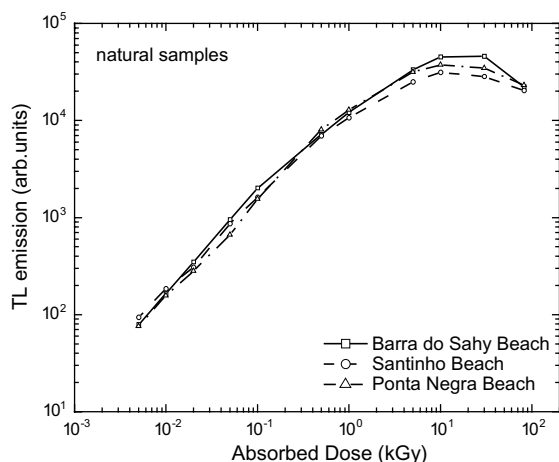


Fig. 3. Calibration curves of sintered sand pellets (natural samples) for ^{60}Co radiation (integrate area at 50–300 °C).

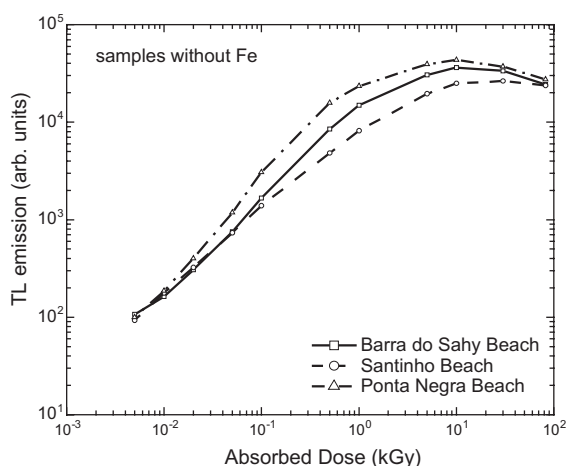


Fig. 4. Calibration curves of sintered sand pellets (without Fe), for ^{60}Co radiation (integrate area at 50–300 °C).