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The response of potassium nitrate for high-dose radiation dosimetry

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Abstract

Different chemical compounds have been studied to optimize dosimetric systems in irradiation processes. In this study the behavior of the potassium nitrate in pellet form was investigated in a ^{60}Co gamma field, in order to verify if it can be used as a dosimeter. Fricke solution was used as reference dosimeter to determine absorbed dose rates of the gamma facilities. The potassium nitrate (KNO_3) solution response is radiation sensitive and reproducible for absorbed doses from 1 to 150 kGy. The detection technique used was spectrophotometry in the visible region, which allows relating optical absorption, before and after irradiation. The potassium nitrate prepared in pellet form was dissolved in pure water for optical measurement. The maximum absorption wavelength was observed at 546 nm. Calibration curves were obtained and are linear in all dose interval studied. All the evaluations are presented in this work.

Keywords: High doses; Dosimetry; Potassium nitrate

1. Introduction

The knowledge on the chemical and biological effects of the radiation and the rapid expansion of the industry influenced the development of the processing industry for radiation (McLaughlin et al., 1989).

In almost all applications of ionizing radiation is necessary to know the absorbed dose by the material in order to optimize irradiation processes in laboratorial or commercial scale. The correct measurement of radiation dose in the dose range required by the researcher or client is the most suitable form to know the quality of the irradiation work. Radiation dosimetry has therefore a vital importance in the irradiation process when conducted in agreement with the requirements, rules and the process optimization (ASTM E 1261-94).

Various kinds of dosimetric materials have already been used in irradiations quality control and a great number of news dosimetric materials are still being researched (McLaughlin and Desroisers, 1995).

Pellets of potassium nitrate were analyzed to verify if it could be used as a routine dosimeter, since KNO_3 has been used in powder form (Dorda and Munõz, 1984). Its characteristics were analyzed before and after irradiation and the obtained results are presented in this work.

2. Experimental

2.1. Dosimeter preparation

Potassium nitrate in powder form was dried in an oven at 80°C, and then it was cold pressed in pellet form by applying a load of 5 tons. Three types of pellets were prepared maintaining the diameter of 6 mm and varying the amount of powder mass. Table 1 shows the characteristics of each pellets type. Each dosimeter consists of three pellets sealed between two polyethylene films of 0.18 mm of thickness and placed between 3 mm thick Lucite® plates to assure electronic equilibrium.

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Table 1
Pellets of potassium nitrate in function of the powder mass and thickness.

Type	Mass (mg)	Thickness (mm)
1	50	0.8
2	75	1.2
3	100	1.7

Each reported value corresponds to the average of three measurements.

2.2. Irradiation facilities

Most of the irradiations were performed using a 38.9×10^{13} Bq (10.508,4 Ci) ^{60}Co source of Gammacell type in the dose range between 1 and 150 kGy. The dose rate was approximately 7.48 kGy/h (January/99). A panoramic ^{60}Co source was also used in the dose range between 10 and 50 kGy. The dose rate was different depending on the distance source-dosimeter. Both sources belong to the Centro de Tecnologia das Radiações, CTR, IPEN/CNEN.

2.3. Dose evaluation

For optical measurements potassium nitrate pellets were dissolved in 50 ml of high purity water in a 100 ml volumetric flask. After dissolution, 20 ml of a coloring solution, composed by solutions A and B in the proportion of 5:1 was added. The solution A was prepared dissolving 2 g of sulfanilamide p.a. in 1 l of 30% of glacial acetic acid p.a solution and solution B was prepared dissolving 1 g of N-1-naphtylethylene diamine dihydrochloride p.a. in 1 l of 30% of glacial acetic acid p.a. solution. Ten minutes after dissolution the absorbance was measured at 546 nm wavelength (Bof, 1997; Dorda and Munõz, 1984; Torres, 1993).

2.4. Measuring instrument

The absorbance of the solutions of irradiated and non-irradiated pellets of KNO_3 was measured against air, at the wavelength range from 500 to 600 nm, using a Shimadzu UV1601PC spectrophotometer.

3. Results and discussions

3.1. Absorption spectrum

The absorption spectrum obtained with solutions prepared with non-irradiated pellets showed the existence of a platform in the wavelength range between 540 and 560 nm.After irradiation an intensification of the absorption output was observed and a peak in 546 nm can be observed as shown in Fig. 1.

3.2. Effect of environmental conditions

The pellets were exposed many hours to the laboratory ambient light and to different temperatures, between 10°C and 35°C. For both experiments the pellets were maintained in low humidity atmospheres. The obtained results show that no variation in the response was observed (Galante et al., 2000).

3.3. Effect of storage time

The solutions were analyzed after storage in different conditions:

1. The solutions prepared with non-irradiated pellets were measured in the same day of preparation. This condition was repeated for several days. As showed in the Fig. 2 no significant variation can be observed.

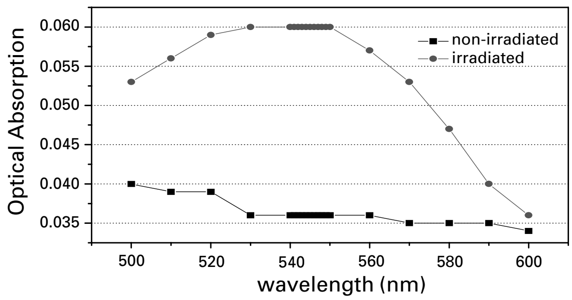

Fig. 1. Absorption spectrum for non-irradiated and irradiated potassium nitrate pellets. Irradiation dose of 5 kGy in the Gammacell source.

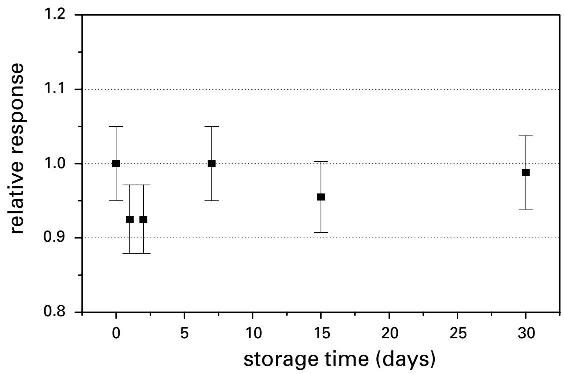

Fig. 2. Relative response of potassium nitrate solution prepared with non-irradiated pellets and measured in the same day of the preparation.

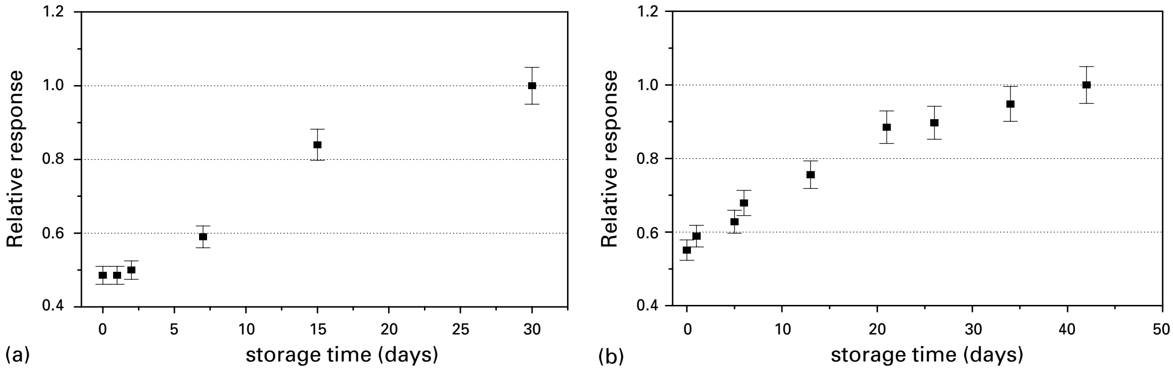

Fig. 3. (a) Relative response of solutions prepared with non-irradiated potassium nitrate pellets. Measurements were made in the first day and subsequent days; (b) Relative response of solutions prepared with irradiated potassium nitrate pellets with dose of 1 kGy. Solutions were measured at the same days of preparation and subsequent days.

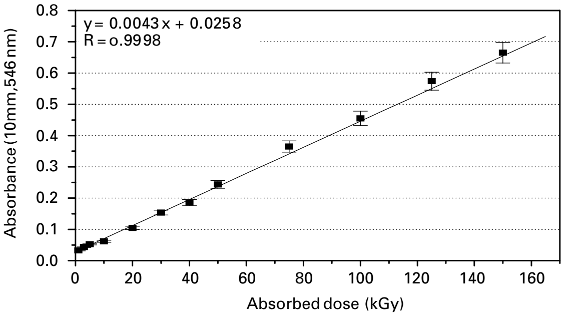

Fig. 4. Calibration curve of irradiated potassium nitrate (pellets with 50 mg) in a ^{60}Co Gammacell source. Optical absorption measured at $\lambda = 546$ nm.

It means that taking the necessary care to minimize the influencing factors the response is reproducible.

2. The solutions were prepared with irradiated and non-irradiated pellets and measured in the same day of the preparation and in subsequent days. An intensification of the optical response was observed. After 30 days the intensity of the optical absorption, for the same solution, grow up to the double of the initial intensity. This fact suggests chemical modifications of the complex formed during the break up, therefore, the measurement should not delay more than one day after prepared the solution. These results can be observed in Figs. 3(a) and (b).

3.4. *Mass dependence response*

Pellets with different mass were irradiated with doses of 10, 30 and 50 kGy in the Gammacell source. The optical absorption shows intensification with the increase of the mass. The three types of pellets presented similar behavior, then for economy subjects it can be used pellets with 50 mg.

3.5. *Calibration curve*

The calibration curve was built from values obtained with solutions prepared with 50 mg potassium nitrate pellets. These pellets were irradiated in a Gammacell source in a dose range between 1 and 150 kGy. Each point of the curve is the average of three measures (three samples for dose). The calibration curve is shown in Fig. 4.

4. Conclusions

The potassium nitrate can be used in pellet form for irradiation and processed for optical measures in the solution form. The obtained solution presents an increasing response when stored for long times. Then, the measurements should be achieved in a time not higher than 1 h after preparation, although the pellets can be stored by long periods.

Although the intensity of the absorbance is higher for pellets with mass of 75 or 100 mg, for economical subjects can be used of pellets with 50 mg.

Environmental conditions do not affect the response. The compound, that is hygroscopic, should be maintained sealed and handled in humidity atmosphere below 60%.

The dosimetric properties of this compound are appropriate for radiation dosimetry applications. The system presents a reproducible response in the interval between 1 and 150 kGy.

Pellets of potassium nitrate appear to be an effective dosimeter for the quality control in routine irradiations.

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