Evaluation of the Mixture KNO_3/MnO_2 for Radiation Processing Dosimetry

A.M.S. Galante*, L.L.Campos
Instituto de Pesquisas Energéticas e Nucleares – Department of Radiation Metrology
Av. Prof. Lineu Prestes, 2242.
05508-000 – Cidade Universitária – São Paulo – Brazil
* E-mail: sgalante@ipen.br

Abstract. The radiolysis of the inorganic nitrates has been shown to be complex, undergoing decomposition when exposed to gamma radiation, producing NO^-_2 and O_2. The radiation dose is absorbed by all components present in the system, including the added substances. This mechanism has been investigated by several researchers and for different mixtures. In the present study mixtures of inorganic compounds were prepared in pellet form and its properties were evaluated by means of spectrophotometric techniques for high doses assessment. Compounds such as $Ba(NO_3)_2$, KBr and MnO_2 were mixed at the pure KNO_3. The mixtures were cold pressed and sealed in polyethylene films. The dosimetric properties were evaluated related to the changes of the optical response when the pellets are exposed to gamma radiation, in the dose range between 200 and 600 kGy. The mixture containing MnO_2 is the only one that presents reduction in the nitrites production rate and, consequently, larger doses can be measured before the saturation. The characteristics studied were absorption spectrum and signal stability of irradiated and non-irradiated detectors; batch reproducibility; effect of the environmental conditions and dose-response useful range. The pellets irradiated with gamma doses present the maximum wavelengths at 540 nm. The batch reproducibility is better than 98% (1σ). To maintain their properties the pellets should be sealed in polyethylene films and stored in ambient with low humidity. Ambient temperature between 10 and 35°C and ambient light don't affect the optical response. The obtained results indicate that this type of dosimeter can be used in radiation process applying doses from 200 to 600 kGy.

Keywords: Dosimetry; Inorganic compounds; High dose

1. Introduction

Dosimetric systems based on radiolytic decomposition of inorganic nitrates are used in quality control programmes of radiation processing. The final products formed are NO_2^- and O_2. The effect of added compounds on gamma irradiated nitrates has been studied. When a sample is exposed to ionising radiation, the energy is absorbed by all the components present in the system such as cation, anions and the added substances. The enhancement/retardation in the decomposition of nitrates by various additives have been explained in terms of their electron donor/acceptor properties [1-9].

In this work are reported the results of gamma radiation decomposition of mixtures that contain KNO_3 and compounds such as $Ba(NO_3)_2$, KBr and MnO_2. The studied parameters were: absorption spectrum and signal stability of irradiated and non-irradiated detectors; batch reproducibility; effect of the environmental conditions and dose-response useful range.

2. Materials and Methods

The KNO_3 was dried and different weights of the KNO_3, between 10 and 60% of pellet mass, and the compounds selected were ground together in agate mortar. The mixtures of uniform composition (80 mesh) were cold pressed in the pellet form with 6 mm diameter and mass between 30 and 60mg, and sealed in polyethylene film.

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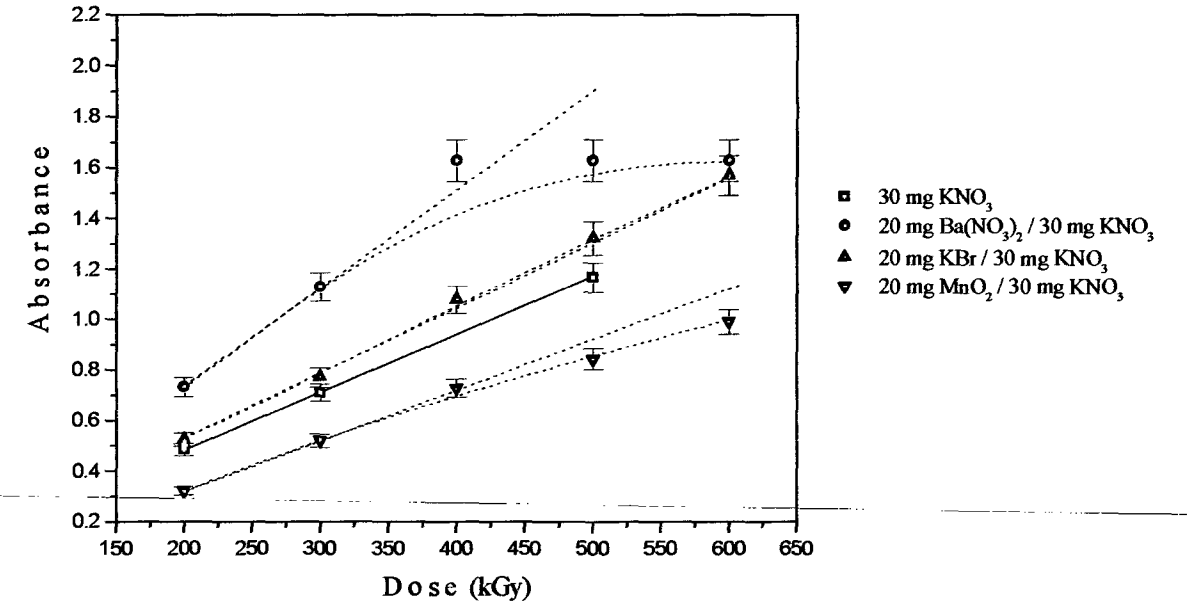

FIG. 6. Dose-response curves of pellets of KNO_3 p.a and pellets of mixtures with $Ba(NO_3)_2$, KBr and MnO_2, irradiated with gamma dose between 200 kGy and 600 kGy.

4. Conclusions

The method used for preparation and evaluation of the solutions containing KNO_3 and MnO_2 is simple and doesn't request special cares.

The better results were obtained with the mixture 40% MnO_2 / 60% KNO_3, since occurs reduction in the decomposition rate of nitrate ions to nitrite ions.

The dosimetric characteristics investigated show that this detector material can be useful in the control of several processes and dosimetric applications for higher doses than that using pure KNO_3. The dose range is large, doses up to 600 kGy can be measured, while using KNO3 p.a. the upper limit is approximately 200kGy.

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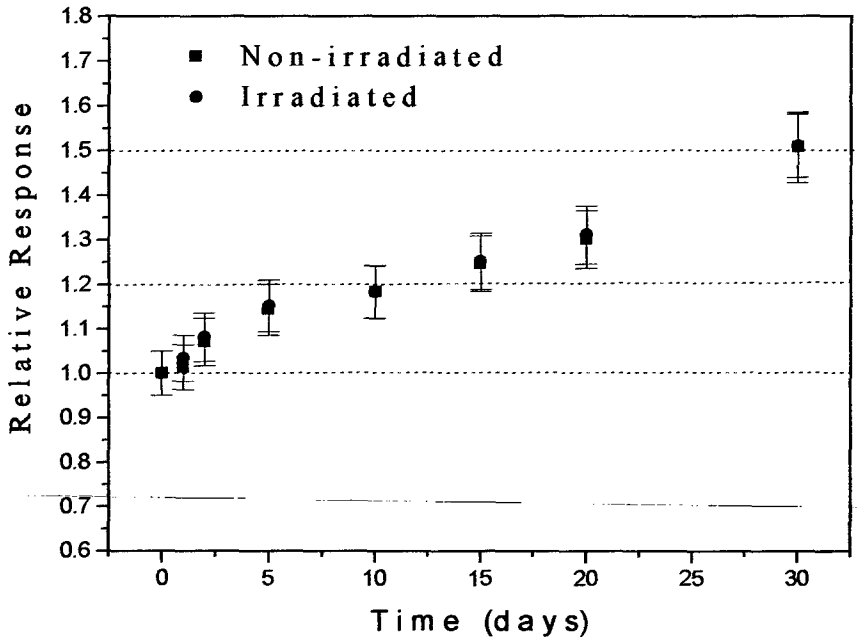

FIG. 5. Relative response of solutions obtained using pellets (40% MnO_2 / 60% KNO_3) irradiated with 200kGy, prepared and evaluated after up to 30 days of storage.

The dose response curves were obtained submitting the pellets to ^{60}Co radiation on the dose range from 200 kGy to 600 kGy. Pellets of KNO_3 and of the mixtures 40% $Ba(NO_3)_2$ / 60% KNO_3, 40% KBr / 60% KNO_3 and 40% MnO_2 / 60% KNO_3 were irradiated and evaluated at same conditions and the calibration curves are showed in the FIG. 6.

Different environmental conditions such as temperatures between 10°C and 30°C, relative humidity between 40% and 60% and ambient light don't affect the response of the detector, however, as the KNO_3 is hygroscope material the pellets should be maintained sealed between polyethylene film.

The solutions must be evaluated during the interval of 1 h after prepared. The maximum colour intensity of the solution is obtained 10 minutes after preparation. The non-irradiated and irradiated pellets can be stored by long periods without any change in their characteristics. The results obtained with solutions evaluated immediately after preparation, using pellets irradiated and stored up to 30 days are shown in the FIG. 4. The results obtained with solutions prepared at same time and evaluated periodically during 1 month of storage are shown in the FIG. 5.

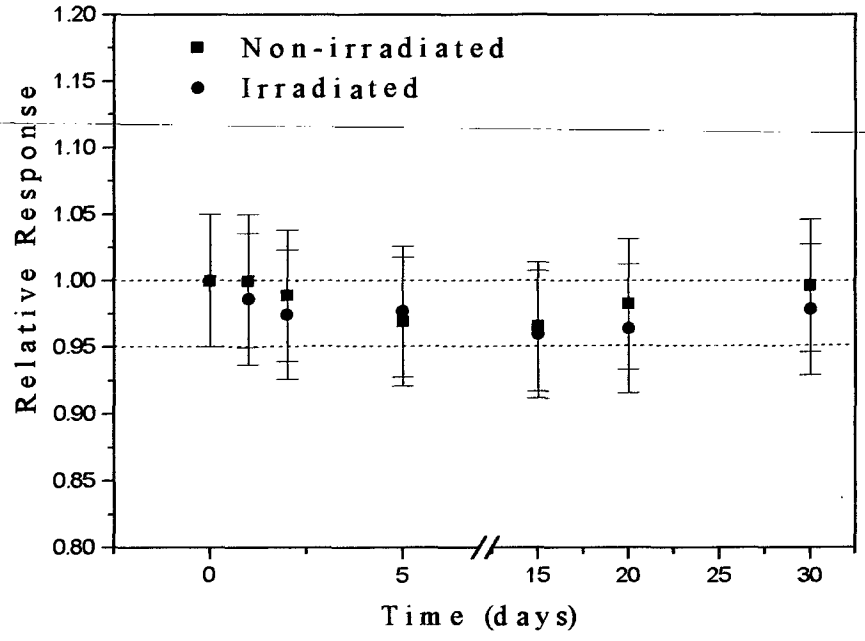

FIG. 4. Relative response obtained with solutions (40% MnO_2 / 60% KNO_3) evaluated immediately after preparation, using pellets irradiated with 200 kGy and stored up to 30 days.

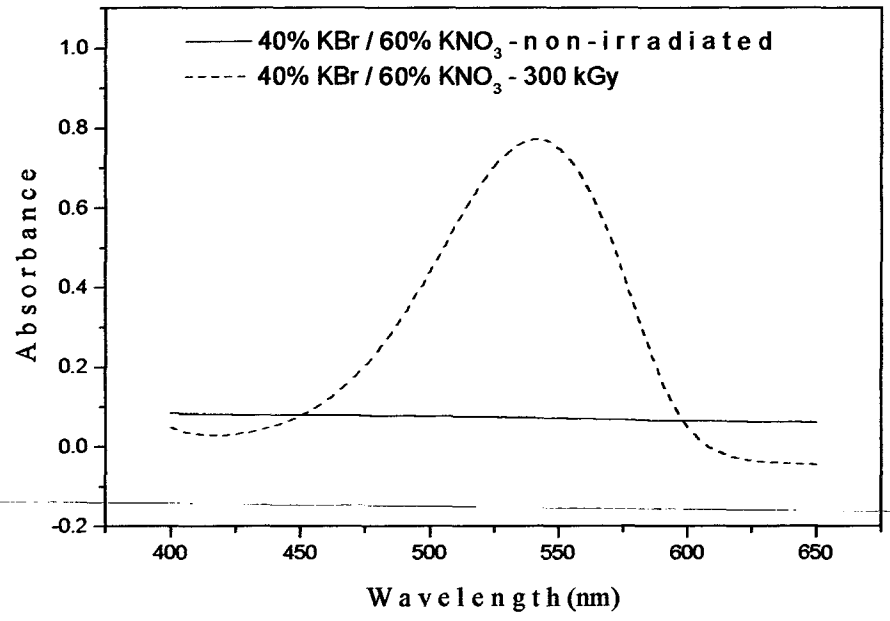

FIG. 2. Optical absorption spectrum of non-irradiated and gamma irradiated (300kGy) pellets.

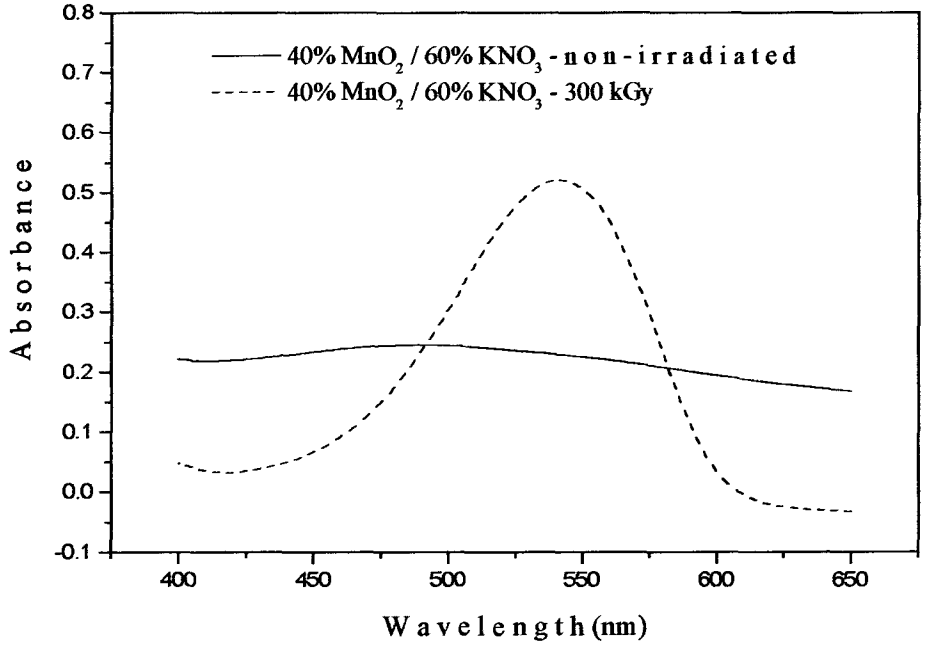

FIG. 3. Optical absorption spectrum of non-irradiated and gamma irradiated (300kGy) pellets

A large number of pellets was produced and same of then were chosen to be evaluated at same conditions, aiming to determine the reproducibility of the pellets production process and the evaluation method. The obtained reproducibility was found to be better than 98% (1σ).

The gamma irradiations, at electronic equilibrium conditions, using a ^{60}Co gamma source calibrated by Fricke dosimetry, were carried out in the dose range between 200 and 600 kGy. The quantity of nitrite ions formed during the radiolysis was estimated by using modified Shinn's method and recording the absorbance spectrum using a Shimadzu UV-VIS spectrophotometer, Model UV 2101PC.

3. Results and Discussion

The absorbance spectrum obtained with irradiated and non-irradiated pellets are showed in FIG. 1, 2 and 3 to the mixtures $Ba(NO_3)_2/KNO_3$, KBr/KNO_3 and MnO_2/KNO_3, respectively. The optical absorption spectrum presents a large band at about 540 nm, characteristic of the presence of NO^{2-} ions radiation induced.

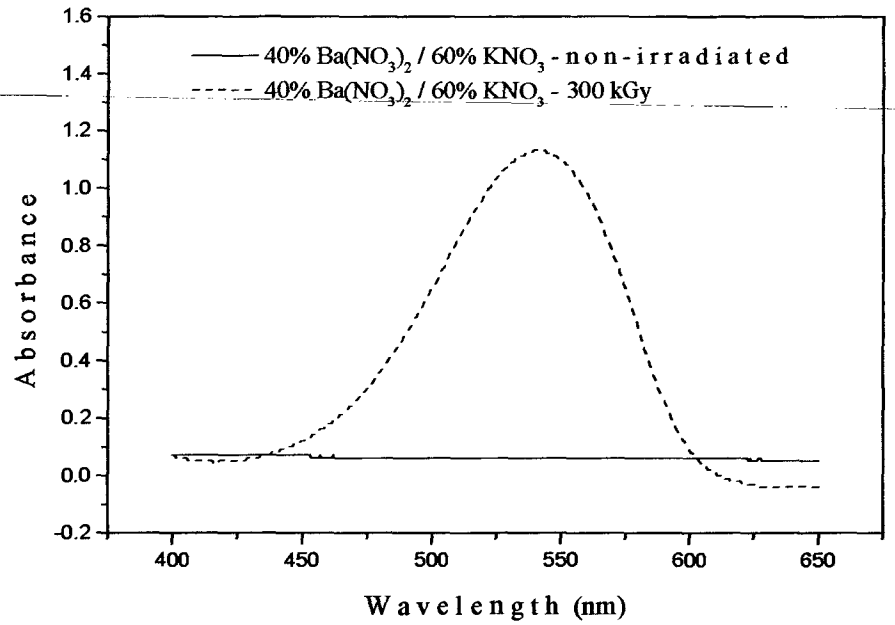

FIG. 1. Optical absorption spectrum of non-irradiated and gamma irradiated (300kGy) pellets.