

EVALUATION OF POTASSIUM NITRATE FOR GAMMA-RADIATION DETECTION

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ABSTRACT

Pellets of potassium nitrate (KNO_3) were evaluated to verify if they can be employed as dosimetric material for high dose measurements in routine use of radiation monitoring in radiation processing plants. The spectrophotometry in the visible region was used as detection technique. Pellets of KNO_3 were dissolved in pure water to allow the optical absorption measurements before and after irradiation with ^{60}Co gamma radiation source, calibrated with Fricke solution reference dosimeter. The absorption spectrum of the KNO_3 solution was investigated in the wavelength region between 500 and 600 nm to determine the maximum absorption wavelength. Dosimetric properties such as dose rate dependence in the interval between 0.059 and 3.82 kGy/h, angular radiation incidence dependence between 0 and 90 degrees and dose response in the range between 1-150 kGy were investigated. The obtained results show that the proposed dosimetric material can be useful in high dose measurements.

Key Words: dosimetry, gamma-radiation, potassium nitrate, and high doses.

I INTRODUCTION

The use of the radiation processes in the industry with the purpose of to improve some properties of several materials comes growing in the whole world. New facilities have been built for this purpose and due to its great interest in the quality these facilities shall adapt to these requirements.

With the implantation of the dosimetric control in radiation processing it is possible to guarantee the requested quality.

The market has a wide variety of products treated by the radiation technique, so there is a concern between researchers to develop and characterize compounds that can be used as dosimeter.

Among some services in radiation processing industry it can be cited [1]:

- Sterilization of a wide range of medical products;
- Sterilization of pharmaceutical products;
- Treatment of cosmetics;
- Pathogen elimination in foods and spices;
- Self-life extension of perishable food;
- Delayed ripening of fruits and vegetables;
- Disinfestations of grains and citrus fruits;
- Curing of plastics and printing inks;
- Cross-linking and degradation of polymer;
- Vulcanization, among another.

The International Standards Laboratories perform the calibration of gamma radiation sources. The dose rates can be determined using reference standard graphite

calorimeters and ionization chambers. The International Atomic Energy Agency (IAEA) supplies through a postal service an alanine dosimeter for calibration of sources and routine dosimeters of the installations. When a discrepancy of more than 10% is indicated between the results of the installation dosimeter and the IAEA dosimeter an investigation is carried out to detect the problem [1,2].

Besides standard systems several dosimetric systems were developed and a great number continues being studied. Examples of the most common dosimeter are [1,3]:

- Liquid dosimeters - ferrous sulphate - known as Fricke solution, ferrous-cupric sulphate, ceric-cerous sulphate and potassium dichromate;
- Solid Dosimeters - polymethylmethacrylate plates (Perspex, Plexiglas, Lucite), films of cellulose triacetate and dyed plastics.

The potassium nitrate is studied in this work and its dosimetric properties are presented. The radiolytic decomposition of the potassium nitrate yields nitrite ions and oxygen molecules. The yield of nitrite ions is proportional to the absorbed dose and this change in the nitrite concentration is detected by optical absorption measures [4,5].

II EXPERIMENTAL

The ^{60}Co radiation sources used in this work, which belongs to the Centro de Tecnologia das Radiações, CTR of IPEN/CNEN, were calibrated by IAEA Calibration Laboratory through the dose guarantee program.

The electron irradiations were performed using a JOB 188 Electron Accelerator of the CTR of IPEN/CNEN, calibrated using a calorimeter.

The potassium nitrate was cold pressed in pellet form with 6 mm diameter and 50 mg mass. The Fred Frey – Model 5ton press machine used belongs to the Departamento

da Metrologia das Radiações, NM of IPEN/CNEN.

For gamma irradiation were prepared sets of tree pellets of potassium nitrate sealed between two polyethylene sheets and placed between two 3 mm thick Lucite[®] plates, to guarantee the electronic equilibrium for ^{60}Co . The Fig. 1 shows the arrangement used for irradiations, the mould and the pellets.

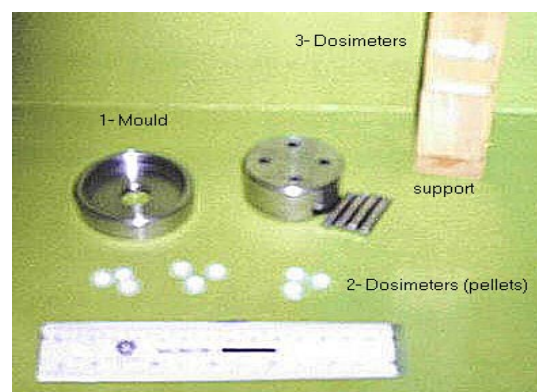


Figure 1. 1 - Mould to press the KNO_3 pellets with 6 mm diameter; 2 - Pellets conditioned between polyethylene sheets and 3 - Dosimeter fixed over a wood support for irradiation.

For optical absorption measures in the visible region of the spectrum a Shimadzu UV1601PC spectrophotometer was used. Each potassium nitrate pellets was dissolved in 50 mL high purity water in a 100 mL volumetric flask. A coloring solution was added and the measurement of the absorbance was performed after 10 minutes in the maximum absorption wavelength that was determined in 546 nm. The coloring solution was prepared by mixing solutions A and B in the proportion of 5:1, respectively. The solution A was prepared dissolving 2 g of sulfanilamide in 1 l of solution 30% of glacial acetic acid. The solution B was prepared dissolving 1 g of N-1 Naphthylethylene-diamine in 1 l of solution 30% of glacial acetic acid [4,5,6].

III RESULTS AND DISCUSSIONS

The nitrite concentration obtained after irradiation increases linearly with the absorbed dose. The Fig. 2 shows the dose - response curve obtained for irradiated pellets in the Gammacell ^{60}Co source with doses between 1 and 150 kGy [7].

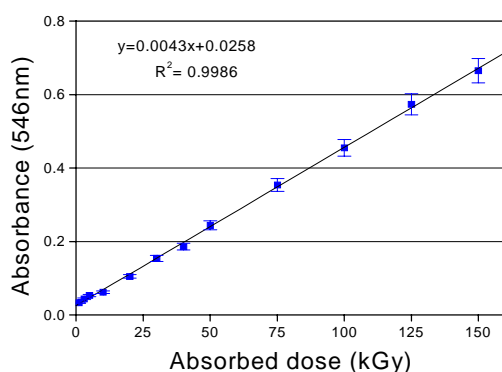


Figure 2. Dose - response curve obtained of the solutions prepared with potassium nitrate pellets irradiated in the Gammacell source with doses between 1 and 150 kGy.

No changes were observed in the response when the dosimeter was submitted to laboratory ambient light and temperatures between 10 and 35°C. Due to the great tendency of the potassium nitrate of absorbing water is important to handle it in atmosphere of low humidity and to conserve the sealed pellets and inside a desiccator.

The Fig. 3 shows the response of irradiated pellets with different dose rates in panoramic ^{60}Co source. An intensification of the response can be seen for the positions next to the source. The used dose rates were 0.059, 0.120, 0.328 and 0.586 kGy/h, that correspond at the distances of 60, 40, 20 and 10 cm, respectively. The intensification in the dosimeter response occurs due to the influence source geometry. To change dose rate in the type camera gamma source

of reduced volume (Gammacell) it is necessary to use lead attenuators. In this case no dose rate dependence was observed between 0.765 and 7.65kGy/h.

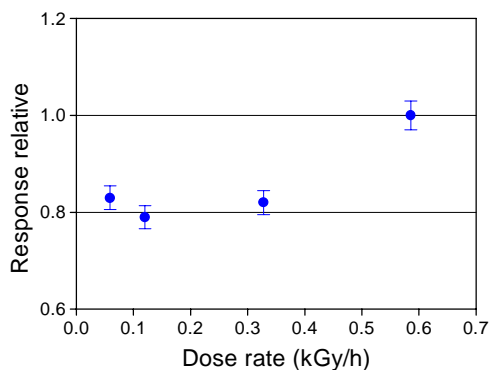


Figure 3. Dose rate response obtained from solution prepared with potassium nitrate pellets for different doses rates, irradiated in the panoramic ^{60}Co source.

The behavior of the dosimeter when exposed the high electron dose rate and low gamma dose rate was also studied. It was observed that in the absorbing wavelength of 546 nm, the absorbance is more intense when the pellets are submitted to accelerated electrons irradiation (high dose rate – 67.4 kGy/s) than that for gamma (low dose rate – 2.2×10^{-3} kGy/s). The pellets presented a dose rate dependence that increase the absorbance of a factor two, while the dose rate of the electrons is approximately 35.000 times higher than the dose rate for the ^{60}Co gamma radiation. The Table 1 shows the parameters used in the irradiations and the Fig. 4 shows optical absorption curves in the range between 500 and 600 nm, after the irradiation with a dose of 30 kGy with gamma rays and accelerated electrons.

Table 1 - Irradiation parameters, in the JOB 188 electrons accelerator.

Parameters	
Dose (kGy)	30.00
Dose rates (kGy/s)	67.39
Energy (MeV)	1.25
Current (mA)	15.20
HVD (mm)	88.20
SCAN (%)	77.00
Tray Velocity (m/min.)	3.36
Beam width (cm)	100.00

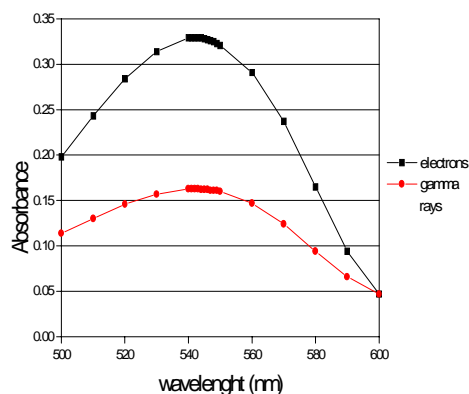


Figure 4. Relative response of the dosimeter when irradiated with gamma radiation (low dose rates) and accelerated electrons (high dose rate). Doses = 30 kGy.

To verify the angular dependence of the dosimeter response the radiation incidence angle was varied between 0 and 90°. The pellets were placed in front or sideways positions relative to the source. In all intermediary positions no variation was observed. In the vertical frontal (0°) and horizontal (90°) position occurs a variation of 2.5% in the intensity of the absorbance.

IV CONCLUSION

The change in the optical absorption of the KNO₃ solution supplies an effective way for the determination of the absorbed dose.

The KNO₃ pellets are not sensitive to the normal ambient conditions and can be handled without need of special cares. The maximum wavelength intensity of the absorption spectrum is 546 nm.

The results obtained in two different radiation fields demonstrate that this compound can be used for dosimetry in gamma fields as well as in accelerated electrons beams; there is only the need of to calibrate them in the field they will be used.

The dosimeter response doesn't present dependence with the radiation incidence angle.

The optical dose - response is linear between 1 and 150 kGy for gamma radiation.

The obtained results show that the potassium nitrate in the form of pellets can be used for the routine quality control in industrial irradiations.

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