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EXPERIMENTAL DOSIMETRY OF Ho-166 BIOGLASS SEED POLYMER-PROTECTED

Luciana B. Nogueira and Tarcisio P. R. Campos

Programa de Pós-Graduação em Ciências e Técnicas Nucleares, Departamento de Engenharia Nuclear
Universidade Federal de Minas Gerais
Av. Antônio Carlos, 6627
CEP: 31270901, Belo Horizonte, MG
lucibn19@yahoo.com.br

ABSTRACT

This study aims to develop experimental dosimetry of Ho-166 bioglass seed for brachytherapy studies using GAFCHROMIC EBT2 radiochromium films. The methodology consists of placement of radiochromium films in a compressed breast phantom, along with bioglass polymer-protected seeds of [Si: Ca: Ho] and [Si: Ca: Ho: Zr]. The bioglass seeds were encapsulated with polyvinyl alcohol, before being activated and used in the study. The bioglass seeds were introduced into the breast phantom, along with radiochromium films for a period of 2 hours. After the exposure time, radiochromium films were removed from phantom and digitized for analysis in ImageDIG 2.0 program, which quantifies the intensity of RGB (Red, Green, Blue). The dose calculation was evaluated by Monte Carlo technique. Experimental and theoretical data were used to calibrate the dose distribution. The results were plotted on graphs and dose isocurves were obtained. As conclusion it is possible to perform dosimetry in Ho-166 seed brachytherapy using radiochromium films, limited to a short exposure time and small activity.

1. INTRODUCTION

Brachytherapy is a method of radiotherapy in which interstitial implants with radioactive devices are placed near the neoplastic region. The advantage of this method is due to high doses of radiation that can be applied to the area to be treated [1-2].
The goal is to replace the metal bioglass seeds of iodine-125 used in brachytherapy treatment for bioglass seeds of holmium-166 that are biodegradable and biocompatible with the body [3-5].

The holmium-166 is a radioisotope that decays by beta radiation followed by gamma rays and has a half-life of 26.6 hours. The emission main of beta rays is 1.85 MeV (51%) and gamma rays is 0.08 MeV (6.2%), which causes a higher dose rate compared with the radioisotope iodine-125 emitting gamma rays of 36 keV and has a half-life of 59.4 days. The range of beta particles of holmium-166 in water is 8.3 mm, which provides the irradiation of a spherical volume of 1.6 cm in diameter. Absorption of beta dose in a limited spherical volume is sufficient to control a tumor following brachytherapy protocol [6-7].

In the process of irradiation, bioglass seeds had to be encapsulated because of the possible radioactive contamination during its various manipulations s. The encapsulation also makes easy the handling of seeds, since their small size from 0.2 to 0.4 mm in diameter and 1.6 mm in length [8].

According RÊGO [9] a major factor in brachytherapy is to provide dosimetry accurately. It refers to the calculation of the absorbed dose spatial distribution through experimental techniques and theoretical models at radial distance of isolated radioactive sources. Systems over time have been modified and improved by clinical experience, by the production of radioactive sources with a higher specific activity, by the use of images to guide dose calculations.

UNIYAL, *et al* [10] presents a method of dosimetry for brachytherapy of high dose rate based on source of iridium-192, comparing dosimetry made by GAFCHROMIC EBT2 film and TLD, using acrylic phantom. The consistency of the data produced using EBT2 film and a value measured by TLD confirms that the EBT2 film is a viable detector for brachytherapy dosimetry of high dose rate. In comparison with other experimental methods, the dosimetry with EBT2 film has cost and feasible method that can be employed in the practice of brachytherapy dosimetry.

The objective of this study is to conduct experimental dosimetry for Ho-166 brachytherapy, based on radiochromium films.

2. MATERIALS AND METHODS

2.1 Protection of Bioglass Seeds with Polyvinyl Alcohol

Bioglass seeds of [Si: Ca: Ho] and [Si: Ca: Ho: Zr] will be encapsulated in membranes of polyvinyl alcohol by dilution method and drying. The compounds and amounts as a percentage of weight for the encapsulation of bioglass seeds of [Si: Ca: Ho] and [Si: Ca: Ho: Zr] are shown in Table 1.

Table1. Composition of PVA membranes

Compounds	Weight (%)
Demineralized water - H_2O	94,0
Polyvinyl alcohol - PVA	6,0

For the encapsulation of the seeds, water will be heated to 100 ° C. Then, the PVA powder is added gradually in mixture until dilution and poured into plastic molds. Thus, the bioglasss seeds of [Si: Ca: Ho] and [Si: Ca: Ho: Zr] will be placed on the membrane formed and dried in an oven at 60 °C.

2.2 Acrylate Resin Protection

Another method for encapsulating bioglass seeds of [Si: Ca: Ho] and [Si: Ca: Ho: Zr] was through direct application of resin over the seeds. The application of acrylic resin was done by a very fine brush, due to the small size of seeds. After, the photopolymerization of the same was performed.

2.3 Irradiation of Polymer-protected Bioglass Seeds

Encapsulated bioglass seeds of [Si: Ca: Ho] and [Si: Ca: Ho: Zr] will be irradiated in the IPR-1 TRIGA Nuclear Reactor (CDTN /CNEN). The radioactivity of the bioglass seeds after the neutron activation was measured in activimetro (Capintec, model CRC-25R), present at the Cyclotron Laboratory / CDTN. The activated seeds will be stored and transported in the lead castle. After the experiment they were stored again in shielding.

2.4 Dosimetry with Radiochromium Film

2.4.1 Implants of seeds and radiochromium film

Radiochromium films were cut and activated bioglass seeds were placed on side. The set was introduced in the glandular equivalent tissue - TE in a compressed breast phantom. Radiochromium films were fixed in contact with external skin TE to estimate of the dose in the skin. The encapsulated radioactive seeds were introduced in glandular TE in contact with radiochromium films. The exposure time was 2 hours.

2.4.2 Dosimetry of radiochromium films

After exposure time, the seeds and films were separated, removed from the breast phantom and stored until radioactive cooling per 6 days. Radiochromium films were scanned and analyzed using ImageDIG program that identifies and quantifies the RGB (Red, Green, Blue).

The calibration process involved the comparison of the areas exposed to doses provided with theoretical data evaluated by the code MCNP. These results are extrapolated to the seed spatial distribution in the film positioned within the breast phantom. The results were plotted on graphs and isodose areas.

3. RESULTS

3.1 Protection of Bioglass Seeds with Polyvinyl Alcohol

The methodology was performed as described. The membranes of polyvinyl alcohol were removed from the molds. Soon, the membranes were cut in size of approximately 0.5 cm, with bioglass seeds centered in the middle, as shown in Fig. 1.

Figure 1 - Bioglass seeds of [Si: Ca: Ho] and [Si: Ca: Ho: Zr], encapsulated in membranes of polyvinyl alcohol.

The encapsulation method made ease the seed handling, due to its small size. Also, it avoided dislodging of seed powder during the various process of manipulation.

3.2 Acrylate Resin Protection

The acrylate resin protection was prepared. The application of resin on the seeds was performed using a fine brush and photopolymerization of 180 seconds. The seeds showed a thin layer of protective resin, which increased the strength of the material and facilitated the manipulation of the same, in Fig. 2.

Figure 2 - Bioglass seeds of [Si: Ca: Ho: Zr] encapsulated with acrylate resin obtained in stereoscopic 80X.

3.3 Irradiation of Polymer-protected Bioglass Seeds

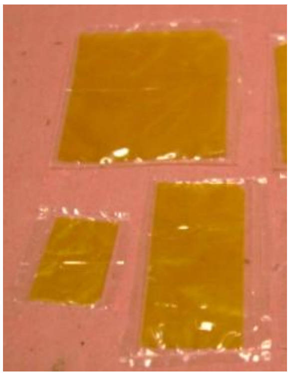
Bioglass seeds of [Si: Ca: Ho] and [Si: Ca: Ho, Zr] were irradiated in the TRIGA Nuclear Reactor of CDTN, for a period of 8 hours on the turntable around the reactor core, with thermal neutron flux of 6.6×10^{11} n / cm ² and of epithermal neutrons is 3.01×10^{10} n/cm ².s [11].

The radioactivity of the bioglass seeds was measured one hour after neutron activation by activimeter. The initial activity of each encapsulated bioglass seed was 0.35 mCi. The initial activity used in study was 0.31 mCi, and the final activity after exposure was 0.29 mCi. The activated seeds were stored and transported by lead shielding.

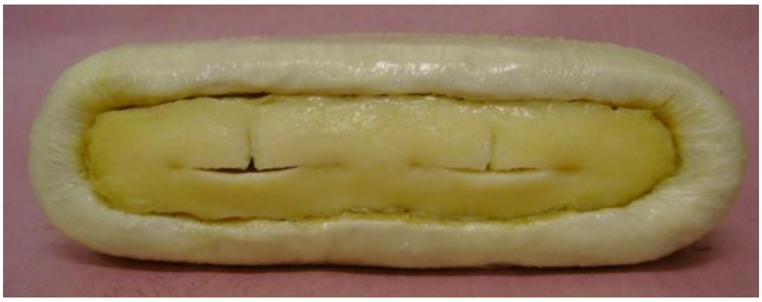
3.4 Dosimetry with Radiochromium Film

3.4.1 Implants of seeds and radiochromium film

On the middle of breast glandular TE was made longitudinal and transversal cuts to receive the activated bioglass seeds and the radiochromium films. Radiochromium films were cut to dimensions of 3.5 cm X 3.5 cm and 1.5 cm X 3.5 cm, and placed onto the glandular TE perpendicular between them. Outside of the phantom two radiochromium films measuring 1.2 cm X 1.7 cm were fixed. All radiochromium films were sealed not to be in direct contact with the TE's, as shown in Fig.3.



A



B

Figure 3 – (A) Cut radiochromium films and (B) Compressed phantom breast with cut in glandular TE.

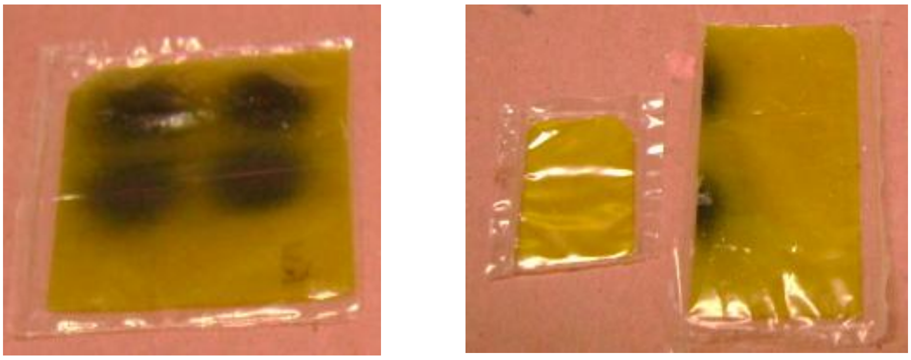
The process was conducted with shield protection. To monitor the exposure of the area, a G1E detector was used with SE-681 detector, which remained below 1μR/h. The measures of contamination were made by MRA 7027 detector with 7026 pancake detector to measure activities on the work surfaces, to assess contamination. Radioactive contamination was not detected after experimentation, with no difference of background.

The activated seeds of [Si: Ca: Ho] and [Si: Ca: Ho, Zr] were mounted on an acrylic plaque and deployed within the glandular TE in contact with radiochromium films for exposure, as shown in Fig. 4. Outside of the breast phantom, two radiochromium films were set in contact with skin TE to estimate the dose in the skin.

Figure 4 – Bioglass seeds of [Si: Ca: Ho] and [Si: Ca: Ho: Zr] mounted on acrylic plaque.

3.4.2 Dosimetry of radiochromium films

Radiochromium films were removed after 2 hours of exposure from the compressed breast phantom, being sensitized by irradiation of the activated seeds of [Si: Ca: Ho] and [Si: Ca: Ho: Zr], as shown in Fig. 5. It is ease noticed in the radiochromium films, the area sensitized by the irradiation.



A B

Figure 5 – Radiochromium films sensitized by seeds of [Si: Ca: Ho] and [Si: Ca: Ho, Zr].

The radiochromium films were scanned on a lighting device made in house, in pure green and red light, with the aid of a digital camera of the high resolution. The degree of color images were taken through the ImageDIG program that identifies and quantifies RGB (Red, Green, Blue).

The reading of the RGB levels was conducted at six points of the radiochromium film, with radial distances of 5 mm each other, taken the red and green RGB. The optical densities were calculated in RGB in red and green, by the expression:

$$OD = \log_{10} \frac{I_0}{I} \qquad (1)$$

Where OD is the optical density of the film; I0 represents the intensity in RGB of the non-irradiated film, I represents the intensity in RGB of the irradiated film.

Through the expression (2), the standard deviation of the optical density of the sensitized radiochromium films were calculated.

$$\sigma_{OD}(D) = \frac{1}{\ln} \cdot \frac{\sqrt{(\sigma \text{ non-irradiated film})^2 + (0.5)^2}}{(\text{mean of the non-irradiated film})^2} + \frac{\sqrt{(\sigma \text{ irradiated film})^2 + (0.5)^2}}{(\text{mean of the irradiated film})^2} \qquad (2)$$

Where $\sigma_{D.O\ is}$ the standard deviation of the optical density of the films, 0 is the RGB level of the scanned opaque film and 0.5 is the value of the standard deviation.

The data generated were plotted in two graphs. Fig. 6, analyzes the optical density as a function of radial distance from the Ho-166 seed. The graph was plotted with three points and analyzed. A polynomial curve was fitted on the points. It represents the darkness variation in red in the function of radial distance from the of Ho -166 seed.

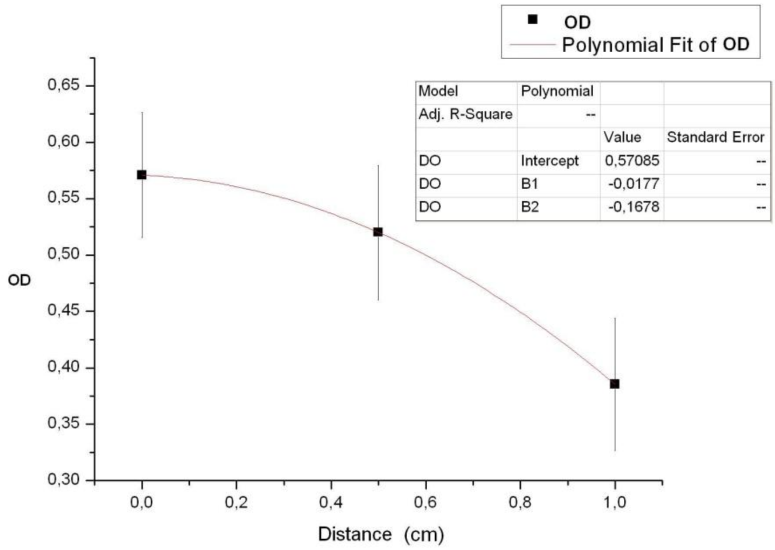


Figure 6 – Optical density versus radial distance from the seed.

The graph shows that the optical density of the film exposed to beta particles decreases with distance increasing. It is kwon that the range of beta particles of ceramic seeds Ho-166 is of 8.3 mm in tissue.

Fig. 7 analyzes the optical density presented by the sensitized films in function of the distance of the exposed areas to the gamma particles. The graph was plotted with four points and adjusted by an exponential curve, which represents the film darkness in red as function of radial distance from the Ho-166 seed.

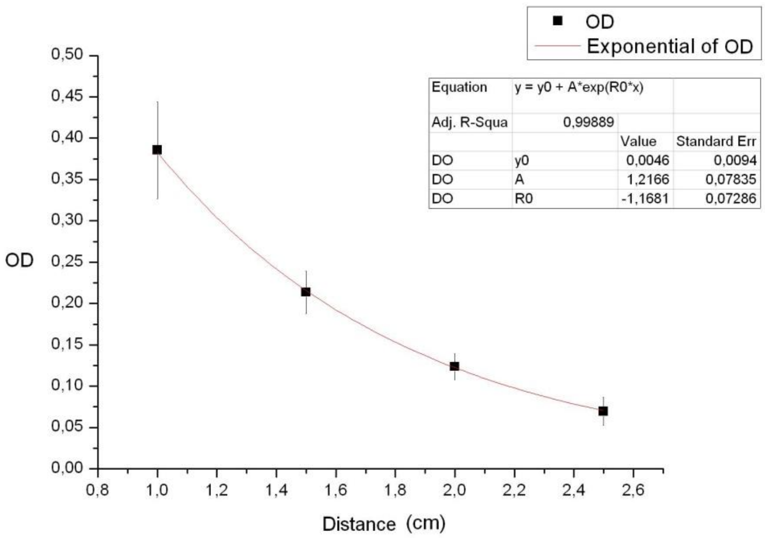


Figure 7 – Optical density versus radial distance from the seed

The graph shows that the optical density of the film for the gamma particles also decreases with increasing distance.

A calibration process must be applied to correlate variation of the optical density with dose. Profiles of depth dose in equivalent tissue for beta rays and gamma emission were generated through computer simulation using the MCNP code.

Homogeneous model in equivalent tissue was adopted, with a centralized cylinder source. Several volumes produced by cylindrical rings were set around the seed. Doses as a function of radial distance from the seeds were then evaluated and plotted. Fig. 8 shows the depth dose profile for the gamma and beta emissions from 0.31mCi Ho-166 seed source.

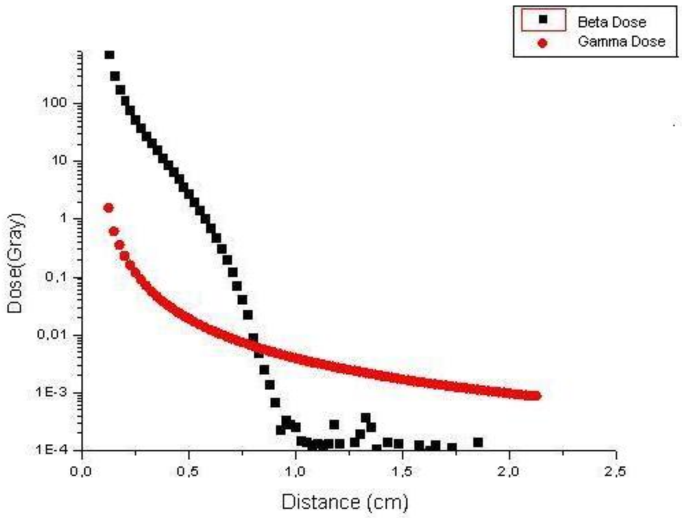


Figure 8 – Beta and gamma dose versus distance

The dose generated by beta particles is presented below 0.1 Gy at a distance of 7.5 mm. The dose generated by the gamma particles decay exponentially, presented 0.01 Gy at a distance of approximately 6 mm.

Analysis of dose limits for the radiochromium film versus optical density in RBG in red was performed. Dose values provided by MCNP simulation and optical density provided by the radiochromium film in the same radial distance were taken. Fig.9 provides this correlation.

Fig. 9 shows that the dose has a linear behavior of the 1cGy up to 10 Gy and subsequently suffers an abrupt change. These data are consistent with information from the manufacturer of the film, which limits the assessment of dose to 10 Gy in red.

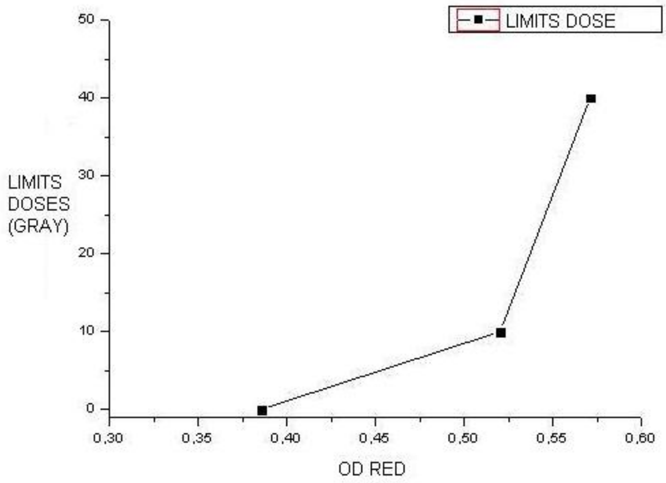


Figura 9 – Limits dose versus optical density in the red RGB.

Fig. 10 presents the dose in function of the optical density of the radiochromium film in green RBG. Saturation limits of the optical density of the radiochromium film are observed at40 Gy. The saturate region is near the seed, since for the activities of seeds and exposure time of the film adopted in the experiment, the doses are much higher than 40 Gy.

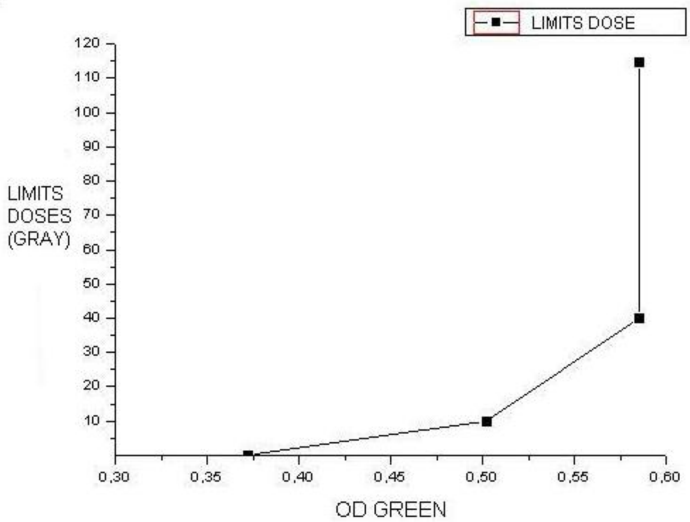


Figura 10 – Limits dose versus optical density in the green RGB.

3. CONCLUSIONS

The results show that it is possible to use radiochromium films for dosimetry studies of radioactive sources for brachytherapy. However, there are limits activity versus exposure for experimentation, because GAFCHROMIC EBT2 films are useful in the upper range of 40 Gy in green and 10 Gy in red. The graphs show that the exposures of gamma radiation after of the distance of 12 mm of seeds are below than 0.01 Gy, demonstrating that irradiation of the neighboring tissues is negligible near the treatment area.

The dose profiles obtained from theoretical and experimental setup with 0.3 mCi seeds show that a cluster of seeds for each other of 16 to 20 mm are sufficient to cover a volume with a minimum dose of 40 Gy.

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