Radiation Physics and Chemistry 96 (2014) 56–59

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem

Beta planar source quality assurance with the Fricke xylenol gel dosimeter

Mirko S. Alva-Sánchez [a,*], Lucas N. de Oliveira [a,b], Paulo C. Petchevist [a,c], Marco V. Moreira [a,c], Adelaide de Almeida [a]

[a] Departamento de Física da Universidade de São Paulo, Av. Bandeirantes 3900, Bloco, P1-14040-901 Ribeirão Preto, SP, Brazil
[b] Instituto Federal de Educação, Ciência e Tecnologia de Goiás, Av. Universitária, s/n, Vale das Goiabeiras, CEP: 75400-000, Inhumas, Goiás, Brazil
[c] Instituto de Radioterapia e Megavoltagem de Ribeirão Preto-IRMEV, Rua Sete de Setembro 1150, CEP 14010-180 Ribeirão Preto, SP, Brazil

HIGHLIGHTS

- Quality assurance for $^{90}Sr/^{90}Y$ source is not easy to do.
- Dosimeter not satisfy the spatial resolution and the effective-atomic-number.
- The Fricke xylenol gel has better characteristics to measurement in 2D and 3D.
- Was demostrated that FXG dosimeter can be used to beta source quality control.

ARTICLE INFO

Article history:
Received 13 March 2013
Accepted 25 August 2013
Available online 6 September 2013

ABSTRACT

Beta therapy is employed in post surgery to treat lesions such as pterygia, keloid and glioblastoma. The beta source most used for these purposes is $^{90}/^{90}Y$, whose quality assurance is a challenge, because the detectors currently used for this evaluation do not satisfy the spatial resolution, the effective atomic number and the tissue equivalent conditions. The Fricke xylenol gel (FXG) has been used in several applications in radiotherapy due to its better characteristics. This dosimeter is associated with the Fe(II) to Fe(III) oxidation, post ionizing irradiation, being the final Fe(III) concentration linearly depended on the absorbed dose. The goal of this present work is to show that the FXG, with atomic effective number (Z_{eff}) of 7.75 and high resolution (<1 mm), accomplishes quality assurance for rectangular and square planar $^{90}Sr/^{90}Y$ sources. In order to demonstrate the quality assurance, calibration curves, percentage depth dose and beam profile from exposed FXG samples were analyzed and from these results, we demonstrate the potential use of the FXG dosimeter for beta source quality control.

1. Introduction

The beta brachytherapy is a convenient and practical method to treat superficial lesions. Since the 1950s, $^{90}Sr/^{90}Y$ sources have been used. They yield 0.55 and 2.27 MeV beta particles that deposit their energies in few millimeters of biological tissue. This radiation is appropriate for some treatments as for pterygia, as well for keloid and glioblastoma (IAEA, 2002; ICRU, 2004; Stefanou et al., 2006). The sources are placed in contact with or near to the target tissue, as the simulated geometry in the experiments described in this work.

The calibration of a radiation source is part of a quality assurance for the brachytherapy dosimetry and it is essential to demonstrate international traceability to an accepted standard. The beta source calibration protocols (ICRU, 2004; IAEA, 2002) recommend that the absorbed dose to be measured at 1 mm depth, from the source surface center in a water equivalent medium. The second calibration quantity is the source uniformity, which is quantified from the radiation field profile (Kelly et al., 1998; Calcina et al., 2007; Oliveira et al., 2007) with a parameter known as the *source non-uniformity U* (ICRU, 2004), Eq. (1). For square and rectangular planar sources, U is equal to the percentage difference values between the absorbed dose maximum (D_{max}) and minimum (D_{min}), related to the averaged absorbed dose (D_{avg}) value, along a distance of 80% of the field size, whose limits are situated where the absorbed dose values fall to 50% of D_{max}. The parameter U can be measured through the beam profiles, at 1 mm depth from the irradiated surface.

$$U = \left[\frac{D_{\max} - D_{\min}}{D_{avg}}\right] 100 \quad (1)$$

The third important quantity that could be measured is the percentage depth dose distribution, *PDD* (Cohen, 1972; ICRU,

* Corresponding author. Tel.: +55 16 36023963; fax: +55 16 36024887.
E-mail addresses: mirkoalva@usp.br (M.S. Alva-Sánchez), lucas@ifg.edu.br (L.N. de Oliveira), petchevist12@usp.br (P.C. Petchevist), marcos_vasques@yahoo.com.br (M.V. Moreira), dalmeida@ffclrp.usp.br (A. de Almeida).

0969-806X/$ - see front matter
http://dx.doi.org/10.1016/j.radphyschem.2013.08.014

2004), Eq. (2). This quantity is defined as the quotient of the absorbed dose D at any depth z, related to the absorbed dose at the maximum ionization depth, $D(\max)$, along the field central axis in water or other material tissue equivalent.

$$PDD = \frac{D(z)}{D(\max)}100 \quad (2)$$

Beta source calibration is a challenge because these sources present high dose gradients, when compared with detector dimensions (Soares et al., 2001; Cross et al., 2001). Although beta source commercial suppliers provide superficial dose rate and source dose spatial distribution chart, quality assurance measurements must be performed for proper treatment control and checking of the source integrity (IAEA, 2000).

Currently the detector recommended by ICRU and IAEA protocols for planar beta sources calibration is an extrapolation chamber, although others, such as radiochromic film or thermoluminescent dosimeters may be used (Antonio et al., 2012; Antonio and Caldas, 2011; Soares et al., 2001; Oliveira and Caldas, 2005). We show here the FXG dosimeter as an innovative chemical system for Brachytherapy beta source quality assurance.

The FXG dosimeter is composed of ferrous sulfate, xylenol orange (XO), 300 bloom gelatin, sulfuric acid and Milli-Q water (Bero et al., 2000; Saur et al., 2005; Oliveira et al., 2007; Caldeira et al., 2007a). When irradiated, the oxidation of Fe^{+2} into Fe^{+3} takes place, forming the [Fe^{+3}–XO] complex, whose maximum optical absorbance peak is centered at 585 nm (Gambarini et al., 2004; Caldeira et al., 2007; Moreira et al., 2004). The concentration of this complex is detected through visible spectrophotometry and is proportional to the absorbed dose (Saur et al., 2005; Calcina et al., 2007; Oliveira et al., 2007).

In this work the $^{90}Sr/^{90}Y$ source quality assurance was accomplished through calibration curves (CC), beam profiles (BP) and percentage depth dose (PDD) curves, using parallel plate ionization chamber, radiographic film and FXG dosimeter. This work shows that FXG is appropriate for these measurements, since its Z_{eff} 7.75 (Oliveira et al., 2007) is near to that of soft tissue 7.64 (Wingate et al., 1962) and it permits high spatial resolution, relative to the absorbed dose gradients involved in brachytherapy (Sato et al., 2009).

2. Materials and methods

In this work, rectangular and square $^{90}Sr/^{90}Y$ planar sources (Amersham England) with active areas of 1×2 and 2×2 cm^2 and surface dose rates, respectively of 2.75 and 2.94 cGy s^{-1} were used. To calibrate these sources, three dosimeters were used: a 0.025 cc parallel plate ionization chamber (PPIC) from Markus/A10, radiographic film Kodak/X-Omat V and the FXG. For the last one, specially fabricated PMMA cuvettes of $21 \times 5 \times 1$ cm^3; $5 \times 5 \times 1$ cm^3 and $6.5 \times 4.5 \times 1$ cm^3 were filled with FXG respectively for CC, BP and PDD measurements (Fig. 1a–c). After the irradiations, the cuvettes optical densities were measured at 585 nm, using an in house quasi monochromatic light intensity reader, with collimator aperture of 1 mm (Calcina et al., 2007; Oliveira et al., 2007). For all the dosimeters used, three measurements were done and averaged for each dose absorbed value. For all measurements (CC, BP, PDD) the FXG was irradiated almost in contact with the sources (separated only by 0.021 mm polyethylene film) to avoid air gaps, as cited in the Netherlands Commission on Radiation Dosimetry (NCS, 2004). The absorbances for these measurements, were realized through an optical length of 1 cm and CC and BP values were inferred from the PDD curves at 1 mm depth, as recommended by the ICRU protocol (ICRU, 2004).

2.1. Calibration curve (CC)

For CC determination, the sources were placed in contact with the dosimeters varying the exposition time to achieve the absorbed dose values (up to 20 Gy, using the nominal dose rate provided by the manufacturer, taking into account the sources decay). For FXG measurements, each source was placed sequentially at each position on the selected cuvette and left for the time required to achieve the desired absorbed dose value, as shown in Fig. 1a. The same procedures were used with the ionization chamber.

2.2. Beam profile (BP)

For the beam profile using the FXG, an absorbed dose of 20 Gy was given at 1 mm depth from the source surface in the center of field. Although the parameter U has to be obtained at 1 mm, we measured it with an optical length of 10 mm, because the sources dimensions needed a bigger cuvette and the optical length could not be of 1 mm, as in the protocol, but we considered that if $^{90}Sr/^{90}Y$ profiles are uniform for a higher depth (the average of absorbances for all depths in the interval up to 10 mm) it will be even more uniform for a lower depth (Soares et al., 2001; ICRU, 2004). For film measurements the geometry used was the same as that used for the FXG, with the absorbed dose value of one tenth the previous one, given at their surfaces.

The FXG and film BP values were obtained respectively through absorbance and optical density readings along straight lines crossing the radiation fields, normalized to the values in the center of these fields.

2.3. Percentage depth dose (PDD)

For the ionization chamber PDD measurements, $5 \times 5 \times 0.1$ cm^3 PMMA plates were used between the PPIC and the sources. For the film PDD, its plane was positioned perpendicularly to the source fields, parallel to their axes. For FXG PDD measurements the sources were positioned on the minor side of the cuvette, as shown in Fig. 1c.

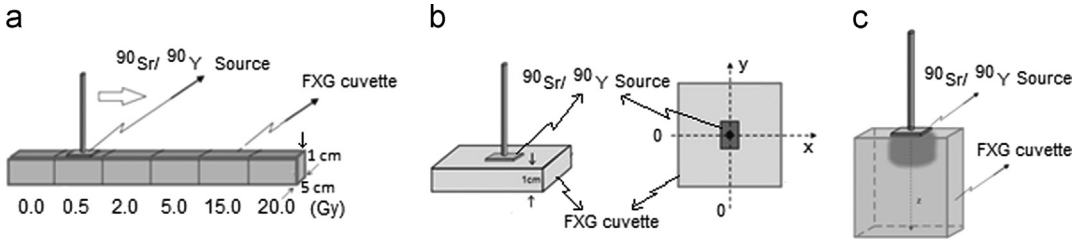

Fig. 1. (a) Set-up to obtain the calibration curves from a $21 \times 1 \times 1$ cm^3 FXG cuvette. The cuvette volumes selected were exposed sequentially to the 1×2 and 2×2 cm^2 rectangular and square $^{90}Sr/^{90}Y$ beta sources, respectively. (b) The beam profiles for two sources were obtained irradiating $5 \times 5 \times 1$ cm^3 FXG cuvettes. (c) The percentage depth dose were obtained irradiating $6.5 \times 4.5 \times 1$ cm^3 FXG cuvettes, the absorbance readings were made with an optical length of 10 mm, with 1 mm step perpendicular to the central axis z.