

A study on dose distribution evaluation using PC detectors and gamma radiation.

Ana Maria Sisti Galante* and Letícia Lucente Campos

Radiation Metrology Centre, Nuclear and Energetic Research Institute, IPEN – CNEN/SP, Av. Prof. Lineu Prestes, 2242, Cidade Universitária, São Paulo, Brazil, 05508-000.

ABSTRACT

The quality control of an irradiated product depends mainly on the knowledge of the absorbed dose in different parts of its volume. Commercial polycarbonate (**PC**) is a type of film detector that suffers yellowing upon radiation exposure. PC detectors films 3 mm thick were used to map isodose curves inside recipients containing a product irradiated with ^{60}Co Gamma sources at IPEN. Different absorbed doses were uniformly delivered to the set. Optical density data were acquired using a spectrophotometer Shimadzu UV2101PC.

Keywords: Dosimetry; isodose map; PC detector; gamma radiation

1. Introduction

Radiation processing is now used on a large scale from the recent successful and huge increases in the adoption of radiation as a tool to change and improve the quality of some products and due to significant advances in radiation chemistry. The areas such as medical (exam or treat patient), industrial (medical products and food sterilization, polymerization and reticulation), agricultural and others are benefited with use of this technique (Progress Report 2005-2007).

Dosimetric systems used in radiation processes monitoring must be able to providing precise and accurate responses in a wide range of interest doses. It is essential that the product receive absorbed dose not less than that specified and it is also important not exceed this dose (McLaughlin and Desrosiers, 1995).

There is a large variety of polymeric materials used in dosimetry, such as cellulose triacetate, nylon, polyester, fluoropolymer and polymethylmethacrylate. The radiation induced changes, characteristic of each material, and, depends on the substrate composition and dye presence (Bhattacharya, 2000; Galante and Campos, 2006, 2008, 2010; Galante et al 2004,2010).

Corresponding author: Tel.: + 55 11 3133-9669

E-mail address: sgalante@ipen.br

Commercial polycarbonate (PC) is a new type of film detector that suffers yellowing upon radiation exposure and is suitable to determine high gamma doses (Chung, 1997; Galante and Campos, 2010; Kumar et al, 2006; Sinha et al, 2004; Sharma et al, 2008).

The present work aims to verify if PC films can be applied to dose measurements of irradiated products in industrial irradiation plants. PC detectors films 3 mm thick were used to map isodose curves inside recipients containing a product to be irradiated with gamma rays. The irradiations were performed in the **Gammacell** and **Panoramic** ^{60}Co gamma sources at **CTR/IPEN**.

2. Materials and Methods

The detectors were prepared cutting small pieces of 3 x 1 cm dimension from a 2 x 1 m commercial PC sheet.

Two measurements were performed using different ^{60}Co gamma radiation sources: a **^{60}Co Gammacell 220 source** that consists of ^{60}Co rods / pellets arranged in pencil form and uniformly distributed around the irradiation chamber; a **^{60}Co Panoramic source** that consists of a concentric single pencil containing the ^{60}Co pellets arranged in an irradiation table.

A cylindrical plastic container (11 x 15 x 1 cm) containing within PC detectors divided into two sets, each one with five layers, in which the spaces were filled with powdered gelatin simulating a typical product to be irradiated, **Fig. 1**, was used as a package simulator. The irradiations were performed in the **^{60}Co Gammacell 220 source**. The samples were placed inside the irradiation chamber between two plates of polymethylmethacrylate with sufficient thickness to maintain electronic equilibrium conditions. An absorbed dose of 30 kGy was uniformly delivered to the package.

To irradiations performed using the **^{60}Co Panoramic source** the PC detectors were distributed in a rectangular container with dimensions: length = 33 cm; width = 19 cm and height = 12 cm as shown in the image of **Fig. 2**. The set was positioned between 10 cm and 40 cm source-set distance behind the source, **Fig. 3**. The nominal absorbed dose delivered was between 9.73 and 69.7 kGy

Optical density data were acquired using a spectrophotometer Shimadzu UV2101PC; measurements were performed in the wavelength of maximum absorption peak of the spectrum, 412 nm, 1 hour after irradiation. Each presented result is the average of five measures and the error bars the standard deviation of the mean.

3. Results and Discussions

The dose distribution was evaluated to the package irradiated at **Gammacell source**. Each one of 66 irradiated detectors was analyzed and the absorbed dose was determined by using the calibration curve presented in **Fig. 4**. The obtained dose ranged between 22.7 kGy and 41.0 kGy. Can be observed that lower doses

were observed to the detector positioned at the irradiation chamber base, in the container half height of the container and about 3 cm from the outer wall (22.7 kGy). The highest dose were observed to the detector positioned in the right lateral and 15 cm from the irradiation chamber base (41.0 kGy), **Fig 5**.

It can be concluded that ^{60}Co rods / pellets distribution around the irradiation compartment is not homogeneous resulting in a 15% variation coefficient, what determines a strong dispersion. These results are in agreement with the isodose map provided by the source manufacturer that presents $\pm 20\%$ variation in the borders of the irradiation compartment. The real dose is close to the nominal dose at geometrical center and half height of the irradiation chamber.

In the graphic of **Fig. 6** can be observed the response variation relative to the detectors positioned during irradiation in the **Panoramic source**. The responses were normalized to the detector positioned at the right vertex and upon a radius of 10 cm from the source. The obtained results indicates that the detector positioned in straight line with the source receives the largest dose, decreasing towards horizontal and, vertically, the detector positioned closer to the irradiation table base received the lower dose. The same behavior can be observed to different positioning regarding the distance to the source.

Due to the fact that the irradiated container configuration (rectangular) is different from the source table configuration (circular), harmonic interpolations were performed to determine the dose rate values at different distances. It can be observed in the image of **Fig. 3** that the container vertexes are positioned exactly on the 10 cm radius, therefore, the geometric center of the front face of container is positioned at 7 cm radius from the source, resulting in a higher absorbed dose; the same behavior is observed in other positions.

In the **Table 1** were shown dose rate interpolated values and its respective variation percentages. The increasing response variation was expected due to the detectors positioning and the presence of gelatin in the container.

The measured dose distributions showed agreement within 95% with the isodose map provided by the manufacturer of the radiation source.

4. Conclusions

PC detectors are easy to prepare and analyze, and of low cost.

The stable color developed when material is exposed to ionizing radiation can be analyzed spectrophotometrically at 412 nm; this characteristic is related with absorbed dose and can be used in the quality control for radiation processes.

Like other routine dosimeters, it is necessary to calibrate the detector against a reference standard dosimeter under the same conditions.

PC detectors present high sensitivity to indicate dose distribution in irradiated products, which favors the control maximum and minimum doses released during the irradiation process.

Acknowledgments

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Distance (cm)	Dose rate (kGy/h)	Variation (%)	Response (k cm⁻¹)
10	0.1612	100.00	0.284
20	0.0645	40.01	0.097
30	0.0373	23.14	0.040
40	0.0225	13.96	0.023
7.0	0.2527	100.00	0.527
18.2	0.0767	30.37	0.117
28.7	0.0402	15.91	0.045
39.1	0.0238	9.40	0.021

Table 1.

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Figure 1

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Figure 2

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Figure 3

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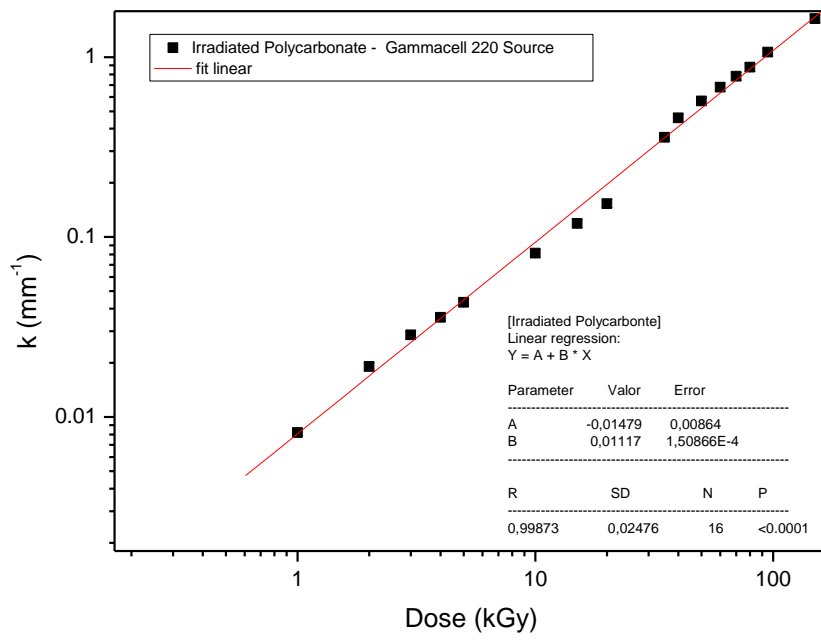


Figure 4

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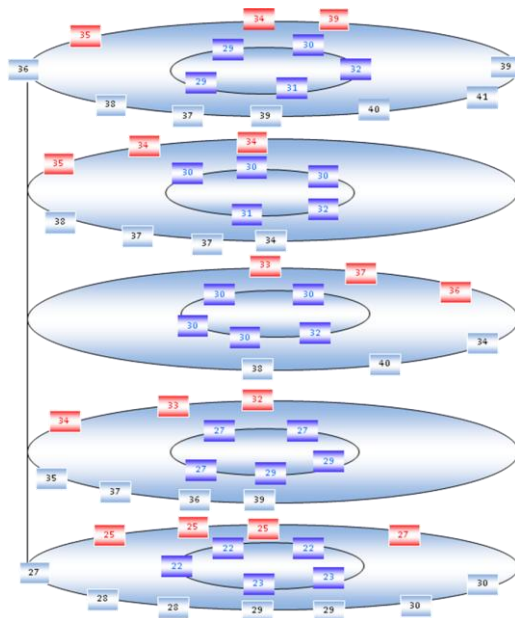


Figura 5

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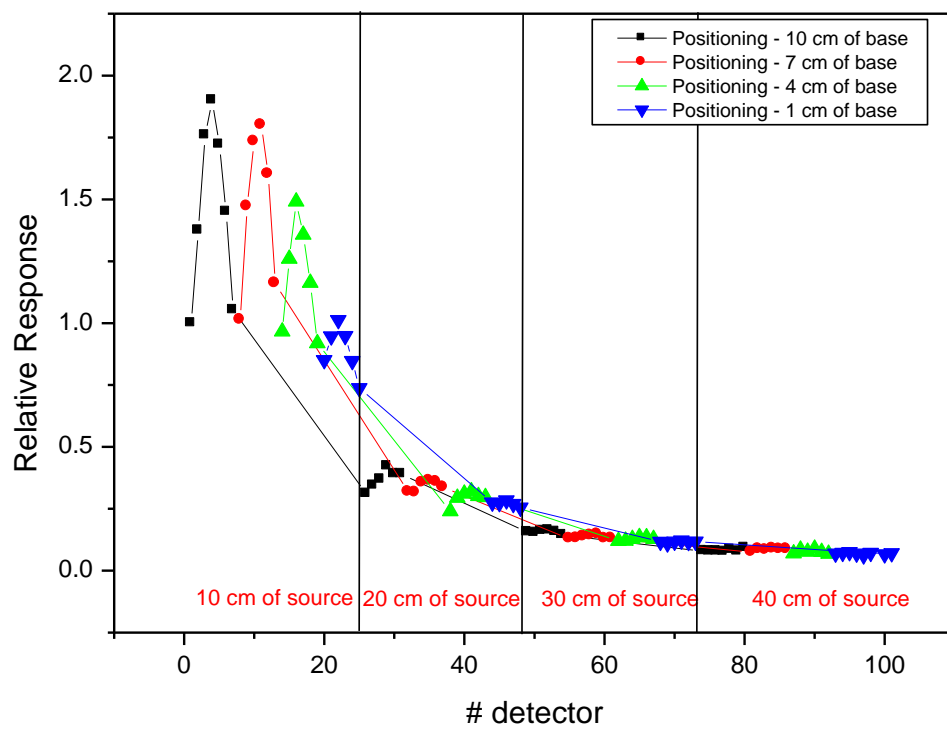


Figure 6

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Table Caption

Table 1. Dose rate values in the different table positioning. ^{60}Co Panoramic source.

Figure Caption

Figure 1. Image set containing PC detectors used to evaluate dose distribution. ^{60}Co Gammacell source.

Figure 2. Image of container and detectors used for evaluation of dose distribution. ^{60}Co Panoramic source.

Figure 3. Image of container with PC detectors positioned to irradiate in the back of the ^{60}Co Panoramic source.

Figure 4. PC detectors dose-response curve. ^{60}Co Gammacell source. $\lambda = 412 \text{ nm}$.

Figure 5. PC detectors absorbed dose distribution map in an irradiated cylindrical container. ^{60}Co Gammacell source.

Figure 6. PC detectors response variation in the different positions during irradiation. ^{60}Co Panoramic source.