Water –Equivalent solid sources prepared by means of two distinct methods

Marina F. Koskinas, **Ione M. Yamazaki, Ademar Potiens Jr.**

Josenilson B. de Lima, Mauro S. Dias

Instituto de Pesquisas Energéticas e Nucleares

E-mail: koskinas@ipen.br

Resumo: O Laboratório de Metrologia Nuclear do IPEN está envolvido no desenvolvimento de fontes radioativas sólidas com densidade equivalente à água preparadas a partir de uma solução aquosa de acrilamida, usando dois métodos distintos para a sua polimerização. Um dos métodos utiliza a radiação gama de uma fonte de ^{60}Co para obter a polimerização; no outro método a matriz sólida de poliacrilamida foi obtida a partir de uma solução aquosa constituída por acrilamida, catalisadores e uma alíquota de radionuclídeo. As fontes foram preparadas em geometria cilíndrica. Neste trabalho, o estudo da distribuição de material radioativo nas fontes sólidas preparadas por ambos os métodos é apresentado.

Palavras-chave: fontes radioativas sólidas, acrilamida, fontes equivalente à água

Abstract: The Nuclear Metrology Laboratory at IPEN is involved in developing radioactive water-equivalent solid sources prepared from an aqueous solution of acrylamide using two distinct methods for polymerization. One of them is the polymerization by high dose of ^{60}Co irradiation; in the other method the solid matrix-polyacrylamide is obtained from an aqueous solution composed by acrylamide, catalysers and an aliquot of a radionuclide. The sources have been prepared in cylindrical geometry. In this paper, the study of the distribution of radioactive material in the solid sources prepared by both methods is presented.

Keywords: radioactive solid standards; water equivalent source; acrylamide polymer

1. INTRODUCTION

Ionization chambers for activity measurements have cylindrical geometry with a re-entrant well [1] and are used to measure liquid radioactive sources in ampoules. In these sources the radioactivity is homogeneously distributed in an aqueous solution with density around 1 g cm^{-3}. The ionization chambers used in Medical Services, generally called “dose calibrators” or “activity calibrators”, are calibrated by the manufacturer using conventional standard solutions. Nevertheless, for quality assurance, a periodic control of the response of these calibrators is required.

In general, the sources used for this control are gamma reference sources with energies in the range from 100 keV up to 700 keV and long half-life. The recommended radionuclides are ^{57}Co, ^{133}Ba and ^{137}Cs, which are characterized in terms of activity. They are used for testing the calibrator stability on a daily basis. To handle with safety and avoid contamination, this kind of source has to be made of resin with the radionuclide distributed uniformly.

In order to supply this type of sources to Medicine Services in Brazil, the Nuclear Metrology Laboratory at IPEN developed the method of preparing radioactive water-equivalent solid sources using an aqueous solution of acrylamide polymerized by a high dose of ^{60}Co irradiation [2]. The sources have been prepared with ^{57}Co, ^{137}Cs and ^{133}Ba radioactive solutions. These sources are suitable for performing stability and accuracy tests, mainly for Medical Radionuclide Calibrators. The sources have a density similar to water and good uniformity.

This kind of sources can be useful also in other areas like environmental sample analysis, radioprotection, waste management, gamma cameras calibration and so on. However, in these applications it is necessary sources of different geometries such as: Marinelli Becker, flat sources or rod sources. For these other geometries the procedure to produce solid sources in a gamma irradiator is not feasible due to the IPEN irradiator chamber geometry.

In order to solve this problem, the LMN developed an alternative methodology to obtain water-equivalent solid sources without need of irradiation to generate the polymerization process. These sources have also a density similar to water and good uniformity. In this paper, the study of the distribution of radioactive material in the solid sources prepared by both methods is presented.

In order to compare the two methods, sources in cylindrical geometry were prepared. The degree of uniformity in the activity distribution is also presented for flat source.

2. EQUIVALENT-WATER SOURCES IN CYLINDRICAL GEOMETRY

The cylindrical source was prepared in a plastic container 2.7 cm in diameter, 5.8 cm high (external dimensions) and 0.13 cm wall thickness, containing 19 ml of solution.

2.1. *Polymerization in High Gamma Dose*

The solid sources were prepared on the basis of the method developed by Sahagia and Grigorescu [2], which consists of dispensing the radioactive solution into a container with distilled water and a colour agent. After 24 hours, an aqueous acrylamide solution mixed with small quantities of EDTA was added to the previous solution, after that the solution is irradiated in a Gammacell-220 manufactured by the Atomic Energy of Canada Ltd., with 4.53 kGy h^{-1} for 1:10 h; this dose was defined previously [3]. The acrylamide cylindrical source is shown in figure 1.

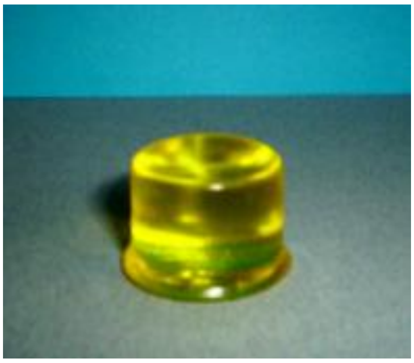

Figure 1 Acrylamide cylindrical source polymerized by high gamma dose irradiation.

2.2. Alternative procedure of polymerization

The alternative procedure of polymerization consists in obtaining a solid polyacrylamide matrix from an aqueous solution composed by acrylamide, bis-acrylamide and an aliquot of the radionuclide. To catalyse the polymerization into solid matrices, small quantities of ammonium persulfate (APS) and 1,2-Bis (dimethylamino) ethane (TEMED) were added to the previous solution. Figure 2 shows the cylindrical source obtained by polymerized acrylamide/bis-acrylamide resin [4].

Figure 2 Plastic container and the cylindrical acrylamide/bis-acrylamide polimerized resin.

3. STUDY OF THE UNIFORMITY

3.1. Cylindrical Sources

The resins obtained have a clear, soft and rubbery texture, free from voids inside the active volume. One of the most important aspects of a volume source is to have a good uniformity. To verify the uniformity, a destructive test consisting of cutting the polymerized cylindrical volume in three sections was applied and their uniformity was checked by activity comparisons.The activities of the polymerized resin pieces were measured in an HPGe spectrometer, previously calibrated with IAEA standard sources of ^{152}Eu, ^{133}Ba and ^{137}Cs. The density value was determined by measuring mass and volume of each resin piece and the average density obtained was (1.06 ± 0.02) g cm^{-3} for those polymerized in high gamma dose and (1.05 ± 0.02) g cm^{-3} with the alternative method.

Figure 3 shows the relative deviation from the mean activity of cylindrical acrylamide sources produced by the two methods.

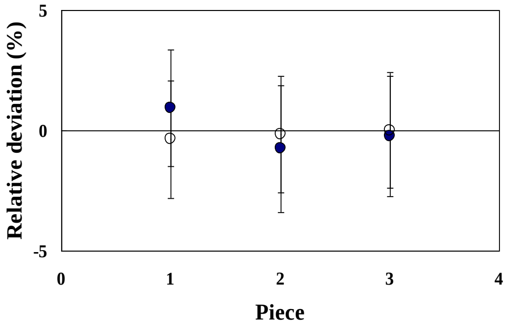

Figure 3. Relative deviation from the mean activity of cylindrical acrylamide sources produced by the two methods. Closed marks correspond to polymerization in high gamma radiation and open marks correspond to the alternative method.

3.2. Flat Source

The flat source was prepared in a 20 x 20 cm square glass container, 0.27 cm thick containing 77 ml of solution. Figure 4 shows the square solid matrix obtained by using the same chemicals as used in the cylindrical source.

Figure 4: The flat acrylamide/bis-acrylamide polimerized resin.

The uniformity of the flat source was verified by measuring the activity of small pieces in an

HPGe spectrometer. Eleven pieces having the same size and shape were obtained by cutting the flat sources randomly using a stainless steel cylinder cutter with 1.72 cm inner diameter.

The eleven round flat pieces sampled throughout the polymerized surface were weighted and their activities measured. The relative deviation from the mean activity is presented in Fig. 5. The maximum difference from the mean was 1.76%.

The density value for the flat resin was determined by measuring mass and volume of the eleven pieces and the average density obtained was (1.06 ± 0.02) g cm^{-3}, in good agreement with the literature [2], [5].

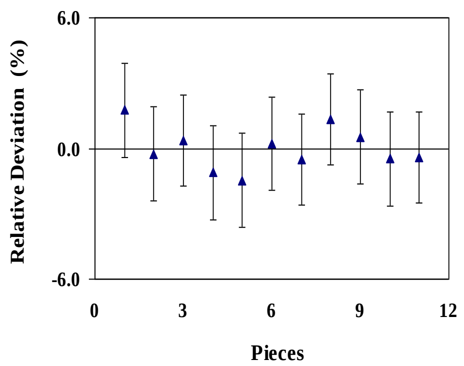

Figure 5. Relative deviation from the mean activity of pieces from the flat acrylamide source.

3.3 Rod source

An $^{152}EuCl_3$ solution purchased from Amersham with 400 kBq was dispersed in the aqueous solution composed by acrylamide plus bis-acrylamide. The polymerization was obtained by using the procedure described in section 2.2; the matrix was then injected into 8 mm outer diameter plastic tube having an inner diameter of 4 mm. The overall and active length of the rod was 86 cm.

The uniformity the rod source is planned to be measured in an HPGe spectrometer by means of a special collimator placed between source and detector.

4. CONCLUSION

The results presented in this paper for cylindrical water-equivalent solid sources by means of two methods developed by the LMN were excellent and the procedure can be considered well succeeded.

The solid sources showed uniformity and density as expected, in good agreement with values presented in the literature.

5. REFERÊNCIAS

1. H. Schrader, "Activity Measurements with Ionization Chambers." *Monographie BIPM-4* (1997)
2. Sahagia M., Grigorescu E. L. 1992. "Water-equivalent solid standard sources." *Nuclear Instrum. and Method in Phys. Res. A* 312**,** 236-239.
3. Yamazaki I. M., Koskinas M. F., Andrade e Silva L. G., Vieira J. M., Dias M. S. "Desenvolvimento de Fontes radioativas sólidas em resina acrilamida" P*roceeding of IX Congresso Brasileiro de Física Médica*, Rio de Janeiro.CD ROM (2004).
4. Koskinas M. F., Yamazaki I. M., Andrade e Silva L. G., Vieira J. M., Dias M. S. Optimization of the method for preparing water-equivalent solid sources". 2007 International Nuclear Atlantic Conference - INAC 2007, Santos, SP, Brazil. CD ROM(2007).
5. Moris W. M., Simpson B. R. S. "Preparation of solid water-equivalent radioactive standards." Applied Radiation and Isotopes 60**,** 557-560, 2004.