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Research Reactor Application to Iridium-192 Production for Cancer Treatment

Maria E. C. M. Rostelato*; Constância P. G. Silva; Paulo R. Rela;
Carlos A. Zeituni; Vladimir Lepki; Anselmo Feher

Instituto de Pesquisas Energéticas e Nucleares-Comissão Nacional de Energia Nuclear IPEN-CNEN
Av. Prof. Lineu Prestes, 2242. Zip Code: 05508-000 Sao Paulo – SP – BRAZIL

The purpose of this work is to settle a laboratory for Iridium –192 sources production, that is, to determine a wire activation method and to build a hot cell for the wires manipulation, quality control and packaging. The paper relates, mainly, the wire activation method and it quality control. The wire activation is carried out at IEA- R1m nuclear reactor.

KEYWORDS: Iridium wires, Iridium-192, Radioactive source production, nuclear reactor application, Brachytherapy

1.0 Introduction

In Brazil, cancer has become one of the major public health problems, reflected in an important cause of mortality. An estimate by the Health Ministry showed that 122.600 people died from cancer and another 337.535 had the disease in the country in 2002.[1] Every year, the number of cancer patients increases in Brazil and some of these patients are treated with Brachytherapy using Iridium -192 wire sources.

Brachytherapy, irradiation at a very close distance, is a form of lesions treatment which is based on the insertion of sources, in this case activated iridium wires inside tumors. During this process, the ionizing radiation destroys very efficiently the malignant cells.[2]

The objective of this work is to establish a laboratory for the production of Iridium – 192 sources. For this purpose, it is necessary to determine a method for activating the wires (we did not find any literature on this subject) and to build a hot cell for the handling, quality control and packaging of the wires. The finality of this project is to enable the country with the production of these sources, making the product accessible to clinics and hospitals, with more adequate prices for the Brazilian reality.

Iridium-192 has been used as a source in Brachytherapy, in wires, since 1960. The isotope is produced in a nuclear reactor by the reaction (n,γ):

$$^{191}_{77}Ir(n,g)^{192}_{77}Ir$$

*Corresponding author: Tel.:+55-11-3816-9274; fax.:+55-11-3816-9186
E-mail address: elisaros@ipen.br (Maria Elisa Rostelato).

It has a half-life of 74 days, high specific activity, it decays by beta emission and gamma to a stable isotope: a Pt-192. The beta rays emitted present energy ranging form 530 keV to 670 keV, and the main gamma rays emitted have an average energy of 370 keV. Iridium-191 has a high absorption section for neutrons (910 barns) [3.4]

The specific activity, for a low dose rate (LDR) therapy, is between 1mCi/cm and 4mCi/cm, being the main requested characteristic the activity homogeneity along the wire, not presenting a variation larger than 5% in a 50cm long wire[3].

These sources are usually shaped as flexible wires with 0.3mm and 0.5mm diameter and can be easily cut in the length requested for each application. These wires comprise a Platinum-Iridium alloy core (80/20), encapsulated in a Platinum or Stainless Steel tube. The coating aims to filter the beta rays.

Brachytherapy treatment can be carried out singly or associated to other techniques. The implants are made for several types of tumors, namely: oral cavity, cervix, breast, brain, skin, prostrate, eye, and others.

Among some specific Brachytherapy advantages over the external radiation, the capacity to give form to the isodose distribution in irregular lesions, the considerable diminishing of dose outside the implant area (saving normal tissues) and the treatment quickness can be highlighted.

2.0 Methods and Materials

The Iridium-Platinum wire (20/80) with 0.3mm diameter was acquired in the international market and submitted to the following analyses:

- scanning electronic microscopy
- X-rays fluorescence
- neutronic activation analysis

The wire was irradiated in the IEA-R1m reactor to define the activation parameters and several irradiation positions and experimental arrangements were tried out, since the literature researched does not specify the activation method for the wires in order to ensure the homogeneity of the activity all along the 50cm of these wires. A special irradiation element was built, the TEI-01, and the flux profile measurement of local neutrons was performed.

Main activated elements:

- Ir-192, half-life 74 days, cross section 924 barns, isotopic abundance 37.3%, some gamma energies 317 keV, 468 keV, 295 keV and 308 keV;
- Pt-197, half-life 18.3 hours, cross section 3.7 barns, isotopic abundance 25.3%, gamma energies 77.7 keV, 191.4 keV.;
- Pt-199, half-life 30.8 minutes, cross section 3.7 barns, isotopic abundance 7.2%, some gamma energies 186 keV, 246 keV, 317 keV, 317 keV, 493 keV, 543 keV and 714 keV.

For the sources manipulation, packaging and quality control, a hot cell was built, based on a iron and acrylic structure and covered with 5 cm thick lead bricks. An operation panel, four remote control pliers and two lead viewers are located in the frontal side.

In the lateral and back sides, two doors were installed, one for the material entrance and the other for maintenance. In the inner cell, the opening device for the irradiation recipient, the mean activity detectors and the wire packaging system have been placed.

A system for the sources quality control was built, comprising a high-tension source, electrometer, ionizing chamber, a 1 cm wide collimator shield and a set of pulleys and straps, so that the wire is allowed to pass centimeter by centimeter in front of the collimator window.

3.0 Results

In the table 1, the neutrons flux profile of the IEA-R1m reactor, in the reactor core position number 48, is shown.

Table 1. Neutron flux profile

Shelf	Thermal Flux ($x10^{13}n.cm^{-2}.s^{-1}$)	Relative Error %	Absolute Error %
1	0.116	3.0	5.0
2	0.387	3.0	5.0
3	0.641	3.0	5.0
4	1.240	3.0	5.0
5	1.670	3.0	5.0
6	1.920	3.0	5.0
7	1.960	3.0	5.0
8	1.880	3.0	5.0

The wire has a diameter of 0.3mm and comprises a Pt-Ir (80/20) nucleus and a platinum coating.

Through the X-rays fluorescence technique, besides the iridium and platinum, the presence of 0.35% of chrome, 0.73% of iron, 0.08% of manganese, 0.05% of cobalt, 0.51% of nickel, 0.21% of copper and 0.59% of zinc were determined in the coating.

The scanning electronic microscopy and the microanalysis showed this wire to be constituted of a well-centered Iridium-Platinum nucleus and a platinum coating.

The EDS analysis (Energy Dispersion Spectroscopy) was carried out in both coating and nucleus (apparatus – M.E.V. Phillips XL-30) and the following results were shown in tables 2 and 3.

Table 2. The wire coating constituents

Element	Weight percentage	Percentage Error
Ir	0.00	0.00
Pt	100.00	0.18

Through the neutronic activation analysis only the iridium and platinum elements were found.
The wire was irradiated in a IEA-R1m nuclear reactor for 40 hours, reactor core position number 48, shelf 7, neutrons flux 1.96 x $10^{13}n.cm^{-2}.s^{-1}$. Activated elements: Iridium-192, Platinum –197 and Platinum-199.

The evaluation of homogeneity was carried out every each centimeter during three times in the quality control system installed inside the hot cell. The percentage of the arithmetic average and deviation in relation to the mean, for each series of measures, were as follows:

The wire:

Measure 1 X= 2.2056 E= 1.74%

Measure 2 X= 2.0228 E= 2.83%

Measure 3 X= 1.9230 E= 0,67 %

Table 3. The wire nucleus constituents

Element	Weight percentage	Percentage Error	Sample Cut
Ir	18.53	0.89	Longitudinal
Pt	81.47	0.44	Longitudinal
Ir	18.83	0.85	Transversal
Pt	81.17	0.42	Transversal

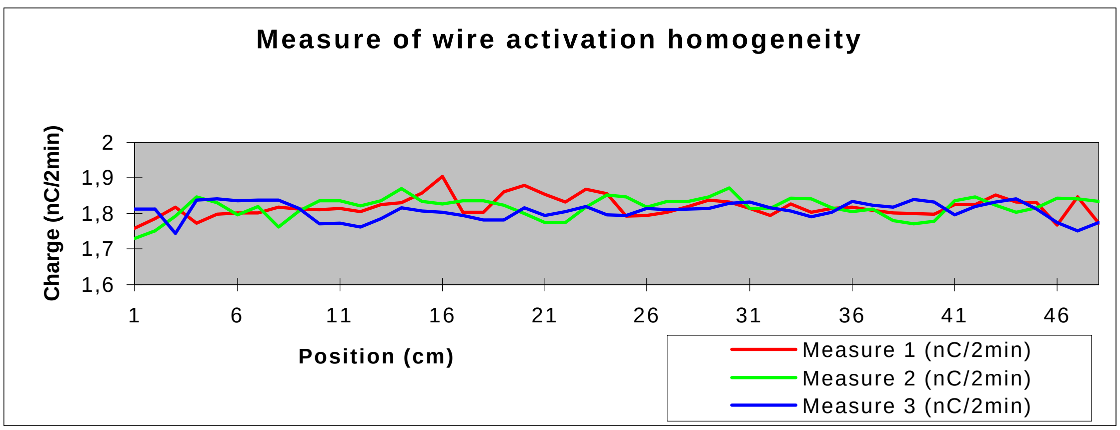

Figure 1. Measure of wire activation homogeneity

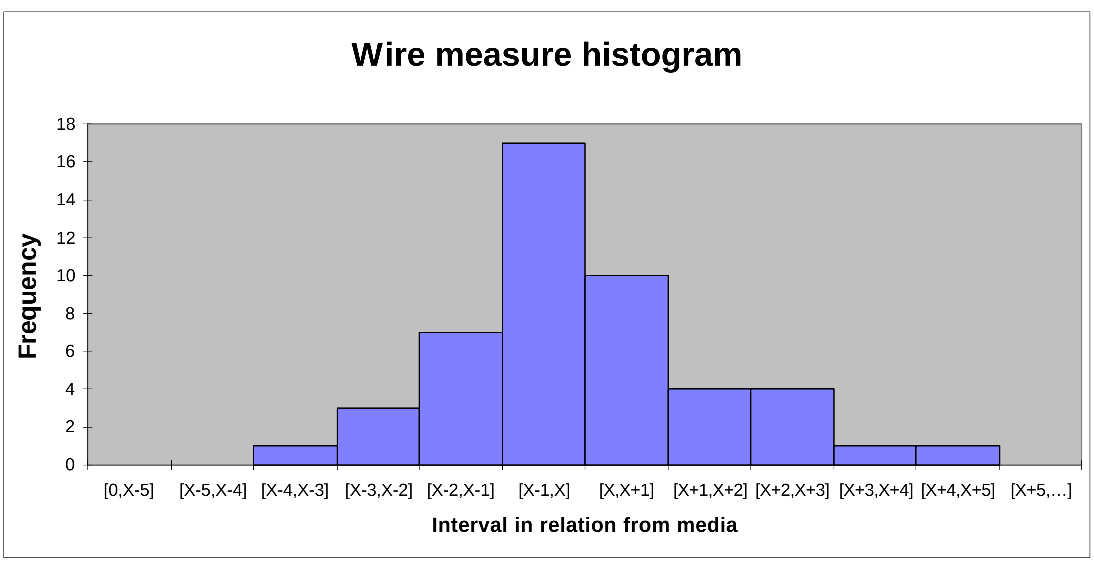

Figure 2. Wire measure histogram

The total activity was measured in an ionizing chamber Capintec model CRC-12. The value achieved was A=79.67mCi =2947.8MBq for a wire of 47 cm length. Specific activity was Ae=1,7mCi/cm = 62.72MBq/cm.

4.0 Conclusion

The wire showed results making it appropriated for brachitherapy application, since the dispersion value of the activity distribution related to the measures arithmetical mean did not surpass 5%.

The laboratory to produce the Iridium-192 wires was carried out. Nowadays, the product is available at low cost to the country.

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