Progress in Nuclear Energy 90 (2016) 175–181

Contents lists available at ScienceDirect

Progress in Nuclear Energy

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

Comparing different methods for radioactive iodine fixation intended for brachytherapy sources manufacture

Carla D. Souza*, Maria Elisa C.M. Rostelato, Carlos A. Zeituni, Fernando S. Peleias Jr., Marcos A.G. Benega, João A. Moura, Anselmo Feher, Osvaldo L. Costa, Rodrigo Tiezzi, Bruna T. Rodrigues, Thaís Hunke da Silva, Anderson Sorgatti, Daiane C. Barbosa de Souza

Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN-SP) Av. Professor Lineu Prestes, 2242. 05508-000 São Paulo, SP, Brazil

A R T I C L E I N F O

Article history:
Received 15 October 2015
Received in revised form
2 March 2016
Accepted 13 March 2016
Available online 31 March 2016

Keywords:
Cancer
Prostate
Brachytherapy
Iodine-125

A B S T R A C T

Brachytherapy, a method of radiotherapy, is being extensively used in the early and intermediate stages of the illness. In this treatment, radioactive seeds are placed inside or next to the area requiring treatment, which reduces the probability of unnecessary damage to surrounding healthy tissues. Currently, the radioactive isotope iodine-125, fixated on silver substrate, is one of the most used in prostate brachytherapy. The present study compares several deposition methods of radioactive iodine on silver substrate, in order to choose the most suitable one to be implemented at the laboratory of radioactive sources production of IPEN. Three methods were selected: method 1 (test based on electrodeposition method, developed by David Kubiatowicz) which presented efficiency of 65.16%; method 2 (chemical reaction based on the method developed by David Kubiatowicz - HCl) which presented efficiency of 70.80%; method 3 (chemical reaction based on the method developed by Dr. Maria Elisa Rostelato) which presented efficiency of 55.80%. Based on the results, the second method is the suggested one to be implemented at the laboratory of radioactive sources production of IPEN.

1. Introduction

Prostate cancer is the sixth most common type in the world, and the second most common cancer in men, with an estimated 1.5 million diagnoses in recent years representing about 10% of all cases of cancer. The number of new cases of prostate cancer in 2012 in Brazil was 60,180 (World Health Organization, 2012).

A method of radiotherapy which has been extensively used in the early and intermediate stages of the illness is brachytherapy, where radioactive seeds are placed inside or next to the area requiring treatment, which reduces the probability of unnecessary damage to surrounding healthy tissues resulting in low rates of sexual impotence and urinary incontinence. Currently, the radioactive isotope iodine-125 is one of the most used in prostate brachytherapy.

Iodine-125 seed permanent implantation features a number of advantages over traditional methods because it is related with low rates of sexual impotence and urinary incontinence, and patients can return to normal activity, including work, within one to three days with little or no pain (Souza, 2009; Srougi, 2002). The main goal of this paper is the comparison of Iodine-125 fixation, in a silver wire substrate, using 3 different methods.

The amount of seeds required for the implantation is 80–120 units 9. In Brazil, the implants are performed with imported seeds. The IPEN-CNEN/SP established a project for development and production of iodine-125 seeds in order to minimize costs and allow the distribution to public health, since there is a considerable demand for this type of therapeutic product (Souza, 2009; Rostelato, 2006).

The seeds-type sources are composed of a titanium capsule, classified as biocompatible, with 0.8 mm of outer diameter, 0.05 mm of wall thickness and 4.5 mm long. The internal structure varies from model to model. Seeds used in Brazil, uses a silver wire as a substrate. The iodine-125 is deposited in the silver substrate that also works as a radioactive marker. The typical activity of seeds

* Corresponding author.
E-mail addresses: carladdsouza@yahoo.com.br (C. D. Souza), elisaros@ipen.br (M.E.C.M. Rostelato), czeituni@ipen.br (C.A. Zeituni), fernandopeleias@gmail.com (F.S. Peleias), marcosagbenega@gmail.com (M.A.G. Benega), jmoura31@yahoo.com.br (J.A. Moura), afeher@ipen.br (A. Feher), costa_osvaldo@yahoo.com.br (O.L. Costa), rktiezzi@gmail.com (R. Tiezzi), bteigarodrigues@gmail.com (B.T. Rodrigues), thaishunke@hotmail.com (T. Hunke da Silva), asorgatti@hotmail.com (A. Sorgatti), dcsouza@ipen.br (D.C. Barbosa de Souza).

http://dx.doi.org/10.1016/j.pnucene.2016.03.013
0149-1970/

of iodine-125 is 0.5 mCi (18.50 MBq) (Souza, 2009; Rostelato, 2006; Lawrence, 1967).

The goal of this work is to compare 3 well-known methods: 1: Electrodeposition method based in Kubiatowicz (Kubiatowicz, 1982); 2: Chemical deposition method also based in Kubiatowicz (Kubiatowicz, 1982); new method developed in IPEN-CNEN/SP in Brazil (Rostelato, 2006).

This comparison is extremely important because the iodine-125 represents almost 95% of the seed cost. Thus, the more efficient this method is, the cheaper the seeds will be. Working with iodine, radioactive or not, is related to several issues. The material is volatile, which is a major concern when working with radioactive material. The reaction must occur in an alkaline media but one must be careful, because a high concentration of OH^- could result in silver hydroxide surface instead of the desirable silver iodide surface. A strict impurities control must be performed since 1 mCi(37 MBq) of iodine-125 corresponds to 10^{-8} g.

The three methods used in this work consider the laboratory infrastructure of IPEN, as well as the desirable configuration of the seed core: silver wire with deposited iodine-125.

The first iodine-125 seeds were developed in 1965 by Donald C. Lawrence (Lawrence, 1967). The shape and dimensions of the seeds were the same of the current used ones. The author recommended the use of plastic materials, as nylon, silicone rubber and Teflon for the core of the seeds. Palladium-103, cesium-131 and iodine-125 may be used as radiation sources. Stainless steel and titanium are recommended for the coating.

The second patent was published in 1982 by David Kubiatowicz (Kubiatowicz, 1982). The author proposes the use of silver chloride or silver bromide for the ion exchange, resulting in silver iodide (AgI^{125}). It is recommended to avoid blue and ultraviolet light exposure.

2. Methodology

All assays were performed in two steps: pretreatment of the silver surface and fixation of iodine-125 on it. The detailed methodology used is described below.

2.1. Method 1: ion exchange of chlorides on iodides based in Kubiatowicz (Kubiatowicz, 1982)

Kubiatowicz published this method in 1982. The silver cores are placed in a 0.1 mol/L sodium chloride solution. The vessel is connected to the positive electrode and a basket, containing the seeds, is connected to the negative electrode. The electric current is applied for 6.5 h. The silver wires are placed in a 0.2 mol/L sodium iodide (NaI^{125}) with 0.01 mol/L sodium hydroxide solution. Nonradioactive iodine in the form of sodium iodide combined with sodium hydroxide solution is added and then, the solution is stirred for 17 h. The author claims 97% efficiency in this process. This methodology was reproduced using the following conditions.

2.1.1. Pretreatment: electrochemical deposition of chlorides on silver wire

In this step, electric current is applied in a sodium chloride solution resulting in the formation of a silver chloride layer. The electroplating device was filled with a solution of sodium chloride (NaCl). The optimal concentrations were stipulated between 0.5 mol/L, 1 mol/L and 2 mol/L. It was used about 1 L of electrolyte solution. A stainless steel plate was attached at the negative electrode and the device, at the positive electrode. The parameters of electric current used were 0.3 mA, 0.5 mA and 1 mA for 4–8 h.

2.1.2. Fixation process

- After pre-treatment, the wires were placed inside a radioactive solution of sodium iodide (NaI^{125}). An ion–exchange reaction must occurs between chloride and iodine;
- The activity of radioactive iodine used was 100 mCi per seed core;
- The fixation reaction was carried for 17 h and 26 h;
- The influence of light and the carrier was tested. The carrier solution used was non-radioactive iodine with a concentration equivalent to half of the concentration of radioactive iodine. The purpose of adding iodine is that by increasing the concentration of it, the equilibrium of the reaction will shift to the formation of AgI. When the carrier was not used, the volume was completed with sodium hydroxide solution with different concentrations (0.1, 0.01 and 0.001 mol/L).

The values used for these parameters are shown in Table 1 and are based on values used in the academic literature consulted.

2.2. Method 2: treatment with chemical reagents also based in Kubiatowicz (Kubiatowicz, 1982)

Kubiatowicz published this method in the same patent as the one mentioned before. The wires are placed in a solution containing a 6 mol/L hydrochloric acid and a 1 mol/L sodium hypochlorite solution. After stirring for 1 h at room temperature, a layer of silver chloride is formed on the wires. The seed cores are placed in a solution with iodine-125 (NaI^{125}) and 10^{-4} mol/L sodium hydroxide and non-radioactive sodium Iodine (carrier solution), in order to standardize the distribution of iodine. After that, the solution is stirred for 19 h in the absence of light. The author claims about 90% efficiency in this process. This methodology was reproduced using the following conditions.

2.2.1. Pretreatment

The silver wires are placed into a beaker containing 20 mL of hydrochloric acid (HCl) with different concentrations—2 mol/L, 4 mol/L and 8 mol/L. Then, 2 mL of sodium hypochlorite (NaClO-oxidant agent), 1 mol/L were added to the solution. The stirring times selected were: 30 min, 2 h and 4 h, at room temperature. After stirring, a layer of silver chloride is formed on the wires.

2.2.2. Fixation process

- The activity of radioactive iodine solution was 100 mCi per seed core;
- The process was carried for 17 h and 26 h;
- The influence of light and presence of a carrier was tested in the same way as described in method 1. The concentration of NaOH was fixed at 10^{-4} mol/L.

Table 2 shows the parameters kept constant in each step of the assays.

Table 1
Parameters kept constant in method 1.

Parameter	Value
Electric current	0.5 mA
Time Using Electric Current	7 h
NaOH Concentration	0.01 mol/L
Reaction Time	20 h
Carrier	Present
Light presence	Not Present