# PROPOSAL FOR RADIOACTIVE LIQUID WASTE MANAGEMENT IN A BRACHYTHERAPY SEALED SOURCES DEVELOPMENT LABORATORY

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## ABSTRACT

The radioactive waste management is addressed in several regulations. Literature survey indicates limited guidance on liquid waste management in Brachytherapy I-125 seeds production. Laboratories for those seeds are under implementation not only in Brazil but in several countries such as Poland, South Korea, Iran, China, and others. This paper may be used as reference to these other groups. For the correct implementation, a plan for radiological protection that has the management of radioactive waste fully specified is necessary. The proposal is that the waste will be deposited in a 20 L and 60 L containers which will take 2 years to fill. For glove box 1, the final activity of this container is $1.91 \times 10^{10}$ Bq (3.19 years to safe release in the environment). For glove box 3, the final activity of this container is $1.28 \times 10^{10}$ Bq (2.85 years to safe release in the environment).

## 1. INTRODUCTION

### 1.1 Brachytherapy and Iodine-125 seeds

Prostate cancer treatment using permanent Iodine-125 seed implantation increased significantly in recent years. The technique is recommended for patients with early and intermediate cancer stages (1,2). The radiation released by Iodine-125 is of low-energy ensuring that most of the dose is released directly into the prostate. For this reason, the side effects are minimized when compared with other types of treatment.

A multidisciplinary team was formed at the Institute for Energy and Nuclear Research - Center for Radiation Technology (IPEN-CTR / SP), an organ of CNEN – Nuclear Energy National Commission, to develop a source of Iodine-125 and implement a national facility for local production. The manufacture of the seeds in Brazil will allow to reduce treatment cost and make it feasible for most patients.

Iodine-125 is fixated on a silver wire that is positioned within a titanium capsule. For the implementation of routine production is necessary to elaborate a plan for radiological protection that has the management of radioactive waste fully specified. The purpose of this work is to develop an initial proposal that helps the team to manage the radioactive wastes that are generated within the manufacturing process. This calculation is complicated because is based on estimates that can easily change. The system must be prepared for the worst case scenario, and, most of the time, those numbers are exaggerated.

### 1.2 History of the waste management in Brazil

It is estimated that approximately 15,000 $m^3$ of radioactive waste was generated throughout the use of nuclear energy in Brazil. In the area of radioactive waste, CNEN is responsible for setting control regulations for managing waste from its origin to the final storage (3,4).

The CNEN performs periodic operations to collect waste throughout the country and in its own facilities, such as IPEN (4).

## 2. BIBLIOGRAPHICAL SURVEY

International Atomic Energy Agency defines radioactive waste as "any material that contains or is contaminated with radionuclides at concentrations or radiation levels greater than the amounts specified by the competent authorities" (5,6). Radioactive Waste lead to public health problems that is not common to other types of waste. In addition most authorities aren't accustomed in how to proceed in case of emergency (7).

The classification of different types of waste determines how to handle every sort of material generated. It can also identify the disposal options available (5).

A treatment hierarchy and organization should be employed in radioactive wastes to minimize the environmental impact through prevention / minimization and recycling (7,8).

The radioactive waste management is addressed in international and national regulations. Not any law, rule or specific article was found (to this date) that provides a basic outline of how the waste management in radioactive facilities for the production of brachytherapy Iodine-125 seeds must be implemented. The survey presented in this topic is a summary of the Brazilian National Nuclear Energy Commission regulation.

**CNEN - NE - 605 - Management of radioactive wastes in radioactive facilities. Brazilian National Commission of Nuclear Energy, 1985 (9)**

This regulation establishes general criteria and basic requirements for waste administration. In it, management of radioactive waste is defined as "set of administrative and technical activities involved in collection, segregation, handling, processing, packaging, transportation, storage, control and deposition of radioactive wastes".

For CNEN, a policy that should be applied, when possible, is the management of the waste inside the own instalation/laboratory. Then final waste destination is made after an radiactive activity evaluation (parameters for Iodine-125 in table 1). The waste can go into the commom trash/ sewer after the material reach final concentration (after dilution in the entire volume released by the facility) equal or less than the limits specified in Table 1.

| | Form | Values | |
|---|---|---|---|
| **I-125** | **Soluble liquid** | **$4x10^{-6}$ µCi/ml** | **$1,5x10^{6}$ Bq/m³** |
| | **Insoluble Liquid** | **$6x10^{-3}$ µCi/ml** | **$2,2x10^{8}$ Bq/m³** |
| | Soluble Gaseous | $8x10^{-11}$ µCi/ml | 3Bq/m³ |
| | Insoluble Gas | $6x10^{-9}$ µCi/ml | $2,2x10^{2}$Bq/m³ |
| | Solid | 2 mCi/kg | 7,5 x $10^{4}$ Bq/kg |

Tab 01: Environmental Release Limits form materials contaminated with different forms of Iodine-125 (9).

## 3. METHODOLOGY

### 3.1 Generation of Radioactive Waste

The laboratory is still under implementation. The team is developing the radioprotection plan, but the waste management has not yet been established. This work was done with interviews and meetings with the group of researchers involved in the project, the design engineer and the radiation protection supervisor.

Figure 1 shows the layout of the laboratory indicating the generation of waste in each glove-box. They are aluminum "boxes" with special gloves for Iodine-125 manipulation.

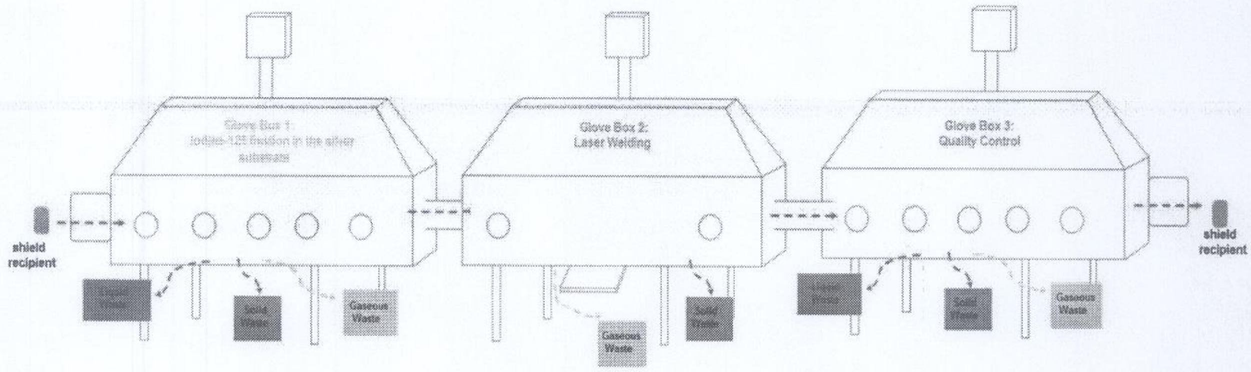


*Figure 1: Waste generation for each production glove-box*

**1. Glove Box 1- Fixation of Iodine-125 on a substrate of silver:** In the first glove box of radioactive solution and the material used in manufacturing will enter the production line. Is inside this glove that the isotope deposition in the silver core takes place. This phase of the process will generate waste liquids, solids and gases.
**2. Glove Box 2- Laser Welding:** In the second glove box core is coated with a titanium capsule and the seed will be sealed with a laser welding. This phase of the process will generate gaseous and solid wastes.
**3. Glove Box 3- Quality Control:** Inside the third glove box occur in the quality control (leakage tests) of material and output sources will occur. This phase of the process will generate liquids, solids and gaseous wastes.

### 3.2 Calculations and Estimates

In the following items the bases of the calculations is presented.

- All the calculations was made considering "the worst case scenario", that means, the highest activity in the final waste as possible. Although this case is unlikely to occur, the waste system must be ready for this situation.
- Four weekly productions will be made that will last five days;
- 1 month = 4 weeks;
- 1 production = 4 procedures and 1 production = 18 tubes;
- The accounts was rounded always "for up " for security reasons. It also considered the installed devices (to date) accurate of and used for the calculations (used "two houses after the comma");
- The liquid waste final activity (inside the drums) must that takes into account the effect of the new activities being added over time.
- Therefore the equation for calculating the final activity is:

$$A = \frac{f}{\lambda}(1 - e^{-\lambda t})$$

CAPTION: A = Activity (for a given time t - $A_{initial}$ in the decay law), f = source term (entry fee of material in the deposit Bq / time), λ = decay constant ($s^{-1}$), t = time

- The time to release the waste bags to the common trash was calculated by the decay law of presented below

$$A_{final} = A_{initial} \cdot [e^{-\lambda t}]$$

CAPTION: A = activity; λ= decay constant; t = time

### 3.2.1 Estimated total volume

**GLOVE BOX 1**

Iodine-125 characteristics: The material is imported from Nordion (Canada) in a tube with 8ml and 3,380mCi activity, per procedure. Then this material is diluted in 42mL of water resulting in a 50ml Iodine-125 solution. The current proposal is that the liquid waste is administered in 20L waste drums. So for the 50ml total:

- 36ml used in 4 productions = 144ml (dried in the end of the process) in 4 weeks makes the total of 576ml used/month → 6,912ml in one year

- 14ml leftover in 4 productions = 56ml in 4 weeks makes the total 224ml leftover/month → 2,688ml in one year

TOTAL VOLUME = 9,600 ml/ year = $9.6 \cdot 10^{-3}$ $m^3$/ year

**GLOVE BOX 3**

***1st PHASE:*** The tubes are washed 3 times and between each time they are replaced in new tubes. Each wash is about 2 ml for every single production. So:

- 2ml of water x 18 tubes x 4 productions x 4 weeks x 3 times = 1,728 ml x 12 months = 20,736 ml/year

***2nd PHASE:*** The tubes are filled one more time and 1ml of the water is measured with a NaI scintillator and the other ml is sucked by the drier. Once a month one tube of the production has it water separated and measured with a liquid scintillator. So:

- 1ml scintillator NaI/liquid x 18 tubes x 4 productions x 4 weeks = 288ml/month x 12 months → 3,456 ml/ year
- 1 ml to the drier x 18 tubes x 4 production x 4 weeks = 288ml/month x 12 months = 3,456 ml/ year
- Once a month = 2ml of liquid from the liquid scintillator x 12 months= 24 ml/year

TOTAL VOLUME = 27,672ml/year ≈ $28 \cdot 10^{-3}$ $m^3$/year

### 3.2.2 Activity Estimation

**GLOVE BOX 1**

The material has 8ml tube and 3.38 Ci activity. It is diluted in 42mL of water resulting in an Iodine-125 solution 50ml.

$$C_{initial} \cdot V_{initial} = C_{final} \cdot V_{final}$$

$$3.38Ci \cdot 8ml = C_{final} \cdot 50ml$$

$$C_{final} = 540.8mCi$$ For all 50ml

According to *Rostelato* (10) the deposition efficiency is 85%.

***Fixation (11ml de leftover):*** 64.90 mCi is the final waste = $2.40 \cdot 10^9$ Bq/week

***Washing (12% leftover):*** 233.63mCi = $8.64 \cdot 10^9$Bq/productions

Adding the activities f=$1.11 \cdot 10^9$ Bq/production;

One operation is realized during 5 days t= $4.32 \cdot 10^5$s;

So, the term f (material entrance rate in the deposit in Bq/unit of time) is:

$$f = \frac{1.11 \cdot 10^9}{4.32 \cdot 10^5} = 2.57 \cdot 10^3 \frac{Bq}{s}$$

Calculating the decay constant:
$T_{\frac{1}{2}} = 59.43\ days$

$$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} = \frac{\ln 2}{59.43 \cdot 24 \cdot 3600\ (sec.)} = 1.35 \cdot 10^{-7}\ \text{s}^{-1}$$

Calculating the final activity in the waste drums:
Time to fulfill the 20 L waste drums: 2 years = $6.23 \cdot 10^7$s

$$A = \frac{f}{\lambda}(1 - e^{-\lambda t})$$

$$A = \frac{2.57 \cdot 10^3 \frac{Bq}{s}}{1.35 \cdot \frac{10^{-7}}{s} \cdot (1 - e^{-1.35 \cdot 10^{-7} s^{-1} \cdot 6.23 \cdot 10^7 s})} = 1.91 \cdot 10^{10}\ Bq$$

Calculating the time to decay, assuming the maximum concentration for disposal given by the regulation:

$$Concentration\ .Volume = A\ .\left[e^{-\lambda t}\right]$$

$$1.5 \cdot 10^6 \frac{Bq}{m^3} \cdot 9.6 \cdot 10^{-3} \frac{m^3}{year} \cdot 2 years = 1.91 \cdot 10^{10}\ Bq \cdot e^{(-1{,}35 \cdot 10^{-7} s^{-1} \cdot t)}$$

$t = 99{,}29 \cdot 10^6 s = 3{,}19 years$ To be release in the environment

**GLOVE BOX 3**
Assuming 5mCi leakage in one production (10).

5mCi x 4 productions= $2 \cdot 10^{-2}$Ci/production = $7.4 \cdot 10^8$Bq/production

One production→ 5 days t=$4.32 \cdot 10^5$s
So, the term f (material entrance rate in the deposit in Bq/unit of time) is:

$$f = \frac{7.4 \cdot 10^8\ Bq/5days}{4.32 \cdot 10^5\ s} = 1.72 \cdot 10^3 \frac{Bq}{s}$$

Calculating the final activity in the waste drums:
Time to fulfill the 20 L waste drums: 2 years = $6.23 \cdot 10^7$s

$$A = \frac{f}{\lambda}(1 - e^{-\lambda t})$$

$$A = \frac{(1.72 \cdot 10^3)\text{Bq/s}}{1.35 \cdot 10^{-7}/s} . \left[1 - e^{-1.35 \cdot 10^{-7} \text{s}^{-1} \cdot\ 6.23 \cdot 10^7 \text{s}}\right]$$

$$A = 1.28 \cdot 10^{10} Bq$$

Calculating the time to decay, assuming the maximum concentration for disposal given by the regulation:

$$Concentration\ .Volume = A\ .\left[e^{-\lambda t}\right]$$

$$1.5 \cdot 10^6 \frac{\text{Bq}}{\text{m}^3} \cdot 28 \cdot 10^{-3} \text{m}^3/\ year(28L)\ \cdot\ 2\ years = 1.28 \cdot 10^{10} \text{Bq}\ \cdot\ \left[e^{-1.35 \cdot 10^{-7} \text{s}^{-1}\ \cdot\ t}\right]$$

$$t = 88.41 \cdot 10^6 s = 2.85\ years\ to\ release\ into\ environment$$

## 4. RESULTS

### 4.1 Proposed Management

The management of radioactive waste generated by the laboratory should be done in the physical space of the laboratory, since it has space available.

Assuming the highest contamination inside the waste system, the Glove Box 1 liquid waste will occupy a $9.6 \cdot 10^{-3}$ $m^3$/year. It was stipulated by the team that the waste will be stored in waste drums with 20L. The time take to fill it is 2 years. After these two years, the decay must occur during 3.20 years before the liquid can be dispensed into the common sewer. The free volume available in the lower glove box *($9.7 \cdot 10^{-1}$ $m^3$)* is large and able to engage several waste drums of this type. That, with the appropriated shielding, allows the local management of the liquid waste.

The Glove Box 3 liquid waste will occupy $28 \cdot 10^{-3}$ $m^3$/year. After the two years take to fill the 60 L waste drums, the decay must occur for 2.85 years before the liquid can be dispensed into the common sewer. The free volume available is, again, enough for local management.

Also, the 11ml leftover must be revised. The best is to do one smaller batch and use all the iodeine-125.

### 4.2 Recommendations

An organized structure and an established procedure facilitate waste reduction (9). To this end, the data calculated should be considered by the team. Among them we can highlight:

- Training of staff involved should be done periodically (every two years);
- Control of waste made by labels and forms must be created by a team of radiological protection;
- Policy for material recycling: recycling procedure should be applied in a specific location and with care.
- Monitoring staff, area and specific for the waste: the use of TLD dosimeters and detectors to monitor the waste, environment and workers;
- Since the case presented in this work is unlikely to occur, periodic measurement of the waste must be done to keep the final activity under surveillance. All of the calculations and sheets developed in this work is available for future use by the radiation protection team;
- Aspects necessary for a save security storage:
- The storage of the drums must be physically and chemically stable;
- Construction materials have to be durable and ideal for handling radioactive materials;
- Passive safety systems;
- Independent systems for monitoring and maintenance;
- Easy access for intervention in case of accident;
- Possibility of packaging inspection and easy removal (9).

## 5. CONCLUSION

The purpose of this study was to survey the team that helps to establish a management plan for the Iodine-125 seeds production laboratory.

For liquid waste management, systems should be implemented 20L drums. To this end, the space beneath the glove box *($9.7 \cdot 10^{-1}$ $m^3$)* should be shielded for be used as waste deposit. The Glove Box 1 waste drums should occupied 20L in 2 years. After these two years, the decay must occur during 3.19 years before the liquid can be dispensed into the common sewer. The Glove Box 3 waste drums should occupied 60L in 2 years. After the two years take to fill the waste drums, the decay must occur for 2.85 years before the liquid can be dispensed into the common sewer.

A policy of reducing and recycling during that process in order to cut unnecessary spending and waste generation must be applied. This work should continue to be developed (studying gaseous and solid waste) and expanded to other the research areas, such as physical and radiological protection of the working environment. As a direct result, an excel work sheet was generated that can be easily adapted to new values.

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