Preliminary proposal for solid radioactive waste management in a laboratory for production of sources used in Brachitherapy

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1. INTRODUCTION
1.1 Prostate Cancer in Brazil and in the world no Brasil

The Brazilian National Cancer Institute estimate 489,270 new cancer cases will occur in the country in 2010. The highest incidence will be, for masculine sex, of protate cancer (about 52 thousand cases) and lung cancer (except for non-melanona skin cancer) (1).

A multi-disciplinary team was created at Instituto de Pesquisas Energéticas e Nucleares – Centro de Tecnologia das Radiações (IPEN –CTR / SP) to develop a national 125-iodine source and start the installation for local manufacture. The seeds production in Brazil will enable to lower the treatment cost and make it feasible for more patients (2).

125-iodine is deposited onto a silver thread, which is positioned in the interior of a titanium capsule. To set up routine production it is necessary to make a radiological protection plan, specifying the radioactive waste management procedures. The purpose of this work is to offer an initial proposal to help the team administrate the solid radioactive waste generated from the production process.

2. METHODOLOGY
2.1 Calculations and Estimates

In the following items, all the calculations which give basis to the proposal will be presented.

Calculation considerations

- Each production has 18 tubes;
- 4 weekly productions, lasting 5 days, will be carried out;
- 1 month is considered to be 4 weeks;
- 1 production = 4 procedures;
- Calculations have been always done “higher”, out of security. The highest precision as for the apparatuses installed has been, also, considered (so far) and used for calculations” two figures after comma”;
- As a conservative measure, 50% of the total volume has been added to the original volume. This is required, according to the radiological protection team, since the solid waste does not maintain its position perfectly, side by side (3).
- The time for the bags release from the repository was calculated by the decay law, as presented below;

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

CAPTION
A = activity
λ = decay constant
t = time (3)

- According to the standart CNEN – NE - 605 – Radioactive waste management in radioactive installations(4) of Comissão Nacional de Energia Nuclear the the environment Release limit for 125-iodine radioactive waste in different forms is presented in table 1.

Table 1: Release limit for 125-iodine radioactive waste into the environment in different forms [4]*.*

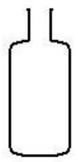
	Form	Value	
I-125	Soluble liquid	$4x10^{-5}$ µCi/ml	$1.5x10^{6}$ Bq/m^3
	unsoluble liquid	$6x10^{-3}$ µCi/ml	$2.2x10^{8}$ Bq/m^3
	Soluble gas	$8x10^{-11}$ µCi/ml	3 Bq/m^3
	unsoluble gas	$6x10^{-9}$ µCi/ml	$2.2x10^{2}$Bq/m^3
	Solid	2 mCi/kg	7.5 x 10^{4} Bq/kg

2.2 Estimative of quantity/volume and mass

Quantity used in production

- 4 glasses of I-125 NORDION per week = 16 tubes/month
- 18 tubes x 4 productions = 72 tubes with lid per week x 4 weeks = 288 tubes/month
- 1 syringe per production x 4 productions x 4 weeks = 16 syringes/month
- 2 becker x 2 (using 2 in the production line) = 4 operations
  4 becker x 4 productions x 4 weeks= 64 becker/month
- 1 decontamination cloth x 4 productions x 4 weeks= 16 cloths/month

LIST OF MATERIALS USED IN THE PRODUCTION



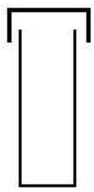
NORDION TUBE
radius (r) = 2cm
heigth (H) = 5cm
mass = 12g

VOLUME

$$V = 2\pi rH$$
$$V = 2 \cdot \pi \cdot 2 \cdot 5$$
$$V = 62.83\ cm^3 \cdot 16/month$$
$$V = 1005.28\ {cm^3}/{month}$$

MASS

$$m_{total} = 12 \cdot 16 = 192\ g/month$$



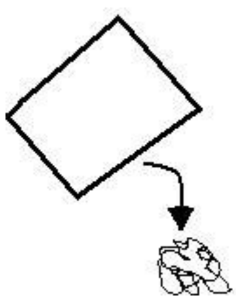
PRODUCTION TUBE
radius (r) = 1cm
heigth (H) = 5cm
mass = 3g

VOLUME

$$V = 2\pi rH$$
$$V = 2 \cdot \pi \cdot 1 \cdot 5$$
$$V = 31.42\ cm^3 \cdot 288/month$$
$$V = 9048.96\ {cm^3}/{month}$$

MASS

$$m_{total} = 288 \cdot 3 = 864\ g/month$$



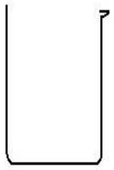
CLEANING CLOTH
radius (r) = 3cm
mass = 0.20g

VOLUME

$$V = \frac{4\pi r^3}{3}$$
$$V = 113.10\ cm^3 \cdot 16/month$$
$$V = 1809.60\ {cm^3}/{month}$$

MASS

$$m_{total} = 0.20 \cdot 16 = 3.20\ g/month$$



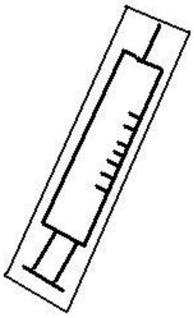
Becker Vial
radius (r) = 3.50cm
heigth (H) = 10cm
mass = 50g

VOLUME

$$V = 2\pi rH$$
$$V = 2 \cdot \pi \cdot 10 \cdot 3.5$$
$$V = 219{,}91\ cm^3 \cdot 64 /month$$
$$V = 14074.24\ {cm^3}/{month}$$

MASS

$$m_{total} = 64 \cdot 50 = 3200\ g/month$$



VOLUME

$$V = 2\pi rH$$
$$V = 2 \cdot \pi \cdot 3 \cdot 15$$
$$V = 282.75\ cm^3 \cdot 16 /month$$
$$V = 4{,}524\ {cm^3}/{month}$$

MASS

$$m_{total} = 8 \cdot 16 = 128\ g/month$$

Syringe (Approximate Volume of a cylinder)
radius (r) = 3cm
heigth (H) = 15cm
mass = 8g

Then, it is obtained:

TOTAL VOLUME = 30462.08 cm^3/month

It is considered that the material positioned in the waste bag does not occupy, perfectly, the possible smallest volume. Therefore, 50% of the total value is added in the nominal volume.

MONTHLY NOMINAL VOLUME = 45693.12 cm^3/month ($4.57 \cdot 10^{-2}\ m^3$/month)
ANNUAL NOMINAL VOLUME = 548317.44 cm^3/year ($5.49 \cdot 10^{-1}\ m^3$/year)
WEEKLY TOTAL MASS = 1.1 kg/week
MONTHLY TOTAL MASS = 4387.2 g = 4.39 kg/month
ANNUAL TOTAL MASS = 52.68 kg/year

2.3 Repository activity estimate

- Admitting that the radioactive material has adherence to the solid waste of approximately 10% of the liquid waste;
- The initial proposal was that the solid waste was managed monthly. As it will be proved it the calculations below, the remaining activity is smaller than that established as discharge limit by CNEN NE 6.02 norm, therefore there is not solid waste. The new proposal is that the material should be taken from production line in 1 bag per week.

$$16.8mCi \cdot 4\ productions = 6.72 \cdot 10^{-2} Ci/production = 2.49 \cdot 10^{9}\ Bq/production$$

Since one production is carried out in 5 days, the result is $t = 4.32 \cdot 10^5 s$.

Then, activity A equals:

$$A = \frac{2.49 \cdot 10^9\ Bq/5days}{4.32 \cdot 10^5\ s} = 5.77 \cdot 10^3 Bq/s$$

Calculating decay time:

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

$$7.5 \cdot 10^4 \frac{\mathrm{Bq}}{\mathrm{kg}} \cdot 1.1 \frac{\mathrm{kg}}{\mathrm{week}} = 5.77 \cdot 10^3\ Bq \cdot \left[\, e^{-1.35 \cdot 10^{-7}\ \mathrm{s}^{-1} \cdot\ \boldsymbol{t}}\right]$$

$$t = -19.71 \cdot 10^6 s$$

Negative time means that the waste does not need to be stored.

3. CONCLUSION
3.1 Management Proposal

Management of radioactive waste generated by the 125-iodine sources production should be done in the own laboratory physical space, since it has enough room for this.

The solid waste will be handle weekly, in bags weighing 1.1kg/week. The collection system will be done with a resistant bag that will be handled by a member of the radiological protection team. The process will still include a sealing machine. The remaining activity in the bag is under discharge limits.

3.2 Recycling Programme

It should be clear that a policy of reduction and recycling during the process is vital, so that costs and unnecessary waste generation may be achieved.

References

1. **MINISTÉRIO DA SAÚDE. INSTITUTO NACIONAL DE CÂNCER.** *Incidência de Câncer no Brasil.* Disponível em: <http://www.inca.gov.br/estimativa/2008/index.asp?link=tabelaestados.asp&UF=BR> Acesso em: 18 de setembro de 2008.

2. **ROSTELATO, M.E.C.M.** *Estudo e Desenvolvimento de uma nova Metodologia para Confecção de Sementes de Iodo-125 para Aplicação em Braquiterapia.* Instituto de Pesquisas Energéticas e Nucleares. São Paulo : s.n., 2006. p. 93, Tese de Doutorado.

3. **HIROMOTO, G**. *Apostila de Rejeitos Radioativos*. Laboratório de Rejeitos Radioativos. Instituto de Pesquisas Energéticas e Nucleares/CNEN. .

4. **CNEN – NE - 605 –** *Gerência de rejeitos radioativos em instalações radioativas*. Comissão nacional de Energia Nuclear, 1985.