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REUSE AND RECYCLING OF RADIOACTIVE MATERIAL PACKAGING

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ABSTRACT

Human development is directly linked to energy consumption. The political decisions (to this human development) result in economic, social and environmental aspects, whose magnitude should maintain the sustainability of every aspect for not to collapsing. The environmental aspect has been a target of research because of the excessive emission of gases which contributes to the greenhouse effect. The production processes emit gases due to the consumption of energy to get it, but it's necessary to maintain the environmental sustainability in order to minimize the contribution to the emission of greenhouse gases. The population control and the energetic efficiency are factors that contribute to the environmental sustainability. Besides them, the culture of consumption is another factor that, when applied to the reduction of emissions, also contributes to the sustainability of the environment. The reuse of materials is one of the sub-factors which contribute to the reduction of emissions. The Radiopharmacy Directory (DIRF) at IPEN-CNEN/SP, produces radiopharmaceuticals that are necessary to improve the Brazilian population's life quality. The radiopharmaceuticals are transported in packaging to the transport of radioactive material. These packages are considered non-biodegradable, because some metals, which make up these packages, pollute the environment. These packages have increased costs, in addition, because it must be approved in tests of integrity. The reuse of packaging in favorable situations to the same purpose is a way to help the environment degradation and costs reduction. The packaging reuse in unfavorable situations disobey rules or return logistics that become effective the transport back, but the consumption culture strengthening can change this situation.
This paper describes IPEN's packaging, form and quantities distribution, and the packaging that comes back to be reused.

1. INTRODUCTION

The sodium pertechnetate ($Na^{99m}TcO_4$) is the most radiotracer used in nuclear medicine for diagnosis purpose of several types of diseases. Currently, drugs labeled with different radionuclides have been used in diagnostic and therapeutic applications, but 90% related to diagnosis. The generator of $^{99}Mo/^{99m}Tc$ is a radioisotope production system. The ^{99m}Tc (technetium - 99 metaestable) is obtained from the decay of ^{99}Mo in the form of sodium pertechnetate ($Na^{99m}TcO_4$) by elution with saline solution. It's a way of easy transport and handling, with ideal physical characteristics for use in human. Technetium – 99 m decays by emission of a 140 keV gamma ray with a half-life of 6 hours. The 140 keV pure gamma emission makes ease the location and monitoring of radiation by means of acquisition of images in nuclear medicine.

The generator is weekly produced by DIRF, starting prior with the preparation of calcined alumina, sieved and conditioned with HCl 1.5 N. Subsequently, packed with 4.0 g of alumina and 0.5 g of teflon, in a glass column as the Fig. 1 diagram.

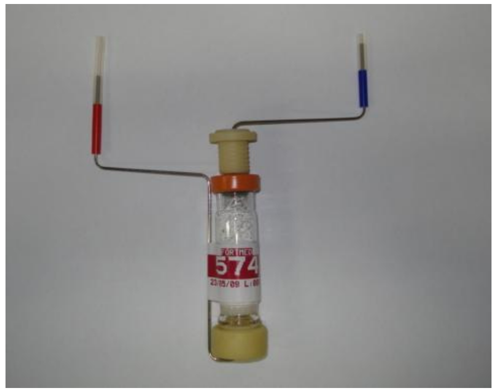


Figure 1. Column.

A glass column is loaded with ^{99}Mo is placed inside a lead container shield to reduce the radiation dose to workers, as illustrated in the cut in Fig. 2 (a) and this shield is within a recipient to generator, RPG, plastic, illustrated in Fig. 2 (b). The RPG and essential accessories for the effective elution of ^{99m}Tc are placed inside the pack order of generator, called EDG, illustrated in Fig. 2 (c). The EDG has a internal lead cylinder coated by plastic that supports 2 sets of glass boxes (14 vials with vacuum and 14 vials with 6.0 mL of 0.9% saline solution), to easy the taking "in-situ" of ^{99m}Tc in nuclear medicine services.

(a) Glass column shielded with lead, in the cut.	**(b) RPG.**	**(c) EDG.**

Figure 2. The ^{99m}Tc generator inserted in a shielded column, RPG and EDG.

The RPG and the EDG is composed of non-biodegradable materials and resistant for use by more than once. The ^{99m}Tc generators are used weekly in hospitals or nuclear medicine services in Brazil and after their use, over time, lose their activity as radioactive decay. However, they are dangerous goods that need to be transported and stored in secure packaging, from the manufacturer to the end user. Packagings, before use, are subject from integrity tests to comply with national and international regulatory requirements, as well as national and international requirements regarding the transport of dangerous goods [1, 2].

Therefore, besides the monetary cost for the design of packaging, the transport of radioactive materials has increased its costs for approval of packages and for transport of dangerous products. In addition to these costs, the RPG and the EDG also generate environmental costs.

Due to the quantity produced (300 - 315 generators / week), the RPG and the EDG durability, the relationship between the manufacture cost and the reuse cost and due to the environmental cost, the RPG and the EDG reusing process contribute greatly to the economic and environmental production sustainability.

The ^{99m}Tc generators with maximum initial activity of 74 GBq is transported in ***type A package***. If the activity of the ^{99m}Tc generator is less than 8 MBq [1], it is transported to the classification of ***excepted package***. The transport of ***excepted package*** dispensing the use of risk labels on the packaging and warning signs on the vehicle.

2. METODOLOGY

A procedure to enable the reuse of RPG and EDG was developed.

2.1 The supply of the ^{99m}Tc generators was conditioned on the return of RPG and EDG;

2.2 The return of the ^{99m}Tc generators now required a minimum time from supply with the aim to simplify and facilitate the transport.

The maximum activity remaining accepted for carriage as ***excepted package*** is achieved if the ^{99m}Tc generator is used by the regulated value (A = 8 MBq) or, when not used, if more restrictive, even for the maximum activity provided (A_0 = 74 GBq), it was passed a minimum time "t" to achieve this activity, such that:

$$t = -\frac{T_{1/2}.\ln\left(\frac{A}{A_0}\right)}{\ln 2} \quad (1)$$

Arise from the:

$$A = A_0 . e^{\frac{-(ln2).t}{T1/2}}, \quad (2)$$

Where T ½ ^{99}Mo = 66 (h);

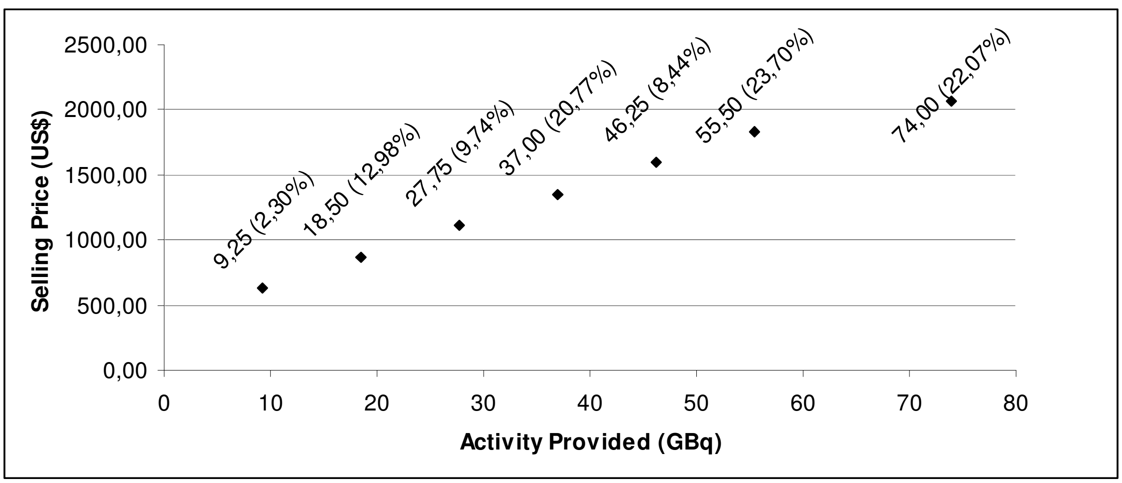
The minimum time to achieve this activity is t = 36days.

Explanatory folders were distributed to customers to request the return of generators after 36 days of supply, so the return transport is classified as ***excepted package***. The preparation of returned generators for reuse of the RPG is a receiving, disassembling, visual inspection, removing the identification stickers, cleaning, labeling to identify and characterize new storage. The used caps are recycled by expert industry.

The preparation for reuse of the EDG consists of receiving, disassembling, visual inspection, monitoring levels of contamination, removing of identification stickers, cleaning, labeling to identify and characterize new storage.

3. RESULTS

The weekly production of ^{99m}Tc generators is approximately 300 units which is expected to increase by 10 % for this year. The generators are prepared and provided with varying from of 9.25 GBq (250 mCi) to 74.00 GBq (2 Ci). The market values and the production percentages of each activity are shown in Graph 1.



Graph 1. The ^{99m}Tc generators market values and the production percentages.

The national distribution made by carriers by road (40%) and by air (60%) is represented in Fig. 3.

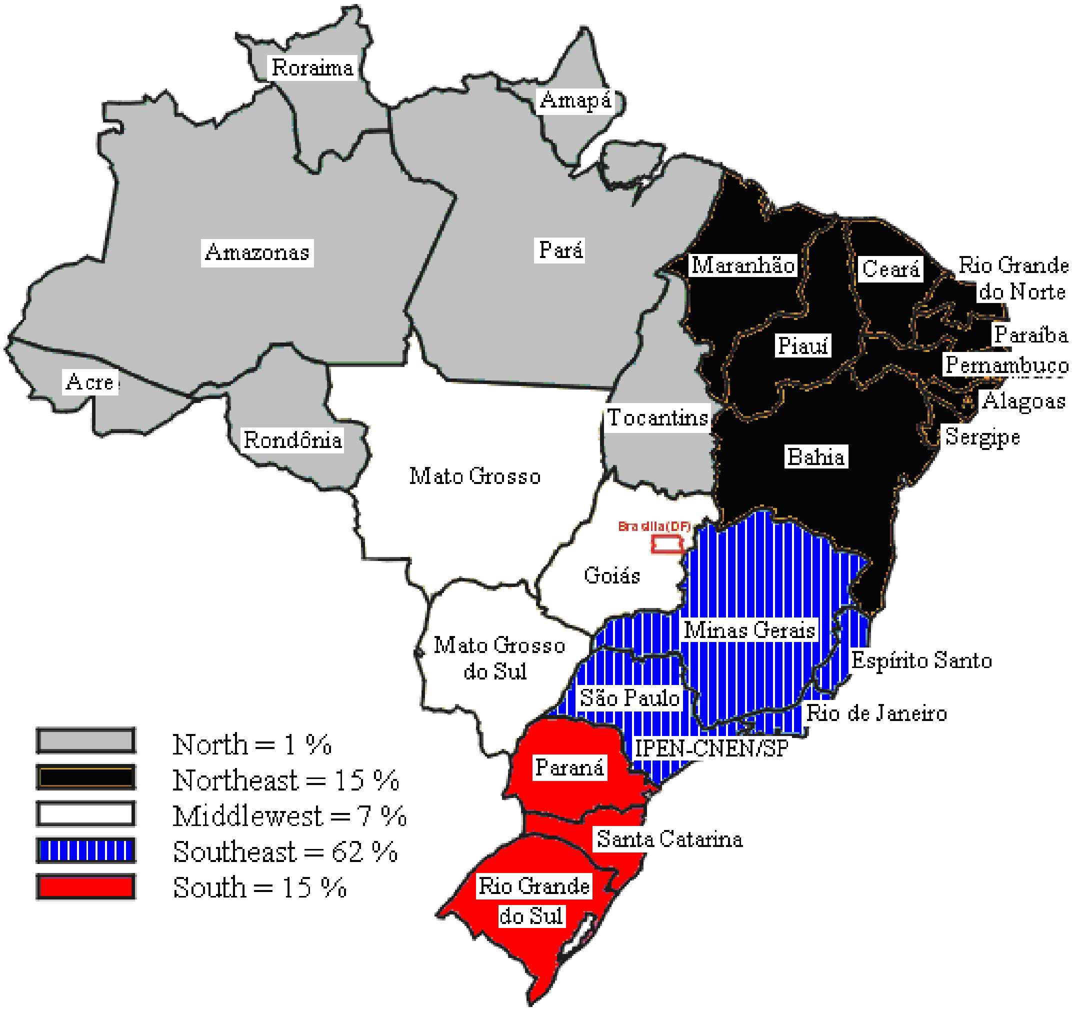


Figure 3. The ^{99m}Tc generators national distribution.

The monetary costs of services for the reuse of RPG and EDG are listed in Table 1.

Table 1. Monetary costs of services.

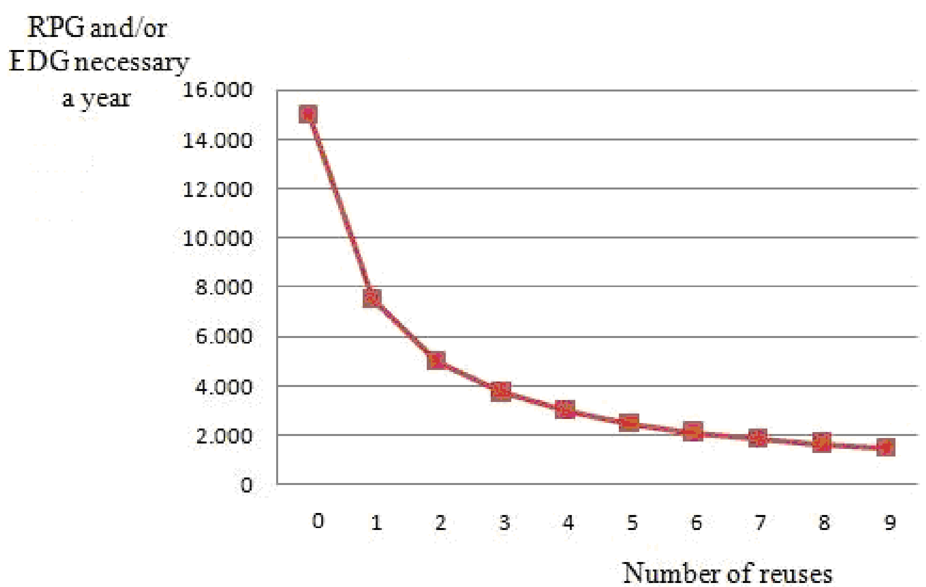
Services:	Approximate money cost (US$)	Who pays
EDG Manufacturing	100.00 / unit	Supplier
RPG Manufacturing	15.00 / unit	Supplier
EDG Integrity Tests	2,000.00 / lot (each new project)	Supplier
Transport for Supply and Return Packaging	25.00 a 700.00 (it depends on the distance / flight way)	End user
Preparation for Reuse of the EDG	450,000.00 / y (3.000 units / y)	Supplier
Preparation for Reuse of the RPG	100,000.00 / y (7.500 units / y)	Supplier

The decomposition time in the environment of the materials that compose the EDG and RPG are shown in Table 2.

Table 2. The decomposition time of the materials that compose the EDG and RPG.

Materials:	Decomposition Time
plastics	From 100 to 450 years
metals	From 100 to 500 years
rubber	More that 600 years
glass	About 1 million years

The Graph 2 illustrates the amount of RPG and / or EDG annual demand in relation to the number of reuses.



Graph 2. The amount of RPG and / or EDG annual demand in relation to the number of reuses.

The lead shielding that make the RPG and the EDG are reused on all productions, about 50 batches a year, although the plastic parts are reused in lower numbers. The plastic part of RPG has been used from 3 to 4 times a year and EDG, about 5 times a year. The amount made necessary for the provision of annual ^{99m}Tc generators decreases with the re-use of EDG and RPG.

Although there are a monetary cost of return a packages and a monetary cost to prepare the reuse of the EDG and the RPG in the DIRF, the sum of these costs is less than the cost of manufacturing the RPG and EDG.

4. CONCLUSIONS

The balance of money costs decide by the EDG and RPG reuse, but the environmental cost is minimized with this approach.

If the EDG and the RPG return in 36 days after delivery time and for 1 year complete reusable, the supply of about 15,000 units of generator per year (about 300 units per week), can be supplied with 1,500 units annually per itens.

It is suggested that a study of package for the reuse of package used in the of radioactive materials and, moreover, are studied biodegradable materials for its manufacture. The reuse is more efficient than the recyclable option and reduces the environmental cost.

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