

## **ALTERNATIVE OPTIMIZED SHIPPING SYSTEM IN THE OPERATIONS OF RADIOACTIVE MATERIALS PRODUCTION**

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### **ABSTRACT**

The optimization principle in radioprotection must indicate that exist a rational balance between the monitoring exposures resources used and the benefit waited for the monitoring program. The personal doses estimates displayed to the ionizing radiation caused by the shipping system operations of radioactive materials are an important tool in the process of radioprotection optimization. For the doses estimate they will be used models that consider the requirements established for the International Commission of Radiological Protection - ICRP and the Radiopharmaceutical Center monitoring program data. The methodology used for the election of the options of radiological protection that contribute for the reduction of the personal doses involves the criteria of decision aid techniques. The main intention of this work is to establish an alternative consistent procedure that assure. the reduction of the doses, when they will be necessary, is trustworthy, and simplest possible and that it presents indispensable quality established in the applicable standards.

### **1. INTRODUCTION**

With the development of the nuclear medicine, the radiopharmaceutical production in the Radiopharmaceutical Center of IPEN (CR) comes having a significant growth since the decade of 80, caused for the increase in the demand of radiopharmaceutical and radioisotopes for diagnosis and therapy in the country.

In this paper are discussed the logic, the figures of merit and the recommendations to develop an optimized shipping system that integrates adequate transportation, security concerns, logistical constraints, individuals radioactive material packages and corporate interests. The study to be improved intends to use individual doses referring to expedition group of radioactive material, the three techniques to reduce the doses and the increasing quantity of radioactive material. The potential complications include the effects of radioactive material volume per shipment, shipment departures spacing, time efficiencies and minimal costs.

For the optimized shipping system are same inlets, that is, the operators group involved, the accumulated doses, the resources used to reduce the doses and the amounts of dispatched materials.

## 2. INCREASE OF THE RADIOPHARMACEUTICAL PRODUCTION AND OPTIMIZED SHIPPING SYSTEM INLETS

The Radiopharmaceutical Center of the Institute of Energy and Nuclear Research is a radioactive installation that researches and produces radiopharmaceutical for diagnosis and therapy for 270 clinics and hospitals in Brazil [1]. In Table 1 we have the relation of the radiopharmaceuticals produced, the regularity with that is distributed and the maximum batch activity capability that the Radiopharmaceutical Center to produce currently:

**Table 1: Radiopharmaceuticals produced and forwarded in the CR.**

<b>Radiopharmaceuticals</b>	<b>Maximum Activity (GBq/Lote)</b>	<b>Regularity</b>
Sodium Iodide ( $^{131}\text{I}$ )	5000	weekly
$^{99}\text{Mo}/^{99\text{m}}\text{Tc}$ Generator	50000	weekly
Gallium Citrate ( $^{67}\text{Ga}$ )	150	weekly
Thallium Chloride ( $^{201}\text{Tl}$ )	800	weekly
Lipiodol - $^{131}\text{I}$	1500	occasional
MIBG - $^{131}\text{I}$	1500	weekly
Iodo-Hippurate - $^{131}\text{I}$	1500	biweekly
Human Serum Albumen - $^{131}\text{I}$	1500	monthly
Sodium Iodide ( $^{123}\text{I}$ )	18000	weekly
MIGB - $^{123}\text{I}$	18000	weekly
FDG - $^{18}\text{F}$	300	weekly
EDTM - $^{153}\text{Sm}$	30000	weekly
Hydroxyapatite - $^{153}\text{Sm}$	30000	biweekly
Sodium Chromate ( $^{51}\text{Cr}$ )	500	biweekly
Human Serum Albumen - $^{51}\text{Cr}$	500	monthly
EDTA - $^{51}\text{Cr}$	500	weekly
Phosphoric Acid ( $^{32}\text{P}$ )	60	biweekly
Sodium Phosphoric ( $^{32}\text{P}$ )	60	biweekly
Sodium Sulphate ( $^{35}\text{P}$ )	150	quarterly
Yttrium Citrate ( $^{90}\text{Y}$ )	12	-
Octeotrideo - $^{111}\text{In}$	60	biweekly

Source: Sector of Quality Control of the Radiopharmaceutical Center - IPEN

From the decade of eighty the production of radiopharmaceuticals in the IPEN had a significant growth, in the Table. 2 is showed the total amount of packages and radiopharmaceuticals activity produced in the period of 2000 up to 2006 and the percentage of this growth with relation to the year of 2000.

**Table 2. Package Number and radiopharmaceuticals activities**

Year	Number of Packages	Activity (TBq)	%
2000	27239	446.17	
2001	29654	499.68	11.99
2002	31925	525.23	17.72
2003	34390	565.04	26.64
2004	36265	608.19	36.31
2005	39649	666.19	49.31
2006	41977	716.36	60.56

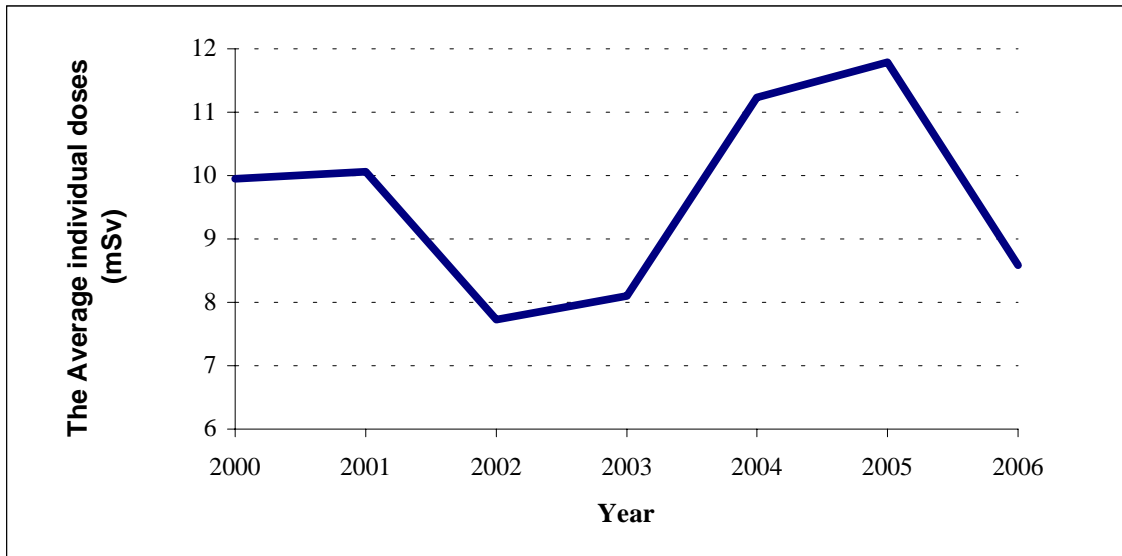
In 2000 the number of packages was of 27239 with a total activity of 446.17 TBq, this number of packages growth to 41977 units in 2006 with a total activity of 716.36 TBq. The growth of the production in this period was in average 10% per year, with a 60.56% greater production in year 2006 with relation to year 2000. In Table 3 we have the main radiopharmaceuticals and the activities with that, they had been produced.

**Table 3. Main produced radiopharmaceuticals in the CR.**

Radiopharmaceuticals	Activity (TBq)						
	2000	2001	2002	2003	2004	2005	2006
<sup>18</sup> F-FDG	0.26	0.48	0.86	3.07	5.61	8.57	10.21
Sodium Iodide ( <sup>131</sup> I) - capsules	2.22	2.88	4.85	6.82	7.72	10.72	14.89
Sodium Iodide ( <sup>131</sup> I) - solution	22.79	27.20	31.02	35.43	41.28	47.26	48.85
Gallium Citrate ( <sup>67</sup> Ga)	1.35	1.39	1.51	1.65	1.85	2.11	2.14
Thallium Chloride ( <sup>201</sup> Tl)	0.70	0.62	0.57	0.56	0.51	0.56	0.66
EDTMP- <sup>153</sup> Sm	1.41	1.22	1.42	1.24	1.22	1.02	0.76
<sup>99</sup> Mo/ <sup>99m</sup> Tc Generator	416.86	465.20	484.20	515.35	549.07	594.93	634.03

We can observe in the Table 3 that the generator of <sup>99m</sup>Tc detaches with the value of the activity varying of 416.86TBq in 2000 for 634.03TBq in 2006, being also the biggest production in number of packages with 10542 units in 2000 and 14034 units in 2006. The radiological protection followed this increase in the production taking had ones provides so that the doses received for the workers are the practicable in the minimis.

In Figure 1 shows the workers average individual doses of the CR expedition sector. Until the year of 2002 they are individual doses of 4 workers, of 2003 up to 2006 are of 5 workers. These 5 workers had been the same ones during the specified period, being that 1 of them started to be part of the group in the year of 2003.



**Figure 1: The Average individual doses.**

With average individual doses, varying between 8.10mSv and 11.79mSv in the CR expedition sector of radiopharmaceuticals it must be analyzed the possible options of protection to reducing the radiation dose received by the workers. In accordance with standard CNEN-NN-3.01 "Basic Standard of Radiological Protection" [2] the doses received for workers must be optimized by repetitive processes until reaching the region of national and internationally acceptable considered doses [3,4].

### **3. OPTIMIZATION OF THE DOSES**

In view of the increase of the production of radiopharmaceuticals and estimates of increase of the individual doses received by the workers in the CR expedition sector it is necessary studies the possible options of radiological protection that could be introduced in the sector to reducing the individual doses. The reduction of the individual doses can be obtained in three ways:

- a) Increasing in the distance between individual and the radiation source.
- b) Reducing the time of exposure of individual together to the source.
- c) Interposing barriers to absorber ionizing radiation between individual and the source.

To chosen one or more option of radiological protection is necessary to apply one or more aid decision techniques that can be: analysis cost-effectiveness, analysis distinguishing cost-benefit, analysis integral cost-benefit, expanded analysis cost-benefit, analysis of priorities with multiple attributes and analysis with exceeding criteria [5, 6, 7].

As per the alternative optimized shipping system requirements, it will be generated the following outputs:

- the time spent waiting at any shipment;
- the number of shipments on a monthly;
- the impact on the individual dose referring to expedition group.

## 4. CONCLUSIONS

We have an annual increase in the production of radiopharmaceuticals and an oscillation in the doses individuals of the workers who work directly in the expedition of the radiopharmaceuticals. From 1995 great improvements in the expedition sector of radiopharmaceuticals had been implemented, being perceivable they in the year of 2002 with a reduction in the individual doses of the workers of the sector. Of 2002 for 2003 these doses if they had kept stabilized. In the years of 2004 and 2005, with it I continue increase in the production and without the implementation of improvements in the sector, the individual doses had had a significant increase, what it compelled the new action to diminish these doses, that already can be seen in 2006. As the radiopharmaceutical production comes increasing year the year is necessary a accompaniment to promote improvements in the sector and training for the workers, so that the individual doses are the practicable minims.

## ACKNOWLEDGMENTS

The author greatly acknowledge the contributions from MSc. Demerval Leônidas Rodrigues and MSc Eduardo Gerulis to this work.

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