Estimation of the Radiation Effective Dose for Workers in ^{99m}Tc Generator Production

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Abstract. In the attempt of a quality life improvement, the use of the nuclear technology is increasing everywhere, fact observed in the increasing use of radioisotopes and radiopharmaceuticals in nuclear medicine diagnosis and therapy. In the radiopharmaceutical facility of "Instituto de Pesquisas Energéticas e Nucleares, IPEN," the productions have had an increase of about 10% per year since the decade of 80. Actually about 20 radiopharmaceuticals are produced and in 2007 approximately 43441 bulks had been distributed that totalized an activity of 723.16 TBq. The main radioisotope produced is the metastable technetium (^{99m}Tc) generated from the molybdenum (^{99}Mo) in a portable generating system. This radioisotope has contributed with 88.54% of the activity produced in 2007 and is important in the nuclear medicine diagnosis because the little gamma rays energy present a small dose to be detectable by external detector. The relatively short physical and effective half-life, become it easy to be transported and can obtained at relatively low price. The ^{99m}Tc generator is produced weekly. Initially the ^{99}Mo is received and inserted in processing cells, after that it is chemical processed, divided and placed in columns. After these the columns containing the ^{99}Mo are inserted in lead containers and these are placed in packages for delivery. The assembly procedures for ^{99m}Tc generator are the major source of radiation exposure to Radiopharmaceutical Facility personnel. This paper has the purpose to analyze the effective doses of workers in the phases of production of ^{99m}Tc generators. Will be presented the annual effective doses of workers involved with the facility. The obtained results provide valuable information about radiation protection.

KEYWORDS: radiological protection, effective dose, radiopharmaceuticals.

1. Introduction

In the second half of the last century a program stimulating to the pacific use of the ionizing radiation was created and with this the uses of radioisotopes and radiopharmaceuticals for diagnosis and therapy of patients [1]. These radioisotopes and radiopharmaceuticals gave excellent results increasing their use with the nuclear medicine development. The "Instituto de Pesquisas Energéticas e Nucleares, IPEN," produces approximately 20 types of radiopharmaceuticals in the Radiopharmacy Center, RC, and has increased the activity production in about 10% per year since the decade of 80, attending this demand. The activities of the radiopharmaceuticals produced in the RC between the years of 2000 and 2007 are presented in table 1.

Table 1: Activities of the radiopharmaceuticals produced in the RC between the years of 2000 and 2007.

Radiopharmaceuticals	**Activity (TBq)**							
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Sodium Pertechnetate	416.86	465,2	484.20	515.35	549.07	594.93	634.03	640.27
Others	29.31	34,48	41.03	49.70	59.12	71.26	78.62	82.88
Total	446.7	499.68	525.23	565.04	608.19	666.19	712.66	723.16

The main radiopharmaceutical produced is the Sodium pertechnetate, with radioisotopes ^{99m}Tc, generated from the decays of ^{99}Mo, known as ^{99m}Tc generator. This radiopharmaceutical is the main because is distributed weekly for the biggest number of customers and in bigger amount of packages in relation to the other radiopharmaceuticals. It is the production that arises more doses to the RC workers. In the year of 2008 the activity production was of 16.32 TBq. The objective of this paper is to estimate the radiation dose received by the involved workers in the ^{99m}Tc generators production.

2. ^{99}Mo/^{99m}Tc Generator Production in the RC

The ^{99m}Tc generator has a great application in the nuclear medicine, diagnostic, because of its characteristics. It has a relatively low price and a system of easy transport and handling. The ^{99m}Tc is a monoenergetic gamma emitter with 141 keV that in diagnostic becomes possible to obtain a good image. It has a half-life of about 6 hours, neither short, nor very long. It decays to ^{99}Tc that it has an half-life of $2x10^5$ years approximately, however the organism eliminates the radiopharmaceutical before ^{99m}Tc decays for ^{99}Tc and thus before to exposure the patient. The ^{99m}Tc it is obtained by elution process in a saline solution, in the following way: the ^{99}Mo is adsorbed in alumina inside a column that has a needle for exit, where is connected to a bottle in vacuum and another needle of entrance, where is connected to a bottle with 2 a barren saline solution [2]. The distribution of activities of the generators of ^{99m}Tc is carried out on the Fridays inside of cells of production, with calibration to use for the following Mondays, 8 o'clock in the morning. The column is inserted inside of a first shield, still inside of the production cell [3]. The shielded column, showed in Fig.1 (a), is placed inside of a container for the generator, CFG, showed in Fig.1 (b), in a mobile mat to be connected needles and covered/closed. To decrease the dose rate emitted for the CFG during the transport, this is inserted in a lead cylinder, obtaining the packages, showed in Fig.1 (c). The stages necessary to accomplish this set for transportation are described in table 2 and showed in Fig.2.

Figure 1: Generator of ^{99m}Tc conditioned in shielded column, RPG and transport packing,

(a) Shielded Column (b) CFG (c) Packing

Table 2: Stages description of the ^{99m}Tc generator production.

<table>
<tr><th colspan="2">Position</th><th colspan="2">Task</th><th colspan="2">Workers Number</th></tr>
<tr><td colspan="2">A</td><td colspan="2">Act of receiving of ^{99}Mo</td><td colspan="2">2</td></tr>
<tr><td colspan="2">B</td><td colspan="2">Insertion of ^{99}Mo in the cell</td><td colspan="2">1</td></tr>
<tr><td rowspan="3">C</td><td>C1</td><td rowspan="3">Handling of clamp of the cell</td><td>Product separation in activities groups</td><td>2</td><td rowspan="3">8</td></tr>
<tr><td>C2</td><td>Pipetting for distribution in columns</td><td>4</td></tr>
<tr><td>C3</td><td>Closing of columns</td><td>2</td></tr>
<tr><td colspan="2">D</td><td colspan="2">Withdrawal of shield with column of the cell SAS*</td><td colspan="2">4</td></tr>
<tr><td colspan="2">E</td><td colspan="2">Column wash</td><td colspan="2">1</td></tr>
<tr><td colspan="2">F</td><td colspan="2">Installation of CFG cover</td><td colspan="2">1</td></tr>
<tr><td colspan="2">G</td><td colspan="2">Connection of constraint and accomplishment of repair in RPG</td><td colspan="2">2</td></tr>
<tr><td colspan="2">H</td><td colspan="2">Elution column test</td><td colspan="2">1</td></tr>
<tr><td colspan="2">I</td><td colspan="2">Column drying</td><td colspan="2">1</td></tr>
<tr><td colspan="2">J</td><td colspan="2">Contamination transference test.
Supplying the SAS of the packing sector with the CFG.</td><td colspan="2">1</td></tr>
<tr><td colspan="2">L</td><td colspan="2">SAS generators withdrawal of the packing sector SAS and insertion of them in packages.</td><td colspan="2">1</td></tr>
<tr><td colspan="2">M</td><td colspan="2">Packages positioning</td><td colspan="2">1</td></tr>
<tr><td colspan="2">N</td><td colspan="2">Dose rate reading and record</td><td colspan="2">1</td></tr>
<tr><td colspan="2">O</td><td colspan="2">Placing the medications directions in package</td><td colspan="2">1</td></tr>
<tr><td colspan="2">P</td><td colspan="2">Packages closing and feeding of the mat</td><td colspan="2">1</td></tr>
<tr><td colspan="2">Q</td><td colspan="2">Packed withdrawal of the mat</td><td colspan="2">2</td></tr>
<tr><td colspan="2">R</td><td colspan="2">Handling of printed documentation</td><td colspan="2">2</td></tr>
<tr><td colspan="2">S/T</td><td colspan="2">Release to the transporter / Vehicles Monitoring</td><td colspan="2">1</td></tr>
<tr><td colspan="2"></td><td colspan="2">Total number of workers involved directly in the production</td><td colspan="2">32</td></tr>
</table>

(grey)	Tasks carried out in the Thursday afternoon, previous to the Fridays
(white)	Tasks carried out in the next day in the morning

*SAS = Servicement d'arrivée et sortie = arrive and leave service

Figure 2: Production of the ^{99m}Tc generator stages described in table 2.

(A) (B) (C)

(D)

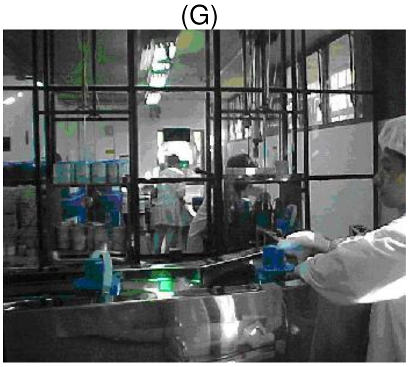
(E)

(F)

(G)

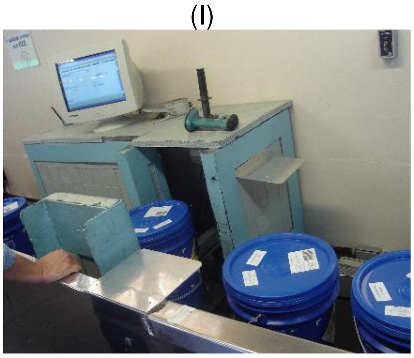
(H)

(I)

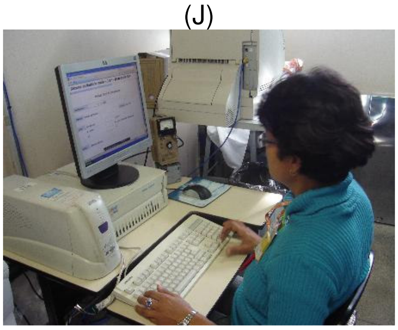


(J)

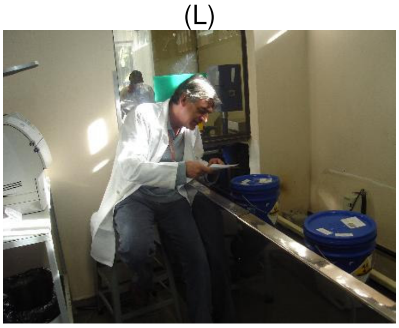
(L)



(M)



(N)



(O)

(P)

(Q)

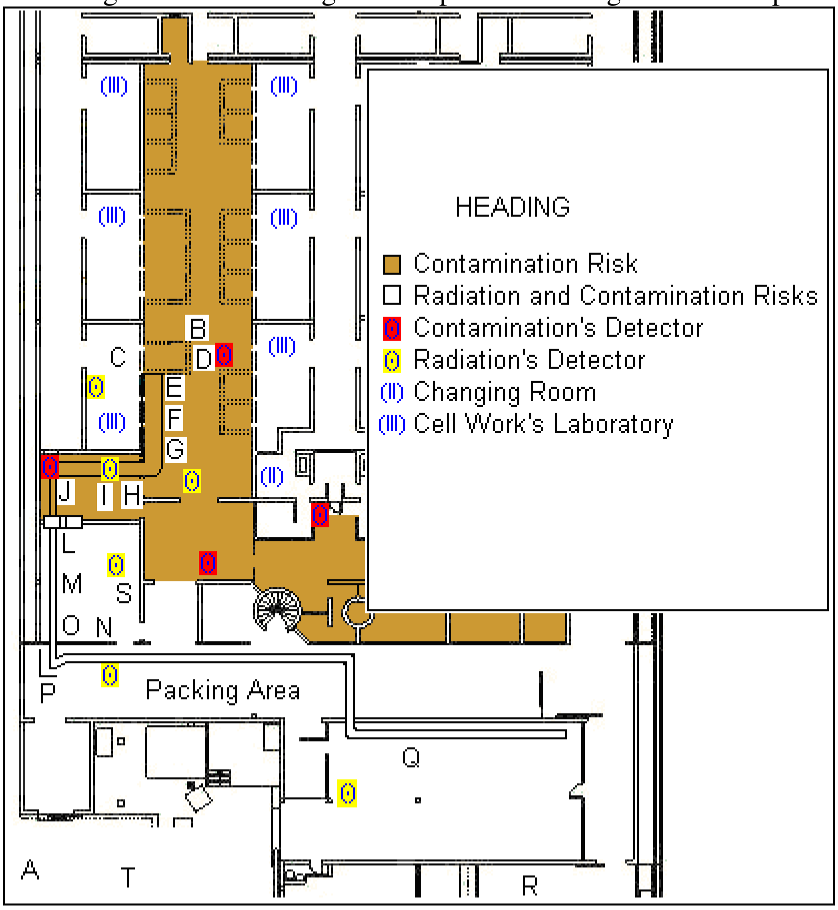
(R)

(T)

In the figure 2 the pictures illustrated the positions described in the table 2. The position S is the same than the N. In the position B the insertion of ^{99}Mo is fast. In the C2 position the pipetting takes a hallding time of the lesser clamp than in the closing of columns (C3), but with a greater concentration of ^{99}Mo. In position D the accumulation of ^{99}Mo in the mobile mat can have unilateral beginning. In positions E and G this accumulation can be bilateral. In position F the ^{99}Mo is suspended to be inserted in the CFG. In positions H, I and L also there is a possibility of CFG accumulation, being that is in position H, for more time. In the positions M / N, O and Q there is the possibility of the worker to move away while the packed is not in place, but with greater physical wear. In positions P, R and S do not have variations of scenes.

The Fig. 3 shows the CR building sector where the production of the ^{99m}Tc generator stages happens.

Figure 3: Sector building CR where ^{99m}Tc generator production stages are accomplished.



3. METHODOLOGY

3.1 Doses received during the production of the ^{99m}Tc generator

To estimate the radiation doses received by workers were examined the production of ^{99m} Tc generator stages, showed in Fig. 2, interviews were conducted with the workers involved and done a special monitoring for 6 weeks representative of the first half of 2008.

4. RESULTS

Dosimeters semiconductor instant-read have been distributed for each workers in each stages of the production and the average values of the doses recorded in dosimeters and corrected by their calibrations are presented in Table 3.

Table 3: Dose of radiation in the production ^{99m}Tc generator.

POSITION		THE AVERAGE DOSES RECORDED IN THE INDIVIDUAL DOSIMETERS (µSv)	THE AVERAGE DOSES TO CARRIED OUT THE TASK (µSv) Individual Average x Numbers of Workers	STANDARD DEVIATION OF THE AVERAGE / AVERAGE (individual dosimeter)
A		0	**0**	0
B		33.3 ± 20.0	33.3 ± 20.0	0.60
C	**C1**	40.24 ± 11.77	80.47 ± 23.53	0.29
	C2	17.76 ± 16.65	71.0 ± 66.6	0.94
	C3	22.2 ± 7.8	44.4 ± 15.5	0.35
D		197.95 ± 54.96	791.78 ± 219.82	0.28
E		382.95 ± 83.25	382.95 ± 83.25	0.22
F		547.56 ± 120.99	547.56 ± 120.99	0.22
G		411.70 ± 210.46	823.40 ± 420.91	0.51
H		551.34 ± 258.74	551.34 ± 258.74	0.47
I		352.98 ± 118.77	352.98 ± 118.77	0.34
J		308.02 ± 16.65	308.02 ± 16.65	0.05
L		532.8 ± 267.5	532.8 ± 267.5	0.50
M / N		16.65 ± 14.43	33.30 ± 28.86	0.87
O		57.35 ± 27.56	57.35 ± 27.56	0.48
P		61.05 ± 24.42	61.05 ± 24.42	0.40
Q		204.07 ± 52.56	408.15 ± 105.12	0.26
R		11.1 ± 0	22.2 ± 0	0
S / T		44 ± 22	44 ± 22	0.50
TOTAL			5146,10 ± 1832,26	32

The average Individual dose for production = (5146,10 ± 1832,26) / 32 = (160,81 ± 57,26) µSv.

Annual average individual dose = (160,81 ± 57,26) x 44 = (7,07 ± 2,52) mSv, since the workers have 6 weeks of vacation.

5. DISCUSSION

The results of the special monitoring show that the standard deviation of the average divided for the average in some positions is lesser than in others positions. In the positions where there is works in rotation, although the individual procedures from worker to be worker of course changeable, this result indicate that the tasks characteristics induce to the same result. However, in the positions where it there is not workers in rotation, the visual accompaniment this lesser value results of vices or individual virtues.

In the analysis of table 3 and Fig 2 we observe that: in the C1 position the ^{99}Mo separation results it in the biggest dose value position. In positions D, E, F and G, although so the variations of the doses are small, according to of the task characteristics induce to the same result, the doses are increasing with discrepancy in F. These results are in accordance with the description presented after Fig 2. In the positions E, H and I the radioactive solution is exposed in a manner to be visualized capable of being viewed within hoses and bottles.

The highest average levels recorded in the individual dosimeters are in positions F, H and L. By the visual accompaniments and the Fig 2 is observed that there is an accumulation of CFG in those positions, since these are placed in sequence or in groups still without the extra layer of shielding introduced in the final packaging, as showed in Fig 1 (c) Between points F, H and L, the standard deviation of the average divided by the average are higher in points H and L. The visual accompaniment showed that in these points, in accordance with ability the worker, there is the possibility to avoid the accumulation of CFG.

In position J, the control of transference of contamination carried out in the CFG, inside to the package, it is useful to indicate some procedure deviation production at the start. This control must be carried out by a gloves continual monitoring for the involved workers. The control of external contamination must be carried out in the package one for transport, as specified in the CNEN-NE 5.01 norm.

6. CONCLUSION

When we analyze the production process with the objective to lower the doses we can issues some positions: the efficiency in the accomplishment of the control of internal contamination, in duplicity in position J, because this control is carried out by the gloves monitoring for the workers. The RPG is handled with gloves later by customers, as hospital procedures. The insertion of the medications directions in the package, in the position O, may also have its efficiency issued, because such information could be placed previously in the packaging, before the CFG. In the package withdrawal from the wake, position Q, could be added stalls shielding.

We observe that the ability of the workers is an important factor to decrease the individual dose. It is necessary that the workers receive periodic training for awareness of that a good performance of its function can obtain a representative reduction of individual dose and the need to comply with the procedures of radioprotection what it according to the rules of permanence in areas containg radioactive material.

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