Evaluations of levels and trends of occupational exposure in a Brazilian Radiopharmaceutical Facility

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ABSTRACT

The study present levels and trends evaluations of exposure in the Brazilian Radiopharmaceutical Facility during 2000-2009 periods, with a view to combining external dose distributions across radioactive production and its handling. Temporal trends in exposure distributions to evaluate effects of changes in regulations (e.g. changes in dose limits or increased attention to optimizing protection), new technological developments and modified work practices were also considered. A statistics data analysis was performed using the individual monitoring records from the local radioprotection management and reports of the radiation protection supervisor. The measurably dose is based on the recording level, which is 2.4 mSv/year according to national regulations. The data analysis reported for 2000-2009 involved a total of 1,507 monitored workers. For each year was identified the total number of monitored worker, collective dose, annual average effective dose, average collective dose, percentage of workers with measurably dose and annual radioisotope production. The reported doses, in the period studied, suggest that the external exposure was the main source of occupational exposure in radioisotope production and distribution areas. The average effective doses over the years remained relatively constant for all monitored workers ranging from 2.83 to 4.16 mSv with a mean value of 3.44 mSv. The collective dose increased by a factor of 1.11 between the first and last year and the radioisotope production increased by a factor of 1.76 except for 2009. The average effective dose for the same period decreased to a factor 0.76 because de number of monitored workers increased. The percentage of workers with measurably dose was approximately 1/3 of the workforce being 17% of them received dose that require investigation. During this time period, the average doses received by the classified workers were very close to the national (2.4 mSv) and international (5.0 mSv) recording level.

Key Words: Dose distribution, low dose, occupational workers, collective dose, radioisotope production

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Introduction

The main source of occupational exposure in radioisotope production is external irradiation although internal exposure may be significant in some cases, and arrangements are then made for individual monitoring.

This study presents evaluations of levels and trends of exposure in a Brazilian Radiopharmaceutical Facility during 2000-2009 periods, with a view to combining external dose distributions across radioisotope production and its handling. Temporal trends in exposure distributions to evaluate effects of changes in regulations (e.g. changes in dose limits or increased attention to optimizing protection), new technological developments and modified work practices were also considered.

The workforce is composed by workers with permanent employment, fellow and others workers contracted for carry out some specific task. The main activities of these workers include the radioisotope production and it distribution, labelling, encapsulation, and packaging of all radiopharmaceutical material processed in the facility. Furthermore, there is a working group engaged with new radiopharmaceuticals development and quality control procedures.

An individual monitoring programme for external radiation exposure is intended to provide information for the optimization of protection, to demonstrate that the worker's exposure has not exceeded any dose limit. Furthermore, it is applied to verify the adequacy of workplace monitoring [1].

In most circumstances, doses due to external radiation can be readily assessed by the routine individual monitoring of workers. In this case, all workers of Radiopharmaceutical Facility use a passive dosimeter, type Thermoluminescent Dosimeter, TLD. This dosimeter generally is worn on the surface of the body for a month period, and at the end of this period it is read and the doses recorded.

In general, all workers have been internally monitored, but the frequency of measurements differs according to the task performed and the work station. The frequency is monthly in the radioisotope production for Occupationally Exposed Individual, OEI. For those workers that carry out task-correlated, the frequency is semester. An annual frequency is for administrative persons of facility, fellow and workers contracted for carry out some specific task.

The data is analyzed and trended over time to provide a measure of Radiopharmaceutical Facility performance in protecting its workers from radiation [2].

Methods

A statistics data analysis was performed using the individual monitoring records from the local radioprotection management and reports of the radiation protection supervisor.

A total of 1,507 registers (all monitored workers in the period) were evaluated and the dose distribution, within the radiopharmaceutical workforce, was shared in intervals.

In this study internal exposures have not been included in reported statistic, although the data from internal doses were evaluated.

The distribution of individual dose has following six different doses ranges (mSv), used to control the OEI, taking into account some flexibility, such as: 0-2.4; >2.4–5; >5–10; >10–15; >15–20; >20 mSv. The measurable dose was based on the recording level, which is 2.4 mSv/y and the investigation level was 6.0 mSv/y according to national regulations [1].

The intention of such monitoring is to provide data to support immediate decisions on the management of operations and optimization of protection.

Results and discussion

The individual dose records were analyzed in terms of trends over time, 2000-2009, are given in Table 1. For each year was identified the number of monitored worker according to the distribution in dose range, the total number of monitored workers, collective dose, annual average effective dose and percentage of workers with measurably dose.

Table 1. Trends in numbers of monitored workers, dose range to workers, collective dose, average annual effective dose, number of measurably exposed workers over ten-year periods.

Dose range (mSv)	***2000***	***2001***	***2002***	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***	**2009**
0 -2.4	87	99	117	100	73	81	88	102	133	127
>2.4 -5.0	15	22	22	46	12	12	26	29	24	39
>5.0 – 10.0	17	20	17	21	13	16	16	18	16	16
>10.0 – 15.0	7	6	3	4	11	4	12	5	4	8
>15.0 – 20.0	1	0	0	0	2	0	0	3	7	1
>20.0	3	1	0	0	0	0	0	1	0	0
Total number of monitored workers	130	148	159	171	111	113	142	158	184	191
Collective dose (person mSv)	540.93	553.73	449.44	519.9	442.13	411.16	490.81	542.06	586.12	600.21
Average effective dose (mSv)	4.16	3.74	2.83	3.04	3.98	3.43	3.46	3.43	3.19	3.14
Number of measurably exposed workers	43	49	42	71	38	32	54	56	51	64

For the period studied 100% of the Radiopharmaceutical Facility workforce was monitored for radiation exposure. In practice, according to national regulatory is adopted the recording level in individual monitoring for external radiation, i.e. recording all measured doses, which is very above the minimum detection level, MDL, for the TLD technique. Approximately 67% of workers received doses below the recording level (2.4 mSv) and the value recorded may be zero. The 33% remainder was considered measurably exposed and subject to the evaluation.

The number of individuals with measurable dose includes any individual with a reported dose greater than zero (individuals with a detectable dose). The analysis focuses mainly on doses received by individuals under investigation level.

According to the Table 1, the average effective doses over the years (2000-2009) remained relatively constant for all monitored workers ranging from 2.83 to 4.16 mSv, with a mean

value of 3.44 mSv. The average collective dose for the reported data was 513.65 person mSv, ranging from 411.16 to 600.21 (person mSv).

The distribution ratios indicated that while a majority of monitored workers get low doses, the percentage of workers with measurable dose was approximately 33% of the workforce, being 17% of them received dose that require investigation.

In 2005, the national regulatory adopted the new legislation to dose limits [1,3-5] changing the limit on effective dose of 50 mSv/year [6] to 20 mSv/y, averaged over five- years period (100 mSv in 5 years) [1]. In Table 1 it is also shown that only one worker in 2007 overpasses the relevant limit of 20 mSv per year. It was assumed to be due a fault in operational procedure.

The reported doses included those arising during the initial production radionuclides and its distribution, labelling, encapsulation and packing. According to the task-related monitoring, the increasing in the number of workers that receiving measurable dose was in the packing task group, attributed to increasing the handling of materials. For this group, about 12% of monitored workers, on average, exceed the investigation level. The average annual effective dose for this group varied from 7.99 mSv (minimum value in 2003) to 15.07 mSv (maximum value in 2008).

From the data set available, it was possible to correlate de collective dose received by workers during 2000 to 2009 with the total amount of radioactive material processed per year, illustrated in Figure 1.

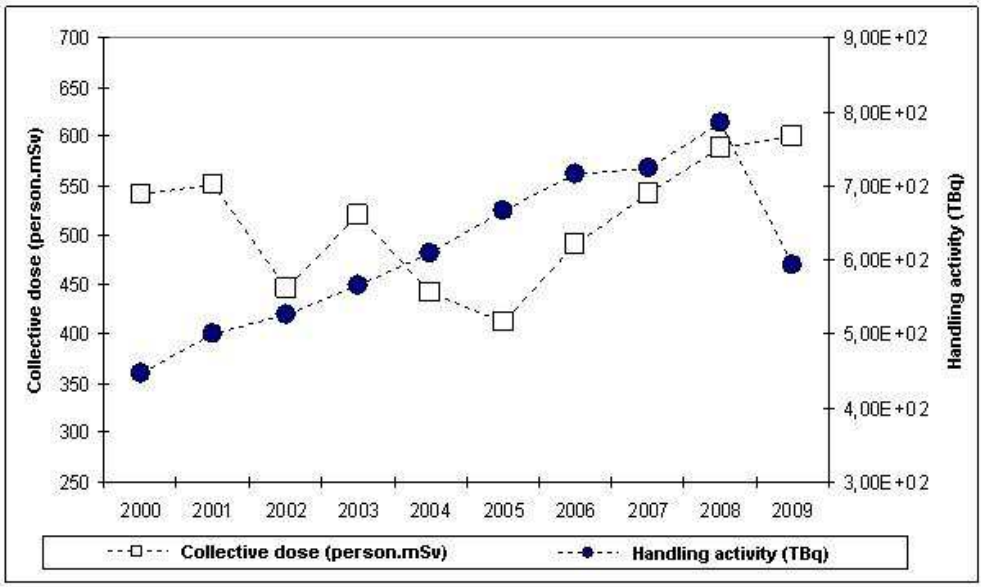

Figure 1. Evolution of collective effective dose to workers and radioisotope production, over last ten years.

The Figure1 summarizes the collective dose of radiopharmaceutical facility workforce associated with activities (TBq) from radioisotope production. Except in 2009, there was a growth of 10% in the production per year. The decrease in this year was due the international crisis in the supply of the radioisotope Mo-99.

As showed in Figure 1, the collective dose has continued increasing from 20005 to 2009, indicating the reversal of this trend. The increasing in collective dose was mainly due handling of materials for shipping off site, maintenance of equipment and tools, and removal of significant amounts of radioactive waste.

The collective dose increased by a factor of 1.11 between the first and last year and the radioisotope production increased by a factor of 1.76 except for 2009. The average effective dose for the same period decreased to a factor 0.76 because of number of monitored workers increased (Table 1).

Despite this fall in production it was observed over the reported data for 2000-2009 a significant contribution from ^{99m}Tc generator activity production, about 87% of total activity handling, and the remainder (13%) for others primary radioisotopes, as shown in Table 2.

Table 2. Radioisotope productions over 2000-2009 periods

RADIOISOTOPES	**TOTAL ACTIVITY (2000-2009) (TBq)**
^{99}Mo/^{99m}Tc Generator	5.49E+03
Others primary radioisotope (^{131}I, ^{123}I, ^{51}Cr, ^{32}P, ^{67}Ga, ^{201}Tl, ^{153}Sm, ^{18}F, ^{111}In, ^{177}Lu, ^{90}Y and ^{35}S)	6.38E+02
Total	6.13E+03

The Figure 2 presents the evolution about the handling activities over the time period.

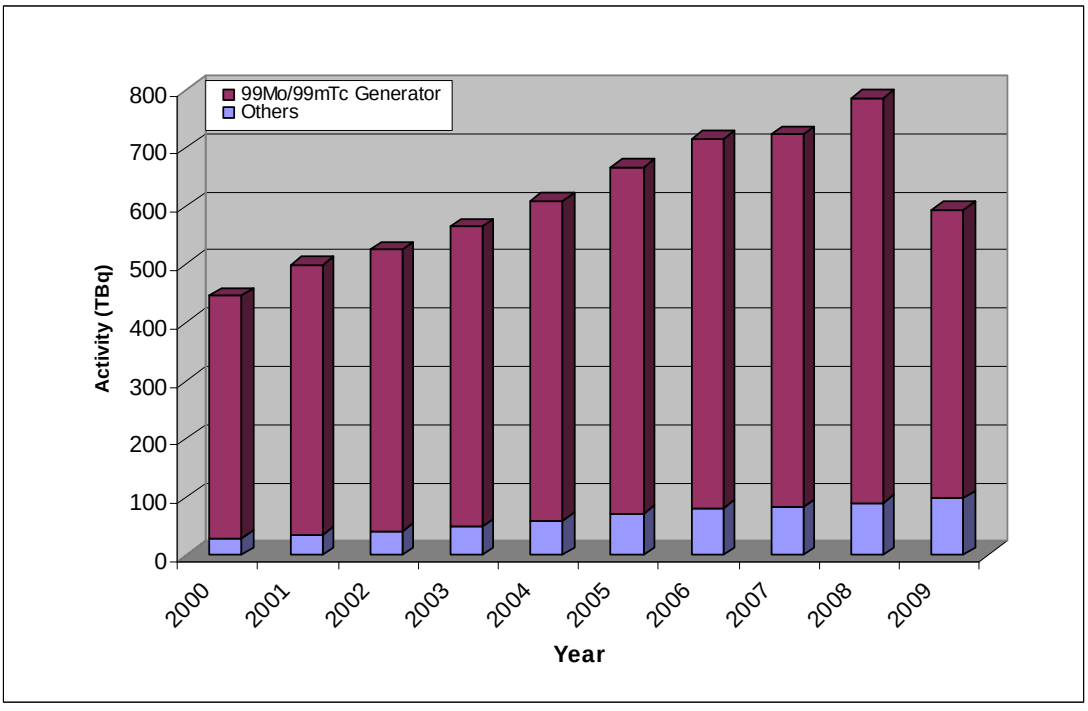

Figure 2. Evolution in the handling activities over the time period.

Conclusions

The reported doses, in the period studied, suggest that the main source of occupational exposure in radioisotope production and distribution areas was the external irradiation. The internal exposure was not included in reported statistics, because it was negligible. The calculation and application of collective dose, particularly with regard to its use to estimate health impact is a tool for the protection optimization. During this time period, the focus on ALARA practices was increased, and then the safety has been improved and the exposure risk was reduced**.**

From the trends observed during the 2000-2009 period, the average effective doses received by workers were very close to the national (2.4 mSv) and international (5.0 mSv) recording level. The levels of individual dose remained satisfactory and are compliance with regulatory requirements.

Great improvements in the expedition sector (packing task group) of radiopharmaceuticals had been implemented, with goal to reduce the individual dose and to ensure acceptably safe and satisfactory radiological conditions in the workplace.

The training of workers in safety principles and good practice in handling radioactive materials should be continuously reinforced, independent of the amount of activity handled.

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