Occupational exposure to ionizing radiation associated with the production of radioisotopes

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Abstract. The main objective was to evaluate the dose distribution of workers in a Brazilian Radioisotope Production during 2000 to 2010. The trends of collective doses from practices were estimated considering the number of individuals monitored and the amount of radioactive material processed, per year. Statistical data analysis was performed using records of individual dose and reports of radiological protection supervisor. The data analysis over 11-year period involved a total of 1,723 workers monitored. The average effective doses over the years (2000-2010) ranged from 2.58 to 4.16 mSv with a mean value of 3.36 mSv. The collective dose has remained relatively constant between the first and last year, but the production of radioisotopes has increased by a factor of 1.76, except for the last two years. The percentage of workers with measurable dose was approximately one third of the workforce, being 16% of them received dose which requires investigation.

1 Introduction

This study presents evaluations of levels and trends of exposure in a Brazilian Radiopharmaceutical Facility during 2000-2010 period, with a view to combining external dose distributions with 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

workerôs 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].

2 Methodology

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 1,723 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; >2.4ï 5; >5ï 10; >10ï 15; >15ï 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.

3. Results and discussion

For the period studied (2000-2010), 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.

The individual dose records were analyzed in terms of trends over time, 2000-2010, are given in Table 1. For each year was identified the number of monitored worker according to the distribution in dose range and the total number of monitored workers per year.

Table 1. Trends in numbers of total number of monitored workers according to the distribution in dose ranging over the period 2000-2010

Dose ranging mSv	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
0 < EÒ2.4	87	99	117	99	73	81	88	102	133	127	159
2.4 <E Ò5.0	15	22	22	47	12	12	26	29	24	39	30
5.0 <E Ò10.0	17	20	17	21	13	16	16	18	16	16	16
10.0<E Ò15.0	7	6	3	4	11	9	12	5	4	8	2
15.0<EÒ20.0	1	0	0	0	2	2	0	3	7	1	2
E>20.0	3	1	0	0	0	0	0	1	0	0	0
Workers	130	148	159	171	111	120	142	158	184	191	209

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.

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-year period (100 mSv in 5 years) [1]. In Table 1 it is also shown that five workers (less than 1% of workforce) exceeding the dose limit of 20 mSv/y in the period of interest. It was assumed to be due a fault in operational procedure.

Trends in exposures over 11-year period for monitored workers and measurably exposed workers, respectively, are presented in Table 2. The average effective doses for the 2000-2010 period, remained relatively constant for all monitored workers ranging from 2.58 mSv to 4.16 mSv, with a mean value of 3.36 mSv. The average collective dose for the reported data was 516.48 person mSv ranging from 411.16 person mSv to 598.21 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 16% of them received dose that require investigation.

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, exceeded the investigation level. The average annual effective dose for this group varied from 7.99 mSv to 15.07 mSv.

Table 2. Trends in exposures over 11-year period for total monitored workers and measurably exposed workers, respectively: average annual ($\overline{E}$) and collective effective doses (S)

Year	S (person mSv) Total monitored workers	OEI Number	$\overline{E}$ (mSv)	S (person mSv) Measurably exposed workers	OEI Number	$\overline{E}$ (mSv)
2000	540.9	130	4.16	374.7	43	8.71
2001	558.7	148	3.78	316.1	49	6.45
2002	449.4	159	2.83	229.4	42	5.46
2003	522.5	171	3.06	329.4	72	4.57
2004	442.1	111	3.98	302.4	38	7.96
2005	411.2	120	3.43	292.6	39	7.50
2006	490.8	142	3.46	341.4	54	6.32
2007	542.3	158	3.43	358.7	56	6.41
2008	586.1	184	3.19	371.5	51	7.28
2009	598.2	191	3.13	355.8	64	5.56
2010	539.0	209	2.58	286.0	50	5.72

OEI ï Occupationally Exposed Individual

In Table 2 it can be seen that the average effective dose decreased by a factor of about 1.6 between the first and last year because of number of monitored workers increased.

From the data set available, it was possible to correlate de collective dose received by workers during 2000 to 2010 with the total amount of radioactive material processed per year, illustrated in Fig. 1.

The Fig.1 summarizes the collective dose of radiopharmaceutical facility workforce associated with activities (GBq) from radioisotope production. Except in 2009, there was a growth of 8% in the production per year. The decrease in this year was due the international crisis in the supply of the radioisotope Mo-99.

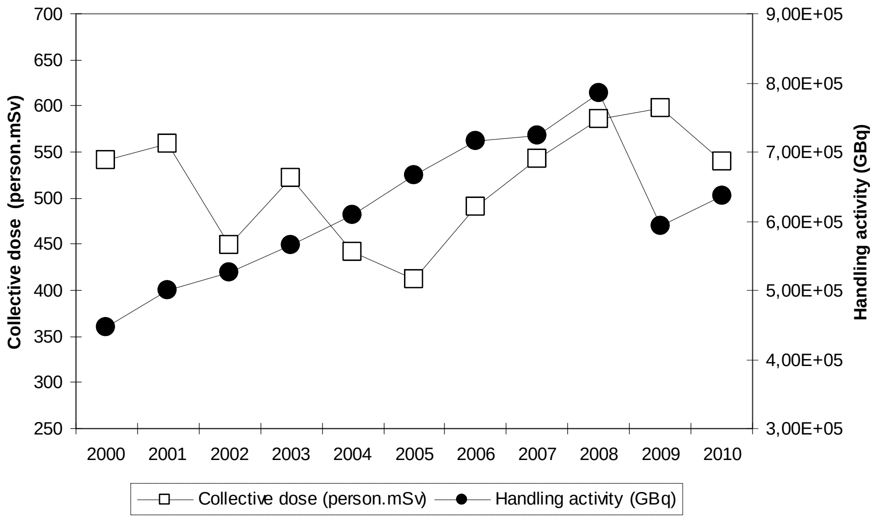

Fig.1. Evolution of collective effective dose to workers and radioisotope production over 11-year period

As showed in Fig. 1. the collective dose has continued increasing from 2005 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 has remained relatively constant between the first and last year, but the production of radioisotopes has increased by a factor of 1.42.

Despite this fall in production it was observed over the reported data for 2000-2010 a significant contribution from ^{99m}Tc generator activity production, about 89% of total activity handling and the remainder (11%) for others primary radioisotopes, as shown in Table 3.

Table 3. Radioisotope productions over 2000-2010 period

Radioisotope	**Total Activity (TBq)**
^{99}Mo/^{99m}Tc Generator	6.03E+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)	7.38E+02
Total	**6.77E+03**

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

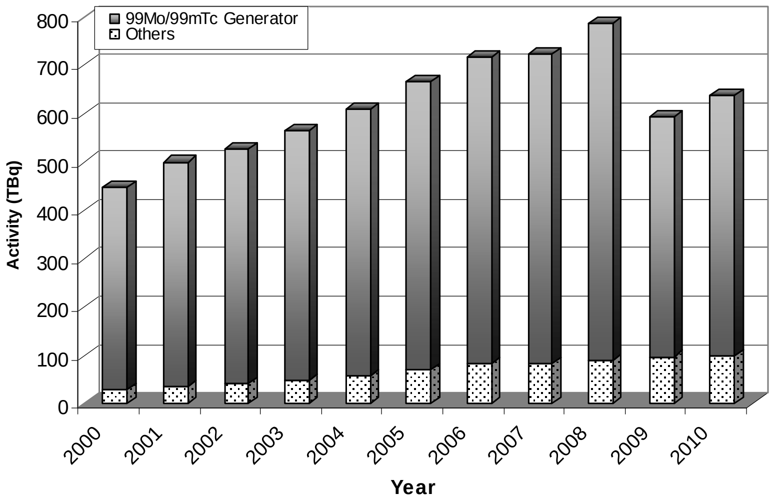

Fig. 2. Evolution in the handling activities over the time period

3. 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 2000-2010 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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