Radiation dose impact on the workers from the radiopharmaceutical facility

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Abstract. Some important indicators useful in the evaluation of radiation occupational exposure were determined for the doses of workers in a Brazilian radiopharmaceutical facility during the last three years. These indicators were analysed to identify and to correlate the main parameters that had an impact on the workers radiation. The data analysis took into account the number of monitored workers, the distribution of dose, the annual effective doses (above recording levels), and the collective effective dose, the radiation monitoring at the workplace and at environment. The conclusions from this paper were used to optimize the radioprotection procedures at this installation. The doses results obtained from monitoring practice, over the last three years, are discussed and they are in agreement with the limits recommended by national and international regulatory authorities**.**

1. Introduction

Occupational exposure is the irradiation of workers during their work, regardless of the exposure situation. For the purpose of establishing practical requirements for protection and safety of workers, two different types of exposure situation cover the situations of occupational exposure: planned exposure situations and emergencies exposure situations [1]. The dose limits are applied only in situations of planned exposure (normal exposure or potential exposure). In such situations, the exposure of individuals shall be restricted neither the total effective dose nor the equivalent dose to relevant organs or tissues, due to the possible combination of exposures from authorized practices that exceeds any established dose limits.

A radiological assessment should identify all aspects presented by the facility operation related to the sources from normal exposures and potential exposures, which result from the surface contamination, air contamination and sources of external and internal radiations.
The nature and magnitude of exposure, and its probability of occurrence, may be associated with any combined or isolated events of system, structure, component, radiological protection and safety procedures such as human failures. In the occurrence of any failure, improvements shall be implemented. A radiological control program in any facility contains several indicators that may be used to control the workplace and to reduce the radiation exposure. The purpose of the monitoring of radiation levels is to characterize the workplace conditions, area classification, to give support to activities involving radiation exposure and to provide information about the external radiation sources. These monitoring procedures are also performed to identify areas that require additional shielding or application of other techniques for dose reduction.

The objective of this work is to present the main indicators that had impact on the radiation dose of workers in a Brazilian radiopharmaceutical facility in Brazil, during the years 2011 to 2013. A radiological programme has been well established in compliance with the national regulatory authorities [2]. This programme includes the workplace monitoring and individual monitoring, which has contributed to control of occupational exposure. In general, the monitored workers are involved in radioisotope production, labelling, encapsulation, packaging and distribution of about 95% of the radiopharmaceutical material in Brazil. Furthermore, the monitoring programme includes also a working group engaged with new radiopharmaceuticals development and quality control procedures [3].

2. Methodology

2.1. Radiation level monitoring

The workplace monitoring included both measures of general areas as those where there is contact with radiation sources. The external irradiation was detected with thermoluminescent dosimeters, placed at different points that may indicate exposures or detect abnormal situations. The monitoring of surface contamination was made using indirect methods by smearing test and counting with a high purity germanium semiconductor detector.

2.2. The environmental monitoring

The monitoring of the airborne radioactivity allowed the detection and the quantification of the concentrations of radioactive material in the air. The purpose is to limit and prevent internal exposure, as well as to provide an indication of the effectiveness of appropriate engineering controls and work practices to prevent the spread of contamination, and to support the choice of appropriate personal protective equipment. Routine monitoring at different points was undertaken, mainly in the cells for the production of ^{131}I and ^{99m}Tc- generator.

2.3. Occupational doses

For occupational exposure, the dose limits were taken into account in compliance with national standards [2]:

(a) An effective dose of 20 mSv per year averaged over five consecutive years (100 mSv in 5 years), and 50 mSv in any single year;
(b) An equivalent dose to the lens of the eye of 20 mSv per year;
(c) An equivalent dose to the extremities (hands and feet) or the skin of 500 mSv in a year.

The concepts of dose constraints and reference level are used in conjunction with the optimization of protection to restrict individual doses. A level of individual dose, either as a dose constraints or a reference level, always needs to be defined [1,4].

2.4. Dose constraints

In the optimization protection process, the ICRP 75 [5] recommends the establishment of the dose constraints to reflect the maximum level of individual exposure that is achievable in a well-designed and managed workplace. In order to ensure an adequate level of protection for workers, the value of 10 mSv/year was adopted as dose constraints to the effective dose in relation to any source or to practices developed in the radiopharmaceutical facility.

2.5. Reference levels

The recording level value is 0.20 mSv per month, according to national regulatory authorities. The doses equal to or greater than this value have to be recorded. For occupational exposure the investigation levels established according to national standards are:

(a) An effective dose of 6 mSv/year or 1 mSv in any month
(b) An equivalent dose to the lens of the eye of 20 mSv/year
(c) An equivalent dose to the extremities (hands and feet) or the skin of 150 mSv in a year or 20 mSv in any month.

3. Results and discussion

The main indicators describing the radiation dose distribution of workers at the radiopharmaceutical facility for 2011-2013 are presented. Radionuclides detected by air monitoring in the workplace during the radioisotope production were ^{131}I, ^{99m}Tc and ^{99}Mo. Measured emission concentrations (Bq/m^3) were below the maximum permissible values, as set out in the national standard [2].

3.1 Occupational doses assessment

Table I presents the number of monitored workers in function of the dose range in the radiopharmaceutical facility over the years.

Table I. Number of monitored workers per year according to the dose range

Dose range(mSv)	2011	2012	2013
0< E ≤2.4	148	177	151
2.4< E ≤5.0	30	22	45
5.0< E ≤10.0	17	15	16
10.0< E 15.0	09	04	07
15.0< E ≤ 20.0	01	01	01
20.0< E ≤ 25.0	00	00	01

The main indicators useful in the assessment of occupational exposure at radiopharmaceutical facility for 2011-2013 periods are shown in Table II.

Table II. Main indicators used in the evaluation of radiation dose for workers

Main indicators	Monitoring period (year)		
	2011	2012	2013
Total number of monitored workers	205	219	221
Collective dose, S(person.mSv)	602.99	469.91	636.67
Average annual effective dose, E(mSv)	2.93±2.67	2.14±2.43	2.88±2.76
Measurable collective dose, S(person.mSv)	342.17	253.29	379.97
Number of measurably exposed workers	57	42	70
Average measurable effective dose, E(mSv)	6.00±3.34	6.03±3.30	5.43±3.66

In summary, according to Table II the following characteristics of dose were considered useful for assessment of occupational workers:

3.1.1. The total number of monitored workers

The number represents the whole workforce of the radiopharmaceutical facility, regardless of the task performed. This data is an indication of the monitoring programme dimension. Nevertheless it is not necessarily an indicator of the measurably exposed workers. This fact is due to a conservative practice at radiopharmaceutical facility, because the management does not expect that workers exceed the dose standards established. Several workers are monitored for reasons of safety in compliance with the radiological programme established for this facility and in accordance with the national standards.

3.1.2. Measurable dose

The number of workers that received measurable doses (Table II) represents the exposed population to radiation. The number of workers with measurable doses included any individual with a reported dose equal to or greater than the value 2.4 mSv/year, the recording level.

3.1.3. External radiation dose

The external radiation was considered the main source exposure of workers at radiopharmaceutical facility. The contribution of this component to the total dose to monitored workers was almost 100 %, with average annual values of 2.92 mSv, 2.13 mSv, and 2.88 mSv in 2011, 2012 and 2013 respectively. The individual monitoring was performed with personal thermoluminescent dosimeters, TLDs, worn on the surface of the body. To evaluate the doses to hands, wrist dosimeters (TLDs) were used. However, no workers received more than three-tenths of the dose limit in the studied period.

3.1.4. Committed effective dose

The internal contamination dose was estimated from measurements performed by area monitoring and *in vivo* measurements using a whole-body counter and thyroid monitoring. The data reported show that in the year 2011, four workers received committed effective dose 0.26 mSv, 0.39 mSv, 0.83 mSv and 1.77 mSv. In 2012, two workers received doses of 0.55 mSv and 0.64 mSv. In 2013 two workers received doses of 0.24 mSv and 0.35 mSv. However, this internal component was not significant when compared with those doses from external irradiation.

3.1.5. Annual effective dose

The highest annual effective doses were received by three different workers (Table 1) 15.02 mSv**,** 19.80 mSv and 21.12 mSv in the years 2011, 2012, and 2013 respectively. The last dose value is above the arithmetic mean value recommended by the national regulatory authority for a year's work, but the values of average effective dose are relatively constant, as given in Table II.

4. Conclusions

According to the results obtained about the occupational exposure at the radiopharmaceutical facility of IPEN during 2011-2013, the dose recorded indicated that the percentage of measurably exposed workers was about 30% of the total number of monitored workers, and their contribution to the collective dose was about 60%. However, no workers exceeded 50 mSv, maximum value for a worker in a single year.

Considerable care should be taken to ensure that the filter systems are appropriate and to check the lifetime of the cells and filters, because the doses increase with the time (over the years).

The optimization included operational measures such as modernization of the production lines, modernization of hot cells and improvement in the packaging system. The continuous training of workers in safety principles and good practices should be reinforced, independent of the amount of handled activity.

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