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ANALYSIS OF THE *IN VIVO* MONITORING PROGRAM AT IPEN IN THE LAST 14 YEARS

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ABSTRACT

This paper presents the results of the *in vivo* monitoring analysis for Occupationally Exposed Individuals that handle unsealed sources at Nuclear and Energy Research Institute (IPEN). The facilities are: the Radiopharmacy Center, the Cyclotron, the IEA-R1 Reactor and Research Laboratories. The *in vivo* monitoring program is carried out in a whole-body counter for radionuclides emitting gamma rays with energy above 100 keV. This system is equipped with 8x4 and 3x3 inch NaI(Tl) detector, for whole body and thyroid measurements, respectively. The objective of this work is to analyze the results of the internal monitoring program according to the dose received by the Occupationally Exposed Individuals from 2005 to 2018. During this period about 6,000 measurements were accomplished. The radionuclides that presented measured values above the detection limit of the system were: ^{131}I, ^{99}Mo, ^{99m}Tc, ^{153}Sm, ^{177}Lu, ^{111}In, ^{192}Ir, ^{125}I, ^{123}I, ^{181}Hf, ^{203}Hg, ^{67}Ga, ^{18}F, ^{51}Cr, ^{201}Tl. These measurements have amounted less than 6.9% of the total whole-body monitoring's performed in this period. Among these radionuclides, ^{131}I, ^{99m}Tc, ^{125}I and ^{18}F have contributed with 69% of all measurements above the limit of detection, but most dose results were below the recording level under installations normal operating conditions. Regarding to the radionuclides that have presented doses above the recording level we can mention the ^{131}I, ^{67}Ga, ^{111}In that occurred in small unexpected situations. The results shown by this analysis give a good support to the internal individual monitoring program implemented by the radioprotection service in these facilities.

1. INTRODUCTION

The assessment of exposure due to intake of radionuclide in the workplace is an integral part of the occupational radiation protection program at Nuclear and Energy Research Institute (IPEN). In practice, this program is carried out by the radioprotection staff of the installations with the participation of the internal dosimetry group and the facility management.
Usually, the internal dosimetry group has limited contact with workers and the communications of any individual monitoring results are made through the radioprotection staff of the facility. Monitoring results are also used by local radiation protection personnel to advise the facility management when intervention on the worker is necessary, such as follow-up sampling or work restriction. Consequently, close cooperation is needed among the groups involved in the occupational protection program.

The monitoring and assessment of internal occupational exposure starts with the identification of situations where there is a contamination risk of workers. The main step is to quantify the likely intake of radioactive material and the resulting committed effective dose. This paper summarizes the analysis of the internal monitoring data recorded, according to the dose received by the occupationally exposed individuals, by the end of 2015 to 2018 at IPEN.

2. METHODOLOGY

Dose records includes all dose received by the individuals along the occupationally exposed period. It is an essential part in the process of monitoring the exposures of individuals, to both external radiation and intakes of radionuclides, demonstrating compliance with dose limits and constraints. It can also provide important information to control exposures.

The main installations at IPEN that require an internal monitoring program for occupationally exposed individual are the Radiopharmacy Center, the Cyclotron facility, the IEA-R1 Reactor, Waste Management facility and Research Laboratories.

In all these installations an operational radiation protection staff is in charge to establish a routine, task related or a special monitoring of the workers [1]. For each installation, the type of radionuclide, its physical and chemical form is clearly identified and the method of individual internal monitoring could be established. All these data are recorded in a database during each step of a monitoring program.

The analysis of the monitoring data will be performed considering the detection limits of the measurement method, the committed effective dose and the reference levels as the recording level and the investigation level.

2.1 Monitoring Data

The *in vivo* monitoring program at IPEN is carried out in a whole-body counter to measure radionuclides emitting gamma rays with energy above 100 keV. This system is equipped with 8x4 and 3x3 inch NaI (Tl) detector for whole body and thyroid measurements, respectively.

2.2. Individual Dose Assessment

The individual dose assessment is made by an independent program called “Activity and Internal Dose Estimation” – AIDE [2]. This program is used to reproduce the original predicted value of the measured quantities following single intake and the dose coefficients from ICRP [3].

2.2 Reference Levels

In general, the assignment of an internal exposure monitoring program to an individual should be based on the likelihood that the individual could receive an intake of radioactive material exceeding a predetermined level as a result of normal operations or in the event of an accident.

According to the National Commission on Nuclear Energy, CNEN [4], these reference levels include recording level, above which a result should be recorded and lower values being ignored; and also, the investigation level above which the cause or the implication of the result should be examined. Presently, the recording level for Occupational Exposed Individual is defined as 0.10 mSv per month for effective dose. Therefore, any dose equal or greater than 0.10 mSv per month should be recorded. The investigation level for occupational individual monitoring is defined as 6 mSv per year or 1 mSv in any month, for effective dose. The

investigation level for the skin and extremity is 150 mSv per year or 20 mSv in any month. In the case of exposition of lens of eyes these levels are 6 mSv per year or 1 mSv in any month. When the monitoring interval is different from the monthly frequency, it must be submitted to CNEN for approval.

The reference levels defined by the Brazilian regulatory body along these 14 years have been changed, following the evolution of the radiation protection procedures (Table 1). This work will make the data analysis according to the CNEN reference levels in force at each period.

Table 1: Evolution of Recording Level and Investigation Level according to CNEN.

Reference Level	CNEN NE-3.01(1988)	CNEN NE-3.01(2005)	CNEN NN-3.01(2011)	CNEN NN-3.01(2014)
Recording Level	0.42 mSv/month	0.20 mSv/month	0.20 mSv/month	0.10 mSv/month
Investigation Level	1.25 mSv/ year	6 mSv/ year 1 mSv/month *50 mSv/y *20 mSv/m	6 mSv/ year 1 mSv/month *6 mSv/y *1 mSv/m	6 mSv/ year 1 mSv/month *6 mSv/y *1 mSv/m

Note: * Lens of Eyes

3. RESULTS

By the end of 2005 to 2018 about 6,000 measurements were accomplished at *In Vivo* Monitoring Laboratory (LMIV). The Fig. 1 presents the whole-body monitoring data with the radionuclides measured along the years.

3.1 Recording Level and Investigation Level

The radionuclides with measured values above the detection limit of the system were ^{131}I, ^{125}I, ^{123}I, ^{99}Mo, ^{99m}Tc, ^{153}Sm, ^{177}Lu, ^{111}In, ^{192}Ir, ^{181}Hf, ^{203}Hg, ^{67}Ga, ^{18}F, ^{51}Cr, ^{201}Tl. These measurements have amounted 6.9% of monitoring's performed in this period (Fig. 2).

Considering only the measurements above the detection limit of the system, 14.3% are greater than 0.20 mSv/month (Fig. 3).

The radionuclides with effective dose above the recording level of 0.20 mSv/month are the ^{131}I, ^{125}I and ^{99m}Tc and they have contributed with 69%. These contributions come from activities performed at Radiopharmacy Center and the Cyclotron Facility. Others radionuclides that have presented doses above the recording level are the ^{67}Ga, ^{111}In, ^{153}Sm, and ^{203}Hg, and the exposure occurred only in one occasion each, under abnormal situations.

The Fig. 4 show the number of workers from Radiopharmaceutical Center being monitored along the years. These workers perform activities in the following tasks: production, quality assurance, quality control, maintenance and radiation protection. The number of monitored workers has decreased since 2009 as a consequence of improvement in the installation, and optimization program carried out.

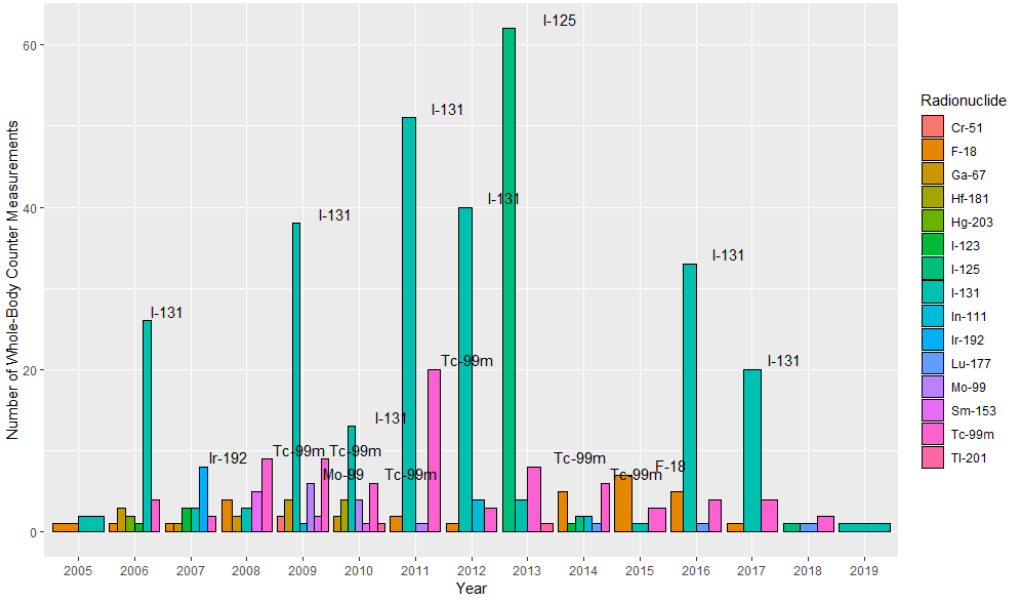

Figure 1: Monitoring data showing the frequency of occurrences of radionuclides measured along the years.

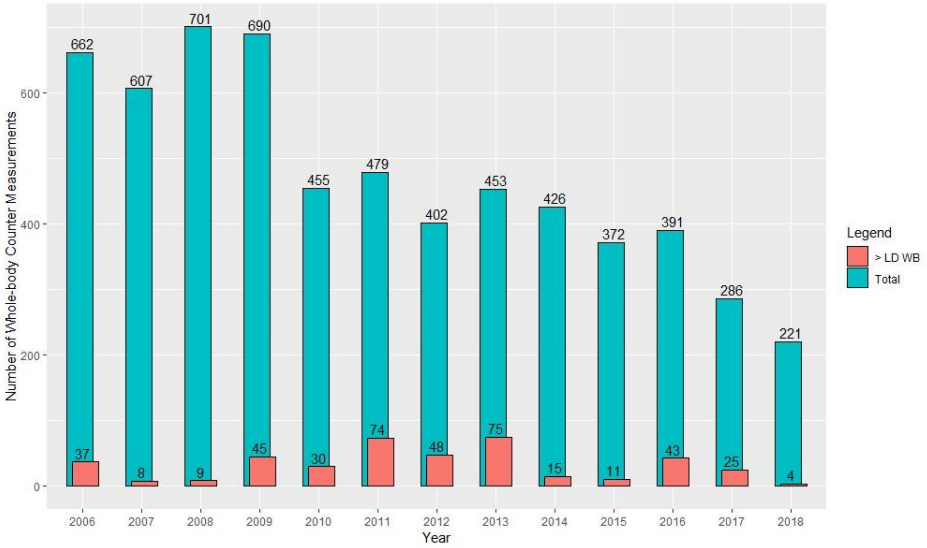

Figure 2: Monitoring data including all results from 2006 to 2018 (Total) as well as the number of measurements above the detection limit of the system (>LD CI). "CI" is the whole-body measurement.

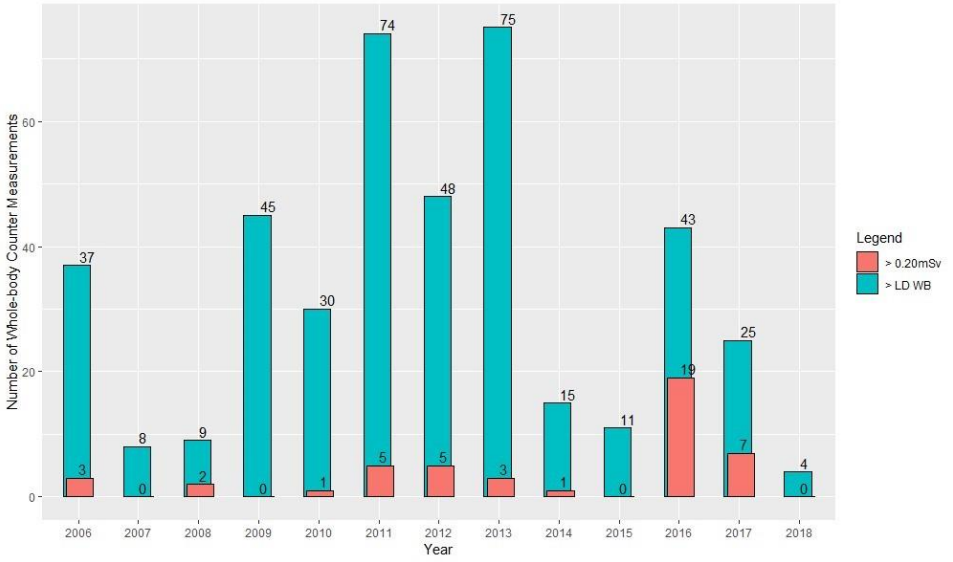

Figure 3: Monitoring data showing the number of whole-body counter measurements including only results greater than recording level along the years (>0.20 mSv).

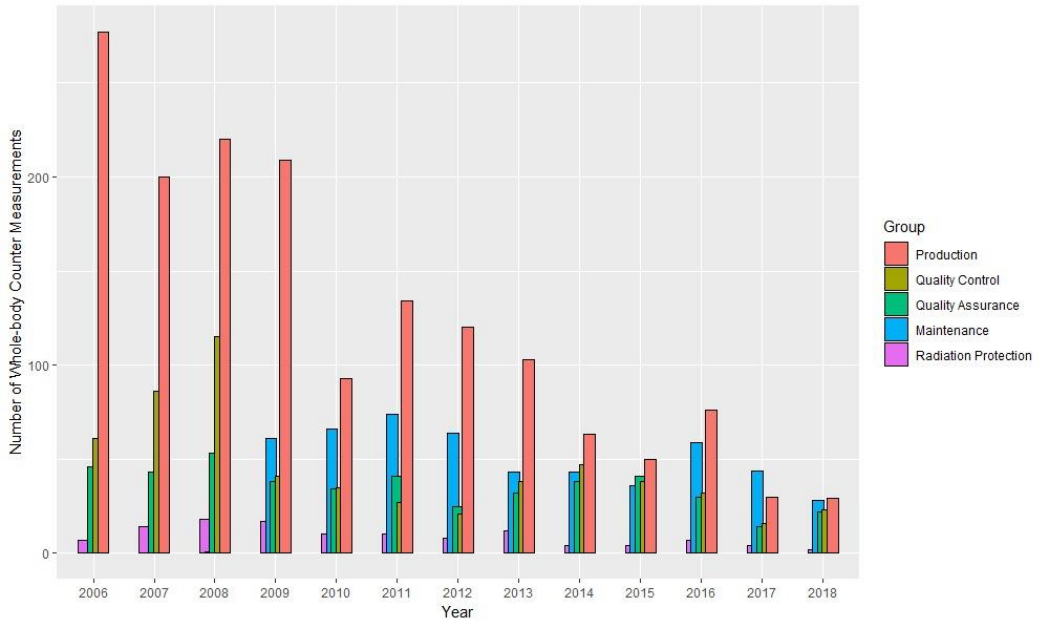

Figure 4: Monitoring data showing the number of whole-body counter measurements from Radiopharmacy Center along the years. The measurement results are separated by activities carried out in the following tasks: Production, Quality Assurance, Quality Control, Maintenance and Radiation Protection.

3.2 Other Considerations

Among the recorded data, 20 workers with 83 measurements had follow-up monitoring in order to help the assessment of the intake and dose. These procedures are accomplished when indications of intake are relevant or the timing of incorporation occurrence was not clearly known. There are 9 cases of workers that was monitored in the whole-body counter, after the

realization of diagnostic procedure. There are also other 65 measurements, mainly for ^{131}I, which represented external contamination.

As mentioned before, the reference level defined by CNEN in last 14 years have been changed at least in three occasions as seen in Table 1. Then, what is the impact in applying the present recording level of 0.10 mSv/month instead of the outdated 0.20 mSv/month? According to the data of our measurements the percentage of cases above recording level will increase from 11% to 14% among the results above de detection limit of our whole-body counting system. The dose above the investigation level represents 2.4%, taking into account the 424 measurements data greater than the limit of detection of the method.

4. CONCLUSIONS

The higher committed effective doses resulted by incorporations of radionuclides come from radiopharmaceutical production activities and abnormal situation. The committed effective dose along these 14 years have decreased at IPEN installations as consequence of improvements accomplished and optimization. The results shown in this paper give a good support to the internal individual monitoring program implemented by the radioprotection personnel in these facilities.

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