

WHOLE-BODY MEASUREMENTS OF WORKERS OCCUPATIONALLY EXPOSED TO RADIONUCLIDES AT IPEN/CNEN-SP

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ABSTRACT

The intake of radioactive material by workers can occur in the radiopharmaceuticals production, during the handling of these in the medical fields (nuclear medicine) and in biological and research laboratories. The workers who work in areas where exposures are significant are routinely monitored to demonstrate that the workers are receiving adequate protection from internal contamination. Direct measurements of whole-body and thyroid contents provide an estimate of the activity of these radionuclides in the potentially exposed workers. The whole-body measurements of the workers, trainees and visitors are routinely performed by the *In Vivo* Monitoring Laboratory (LMIV) of the Energy and Nuclear Research Institute (IPEN/CNEN-SP). The frequency of measurements is defined by the Radioprotection Service (SRP) and the Dose Calculation Group of IPEN. For this purpose LMIV has two counters, whole body, NaI(Tl) (8x4''), and thyroid one, NaI(Tl) (3x3''). The system was calibrated in energy and efficiency, with calibration sources of Eu-152, Am-241 and Co-60 with gamma emissions between 59.54 and 1408.08 keV, positioned within Alderson Research Labs. anthropomorphic phantom. The background measures were obtained of worker's spectrum that wasn't exposed occupationally yet. The concepts adopted in the HPS N13.30 Standard and proposed in ISO documents for standardization were used for activity measurements. During the period January 2007 to December 2012, approximately 6700 measurements had been carried in workers who develop tasks related to the production and research. The activities of the radionuclides and the workers' tasks relationship had been evaluated.

1. INTRODUCTION

The workers who work in areas where material radioactive are handled, processed or produced require a monitoring programme to allow the estimate of the exposition level, an evaluation of the total body or organ deposition and the assessment of dose from this measurements, beyond a comparison of this dose with the legal constraints [1,2]. The International Commission on Radiological Protection (ICRP) provides general recommendations for the individual monitoring programmes and the interpretation of results of estimates of intakes of radionuclides by workers [3].

When working with radioactive iodine ^{125}I , ^{131}I , and ^{123}I , there is a chance the iodine may enter the body via inhalation, ingestion, or absorption through the skin. When this occurs, approximately 30% of the iodine accumulates in the thyroid gland, taking several hours to reach maximum levels (normally within 24 hours). The effective half-lives in the thyroid gland for iodine are 40 days for ^{125}I , eight days for ^{131}I , and 13 hours for ^{123}I . The iodine that

does not become incorporated in the thyroid is eliminated from the body, usually within three days.

The direct measurement of body or organ activities is commonly used for radionuclides that emit radiation with energies greater than 100 keV. The application of these results as base for the dose calculation is valid normally for radionuclides distributed uniformly in the organism even previous studies of incorporations allowed the use of this kind of measure [1].

At the *In Vivo* Monitoring Laboratory (LMIV) of the Energy and Nuclear Research Institute (IPEN/CNEN-SP) whole-body and thyroid measurements are routinely carried out in workers of the IPEN, visitors, trainees and contract workers. The frequency of measurements is established by the Radioprotection Service (SRP) and the Dose Calculation Group of IPEN.

Between 2007 and 2012 an average of 1340 measurements were performed per year considering whole-body and thyroid measurements. In the year of 2012, 854 measurements were carried out.

2. MATERIALS AND METHODS

The detection system consists of two NaI(Tl) detectors, one 8-inch diameter by 4-inch length crystal for whole-body measurements, and one 3-inch diameter by 3-inch length crystal for thyroid measurements, both connected to a Ortec 556 high-voltage supply, a Canberra 2022 amplifier and a Canberra Multiport II Multichannel Analyzer. The data acquisition, display and analysis of gamma spectrometry data were performed with the Canberra Genie 2000 software. This detector had an effective energy range of 100 keV to 2000 keV.

The walls of the shielded room consist of 130 mm-thick steel sheet lined with 5 mm of lead and 5 mm of copper. The internal dimensions are 2.6 m x 1.7 m x 1.85 m, with air filtration. The temperature and humidity of the Laboratory were monitored and maintained around 22°C and relative humidity of 50%, respectively. The room was built of pre-WWII steel that was originally fabricated as armor for a battleship. Pre-WWII steel was selected because it did not contain manmade radionuclides (fallout Cs-137 and Co-60 from smelters) that can increase the background in the room.

The whole-body counting geometry, or source and detector position, used was the 50-cm arc. The person sat in a reclining chair and the detector was suspended above the pelvic area. The chair geometry placed the body from chin to knees approximately 50 cm from the detector. Additional counts of the thyroid were available with the detector placed 35 cm from the neck.

The counting time was 15 and 5 min for whole-body and thyroid measurements, respectively. Minimum detectable activity (MDA) values for some radionuclides typically measured with the whole-body counter were calculated as follows: 10 Bq for ^{131}I , 40 Bq for ^{123}I and 70 Bq for $^{99\text{m}}\text{Tc}$. The thyroid counter MDA values were 30 Bq for ^{131}I , 65 Bq for ^{123}I and 130 Bq for $^{99\text{m}}\text{Tc}$ [4].

A total of 6688 results of whole-body and thyroid measurements taken during five consecutive years were evaluated. The most frequent radioisotopes were assessed as well the

fields of tasks of workers who had presented activities values greater than the minimum detection limit (MDL) and smoking habits these workers.

3. RESULTS AND DISCUSSION

3.1. Results by Work Type

The fields of tasks of workers were: 81% in production, 11% in operation of systems, 4% in radioprotection, 2% in maintenance and 1% in research. As expected, the great majority of the workers who had results above the detection limit was in group involved in radiopharmaceuticals' production (Fig. 1). In the same way, it was observed in sequence two groups compound by the workers who performed tasks of production's support. It's important to remember that the number of workers who had results above the detection limit was around 2.5% of the total of evaluated measurements.

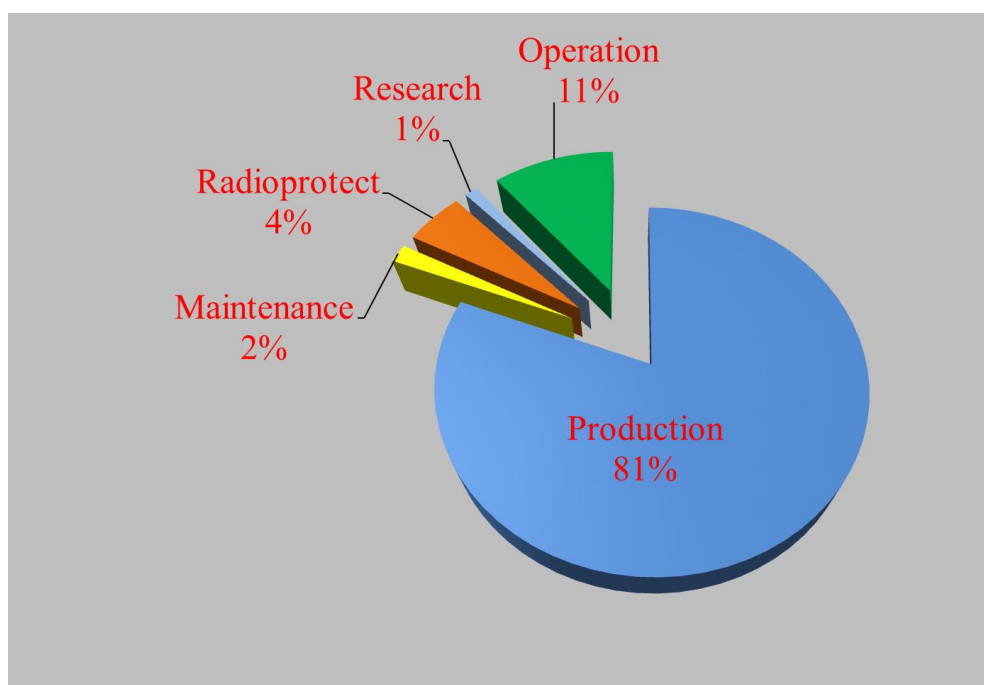


Figure 1: Fields of tasks of workers who had results above the detection limit.

3.2. Detected Radionuclides

A total of 9 radioisotopes were assessed and the three most frequent of them (^{131}I , $^{99\text{m}}\text{Tc}$ and ^{18}F) were requested respectively for 68%, 12% and 4% of the workers who had results above the detection limit (Fig. 2).

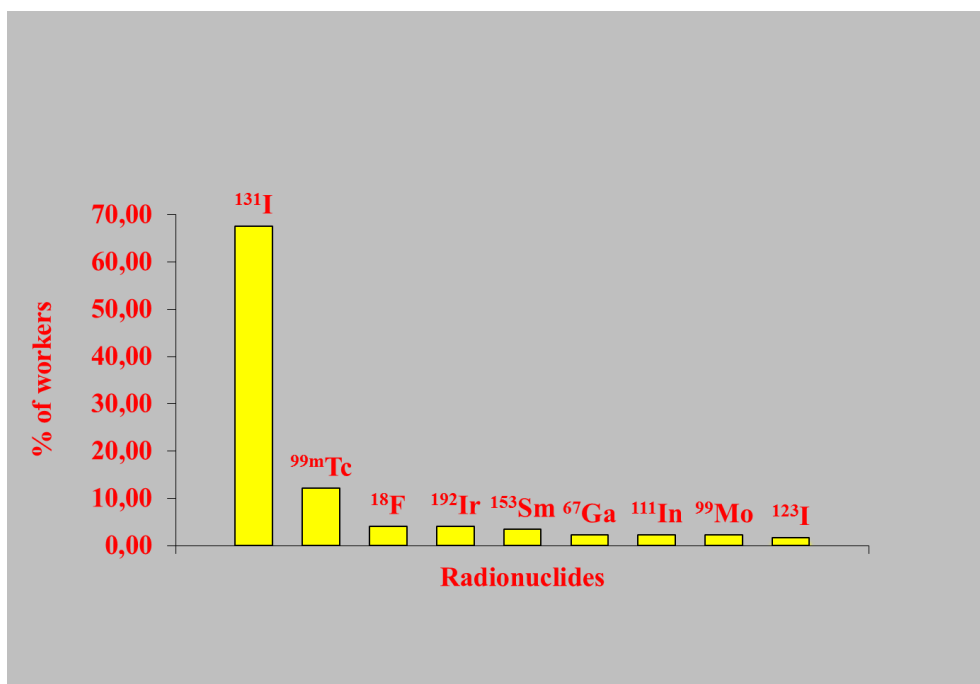


Figure 2: Most frequently requested radioisotopes.

3.3. Committed Effective Dose

The levels of activity detected are considerably low. Committed effective dose coefficients for inhalation intakes of radionuclides by workers are compiled in Publication 119 of ICRP [5]. The detected maximum activities for each radionuclide and the estimated dose resultant of this incorporated activity considering the dose coefficients adopted by the ICRP are showed in Tab. 1.

Table 1: Maximum activity measured and effective dose calculated by radionuclide.

	¹⁸ F	⁶⁷ Ga	¹²³ I	¹³¹ I	¹¹¹ In	¹⁹² Ir	⁹⁹ Mo	¹⁵³ Sm	^{99m} Tc
Activity (kBq)	54,3	45,1	42,4	77,7	162,6	22,1	135,6	17,9	97,7
Eff (μSv)	5,0	12,6	4,7	855,2	50,4	62,3	149,1	12,2	2,8

The choice of the committed effective dose coefficients was based a most restrictive default activity median aerodynamic diameter (AMAD) of 5 μm, except radionuclide ¹⁹²Ir which was used 1- μm particles.

In the same way, the solubility of particulate materials deposited in the respiratory tract was specified in terms of lung clearance types, with type fast rate of absorption into blood (F) for ¹²³I and ¹³¹I nuclides, moderate (M) for ⁶⁷Ga, ¹¹¹In, ¹⁵³Sm and ^{99m}Tc, and slow (S) for ¹⁸F, ¹⁹²Ir and ⁹⁹Mo.

3.4. Smoking Habit

The smoking habit was no significant to the internal contamination of the workers because around 90% of the workers who had results above the detection limit was nonsmokers.

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