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Evaluation of the Minimum Detectable Activity of Whole-Body and Thyroid Counters of the *In Vivo* Monitoring Laboratory of IPEN/CNEN-SP.

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Resumo

Quality assurance in whole-body measurement includes quality control with procedure descriptions, detector calibrations, instrument control and evaluation internally or by outside persons. The *In Vivo* Monitoring Laboratory of IPEN/CNEN-SP (LMIV) provides a direct way activity measure of internally incorporated radionuclides in occupationally exposed workers. LMIV has two NaI(Tl) of 8x4 " and 2x2 " to perform the monitoring of whole-body and thyroid, respectively. The acquisition and analysis software was Genie2000 3.2, Canberra. The system calibration was carried out with Eu-152, Am-241 and Co-60 sources positioned within Alderson Research Labs. anthropomorphic phantom. Minimum detectable activity (MDA) and critical level (Lc) values for nuclides of interest were determined, since these values are an indication of the sensitivity of the detection system. The background counts were obtained from the first monitoring of some workers, blank measurements. The concepts adopted in the HPS N13.30 Standard and proposed in ISO documents for standardization were used for activity measurements.

Palavras chave: *In Vivo* Monitoring; Minimum detectable activity; critical level;

1. Introduction

In the *In Vivo* Monitoring Laboratory (LMIV) of Energy and Nuclear Research Institute (IPEN/CNEN-SP) whole-body measurements are routinely carried out in workers, visitors, trainees and contract workers. The frequency of measurements is established by the Radiation Protection Management (GRP) and by the Dose Calculation Group of IPEN. Between 2008 and 2010 an average of 1225 measurements were performed per year considering whole-body and thyroid measurements.

Although the whole-body counting is a gamma spectrometric measurement, the efficiency calibrations are considerably more difficult than for radioactive sample measurements. It is because the distribution of radionuclide in the body is often inhomogeneous and there is the need for reproducing the body auto-absorption, which can be done using a phantom [1].

In a usual routine of whole-body monitoring two types of detectors are the most useful: semiconductors and/or scintillators. In LMIV NaI(Tl) crystals are used for the measurement of radionuclides emitting photons with energies above 100 keV.

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When the calibration of the *in vivo* monitoring system is performed, it is necessary to establish the detection limits, as the critical level (L_c) and minimum detectable activity (MDA) for example. The L_c is the value above which the gross signal can be considered statistically different from the background signal, reducing the probability of adopting a false negative result, setting a type I error or α . The MDA is defined qualitatively as the smallest amount of radionuclide that can be reliably determined, given the prevailing conditions of the particular spectral measurement [2], reducing the probability of adopting a false positive result, setting a type II error or β .

2. Materials and methods

The MDA for whole-body measurements were calculated for one NaI(Tl) 8x4" (detector A) and one NaI(Tl) 2x2" (detector B). The walls of the shielded room consist of 130 mm-thick lined with 5 mm of lead and 5 mm of copper, with air filtration and maintained at a temperature of 20°C, to minimize the background radiation and to allow the evaluation of very low activities.

An anthropomorphic phantom (Alderson Research Labs.) was used for the calibration of the detectors. The phantom was supplied with ^{152}Eu , ^{241}Am , Eckert & Ziegler, and ^{137}Cs , IPEN, sources. The sources were positioned in the thoracic region and the region of the thyroid to the detectors A and B, respectively. The activities used in experiments are reported in Table 1.

Table 1. Activities and energy peaks used in calibration

Source	Activity (kBq)	Uncertainty (%) ^a	Energy peaks (keV)
^{241}Am	12.24	3.6	59.54
^{137}Cs	120.0	5.0	661.65 121.78 344.3
^{152}Eu	10.12	3.0	778.98 964.0 1408.08

a. Uncertainty reported with 99% confidence level.

Since chair geometry is used in the laboratory, the same geometry was reproduced with the phantom and the efficiency calibration was performed using energies between 59.54 – 1408.08 keV. MDA and L_c values were calculated for counting times of 900 s and 300 s for detectors A and B, respectively.

The software Genie200 (model S500), supplied by Canberra Industries, was used for the spectra analysis. The calculation applied of the MDA follows the procedure adopted by Battist et. al [3] as

$$MDA = \frac{3 + 4.65\sqrt{B}}{t \cdot \varepsilon} \quad (1)$$

where: B is the background counts, t is the acquisition time (s) and ε is the efficiency for the energy peak (counts.s⁻¹.Bq⁻¹).

Following Hurtgen et. al. [4], for less than 10 background counts, Lc can be calculated based on Eq.(1), as described below:

$$L_c = k_{1-\alpha} \cdot (3 + 4.65\sqrt{b}) \quad (2)$$

where Lc is given in (Bq) and b is the rate of background counts per second and $k_{1-\alpha}$ is the coverage factor (1.645 for 95% confidence level, $\alpha = 0,05$).

3. Results and discussion

The difference between efficiency curves of detectors was expected because of the sensitive areas of the NaI(Tl) crystals, the smaller the area the lower efficiency as showed in Fig.1.

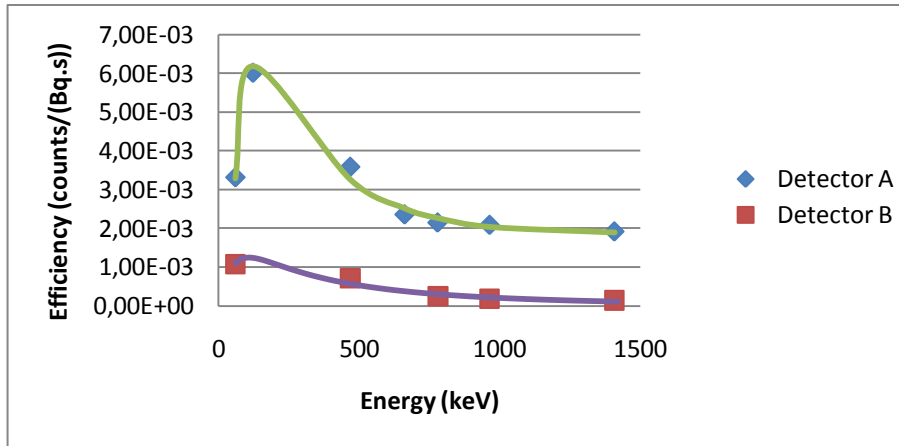


Figure 1. Detectors counting efficiency as a function of gamma-ray energy (Detector A: NaI8x4; Detector B: NaI2x2)

The MDA values were calculated using Eq. (1) and reported in Table 2 along with the critical level for each energy using Eq.(2). For MDA calculation energy peaks between 344.4 and 1173.23 keV were considered for detector A and the peak of the I-131 (364.8 keV) to the detector B. The MDA values obtained were compared with derived limits of incorporation (DLI) [5] and with minimum detection limits (MDL) [5] and MDA values [6]. This

comparison shows that the values obtained in LMIV, for whole body, are equivalent to other laboratories, and in comparison with DLI all techniques are adequate for those radionuclides.

Regarding MDA in the thyroid counting geometry, the value obtained was significantly higher than the values available in the literature [5, 6], This result was considered unsatisfactory and then Detector B was replaced by a NaI(Tl)3x3" in order to increase system sensitivity. Anyway, the MDA value is still lower than the DLI available in the literature [5].

For critical levels were expected the values about 5 to 10 times smaller than the MDA and the obtained values were about 9.4 times smaller than MDA values.

Table 2. MDA and Lc values obtained and the MDL, MDA and DLI values in literature

Radionuclide (Energy keV)	Detector	Geometry	MDA (Bq)	Lc	MDL (Bq) ^a	MDA (Bq) ^b	DLI ^a (Bq) Inhalation
¹⁵² Eu (344.3)	A	Whole body	72.4	19.6	-	-	-
¹³⁷ Cs (661.62)	A	Whole body	111.9	18.9	110	120	5.6 x 10 ⁵
⁶⁰ Co (1173.23)	A	Whole body	96.5	13.9	110	84	1.2 x 10 ⁵
¹³¹ I (364.8)	B	Thyroid	183.5	65.5	59	26	6.7 x 10 ³

^a Dantas et al.[5] values. ^b Bento et al.[6] values.

4. Conclusion

The sensitivity of the LMIV detection systems, expressed in terms of Lc and MDA, for whole body monitoring is equivalent to the values available in the literature. In the case of thyroid geometry, the MDA was much higher than the value found in literature, but it is still lower than the DLI proposed in the literature.

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