

Evaluation of the minimum detectable activity of whole-body and thyroid counters of the *in vivo* monitoring laboratory of IPEN/ CNEN-SP

Avaliação da atividade mínima detectável de contadores de corpo inteiro e tireóide do laboratório de monitoramento *in vivo* do IPEN / CNEN-SP

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Abstract 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.

Keywords: *In Vivo* Monitoring; Minimum detectable activity; critical level

A garantia da qualidade resumo em todo o corpo medição inclui controle de qualidade com descrições de procedimentos, calibrações, controle de detector de instrumento e avaliação internamente ou por pessoas de fora. O *In Vivo* Laboratório de Monitoramento do IPEN / CNEN-SP (LMIV) fornece uma medida atividade direta maneira de radionuclídeos incorporados internamente em trabalhadores expostos. LMIV tem dois NaI (TI) de 8x4 "e 2x2" para realizar o controle de todo o organismo e tireóide, respectivamente. A aquisição e análise de software foi Genie2000 3,2, Canberra. A calibração do sistema foi realizado com Eu-152, Am-241 e Co-60 fontes posicionado dentro Alderson Research Labs. phantom antropomórfico. Atividade mínima detectável (MDA) e críticos de nível (Lc) os valores para os núclídeos de interesse foram determinados, uma vez que estes valores são uma indicação da sensibilidade do sistema de detecção. As contagens de fundo foram obtidos a partir do primeiro controle de alguns operários, medições em branco. Os conceitos adotados na Norma N13.30 HPS e propostos em documentos ISO para a padronização foram utilizados para a medição da atividade.

Palavras-chave: monitorização *in vivo*; atividade mínima detectável; nível crítico

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.

When the calibration of the *in vivo* monitoring system is performed, it is necessary to establish the detection limits, as the critical level (Lc) and minimum detectable activity (MDA) for example. The Lc 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 activities as low as necessary for routine monitoring purposes.

An anthropomorphic phantom (Alderson Research Labs.) was used for the calibration of the detectors. The phantom was supplied with ¹⁵²Eu, ²⁴¹Am, Eckert & Ziegler, and ¹³⁷Cs, 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 Lc values were calculated for counting times of 900 s and 300 s for detectors A and B, respectively.

The software Genie200 (version 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

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

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 L_c 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.

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.

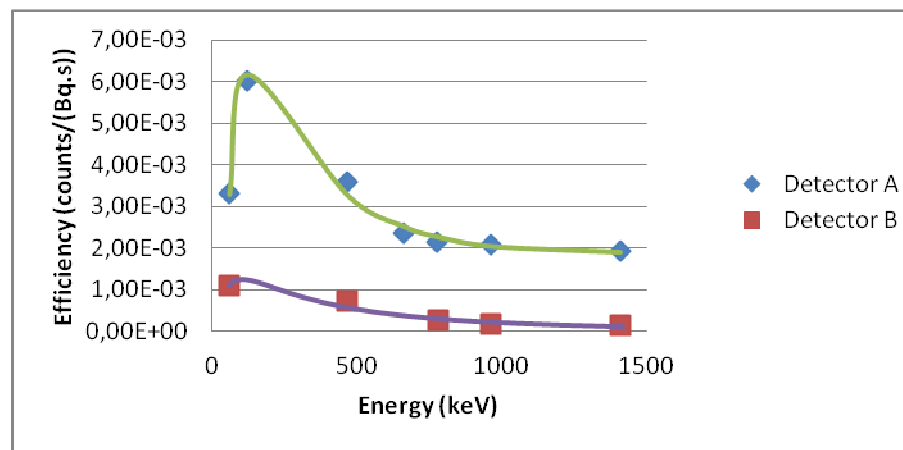


Figure 1: Detectors counting efficiency as a function of gamma-ray energy (DetectorA: NaI 8x4"; Detector B: NaI 2x2")

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 L_c values obtained and the MDL, MDA and DLI values in literature

Radionuclide (Energy keV)	Detector	Geometry	MDA (Bq)	L_c	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, MDA obtained by the LMIV was significantly higher than the values reported in literature, probably, because of the crystal dimensions. Our crystal was 2x2” and the one used by Dantas *et al* ^[5] was 3x3”. Nevertheless, it is still lower than the DLI proposed in the literature.

5. ACKNOWLEDGEMENTS

The authors thank CAPES and Ipen/CNEN-SP for financial support of research project.

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1. Rahola T, Falk R. Whole-body measurement and quality assurance. *Radiat Prot Dosimetry*. 2000; 89: 243-245.
 2. INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY. Nomenclature in evaluation of analytical methods including detection and quantification capabilities. 1995; 67: 1699-1723 (No. 10).
 3. Battist P, Castellani CM, Doerfel H, Tarroni G. Problems in defining the minimum detectable activity in lungs measurement of low energy photon emitters. *Radiat Prot Dosimetry*. 2000; 89: 251-254.
 4. Hurtgen T, Jerome S, Woods M. Revisiting Currie - how low can you go?. *Appl Radiat Isot*. 2000; 53: 45-50.
 5. Dantas BM, Bertelli L, Lipsztein JL. Evaluation of whole-body counting capabilities based on ICRP limits. *Radiat Prot Dosimetry*. 2000; 89: 255-258.
 6. Bento J, Teles P, Silva L, Nogueira P, Neves M, Vaz P. Performance parameters of a whole body counter. *Radiat Meas*. 2010; 45: 190–195.