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EVALUATION OF THE MINIMUM DETECTABLE ACTIVITY OF WHOLE BODY AND THYROID COUNTERS AT *IN VIVO* MONITORING LABORATORY OF 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 (LMIV) of Energy and Nuclear Research Institute (IPEN/CNEN-SP) provides an estimate of activity, in the body, by direct measure of whole body or thyroid content in occupationally exposed workers. LMIV has two NaI(Tl) detectors of 8x4 " and 2x2 " respectively, to carry out the whole-body and thyroid monitoring, respectively. The system calibration was carried out with ^{152}Eu, ^{241}Am and ^{60}Co sources positioned within Alderson Research Labs, anthropomorphic phantom. Minimum detectable activity (MDA) and critical level values for nuclides of interest were determined, since these values are an indication of the sensitivity of the detection system. The background measures were obtained from the first monitoring of some workers, blank measures. The concepts adopted in the HPS N13.30 Standard and proposed in ISO documents for standardization were used for activity measurements.

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 necessity of reproducing the body auto-absorption, what can be done using a phantom [1].

In a usual routine of whole-body monitoring two types of detectors are most useful: semiconductors and scintillators. In LMIV are used NaI crystals, recommended for energies above 100 keV.

One of the most important quantities to determine in a whole-body counter system in operation, the Minimum Detectable Activity (MDA), must be determined together with the critical level (L_c). 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 of steel lined with 5 mm of lead and 5 mm of copper, with air filtration and maintained at a temperature of 20ºC, to minimize the background radiation and to allow the evaluation of very low activities.

Was used an anthropomorphic phantom (Alderson Research Labs.) for the measures. The phantom was supplied with ^{152}Eu, ^{241}Am and ^{60}Co sources, Eckert & Ziegler. 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 experiment

Source	Activity (kBq)	Uncertainty (%)[a]	Energy peaks (keV)
^{241}Am	12.24	3.6	59.54
^{152}Eu	10.12	3.0	121.78
			344.3
			778.98
			964.0
			1408.08
^{60}Co	10.26	3.1	1173.23

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 program Ortec *Renaissance 32* was used for the spectra analysis. The procedures employed for MDA estimation is that one suggested in the HPS N13.30 Standard and proposed in ISO documents for standardization [3] as

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

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], when less than 10 background measures are carried out Eq.(1) will be considered. The Lc can be given as

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

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, α = 0,05).

3. RESULTS AND DISCUSSION

Counting efficiencies for each detector were plotted against gamma-ray energy (Figure 1).

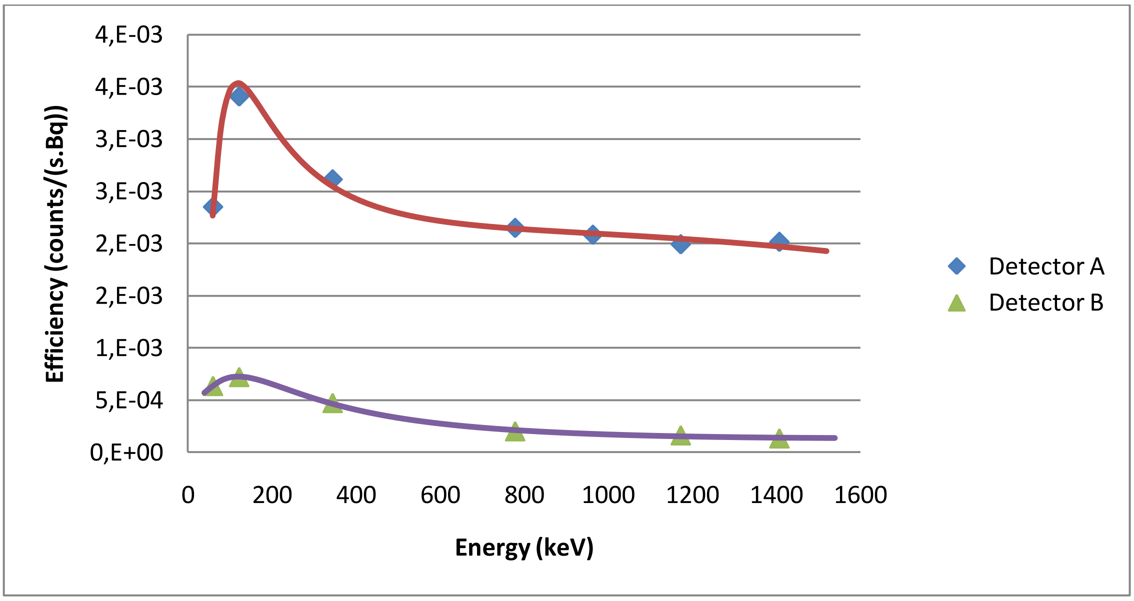

Figure 1. Detectors counting efficiency as a function of gamma-ray energy.

The difference between the 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 were considered energy peaks between 344.4 and 1173.23 keV 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 limit of incorporation (DLI) [5] and with minimum detection limit (MDL) [5] and MDA [6] values. This comparison shows that the values obtained in LMIV, for whole body, are according with others laboratories, and in comparison with DLI all techniques are adequate for those radionuclides.

For MDA to thyroid counting geometry the value obtained was too different of ones in literature [5] and [6], This response was deemed unsatisfactory and the B detector was replaced by a NaI(Tl) detector 3x3" in order to obtain the lowest MDA. But, the MDA value is still lower than the DLI proposed by [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	113.1	17.9	-	-	-
^{137}Cs (661.62)	A	Whole body	90.1	16.9	110	120	5.6 x 10^5
^{60}Co (1173.23)	A	Whole body	104.8	16.2	110	84	1.2 x 10^5
^{131}I (364.8)	B	Thyroid	185.8	40.1	59	26	6.7 x 10^3

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

4. CONCLUSIONS

This paper showed the minimum limits of activity detectable at LMIV, considering type I and type II errors, Lc and MDA values, respectively. For geometry of whole body counting, MDA values were obtained close to those found in the literature and the Lc value within the expected for measurements *in vivo*. For the MDA the geometry of the thyroid value was much higher than found in literature, but is still lower than the DLI proposed in literature.

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