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EVALUATION OF THE MINIMUM DETECTABLE ACTIVITY IN WHOLE-BODY MEASUREMENTS OF PHOTON EMITTERS

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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. It is well know that some or several characteristics can be affected when the detector has been used in different energy radiation beams. A comparison and evaluation of the NaI(Tl) and HPGe based detector systems' performances has been carried out at *In Vivo* Monitoring Laboratory of IPEN/CNEN-SP for measurements of elements used in radiopharmacy (^{131}I, ^{123}I and ^{99m}Tc) in chest regions. Alderson Research Labs. anthropomorphic phantom was used for the calibration. The concepts adopted in the HPS N13.30 Standard and proposed in ISO documents for standardization were used for activity measurements. Results of this comparison are presented together relative efficiencies and MDA values for all NaI(Tl) and HPGe based detector systems involved.

1. INTRODUTION

In the *In Vivo* Monitoring Laboratory (LMIV) of the Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN-SP) whole-body measurements is routinely carried out in workers of the IPEN, visitors, trainees and contract workers. The frequency of measurements is established by the Radiation Protection Service (SRP) and by the Dose Calculation Group of IPEN. Between 2002 and 2004 an average of 845 measurements were performed per year considering whole-body and thyroid measurements. In 2006 the number of 1320 measurements was reached by the adoption of a new methodology of people to be monitored invocation.

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 routine of whole-body monitoring two types of detectors are most useful: semiconductors and/or scintillators. At the *In Vivo* Monitoring Laboratory of IPEN the both kinds of detectors have been tested. The system used employs four detectors, two high-purity germaniums (HPGe) and two thallium-activated sodium iodines (NaI(Tl)).

Among other advantages, the use of high-purity germanium detector improves the performance of the measurements due to its higher energy resolution. However it also has some disadvantages as the constant supply of liquid nitrogen. A thallium-activated sodium iodine detector has a bad energy resolution, by comparison with HPGe. It is hygroscopic but don't need liquid nitrogen for cooling. This work presents a comparison only among the minimum detectable activity (MDA) in whole-body measurements with these detectors.

It is necessary to know the efficiency for each specific radionuclide used and the variability of the gross count in the region of interest (ROI) for a good MDA experimental evaluation in whole-body measurements.

2. MATERIALS AND METHODS

The MDA for whole-body measurements were calculated for one NaI(Tl) 203.2 mm x 101.6 mm (detector A), one NaI(Tl) 76.2 mm x 76.2 mm (detector B), one HPGe 70.7 mm x 33.2 mm (detector C) and one HPGe 35.7 mm x 15.0 (detector D). 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 25ºC, to minimize the background radiation and to allow the evaluation of very low activities.

An anthropomorphic phantom (Alderson Research Labs.) was used for the measures. The phantom was supplied with ^{123}I, ^{131}I and ^{99m}Tc sources, produced in IPEN/CNEN – SP, according to their body affinity. The activities used in experiments are reported in Table 1.

Table 1. Activities used in experiments (kBq)

Radionuclides	Detector A	Detector B	Detector C	Detector D
^{123}I	75	245	250	240
^{131}I	1200	1200	720	1200
^{99m}Tc	100	210	125	205

Since chair geometry is used in the laboratory, the same geometry was reproduced with the phantom. All MDA values were calculated for a standard counting time of 900 s.

The program Ortec *Renaissance 32* was used for the spectra analysis. The procedure employed for MDA estimation is that one suggested in the HPS N13.30 Standard and proposed in ISO documents for standardization [2], where:

$$MDA = \frac{3 + 4,65.S_B}{t.\varepsilon} \quad (1)$$

Where:

MDA = value of MDA (Bq)

ε = *in vivo* detection efficiency for the specific radionuclide (counts.s^{-1}. Bq^{-1})

t = measuring time (s)

S_B = uncertainty of counts in the ROI for the blank measurements

In order to determine S_B twenty measurements were performed with the phantom filled just with water, and then S_B is the total variability of the gross count in the ROI.

3. RESULTS

The MDA values presented in Table 2 were calculated using the standard deviation of the background counts. Counting efficiencies for each detector were plotted against gamma-ray energy (Figure 1).

Table 2. MDA (Bq)

Radionuclides	Detector A	Detector B	Detector C	Detector D
^{123}I (159 keV)	40	65	60	220
^{131}I (364 keV)	10	30	270	260
^{99m}Tc (140 keV)	70	130	140	360

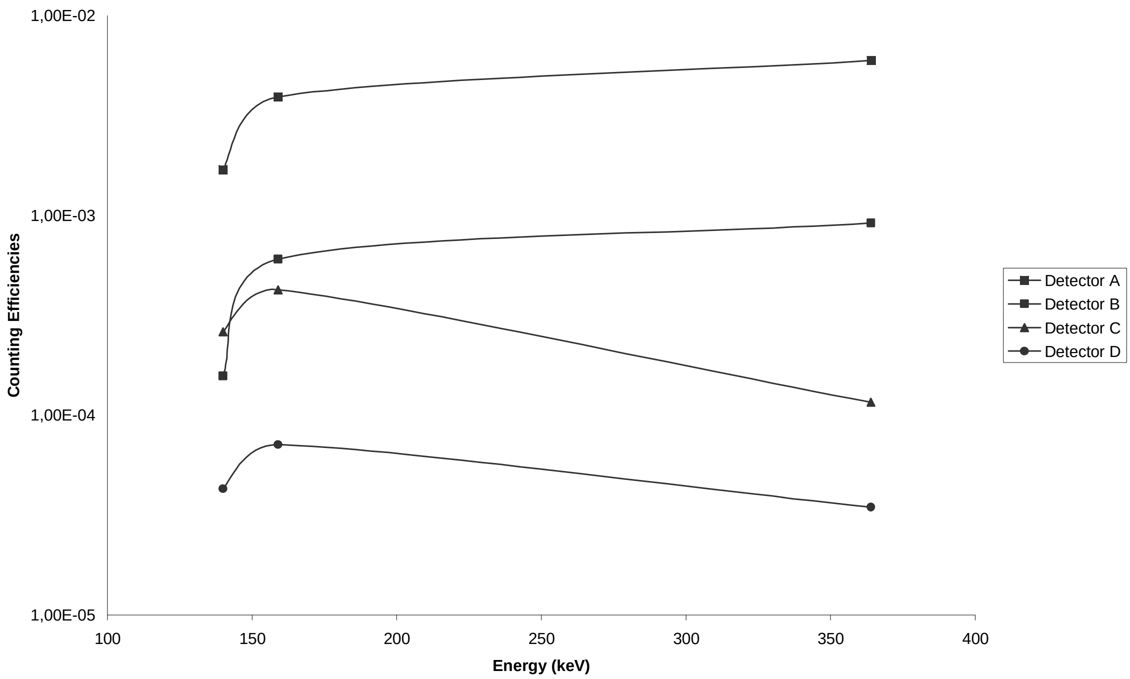

Figure 1. Detectors counting efficiency as a function of gamma-ray energy.

The Detector A showed higher counting efficiencies than other detectors as expected. In the same way Detector D showed lower counting efficiencies than other. The counting efficiency of Detector C was about 1.7 times larger than that of Detector B in the case of the region around the ^{99m}Tc peak. Instead, the counting efficiency of Detector B was about 1.4 times larger than that of Detector C in the case of the region around the ^{123}I peak.

4. CONCLUSIONS

According to ICRP 78 [3], 100 Bq is a typical detection limit for ^{131}I in spectrometry *in vivo*. Dantas and associates [4] calculated a value of 120 Bq like a minimum detection limits for ^{99m}Tc whole-body measurements. The results of MDA are satisfactory even so one detector has deviated from these references values.

In the case of the nuclides of interest, monitoring can be carried out with a NaI(Tl) or a HPGe detector of reduced dimensions. However, more work is needed to maintain the HPGe detectors because the supply of liquid nitrogen needs to be replaced manually approximately every 1.5 days [5].

Quality assurance includes quality control with detector calibrations and instrument control. This evaluation also involves regularly test measurements.

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