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INTERCOMPARISON OF CDTN AND IRD WHOLE-BODY COUNTER FOR *IN VIVO* MEASUREMENTS OF HIGH ENERGY PHOTON EMITTERS

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ABSTRACT

The CDTN has one *in vivo* monitoring system, generically referred as Whole-Body Counter (WBC) that aims to identify and quantify radionuclides in organs and tissues for radiological protection purposes and to provide useful information for studies on biokinectic behavior of radionuclides in humans and animals. The CDTN-WBC has one NaI(Tl) 6"x4" scintillation detector installed in a shadow-shield, made with an assembly of lead bricks with dimensions of $(10x10x5)cm^3$ and $(10x5x5)cm^3$. The detector is surrounded by 12cm lead rings and the Photo Multiplier Tubes covered with a lead cone. This detection system is set to measure radionuclides emitting photons in the energy range from 100 to 2000 keV. The objective of this work is to present the energy *vs*. efficiency calibration curves determined for two similar counting systems installed at CDTN and IRD, both CNEN institutes. The calibration performed at the CDTN-WBC has been accomplished by using a whole-body phantom containing a standard solution with four gamma emitting radionuclides (^{57}Co, ^{137}Cs, ^{54}Mn, ^{65}Zn) supplied by the Metrology Laboratory of IRD. The phantom was positioned lying on a bed at a distance of 31, 5 cm from the scintillation detector front face. The results show that the CDTN-WBC presents efficiencies equivalent to the IRD-WBC at similar calibration conditions.

1. INTRODUCTION

Occupational exposure to ionizing radiation can occur as a result of several human activities such as industrial, medical, educational and research and in nuclear fuel cycle facilities [1]. *In vivo* monitoring systems, generically referred as whole-body counter (WBC) are worldwide used in routine monitoring of workers occupationally exposed to high energy photon emitters [2].

The CDTN has one WBC used to identify and quantify radionuclides in organs and tissues for radiological protection purpose and to provide useful information for studies on biokinectic behavior of radionuclides in humans and animals. Such detection system is set to measure radionuclides emitting photons in the energy range from 100 to 2000 keV.

This paper presents an evaluation of calibration curves obtained at the CDTN-WBC in terms of efficiency and sensitivity for *in vivo* measurements of high energy photon emitters radionuclides such as ^{57}Co, ^{137}Cs, ^{54}Mn, ^{65}Zn. Furthermore, these results were compared to the IRD-WBC efficiency calibration curve in a similar counting geometry and measurement conditions.

2. LABORATORIES DESCRIPTION

The WBC laboratory installed at the CDTN has a NaI(Tl) 6”x4” scintillation detector used to identify and quantify photon homogeneously distributed in the whole body. The detector is installed in a *shadow shield* configuration in order to reduce interference from ambient external sources. It consists on an assembly of lead bricks with dimensions of $(10x10x5)cm^3$ and $(10x5x5)cm^3$ and approximately 600 kg. The detector is surrounded by 12 cm lead rings and the Photo Multiplier Tubes covered with a lead cone. This system is showed in Fig. 1.

Figure 1. CDTN-WBC system: a) detector 6”x4” and b) geometry system

The IRD-WBC system has a NaI(Tl) 8”x4”scintillation detector installed in a shielded room with 15cm thickness, demonstrated in Fig. 2. This counting system is able to identify and quantify radionuclides in the energy range from 100 to 3000 keV [3, 4]. It is applied routinely for the monitoring of approximately 200 occupationally exposed workers from industrial, medical and nuclear facilities. The system has also been used since the 80’s in research projects related to the development of specific *in vivo* monitoring procedures to be applied in the study of biokinectic behavior of radionuclides in human body. Among such research projects it can be cited the studies about estimation of thorium incorporation [5], ^{90}Mo metabolism in nuclear medicine patients [6], ^{40}K in public individuals [7], evaluation of internal exposure of Nuclear medicine staff [8, 9].

Figure 2. In vivo monitoring using the NaI(Tl) 8"x4" scintillation detector positioned at whole body geometry

3. METHODOLOGY

The scintillation detector of *in vivo* counting system of CDTN is positioned above the monitoring bed. The person or the phantom must be positioned lying at a distance of 31, 5 cm from the detector front face.

A glass vial containing 2.6615g of a standard solution with four gamma emitters (^{57}Co, ^{137}Cs, ^{54}Mn, ^{65}Zn), supplied by the Metrology Laboratory of IRD (LNMRI-IRD) to the CDTN was transferred to a whole-body phantom composed by two 20 liters polyethylene bottles of rectangular cross-section. The bottles were assembled together simulating whole body geometry and measured for 30 minutes with the detection system (Fig. 3). A calibration curve expressed in terms of *Energy (keV) vs Efficiency (cpm/dpm)* was determined based on the count rates recorded at each radionuclide region of interest.

The standard solution radiochemical characteristics are presented in Table 1.

Table 1. Radiochemical characteristics of the standard solution

Radionuclides	Half-live (day)	Activity (Bq/g)	Uncertainty (Bq/g)	Total activity (Bq)	Uncertainty (Bq)
^{57}Co	271.8	1816.22	32.7	4833.9	87.0
^{137}Cs	10956.57	1599.67	14.2	4257.6	37.9
^{54}Mn	312.3	1500.4	24.0	3993.3	63.9
^{65}Zn	244.01	1475.6	36.9	3927.3	98.2

Figure 3. Phantom counting at CDTN-WBC system with bottles filled with standard solution

4. RESULTS AND DISCUSSION

A sequence of five measures was carried out to each radionuclide in CDTN-WBC. The arithmetic mean and standard deviations of the count rate (cpm) were calculated. The Table 2 presents the data obtained from each radionuclide measurement, including its regions of interest (ROI) in channels and correspondent energies.

Table 2. Measurements data from the radionuclides (CDTN-WBC)

Radionuclides	ROI (Channels)	ROI (keV)	Counts/30 (min.)	Count rate (cpm)	Standard deviations (cpm)
^{57}Co	130-220	106.1-179.5	62455	2082	572
^{137}Cs	710-890	579.3-726.1	37638	1255	113
^{54}Mn	900-1100	734.1-897.4	28315	944	95
^{65}Zn	1210-1430	987.2-1166.7	10106	337	27

The Table 3 presents the calibration parameters. Original standard activities were corrected taking in account the time elapsed between the preparation and the measurement day. The calibration curve in terms of efficiency is presented in Fig. 4.

Table 3. Activities and efficiencies of the radionuclides (CDTN-WBC)

Radionuclides	Energy (keV)	Intensity	Corrected Activity (Bq)	Corrected Activity (dpm)	Standard deviation (dpm)	Efficiency (cpm/dpm)	Uncertainty (cpm/dpm)
^{57}Co	122.06	0.9628	3784.4	227063.8	4087.1	0.0095	0.0027
^{137}Cs	661.66	0.8510	4231.9	253911.6	2259.8	0.0058	0.0006
^{54}Mn	834.85	0.9998	3226.8	193607.3	3097.7	0.0049	0.0005
^{65}Zn	1115.55	0.5060	2990.1	179407.9	4485.2	0.0037	0.0006

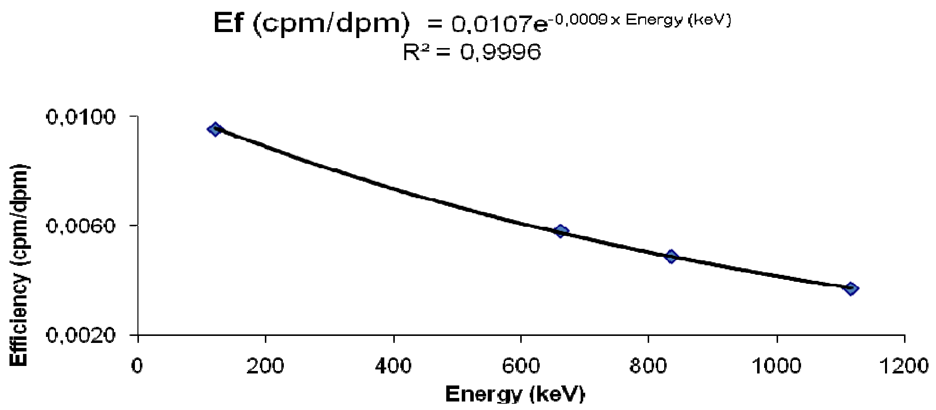

Figure 4. Efficiency curve of CDTN-WBC *In Vivo* Monitoring System for Whole body Geometry

The efficiency calibration curve from CDTN-WBC is presented in the following equation:

$$Ef\ (cpm/dpm) = 0{,}0107\ e^{-0{,}0009\ x\ Energy\ (kev)} \quad . \qquad (1)$$

In order to evaluate the calibration performance of CDTN-WBC *in vivo* monitoring system was carried out the comparison to the IRD-WBC efficiency detection presented in Fig. 5, obtained in similar calibrations conditions.

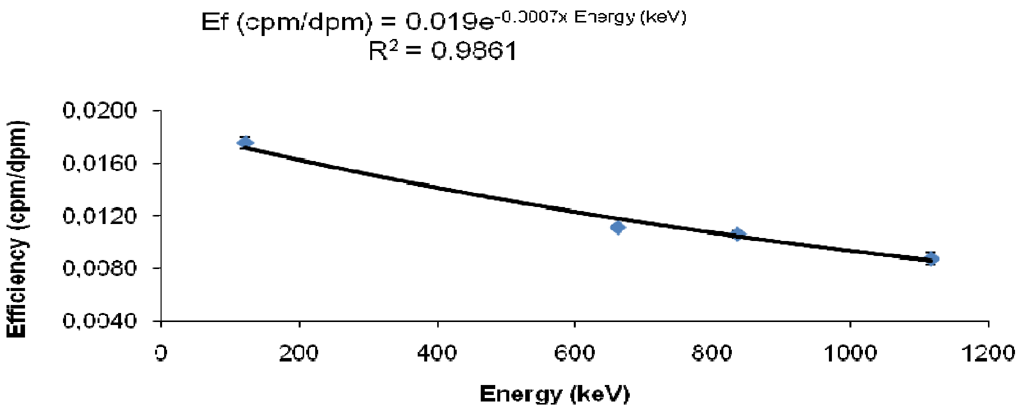

Figure 5. Efficiency curve of IRD-WBC system

The detector efficiency equation from IRD-WBC presented by the graphic in Fig. 5 is:

$$Ef\,(cpm/dpm) = 0{,}019\; e^{-0{,}0007 \times Energy\,(kev)} \quad . \qquad (2)$$

5. CONCLUSIONS

The results of the calibration curves obtained at the CDTN-WBC showed equivalent efficiencies in comparison to the calibration results of IRD-WBC based on the similar whole-body geometries and calibrations conditions. Furthermore, the systems present enough sensitivity for *in vivo* measurements to be applied in routine monitoring of workers occupationally exposed to photon emitters, in the energy range from 100 to 2000 keV.

This comparison exercise could be used as an intercalibration methodology involving whole-body monitoring systems in order to harmonize analytical techniques and ensure reliability of measurement results performed in a laboratory network.

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