

Implementation of a Low Cost For Internal Dosimetry Radiological Survey of Ionization Radiation Exposed Workers In Nuclear Medicine Services

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Abstract Because the nature of the routine activities carried on in nuclear medicine services, where several not sealed radioactive sources are used, the occupational personal exposed to ionization radiation (POE) is exposed to both, internal and external radioactive contamination and direct radiation also. The most important radioisotope from the point of view of radiological risk in such Nuclear Medicine Services (NMS) is the ¹³¹I. The Mexican official regulatory organization in radiological and nuclear safety: *Comisión de Seguridad Nuclear y Salvaguardias* (CNSNS) specify, as a requirement in the operation license of Nuclear Medicine Services the mandatory of internal and external dosimetry survey of POE. The external dosimetry survey is normally carried out but the internal dosimetry survey is not easy to do, because internal dosimetry systems are too expensive and in Mexico there are only three organizations (CFE-CLV, ININ, CNSNS) where there are these systems but they aren't easily available for the Nuclear Medicine Services. Because that before fact, we propose a single, and low cost system (SLCS) to survey the internal dosimetry of POE. This system is based in a scintillation NaI(Tl) 2x2 detector and a common radiation monitor typically used in the routine radiation and contamination measures, with a minimal infrastructure investment. This system is numerical calibrated with Montecarlo method, and compared with an well established commercial System being a good function corresponding. This system is easy to implementing in any nuclear medicine to complain the requirement of operation license in the internal dosimetry POE survey.

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1. INTRODUCTION

^{131}I is a radionuclide commonly used in NMS, during its use, exposed workers have risk to intake it by inhalation therefore is necessary a survey program for the evaluation of radionuclides intake. The radioactive half life of ^{131}I is 8.04 days, when is incorporated in the body organs, radiation is emitted within the body, the contributions due penetrating radiations from the other organs should estimate, for its evaluation it is necessary measure of activity intake with counter systems of whole body.

In recent years the number of centers that provide services nuclear medicine increased, in year 2013 the number of centers registered by (CNSNS) were around 146 and none had a counter system for internal dosimetry. At the present work we proposed a low cost system for internal radiological survey. The proposed system. Is based in a 2x2 NaI (Tl) scintillation detector, associated to a commercial monitor with single channel analyzer, currently used in nuclear medicine services.

The system was calibrated in energy for the main gamma energy of ^{131}I (364.5 keV) and efficiency for a thyroid gland geometry by Montecarlo Method and verified with a reference source of ^{133}Ba that is frequently used to simulate ^{131}I , because the close of energy values (364.5 and 356.0 keV).

Finally the measurement of ^{131}I in thyroid person was made with the SLCS and it was compared with the measurement obtained whit a commercial system for internal dosimetry.

2. METHODOLOGY

2.1 Calibration

2.1.1 Energy Calibration

The energy calibration consists in set up the energy window in the range of main photopeak of ^{131}I .

An spectrum with a source of ^{131}I (364.5 keV) was obtained doing a gross “scan” of 50 mV between the Lower Level discriminator (LLD) and Upper Level Discriminator (ULD) with steps of 50 mV, then a fine scan with a difference of 10 mV in steps 10 mV was made once located the photopeak in its neighbourhood (Fig 2.1).

The amplitude of the pulse generated is proportional to the energy deposited by the photon for interaction with the detector, therefore the number

of pulses that contribute of photopeak are all those that have interacted by photoelectric effect.

2.1.2 Efficiency Calibration

For a specific geometry, the efficiency calibration is the ratio of the events registered in the energy window with the radiological activity of the reference source. The Geometry is the location of the reference source with relation to radiation detector. An important aspect is the density of the reference source that must be the same that the sample (in this case the thyroid gland)

A reference source (with an activity known of ^{133}Ba) is located in front of the entrance window from detector and the photons from the reference source that interact in detector by photoelectric effect are registered in the counting system. The efficiency Calibration ϵ is calculated as:

$$\epsilon = \frac{N(E)}{T A_c Y} \quad (1)$$

where

$N(E)$ are the counts in the window of photopeak of 356 KeV”

T , is the time count

Y gamma emission probability(gamma/des =62.05%)

A_c , reference source activity (Bq).

2.2 Gamma Spectrometry System Resolution

Resolution is the capacity in a gamma spectrometry system to distinguish between photopeaks with closed energies. Resolution is described in terms of FWHM (Full Width at Half Maximum of potopeak), For a system with a detector of NaI(Tl) a typical value of FWHM for 356.05 keV is about 30 KeV. Lower level detection (LLD).

The lower level detection is the smallest signal that can be detected for a counting system for the posible presence of radiactivity contaminants during radiological monitoring, for a level confidence.

For a level confidence of 95%

$$LLD = \frac{4.66\sqrt{T_{cf} * T_c}}{E_f \cdot Y \cdot T_c} \quad (2)$$

where

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T_{cf} , counting rate of Background
 T_c , count time
 E_f = Efficiency
 Y , gamma emission probability (gamma/des).

2.3 Monte Carlo

The Monte Carlo is a method stochastic for numerical integration based in generate N random points in the problem space. The Monte Carlo Neutral-Particle eXtend (MCNP) is a code of transport neutrons, protons, photons, electrons etc. It was developed by Los Alamos National Laboratory. In the present work the efficiency calibration for thyroid gland geometry was modelling with MCNP and compared with an experimental array with a source of ^{133}Ba .

2.4 Numerical Calibration

2.4.1 Source-Detector specification and Monte Carlo simulation

To know details of dimensions of the NaI detector to modelate with MCNP, a radiograph of detector was obtained with a tomograph (Figure 1). The model of the system contain:

The outside of the NaI detector is covered by two layers of aluminium, one primary of 20 mm and another one of 15 mm of thickness, The secondary aluminium layer keep scintillation NaI volume and the photomultiplier tube (Figure 2).

In this case the source is thyroid gland, so a model of thyroid was made considering a couple of ellipsoids that represent each thyroid lobe and one

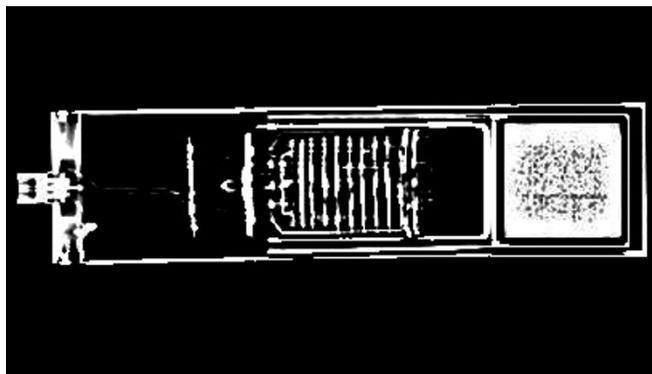


Figure 1: Radiograph of NaI Detector.

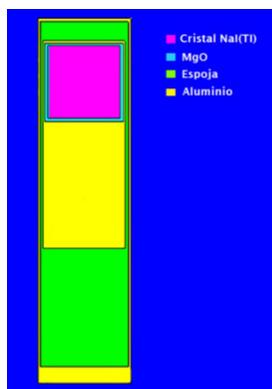


Figure 2: NaI detector model with MCNP.

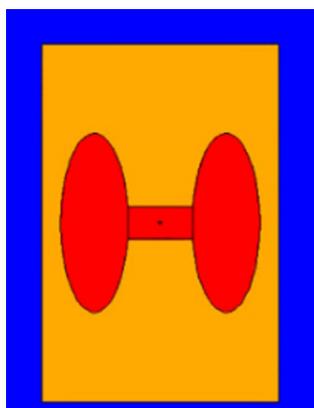


Figure 3: Thyroid model with MCNP.

cylinder that represent central isthmus (Figure 3). The thyroid dimensions were the recommended from ICRP 23 publication.

3. RESULTS AND DISCUSSION

3.1 Energy Calibration

The spectrum window for 364.5 KeV was established from 334 (LLD) until 394 (ULD) KeV (Figure 4).

3.2 Efficiency Calibration

Numerical efficiency calibration was made for 3,6,12 and 18 centimeters of distance from detector to thyroid. Experimental efficiency calibration

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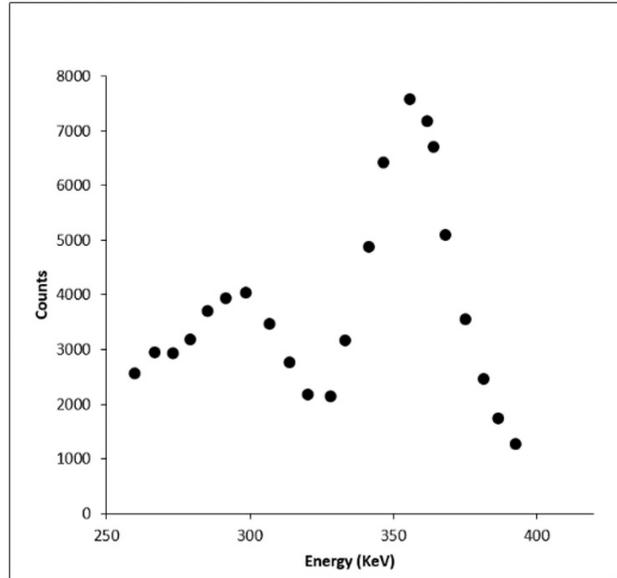


Figure 4: Energy window of ^{131}I .

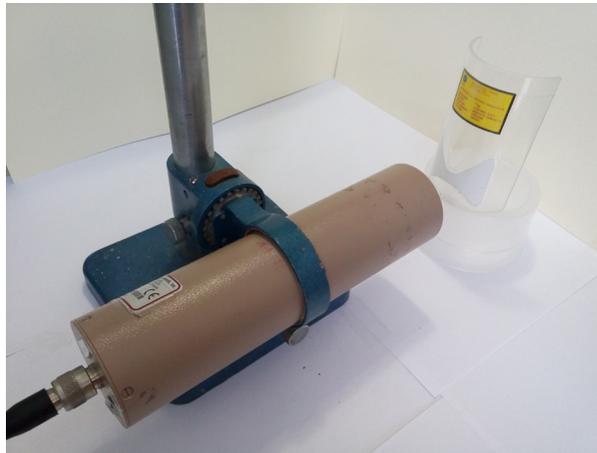


Figure 5: Experimental efficiency calibration.

was made for the same distances that numerical, the values are presented in table 1

In the processes of numerical efficiency, calibration the spectrums were obtained from the MCNP code “run” Figure 6

Table 1: Values of experimental and numerical efficiency calibration.

Distance (cm)	Experimental Efficiency	MCNP Efficiency	Diference (%)
3	1.08E-03 ±5%	1.10E-03 ±1%	2
6	6.46E-04 ±5%	6.25E-04 ±1%	-3
12	3.35E-04 ±5%	3.46E-04 ±1%	3
18	2.03E-04 ±5%	2.48E-04 ±1%	4

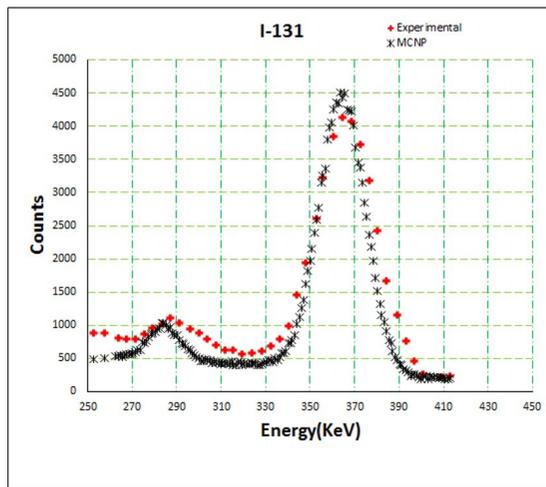


Figure 6: Numerical spectrums of ^{131}I .

3.3 Practical case

A background count of ten minute was made to calculate the lower level detection that results of 220 Bq of ^{131}I for the geometry of 3 centimeters (distance source-detector).

In order to compare the response of SLCS an analysis a person with ^{131}I in thyroid because a medical treatment was made (Figure 7).

The value of ^{131}I activity with whole body system was $3.26\text{E}+05 \pm 4 \%$ Bq and the value with SLCS was $3.12\text{E}+05 \pm 6 \%$ Bq. In both cases the time of counting was ten minutes.

From the results of efficiency calibration between numerical and experimental method we can note that values are quite similar considering the stochastic and systematic uncertainties. As a consequent of the values of the

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Figure 7: Count of background and practical case.

efficiency the activity calculated for the practical case are statistically similar too.

In the practical case the stochastic error is too small because the amount of ^{131}I in the person selected is too high because the activity used in medical treatment was 5 mCi so its only important the systematic component of uncertainty. This fact indicate that the SLCS is reliable to ^{131}I activity measures.

CONCLUSIONS

SLCS for measure of ^{131}I was implemented.

The Efficiency comparison between experimental and numerical method differences are in range of normal systematic and stochastic uncertainties $\approx 5\%$.

Activity Measured in a person with ^{131}I in thyroid for a medical treatment measures with a well established whole body counter and the system proposed results in a similar values with a difference about 5% with 95% confidence, that is an acceptable value considering the uncertainties in the process of measures.

This system could be of great value for observance the regulatory survey of workers in nuclear medicine services in hospitals using equipment generally available in nuclear medical services.

The system is easy to operate for the Safety Radiological Person in Charge to survey the regulatory internal dosimetry.

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