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OVERCOMING THE REFERENCE LARGE-AREA SOURCES NON-UNIFORMITY IN SURFACE AREA MONITOR CALIBRATION

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ABSTRACT

This paper describes a study using MCNP5 simulations, a Monte Carlo based radiation transport code, in order to evaluate the possibility of using reference large-area sources that do not meet the uniformity recommendations of the ISO 8769:2010 in surface contamination monitors calibration. ^{14}C, ^{36}Cl, ^{99}Tc, ^{137}Cs and ^{90}Sr+^{90}Y large area reference sources were simulated as well as the setup and the detector probe. Simulations were carried out for both uniform and non-uniform surface distributions. In the case of uniform distribution, specific weights for each region were considered, as obtained in the uniformity evaluation measurements. To each simulation, it was considered the average number of signals generated in each detector probe, i.e., it was determined the fraction of stories depositing energy in the corresponding gas filled region of the detector. Simulations results show differences in detection efficiency values up to 15%.

1. INTRODUCTION

Nuclear Medicine has been facing a continuous increment on the number of procedures carried out as a larger number of people are having access to its benefits. As a consequence, a larger number of radiation detectors have been acquired by the nuclear medicine clinics, as they consist as one of necessary equipments to perform surface contamination measurements. In order to attend legal requirements, these radiation monitors must be submitted to calibration tests every two years. Standard wide area radiation sources have to be used in order to perform calibration tests.

The standard ISO 8769:2010 [1] is an international protocol which asserts about calibration requirements and recommendations on radiation detector calibration procedures. One of its subjects, deals with the characteristics of the standard calibration sources used in the calibration process. The uniformity of a Class 2 reference source expressed in terms of the standard deviation of the surface emission rates from each individual portion of the whole source shall be no greater than 10 % [1].

However, some recent works [2,3] have found out that the standard wide area radiation sources under use at Instruments Calibration Laboratory at the Instituto de Pesquisas Energéticas e Nucleares (LCI-IPEN/CNEN-SP) do not meet the uniformity criteria stated at this document. It has not been an easy task to cope with this requirement as the sources replacement is difficult, i.e., not only they are made overseas but they are also off the shelf for the last few years. This paper presents a methodology to correct the radiation monitor (pancake type) calibration response considering the wide area radiation source lack of uniformity. This methodology is based on source characterization and simulations, carried out with MCNP5 [4], a Monte Carlo radiation transport code, for all large area β emitting sources used at LCI -IPEN (^{14}C, ^{36}Cl, ^{99}Tc, ^{137}Cs and ^{90}Sr/^{90}Y).

2. MATERIALS AND METHODS

2.1 Source uniformity characterization

The ^{14}C, ^{36}Cl, ^{99}Tc, ^{137}Cs and ^{90}Sr/^{90}Y wide area reference sources used at LCI-IPEN and studied in this work were all manufactured by Amersham & Co and have been undergone calibration tests at DKD-PTB, the German Calibration Office. They all have an aluminum backing with a 10.0 cm × 15.0 cm active area.

A portable monitor FH 40G with a pancake probe FHZ 732 GM were used in all experiments shown in this work. The experimental procedure consisted on the measurement of the equipment count rate during seven minutes for each experimental configuration. It is expect an statistical uncertainty lower than 5% for this time range according to equipment producer [5]. A background evaluation was performed prior to each experiment in order to take into account only the source net response.

An aluminum mask with a 2.5 cm × 2.5 cm square aperture was used to evaluate the large area surface source uniformity under the ISO 8769:2010 criteria. Surface sources distribution was therefore segmented into 24 individual areas (**Figure 1**) and the relative source intensity distribution was carried out by placing the mask on each square segments at a source-detector distance of (3.75 ± 0.25) mm.

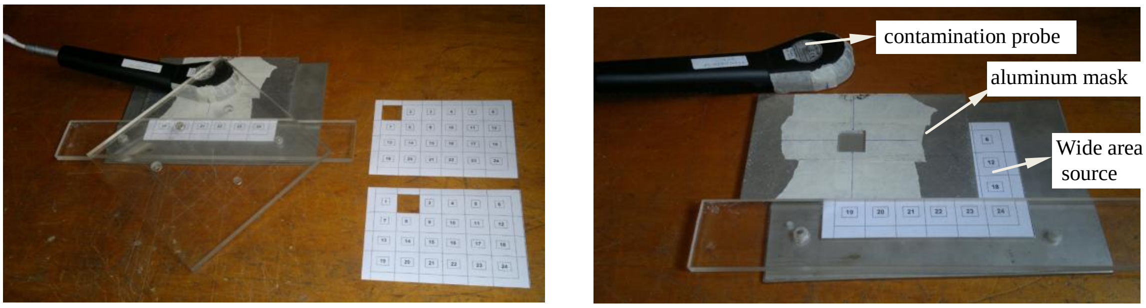
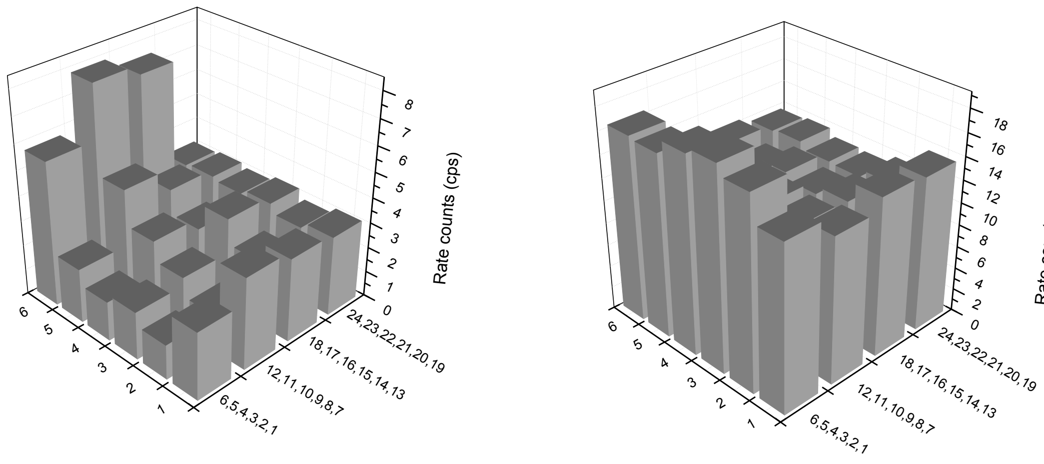
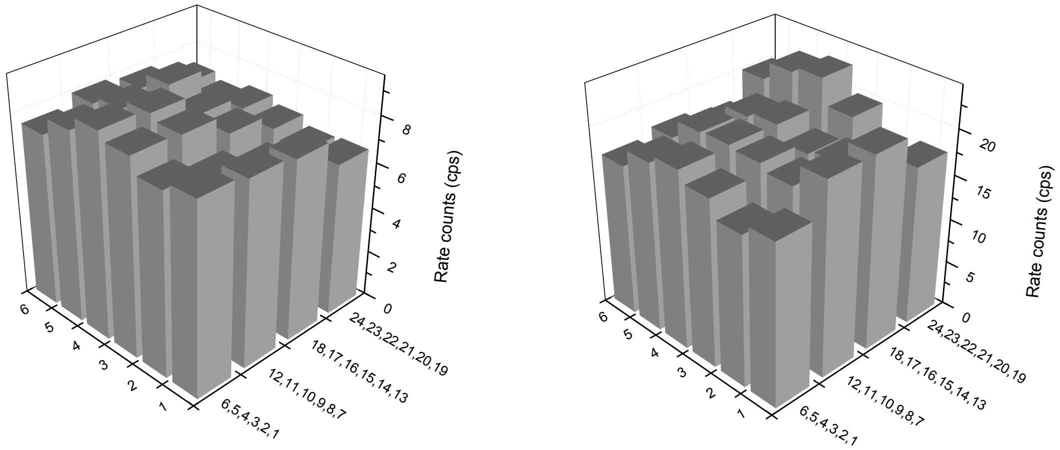


Figure 1: Experimental setup for measuring the count rates for each portion of the surface contamination source.

Figure 2 shows the relative source intensity distributions found for each evaluated source used in this study while Table 1 shows their averages, standard deviations an estimated uniformity, which is given by ratio between the standard deviation and average obtained values.


a) ^{14}C Source

b) ^{36}Cl Source


c) ^{137}Cs Source

d) ^{90}Sr/^{90}Y Source

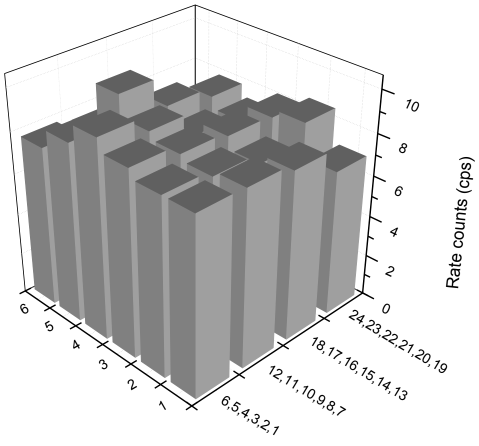

e) ^{99}Tc Source

Figure 2: Experimental relative source intensity distribution: a) ^{14}C; b) ^{38}Cl; c) ^{137}Cs; d)^{90}Sr/^{90}Y and e) ^{99}Tc.

Table 1: LCI –IPEN β sources relative surface intensity distribution.

	^{14}C	^{36}Cl	^{137}Cs	^{90}Sr/^{90}Y	^{99}Tc
Average	3.08 (cps)	12.54 (cps)	7.81 (cps)	19.14 (cps)	8.26 (cps)
Standard deviation	1.64 (cps)	2.08 (cps)	0.69 (cps)	1.69 (cps)	0.76 (cps)
Uniformity	53.3 (%)	16.6 (%)	8.8 (%)	8.8 (%)	9.2 (%)

According to **Table 1**, the source of ^{14}C and ^{36}Cl are not in accordance with the specifications of ISO 8769:2010[1] and is not recommended its use in the calibration process.

2.2 Simulations

The MCNP5 radiation transport code was used to study the influence of the irregular source distribution on monitor response. **Figure 3** presents the simulated geometrical representation of the experimental setup. It was simulated as comprising of an aluminum detector support (1) , detector (2 and 3) and source backing (4) immersed in air (5).

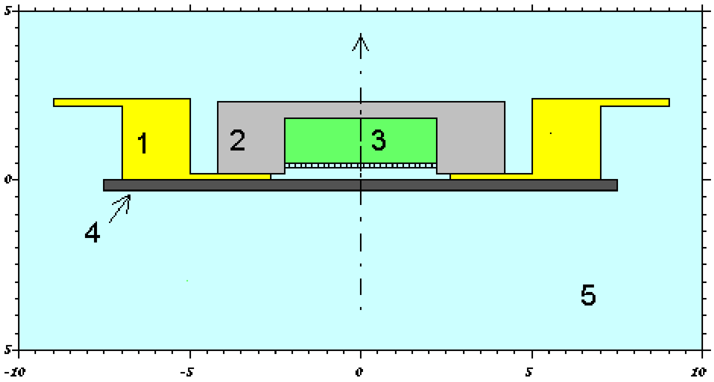


Figure 3: Geometric representation of the simulated system.

The pancake probe FHZ 732 GM was simulated as a cylindrical stainless steel chassis (label 2 in **Figure 3**), with a cylindrical sensitive volume (label 3 in **Figure 3**), limited at its lower face by a thin mica slab followed by a stainless steel thin wire grid.

The source was simulated embracing a 10.0 cm × 15.0 cm area and being uniformly distributed along the outermost 7.067 × 10^{-4} cm depth of the aluminum slab. Beta source energy spectra were driven from Radar [6] and its emission was isotropic.

The count rates were estimated by tallying the histories which led to deposition of any amount of energy at the sensitive volume. It is accomplished in MCNP5 by using the F8 card.

Simulations were validated by comparing the simulated results with experimental results driven from the decrease of detection efficiency with source to detector distance, the **Figure 4** shows a graph of experimental data with dashed line connecting the points to facilitate the visualization of the decrease counts rates, data from simulations behaved similarly experimental.

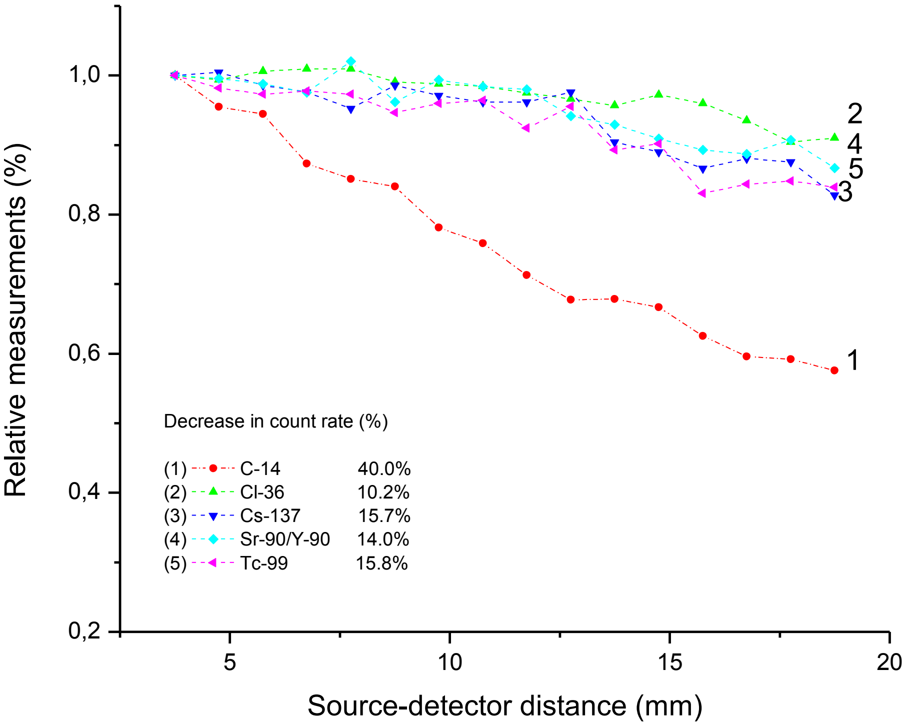


Figure 4: Detection Efficiency dependence on source-detector distance.

Simulations were carried out to evaluate the expected differences on detector responses due to differences in β source superficial distribution. Therefore, two simulations were carried out for each experimental distribution, i.e., one assigning a uniformity source surface distribution along the 10.0 cm × 15.0 cm area and another one described as composed by 24 for uniformity square areas, such as shown in **Figure 1**, whose relative intensities were driven from the experimental data presented in **Figure 2**.

The simulations were setup to run for two hours in each experimental configuration. Although the number of histories has changed with the source mean energy, all tallied results showed statistical uncertainties bellow 0.1%.

Table 2 shows the tallied values obtained for each one of the five studied sources described by the two surface distributions, i.e., the uniformity and the more realistic one.

Table 2: Simulated count efficiency of the LCI –IPEN β sources under 2 source distribution specification

Emitter	**Mean Energy (keV)**	**Source Distribution**		**Difference (%)**
		Uniformity	Non-uniformity	
^{14}C	50	9.663×10^{-3}	8.207×10^{-3}	15.1
^{99}Tc	102	2.194×10^{-2}	2.229×10^{-2}	-1.6
^{137}Cs	177	2.784×10^{-2}	2.901×10^{-2}	-4.2
^{36}Cl	279	3.624×10^{-2}	3.383×10^{-2}	6.6
^{90}Sr/^{90}Y	566	3.938×10^{-2}	3.997×10^{-2}	-1.5

3. CONCLUSIONS

Based on these simulations it is possible conclude that using these β wide area reference sources in calibration procedures can take to the inference of wrong detection efficiencies to the detectors. Response underestimation as large as 15 % shall be observed if it is assumed that the ^{14}C source presents a uniformity superficial distribution.

Evaluation of the source uniformity followed by the application of the present methodology might stand as detector calibration procedure, at least as long as the standard radiation sources which comply with the ISO 8769:2010 criteria.

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