**Management of Co-57 & Ge-68/Ga-68 sealed**

**radioactive sources that are used for**

**calibration of nuclear medicine systems**

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**Abstract**

The aim of this work is to determine the activity of spent sealed radioactive sources of Co-57and Ge-68/Ga-68. Based on Monte Carlo simulation, a semi-empirical method was developed by utilizing the MCNPX code for evaluation of the 3’x3’ NaI(Tl) detector efficiency for specific source– detector geometries. The method proved to be accurate. More specifically, gamma-ray spectrums taken for different time intervals (7h, 2h, 15min for Co-57 and 7h, 1h, 15min for Ge-68/Ga-68) showed that, 2h measurement was adequate for the activity determination of the flood source Co-57, while 1h measurement provided adequate statistics for the activity determination of the line source Ge-68/Ga-68.

## INTRODUCTION

A variety of sealed radioactive sources, such as Co-57 and Ge-68/Ga-68, are used for the precise calibration of nuclear medicine systems. These sources need to be handled and kept into storage until they meet the general clearance criterion, after their useful life. For the experimental determination of the source activity, the detector efficiency should be evaluated for the specific source-detector geometry. In case of complex geometries, Monte Carlo simulation techniques is a common approach to perform the efficiency calibration. In the present study, a semi-empirical method was developed based on Monte Carlo simulation by utilizing the MCNPX code for evaluation of the 3'x3' NaI(Tl) scintillator efficiency for specific source-detector geometries.

More specifically, gamma-ray spectrums were taken by a NaI(Tl) detector for two types of sealed radioactive sources: (a) a flood source containing Co-57; (b) a line source containing Ge-68/Ga-68. For these source-detector geometries and the specific gamma ray energies, simulations were performed with the MCNPX code. The MCNPX models were validated by the use of sources of the mentioned types with certified nominal activities.

## materials and methods

Two different types of sealed radioactive sources were used:

1. a flood source containing Co-57(length 61cm and height 41.9cm) (Fig.1a)
2. a line source containing Ge-68/Ga-68(ceramic, height 16.3cm, radius 0.07cm) (Fig.1b)

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| *Fig. 1a. Experimental setup for Co-57 flood source* *(length 61cm and height 41.9cm)* | *Fig 1b. Experimental setup* *for Ge-68/Ga-68 line source**(ceramic, height 16.3cm, radius 0.07cm), with Pb shielding* |

The sources were placed at such distances from the detector, in order an acceptable dead time (less than 5%) to be achieved. Regarding the source-detector geometry, the flood source (length 61cm and height 41.9cm) was placed at the distance of 47cm from the detector and the detector main axis of symmetry was placed perpendicular to the sources flat surfaces (Fig. 1a). In case of the Ge-68/Ga-68 line source (ceramic, height 16.3cm, radius 0.07cm) a cylindrical Pb shielding (height 37cm, radius 2.85cm, thickness 1.52cm) for radiation protection purposes covers the source (Fig. 1b). Furthermore a Pb cylindrical shielding was placed around the detector to reduce the background radiation (height 18cm, radius 7.5cm, thickness 3.3cm). The shielding of the source was placed at the distance of 25cm from the detector (Fig. 1b).

Gamma-ray spectrums were taken for different acquisition time by the 3'x3' NaI(Tl) detector, using the GenieTM 2000 spectroscopy software for spectrum acquisition [1].

For each one source, several acquisition times were chosen. More specifically, for the Co-57 flood source, acquisition time of 7 hours, 2 hours and 15 min were chosen, while for the Ge-68/Ga-68 line source acquisition time of 7 hours, 1 hour and 15 min were chosen respectively.

The gamma-lines of energy 122 keV (85.6%), 136 keV (10.68%) and 692.03 keV (0.157%) are characteristic of the Co-57 source, while the gamma line of 1077 keV energy (2.93%) is characteristic of the Ge-68/Ga-68 line source [2]. The characteristic gamma ray peaks in the resulted spectra were analysed with the software package SPECTRW [3]. For the Co-57 source, deconvolution of the peak energies 122 keV and 136 keV was carried out by using this software package [3]

For the specific source-detector geometries and gamma ray energies, simulations were performed with the MCNPX code for evaluation of the NaI(Tl) detector efficiencies (Figures 2a, 2b). The MCNPX models were validated by the use of sources of the mentioned types with certified nominal activities.

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| *Fig. 2a. Co-57 flood source MCNPX visualization* | *Fig 2b. Ge-68/Ga-68 line source MCNPX visualization* |

## results and discussion

The results of the study show that the acquisition time of two hours provided adequate statistics for the activity determination of the flood source Co-57 and the determined activity has a deviation of 13,6% from the source nominal activity. In case of the line source Ge-68, one hour measurement was adequate for the activity determination with a deviation of 26,9% from the nominal activity.

 The deviation between the evaluated and nominal activities can be attributed mainly to the 15% uncertainty of the certified sources activities. This deviation is acceptable if we consider the half-life of 0.74 y of Co-57 and Ge-68.

After meeting the general clearance criterion, the sources can be kept in the interim storage additionally for few more months before release from regulatory control. The general clearance criterion for Co-57 is 1 Bq/g and for Ge-68/Ga-68 is 10 Bq/g [5, 6].

The minimum detectable activities (MDA) have been calculated for the specific experimental set-ups. For the Co-57 flood source, the MDA is 1.00 Bq/g, while for the Ge-68/Ga-68 line source the MDA is 812 Bq/g. So, the technique for the clearance of flood sealed radioactive sources of Co-57 is accurate with adequate sensitivity, while for Ge-68/Ga-68 line sources is accurate but the sensitivity needs improvement.

Future clearance measurements for Ge-68/Ga-68 line source are planned, without the source shielding structure in order to achieve higher sensitivity. In addition, positron simulation and use of the annihilation peak will improve the sensitivity of the technique.

## conclusions

Gamma-ray spectrums taken for different time intervals (7h, 2h, 15min for Co-57 and 7h, 1h, 15min for Ge-68/Ga-68) showed that, 2h measurement was adequate for the activity determination of the flood source Co-57, while 1h measurement provided adequate statistics for the activity determination of the line source Ge-68/Ga-68. The deviation from the nominal activity was 13.6% and 26.8% for Co-57 and Ge-68/Ga-68 source respectively and can be interpreted by the 15% uncertainty of the certified sources activities. The sources after meeting the clearance criterion can conservatively be kept in the interim storage additionally for four months before release from regulatory control.

These techniques proved accurate for the clearance of Co-57 and Ge-68/Ga-68 sealed radioactive sources.

References

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