Detector characterization for efficiency calibration in different measurement geometries

M. TOMA[1], L. DINESCU[1], O. SIMA[2]

[1]*Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest, Romania,*
magdalenatoma@yahoo.com
[2]University of Bucharest, Department of Atomic and Nuclear Physics, Bucharest, Romania,
osima@olimp.fiz.infim.ro

Abstract. In order to perform an efficiency calibration for different measurement geometries a good knowledge of the detector characterstics is required. The Monte Carlo simulation program GESPECOR is used. The detector characterization required for Monte Carlo simulation is achieved by a trial and error procedure using the efficiency values measured with point sources placed in several positions.

Key words: gamma spectrometry, detector characterization, efficiency calibration

Detector characterization for efficiency calibration

1. Introduction

The waste characterization is a complex task. The waste is usually not homogeneously placed inside waste drums and afterwards there is little to no information concerning the composition of the waste or its disposal inside the drum. Worldwide to assess this type of waste drums, waste characterization systems are used. Such a system is MADERA, installed in the National Institute for Physics and Nuclear Engineering, Bucharest, Romania. The system has to measure waste drums filled with low to intermediate activity wastes. The uncertainties regarding the inner matrix structure of the drum means that this system (as all the others) will rely heavily on both experimental and Monte-Carlo simulation methods in the effort of describing the matrix effects (3,4) as thoroughly as possible.

The centerpiece of the characterization system MADERA is the HPGe detector. A good knowledge of the parameters describing the detector is always necessary as these parameters greatly influence the results of the study. Although in the detector's technical specification these parameters may be given, they are not always accurate and a supplementary study is required in order to investigate them. Parameters such as the crystal radius and length, the crystal position inside the end cap, the thickness of the germanium dead layer must be known as accurately as possible (1). The *trial and error* method is used in this work to characterize the parameters of the HPGe detector. Experimental results are compared with simulated results and the detector parameters are adjusted for optimal correspondence between the results. To this aim the detection efficiency was invesigated in this study.

2. Experimental measurements

The vertical HPGe detector's characterization was carried out. The detector has 30% relative efficiency and 1.8 keV energy resolution (at 1332 keV).

First, the detector efficiency was determined experimentally, using a point source of [152]Eu that was placed in three geometries:

(a)   rotated around the detector in a vertical plane containing the detector axis of symmetry (see Fig.1). In the vertical plane, the source is moved in steps of 15° from vertical axis to 135°. The source was measured at R=20 cm from detector center.
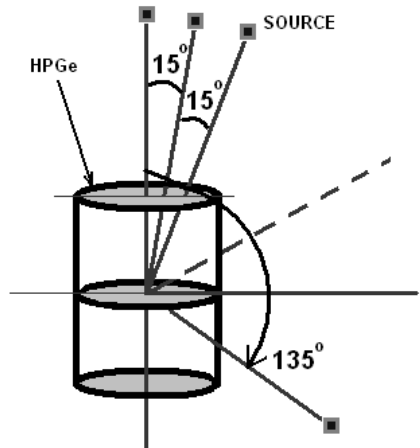
Fig. 1 - Vertical movement of the source around the detector

(b) rotated around the detector in the horizontal plane containing the detector center (see Fig.2). In the horizontal plane, the moving step is 30°. The distance between the detector center and the source was 19.5 cm.

(c) Measurements have been also performed with the point source placed directly on the detector's end cap and at 2 cm above the end cap.

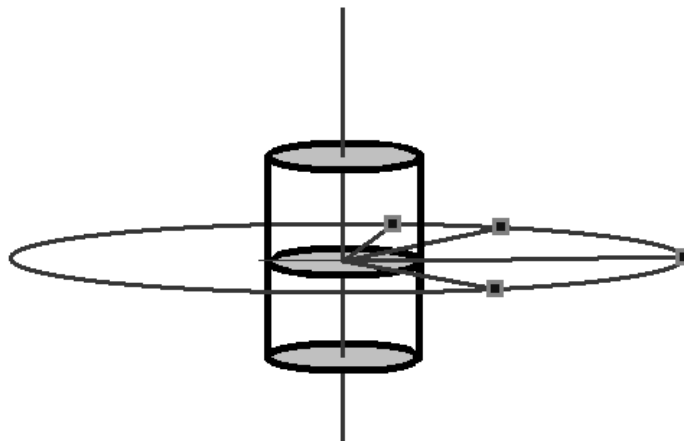In order to perform these measurements, the detector was not collimated.

Fig. 2 - Horizontal movement of the point source around the detector

Three sets of data were collected for each measurement geometry. The peak efficiencies for a set of six representative energies of ^{152}Eu were obtained in each case.

Two [152]Eu point sources were used. For the measurement in the vertical and horizontal plane the activity of the used sources was (50490+1010) Bq. In order to minimize the detector's dead time, for the measurements with the source placed on the detector a different [152]Eu point source was used, having the activity   (2877+58) Bq. In each measurement the dead time correction was smaller than 3%.

3. The Monte-Carlo simulations

The second step consists of Monte - Carlo simulations for the same detector – source geometry. The simulations are performed using the GESPECOR Monte-Carlo simulation software. A set of detector parameters has been considered at the start of the study. The detector efficiency has been calculated again and compared to the experimental results. Then the detector parameters have been adjusted to best fit the experimental data. Some of the obtained results are presented as follows.

From the measurements in the horizontal plane, the cylindrical symmetry of the detector was studied. As it can be seen in the Fig. 3, the detector is symmetrical.
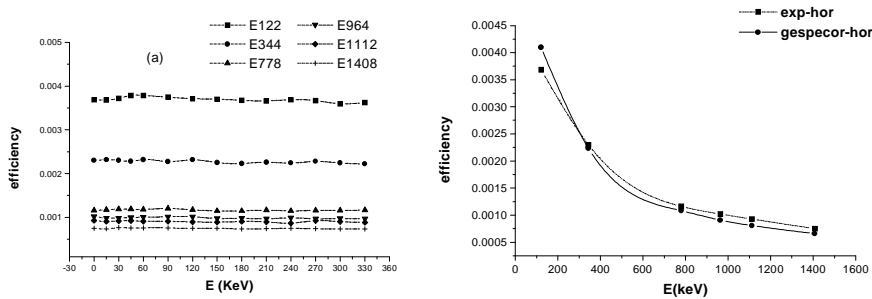

Fig. 3 - The detection efficiency for the point source measured in the horizontal plane
(a) experimental values; (b) comparation with the computed values.

The measurements on the detector and in the vertical plane offer information about various detector parameters. The results in the case of the vertical position of the source (0°) and also in the case of the source measured on the detector's end-cap give us information especially about the detector radius, the distance between the crystal and the end cap and the thickness of the front dead layer (at low energies), because the efficiency is most sensitive to these parameters but it is less sensitive to the length of the crystal.

The results obtained for the 90° position offer information about the length and radius of the crystal, the side dead layer and the details of the detector holder (at low energies).

In Fig. 4, a comparison between the measured and the computed values of the efficiency in the case of vertical geometries is presented.

The experimental values of the efficiency were corrected for coincidence summing effects.
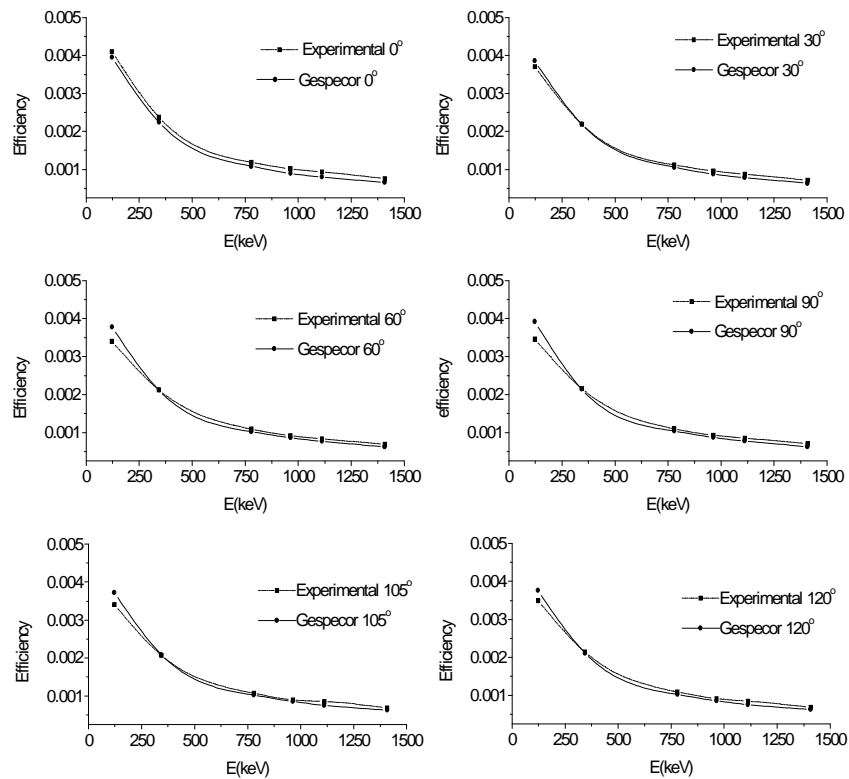
Fig. 4 - A comparison between the measured and the computed values of the efficiency
in the case of measurements in the vertical plane.

As it can be seen the experimental values of the efficiency and the computed ones are in reasonable agreement.

The determined detector parameters will be used to complete the study of the efficiency calibration of gamma spectrommetry system for high volume samples.

4. CONCLUSIONS

When trying to characterize a waste drum one deals with a great number of uncertainties, most notable the waste composition and second the waste disposal inside the drum. This means that the final result will be subjected to a considerable amount of error coming from these uncertainties. All other system parameters must be known as accurately as possible. This study investigated the core of the detection system MADERA, the HPGe detector. Its parameters were found using a *trial and error* method. Experimental measurements of the detection efficiency were conducted and the results compared to similar results obtained by means of Monte-Carlo simulation. The detector parameters were studied and adjusted to best fit the experimental curves, thus finally having an accurate description of the detector. The determined detector parameters will be used in the study of efficiency callibration of gamma spectrometry system for high volume samples.

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