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ON THE EFFICIENCY CALIBRATION FOR DIFFERENT SYSTEMS USED FOR THE ASSAY OF RADIOACTIVE WASTE CONTAINERS*

M. TOMA[1], C. OLTEANU[1], L. DONE[1], F. DRAGOLICI[1], O. SIMA[2]

[1] *"Horia Hulubei" National Institute of Physics and Nuclear Engineering, 407 Atomistilor, Magurele-Bucharest, 077126, Romania, E-mail: magdalenatoma@nipne.ro*
[2] *Physics Department, Bucharest University, 405 Atomistilor, Magurele-Bucharest P.O.Box MG-11, 077125, Romania, E-mail: octaviansima@yahoo.com*

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Abstract. In the characterization of the radioactive waste containers, a reliable non-destructive method is high-resolution gamma spectrometry. However, the non-homogenous composition of the radioactive waste inside the drum makes the quantitative characterization of the radioactive waste drum a difficult task. The efficiency calibration procedure is difficult and dependent on different parameters such as experimental set-up, the sources distribution inside the drum etc. An experimental calibration of the measurement system is difficult and expensive and especially cannot cover all the cases of interest. Experimental studies complemented with Monte Carlo calculations performed for two different measurement geometries are presented in this study.

Key words: gamma spectrometry, efficiency calibration, radioactive waste.

1. INTRODUCTION

Safe management and disposal of radioactive wastes is a problem of outmost importance in our country and in the world, for the safety of radioactive waste management is to protect health and the environment, now and in the future. In order to solve this problem it is necessary to analyze, to classify and to dispose the radioactive wastes. The classification and the disposal solution are based on the information concerning the risk degree of these wastes, which depends on their composition (radionuclides, disintegration type, lifetime, activity) and also on their matrix.

The gamma spectrometry technique [1] is a powerful nondestructive tool used for the radionuclide assay of the radioactive waste containers. An accurate assessment of waste containers requires a proper efficiency calibration of the

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measurement system. The direct experimental calibration is difficult and expensive; it should be carried out with reference sources that have the same geometry and the same matrix with the measured waste container. Furthermore the radionuclides distribution inside a drum is frequently non-homogeneous so an experimental calibration cannot accurately describe all real waste configurations inside the drum. As there are no reference sources with the required properties for direct calibration of the detection system, indirect efficiency calibration using flexible computational methods should be applied to complement experimental calibration [2-4].

In this respect, experimental calibrations of MADERA and Iso-cart systems used for characterisation of radioactive waste drums are presented and test cases are compared with Monte Carlo simulations carried out with GESPECOR software.

2. EXPERIMENTAL SET-UP

Experimental calibration for two waste assay systems was carried out: Madera and Iso-cart.

For the Madera System in the geometry of the experimental setup we used a lead-collimated vertical HPGe detector (Fig. 1), of 30% relative efficiency and 1.8 keV energy resolution (at 1332 keV). The rectangular collimator window has the length 10 cm and the width 4 cm. The lead shield has the inner diameter 9 cm and the wall thickness 4.4 cm. The detector was located at 32.5 cm radially from the surface of the calibration drum.

The Madera system is a fixed-position measurement system and the drum is rotated and translated in front of the HPGe collimated detector, while the measurement is performed.

The measurement geometry for the Madera system is presented in Fig. 1.

Fig. 1 – A schematic representation of the Madera measurement geometry with the calibration drum.

In the case of the Iso-cart System in the geometry of the experimental setup we used a lead-collimated horizontal HPGe detector (Fig. 2), of 40% relative efficiency and 1.9 keV energy resolution (at 1332 keV). The standard collimator is 1.6 cm thick, 20.3 cm long and 11 cm diameter. It is composed of lead with a 2 mm copper liner.

The Iso-cart system is a mobile measurement system and the drum is only rotated in front of the HPGe detector, during the measurement.

For the calibration measurements the detector was located at 100 cm radially from the surface of the calibration drum. At this distance the detector “sees” the entire lenght of the drum.

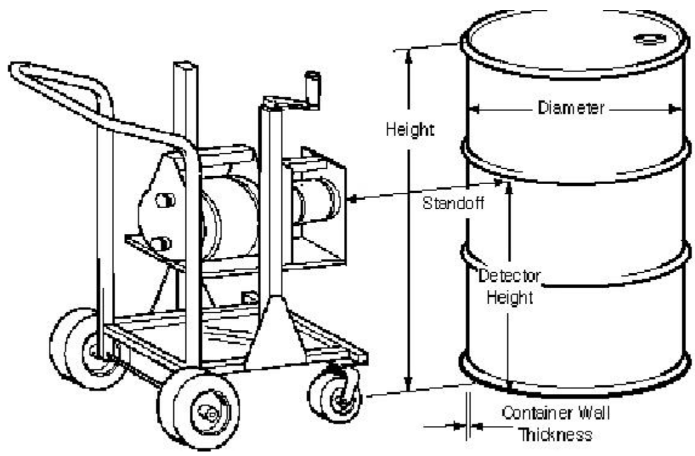

Fig. 2 –A schematic representation of the Iso-cart measurement geometry.

The radioactive waste is generally packed in type A containers (220l drums). For the intermediate and final disposal of medium and low activity radioactive waste, the Romanian law authorizes this kind of packing.

For the efficiency calibration a drum of this type filled with Portland cement and a linear reference source of ^{152}Eu were used. The calibration drum and the reference source were described elsewhere [5-8].

3. EXPERIMENTAL RESULTS

The efficiency calibration for a uniformly distributed radioactive waste was performed using the shell-sources method [9, 2-4]. This method provides the efficiency values for the case when only a part of the drum, namely a cylinder of radius *x*, coaxial with the drum, contains radioactive sources. In Fig. 3 the corresponding efficiencies are presented for several values of *x*. From this figure it can be observed that for a source distributed in the entire volume of the drum, the calibration curve has a pattern approximately similar to a typical one, obtained in the case of small volume sources. For a source distributed in smaller volumes (cylinders of the same length as the drum, but with the radius *r* smaller than the radius *R* of the drum), the attenuation of gamma rays of low energy in the cement layer is much stronger than that of the high-energy gammas. In this case the low energy photon attenuation in the source overrides the higher intrinsic efficiency for these photons resulting in a smaller efficiency for photon energies that typically are around the maximum of the efficiency curve than for photons of higher energies.

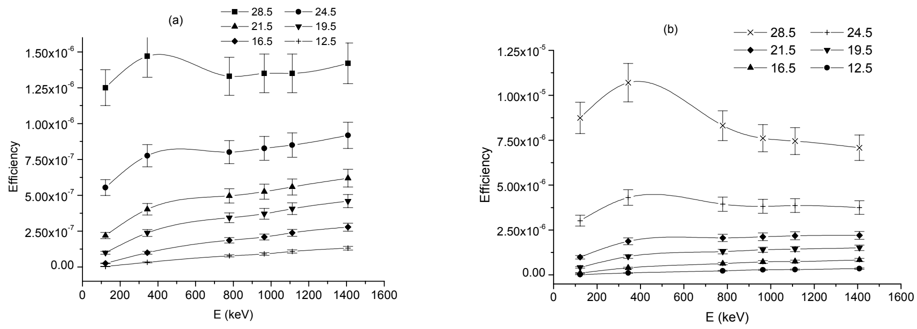

Fig. 3 – The dependence ε = *f (E)* for six waste cylinders having different radii, embedded into the drum in the case of Madera system (a) and Iso-cart system (b).

4. MONTE CARLO CALCULATION

Using the Monte Carlo based software-GESPECOR [10-13] the efficiency values for different geometries were obtained and compared with the experimental values for both measurement systems.

Figs. 4 and 5 display the comparison between the experimental and computed values of the efficiency for two positions of the radioactive source inside the drum: in the center and at $r = 7$ cm from the center for Madera system respectively $r = 12$ cm for Iso-cart system. These values of *r* (7 and 12 cm) were chosen because these are the radii of the cylinders typically used for the insertion of the waste in real conditioning of the radioactive waste.

The comparison between the Monte Carlo results and the measured values indicates that the calculation model is appropriate for the cases presented above. In order to establish its general validity, the sensitivity of the results to various experimental parameters should be studied.

The results for the case of the Madera System are presented in Fig. 4.

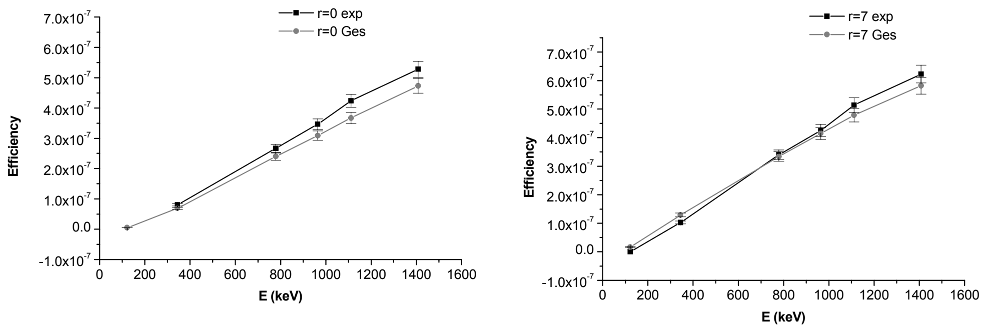

Fig. 4 – The dependence ε = *f (E)* of the computed and the experimental values of the efficiency, for the Linear Source placed at r = 0 and 7 cm from the center for Madera System.

In the case of the Iso-cart system the results are presented in Fig. 5.

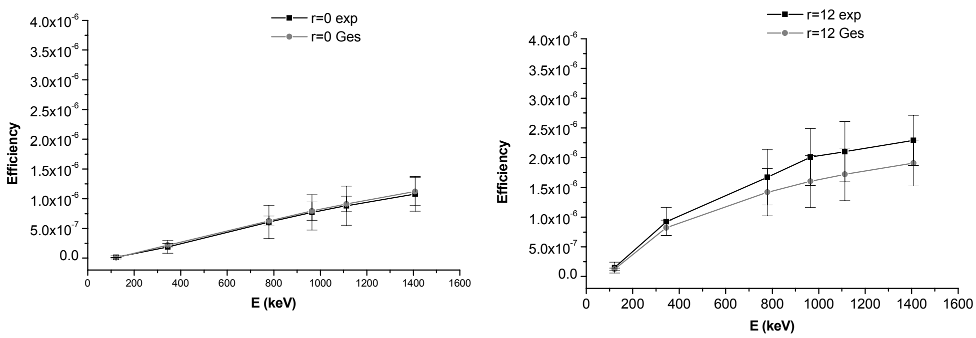

Fig. 5 – The dependence ε = f (E) of the computed and the experimental values of the efficiency, for the Linear Source placed at r = 0 and 12 cm from the center for Iso-cart system.

5. SUMMARY AND CONCLUSIONS

The efficiency calibration for a uniformly distributed radioactive waste was performed using the shell-sources method for two waste assay systems: Madera and Iso-cart

Using Monte Carlo software the efficiency values for different geometries were obtained and compared with the experimental values. The computed and the experimental values of the efficiency are in close agreement.

The comparison between the computed and the measured values of the efficiency represents a validation of the Monte Carlo method. This encourages us to use Monte-Carlo calculations in situations which are not accessible experimentally, such as efficiency calibration for different matrix density, for different positions of a radioactive source inside the drum etc.

The work is in progress.

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