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MONTE CARLO METHOD TO CHARACTERIZE RADIOACTIVE WASTE DRUMS

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ABSTRACT

Non-destructive methods for radioactive waste drums characterization have being developed in the Waste Management Department (GRR) at Nuclear and Energy Research Institute IPEN. This study was conducted as part of the radioactive wastes characterization program in order to meet specifications and acceptance criteria for final disposal imposed by regulatory control by gamma spectrometry. One of the main difficulties in the detectors calibration process is to obtain the counting efficiencies that can be solved by the use of mathematical techniques. The aim of this work was to develop a methodology to characterize drums using gamma spectrometry and Monte Carlo method. Monte Carlo is a widely used mathematical technique, which simulates the radiation transport in the medium, thus obtaining the efficiencies calibration of the detector. The equipment used in this work is a heavily shielded Hyperpure Germanium (HPGe) detector coupled with an electronic setup composed of high voltage source, amplifier and multiport multichannel analyzer and MCNP software for Monte Carlo simulation. The developing of this methodology will allow the characterization of solid radioactive wastes packed in drums and stored at GRR.

1. INTRODUCTION

Non-destructive methods for radioactive waste drums characterization have being developed in the Waste Management Department (GRR) at the Nuclear and Energy Research Institute IPEN. This study was carried out as part of the radioactive waste characterization program in order to meet specifications and acceptance criteria for the final disposal imposed by regulatory control[1]. The laboratory has developed a methodology for characterization of radioactive waste drums using artificial neural networks [2]. Among the various steps that comprise the management of radioactive waste, the characterization is one that produces information about the physical, chemical, and radiological characteristics of the radioactive waste. One of the main difficulties in the detectors calibration process is the counting efficiencies determination, which are related to different parameters and to solve this problem the mathematical technics is used. One of these techniques that have been widely used is the Monte Carlo method [3], which allows the simulation of complex systems such as the radiation transport in the medium to obtain counting efficiency of the detector. Monte Carlo N-Particle Transport (MCNP) is a software for radiation transport which has libraries of cross-section for neutrons, photons, and electrons. The aim of this work was to develop a methodology to characterize these drums using gamma spectrometry and the Monte Carlo method as a mathematical technique.

2. MATERIALS AND METHODS

Four calibration drums were prepared and filled each one with different materials (compressed paper, water, sand and Portland cement paste) to simulate the compactable radioactive waste drums stored at GRR. The calibration drum was divided into nine regions, called "shells". Then, a 15mm-diameter hole was opened with its length equal to the height of the drum. Finally a radioactive source was inserted in each of the nine shells. The drum was positioned on a platform that allows rotation and vertical movement; this drum will be used for future validation of the simulated method, which was performed using mathematical modeling.

The calibration drum and mixed sources of ^{152}Eu and ^{241}Am are shown in figure-1.

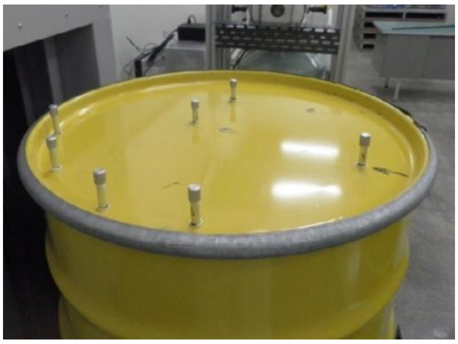

Figure-1: Calibration drum filled with compressed paper positioned on the moving platform and mixed sources of ^{152}Eu and ^{241}Am.

For the simulations mathematical modeling were used to described the system and physical dimensions and composition of all materials of the data acquisition system, including the calibration drum, the mixed source of ^{152}Eu and ^{241}Am, and the detector were taken into account. In this study theoretical count efficiencies were obtained for each of the nine shells in the calibration drum by the MCNP-4C software.

The drum is made of carbon steel, and filled up with compressed paper. The densities are 7.86g/cm^3 for carbon steel, for the compressed paper is 0.5 g/cm^3, for water 1.0 g/cm^3, for sand 1.5 g/cm^3 and for Portland cement paste 2.0 g/cm^3. The table-1 shows the drum dimensions.

Table-1: Drum dimensions.

Height	**86 cm**
External radius	**28 cm**
Wall thickness	**0.1125 cm**
Cover thickness	**0.1125 cm**
Base thickness	**0.1125 cm**

The detector has a germanium crystal surrounded by two layers of aluminum; it was modeled according to the manufacturer's specifications. The germanium crystal density is 5.36g/cm^3 and the aluminum density is 2.7g/cm^3. The detector dimensions are shown in table-2.

Table-2: detector dimensions.

Detector	Radius(cm)	Height(cm)	Thickness(cm)
Ge crystal	**2.59**	**3.6**	**-**
Cristal cavity	**0.6**	**1.6**	**-**
1st aluminum layer	**2.67**	**3.6**	**0.08**
2nd aluminum layer	**3.5**	**3.6**	**0.1**

Figure-2 shows the geometric description of the detector as seen by MCNP code

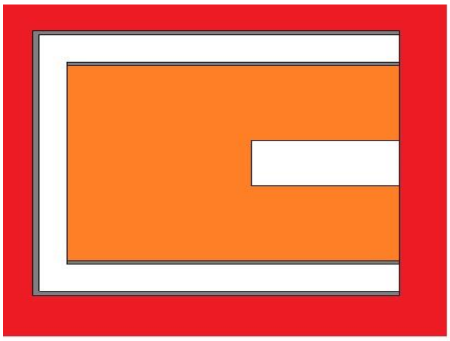

Figure-2: Lateral view of the detector. Orange color: Ge crystal; grey color: aluminum; white color: vacuum; red color: air.

The geometric description of the experimental arrangement after modeled by MCNP code is shown in figure-3.

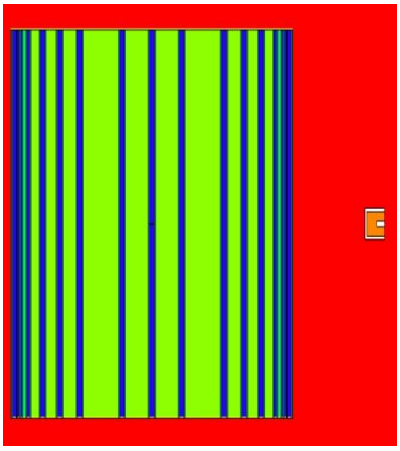

Figure-3: Longitudinal view of the complete experimental setup, showing the position of the detector and location of radioactive sources. Orange color: Ge crystal; grey color: aluminum; white color: vacuum; red color: air; blue color: mixed source of ^{152}Eu and ^{241}Am; green color: compressed paper.

The experimental setup consists of a 200L drum, a radioactive source mixed ^{152}Eu and ^{241}Am, positioned in determined regions of the drum and an HPGe detector. Table-3 and figure 4 show the position of each source and their respective radius.

Table-3: Radius in cm for the nine shells that divide the drum.

Shell-1	Shell-2	Shell-3	Shell-4	Shell-5	Shell-6	Shell-7	Shell-8	Shell-9
0.0	5.9	14.3	18.3	21.7	24.7	25.5	26.2	27.3

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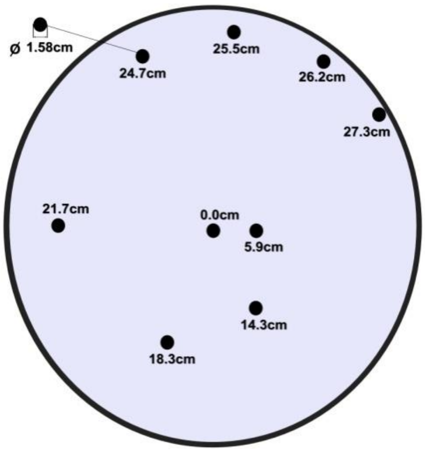

Figure-4: Top view of the drum indicating the position of the sources

In this study two parameters were analyzed: the material density (0.5 g/cm^3, 1.0 g/cm^3, 1.5 g/cm^3 and 2.0 g/cm^3) inside the drum and the detector distance (15cm, 50cm and 100cm) from the drum.

3. RESULTS

The efficiencies obtained for the distance of 15 cm are shown in figure 4.

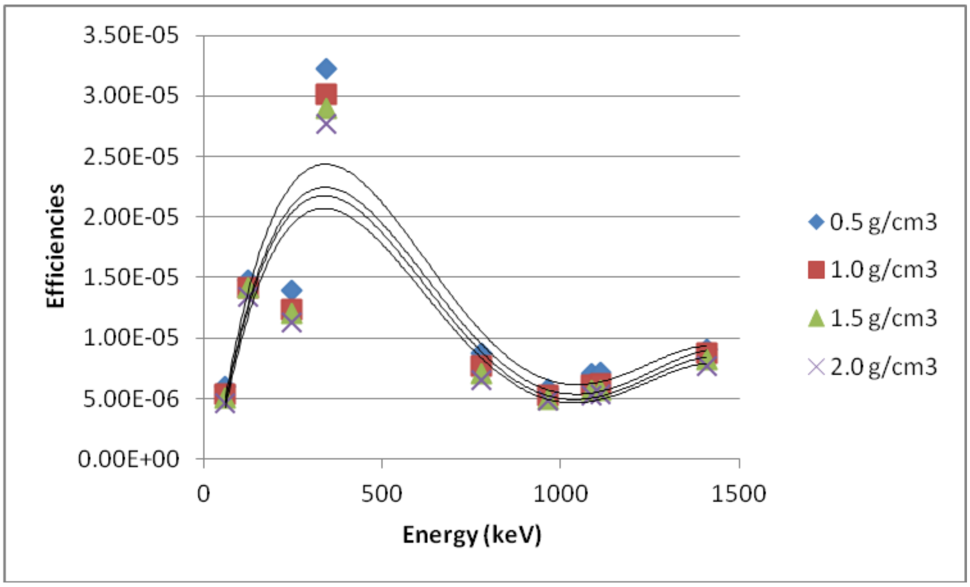

Figure-4: Distribution of efficiencies as a function of densities.

The efficiency curve keeps the same behavior even varying the densities.

The efficiencies obtained for the distance of 50 cm are shown in figure-5.

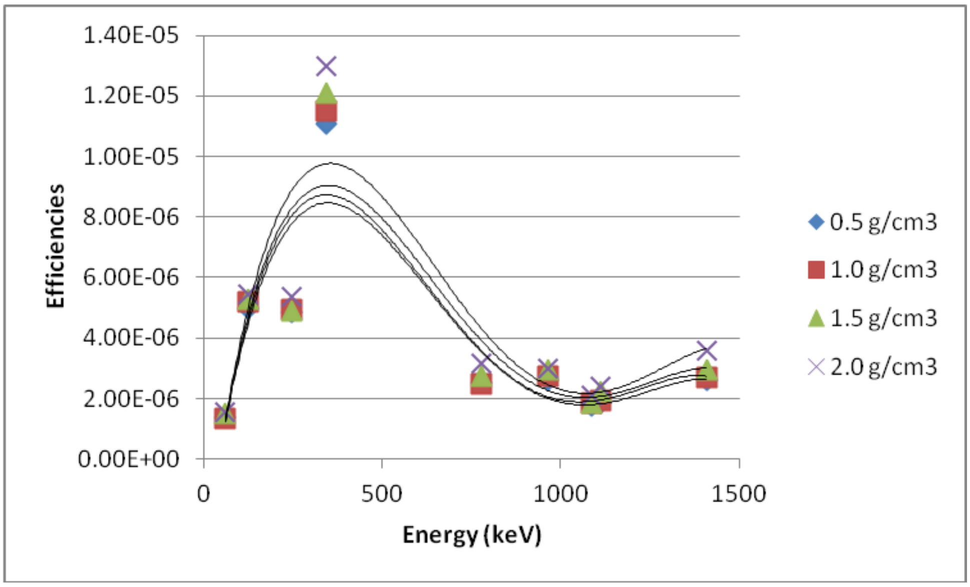

Figure-5: Distribution of efficiencies as a function of densities.

The efficiency curve keeps the same behavior even varying the densities.

The efficiencies obtained for the distance of 100 cm are shown in figure-6.

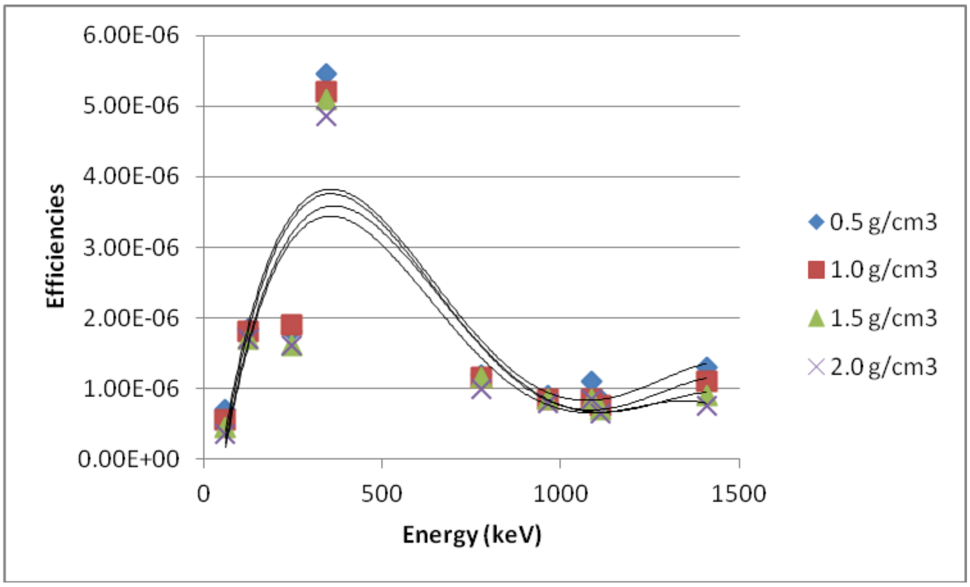

Figure-6: Distribution of efficiencies as a function of densities.

The efficiency curve keeps the same behavior even varying the densities.

It was observed that the counting efficiency decreases when the detector is positioned furthest positions in relation to radioactive source.

The best performance was observed by positioning the detector at 15 cm distance of the source.

4. CONCLUSIONS

With the results obtained varying the drum density and the relative position between the radioactive waste drum and the detector is possible to understand the behavior of the efficiency curves for different geometry measures. This technique allows the characterization of the radioactive waste drums stored in GRR for different categories.

ACKNOWLEDGMENTS

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