EFFICIENCY CALIBRATION OF A GAMMA SPECTROMETRY MEASUREMENT SYSTEM

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This study validates two methods used for full-energy peak efficiency calibration of a device developed by ENVINET a.s. The device is based on gamma spectrometry. The device is designed to determine activity in a drum with radioactive waste in various matrices.

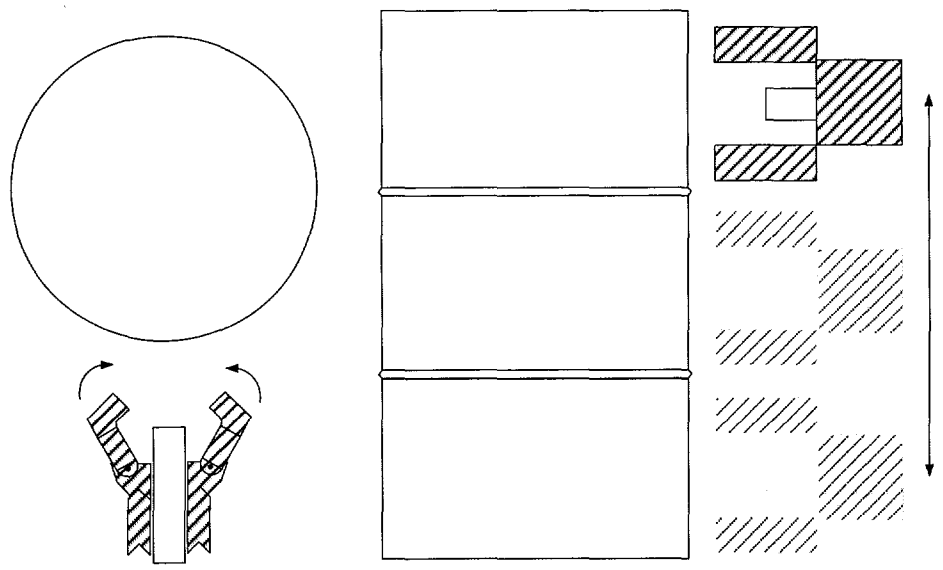
The full-energy peak efficiency is the ratio between the number of counts detected in net peak area to the number of photons of given energy emmited from the drum. The calibration has to be performed for various types of matrices and for homogenously distributed activity in the volume.

A special drum which allows validation of calibration methods described in section B was developed. The first method is based on Monte Carlo simulation of the whole system. The second method is called shell-method and is based on line source which is placed to various positions in the drum which is rotated during the acquisition. The summed spectrum from all positions is used for calibration so that the detector sees activity as homogenously spread in a volume.

A) DESCRIPTION OF SPECTROMETRY SYSTEM

The device contains one ORTEC® GEM HPGe detector of 40% relative efficiency and a special collimator with adjustable field of view to perform measurement in a wide range of activities. The drum is scanned in three positions to determine the intensity of emmited radiation along its height. Schematic view of the detector is in the Fig. 1.

Fig. 1: Schematic view of the gamma spectrometry measurement system.



B) CALIBRATION METHODS

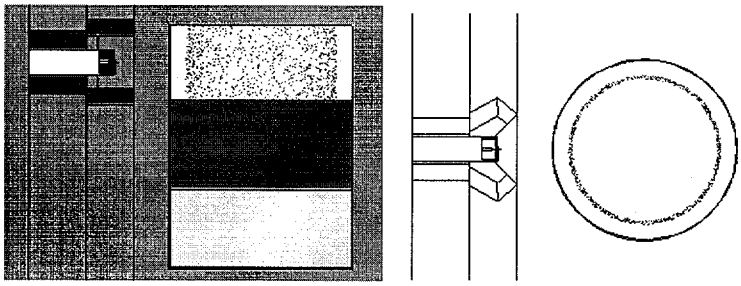
For each field of view one calibration for each matrix has to be done because the geometry changes with each motion of collimator. The following methods have been tested in this study.

1. Monte Carlo Simulation

MCNP Monte Carlo simulation package has been used for the purposes of efficiency calibration of the system. The inputs to the model are precise dimensions of all objects, their densities and kinds of material, a description of the source (it means energy, spatial and angular distribution of emitted photons). The most sensitive inputs to the model are precise dimensions and inner structure of the HPGe detector, which were kindly provided by the manufacturers.

The efficiency curve was counted by means of tally 8 which is used in MCNP to score counts created in the crystal per one primary particle. The simulation was performed separately for each energy. Schematic arrangement of the model is in Fig 2.

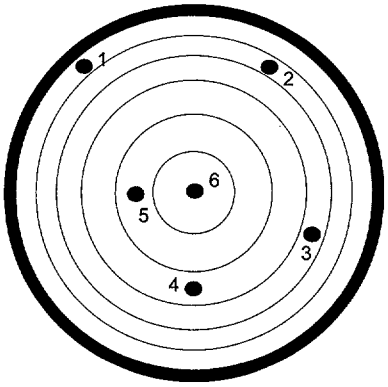
Fig. 2: MCNP model visualisation.



2. Shell-method

Shell-method requires to develop a calibration drum loaded with material as the matrix has. The matrix is divided into 6 shells of equal volume. A set of hollow tubes are mounted in the matrix in order to allow a calibration line source to be placed inside them. The source tubes extend the full height of the matrix, and are mounted parallel to the center of the axis of the drum at the positions shown in Figure 3.

Fig. 3: Cross section of the drum used for shell method of calibration.

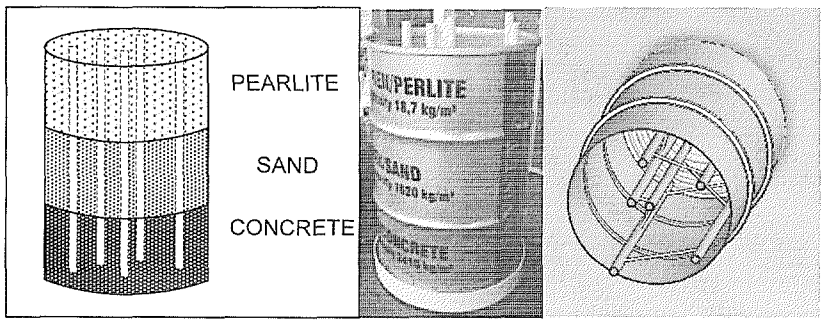


The drum has to be placed on the turntable platform and rotated at constant speed during an acquisition. The axis of rotation is perpendicular to the axis of the system. In this case a line geometry source (with equal activity per unit length) position in a source tube provides counting results equivalent to a cylindrical shell-geometry source with the same radial distance from the center axis of the drum. Spectrum is acquired from each position after equal number of rotation. If these spectra are summed, homogeneous source distribution throughout the matrix is seen by the detector. And the activity of the drum is 6 times the activity of the line source. Mixed radionuclide source containing Eu-152 and Cs-137 was used in the experiment.

C) A DRUM DEVELOPED FOR CALIBRATION CHECK

A scheme, photo and model of the calibration check drum is in the Fig. 4. It serves as a model of homogenously distributed matrix within a one third of the drum. There are six tubes mounted to hold a linear source which can be put inside them. The principle of a simulation of homogenously distributed activity is described in chapter B.

Fig. 4: A Scheme, a photo and a model of the calibration check drum.



D) A PROCESS OF VALIDATION DESCRIPTION

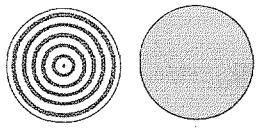
A process of validation of MCNP model included

- spectra acquisition in each material with the source in positions 1 and 6. The live time was set to 180 s.
- full-energy peak efficiency determination by means of appropriate software for each source position and matrix.
- computation of full-energy peak efficiency in the same arrangement as experiment had by means of MCNP software
- comparison of efficiencies

A process of validation of shell-method included

- computation of the efficiency with distribution of activity as the calibration drum has. See Fig. 5
- computation of the efficiency with homogenously distributed activity
- comparison of the results

Fig. 5: Distribution of the activity seen by the detector in case of shell-method and homogenously distributed activity.



E) RESULTS

Fig. 6: Measured and calculated efficiencies in pearlite for the source in position 1 and 6

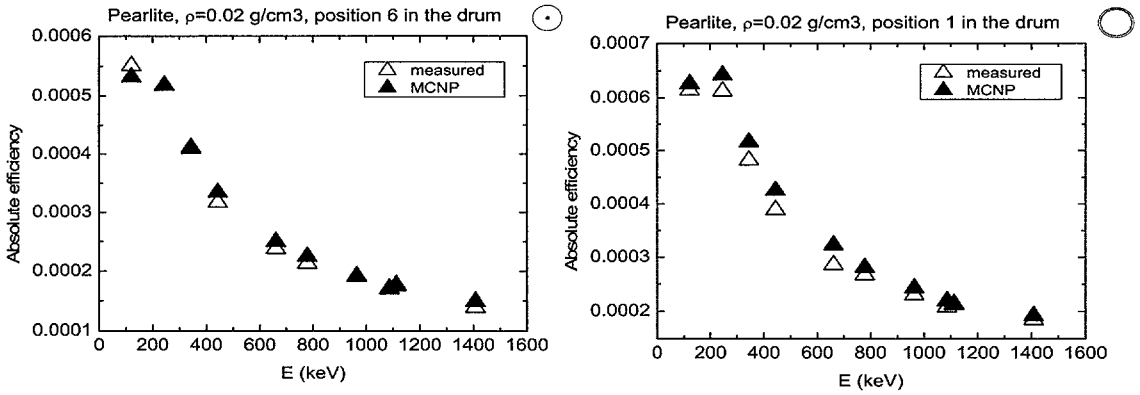


Fig. 7: Measured and calculated efficiencies in sand for the source in position 1 and 6

The discrepancies in position 6 were caused by bad statistics. For better results live time and the number of simulated histories should be increased.

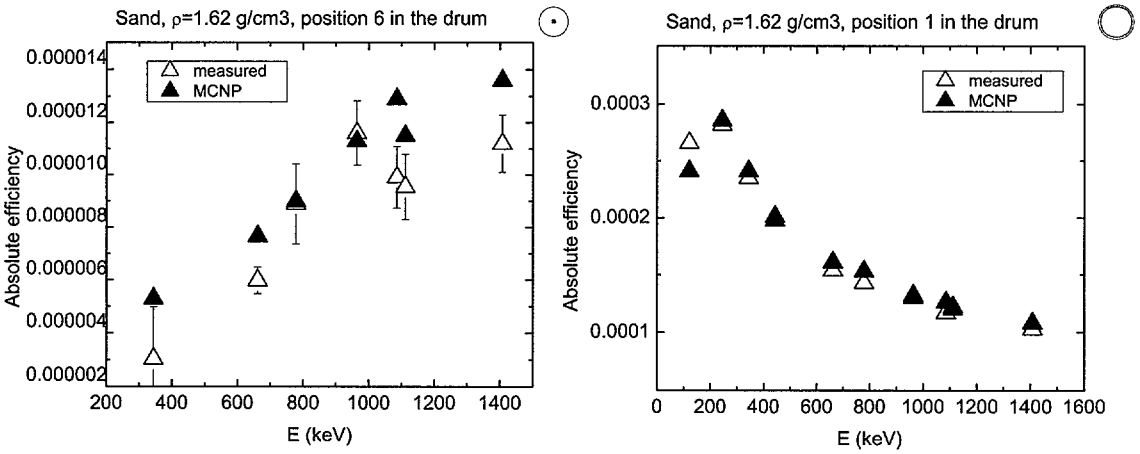
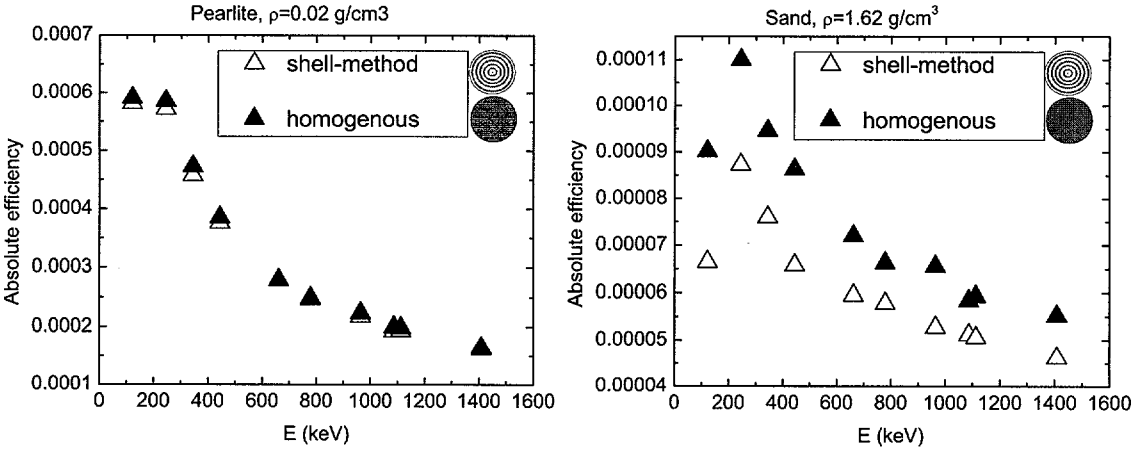


Fig. 8: Shell-method validation – comparison of calculated efficiencies for shell-method and for homogenously distributed activity within the matrix



F) CONCLUSION

The experiment showed that the MCNP model of the detector mounted in collimator in front of the drum with line source in positions 1 and 6 agreed well with the experimental results in

both matrices. The calculations in other matrices haven't been performed yet. A validation of the model with point source should be also performed.

The calculations of shell-methods showed that shell-method was sufficient for matrices of low density. In the case of ρ=0.02 g/cm^3 the discrepancies between homogenously distributed activity were within 3 %. In the case of ρ=1.62 g/cm^3 the shell method overestimates the efficiency over 30 %.

REFERENCES

[1.] M. HARALAMBIE, L. DINESCU, O. SIMA, New data concerning the efficiency calibration of a drum waste assay system Part I: Experimental calibration. Romanian Reports in Physics, Vol. 56, No. 4, (2004) P. 711-720