

Comparison of real and generated by MCNP simulation spectrums for validation of neutron activation calculations



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Scope/ Introduction

One aim of decommissioning planning, is to obtain a radiological understanding of the involved installation. The characterization could be carried out by: (a) neutron activation calculations; (b) dose rate measurements; (c) in-situ gamma spectrometry; (d) sampling for determination of the scaling factors (SF).

Neutron activation calculations contains several uncertainties based on: (a) input data - such as material data (composition and impurities); (b) neutron flux and energy; (c) nuclear data libraries; (d) the methodology of the process and the simulation codes.

This work is focused on the development of a technique for validation of neutron calculations.

A non-destructive gamma spectrometry technique by using MCNP6 simulations is under development for interpretation of the resulting gamma-ray spectra of the radionuclides in activated components. In particular, a spectrum will be produced, based on the activities of the main radionuclides in the activated component and the results of MCNP6 simulations. This spectrum will be compared with the experimental spectrum.

Background

- Many of the important long lived radionuclides in radioactive waste are difficult to measure (DTM) by non-destructive techniques.
- Identification of these DTM nuclides requires radiochemical techniques to separate the various radionuclides for measurement and determination of the SF.
- SF are used for determination of the activities of DTM radionuclides, based on the correlation between easily measurable gamma emitting nuclides (key nuclides) and DTM nuclides.
- The key radionuclides are Co-60 which is an activation product and Cs-137 - a main fission product - which due to its high water solubility is easily transported and settled as surface contamination.
- The spectrum of these two radionuclides as well as of Sr-90 - a fission product and a pure β^- emitter - is generated by the MCNP6 code and compared with the corresponding experimental one.

Materials & Methods

- Bicron Monoline Scintillation detector NaI(Tl) (Model 3M3/3) with a 3" x 3" crystal
- GenieTM 2000 spectroscopy software for spectrum acquisition
- MCNP6 simulation code
- Point source geometry for Co-60, Cs-137 and Sr-90 placed at 15 cm distance in front of the scintillation detector NaI(Tl), on the main axis of symmetry.
- Regarding the simulated spectra, F8 pulse-height tally combined with the “FT8 GEB card” of MCNP6 code is used.
- The Gaussian Energy Broadening (GEB) option defines the energy broadening according to the Gaussian formula:

$$f(E) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(E-E_0)^2}{2\sigma^2}}$$

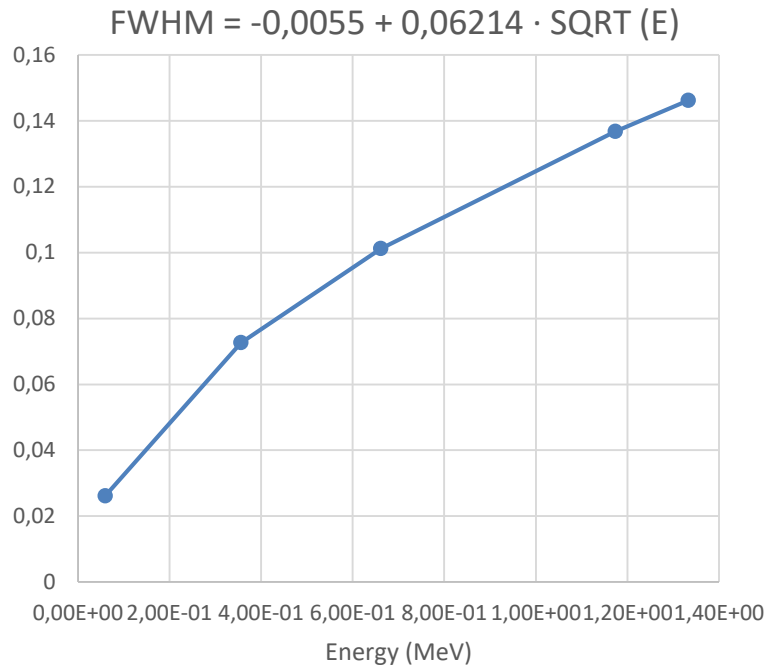
σ : standard deviation depends on $FWHM = 2\sqrt{2 \cdot \ln 2} \cdot \sigma \approx 2,35482 \cdot \sigma$

- FWHM is defined experimentally from $FWHM = a + b\sqrt{E} + cE^2$

A non-linear function adjusted by least-squares procedure is applied to determine the values of a, b and c coefficients (Fig. 1).

The adjustment coefficients of the resolution curve for the Na(Tl) detector were obtained by the method of least squares and the values are $a = -0.0055$ MeV, $b = 0.06214$ MeV^{1/2} and $c = 0$ MeV⁻¹, using data from four radioactive sources of ⁶⁰Co, ¹³⁷Cs, ¹³³Ba, ²⁴¹Am (Table 1).

Materials & Methods



Source	Energy (MeV)	FWHM
Am-241	5.95E-02	0.026139
Ba-133	3.56E-01	0.072639
Cs-137	6.62E-01	0.101197
Co-60	1.17E+00	0.136747
	1.33E+00	0.14613

Table 1. Energy and resolution calibration of NaI scintillation detector

Fig. 1. Function of FWHM for Bicron Monoline scintillation detector NaI(Tl) (Model 3M3/3) with a 3" x 3" crystal.

Results

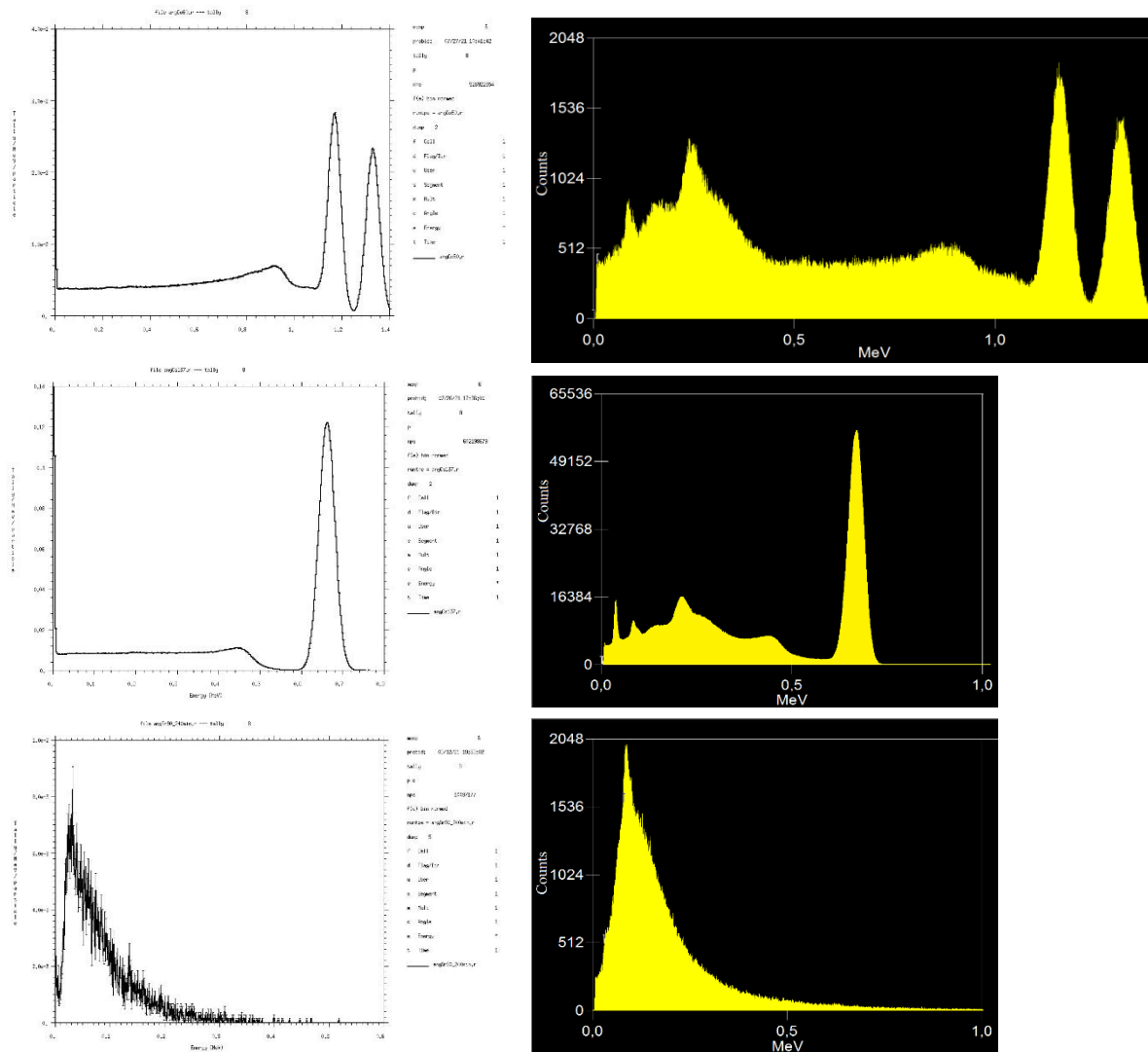


Fig. 2. Comparison between simulated and experimental pulse height distribution to Co-60, Cs-137 and Sr-90 sources.

Results

- The comparison of simulated and the experimental spectrum of ^{60}Co , ^{137}Cs and ^{90}Sr sources shows that they are in perfect agreement (Fig. 2).
- The experimental spectrum at the very low energy in both the Co-60 and Cs-137 spectrum has the same form leading us to the conclusion that the background as well as additional effects of photon collection from the NaI crystal in the real detector are taking place.

Conclusions

- The qualitative agreement between the simulated and experimental spectrums justifies the validity of the simulation results for the radioactive sources.
- The simulated spectrums presented in this work show that not only the gamma peaks are characteristic but also the continuum are representative for each of the radionuclide.
- Radiological characterization of activated components, which appeared with surface contamination, is essential for the decision making process during decommissioning. The cutting techniques in order to reduce the production of secondary waste and limit the doses to personnel and the selection of decontamination techniques should be based on accurate determination of the radionuclides inside the material and/ or in the surface contamination.

The next step includes the quantitative comparison of simulated real spectrums in case of complex geometries of sources with multiple radionuclides.

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