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Validation of the MCNP6 and GEANT4 modeling of the RDS-80A surface contamination meter in with beta emitting sources

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1. Introduction

Geiger counters have been widely used in radiological protection as both external field detectors and surface contamination monitors (SCM). The main reasons for its use are: simplicity, low cost, easy operation and robustness [1].

When used as SCM, it is possible to perform a calibration of these detectors for the radioisotope that will be monitored so that the counting rate (CPS) can be converted into activity per area (Bq.cm^{-2}). Planar sources of pure beta-emitting radioisotopes with different energies such as C-14 (49 keV), Cl-36 (278 keV) and Sr-90/Y-90 (564 keV) are used in these calibrations. It is possible to generate a calibration coefficients (CC) curve as a function of the average energy of the beta particle using these sources. With such curves it is possible to obtain CC for different beta-emitting radioisotopes. However, many radioisotopes are not pure beta emitters and other emission types can be detected, influencing the CC.

An alternative way to obtain calibration coefficients is to use Monte Carlo (MC) codes to simulate the detector and calibration procedure. Various types of detectors have already been modeled for various purposes using MC codes [2]–[4], including Geiger Counters [5].

In this work, the calibration procedure of the RDS-80A surface contamination monitor was modeled on MCNP6 and GEANT4 and the simulated count rates for C-14, Cl-36 and Sr-90/Y-90 planar sources were compared with experimental values.

2. Methodology

Count rate experimental measurements

The SCM RDS-80A (Figure 1A), manufactured by RADOS® was modeled in this study [6]. In the calibration procedure, this type of detector is placed in an acrylic device (Figure 1B) over the planar source so that the distance between the detector surface and the source is 3 mm (Figure 2B). The RDS-80A uses the pancake Geiger Müeller (GM), model 7313, from LND INC. (Figure 1C) [7].

The experimental measurements were carried out with planar sources C-14, Cl-36 and Sr-90/Y-90 produced by Amersham Buchler with activities of 7.89 kBq ± 5%, 5.78 kBq ± 5%, and 2.15 kBq ± 5%, respectively. According to the calibration certificates, the beta emission rate in 2π steradians on the source surfaces is 3010 $\beta.s^{-1}$ ± 5% (C-14), 3650 $\beta.s^{-1}$ ± 5% (Cl-36) and 2710 $\beta.s^{-1}$ ± 5% (Sr-90/Y-90). The count rates, for each source, were obtained as the average of fifteen measurements from two different RDS-80A detectors. The detector's protective grid (Figure 1A) was removed because the grids had different thicknesses witch show a considerable influence on the measured count rates. The count rates obtained were corrected for the detector dead time.

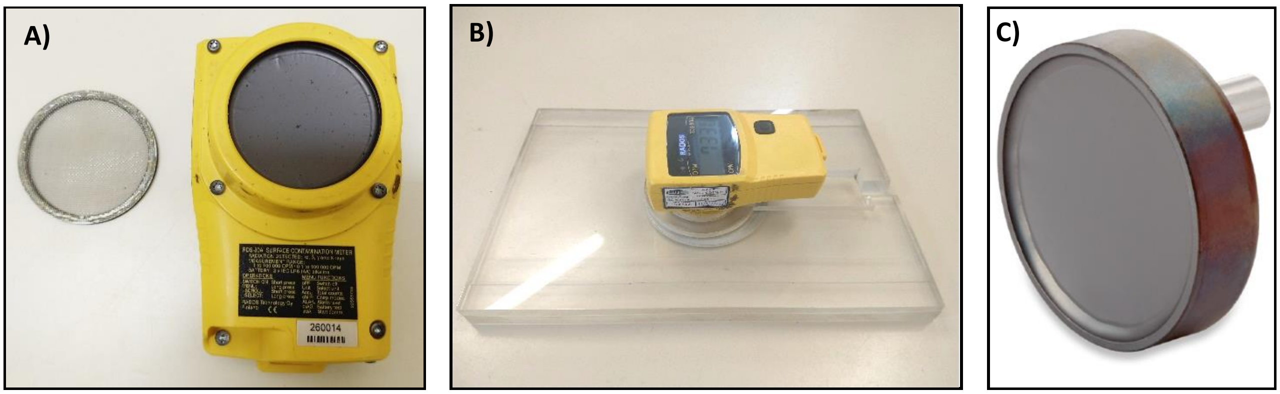

Figure 1: Detector and experimental setup. A) RDS-80A detector with the protective grid removed; B) Acrylic calibration apparatus with planar source; C) Geiger LND Counter – 7313..

MCNP6 modelling.

The MCNP6.1 version was used in the simulations [8]. The Geiger LND 7313 was modeled according to the dimensions and materials informed by the manufacturer. The anode was not included in the simulation. The yellow ABS frame of the RDS-80A was simulated maintaining the distance (9.4 mm) between the sensitive volume and the planar source mimicking the calibration conditions. Details of the geometry are shown in Figure 2. The chemical compositions and densities of the materials were obtained from the Compendium of Material Composition Data for Radiation Transport Modeling [9]. The source was modeled with isotropic emissions in 2π steradians. The beta spectrum of each source was provided by ICRP's DECDATA software [10]. The tally F8:e was used to estimate the number of pulses (counts) detected in the sensitive volume. The histories of 1.0E6 particles (NPS) were followed.

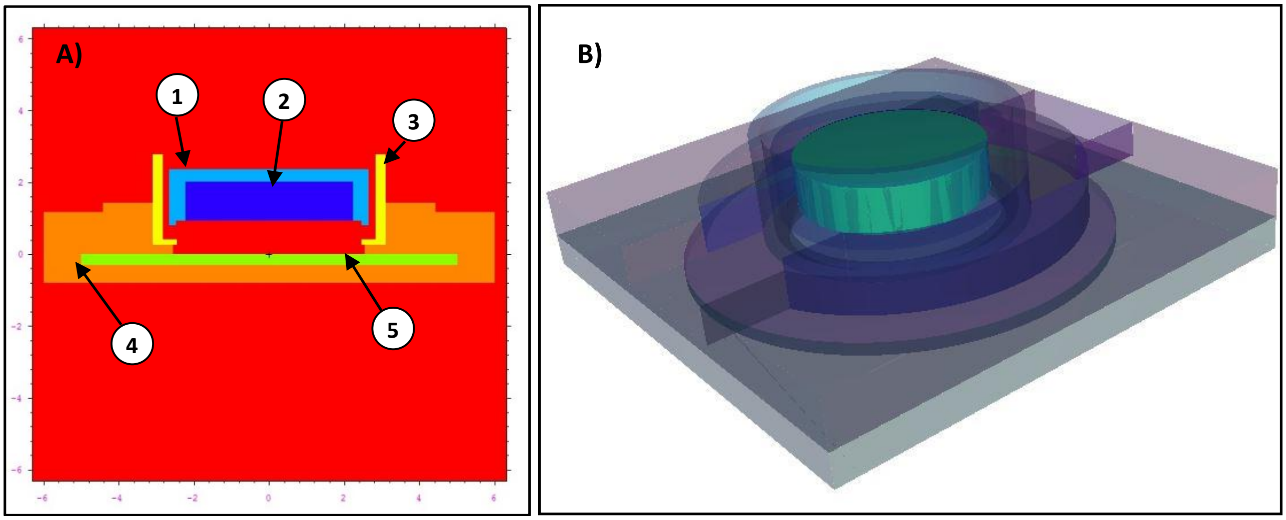

Figure 2: MCNP6 modeling. A) Vised® image of the model in the YZ plane showing: 1) 440 stainless steel cathode; 2) Sensitive volume (Ne/Cl gas); 3) ABS frame; 4) Acrylic calibration apparatus; 5) Planar aluminum source. B) Three-dimensional representation of the model with the GM detector in green.

GEANT4 Modelling

Geant4, version.4.10.07, was also used in the MC simulations, maintaining the geometry setup similar to the experimental conditions and those used at the MCNP6 simulation. The details of the structure simulated in Geant4 can be seen in the Figure 3.

The chemical compositions and densities were obtained, for Geant4, using the database of the National Institute of Standand and Technology (NIST) which is available for the code from the header G4NistManager.hh. The beta sources were simulated using the GeneratePrimaries (G4Event*) method of the G4VUserPrimaryGeneratorAction class. Within this method, the object fparticleGun was created, which was assigned the task of randomly placing the radionuclides in points in the source surface so that they would decay immediately, at each start of the event. The decay of these radionuclides was achieved by including the classes G4DecayPhysics and G4RadioactiveDecayPhysics in the list of Physics which simulations should obey.

The definition of the sensitive volume of the detector was implemented from the definition of the gas volume as fScoringVolume. When a particle (beta, gamma or x-ray) enters this sensitive volume and interacts before leaving, a count is scored. Care was taken in programming the code to avoid accounting for events such as the passage of neutrinos and other particles when they did not interact in the sensitive medium.

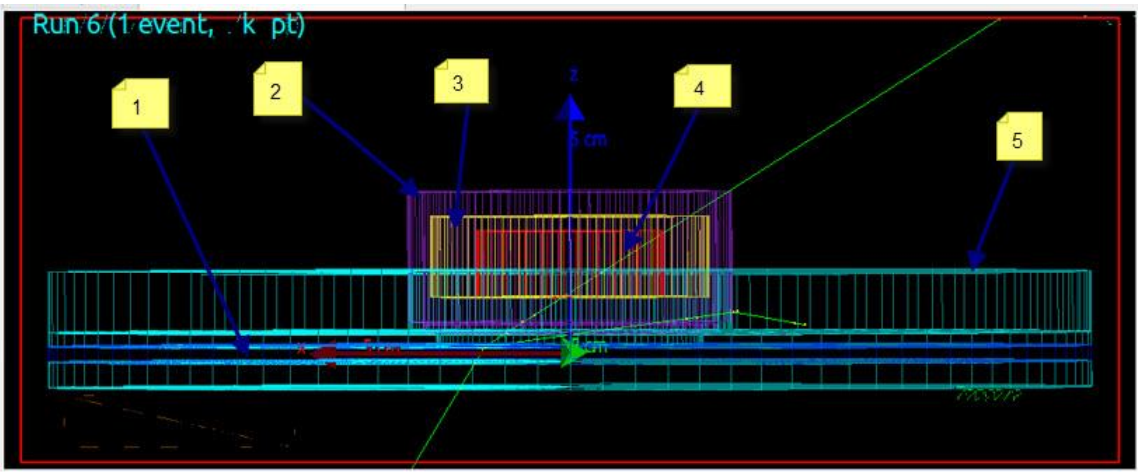

Figure 3 : Geant4 simulation structure - 1) Planar Source; 2) ABS frame; 3) LND Pancake; 4) Sensible volume (Ne/Cl); 5) Acrylic calibration apparatus.

3. Results and Discussion

The count rates obtained experimentally using the RDS-80A detector exposed to planar sources of pure beta emitters were presented in Table 1. In this table, the count rates obtained computationally with the codes MCNP6 and GEANT4 under the same conditions were also presented. Differences in count rates obtained with MCNP6 were less than ± 5%. The Cl-36 source simulation showed the greatest difference -4.3 %. In the cases simulated with GEANT4, the differences in counting rates were presented with a modulus around 15%, with the Sr-90/Y-90 source being the one with the greatest difference (15.4%).

The results show that both codes can be used to simulate the experimental procedures for SCM calibration. New tests will be carried out to evaluate differences in MCNP and GEANT simulations. The planar sources were simulated differently in each code. While in GEANT, the source activity data were used with isotropic emissions, in MCNP, beta 2π steradians emissions data were used.

Table I: Count rate experimentally obtained for beta emitter sources and comparison with MCNP6 and GEANT 4 simulation results.

	Count rate (CPS) in experimental and simulated systems							
Source	Experimental		MCNP6			GEANT4		
	Mean	SD	Mean	SD	% Diff	Mean	SD	%Diff.
C-14	137	7	135	7	-1.3%	124	15	- 10.5%
Cl-36	461	6	442	22	-4.3%	516	33	10.1%
Sr-90/Y-90	175	7	178	9	1.7%	207	24	15.4%

4. Conclusions

The RDS-80A Geiger Muller was modeled with MCNP and GEANT. Experimental measurements validated the simulation results for beta emitting planar sources with different energies. In these preliminary tests MCNP showed better correlation with experimental data than GEANT. However, the source modelling was slightly different.

The validated modeling will be very useful to evaluate uncertainties in the calibration procedure and to define calibration coefficients for different radionuclides.

Future work will focus in the extension of the validation studies to other planar and point sources and in the modelling of the protective steel grid.

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