Monte-Carlo Evaluations for Response of the Gamma-ray Spectrometer with Various Locations on Calibration Pads

Suk-Hoon Kim [a*], Hyeong-Ki Shin [b], Ju-Youl Kim [a]
[a]*FNC Technology, Rm.#312, Bldg.#135, Seoul Nat'l Univ., Daehak-dong, Gwanak-gu, Seoul 151-742, Korea*
[b]*Korea Institute of Nuclear Safety, 34 Gwahak-ro, Yuseong-gu, Daejeon 335-338, Korea*
[*]*Corresponding author: kuni0808@fnctech.com*

1. Introduction

During a radiation emergency, especially due to accidental releases of radionuclides or weapon fallout, it is of prime importance to quickly determine the ground contamination and resulting exposure in planning and taking the necessary measures and controls if required. Up to now, many methods have been developed for the purpose of doing this and aerial gamma spectrometry can be regarded as a very effective method for a rapid survey of large areas which might be possibly contaminated.

Figure 1 shows the airborne gamma-ray spectrometer introduced from Sweden for the purpose of constructing the radiological survey system using aircraft (i.e. fixed-wing or helicopter) in South Korea. A large NaI detector, which has a dimension of 4″x4″x16″ and is frequently used for high efficiency measurements of low level of gamma emitting radioactivity, is employed in the spectrometer.

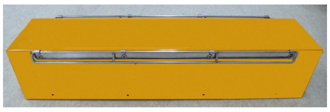

Fig. 1. The spectrometer introduced from Sweden.

This paper describes Monte-Carlo investigations for response of the airborne gamma-ray spectrometer with various locations on transportable concrete pads.

2. Methods and Results

2.1 Transportable Concrete Pads

Set of transportable concrete pads, which is used for calibrating portable gamma-ray spectrometers, usually consists of a low radioactivity background pad and three pads of radioelements (i.e. K, U, and Th) with known concentrations. They are used to derive the calibration constants for converting the count rates in the K-, U-, and Th-windows to ground concentration of each radioelement. Each pad that has a dimension of 1m x 1m x 30cm and made of typical concrete of density 2.25g/cm^3 will weigh 675kg.[1]

In calibrating a spectrometer with small transportable pads, the count rates will vary with positions of the detector even though the pads are homogeneous. For example, near the edge of the pads, it is presumed that the counts will be decreased due to the reduced volume viewed by the spectrometer.

The window count rates affect the accuracy of the calibration constants. Therefore, it is important to assess response variation of the spectrometer with various locations on the pads.

2.2 Computer Code System

Responses of the spectrometer with various locations on the pads were simulated using MCNP5, which has been one of the most commonly used codes for radiation transport analyses. This code has proved to be very effective in modeling the detector response providing that the detection system can be simulated accurately.[2]

In this work, responses for the combination (i.e. 18 cases) of the following variables were simulated.

- Type of source: Volume (uniformly distributed in each pad)
- Photon energy emitted
  - from K-pad: 1.460MeV
  - from U-pad: 1.764MeV(This is owing to ^{214}Bi, which is a daughter product in the ^{238}U decay series)
  - from Th-pad: 2.615MeV(This is owing to ^{208}Tl, which is a daughter product in the ^{232}Th decay series)
- Gap between centerline of a pad and spectrometer: 0, 10, 20, 30, 40, diagonal (Refer to Figure 2.)

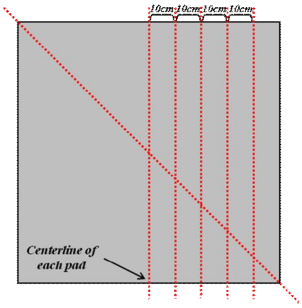

Fig. 2. Simulated locations of the spectrometer on each pad.

2.3 Geometry Modeling

Figure 3 shows a representative geometry of the spectrometer on each pad that was modeled. Some reasonable assumptions were introduced due to limited information on detailed specification of the spectrometer and transportable pads.

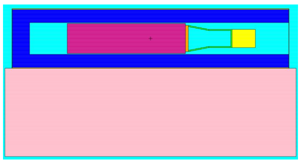

Fig. 3. A representative MCNP modeling for the spectrometer on a calibration pad (Vertical cut).

2.4 Material Compositions and Cross-section Library

In order to simulate the detector response more realistically, it is necessary to input the elemental composition and density of each material more accurately – i.e. NaI crystal, optical window, PMT, metal shield, filling, housing, concrete, and etc. Detailed information used (including some assumptions) is omitted in this paper.

Among four photon libraries and two electron libraries basically provided in MCNP, 'MCPLIB04' and 'EL03' were applied for photons and electrons, respectively.

2.5 Tally

Each response was simulated by performing a photon-electron transport calculation using F8 (especially called 'pulse-height') tally which could provide the energy distribution of pulses created in a cell that models a physical detector by radiation.

The energy deposition was evaluated for the standard spectral windows shown in Table I which are particularly sensitive to energies associated with potassium, or the uranium or thorium decay series. These energy boundaries of windows conform to those recommended by the IAEA (International Atomic Energy Agency).[3]

Table I: Standard spectral windows applied to this work.

Window	Energy[keV]	Major Peak[keV]	Nuclide
Potassium	1370~1570	1460	^{40}K
Uranium	1660~1860	1765	^{214}Bi
Thorium	2410~2810	2614	^{208}Tl

The number of particle history (i.e. 'nps' variable in MCNP) set to be fairly large to achieve a statistically reasonable and accurate result. For each run, statistical behavior of the result was assessed by checking the associated tables in the tally fluctuation chart bin.

2.5 Variance reduction technique

In all cases simulated, source biasing was applied, which is the only variance reduction technique allowed with F8 tallies having energy bins in the present version (i.e. v5.1.40) of MCNP. It allows the production of more source particles, with suitably reduced weights not to distort score of each particle, in preferred directions, generally towards tally regions.

2.6 Results

As previously stated, responses of the spectrometer were simulated for directionally biased particles emitted from a volume source that had a discrete photon energy.

Figure 4 provides the response variation of the specific windows for each radioelement with various locations of the spectrometer on each pad. The values on y-axis are normalized for a source particle.

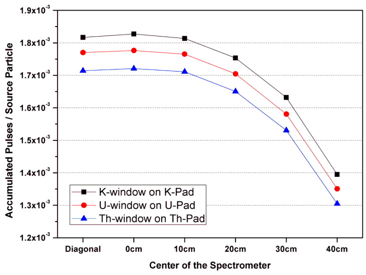

Fig. 4. Response variation of the specific windows with various locations of the spectrometer on each pad.

3. Conclusions

In this paper, responses of the spectrometer with various locations on the pads were simulated using MCNP5. These results normalized into a source particle are shown in Figure 4.

From this figure, it is found that the maximum value of window responses appears when the spectrometer is horizontally placed in the very center of each pad and the response is rapidly decreased as the gap between centerlines exceeds more than 10cm. As above mentioned, it is presumed that this is due to the reduced volume viewed by the spectrometer.

It is obvious that the time required for acquiring the reliable data is reduced as the count rates is increased. According to these results, it is judged that it is desirable to place the spectrometer on the center of each pad for calibrating the spectrometer and deriving the calibration constants.

REFERENCES

[1] R.L. Grasty, P.B. Holman, and Y.B. Blanchard, Transportable Calibration Pads for Ground and Airborne Gamma-ray Spectrometers, Geological Survey of Canada, Paper 90-23, 1991.

[2] MCNP-A General Monte Carlo N Particle Transport Code, Version 5, LA-UR-03-1987, Release 1.40, November 2005.

[3] IAEA, Airborne Gamma Ray Spectrometer Surveying, Technical Report Series, No. 323, International Atomic Energy Agency, Vienna, 1991.