Evaluation on the Counting Efficiency of a Chair-type Whole Body Counter for Accident Monitoring of Internal Contamination

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1. Introduction

Major accidental release of radionuclides has the potential for significant radiation exposure in large populations.[1] Rapid monitoring for internally contaminated people is required in radiation accident. If the release contains radionuclides which emit high energy gamma ray, the most suitable mean of providing this monitoring is Whole Body Counter(WBC).[2] Chair-type WBC is more suitable than other geometry at the scene in the vicinity of radiation accident.[3] Traditionally, BOttle Mannkin ABsorber(BOMAB) phantom has been used for calibration of the WBC.[4,5]

In this study, evaluation on the counting efficiency of the chair-type WBC was performed to effectively calibrate the system. Counting efficiencies were obtained by using Monte Carlo simulation and conventional calibration experiment. It was reported that the purchase and use of a BOMAB phantom family can be both expensive and time consuming.[4] However, Monte Carlo simulation is an alternative to obtain the counting efficiency of the chair-type WBC. The counting efficiency by Monte Carlo simulation was compared with experimental data. The aim of such a comparison is to provide inexpensive alternative for conventional calibration procedure and to develop more convenient and accurate calibration method.

2. Materials and Methods

Our chair-type WBC uses p-type HPGe coaxial detector(CANBERRA Model GC9021). The use of germanium detector has improved the performance of counting system, especially the ability to distinguish among and between gamma rays that have similar energies.[6] Relative efficiency of the HPGe detector compared with a 3×3 inch NaI(Tl) detector is 90%, and measured resolution of the detector is 2.1 keV at the 1,332 keV gamma emission. The germanium crystal is a cylinder of 80 mm in diameter and 63 mm in length.

The single HPGe detector is located in position that the detector centre is 35 cm above the seat of the chair and the front face is 38 cm from the backrest. This position recommended by Youngman can be used for reference adults.[2]

The backrest and the seat of the chair consist of 4 cm lead in thickness. The HPGe detector is covered with the lead of 5 cm thickness. Collimator in front of the detector is also made by lead, and an opening angle of the collimator is 90°. The chair leg and frames of the system were built of steel. The total mass of the system is about 600 kg. Table 1 shows mass of each component.[7,8]

Table 1. Mass of the System Component.

Component	Weight (kg)
Detector Shield	60
Chair Shield	250
Detector and Electronics	20
Body Frames	170
Bottom Frame and Wheels	100
Total	**600**

In order to obtain counting efficiency, Monte Carlo simulation was carried out by using MCNPX code v. 2.5.0.[9] The HPGe detector, lead shields and main body of the WBC were modelled to meet actual characteristics as accurately as possible. The walls of the BOMAB phantom are polyethylene, and its thickness is 0.25cm. A BOMAB phantom consisting of ten elliptical containers was modelled under condition of sitting at the chair. Fig. 1 shows MCNP modeling result of the major components.
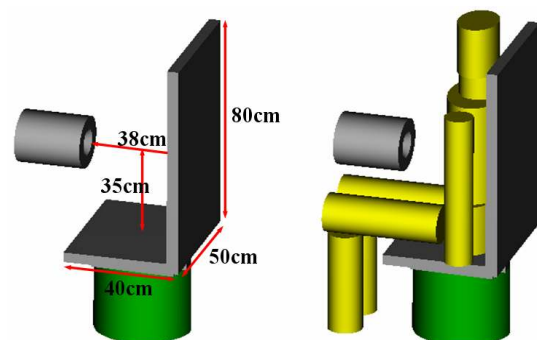

Fig. 1. MCNP Modeling Result of the Major Components

The photon source was assumed to be isotropic, and to be uniformly distributed within the BOMAB phantom. A pulse height tally, which is provided with MCNPX code, was used for calculating counting efficiency in the HPGe detector.[9] Energies simulated were 88, 122, 166, 279,

392, 662, 898, 1,173, 1,332 and 1,836 keV. Each run was mono-energetic, and the number of emitted photons in the simulation was determined to be 10^7 in order to reduce the relative error below 0.05 for all simulations.

The chair-type WBC was calibrated using a BOMAB phantom where the radionuclides were homogenously distributed with 0.1M HCl. ^{57}Co, ^{60}Co, ^{88}Y, ^{109}Cd, ^{113}Sn, ^{137}Cs, ^{139}Ce and ^{203}Hg were included in the standard radionuclides. Counting time was 86,400 seconds to obtain efficiency curve from the measurements. The simulation was benchmarked by measuring counting efficiency through conventional calibration procedure.

3. Results

Simulation result was compared with the experimental data. Counting efficiencies as a function of photon energy under both Monte Carlo simulation and conventional calibration are shown in Fig. 2. The measurements by experiment were much higher than the calculations by simulation result, and ratios of measurement to calibration were 1.08 to 1.12 in the region below 500 keV. On the other hand, in 1,836 keV, the measurement was much lower than the calculation, and ratio was 0.90. In the low energy region, it was inferred that background radiations caused a little difference between the measurements and the calculations. However, it is clear from comparison that efficiency curves are similar in 500 to 1,500 keV, although there are some discrepancies in the other energy regions.
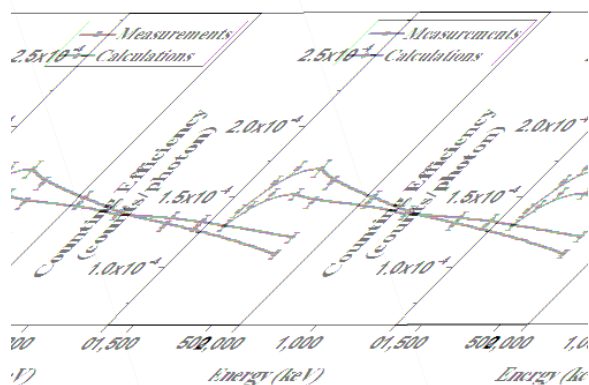

Fig. 2. Counting Efficiencies as a Function of Photon Energy

4. Conclusions

It has been shown that the counting efficiency can be determined by computational calculation. This paper shows that Monte Carlo simulation offer an effective calibration method as an inexpensive alternative. Correction factor in the some energy regions would be employed to obtain more identical efficiency curve between the measurements and the calculations.

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