MDA calculation through Simulation of Sampled Kr-85 using Monte Carlo code MCNP

HaJin Song*, Young Gun Ko, Hyuncheol Kim, Jin Hyung Lee, Jong-Myoung Lim, Wanno Lee
Nuclear Energy & Environment Research Laboratory, Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon 34057, Korea
**hjsong@kaeri.re.kr*

1. Introduction

Basically, some countries measure atmospheric Xenon and Kr-85 in order to confirm nuclear activity. There are generated by nuclear power plants and by nuclear reprocessing [1]. Nuclear reprocessing is the biggest issue in the world. In particular, it can make nuclear weapons. So we need a measurement system to monitor North Korea`s nuclear reprocessing. When measuring Xenon and Kr-85, this radioactive noble gas can be detected by BfS-IAR system [2,3]. This system is most suitable for measuring Xenon and Kr-85. A well-used method is to capture Xenon and Kr-85 in the air. Measure atmospheric radioactive noble gas sampled using a gas proportional counter. The gas proportional counter is used while charging the noble gas shows an efficiency of 70 % [3,4]. However, gas proportional counter has disadvantages. First, in order to measure, the operator must constantly add P-10 gas. Second, the sample should be left for the sake of certainty, but the carrier gas and the P-10 gas are mixed and the sample becomes uncertain. Therefore, in this paper, we want to develop a new detector than gas proportional counter to overcome the disadvantages. Monte Carlo code MCNP 6.2.1 version simulation was used to design the plastic scintillator. Measurements were made to determine if Kr-85 in a volumetric scintillator vessel is measured on a 0.5 cm thick plastic scintillator. And we calculated the incident rate of radiation by changing the condition of the detector. The plastic scintillator is with a diameter of 5.08 cm, a thickness of 0.5 cm and a density of 1.032 g/cm^3. MDA(minimum detectable amount of activity) was calculated using the simulation values. In the whole system, the sampling amount of Kr-85 is known. This equation is the Currie expression [5]. When measuring Kr-85, which is a low-level sample, close to the background level. It is necessary to judge whether the coefficient is due to background fluctuation or whether there is a significant difference from the background. Background measurement time is not suitable for monitoring if it is the same as sample measurement time. So we set the background measurement time to 3 hours.

2. Methods

Monte Carlo code MCNP 6.2.1 was used. It can be applied for neutron, photon, electron, coupled neutron, coupled photon, coupled electron transport [Polo et al., 2018]. Geometry was constructed with a plastic scintillator with a diameter of 5.08 cm, a thickness of 0.5 cm, and a density of 1.032 g/cm3. The volume of collected Kr-85 was increased to set the collection vessels to 0.5, 1, 1.5, 2, 2.5 and 3 cm in thickness. So each volume was 11.53, 23.06, 34.59, 46.12, 57.65 and 69.18 cm3. The information on the source of the data card was inputted on the former of the Kr-85. The reason was set by judging that only krypton is collected in the sampling method. The energy cut-off less than 50 keV. The efficiency of the detector was determined using the emission probability between 50 and 700 keV. The detector is constructed as show in Fig. 1.

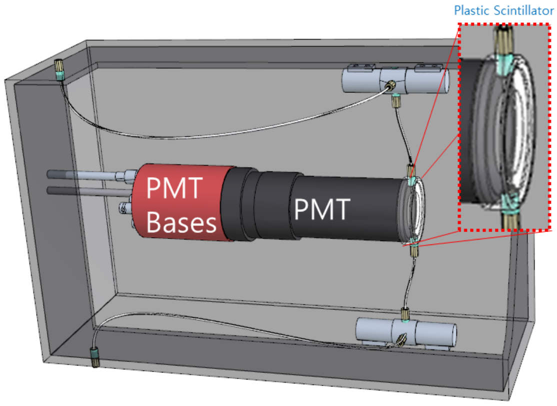

Fig. 1. Detector Configuration.

3. Results and Discussion

Assuming that the ^{85}Kr collection amount is 40%, The spectrum of each thickness are shown in Fig. 4. The efficiency was determined as the emission probability between 50 keV and 700 keV. The efficiency of the instrument is shown in Table. 1. When the length is 0.5 cm, the efficiency is the best at 13.9 % and the volume at this time is 11.53024 cm^3. It can be seen that the efficiency becomes maximum then the amount is the smallest, and the efficiency decreases as the volume increases. Because of the nature of the beta-emitting nuclides, it is important to know how close to the detector, as the volume increases and the efficiency is not so good. The reason for this is that ^{85}Kr is a beta-emitting nuclide. It is short range. Figure 3 shows the MDA values calculated by sampling 40 % of Kr-85 in a BfS-IAR system and converting the sampled Kr-85 into light by 10 %. Figure 4 shows the 20 % conversion of Kr-85 to light and enters the detector, which is enough to meet the MDA, unlike Figure 3. This is due to the short range of the beta-rays, also the amount of conversion to light is different thickness. It is necessary to find out how much electrons are converted to light by experimentation later, but it seems to have enough level to meet MDA.

Table. 1. Coincidence mode Efficiency results for each distance.

Length(cm)	Volume(cm^3)	50keV~700keV	Efficiency(%)
0.5	11.53024	1.39E-01	1.39E+01
1	23.06047	1.16E-01	1.16E+01
1.5	34.59071	1.00E-01	1.00E+01
2	46.12095	8.85E-02	8.85E+00
2.5	57.65119	7.93E-02	7.93E+00
3	69.18142	7.19E-02	7.19E+00

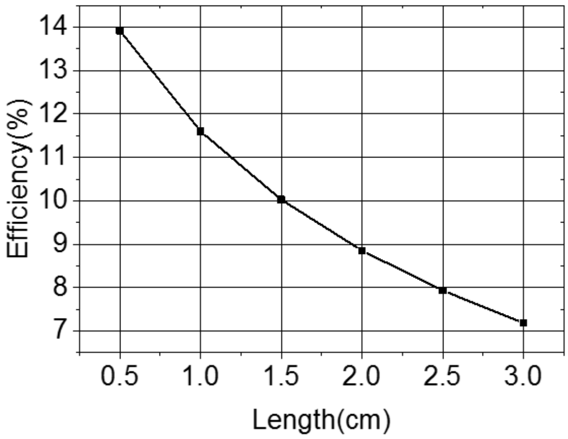

Fig. 2. Coincidence mode Graph of efficiency for each volume using MCNP.

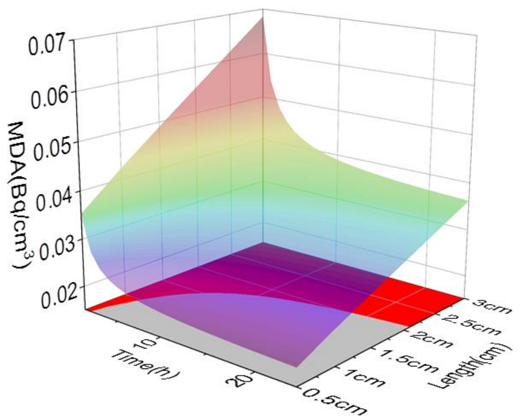

Fig. 3. 10 % converted light calculated MDA for 40 % sampling.

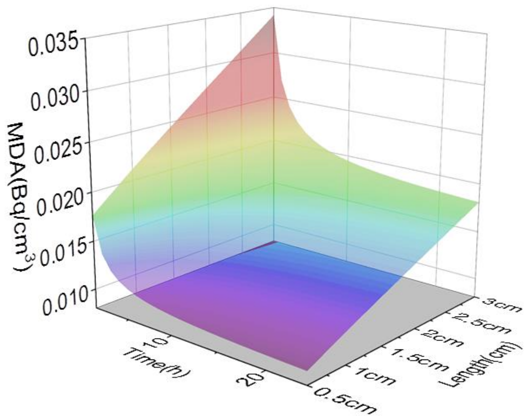

Fig. 4. 20 % converted light calculated MDA for 40 % sampling.

4. Conclusions

This paper is based on MCNP simulation, so there is no definite evidence. We use MCNP to calculate the efficiency of the instrument when we assume that ^{85}Kr is 40 % collected. The best efficiency is obtained at 0.5 cm thickness, but volume is 22 cm^3 when using PE vial to collect existing ^{85}Kr. Although the volume dose not increase significantly, the ideal volume is assumed to be 1 cm, and it is believed that more than 22m^3 can be as efficient as a proportional counter. Also MDA value is met. And it is expected that efficiency will be lower than Monte Carlo code MCNP if we do accurate experiment. However, since the tendency is somewhat visible, future research will measure the collected ^{85}Kr directly by making instrument.

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