Efficiency Analysis for In-situ Beta Measurement System in Groundwater

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1. Introduction

Monitoring of site groundwater is required before and after decommissioning of nuclear facilities. But the range of low-energy beta radionuclide is short, so the radioactivity is analyzed through a pretreatment process after sample sampling using a liquid scintillation counter which requires much time and labor [1]. So, in-situ measurement techniques for beta radioactive contamination such as ^{3}H during decommissioning site are required. Design of detecting system that directly contacts the radiation source with the scintillator for detecting short range beta ray is shown in Fig. 1.

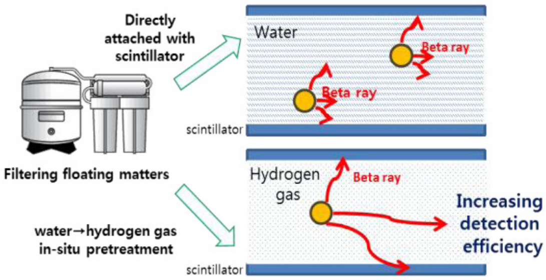

Fig. 1. Concept of in-situ beta monitoring with scintillator.

2. Method

2.1 Concept of radiation monitoring in water

The monitoring system was designed by using plastic scintillator which does not react with water. Also, PMT (Photo Multiplier Tube) based detection signal processing system was constructed. Fig. 2 shows establishment of on-site monitoring system based on time reduction with increasing detection efficiency. 556 HV Power Supply apply power to 276 PM Base/Preamplifier and then the photons amplification from 855 Amplifier. Then the photons are changed to signal by passing 551 Timing SCA & 567 Time to Amplitude Converter, after that we can check the total counts.

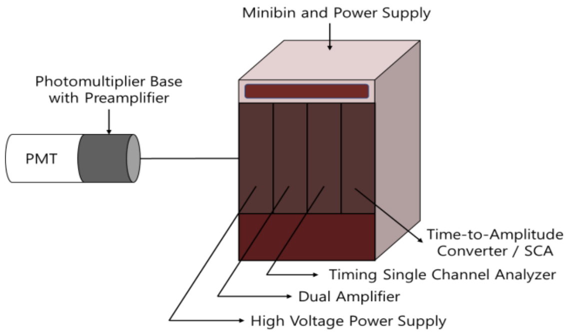

Fig. 2. Components of detecting system.

The major open beta nuclide sources such as ^{3}H, ^{14}C, ^{32}P and ^{90}Sr were used.

2.2 Simulation for detecting system about thickness of plastic scintillator

To calculate the efficiency of plastic scintillator with different thickness, namely 1 mm and 5 mm the MCNP simulation was used [2]. The simulated geometry for source and scintillator are shown in Fig. 3.

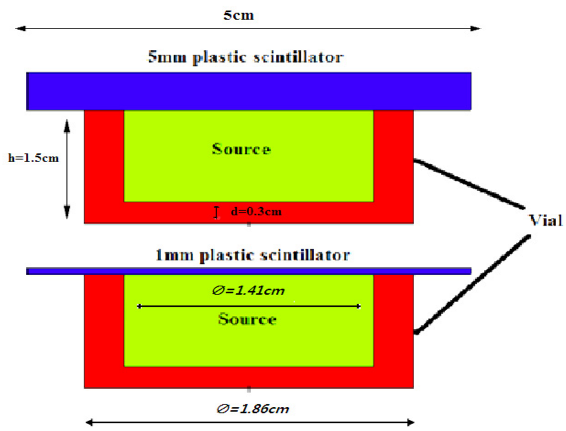

Fig. 3. Simulated geometry for source and scintillator.

2.3 Simulation for detecting system about diameter of scintillator and height of source

Detection efficiency according to diameter (2, 3, 5 cm) of scintillator and height of water sample (5, 10, 30, 50 cm) by nuclide were also calculated by MCNP.

2.4 Simulation for detecting system about thickness of air layer

Detection efficiency according to thickness of air layer (0, 0.025, 0.05, 0.1 and 0.2) was detected by MCNP.

3. Result and Discussion

A good match between the MCNP simulation and experimental results was observed on ^{32}P and ^{90}Sr showing the relative difference of 1.95% and 0.43% for ^{32}P and ^{90}Sr compared to simulation efficiency, respectively. However, beta particles have a short range in water (ex. ^{3}H range in air is 6 mm and in water is 6 μm), the efficiency for both ^{3}H and ^{14}C was rather low, and these radionuclides could not be detected or the value of relative difference was calculated little high as shown in Table 1.

Table 3. Efficiency and comparison with simulation results

Nuclides	Net counts (#)	Detection efficiency (%)	Relative difference (%)
^{3}H	Not available	Not available	Not available
^{14}C	241±85	0.10±0.04	6.54
^{32}P	9,224±112	5.54±0.07	1.95
^{90}Sr /^{90}Y	21,570±158	4.60±0.03	0.43

The efficiency was not affected by the thickness of the plastic scintillator. That is, the efficiency of 1 mm and 5 mm plastic scintillator was same. The amount of deposition energy is different, but any non-zero energy deposition of the beta particles in the scintillator is counted as one count in the F8 tally calculation.

Detection efficiency calculated according to diameter of scintillator and height of water sample by nuclide. As shown in Fig. 4 which is about ^{14}C, as the height of the water sample increases, the detection efficiency decreases and the influence of the diameter of the scintillator can be ignored. Radionuclides such as ^{3}H, ^{32}P and ^{90}Sr have similar results like Fig. 4.

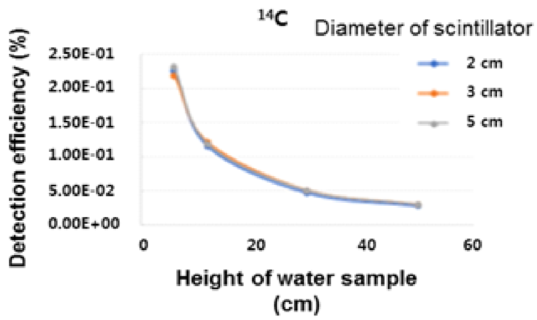

Fig. 4. Detection efficiency according to diameter of scintillator and height of water sample.

As shown in Fig. 5, low energy beta release radionuclides are strongly affected by the thickness of the air layer between the scintillator and the beta nuclide.

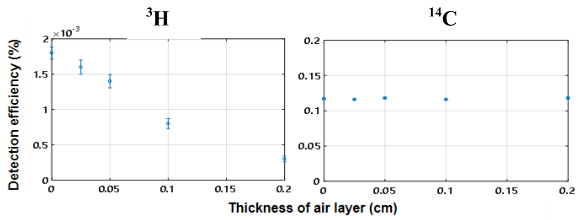

Fig. 5. Detection efficiency according to thickness of air layer.

4. Conclusion

A plastic scintillator could be used in an in-situ system as its efficiency was adequate to meet the task, for applications to monitor major beta-emitting nuclides at a decommissioning site. Further research is needed relating to the efficiency of the detection system, focusing more on radionuclides that emit weak beta particles.

REFERENCES

[1] S. W. DUCE, et al. "In-situ radiation detection demonstration.", WM'00 Conference, Tucson, AZ, February 27-March 2 (2000).

[2] T. GOORLEY, et al. "Initial MCNP6 Release Overview." Nuclear Technology, 180, 298-315 (2012).