Contribution ID: **126** Type: **Oral**

Performance Evaluation of Multi-Array Plastic Scintillation Detector using Static and Dynamic Source Conditions

Thursday 11 July 2019 12:00 (15 minutes)

Radiation portal monitor systems have been deployed to monitor the inflow or outflow of illegal radionuclides at border crossings world widely. Large-sized plastic scintillation detector has been commonly used for RPM system, but due to the components of the plastic scintillator are carbon and hydrogen, which are low Z-number material, it has poor energy resolution that shows the broad Compton edge area from Compton scattering rather than a clear peak from photo-electric effect in the measured energy spectrum, identifying the illegal radionuclides from numerous cargos is very challengeable. Therefore, we proposed a minimized and multiply arranged plastic scintillation detector to improve the detection efficiency of the plastic scintillation detector and evaluated the performance of the detector using radionuclides sources.

The detector consists of a total of 14 hexagonal pillar plastic scintillators with a diameter of 24 cm and a thickness of 15 cm, and each scintillator has a PMT attached to the back center. The energy spectra were measured to evaluate the performance of the detector. And radiation sources used for evaluation were 137Cs (8.6, 74.6 μCi) and 60Co (6.6, 13.2 μCi) with activities corresponding to international spectroscopy criteria for the RPM system for both static and dynamic conditions. Sources were individually measured under static condition 20 times repetition for one to ten seconds 2.5 m from the center of the detector for static condition. 137Cs and 60Co were measured individually with 10 times repetitions in 10, 20, and 30 km/h using a vehicle to measure the energy spectra under dynamic condition criteria.

The energy spectra measured with static sources showed narrower half-width at half maximum (HWHM) Compton edge area by 26.32% and 29.85% from the energy spectra measured with large-sizes plastic scintillation detector for 137Cs and 60Co. Compared to the large-sized plastic scintillation detector, the shape and size of individual scintillators of the multi-array system was changed and the number of the PMT was increased to 14. By this reason, the probability of generated light reaches the PMT increases, resulting in the improvement of energy resolution of the detector. Even though the measured energy spectra showed increased statistical fluctuation as the measurement time was shortened from ten to one second, the location of the maximum Compton edge energy was within the short range of 0.5% (0.002 MeV) and 3.5% (0.037 MeV) of the theoretical Compton edge energy for 137Cs (0.478 MeV) and 60Co (1.041 MeV), respectively. It is estimated that the Compton edge area of the spectra measured with this system shows a value almost equal to the theoretical Compton edge energy. In case of the energy spectra with dynamic sources, considering that the direction of the radiation incident to the detector changes continuously as the source moves, lower counts were measured compared to the spectra of the static condition measured during the time it takes for the sources to move.

In this study, the improved performance of multiply arranged plastic scintillation detector was evaluated using radionuclides with static and dynamic conditions. In addition, since the energy spectra from multi-array system showed emphasized Compton edge area than conventional system, the development of classification algorithm between artificial radionuclides and naturally occurred radioactive materials which have similar theoretical Compton edge energies (137Cs: 0.478 MeV –226Ra: 0.412 MeV and 60Co: 1.041 MeV –40K: 1.243 MeV) is expected with high accuracy using the multi-array plastic scintillation detector.

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Session Classification: Dosimeters, Neutrons, chair: Ulrich Parzefall

Track Classification: general