Identification of Radioactive Material Using Plastic Scintillator-Based Radiation Detector

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keyword : plastic scintillator-based radiation detector, nuclear terrorism, algorithmic method, illicit trafficking, nuclear material,

Introduction

Recently the potential of threats relating to nuclear and other radioactive materials are becoming a world-wide concern. The plastic scintillator-based radiation portal monitoring system is the most common instrument deployed at border crossings, seaports, airports and within country for detecting nuclear and other radioactive materials hidden in a vehicle or cargo. Because a plastic scintillator-based radiation detector can not provide detailed spectroscopic information, there is a limitation in discriminating radioactive materials of concern from NORM or ambient background radiation. This paper discusses the algorithmic method for a plastic scintillator-based radiation detection system and how to determine the optimal boundary of the energy windowing to determine certain threat materials from NORM or background radiation. Experiments are also conducted to verify how to determine optimal boundary of a spectral analysis method proposed in this paper.

Calculation

To present new spectral analysis method for a plastic scintillator-based radiation portal monitor and determine the optimal edge of several sub-regions, a theoretical calculation was conducted using MCNPX [1]. Fig. 1 is spectral distributions of several sources calculated by MCNPX. The spectral area for each source in Fig. 1 was normalized to unit for convenient comparison. The peaks in 137Cs, 60Co and 40K spectra in Fig.1 correspond to the Compton edge. It can be seen that there are two distinct things in Fig. 1 : the Compton edge and sharp decrease in energy. Thus, to discriminate each radioisotope, spectral distributions in Fig.1, based on their locations of sharp decrease and the Compton edge, were segregated into five energy sub-regions as follows : 0.02 ~ 0.130 MeV (G1), 0.130 ~ 0.3 MeV (G2), 0.3 ~ 0.6 MeV (G3), 0.6 ~ 1.1 MeV (G4), and 1.1 ~ 2.0 MeV (G5).

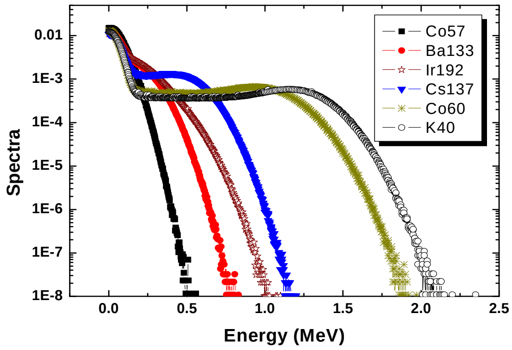

Fig. 1. Spectral distributions of various sources.

To analyze the behavior of the count of various radioactive sources with each energy group, the detection efficiency in each sub-region defined above is summed up and figured in Fig. 2. From Fig. 2, each source has a distinct behavior with each energy group : ^{57}Co decreases sharply and reaches almost zero in energy group 2 while ^{133}Ba and ^{192}Ir decreases slowly up to group 3 ; ^{137}Cs, ^{60}Co, and ^{40}K emitting energetic gamma-ray have their distinct maximal peaks in their specific energy group.

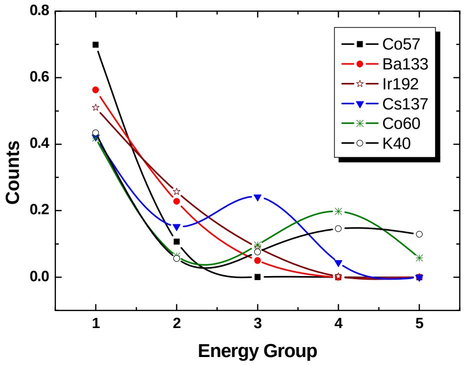

Fig. 2. Characteristic curves of various sources calculated by theoretical simulation.

Experiments

Experiments were carried out to verify the spectral analysis method presented in this paper. Radioactive sources (25.5 mCi 57Co, 51.2 mCi 133Ba, 48.8 mCi 137Cs, 19.2 mCi 60Co) were placed at 150 cm from the center of one BC-412 plastic scintillator of 5.7cm x 30cm x 30cm. Fig. 3 shows spectra of some sources and background radiation obtained using 2,048 energy channels and 1,200-sec collection times. There were two things where attention should be paid : the Compton edges of radioactive sources emitting high energy gamma-ray (137Cs, 60Co) could be seen in their spectral distribution even though those were broader ; and the decreasing positions of 57Co and 133Ba were remarkably different.

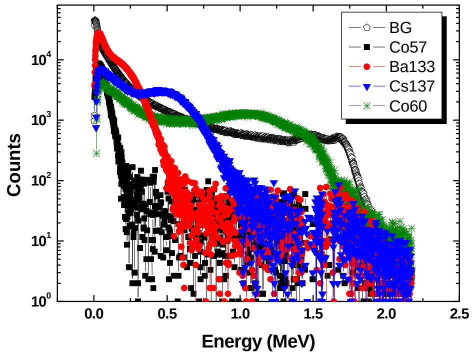

Fig. 3. Measured spectral distributions of four radioactive sources and background radiation obtained with a plastic scintillator detector.

The full spectra in Fig. 3 were divided into 5 sub-regions according to the method described previously. The behavior of each curve in Fig.4 agreed with the calculated results(Fig.2). Therefore, each radioactive sources could be discriminated by comparing the behaviors of its characteristic curve from the full spectral distribution.

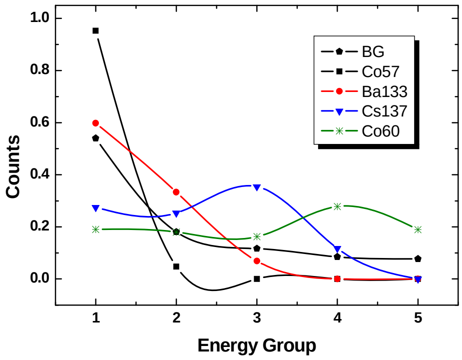

Fig. 4. Characteristic curves of various sources obtained with experimental results

Results and Disscussion

To make use of the limited spectroscopic information available from a plastic-scintillator material, this paper presented energy windows consisting of 5 energy sub-regions, 0.02 ~ 0.130 MeV (G1), 0.130 ~ 0.3 MeV (G2), 0.3 ~ 0.6 MeV (G3), 0.6 ~ 1.1 MeV (G4), and 1.1 ~ 2.0 MeV (G5), based on the result of MCNPX simulation. Experimental results showed that the algorithmic method of this paper could be used to discriminate not only radioactive sources of concern from NORM or background radiation but also natural and LEU from background radiation.

참 고 문 헌

1. Denise B. Pelowitz et al., “MCNPX User's Manual version 2.5.0,”, LA-CP-05-0369, LANL, (2005).