Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Radiation Detection System for Prevention of Radiological and Nuclear Terrorism

Sung-Woo Kwak, Ho-Sik Yoo, Sung-Sun Jang, Jae-kwang Kim, and Jung-Soo Kim
Korea Institute of Nuclear Nonproliferation and Control, Truth Hall in ICU, Munji-dong, Yuseong-gu, Daejeon, 305-732, KOREA

1. Introduction

After the September 11 terrorist attack, the threat of a potential for a radiological or nuclear terrorist attack became more apparent. The threats relating to radiological or nuclear materials include a Radiological Dispersion Device (RDD), an Improved Nuclear Device (IND) or a State Nuclear Device (such as a Soviet manufactured suitcase nuclear weapon). For more effective countermeasures against the disaster, multi-layer protection concept - prevention of smuggling of radioactive or nuclear material into our country through seaports or airports, detection and prevention of the threat materials in transit on a road, and prevention of their entry into a target building - is recommended[1,2]. Due to different surrounding circumstances of where detection system is deployed, different types of radiation detection systems are required. There have been no studies on characteristics of detection equipment required under Korean specific conditions. This paper provides information on technical requirements of radiation detection system to achieve multi-layer countermeasures for the purpose of protecting the public and environment against radiological and nuclear terrorism.

2. Radiation Detection System

2.1 Portal Monitor

The first-step for prevention of radiological and nuclear terrorism is to deter a terrorist from smuggling illegal materials into our country through seaports, airports and border crossings. The radioactive or nuclear materials which are smuggled are transported by means of a vehicle on a highway. Therefore, installing separately detection system of illicit trafficking of radiological and nuclear materials at two different places - portals of seaports or airports and key checkpoints of a road - is much more effective in addressing the threat. The portal monitor systems were reviewed to determine an optimal detector type depending on the employment place of the equipment.

There are four different types of detector for portal monitor : plastic scintillator, sodium iodide (NaI), cadmium zinc telluride (CZT), and high purity germanium detectors (HPGe). Plastic scintillation detector, one of gross counters, has good performance in sensitivity respect and useful for screening people, packages, luggage, cargo and vehicles for the presence of gamma or neutron. However, as shown in Figure 1[3], it has no ability to resolve γ-ray energy. NaI based detector has good efficiency but low energy resolution. CZT detector is adequate energy resolution, but low efficiency. NaI detector provides only a rough approximation of the energies emitted from radioactive materials and has very limited ability to interpret or analyze the radioactive material. Such a detector could not identify the presence of Special Nuclear Material which has been hidden inside one of legal radioactive materials within a given short time[4]. In addition to detection efficiency and energy resolution, the other important parameter is measurement time. Although CZT has medium energy resolution, it cannot be applied for a portal monitor because of its unreasonably long measurement times to clear a suspect case. Radiation detectors with no or low energy resolution give an alarm at any indication of high radioactivity in the shipment, the vehicle or even people. The innocent alarm rate, due to legal shipment of sources and nationally occurring radioactive materials (NORM), or medical isotopes in patients, caused interruptions and delays in commerce while the legality of the shipment was verified. To reduce unnecessary interruption of legitimate material transport, identification of in-transit radionuclide is necessary function. From detector characteristics like detection efficiency, energy resolution, and measurement time, HPGe which can quickly and accurately locate and identify the radioactive material appears to be appropriate for a portal monitor.

2.2 Mobile Detection System

The radiation detection systems for portal monitor usually are large and heavy and can't easily be moved to a different location[5]. For the system to provide effective protection, the radiological and nuclear terrorism must be interdicted at a significant distance from a target building such as a crowded city, a transportation center, an important official building and so on. Secrecy screening at a roadside can be more effective in inspecting a suspect container or vehicle. The police or emergency responders can be interested in monitoring radiation level of a suspicious vehicle with tracking it.

Due to these reasons, an inconspicuous and mobile system for the detection of radioactive and nuclear material during road transport is needed. Key characteritics of the mobile system can be summarized as follows : mobile, excellent sensitivity, real-time isotope identification, low false-alarm rate, wireless communication to command post, flexibility of deployment[6]. To avoid disruption of normal vehicle traffic, radiation detector must be able to screen a vehicle of about 100 km/hr speed at stand-off distance of 2-5 meter. Therefore, the radiation detector must have very good sensitivity and short measurement time for detecting and identifying quickly and accurately weak radiation source moving fast. Among detector types mentioned in section 2.2, NaI detector – even though it has low energy resolution – is superior to others. Compared with HPGe, NaI detector is cheap and employs simple cooling method. A module consisting of some NaI detectors can be used together to improve its sensitivity.

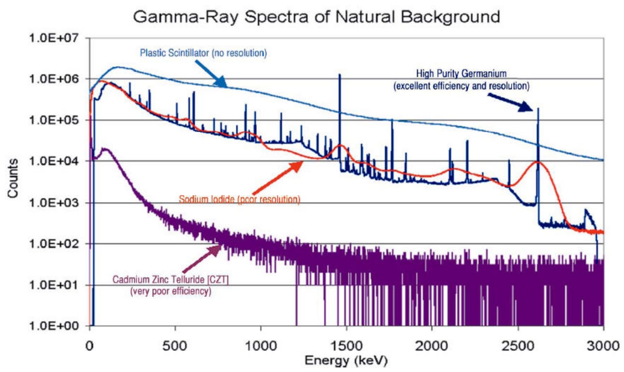

Figure 1. Comparison of difference detectors

2.3 Neutron Detector

Usually, radiation detection system for prevention of radiological and nuclear terrorism is equipped with neutron detector. This is for neutron-emitting nuclear material like plutonium. Plutonium is extremely dangerous and hard to detect over large distances. The α-particles and X-rays which are emitted by plutonium isotopes can easily be shielded by the material itself or by the surroundings. Besides a few γ-rays, the only penetrating radiation emitted by plutonium samples are neutrons from spontaneous fission. The spontaneous fission yields, Y_{SF} and the spontaneous fission neutron yields, Y_{SFN} for plutonium isotopes of even mass number are given in Table 1[7,8]. The fission yields of the odd numbered isotopes are negligible. Q_N in the fourth column of Table 1 is the number of neutrons emitted per second and per unit mass.

Table 1 Spontaneous fission neutron emission of plutonium

Nuclide	$Y_{SF}(Bq^{-1})$	$Y_{SFN}(Bq^{-1})$	$Q_N(g^{-1}s^{-1})$
^{236}Pu	$8.10x10^{-10}$	$1.81\ x10^{-10}$	3560
^{238}Pu	$1.84x\ x10^{-9}$	$4.20\ x10^{-9}$	2660
^{240}Pu	$4.95\ x10^{-8}$	$1.09\ x10^{-7}$	920
^{242}Pu	$5.50\ x10^{-6}$	$1.23\ x10^{-5}$	1790
^{244}Pu	$1.25\ x10^{-3}$	$2.85\ x10^{-3}$	1870

There are several types of detectors available for neutron detection. For a plutonium survey with neutrons, a detector with extremely high sensitivity for fission neutron is required. R.M. Keyser et al. showed that ^3He gas detector has more larger detection efficiency than lithium glass (LiG) detector[9]. Other papers also showed that ^3He gas detector was appropriate for weak neutron detection.

3. Conclusion

For prevention of radiological and nuclear terrorism which became more apparent, it is more effective, based on multi-layer approach, to install separately different types of radiation detection system at different places. HPGe based detector is superior in detecting illicit trafficking of radiological and nuclear materials at portals of seaports or airports and key points of a road. On the other hand, NaI detector appears to have better performance in detecting illicit materials moving fast on a highway. There are several types of detectors available for neutron detection. For special nuclear material emitting neutron, ^3He gas detector moderated with polyethylene is more suitable than others. The results of this study will be useful in establishing integral radiation detection system against radiological and nuclear terrorism.

Acknowledgement

This work has been carried out under the Nuclear Research and Development program supported by MOST.

REFERENCES

[1] IAEA INFCIRC/225/Rev.4, The Physical Protection of Nuclear Material and Nuclear Facilities, 1999.
[2] Charles D. Ferguson and William C. Potter, The Four Faces of Nuclear Terrorism, Monterey Institute of International Studies, 2004.
[3] John Samlling, New Technology Gives Bombs Squads the Upper Hand in the Fight Against Radiological or Nuclear Terrorism, The Detonator, Vol. 31, No.5, pp48-52.
[4] Ronald M. Keyser, Daniel L. Upp, and Timothy R. Twomey, Performance of an HPGe-based and NaI-based Radionuclide Identifier(RIID) in the Identification of Radioactive Materials.
[5] T. Köble, W. Rosenstock, M. Risse, and J. Peter, Detection of Nuclear Material During Fast Road Transport, INMM 44, Annual Meeting, 2003.
[6] Randy Jones, Rollin Evans, and Gary Smith, A Mobile Radiation Detection System for the Sensitive Detection and Identification of Radiological/Nuclear Threats, INMM 45, Annual Meeting, 2004.
[7] The International Commission on Radiological Protection, Radionuclide Transformations Energy and Intensity of Emissions, ICRP Publication 39, Annals of the ICRP, Volume 11-13, 1983.
[8] Alfred Klett, Plutonium Detection with A New Fission Neutron Survey Meter, IEEE Trans. Nucl. Sci. Vol.46, No.4, 1999, pp877-879.
[9] R.M. Keyser, T.R. Twomey, and D.L. Upp, An Improved Handheld Radioisotope Identifier (RID) for both Locating and Identifying Radioactive Materials.