

Radiation Detection System for Prevention of Illicit Trafficking of Nuclear and Radioactive Materials

SUNG-WOO KWAK, SUNG-SOON CHANG, and HO-SIK YOO

Korea Institute of Nuclear Nonproliferation and Control

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Fixed radiation portal monitors (RPMs) deployed at border, seaport, airport and key traffic checkpoints have played an important role in preventing the illicit trafficking and transport of nuclear and radioactive materials. However, the RPM is usually large and heavy and can't easily be moved to different locations. These reasons motivate us to develop a mobile radiation detection system. The objective of this paper is to report our experience on developing the mobile radiation detection system for search and detection of nuclear and radioactive materials during road transport. Field tests to characterize the developed detection system were performed at various speeds and distances between the radioactive isotope (RI) transporting car and the measurement car. Results of measurements and detection limits of our system are described in this paper. The mobile radiation detection system developed should contribute to defending public's health and safety and the environment against nuclear and radiological terrorism by detecting nuclear or radioactive material hidden illegally in a vehicle.

Keywords : mobile radiation detection system, nuclear terrorism, illicit trafficking and transport, gamma-ray detector, neutron detector

1. INTRODUCTION

Recent events - the 9/11 terrorist attacks, the discovery of Al-Qaeda's experimentation to build a dirty bomb and the death of a former officer of the Russian Federal Security Service from Po-210-induced acute radiation exposure - show that the threats relating to nuclear and radioactive materials are not more incredible but serious and credible. Therefore, appropriate and effective measures should be considered to prevent, detect and respond to such threats. Instruments for these goals can be divided into four types : fixed radiation portal monitors (RPMs), personal radiation detectors (PRDs), hand-held radionuclide identification devices (RIDs), and hand-held neutron search detectors (NSDs) [1]. In particular, increasingly large number of fixed RPMs have been deployed to prevent and detect nuclear and radioactive materials from being smuggled into one's own country and to ensure that such materials don't fall into the hands of terrorist groups or criminal organizations. The RPM is usually large and heavy and can't easily be moved to different locations. An intelligent nuclear or radiological terrorist may also

circumvent the fixed RPM to avoid being detected. Attention has been paid to a mobile radiation detection system to address these problems. On the other hand, secrecy screening at a roadside would increase effectiveness of inspection of any suspect container or vehicle. Over the past few years, there have been some reports on system for search and detection of nuclear and radioactive materials during road transport [2-4]. Performance of the system reported in the previous study was dependent on characteristics of a radiation detector and background noise reduction technique.

We have developed a mobile radiation detection system consisting of some radiation detectors (two He-3 gas detectors for neutron detection, two plastic scintillation detectors and one NaI(Tl) for gamma ray detection), a data acquisition system (DAS), a GPS (Global Positioning System), a mobile unit (SUV) and an operation software. Field tests using various radioactive sources (Ba-133, Cs-137, Co-60, Cf-252) were conducted to characterize performance of the developed mobile radiation detection system. This mobile radiation detection system is complementary to a fixed RPM. Its application would not only achieve defense-in-depth concept suggested by international recommendations but also improve the ability to detect

Corresponding author : Sung-Woo Kwak, swkwak@kinac.re.kr
Korea Institute of Nuclear Non-proliferation and Control
573 Expo-ro, Yuseong-gu, Daejeon, 305-348



Fig. 1. The developed mobile radiation detection system consisting of some radiation detectors, a GPS, a DAS, an operation software, and a mobile unit.

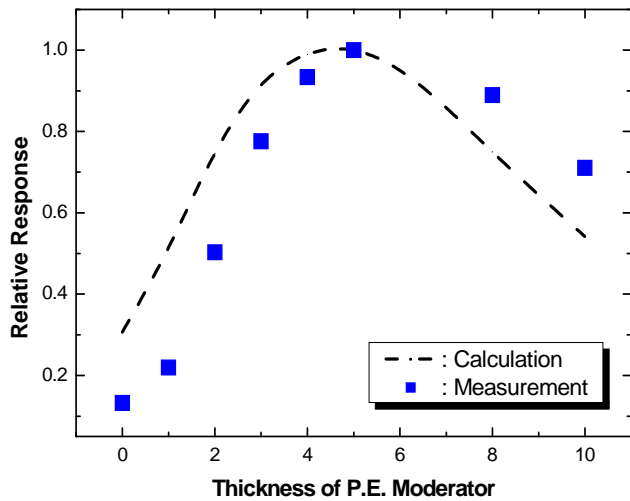


Fig. 2. Response of the He-3 gas detector obtained by MCNP simulation and experiment.



Fig. 3. Field test to characterize performance of the developed mobile radiation detection system.

illicit trafficking and transport of nuclear and radioactive materials [5,6]. Thus, deployment of this inconspicuous and mobile detection system should contrib-

ute to protect the people’s safety and health and the environment from nuclear and radiological terrorism.

2. Material and Method

The mobile radiation detection system discussed in this paper consists of some radiation detectors (one NaI(Tl), two 30 cm x 30 cm x 5.7 cm BC412 plastic scintillation, and two He-3 neutron detectors), a GPS, a DAS, an operation software, and a mobile unit. Figure 1 shows the developed mobile radiation detection system. In Figure 1, a 7.62 cm (3 inch) diameter x 7.62 cm (3 inch) length NaI(Tl) and two plastic scintillators are used to decide whether any targeted material is present in a suspect vehicle. A 3.81 cm (1.5 inch) PMT is mounted on a 30 cm x 5.7 cm edges to collect signal generated in the plastic scintillator. Except of one 30 cm x 30 cm face of the plastic scintillation detector which radiation is incident on, the other sides are shielded with metal plates of Fe, Pb and Al to increase SNR (Signal-to-Noise

Ration) through reduction of background radiation. Two He-3 neutron detectors are in a vehicle as shown in Figure 1. Its dimension and gas pressure are 7.62 cm (3 inch) diameter x 22.86 cm (9 inch) length and 4 atm, respectively. To determine the optimal thickness of polyethylene (P.E.) moderator to improve sensitivity of the He-3 gas detector, theoretical simulation was conducted in consideration of characteristics of the real He-3 gas characteristics and bare Cf-252 spectrum. Figure 2 is response of the He-3 gas detector obtained with MCNP simulation and experiment. From Figure 2, the optimal thickness of P.E. moderator for the He-3 gas detector appeared to be about 5 cm. The gamma ray detectors can be placed not only on the roof of a mobile vehicle but also inside a vehicle. A pan and tilt machine is used to adjust direction of incident surface of the gamma detectors when it is on vehicle's roof.

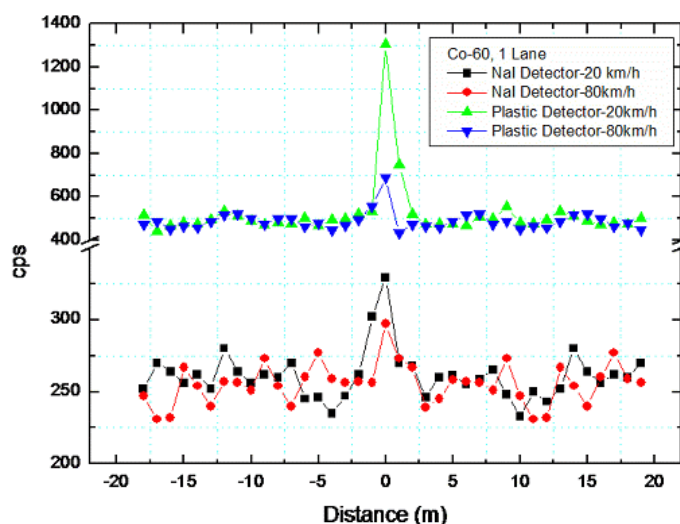


Fig. 4. Detection signal when the Co-60 transporting car moved with speed of 20 km/hr and 80 km/hr along traffic lane 1.

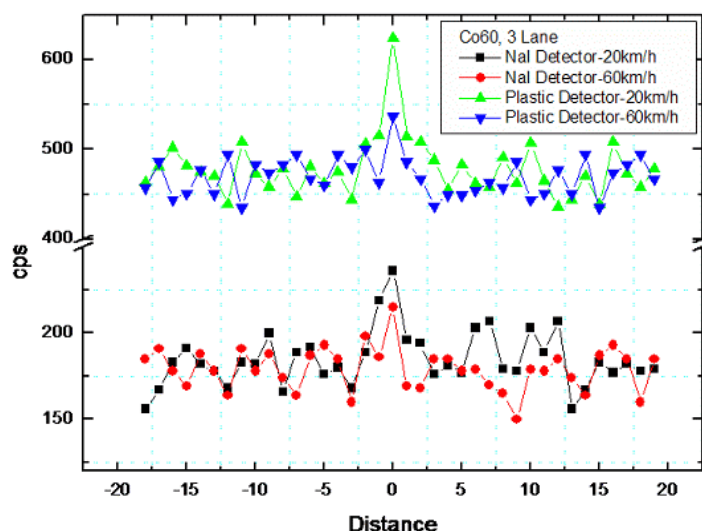


Fig. 5. Detection signal when the Co-60 transporting car moved with speed of 20 km/hr and 60 km/hr along traffic lane 3.

3. Results

Experiments to characterize our system's ability to detect nuclear and radioactive materials hidden in a car were made at various speed and at various distances between the RI source transporting car and the measurement car (mobile radiation detection system). As shown Figure 3, the mobile radiation detection system was parked at a roadside and another car transporting a radioactive source moved along three traffic lanes (traffic lane 1, 2, and 3 in Figure 2). Each traffic lane in a road has a width of 3.5m. The sources used in experiment are about 50 μCi Ba-133, 50 μCi Cs-137, 20 μCi Co-60, and 4.4 μCi Cf-252.

Figure 4 was obtained when the 20 μCi Co-60 transporting car moved at the speed of 20 $\text{km}\cdot\text{h}^{-1}$ and 80 $\text{km}\cdot\text{h}^{-1}$ in traffic lane 1. Count rate of the plastic detector in Figure 4 is a sum of count rates of two plastic detectors. In Figure 4, the x-axis is the distance between the RI source (Co-60) transporting car and the measurement car; The minus distance in the x-axis means that the source transporting car approaches the measurement car; The zero is the very moment when the source transporting car passes by the measurement car. For 20 $\text{km}\cdot\text{h}^{-1}$, radiation count rates of both NaI(Tl) and plastic detectors are obviously distinguishable from ambient background radiation. In contrast to 20 $\text{km}\cdot\text{h}^{-1}$, signals at 80 $\text{km}\cdot\text{h}^{-1}$ speed are relatively small even though those can be distinguished from background. Figure 5 is the results obtained when the

RI transporting car moved along traffic lane 3. The radiation signal of 80 $\text{km}\cdot\text{h}^{-1}$ was not distinguishable from background radiation. Figure 5 shows that our detection system can detect about up to 20 μCi Co-60 when it is transported at the speed of 60 $\text{km}\cdot\text{h}^{-1}$ in traffic lane 3. The ability to detect Ba-133, Cs-137, and Cf-252 was also determined in the same way. From the measurement results, it appeared that detection limits of our system for Ba-133, Cs-137, and Cf-252 were speed of 30 $\text{km}\cdot\text{h}^{-1}$ in traffic lane 1, 30 $\text{km}\cdot\text{h}^{-1}$ in traffic lane 2, and 60 $\text{km}\cdot\text{h}^{-1}$ in traffic lane 3, respectively.

Information from radiation detectors is displayed in operation software. The operation software provides real-time location information, radiation (gamma-ray and neutron) count rate, a emergency contact point of competent authorities responsible for response measure and procedure. Under normal condition, the main window of the operation software as shown in Figure 6 exhibits location information of the detection car on the left and radiation count rate in blue on the right. But when detection radiation signal is higher than a given threshold, an alarm window appears automatically as an overlap on the map. A radiation indication in main and alarm windows changes from blue to red. An audible alarm also sounds. An operator of the mobile radiation detection system can identify the unknown radioactive material using energy spectrum obtained with NaI(Tl) and plastic detectors.

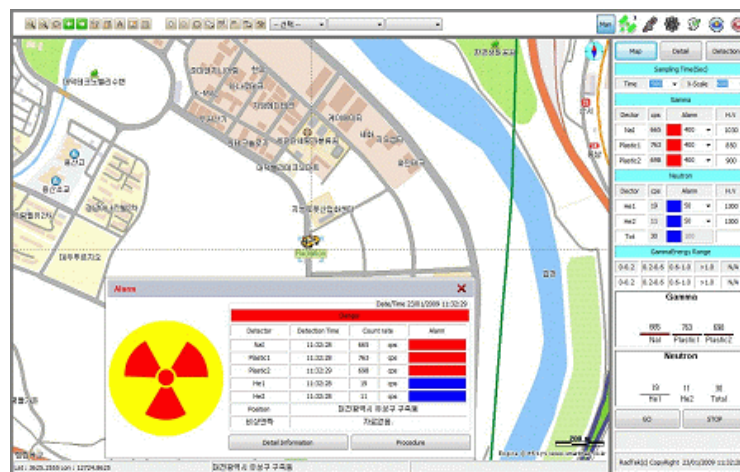


Fig. 6. Alarm window appearing when nuclear or radioactive material is detected.

4. Conclusion and Discussion

A mobile radiation detection system has been designed, assembled and tested. The detection sensitivity of the system depends on several factors such as the characteristics of radiation detector, the speed that a radiation source is moving, the distance between the

source transporting car and the measurement car, and the ambient background radiation. The test results showed that detection limits of our system for 50 μCi Ba-133, 50 μCi Cs-137, 20 μCi Co-60, and 4.4 μCi Cf-252 were speed of 30 $\text{km}\cdot\text{h}^{-1}$ in traffic lane 1, 30 $\text{km}\cdot\text{h}^{-1}$ in traffic lane 2, 60 $\text{km}\cdot\text{h}^{-1}$ in traffic lane 3, and 60 $\text{km}\cdot\text{h}^{-1}$ in traffic lane 2, respectively. Randy Jones

et al. reported that the mobile RN sensor system could detect and identify 70 μCi Cs-137 at up to 112.63 $\text{km}\cdot\text{h}^{-1}$ (70 mph) [5]. Upp D.L. et al. concluded that their system could be used at 16.09 $\text{km}\cdot\text{h}^{-1}$ (10 mph) to 32.18 $\text{km}\cdot\text{h}^{-1}$ (20 mph) for the best results and the useful distances for sources in the 10s of μCi is 12 m or less [6]. The neutron signal has similar sensitivities. Also, it is reported that one commercial product can detect 10 μCi Cs-137 in a distance of 3 m, 17 μCi Co-60 in a distance of 6 m, and 36 μCi Cf-252 in the distance of 5 m when these sources move at the speed of 16.09 $\text{km}\cdot\text{h}^{-1}$ [7]. The detection limit of our system is compared with the commercial product in Table 1. From Table 1, it can be concluded that performance of our system is comparable to those of the commercial system.

Table 1. Comparison of Detection Limit of Our System and a Commercial Product.

Source	Our System	Commercial Product
Cs-137	activity : 50 μCi speed : 30 km/hr distance : 4.0 m	activity : 10 μCi speed : 16 km/hr distance : 3.0 m
Co-60	activity : 20 μCi speed : 60 km/hr distance : 7.5 m	activity : 17 μCi speed : 16 km/hr distance : 6.0 m
Cf-252	activity : 4.4 μCi speed : 60 km/hr distance : 4.0 m	activity : 36 μCi speed : 16 km/hr distance : 5.0 m

The mobile detection system described in this paper could be deployed to prevent and detect illicit traffick-

ing and transport of nuclear and radioactive materials. However, there is something to be improved. The first is the ability to identify a radionuclide in very short time. The second is to make the operation software simple for end-user to use easily it.

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