Vehicle Radiation Monitoring Systems for Medical Waste Disposal - 12102

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ABSTRACT

Hospitals often declare their waste as being "non-radioactive"; however this material often has excessive levels of radiation caused either by an accident or lack of control. To ensure the best possible protection against the accidental receipt of radioactive materials and as a safety precaution for their employees, waste-handling companies have installed large-scale radiation portal monitors at their weigh scales or entry gates of the incinerator plant, waste transfer station, and/or landfill. Large-volume plastic scintillator-based systems can be used to monitor radiation levels at entry points to companies handling medical waste.

INTRODUCTION

In accordance with Canada's regulation [1], hospitals can store low-level radioactive waste with short half-life isotopes (e.g., Tc-99m, I-131) until they have decayed and then dispose of it as clean waste [2]. In terms of document [1], "non-radioactive" means that the material produces equivalent dose less than 0.05 mSv/a. The hospital waste is then transported, handled, and either incinerated or placed in a landfill by government-owned or privately held companies.

Despite declared as "non-radioactive," the hospital waste sometimes has levels of radiation higher than would be expected due to the lack of control or an accident. To ensure the best possible protection against the accidental receipt of radioactive materials and as a safety precaution for their employees, waste-handling companies only accept waste that is less than double the background level. There are two reasons that have driven this level of acceptance: first, the problem of accumulated radiological waste at the same facility; second, materials passing into the United States from Canada have been subjected to severe fines after setting off the security-based Border radiation portal monitors.

For these reasons companies have installed large radiation portal monitors at their weigh scales or entry gates of the Incinerator plant, waste transfer station, and/or landfill.

For large radiation portal monitors the most practical solution is the use of high grade plastic scintillation detectors. The reasons for the widespread popularity of plastic scintillators are as follows: relatively good sensitivity, easy to fabricate and most important its low cost compared to other scintillation materials. The popular plastic scintillator polyvinyl toluene (PVT) has an order of magnitude lower cost in comparison with a higher efficiency inorganic scintillator such as sodium iodide (NaI)

A plastic scintillator has poor energy resolution and cannot be used for nuclide identification by gamma-spectra. Regardless of this drawback, good radiation sensitivity (20-30% of NaI) makes them effective tools as radiation screening devices.

Despite the naturally degradation processes which is associated with plastic scintillators, the life-span of PVT radiation detectors is considered to be 10-12 years, making this material a long-term solution for waste-management companies.

This presentation describes these systems and addresses the problem of radiation dose assessment with a plastic scintillator.

METHOD

Radiation detection technique

The plastic scintillator (PVT based) RC4000 systems are typically configured with two detector panels, a dedicated PC with a network connection allowing remote monitoring, data retrieval and maintenance/service functions. The internal software and hardware designs are extremely flexible, allowing remote software updates and electronic hardware adjustments when necessary. Supervisors can monitor the system operation in real-time to ensure normal system operation is always maintained. if a network connection is provided, the system has the capability of emailing alarms and system malfunctions. Detailed logging of critical historic information is a useful feature of these systems. A case in point is Japan, where historical data had been retrieved before and during the earthquake, during the tsunami and the months that followed. The data provided critical information about the radiation in the atmosphere in specific areas. In addition, course energy-analysis information was determined to assist with improved alarm threshold analyses. The principal block-diagram of a typical portal radiation-monitoring system offered for waste-handling companies is shown in Figure 1.

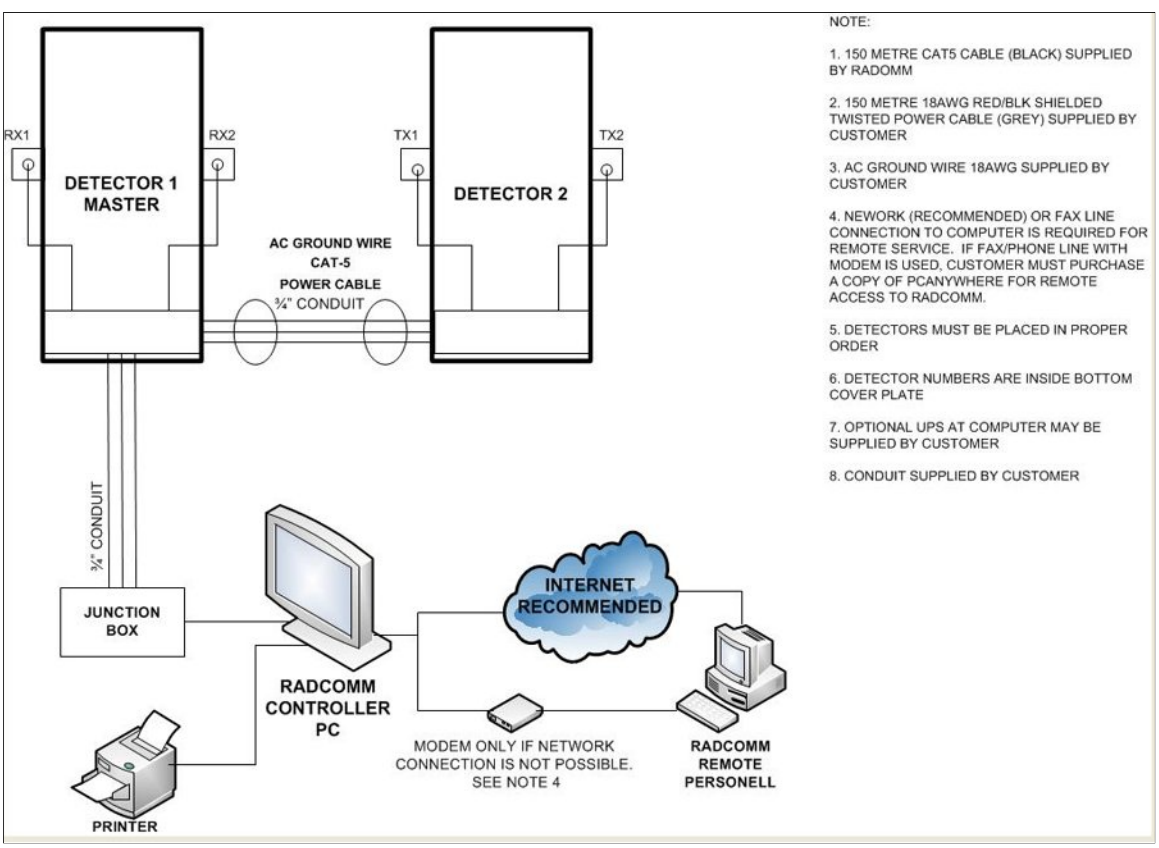

Fig 1. This diagram shows a typical layout for a vehicle radiation-detection monitor with two detectors.

Dose rate assessment

Waste-management companies require displayed radiation levels and/or alarm assessment primarily in dose rates, unlike the systems for steel and metal scrap plants where total count (CPS) information is considered the normal units of measured radiation levels. To achieve this goal RadComm Systems has designed and implemented a special approach for plastic scintillators (PVT). This approach incorporates real-time analysis algorithms providing energy compensation and calibration for assessment of Dose Rates.

The major Dose Rate correction factor originates from the spectral response from the plastic scintillator 'Compton Edges'. Unlike an inorganic scintillator or semiconductor detectors, the plastic has no Photo Peaks and experimental spectral response can be seen in Figure 2 (for Cs-137, 662 keV).

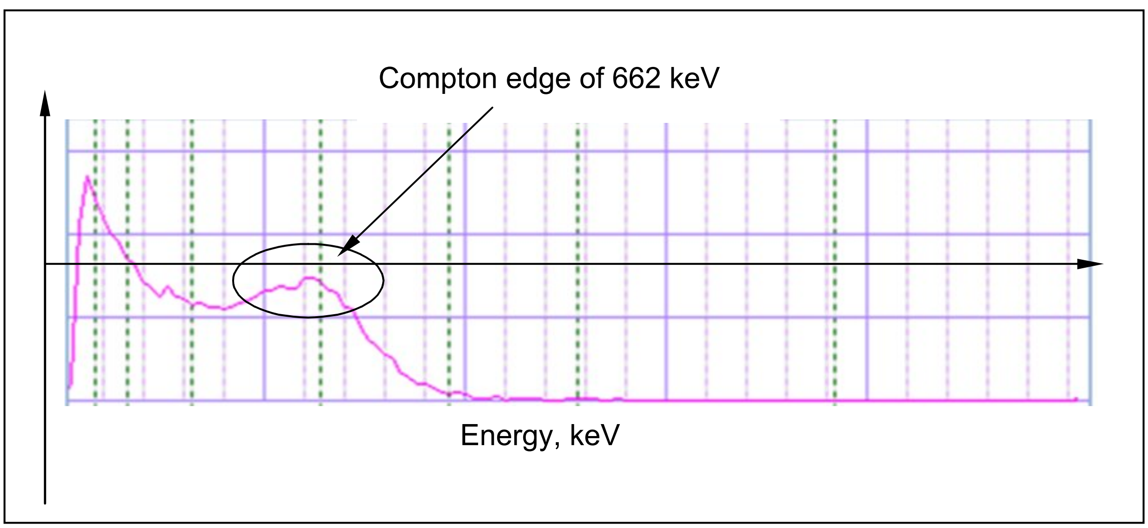

Fig 2. Actual experimental response of plastic scintillator (PVT) for Cs-137 radioisotope

The Compton edges are the primary source of information produced by plastic scintillators. In order to properly evaluate Dose Rates, the correction factors of incident photons must be introduced. The Compton edge shifts the incident spectral response to lower energy regions.

As the vehicle passes through the radiation detection scanning zone and if a photon produced by a radioactive source in the load of waste reaches the plastic scintillator, as an approximation the direct hit by the incident photon on the scintillator’s electron would be assumed for further consideration. In this situation the backscatter photon has well-known predictable energy E_{b_sc}, keV:

$$_{\_} = \frac{}{1 + 2\frac{}{511}} \qquad (\; .1)$$

where the E_0 is incident photon energy in keV.

Therefore, the Compton electron energy becomes the maximal:

$$_{\_} = - {}_{\_} \qquad (\; .2)$$

or,

$$_{\_} = \frac{1}{1 + \frac{511}{2}} \qquad (\; .3)$$

The Compton electron deposits this energy into the plastic scintillator and generates the scintillator response. However, as it follows from (Eq. 3) this energy is lower in comparison with the incident photon by the factor outlined below:

$$\frac{}{\frac{}{}}$$

Therefore, to correct the estimated dose rate based on PVT Compton energy response, one should multiply the evaluated dose rate on incident photons by the following correction factor:

$$= \qquad 1 + \frac{}{} \qquad (\; .4)$$

Where the $Dose_{corr}$ – is the dose correction for incident photons and $Dose_{scint}$ is directly obtained from plastic scintillator. For example, the correction factor for Cs-137 producing 662 keV is 1.39.

RESULTS AND DICUSSION

To satisfy waste-management companies with their requirement for alarm thresholds and dose rate displayed measurements,i.e., to alarm if radiation from load of waste materials exceeds twice the ambient background and to provide the readings in dose rate units, two principal objectives were required:

A) Control the maximum allowable radiation response from a passing vehicle

B) Permanent dose rate assessment

To achieve the first objective, a reliable and continuous real-time background tracking algorithm was developed. This algorithm incorporates an especially designed 'locking' radiation response technique to evaluate maximum amplitude of radiation signals for alarm threshold settings. The second objective was achieved as described earlier in the Dose Rate Assessment section for plastic scintillators.

The typical response of the PVT-based system where the measured radiation signal has exceeded the allowable limit is shown on Figure 3.

Fig 3. The background updating and alarm response of the PVT-based systems (time radiation profile)

Figure 3 shows the Real-Time vehicle radiation profile (blue line) of the systems installed at landfills. The red line represents the accurate updating alarm threshold, which 'locks' when the measured radiation Dose Rate from the detected radioactive source inside the vehicle exceeds twice background. The result causes the system to set an alarm condition.

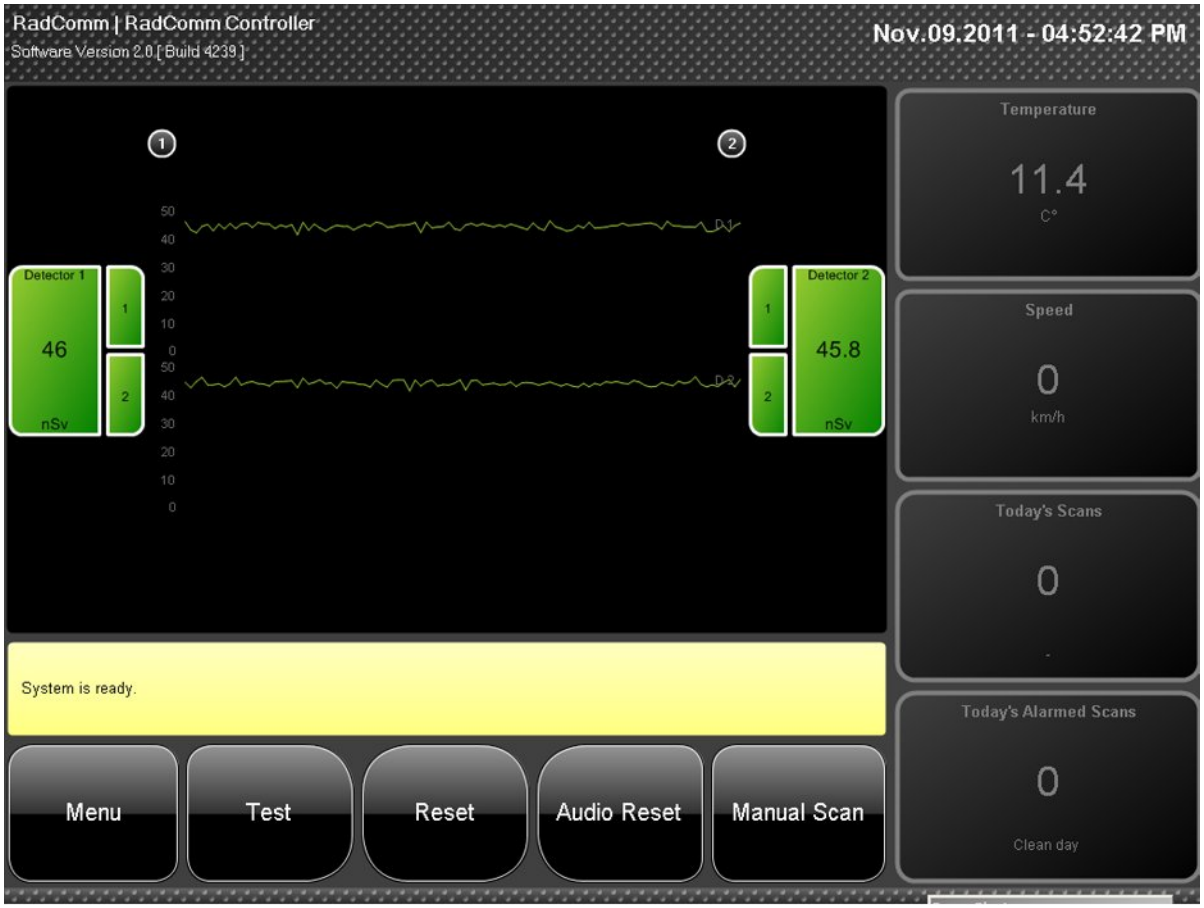

Fig 4. View of the standard User Interface with radiation time profile (green lines) displayed in Equivalent Dose Rate units (nSv/hr).

Nevertheless, the plastic scintillator based radiation detection systems cannot properly differentiate between medical and non-medical isotopes. To address this issue of isotopic identification and for detailed investigation of waste which has generated an alarm condition on the PVT-based portal radiation detection system, RadComm offers the handheld Gamma-Ray Spectrometer with nuclide ID and neutron detection capability.

CONCLUSION

The recent and intensive field tests together with the thousands of accumulated hours of actual real-life vehicle scanning have proven that the plastic scintillation based system is an appropriate radiation control instrument for waste management companies. The Real-Time background compensation algorithm is flexible with automatic adjustable coefficients that will response to rapidly changing environmental and weather conditions maintaining the preset alarm threshold levels. The Dose Rate correction algorithms further enhance the system's ability to meet the stringent requirements of the waste industries need for Dose Rate measurements.

REFERENCES

1. Radiation Safety Requisites for Exemption of Certain Radioactive Materials from further licensing upon transferral for disposal. Ottawa: Atomic Energy Control Board, 1989. Regulatory document R-85
2. Assessing the Long Term Safety of Radioactive Waste Management. Canadian Nuclear Safety Commission, 2006. Regulatory Guide G-320