Evaluating Scan MDC of MicroGe Detector in Land Area Applications

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1. Introduction

The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), NUREG-1575, provides guidance for planning, implementing, and evaluating environmental and facility radiological surveys in decommissioning sites [1]. The detection sensitivity of a survey instrument for detecting radioactive contamination is expressed in terms of the minimum detectable concentration (MDC) in MARSSIM. This is a critical factor in the selection of a survey instrument for contamination detection. It is important to verify that the selected survey instrument has sufficient sensitivity to detect radioactive contamination prior to its usage.

The purpose of scanning at decommissioning is to find unexpected contamination, and the scan MDC for evaluating the performance of scanning is described in MARSSIM. There are currently no specific guidelines available for evaluating the scanning performance of the detector in situations other than decommissioning. Therefore, in this paper, the scan MDC evaluation process described in MARSSIM was applied to evaluate the scan performance of the detector.

2. MicroGe detector

The MicroGe detector shown in Figure 1 was prepared for the purpose of effective environmental monitoring during nuclear emergencies. This detector is characterized by its compact size, electrically-cooling, fanless operation, light weight, and suitability for measuring radiation in high dose environments. Further detailed specifications can be found in Table 1.

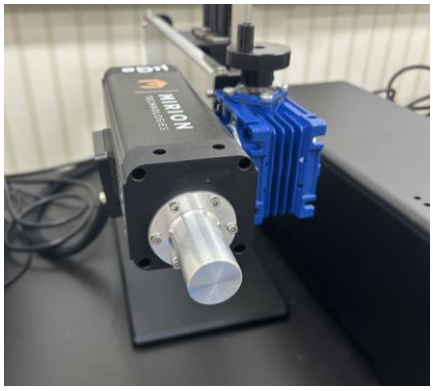

Figure 1 MicroGe detector

Table.1 Detection head characteristic

Parameters	Value
HPGe crystal	10 mm diameter × 10 mm long
End cap	26.5 diameter × 43.5 mm long Thickness: 1 mm aluminium
Housing	245 ×71×66 mm
Cooling	Fully automatic electrical cryocooler
Weight	1.7 kg
Energy range	From ~ 10 keV up to 3 MeV
Relative efficiency	0.04 % at 1332.5 keV
Energy resolution (typical) 2 μs Gaussian shaping time Count rate: 1 kcps	1.0 keV at 122 keV
	1.6 keV at 661 keV
	2.2 keV at 1332 keV

3. Scan MDC for land areas

The scan MDC depends on various factors such as detector characteristics (e.g., efficiency and window area), nature of target nuclide (e.g., emission type and energy), relative distribution of potential contamination (e.g., point or distributed sources and depth of contamination) and other physical survey environment factors. In addition to the above factors, the scan MDC can also be affected by the surveyor's technique (e.g., scan speed) and detector's ability to distinguish between the background count response and a signal that may indicate residual contamination above the background detector response. The scan MDC for a land area can be calculated by Eq. (1) [1-3].

$$\textit{Scan MDC for land areas} = \frac{MDCR}{(Surveyor\ Eff.) \times (Instrument\ Effs.) \times (source\ Effs.)}$$

$$= \frac{s_i \times (60/i)}{\sqrt{p} \times CPMR \times ERC} = \frac{(d' \times \sqrt{b_i}) \times (60/i)}{\sqrt{p} \times CPMR \times ERC}\ \text{[Bq/g]} \qquad (1)$$

where,
$MDCR$ = minimum detectable net count rate in cpm [cpm]
$CPMR$ = count rate to exposure rate ratio [cpm per μSv/h]
ERC = exposure rate to contamination ratio [μSv/h per Bq/g]
s_i = minimum detectable net counts in the observation interval [counts]
p = surveyor's efficiency [unitless]
d' = detectability index based on true-positive and false-positive rates [unitless]
i = observational interval [seconds]
b_i = background count in observation interval [counts]

The surveyor's efficiency (p) was considered as 0.5, which is the value usually used in MARSSIM [1]. The instrument efficiency is defined as the CPMR, which is provided by the manufacturers or can be obtained from the literature. The source efficiency is defined as the ERC, which represents the measured or estimated exposure rate at a certain distance from a source with a specified areal extent and depth, and is calculated by the modelling code. In this study, an alternative assumption of CPMR was made based on values obtained from simultaneous measurements of a Cs-137 check source with a MicroGe detector and a radiation dosimeter. The ERC was calculated by modelling the contaminated area with the Microshield code.

For the evaluation of the scan MDC, the contamination area and the scanning conditions were assumed to be as shown in Figure 2. The cylindrical soil with a surface area of 0.25 m^2 (with a diameter of 0.56 m) and a depth of 0.15 m was considered to be uniformly contaminated with Cs-137 at a concentration of 1 Bq/g. This contaminated area is considered a reasonable size for many decontamination and decommissioning (D&D) sites [3]. It was also assumed that a detector moving at 0.5 m/s maintains a distance of 0.1 m from the ground as it passes over the contaminated area. The observation interval (i) is contingent upon the scan speed and the size of the contaminated area.

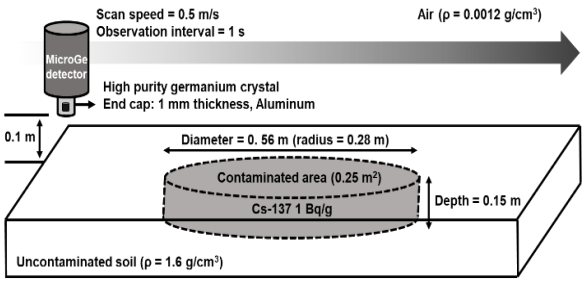

Figure 2 Diagram showing a soil contaminated with Cs-137 and scanning conditions

4. Results and discussion

The observation interval (i) was 1 seconds. The measured background count rate for Cs-137 at 662 keV was confirmed to be 0.004 cps. The value of d′ was selected as 1.38 with 95% true positive (1-β) and 60% false positive (α) based on the MARSSIM [1]. This resulted in an MDCR of 5.24 cpm. The CPMR was estimated at 104.81 cpm per μSv/h. The Microshield code was performed to compute the exposure rate (with build-up) at a height of 0.1 m above a cylindrical soil with a surface area of 25 m^2, a thickness of 0.15 m, and contamination of 1 Bq/g of Cs-137. This calculation yielded a result of 0.070 μSv/h per Bq/g. The scan MDC of the MicroGe detector was evaluated to be 0.32 Bq/g for land area, which means that the detector has the ability to detect concentrations above 0.32 Bq/g of Cs-137 when scanning at a speed of 0.5 m/s.

5. Conclusion

In order to evaluate the scan MDC for land areas, it is necessary to assume the area of soil contamination, the depth of soil contamination, the concentration of nuclides and the scan speed of the detector. In this study, the scan MDC was derived on the basis of an assumption of reasonable soil contamination, which was validated by survey experience at D&D sites. It is believed that scan MDC can be accurately assessed if the expected characteristics of the contamination in the land areas to be scanned can be adequately estimated in the future.

Acknowledgements

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