Study on improvement of scan survey system performance using collimator

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Introduction

- Radiological characterization assessment is required for the free release of the decommissioning site, and the scan survey method is used to assess the radioactivity distribution in the decommissioning site.
- The scan survey method, low scan MDC(Minimum Detectable Concentration) equipment is required, and the actual scan survey result can overestimate the hotspot size.
- In this study, evaluate the change of scan MDC value and quantitatively evaluate the reduction level of overestimation using a collimator.
- To this end, a scan survey experiment was conducted using a 3inch NaI(Tl) detector, collimator, and constant motion equipment to assess the overestimation level and the scan MDC value.

Method & Materials

The formula in the NUREG-1507 report was used to evaluate the scan MDC. For the calculation of the Minimum Detectable Count Rate(MDCR), 95% of the true positive proportion and 60% of the false positive rate were applied. The surveyor efficiency then applied to 0.5, as suggested in the NUREG-1507 report.

$$\mathrm{MDCR} = \mathrm{d}' \times \sqrt{b_i} \times (60/i)$$

$$\mathrm{MDCR_{surveyor}\ (cpm)} = \frac{\mathrm{MDCR\ (cpm)}}{\sqrt{\mathrm{p}}}$$

d' = Index of sensitivity, $\mathrm{b_i}$ = Background count rate (cpm), p = surveyor efficiency

The formula below was used to convert the calculated $\mathrm{MDCR_{surveyor}}$ to Minimum Detectable Exposure Rate(MDER) and evaluate the Scan MDC.

$$\mathrm{MDER\ (\mu R/h)} = \frac{\mathrm{MDCR_{surveyor}\ (cpm)}}{\mathrm{Detector\ sensitivity(cpm/\mu R/hr)}}$$

$$\mathrm{Scan\ MDC(pCi/g)} = \mathrm{MDER(\mu R/hr)} \times \mathrm{Exposurerate\ by\ concentration(pCi/g/\mu R/h)}$$

In this study, the detector sensitivity was evaluated with MCNP computer simulation and in-situ measurement to evaluate scan MDC. The collimator for the 3 inch NaI(Tl) detector was used to evaluate the changes in the scan survey performance following the collimator application (Fig.1).

Figure.1 45° collimator for 3inch NaI(Tl) detector

The uniform motion equipment was used to simulate the scan survey for soil, and the area source with a diameter of 56cm, a hotspot presented in the NUREG-1507 report, was used(Fig.2).

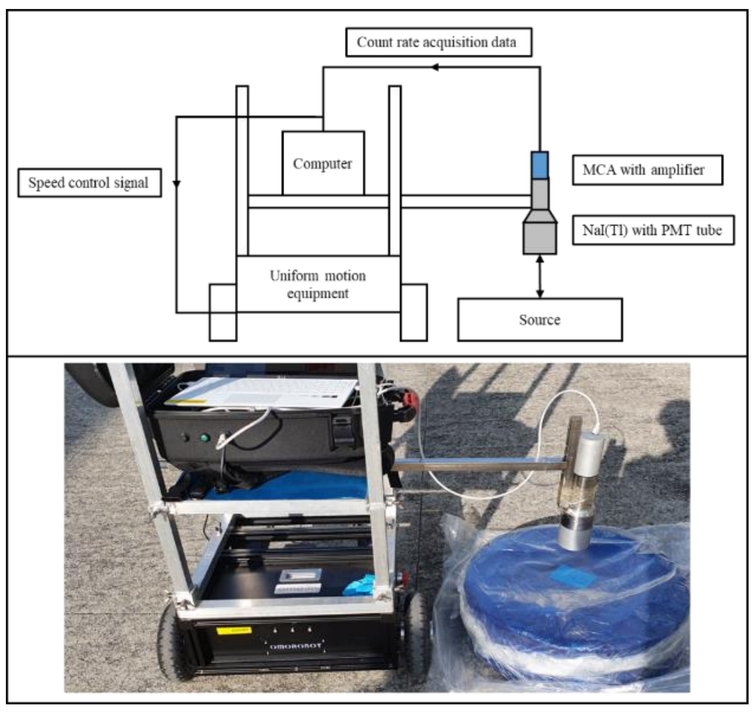

Figure.2 Uniform motion equipment for scan survey experiment

Result

The change in detector sensitivity by collimator application was evaluated for 3inch NaI detector (Table.1).

Table.1 Assessment of detector sensitivity change by detector condition

Detector condition	3inch NaI(Tl) detector with collimator		3inch NaI(Tl) detector	
Isotopes	^{137}Cs	^{60}Co	^{137}Cs	^{60}Co
Exposure rate (μR/h)	1.73	66.2	1.73	66.25
Net count rate (cpm)	1646	46682	2897	70874
Detector sensitivity (cpm/μR/hr)	954	705	1678	1070

As a result, the detector sensitivity was reduced by 34.11% on ^{137}Cs and 43.15% on ^{60}Co. Also, using the detector sensitivity, the scan MDC was evaluated (Table.2).

Table.2 Assessment of scan MDC change by detector condition

Detector condition	3inch NaI(Tl) detector with collimator		3inch NaI(Tl) detector	
Isotopes	^{137}Cs	^{60}Co	^{137}Cs	^{60}Co
Background count rate (cpm)	11930		42067	
$\mathrm{MDCR_{surveyor}}$ (cpm)	1651		3101	
MDER (μR/hr)	1.73	2.34	1.85	2.90
Scan MDC (pCi/g)	8.09	2.68	8.63	3.32

As a result, the application of the collimator reduced the scan MDC by 6.33% for ^{137}Cs and 19.18% for ^{60}Co. Therefore, it was confirmed that the range of measurable radioactive concentrations was improved. The overestimation factor is defined as below to confirm the overestimation level when conducting the scan survey.

$$\mathrm{Overestimation\ factor} = \frac{\mathrm{Estimated\ source\ size}}{\mathrm{Real\ source\ size(56cm)}}$$

The above formula was used to assess how overestimated the source size that count rates was above MDCR compared to actual sources size(Fig.3).

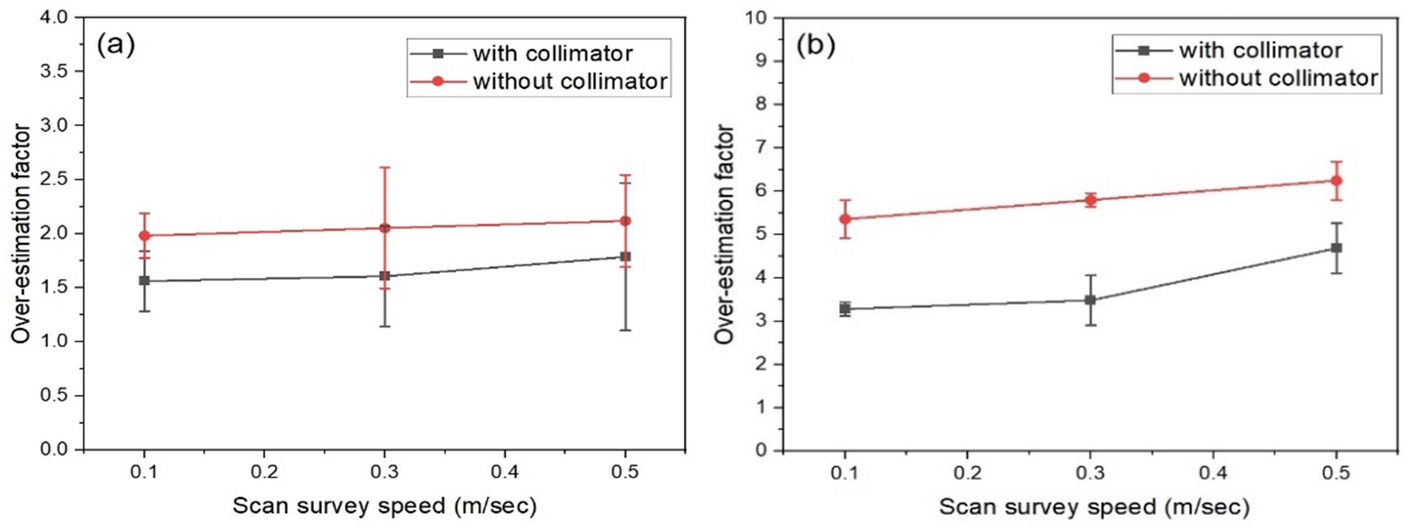

Figure.3 Overestimation factor change by detector condition and survey speed (a) ^{137}Cs,(b) ^{60}Co

The scan survey experiments show that the source overestimation level has increased as the scan survey speed increases. In addition, the overestimation level was reduced by 15.79% to 21.74% for ^{137}Cs nuclides and by 25.01% to 41.34% for ^{60}Co nuclides by using the collimator.

Conclusion

- The result of scan MDC changes following the collimator application in a 3inch NaI(Tl) detector, scan MDC reduced 34.11% on ^{137}Cs and 43.15% on ^{60}Co.
- The overestimation factor was reduced by 15.79% to 21.74% on ^{137}Cs and 25.01% to 41.34% on ^{60}Co, depending on the scan survey speed by using the collimator.
- The improvement of scan survey performance and accuracy was confirmed by using the collimator through the scan survey experiment.
- The results of this study will contribute to scan survey equipment selection and achievement of good hotspot characterization performance in decommissioning sites.

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