Development of a Device for Measuring the Vertical Distribution of Radioactivity in Soil using Geiger-Mullar Tubes

Shinya SUZUKI*, Masaru MIZOGUCHI*
*Graduate School of Agricultural and Life Sciences, The University of Tokyo

Introduction

On March 11, 2011, great earthquake hit in northeast Japan that caused Fukushima Daiichi Nuclear Power Plant accident. Although radiocaesium (^{134}Cs, ^{137}Cs) was fixed strongly to the soil from surface to 3～5 cm in depth, agricultural fields have been disturbed by wild boar and weed after three years passed from the accident. For the effective decontamination of the agricultural fields, it is needed to measure the vertical distribution of radiocaesium concentration in the soil in a short time. In this study, we have developed an in-situ device using Geiger-Mullar tubes to measure the vertical distribution of radiocaesium concentration.

Materials & Methods

1. Development of the in-situ device

The in-situ device is developed with MISAO Network Org. to measure the vertical distribution of radioactivity in soil in three minutes.

2. Calibration of the in-situ device (Komiya, Iitate-village)

Soil samples were taken in agricultural field to analyze radiocaesium concentration every 1cm by Ge semiconductor detector. Also, the vertical distribution of radioactivity in soil was measured by the in-situ device.

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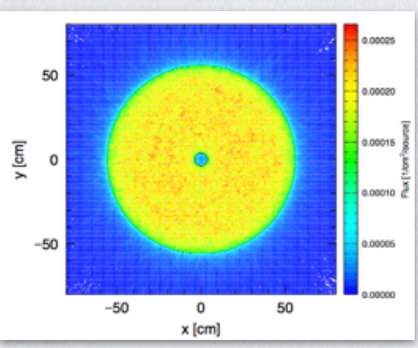

Effects of radiation on the in-situ device in contaminated soil were simulated by PHITS (Particle and Heavy Ion Transport code System) which is a software that can analyze the radiation behavior in arbitrarily-shaped three dimensions system using general-purpose Monte Carlo calculation code. We used it to quantify and visualize the complex radiation behavior in contaminated soil.

▼

$$L = \begin{bmatrix} L_{i,i} & \cdots & L_{i,j} \\ \vdots & \ddots & \vdots \\ L_{j,i} & \cdots & L_{j,j} \end{bmatrix}$$

$$y = ax + b$$

Calibration formula was obtained between radiocaesium concentration and counting rate.

3. Application of the in-situ device (Sasu, Iitate-village)

Radiocaesium concentration with the in-situ device was compared to that of soil samples taken.

*Left: the in-situ device
Right: sampling soils

Conclusions

An in-situ device using Geiger-Mullar tubes was developed for measuring radiocaesium concentration in soil at each depth level.

However, some improvements are still needed:
(1) Evaluation to effects of leakage coefficients by PHITS.
(2) Non-disturbed digging hole method for setting the in-situ device.

Anyhow, farmers are now using the in-situ device to monitor the vertical distribution of radiocaesium concentration in agricultural fields in Fukushima.

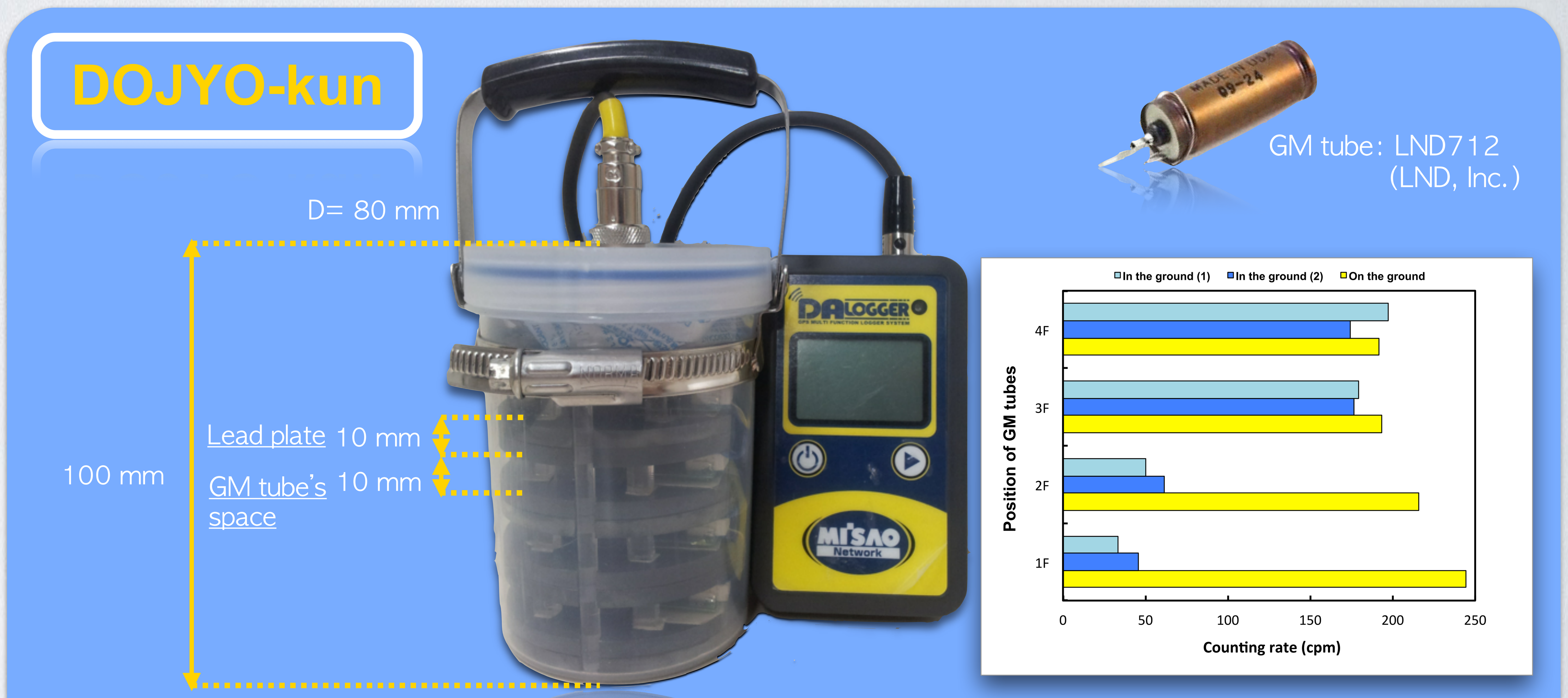

Fig. 1 Measuring example of the in-situ device "DOJYO-kun".

Results & Discussions

Simulation by PHITS

Effects of contaminated soil on the in-situ device were simulated by PHITS. If soil is contaminated, the radiation of the soil has effect on each Geiger-Mullar tube which is located in different from the contaminated soil (Fig. 2). Therefore, PHITS simulates effects of contaminated soil as "Leakage coefficients" at each depth level of Geiger-Mullar tubes (1-2, 3-4, 5-6, 6-7 cm).

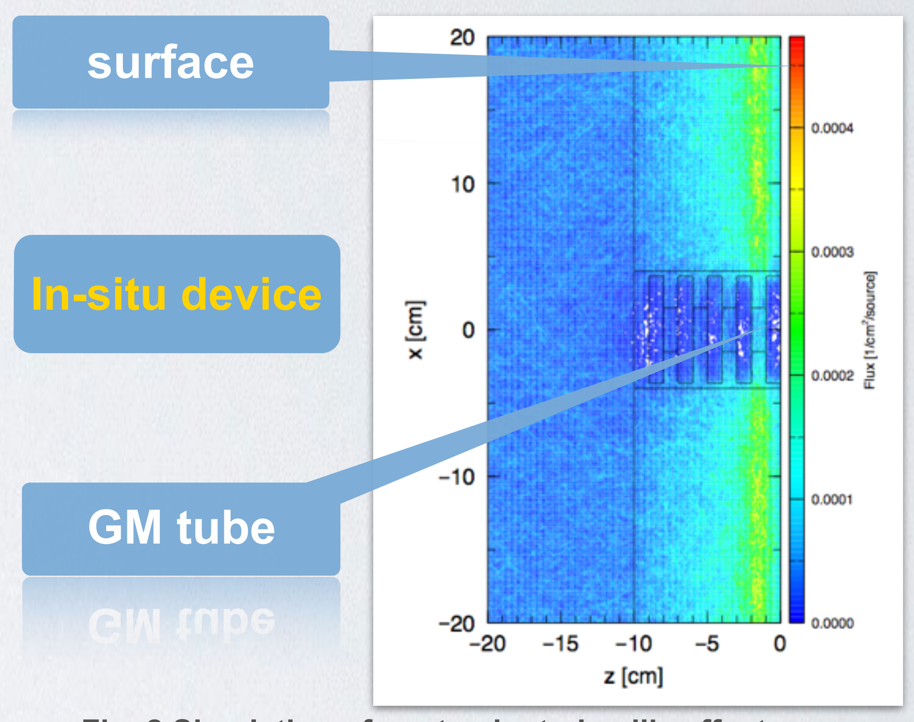

Fig. 2 Simulation of contaminated soil's effects on the in-situ device by PHITS (1-2 cm).

Calibration

Calibration formula in consideration of leakage coefficients by PHITS (Eq. 2) has higher correlation coefficients than Eq. 1 without consideration of leakage coefficients.

The leakage coefficients is defined as the ratio of flux through Geiger-Mullar tube:

$$L_{ij} = \frac{F_j}{F_i} \qquad [1]$$

where F_i is flux through Geiger-Mullar tube at the same depth as the contaminated soil (cm^{-2} source^{-1}), F_j is flux through Geiger-Mullar tube at the different depth from the contaminated soil (cm^{-2} source^{-1}).

The vertical distribution of radiocaesium concentration in real-soil conditions can be duplicated to correct leakage coefficients of the in-situ device in detail.

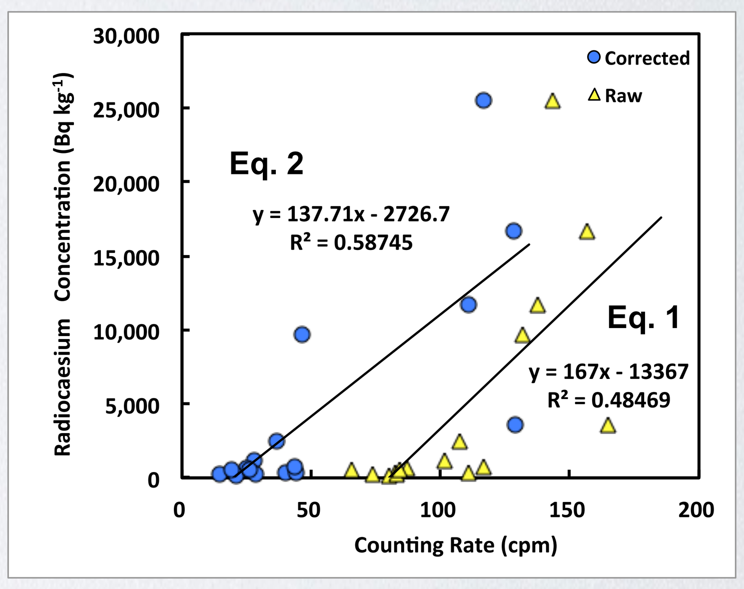

Fig. 3 Calibration between radiocaesium concentration and counting rate (Eq. 1 is without any consideration of leakage coefficients, Eq. 2 is considered leakage coefficients.).

Comparison of radiocaesium concentration between the in-situ device and sampling soil.

The vertical distribution of radiocaesium concentration by Eq. 2 approximately coincides with that of soil sampling (Fig. 4a～c). However radiocaesium concentration of the 1-2 cm soil measured with the in-situ device is smaller than that of sampled soil.

These results are attributable to two reasons: (1) Disturbance of surface soil and (2) mismatch of 0 cm's reference between the in-situ device and actual soil surface which is made in agricultural fields.

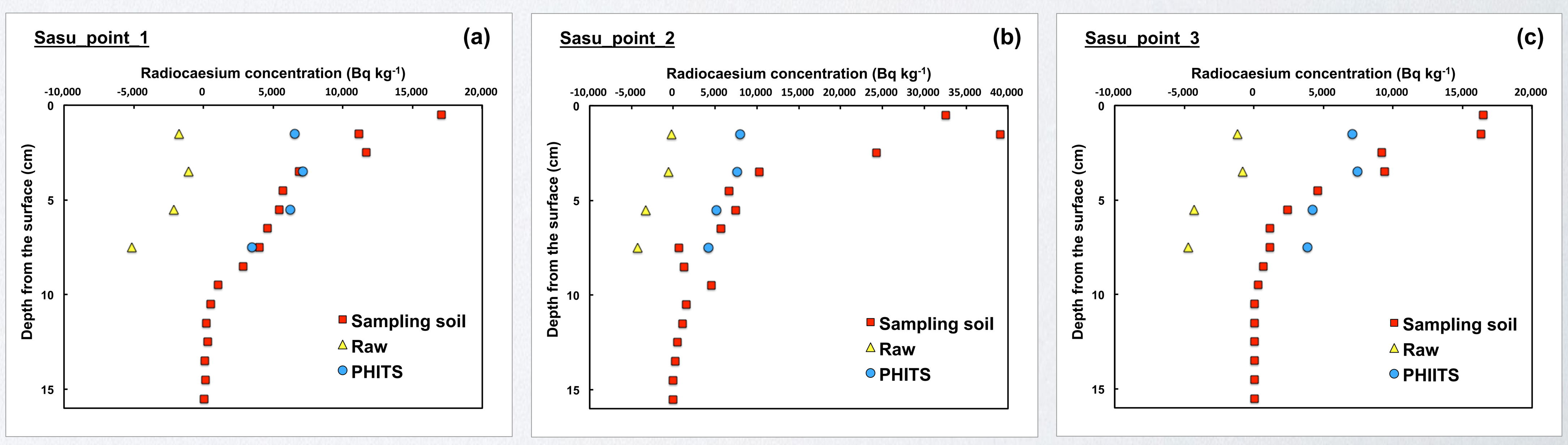

Fig. 4 Comparison of radiocaesium concentration between the in-situ device and sampling.

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