Correlation between Radiation Measurement on the Field Slopes using KURAMA-II(Kyoto University RAdiation MApping system) and Environmental Radioactivity in the Soil Depth Direction

Yoshikatsu Ueda[1], Naoto Nihei[2], Rattanaporn Norarat[3], Minoru Tanigaki[4]

[1] Research Institute for Sustainable Humanosphere, Kyoto University, Gokasho, Uji, Kyoto 611-0011, Japan
[2] Faculty of Food and Agricultural Sciences, Fukushima University
[3] Rajamangala University of Technology Lanna
[4] Institute for Integrated Radiation and Nuclear Science, Kyoto University
yueda@rish.kyoto-u.ac.jp

Abstract. Using KURAMA-II (Kyoto University Radiation Measurement System), we investigated the environmental radioactivity after decontamination in the rice fields of Iitate Village, Fukushima Prefecture. We compared the cross-correlation between the measurement results of KURAMA-II and those of actual soil sampling to confirm the measurement error, especially in the sloping area around the rice field. The results showed an excellent agreement between the soil sample of 5 cm surface layer even in slope.

Keywords: Fukushima, Great East Japan Earthquake, Radiation Monitoring

1 Introduction

Tohoku region in Japan was suffered from the triple disaster of the earthquake, the tsunami and Fukushima Daiichi Nuclear Power Plant accident on March 11, 2011. More than 15,000 people lost their lives, and over 2,500 are still officially reported as missing, while a further 6,000 suffered injuries. In total, over 470,000 people were evacuated from their homes because of radioactive leakage from the power plant. There were about four types of radioactive materials that were diffused: Cs-134, Cs-137, I-131, and Sr-90. Iodine-131, which has a short half-life, had no effect in a long time, and Sr-90 was not a problem because the amount diffused was small in Fukushima. Since radioactive cesium(Cs-134, Cs-137) has a large impact on the environment, research on its decontamination attracted much attention. Since 2011, the Japanese government promoted decontamination works, such as contaminated surface soil removal and re-covering the area with uncontaminated soil to reduce and block the radiation. Meanwhile, continuous monitoring of radioactive cesium in soil and air dose is required to evaluate the fate of radiocesium and establish strategies for remediation and management of the contaminated land. In 2011, to measure radiocerium that has fallen to the ground surface, Kyoto University Research Reactor Institute (now Institute for Integrated Radiation and Nuclear Science) had developed a system that can measure the density of radioactive cesium on the ground surface in situ using simple measurements[1]. This system can be used to measure the density of radiocesium contamination on the surface of the ground as you move around, either on a vehicle or on a motorcycle, and the data is stored on a cloud server via the Internet, so that the measured data can be analyzed immediately[2, 3].

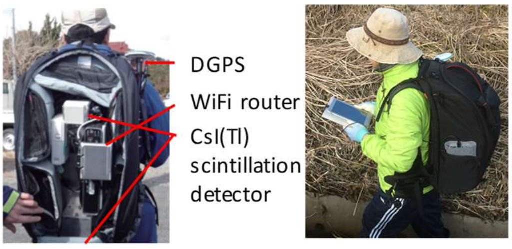

Fig 1. KURAMA-II system

In the observation with the walking survey KURAMA-II (Fig. 1), the method of measuring the ground surface dose rate is based on the use of two CsI sensors. The lower CsI sensor is set up to detect radiation only in the lower direction by covering the surrounding area (upper and lateral directions) with lead except for the lower direction. From the radiation intensity of the entire space measured by the upper sensor, only the contamination density on the ground surface is detected. Walking surveys can measure the radiation intensity every second, which is a great tool, especially for the observation of narrow roads and rivers where cars and motorcycles cannot enter. On the other hand, there is a problem with the height of the observer, the posture of the walker, and a large number of errors in the measurement of non-flat areas. We confirm this data error due to posture and on the slope. We have checked what kind of error is caused by various walking.

We have measured the surface contamination density of agricultural land in Fukushima prefecture using the KURAMA-II system. In particular, in mountainous areas such as Iitate Village, the influence of the environment around the field (irrigation rivers, etc.) and the slope of the mountain next to the field can be more significant. In mountainous forest areas, there are many places where decontamination work has not been done yet, and there is a possibility of radiocesium leakage. In particular, we have been trying to determine the effect of KURAMA-II measurements on the accuracy of surface contamination densities on this slope. In this paper, we report on these results.

2 Experimental

2.1 Experimental Setup

For the slope measurements by KURAMA-II, we used a field in Iitate Village, Fukushima Prefecture (Fig. 2), to carry out the measurements. Specifically, we conducted walking survey measurements in the rice fields and areas with some slopes, and collected more measurement data, especially in the slopes around the irrigation rivers next to the rice fields. The measurements were conducted on December 15, 2017 and March 17, 2018. To simultaneously compare the results of measurements by KURAMA-II with actual soil sampling, soil sampling of the top and bottom of the slope (December 15, 2017) and also the middle part of the slope was additionally conducted (March 17, 2018). During this sampling, in order to check the concentration of radiocesium in the soil in the direction of depth from the ground surface, the concentrations in the soil were measured[4] in three levels of depth: 0-5 cm, 5-10 cm, and 10-15 cm starting from the ground surface (0 cm).

Fig. 2 Iitate Village

The results of the walking sampling by KURAMA-II are shown in the color map, and the soil sampling points are shown in Fig. 3: 8 points (upper and lower) from 17-A to H for the 2017 sample, and 8 points (upper, middle, and lower) from 18-A to 18-H for the 2018 sample. We also measured the concentration of radiocesium in the walking survey of KURAMA-II. The ground surface contamination density was measured from the following formula for calculating the ground surface contamination density [2, 3].

$$\mathrm{C}_{\mathrm{KURAMAII}} = \left(\mathrm{D}_{\mathrm{Lower}} - \mathrm{D}_{\mathrm{Upper}}\right) \times 4000 + 48$$

$$\mathrm{C}_{\mathrm{KURAMAII}} \ldots Surface\ Contamination\ Density\ (Bq/kg)$$

$$\mathrm{D}_{\mathrm{Upper}} \ldots Dose\ rate\ (Upper)$$

$$\mathrm{D}_{\mathrm{Lower}} \ldots Dose\ rate\ (Lower)$$

To compare the surface contamination density of KURAMA-II ($C_{KURAMAII}$) with that of soil samples, an x-y plot (y-axis: KURAMA-II, x-axis: soil samples) was prepared as a correlation chart. samples) were prepared. In particular, for soil samples, the correlation by the depth and the overall average was charted, and the correlation was evaluated by Coefficient of determination (COD).

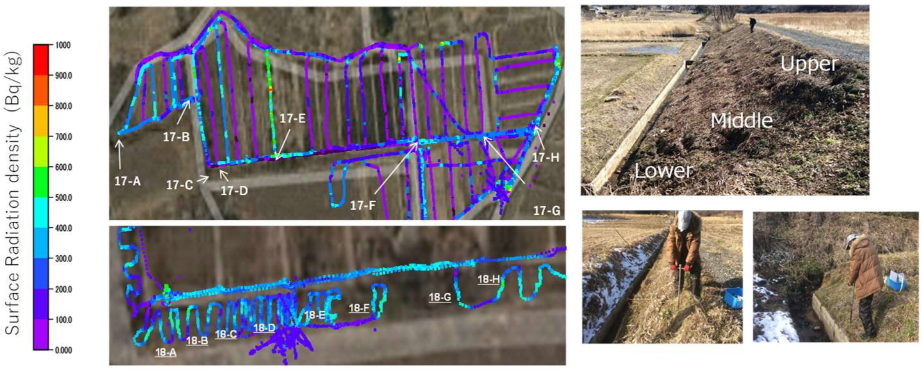

Fig. 3 Survey results by KURAMA-II and Soil sampling points

3 Results and Discussion

3.1 Concentration of radiocesium in sampled soil

The results for radiocesium concentrations in soil sampled in 2017 and 2018 are shown in Fig. 4.

Fig. 4 Radiation densities of soil samples by depth (upper graph: 2017, lower graph: 2018 and Upper(upper slope), Middle(middle slope), Lower(lower slope))

The trend in sampling at both years was that the concentration of radiocesium in the soil decreased with depth, although there were some exceptions (17-H). This indicates that radiocesium does not penetrate very deep into the soil, but only up to about 5 cm in the surface layer. Regarding the comparison of cesium concentrations at different locations on the upper, middle, and lower slopes, radiocesium concentrations were higher in the middle and lower parts of the slope in the surface layer (0-5 cm, left graphs). This result is also considered reasonable, since radiocesium may move from the top to the bottom of a slope due to external influences such as rain. Regarding the distribution of concentration in the lower layer (10-15 cm) in 2018, the fact that only the concentration of radiocesium in the upper part of the slope was detected at many points suggests that the points where soil samples were taken in 2018 were places where there was still minimal human movement. Soil erosion was kept to a minimum. In addition, there was a constant transfer of radiocesium from the mountain next to the slope, which may have resulted in a certain amount of radiocesium in the deep soil.

The results of the correlation between KURAMA-II and the soil samples are then shown in Fig. 5 and 6.

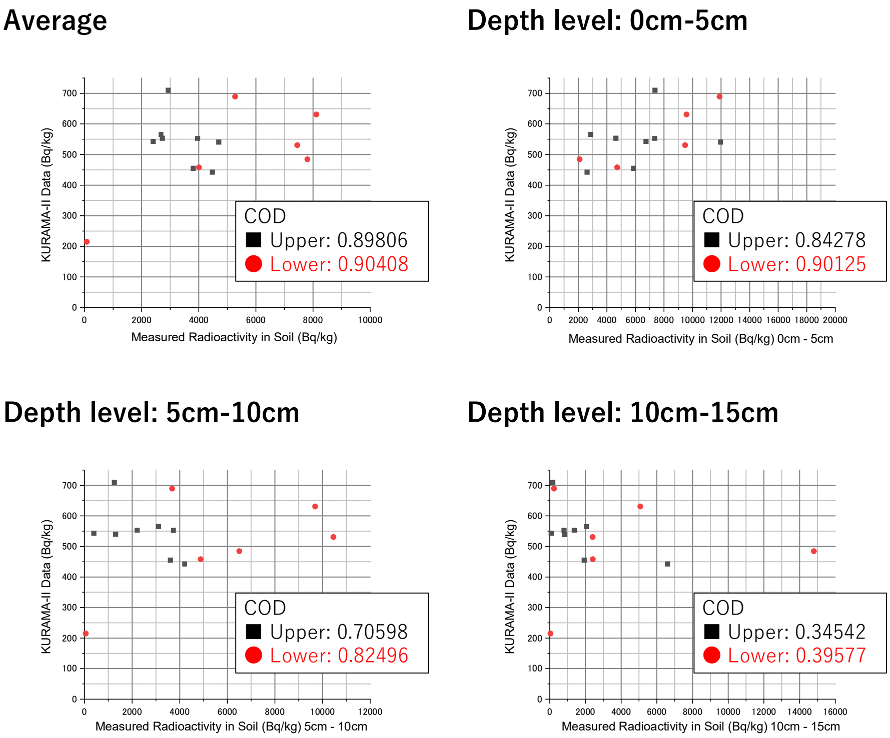

Fig. 5 Comparison of radiation density of soil samples with measurements by KURAMA-II (2017).

The COD shows a high correlation between the overall mean and the 0-5 cm surface layer in Fig. 5. In particular, the correlation with the surface layer is excellent, indicating that KURAMA-II can measure the surface contamination density well. On the other hand, there is a 7-fold difference between the results and the actual measurement of the soil, so it is necessary to conduct calibration sampling to match the precise measurement. It was also found that there was a gradual increase in variability below a depth of 5 cm. The accuracy of KURAMA-II was not very good for underground contamination concentrations because of the principle of measuring the surface contamination density from the air.

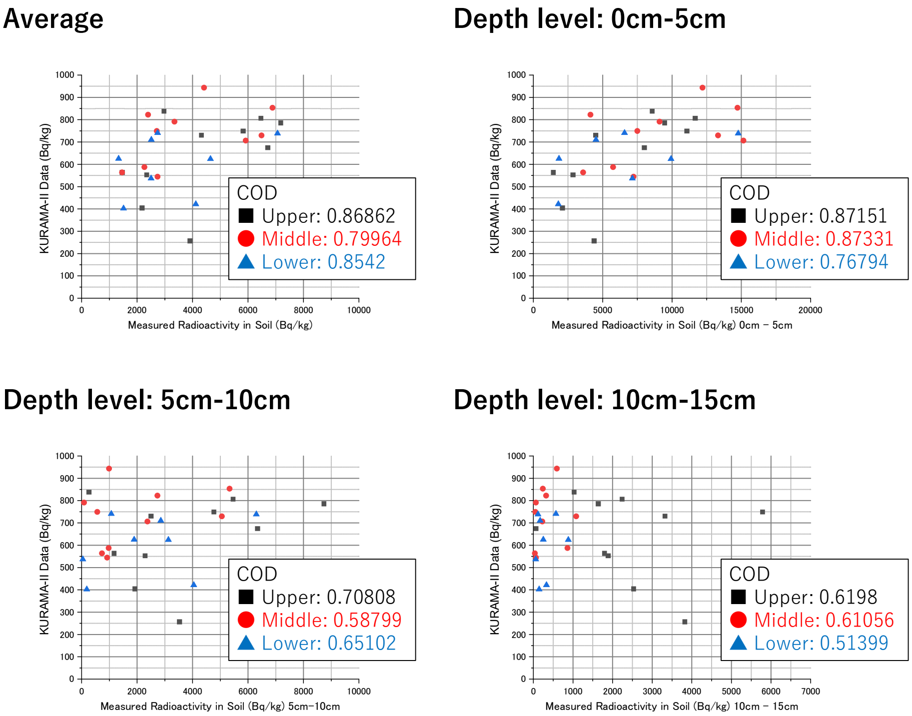

Fig. 6 Comparison of radiation density of soil samples with measurements by KURAMA-II (2018).

The sample results for 2018 are shown in Fig. 6. The trend of the graphs is similar to that of 2017, with excellent correlations, especially with soil samples in the surface layer 0 cm - 5 cm. On the other hand, there is a poor correlation in the middle and lower part of the slope. These results may be due to the fact that the 2017 slope was measured on a relatively gentle slope with a low height, while the 2018 slope, as shown in the photo (Fig. 3), is about 5 m high and is easily affected by the sides of the slope, resulting in a low correlation. However, even on a slope with a certain degree of steepness and height, the surface contamination density measured by KURAMA-II was sufficient.

4 Conclusion

In this study, we confirmed the difference between the surface contamination density measurement by KURAMA-II and the actual soil sampling, especially in the slope area of a rural field. Comparison of correlation plots showed that the correlation was very high, especially in the surface layer of 0-5 cm. KURAMA-II was able to measure the surface contamination density accurately. On the other hand, there was a 7-fold difference between the measured and measured densities on the slope, indicating that the initial measurement is essential to calibrate the difference. In the future, we would like to collect calibration data for more accurate measurement and use this system to measure the surface contamination density in the soil more accurately, even if it is simple.

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References

[1] M. Tanigaki, R. Okumura, K. Takamiya, N. Sato, H. Yoshino, H. Yoshinaga, Y. Kobayashi, A. Uehara, and H. Yamana, "Development of KURAMA-II and its operation in Fukushima," *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment,* vol. 781, pp. 57-64, 2015.

[2] M. Andoh, S. Mikami, S. Tsuda, T. Yoshida, N. Matsuda, and K. Saito, "Decreasing trend of ambient dose equivalent rates over a wide area in eastern Japan until 2016 evaluated by car-borne surveys using KURAMA systems," *J Environ Radioact,* vol. 210, pp. 105813, Dec, 2019.

[3] M. Andoh, H. Yamamoto, T. Kanno, and K. Saito, "Measurement of ambient dose equivalent rates by walk survey around Fukushima Dai-ichi Nuclear Power Plant using KURAMA-II until 2016," *J Environ Radioact,* vol. 210, pp. 105812, Dec, 2019.

[4] T. Nobori, K. Tanoi, and T. Nakanishi, "Measurement of radiocesium in soil and crops using NaI(Tl) scintillation counter with autosampler," *Japanese Journal of Soil Science and Fertilizer,* vol. 84, no. 3, pp. 182-186, 2013.