Radioactivity Measurement of Fruits and Soil in the Hamadori Region, Fukushima Prefecture

Mai Kondo[1)], Mizuki Sumihama[1)2)], Michio Okada[3)], Hiroaki Tanigawa[2)], Isao Tanihata[2)], Ayuto Kato[1)], Sawa Ishikawa[4)]

Gifu University Faculty of Education[1)], The University of Osaka RCNP [2)], The University of Osaka IRS [3)], Tohoku University GSIS[4)]

Abstract

On March 11, 2011, the Great East Japan Earthquake triggered an accident at the Fukushima Daiichi Nuclear Power Plant (1F), resulting in the release of radioactive materials into the atmosphere. Okuma Town, Futaba District, Fukushima Prefecture, where 1F is located, was once well known for its fruit production. However, many orchards have remained abandoned due to radioactive contamination.

In this study, the uptake of Cs-137 by kiwifruit and yuzu trees was investigated. In October and November 2025, fruits and leaves of kiwifruit and yuzu trees, as well as surface soil where the trees were growing, were collected within **the Difficult-to-return zone of Okuma Town**. The radioactivity concentrations of these samples were measured using a high-purity germanium (HPGe) detector.

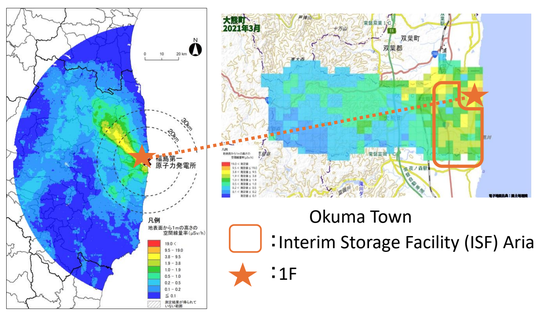
The results of these measurements and their implications are presented and discussed here.

Background

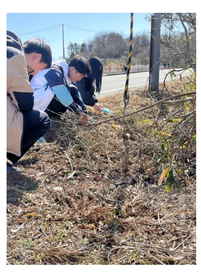
As a result of the 1F accident, radioactive materials were released into the atmosphere and dispersed over the Hamadori region. Among these radionuclides, Cs-137, which has a relatively long half-life of approximately 30 years, continues to have significant impacts on the environment and daily life in the Hamadori region of Fukushima Prefecture.

【Okuma Town】

Okuma Town was once known for the cultivation of fruits such as kiwifruit and Japanese pear. However, the 1F accident resulted in the contamination of many orchards with radioactive materials. Even 15 years after the accident, many of these orchards remain within the Difficult-to-return zone and continue to be unmanaged.



Ambient dose rate map using a 500-m mesh (March 2021)

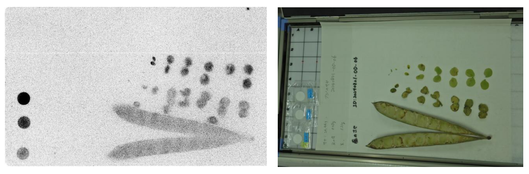


Measurement of ambient dose rates in the Difficult-to-Return Zone

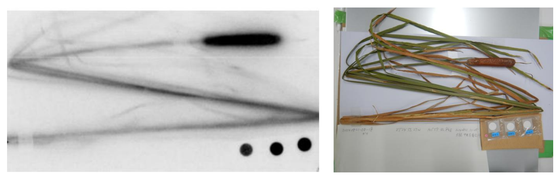
An orchard in the Difficult-to-Return Zone

【Previous Research】

- Cesium is known to be taken up by plants because its chemical properties are similar to those of potassium, an essential nutrient for plant growth.
- Previous studies have suggested that the concentration of Cs-137 may vary among different plant parts. As an example, imaging plate (IP) autoradiographs of Japanese wisteria (*Fuji*) and cattail (*Gama*) samples collected from the Difficult-to-return zone in Okuma Town are shown below. These images indicate that relatively high levels of radioactivity are concentrated in the seeds of Japanese wisteria and in the spikes (seed heads) of cattail.



IP image of Wisteria fruit



IP image of Cattail

Objective

Fruit tree and soil samples were collected from the Difficult-to-return zone in Okuma Town, located in the Hamadori region of Fukushima Prefecture, to evaluate differences in Cs-137 accumulation among **fruit tree species and plant parts**.

Methods

【Sampling】 Okuma Town
within approximately 5 km of 1F, including the Interim Storage Facility (ISF) area

Kiwifruit samples were collected at four locations, October 2025

Kiwifruit cultivation was once a major agricultural activity in Okuma Town. Consequently, orchards that have remained unmanaged since the 1F accident are still present in the area.

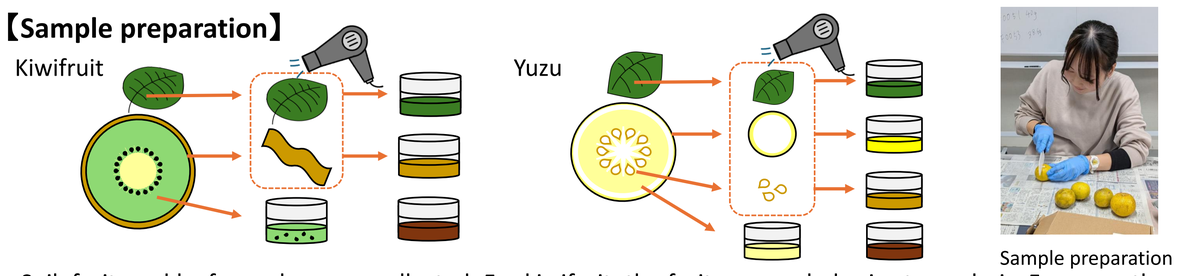
Yuzu samples were collected at nine locations, November 2025

Yuzu (*Citrus junos*) is a citrus fruit widely appreciated in Japan and is commonly grown in residential gardens. In Okuma Town, yuzu trees abandoned after the 1F accident can still be found around remaining houses.

Kiwifruit sampling

Yuzu tree in a residential garden

【Sample preparation】



Sample preparation

Soil, fruit, and leaf samples were collected. For kiwifruit, the fruit was peeled prior to analysis. For yuzu, the seeds and peel were removed. The edible portions (juice) were homogenized using a blender and packed into containers. The peels, seeds, and leaves were dried, homogenized, and packed into containers for radioactivity measurement. The soil samples were also packed into containers.

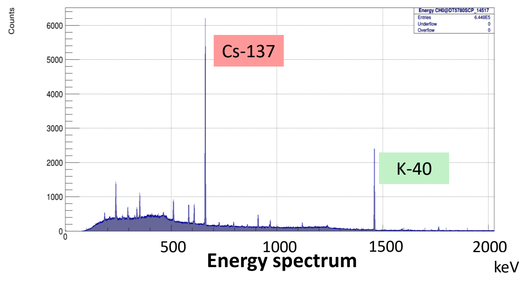
【Measurement】

A high-purity germanium (HPGe) detector was used to observe the characteristic gamma-ray peaks of Cs-137 at 662 keV and K-40 at 1461 keV, and to determine the radioactivity concentrations (Bq/kg). For dried samples, the radioactivity concentrations were calculated using the pre-drying mass to estimate the concentrations before drying.

Ge semiconductor detector
- GEM25 MCA7 SEIKO EG&G(ORTEC)
- CANBERRA GX4018

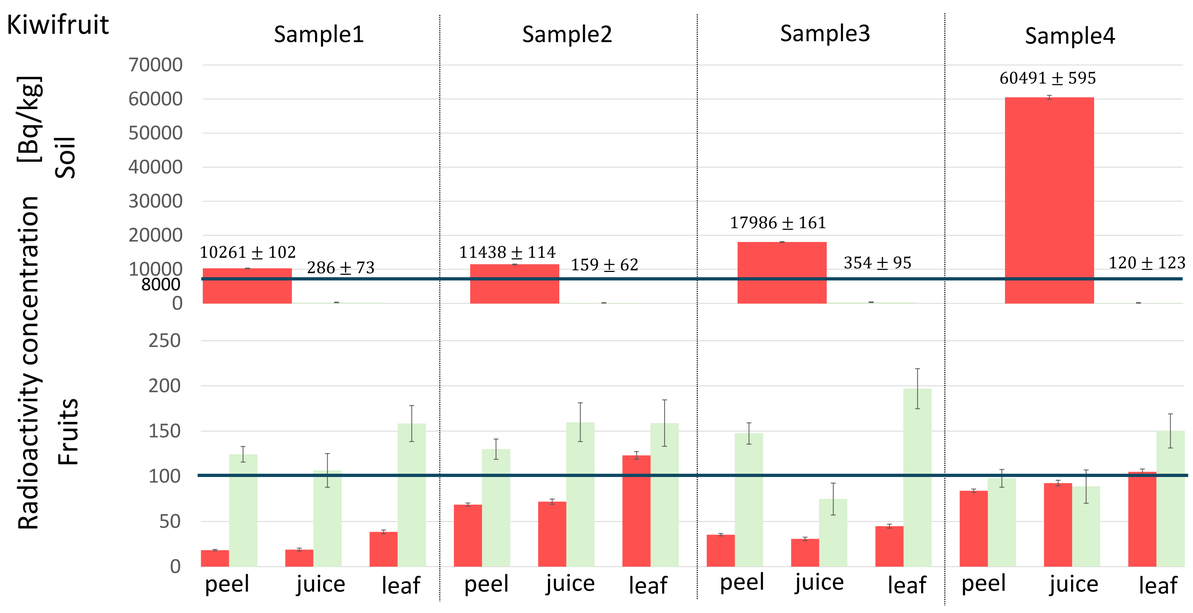
Crystal size : Ø6.00 cm × 5.00 cm

Resolution(FWHM) : 1.3 keV @662 keV
Detection efficiency : 1.2~3.0%@662 keV

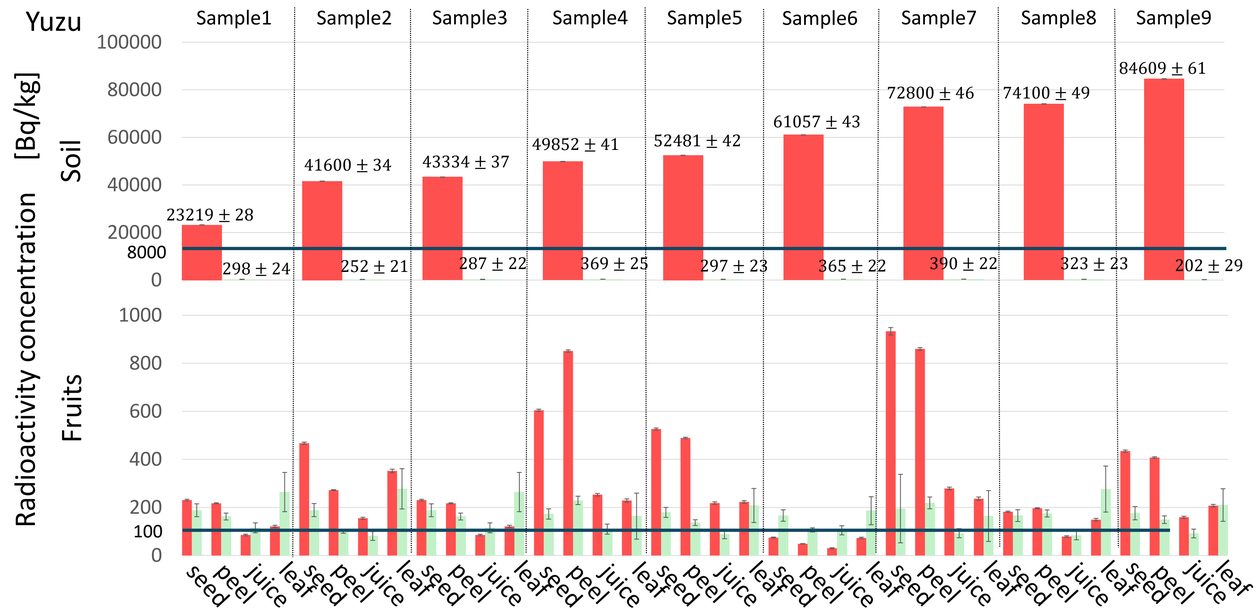


Results

※For soil samples, the reference value of 8,000 Bq/kg, which is the safety criterion for the reuse of waste materials in Japan, is indicated. For plants, the regular limit of 100 Bq/kg for radiocesium in general foods in Japan is indicated. Cs-137 [Bq/kg] K-40 [Bq/kg]



- The Cs-137 concentrations in all surface soil samples exceeded 8,000 Bq/kg, whereas those in all edible parts were found to be below the Japanese limit of 100 Bq/kg. → We can eat.
- The K-40 concentrations in surface soil samples ranged from 120 to 350 Bq/kg, whereas those in edible parts were comparable to, or even higher than, the Cs-137 concentrations.
- The leaves of kiwifruit tended to show higher Cs-137 concentrations than other plant parts.
- No correlation between soil and plant Cs-137 concentrations was observed.

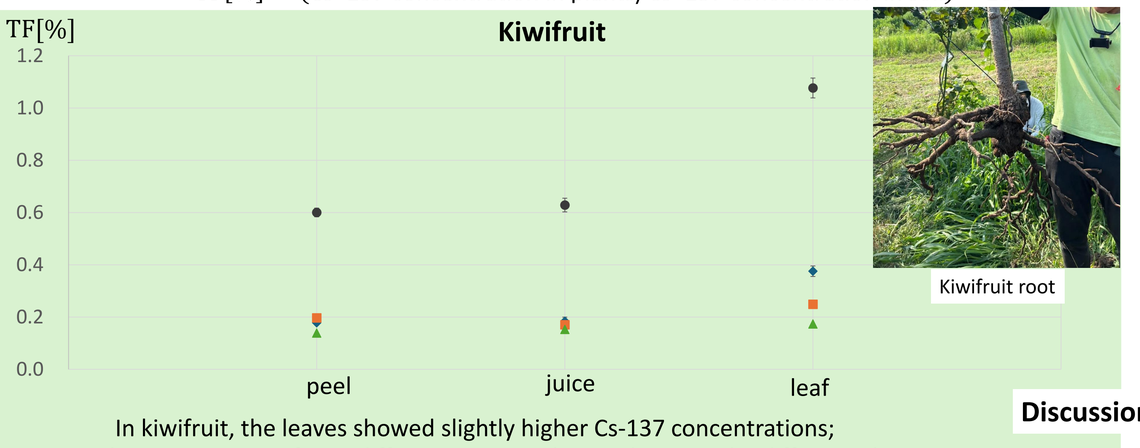


- The Cs-137 concentrations in surface soil samples ranged from 20,000 to 80,000 Bq/kg, whereas those in both fruits and leaves were below 1,000 Bq/kg.
- The K-40 concentrations in surface soil samples ranged from 200 to 400 Bq/kg, and those in both fruits and leaves were at comparable levels.
- In yuzu, the peel and seeds tended to show higher Cs-137 concentrations than other parts; however, no such tendency was observed for K-40 concentrations.
- Yuzu showed large variations in Cs-137 concentrations among individual samples.
- No correlation between soil and plant Cs-137 concentrations was observed.

Consideration

Based on the above results, transfer factors (TF) were calculated and are shown below.

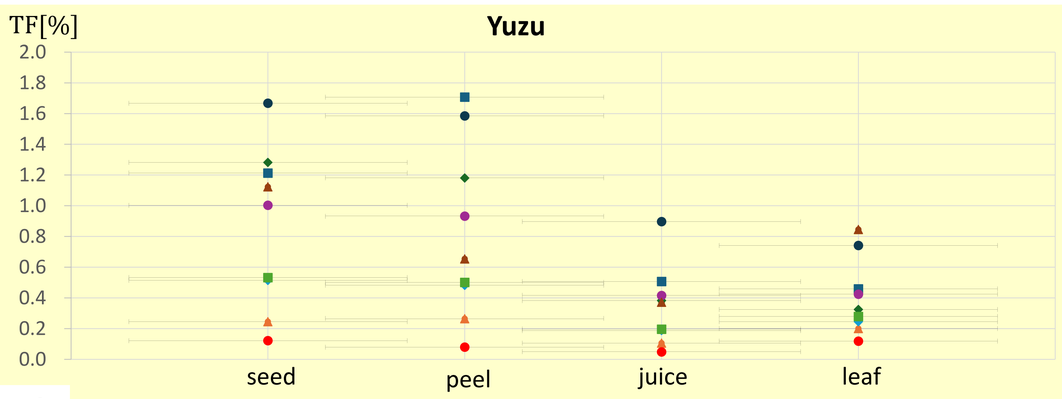
$$TF[\%] = (\text{Cs-137 concentration in plants} / \text{Cs-137 concentration in soil}) \times 100$$



Kiwifruit root

In kiwifruit, the leaves showed slightly higher Cs-137 concentrations; however, no significant differences were observed among the different plant parts.

Discussion for plant parts



In yuzu, the Cs-137 concentrations in the peel and seeds were approximately twice those in the juice and leaves.

Discussion for each plant

Kiwifruit is generally a plant rich in potassium (approximately 300 mg/100 g) and has a shallow, spreading root system. Since Cs-137 is strongly adsorbed in surface soil, relatively high Cs-137 concentrations in kiwifruit were expected. However, the results showed that Cs-137 concentrations in kiwifruit were lower than those in yuzu. It was also found to be lower than the values observed for akebi (*Akebia quinata*) and chestnut. →These results suggest that kiwifruit may have a lower capacity for Cs-137 uptake.

Yuzu is generally a deep-rooted plant, but the depth of its roots varies depending on tree age and height. This may be a factor contributing to the observed variability in Cs-137 concentrations in yuzu. It might also have been necessary to investigate the age and height of yuzu trees.

Summary

① **Slight differences in Cs-137 uptake were observed among plant parts.**

② **Differences in Cs-137 and K-40 uptake were observed between the fruit tree species , kiwifruit and yuzu.**
These may be influenced by factors such as the relationship between root distribution and the distributions of Cs-137 and K in the soil and potassium content in fruit trees; however, other contributing factors are also possible.

Future prospects

To clarify the factors underlying these differences, we will continue this study by increasing the number of samples and the variety of fruit tree species analyzed.

Acknowledgments

This research is supported by the Nuclear Human Resources Development Promotion Project Subsidy “Nuclear Regulation Human Resources Development Program through Co-creation with Society,” the Fukushima Innovation Coast Framework “Human Resource Development Infrastructure Construction Projects Utilizing the ‘Reconstruction Knowledge’ of Universities, etc.”, and the FY2025 Okuma Town Related/Exchange Population Expansion Project Subsidy. Furthermore, this research is conducted under the agreement for collaboration and cooperation between Okuma Town and The University of Osaka, with the cooperation of the local government and its residents. We also express our gratitude to Fukushima Center, The University of Osaka and all related parties for their cooperation.

References

- https://fooddb.mext.go.jp/MEXT Food Composition Database
- M. Takahashi et al.," Environmental radiation workshop held in Iitate village, Fukushima prefecture" Proceedings of the 22nd Workshop on Environmental Radioactivity, KEK proceedings 2021-2, 170-175 (2021)
- 山口紀子 他「土壌－植物系における放射性セシウムの挙動とその変動要因」農業環境技術研究所報告, 第31号, pp. 75-129 (2012).
- Smolders, E. & Mertens, J. (2011) “The transfer of radiocesium from soil to plants.” *Integrated Environmental Assessment and Management*