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The role of potassium on the remediation for the radiocesium contaminated soil

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Abstract

The Tokyo Electric Company's Fukushima Dai-ichi Nuclear Power Plant accident contaminated a large area of agricultural land with radioactive cesium. If the contamination levels were high, topsoil removal or inversion tillage were the major countermeasures used to decrease the radioactivity of the soil. However, a substantial level of radioactive cesium remained in the soil, even after decontamination and some fields weren't decontaminated. To mitigate radioactive cesium transfer from soil to plant, we tested increasing potassium levels in the soil. In this paper, we demonstrate how we developed these countermeasures in Fukushima.

Key words: radioactive cesium, TEPCO’s Fukushima Daiichi Nuclear Power Plant, potassium, transfer factor, topsoil removal

Introduction

Ten years has changed the view of agricultural fields in Fukushima prefecture. In March, 2011, after the Great Eastern Japan earthquake, Tokyo Electric Company’s Fukushima Dai-ichi Nuclear Power Plant (FDNPP) was struck by Tsunami and subsequently the power supply loss caused hydrogen explosion three times during March 12 to 15th. It is estimated that about 2.7 Peta Bq of radioactive cesium (^{134}Cs + ^{137}Cs) was dispersed within a radius of 80 kilometers from FDNPP and the basin of Abukuma river (Onda et al. 2020). Though the actual weight of the radioactive cesium was only about 53 g, the soil was contaminated with radioactive cesium. And when the radioactivity of the soil was high, the contaminated topsoil must be removed. It is generally recommended to remove 5cm of soil and replace it with non-contaminated mountainous soil. The removal was carried out using construction machinery, and it is easy to imagine that complete removal of radioactive cesium is unrealistic. In some cases, the remaining radioactivity makes the field radioactive cesium level in the cultivation zone, (15 cm depth) more than 3,000 Bq/kg. Furthermore, no topsoil removal was carried out if the soil was found to be lower than 5,000 Bq/kg. The limit for general food was 500 Bq/kg in 2011 (MHLW 2011a, b) and 100 Bq/kg from 2012 (MHLW 2011c, 2019). This change required the development of countermeasures to mitigate the radioactive cesium transfer from soil to plant. Based on a soil survey, it was found that the level of available potassium is critical to regulating this process (Kato et al. 2015).

Limitation determined based on the data after global fallout

Based on a literature survey of the effect of radioactive cesium on paddy rice production, a very limited number of experiments have been reported. In 2011, the standard limit for general foods was set at 500 Bq/kg (which has since been changed to 100 Bq/kg from 2012) and the maximum transfer factor of radioactive Cs was evaluated based on the monitoring data obtained in 15 representative paddy fields in Japan after global fall out (Fig. 1). Based on this data the maximum transfer factor was designated as 0.1 for rice (NERH 2011). If the soil radioactive Cs concentration is lower than 5,000 Bq/kg it is possible to grow rice without countermeasures. Based on this estimation, rice production is allowed in those areas with 5,000 Bq/kg soil. While we have failed to overcome the problem in several areas with lower than 5,000 Bq/kg soil, radioactive Cs content of brown rice still exceeded 500 Bq/kg. By analyzing plant and soil samples, we found soil exchangeable potassium content is a critical factor determining the transfer factor of radioactive Cs (Fukushima prefecture and MAFF 2011).

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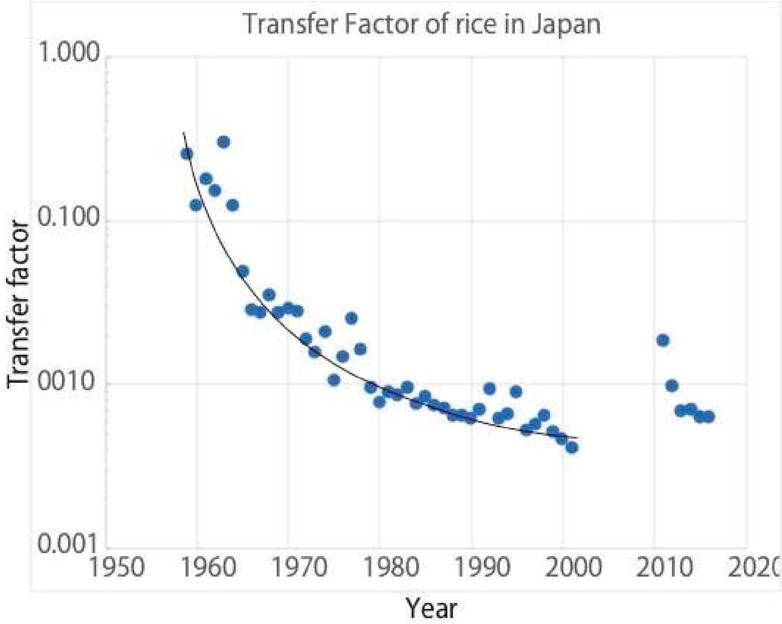

Figure 1. Transfer factor of ^{137}Cs to brown rice during and after global fallout in representative paddy fields in Japan. Data provided by the National Institute of Agrobiological Sciences (Data were obtained from https://vgai.rad.naro.go.jp/).

Physical decontamination

In those areas where the topsoil contamination level is over 5,000 Bq/kg, the removal of 5 cm of topsoil is progressing. In Japan, topsoil removal is considered the best way to reduce radiation exposure from soil and reduce the migration of radioactive cesium from soil to plants. However, the decontamination of soil also brings several problems. A massive amount of contaminated soil must be stored in an interim storage facility for 30 years. There is soil erosion because there is a time gap between decontamination and the beginning of agricultural cultivation (Wakabayashi et al. 2018). Weed invasion and low fertility of the remediated soil are also problems (Yoshino et al. 2015). As these decontaminated areas are intended for agricultural use within a few years, keeping the fields ready for agriculture is necessary. Therefore, it is recommended that cover crops be introduced and a labor-saving management system be studied.

Countermeasure by potassium

Therefore, in 2012 an alternative method to increase the exchangeable potassium concentration in the soil above a certain level was established as a new countermeasure for planting (Kato et al. 2015). In addition to potassium fertilizers, compost and other potassium-containing materials have been shown to have similar effects. This countermeasure is used for rice but also for various crops

Photo 1. Temporary storage of stripped top soil from the field. June 2014 in Kawamata town.

such as soybeans, buckwheat, and pasture. However, it should be mentioned that the effect of potassium on the mitigation of radiocesium to the plant is different among crop species, i.e., it is rather difficult to decrease the TF in soybean and buckwheat when compared to rice (IAEA 2020). And in the case of pasture, as the harvesting organ is the whole shoot which makes the radioactivity rather higher than in grains, it is required to keep the exchangeable potassium level higher than that of rice (NARO 2019). Furthermore, the difference was also observed among soil types (Yamamura et al. 2018). In addition, it is difficult to completely remove radioactive cesium, even from a field that has been decontaminated by stripping the topsoil, so applying potassium fertilizer is extremely effective in controlling the transfer of the remaining radioactive materials in the agricultural fields.

Conclusion

Remediation of the radioactive cesium in contaminated agricultural fields after the nuclear accident seems to have achieved a measure of success. The number of brown rice bags which exceeded the limit (100Bq/kg) was about 1.5% in 2011, but it decreased to 0.0007% in 2012, and there has been no report of bags exceeding the limit since 2015 (Fukushima no megumi 2021).

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