Report on "Radiation Disaster Recovery Studies"

Course: Radioactivity Environmental Protection
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○Regarding "Radiation Disaster Recovery Studies"

In 2011, earthquakes, tsunamis and nuclear incidents in Fukushima Prefecture, Japan made the whole world concerned. Once again Chernobyl disaster's obsession returned to humanity. From Vietnam, with little knowledge of radiation incidents, I monitored the daily situation with anxiety about the development and disaster recovery in Fukushima in media. Fortunately in 2013 I learned about the Phoenix Leader Education program (Hiroshima Initiative) for Renaissance from Radiation Disaster (PLEP) and was fortunate enough to be accepted to study Radioactivity Environmental Protection at Hiroshima University.

At Phoenix Program, I have learned the knowledge related to radiation, radioactive disaster and recovery after radiation disaster. More importantly, I learned not only in the field of environmental protection after a nuclear disaster but also in social rehabilitation and radiation disaster medicine. All three fields - environmental, social and health are closely related and inseparable from the Radiation Disaster Recovery study. My understanding of this correlation is increasingly strengthened through the Phoenix Program's first two-year subjects spread across the fields of environment, society and medicine. Besides, I also participate in scientific seminars, short-term training courses and field trips to research and management centers related to radiation safety and nuclear power plants, disaster site locations, etc. Attending lectures by leading experts in the field of radioactive disaster research and attending meetings with people affected by the Fukushima radiation accident have given me a lot of knowledge and experiences for my own study.

According to The Nuclear and Industrial Safety Agency (NISA) within the Ministry of Economy, Trade and Industry of Japan, the total discharge amounts to the air from the reactors of Fukushima Dai-ichi NNP were approximate 1.6×10^{17}Bq for Iodine 131 and approximate 1.5×10^{16}Bq for Cesium 137[1)]. Fukushima before the 2011 tsunami was an important agricultural area in Japan. Therefore, the task of assessing the impact of radioactive pollution on rice in Fukushima is very important. After the FDNPP disaster occurred, the top concern of the people (not just farmers in Fukushima) is that the agriculture produces is safe? For government authorities, the issue of assessing the level of radioactive contamination in the soil, even after decontamination, evaluating the level of radiation safety in local agricultural products has become urgent. The study of recovery from radioactive disasters is not only a matter of natural science but also covers the socio-economic and health issues. For example, how long does it take to ban farm produces in Fukushima to be eligible for sale? There are many studies on radioactive contamination in rice and the mechanisms of spreading cesium radioactivity to rice were published[2-6]. The effect of potassium on the absorption of radioactive cesium into rice plant has been shown; however, there are some points which deviate from the correlation[7]. In order to clarify these above, we conducted a study on four rice fields in Fukushima City, 60 km northwest of the FDNNP. From 2014 to 2018, we sampled soil and rice plant, analyzed soil particle size, analyzed radioactive Cesium 134, Cesium 137 and Potassium 40 with Ge semiconductor detector (GEM 30-70, ORTEC). We also used the ^{57}Fe Mössbauer spectroscopy to study soil oxidation/reduction properties in the soil through the relative area of Fe^{II}. From which many important conclusions are drawn such as: The change of the circumference around the rice field may affect the uptake of radioactive cesium into rice. The effect of fallowing field to downstream fields should be monitored for years to consider more. It has already been shown that some factors such as the concentration of potassium and grain size distribution in soils contribute the appearance of contaminated rice, however, our results suggest that dynamics of soil among the neighboring fields should be explored in future studies.

In conclusion, after being trained in the PLEP, my personal awareness of the nature and processes in the radiation disaster has changed drastically. The most important thing that I have learnt from the PLEP is related to radiation disaster, the recovery itself not only in the approaching of environmental field but strongly connect with social recovery, and the preparedness of medicine supply and prevent and healing the damage caused by radioactivity to human. The recovery is a long-term process and it takes lot of resources, not only time, finances. Our research has contributed a small part to raising people's awareness of radioactive environmental pollution in Fukushima prefecture, especially the spread of radioactive cesium in soil and rice. These perceptions are important to people who work in management, policy making and people living in/outside areas affected by radiation incidents. The Radiation Disaster Recovery Studies does not only apply to disasters caused by nuclear power plants but also includes research for possible disaster risks for all other areas of life that are related to the use of radioactive energy.

References:

1) Nuclear Emergency Response Headquarters Government of Japan, Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety- The Accident at TEPCO's Fukushima Nuclear Power Stations, June 2011.

2) Philip J. White and Martin R. Broadley, Mechanisms of caesium uptake by plants, Sciences, E., 113, 241–256 (2000).

3) Endo, S., Kajimoto, T., and Shizuma, K.: Paddy-field contamination with 134Cs and 137Cs due to Fukushima Dai-ichi Nuclear Power Plant accident and soil-to-rice transfer coefficients, J. Environ. Radioact., 116, 59 - 64. (2013).

4) Nakanishi, M., T. and Kobayashi, I., K.: Radioactive cesium deposition on rice, wheat, peach tree and soil after nuclear accident in Fukushima, J. Radioanal. Nucl. Chem., 296, 985-989 (2013).

5) Ohmori, Y., Inui, Y., Kajikawa, M., Nakata, A., Sotta, N., Kasai, K., Uraguchi, S., Tanaka, N., Nishida, S., Hasegawa, T., Sakamoto, T., Kawara, Y., Aizawa, K., Fujita, H., Li, K., Sawaki, N., Oda, K., Futagoishi, R., Tsusaka, T., Takahashi, S., Takano, J., Wakuta, S., Yoshinari, A., Uehara, M., Takada, S., Nagano, H., Miwa, K., Aibara, I., Ojima, T., Ebana, K., Ishikawa, S., Sueyoshi, K., Hasegawa, H., Mimura, T., Mimura, M., Kobayashi, I., N., Furukawa, J., Kobayashi, D., Okouchi, T., Tanoi, K., and Fujiwara, T.: Difference in cesium accumulation among rice cultivars grown in the paddy field in Fukushima Prefecture in 2011 and 2012, J. Plant Res., 127, 57-66 (2014).

6) Nihei, N., Tanoi, K., and Nakanishi, M., T.: Inspections of radiocesium concentration levels in rice from Fukushima Prefecture after the Fukushima Dai-ichi Nuclear Power Plant accident, Sci. Rep., 5, 8653 (2015).

7) T. Saito, S. Ohkoshi, S. Fujimura, K. Iwabuchi, M. Saito, T. Nemoto, M. Sato, K. Yoshioka and H. Tsukada , Effect of potassium application on root uptake of radiocesium in rice, Proceedings of Int. Symp Environmental Monitoring and Dose Estimation of Residents after Accident of TEPCO's Fukushima Daiichi Nuclear Power Stations. Part 3–5, Kyoto Univ. Res. Reactor Inst. 2012.

○Title of Doctoral Thesis

Properties of the Soil in Rice Fields and Transfer of Cesium to Rice Plants

○Summary of Doctoral Thesis

On 11th March 2011, The Great East Japan Earthquake of magnitude 9.0 and the following 15 m tsunami hit the Tohoku area. This led to the cause of Fukushima Dai-ichi Nuclear Power Plant (FDNPP) accident, where ^{134}Cs and ^{137}Cs were released to the air and made land and rice fields contaminated. As Phoenix student, I learnt the radiation disaster and restoration from the disaster in Fukushima Prefecture. After the accident, the food safety has emerged as a very important problem. Contaminated rice from paddy fields was observed in Fukushima City. How the contaminated rice is reduced was the basis for my doctoral dissertation. Although there are many studies concerning the contamination of radioactive cesium and the transfer of radioactive cesium from soil to ears of rice in the paddy fields of the Fukushima after the FDNPP accident has been carried out, the mechanism of the up-taking of cesium into rice, the migration of cesium and the factors that affect are still required. An investigation in 2013 showed the concentration of radioactivity of ^{137}Cs and ^{134}Cs in rice which was collected from one of neighbor rice fields was relatively high. This study aims to investigate the contamination of radiocesium in rice and paddy field's soil, and the factors that affect the contamination and the transfer of ^{137}Cs and ^{134}Cs into rice. In order to understand the factors, the soil samples were collected, and the radioactive concentrations, the depth distribution, the soil size distribution were investigated and the oxidative/reductive atmosphere in the paddy field was investigated using ^{57}Fe Mössbauer spectroscopy. Background and objective of the research are given in Chapter 1.

The chapter 2 shows the method. Our study performs in 4 paddy fields (which are named as A, B, C, and D) in Fukushima City, which are 60 km Northwest far from Fukushima Dai-ichi Nuclear Power Plant. We monitored the fields from 2014 to 2018. The paddy fields are irrigated by a nearby pond and partial water from Abukuma River. Four fields were cultivated in 2013 and 2014, although the upper two fields were not cultivated from 2015. The samples were taken from 4 paddy fields with 5 sample sites for each field. The samples were contained in U-8 vessels and the radioactivity was measured by Ge semiconductor detector (GEM 30-70, ORTEC). The radioactivity was calibrated using MX033U8PP source set (Japan Radioisotope Association). ^{57}Fe Mössbauer spectroscopic measurement was performed at room temperature with a ^{57}Co (Rh) radiation source moving in a constant acceleration mode on Wissel MB-500. The Mössbauer parameters were obtained by least-squares fitting to Lorentzian peaks. The spectra were calibrated by the six lines of α-Fe, the center of which was taken as zero isomer shift.

Chapter 3 is the study about depth distribution of radioactive cesium in soil after cultivating and the difference by the year of the uptake of radioactive cesium in rice in these fields. The average value of five points in each field was compared to each other. The ^{137}Cs concentration decreased

depending on the depth. The same trend was also observed in the depth dependence of ^{134}Cs concentration. The ratio of radioactivity concentration of ^{134}Cs to ^{137}Cs was 0.373. This value corresponds well with the expected ratio (0.376) on the sampling day declined according to reduction of ^{134}Cs by shorter half-life than that of ^{137}Cs, given that the same amount of radioactivity of ^{137}Cs and ^{134}Cs was released from the FDNPP reactor. These fields were cultivated, ploughed and irrigated before transplanting rice seedlings in 2013. Nevertheless, the concentrations of ^{137}Cs and ^{134}Cs in soils were not uniform and there was depth dependency in 2014. It is expected that small particles such as clay include a large amount of radioactive cesium. One of the possibilities is that bigger particles fell down quickly but the small particles such as clay fell down slowly in the sedimentation process after ploughing and irrigating, although the soils were mixed. There is a difference between Fields A, B and Fields C, D. The radioactivity of ^{137}Cs and ^{134}Cs for 0-5 cm depth was higher in Fields C and D than in Fields A and B, while the radioactivity for 5-10 cm was lower in Fields C and D than in Fields A and B. Relatively higher radioactivity of ^{137}Cs and ^{134}Cs was found at greater depth in Fields A and B than in Fields C and D.

In Chapter 4 the ^{57}Fe Mössbauer spectroscopy was used to determine the oxidative/reductive characteristic of soil samples. The iron concentration variation was also investigated based on soil size distribution. It was thought that Fields A, C, and D are in relatively in reductive atmosphere, while Field B is in relatively oxidative atmosphere. It was suggested that the oxidative/reductive condition of iron state may reflect the features of the soils and then affect the solubility of potassium and radioactive cesium in the field. We checked the change of ^{57}Fe Mössbauer absorption depending on the soil size. Consequently, the iron in the larger size soil is much abundant in Fields A and B compared with that in Fields C and D. It is known that the small sized soil includes clay much. And the radioactive cesium is adsorbed strongly to the clay. It is also thought that the cesium adsorbed to large sized soil is relatively easily desorbed and absorbed to rice body. The amount of iron may affect desorption of radioactive cesium from large sized soil. One of the possibilities is that the iron works as catalyst to dissolve radioactive cesium from soil. In conclusion, oxidative atmosphere and in particular more abundant iron in larger size soil may affect the transfer of radioactive cesium from soil to rice grain.

Chapter 5 shows the change in the characters of soil of Fields A-D. The depth dependence of ^{137}Cs for the soil changed from 2014 to 2018. The difference between Fields A, B and Fields C, D became larger. Slightly contaminated rice ears appeared in Fields C and D after the fallowing Fields A and B. The radioactivity concentration was relatively higher in rice ears obtained from the field near irrigation entrance of water. It was thought that the ratio of clay and silt decreased by this water flow, which became one of the reasons of relatively higher ^{137}Cs concentration in ears. But, this should be explored in future studies.

Chapter 6 shows general conclusion.

○Other theses published in academic research journals

・Title of academic research journals

1) Nguyen Thanh Hai, Masaya Tsujimoto, Sunao Miyashita, Satoru Nakashima, Depth Distribution of Radioactive Caesium in Soil after Cultivation and the Difference by Year of the Uptake of Radioactive Caesium in Rice in Fukushima Prefecture after the 2011 Nuclear Accident, Radioisotopes, 68(1), 13-18, 2019.

2) Nguyen Thanh Hai, Masaya Tsujimoto, Satoru Nakashima, Study on paddy soil in Fukushima using Mössbauer spectroscopy, Hyperfine Interactions, 240, 122 (7 pages), 2019.

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1) Masaya Tsujimoto, Sunao Miyashita, Nguyen Thanh Hai, Satoru Nakashima, A correlation between the transfer factor of radioactive cesium from soil into rice plants and the grain size distribution of paddy soil in Fukushima, Radiation Safety Management, 15, 1–8, 2016.